

*Incorporating
Genetic Diversity
for Crop Improvement*



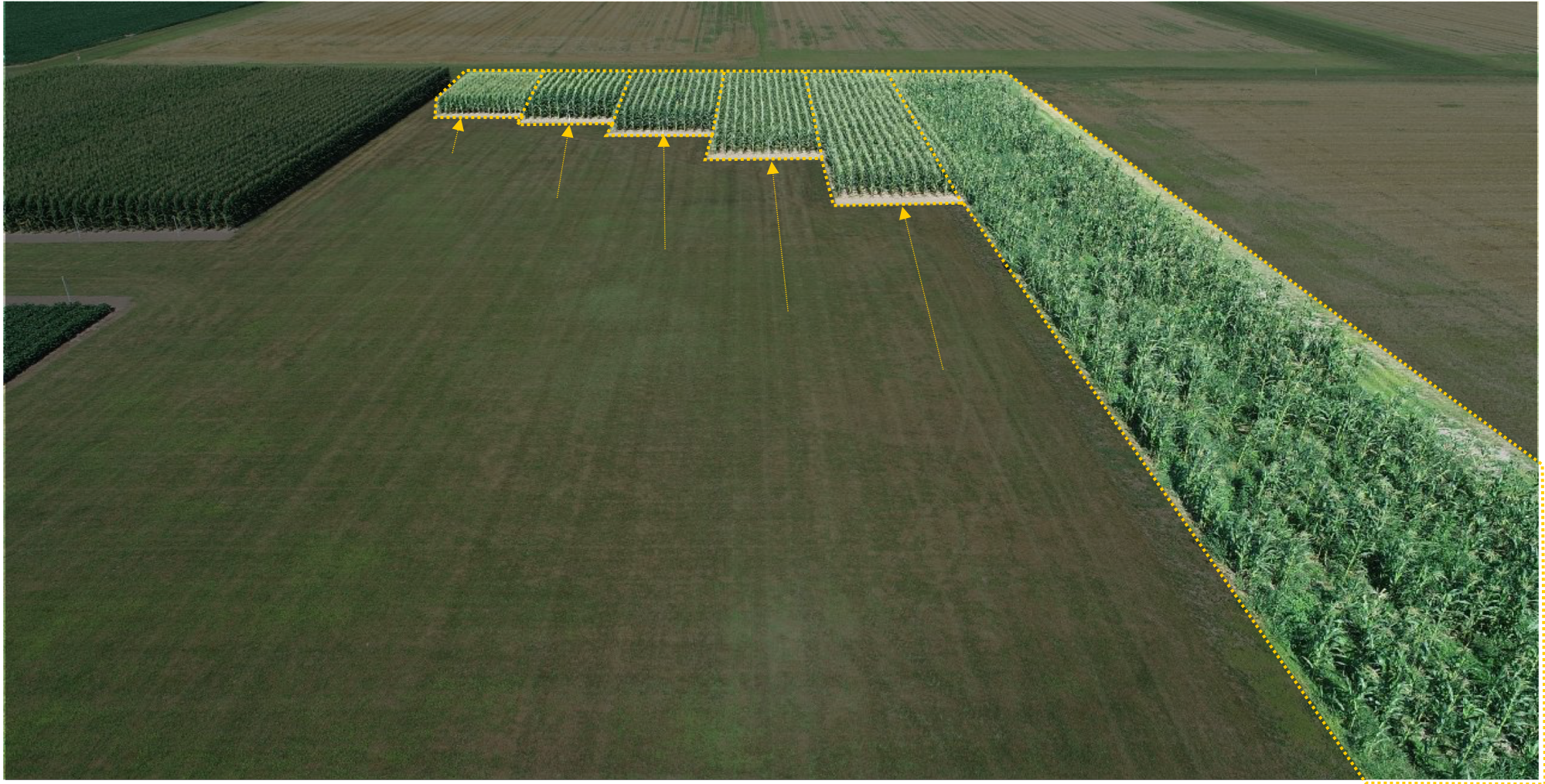
Shilpa Swarup
Regulatory Scientific Affairs
Bayer Crop Sciences



Key Take home Messages

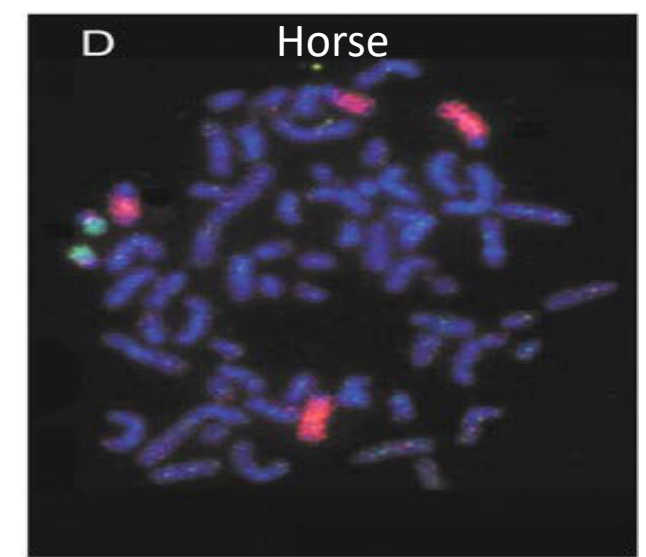
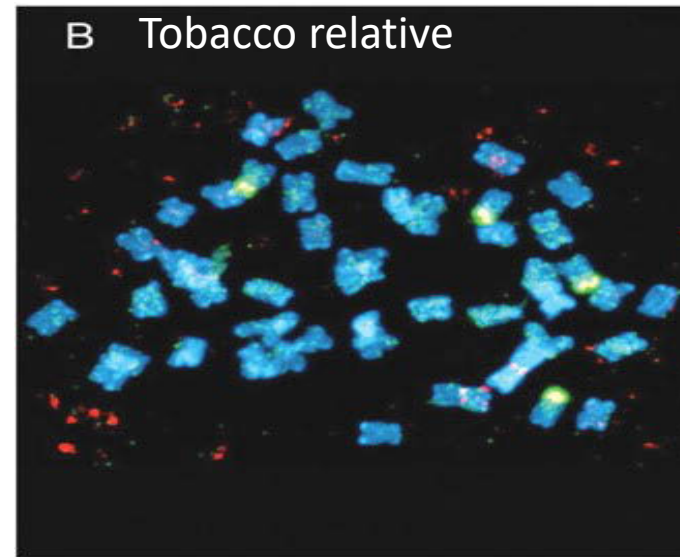
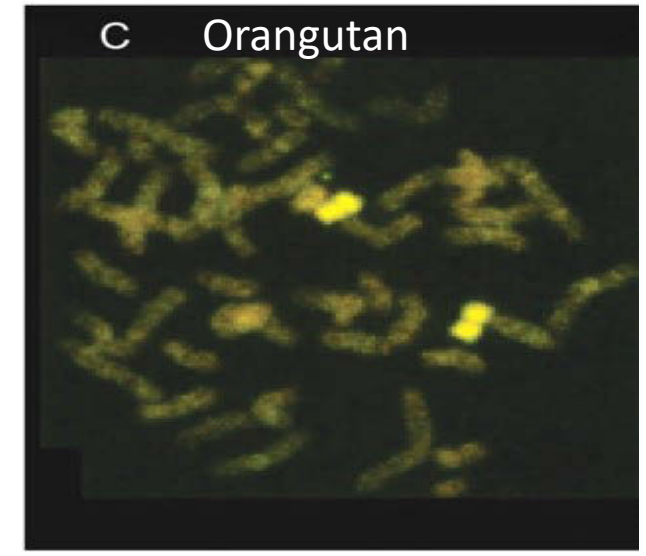
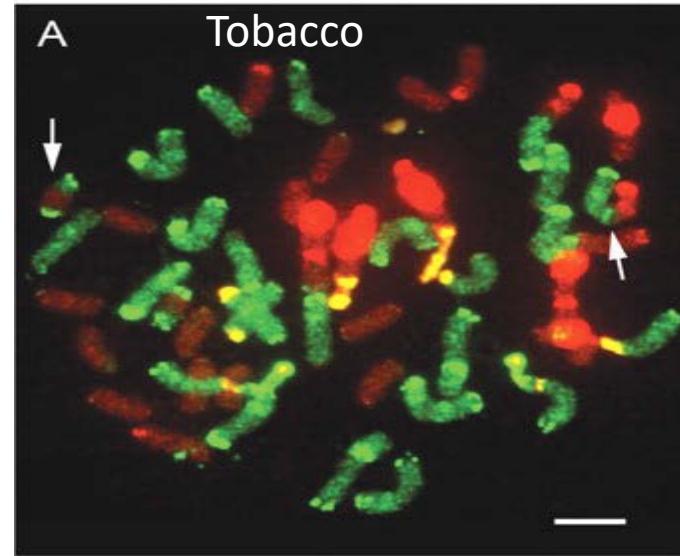
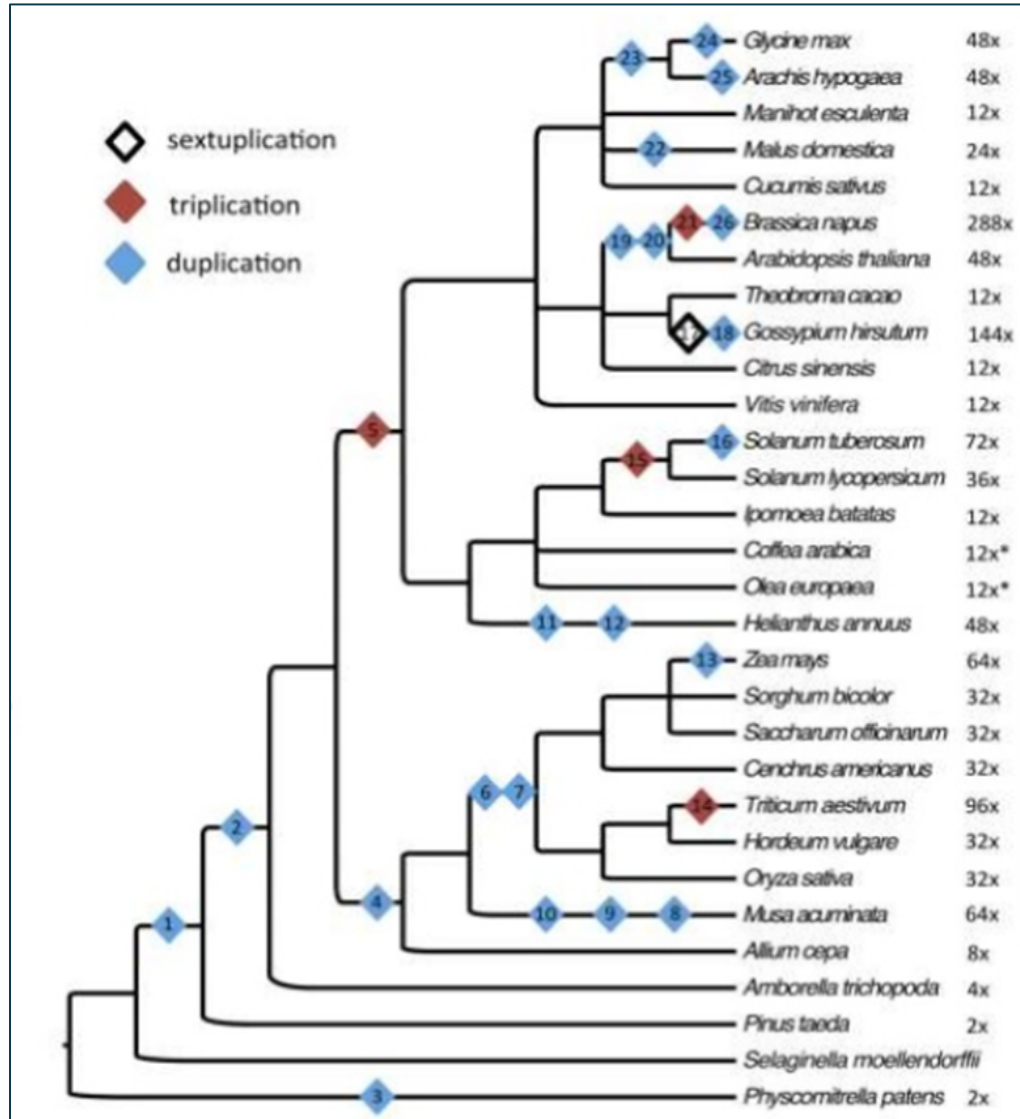
- Plants are not animals: plant breeders can throw away plants.
- Plant genomes are labile in nature.
- Three concepts used to incorporate genetic diversity into a variety: backcrossing, cell division and selection.
- Breeding methods are used to introduce traits from technologies.

Plants are not Animals: You can grow many plants, discard progeny and focus on what you want



The process of field testing is a powerful tool used by breeders to eliminate off types

Plant Genomes Have More Plasticity than Mammal Genomes



A. R. Leitch, and I. J. Leitch Science 2008;320:481-483

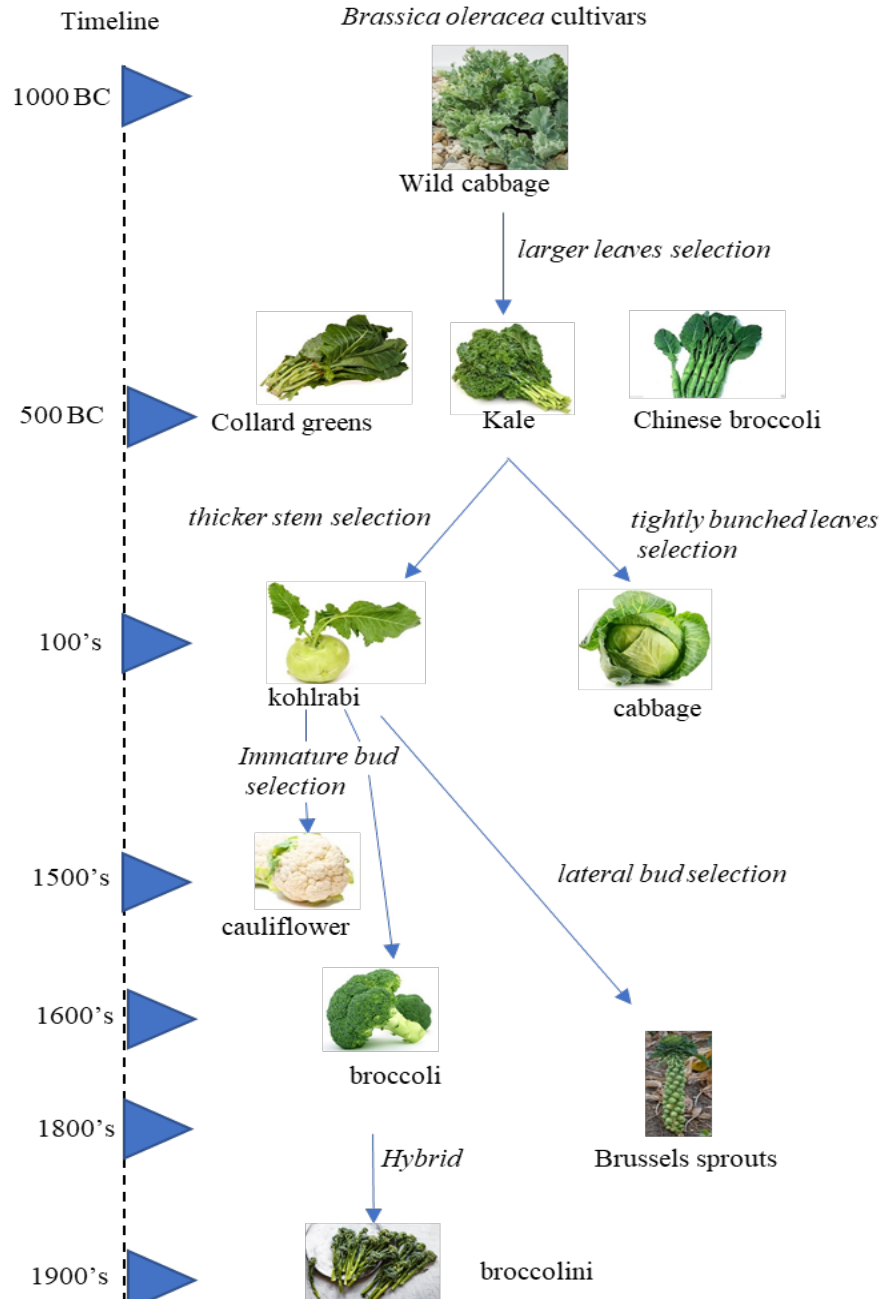
Genetic changes are common in plants while one chromosome change in humans can be lethal

Naturally Occurring Genetic Changes Are Common in Plants

Genetic Change	Genotypic/Phenotypic Example	Reference
Transposable elements (transposons)	White grapes , blood oranges	Lisch (2013)
	>25K unique insertions detected across 31 varieties of soybean	Tian et al. (2012)
	Yellow maize	Palaisa et al. (2003)
	>50 new inserts of a transposon per rice plant per generation	Naito et al. (2006)
	Elongated tomato fruit	Xiao et al. (2008)
	Round or wrinkled peas (Mendel)	Ellis et al. (2011)
	2 million transposons exchanged between higher plants	El Baidouri et al. (2014)
Organellar DNA in nuclear DNA	Gain and loss of mtDNA common to maize inbred lines	Lough et al. (2008)
	Gain and loss of cpDNA common to maize inbred lines	Roark et al. (2010)
Bacterial genes	Expression of several bacterial genes in sweet potatoes	Kyndt et al. (2015)
Crossing with wild relatives	>60 wild relatives have been used for >100 characteristics (80% involve pest or disease resistance) in 13 crops	Hajjar and Hodgkin (2007)
	Dozens of alien genes used in wheat breeding	Jones et al. (1995)
Pararetroviruses	Stable viral DNA in rice genome	Liu et al. (2012)
	Stable viral DNA in tomato (previously also seen in potato)	Staginnus et al. (2007)
Florendoviruses	Stable integrations in all plants	Geering et al. (2014)
Indels	Submergence-tolerant rice	Xu et al. (2006)
	Dwarf sorghum	Multani et al. (2003)
	Yellow soybean seeds	Tuteja et al. (2004)

Genetic Change	Genotypic/Phenotypic Example	Reference
Single nucleotide polymorphisms (SNPs)	Maize proteins (300-400 aa long) from 2 alleles differ by 3-4 aa	Tenaillon et al. (2001)
	Maize genome has 55 million SNPs	Gore et al. (2009)
	Green Revolution gene has 2 SNPs for dwarf wheat	Peng et al. (1999)
	One SNP caused loss of shattering in domestic rice	Konishi et al. (2006)
	Tall or short pea plants (Mendel)	Ellis et al. (2011)
	7 new SNPs created per meiosis per billion base pairs	Ossowski et al. (2010)
	Presence/absence/copy number of genes	856 wild-type soybean genes absent in cultivated varieties (and >186K DNA insertions/deletions)
>10 ⁶ SNPs, 30K insertion/ deletions and a few large chromosomal deletions (>18 genes) in 6 elite maize varieties		Lai et al. (2010)
Copy number variation relates to soybean cyst nematode resistance		Cook et al. (2012)
Pinot Noir, Corvina & Tannat wine grapes have 1873 genes not found in other wine grapes		Da Silva et al. (2013)
Only 81% of Brassica genes are always present in the same number		Golicz et al. (2016)
2500 genes found only in either B73 or PH207		Hirsch et al. (2016)
G. soja genotypes can vary by 1000-3000 gene families from each other		Li et al. (2014) Glenn, K., et al. (2017)

Some Genetic Differences Can be Visible e.g. Brassica family



Nine vegetable species are all derived from a common ancestor by selecting for traits or combining traits

Phenotypic Differences Does Not Always Reflect Genotypic Differences in Plants



Corn is 14 times more diverse than humans



Chen and Li, 2001

Genomic tools can differentiate a plant with desired characteristics in a mix of plants

Genetic Change (Mutations) is the Source of Genetic Diversity

Natural mutations



70 *denovo* mutations per generation



17 bp per generation



1 every 2000 bp mutations per generation



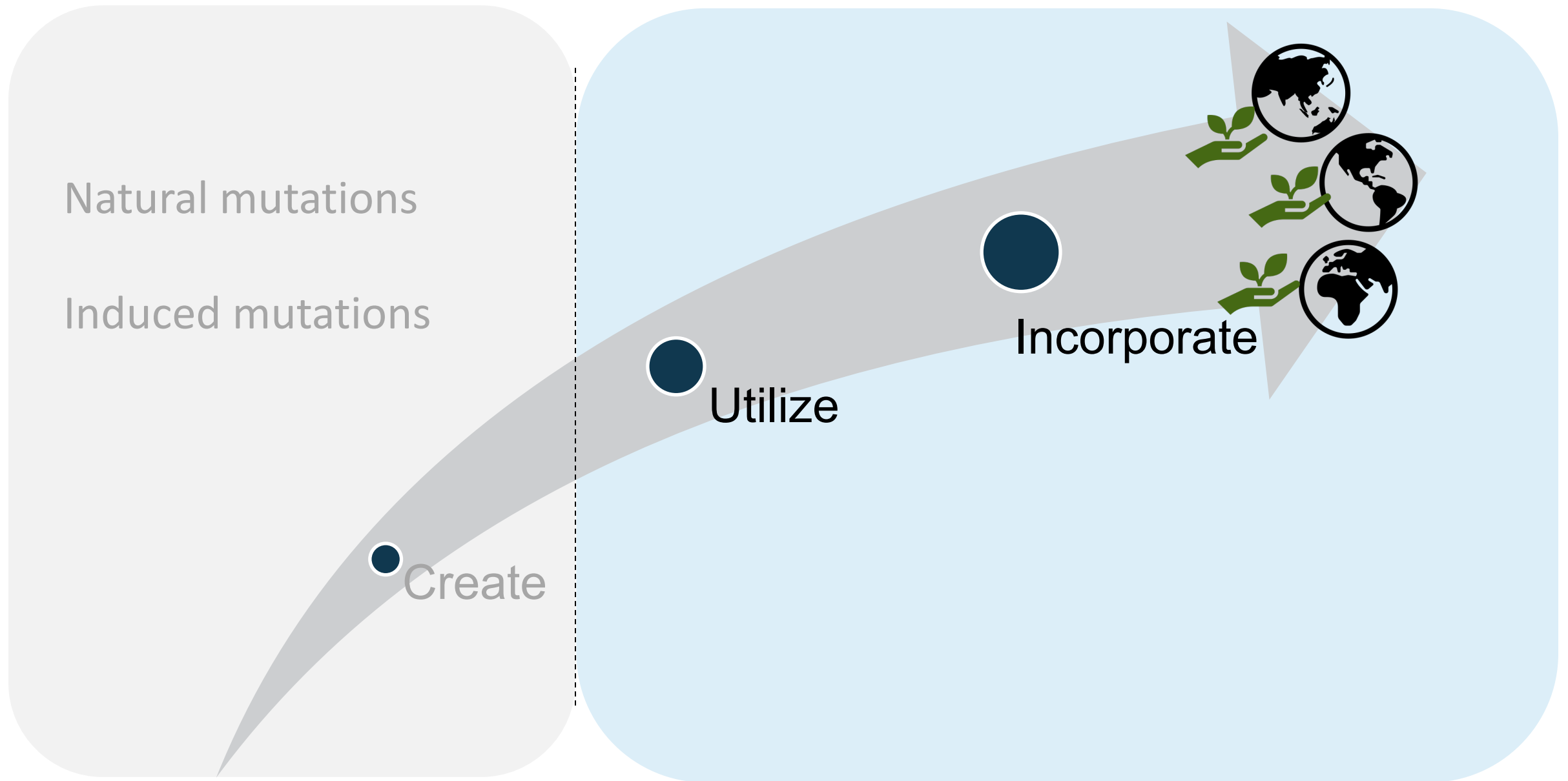
1 every 540 bp mutations per generation

Induced mutations

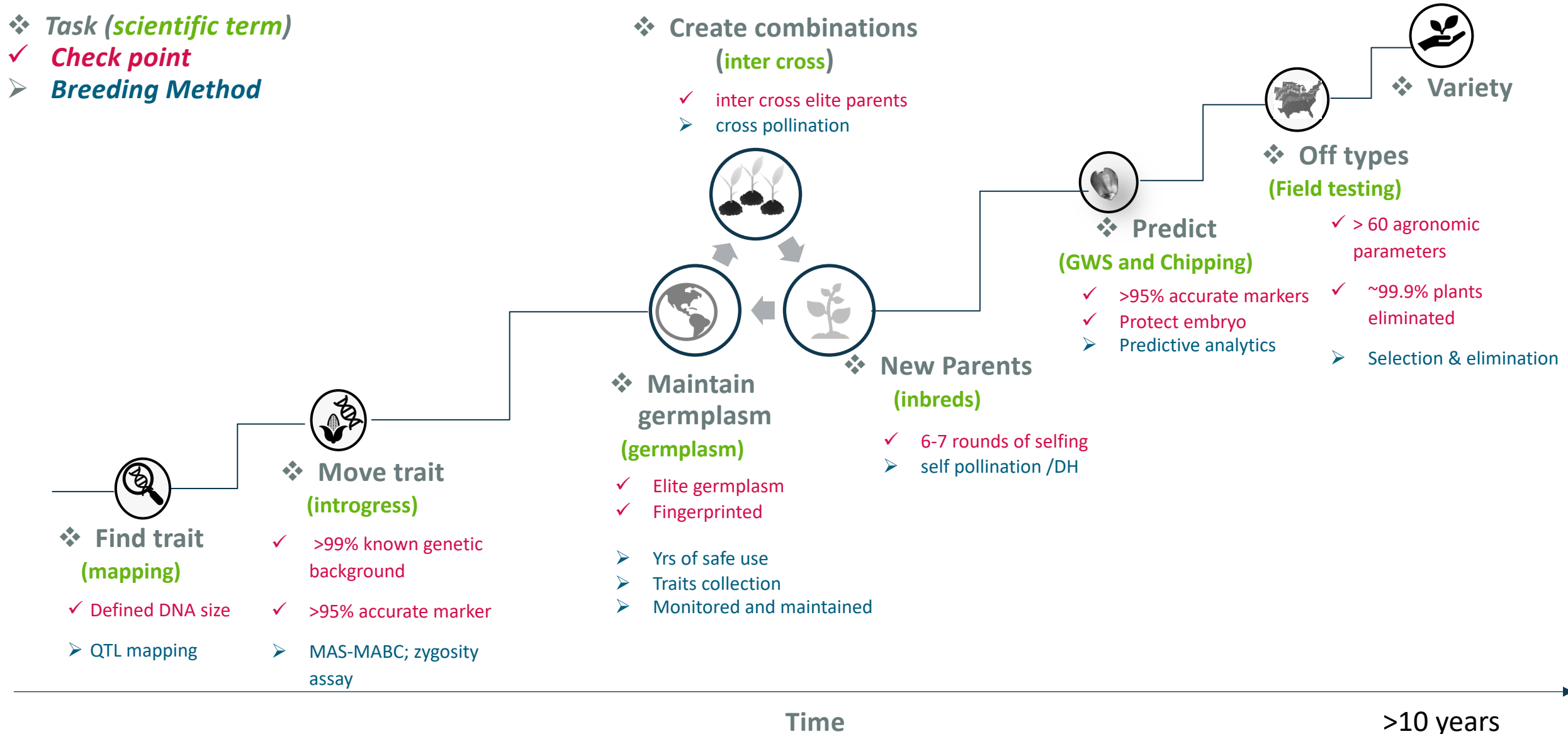


2-10 mutations every Mb

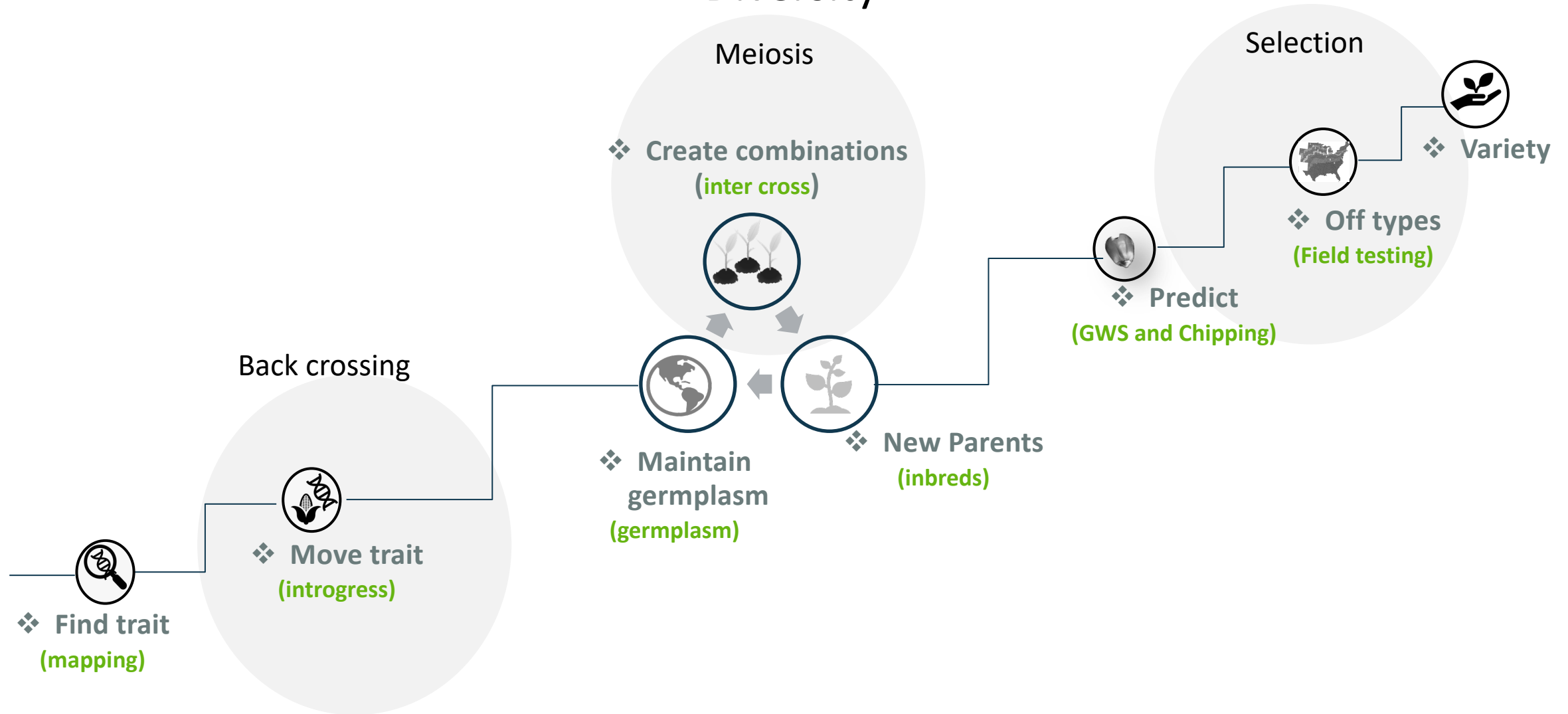
How is Genetic Diversity Incorporated Into a Crop Variety?



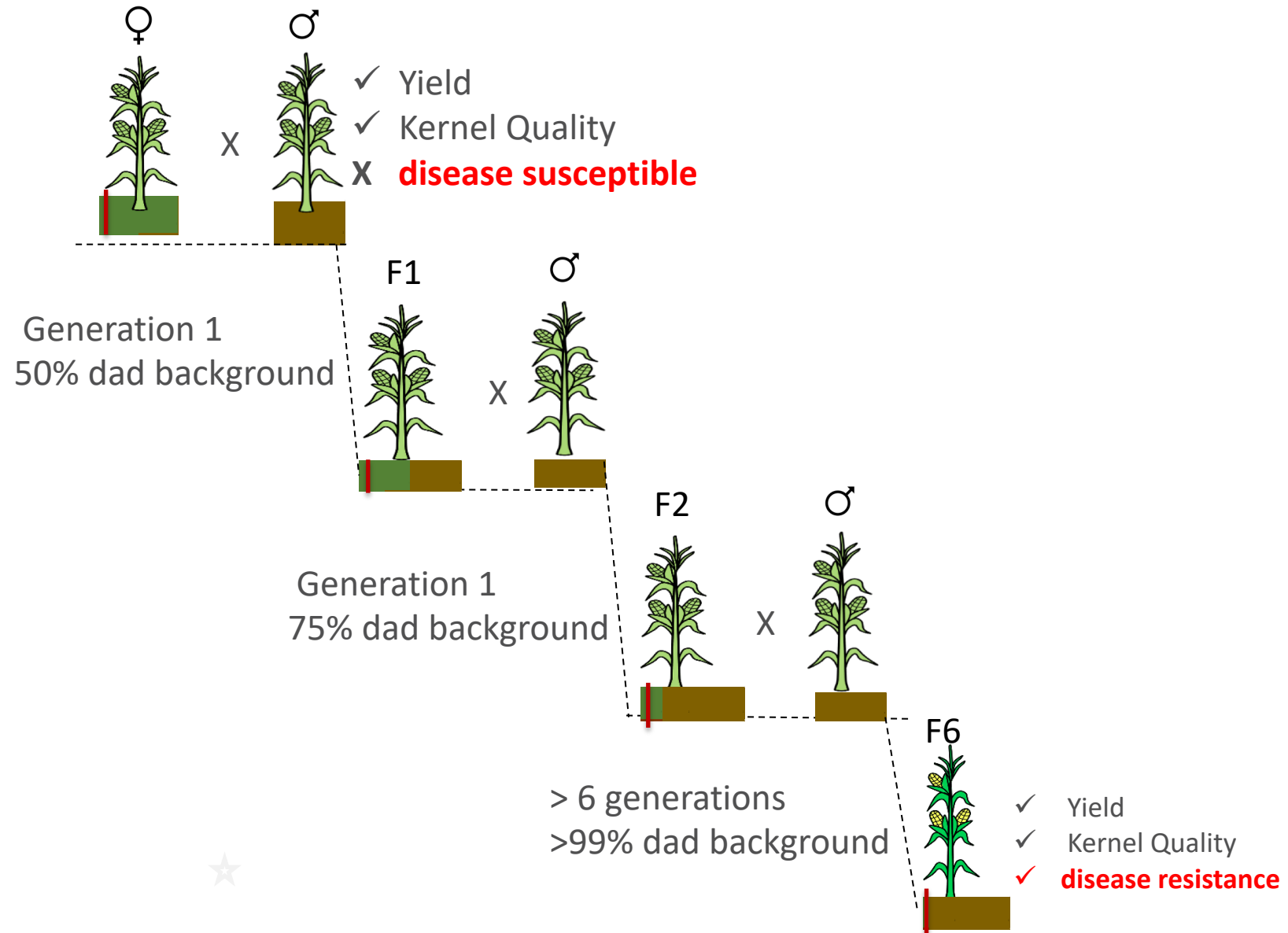
Genetic Diversity Is Strategically Added into Varieties: Keep Out Unwanted Characteristics and Retain Wanted Characteristics



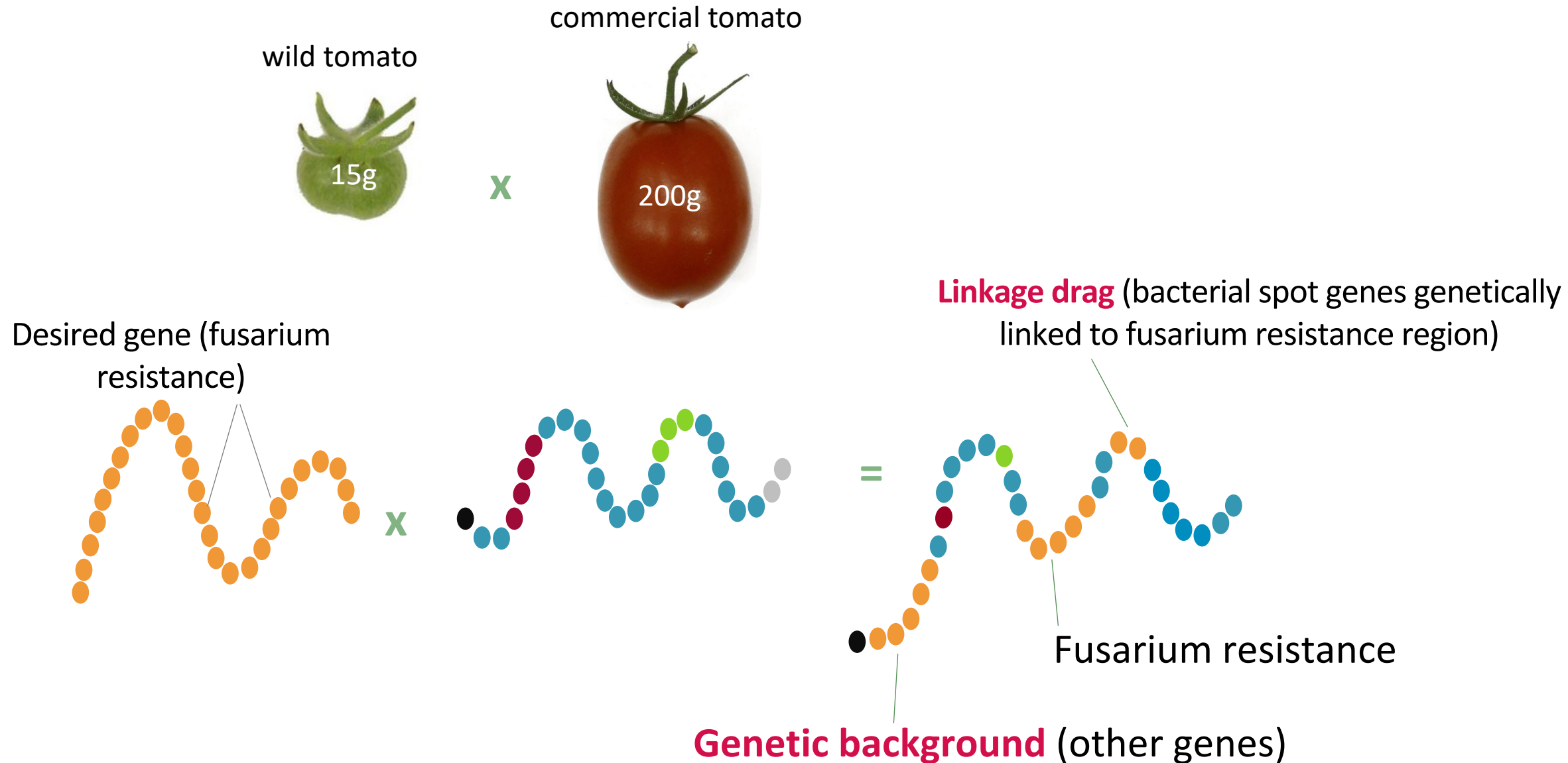
Conventional Breeding Uses **Backcrossing, Meiosis and Selection** to Incorporate Diversity



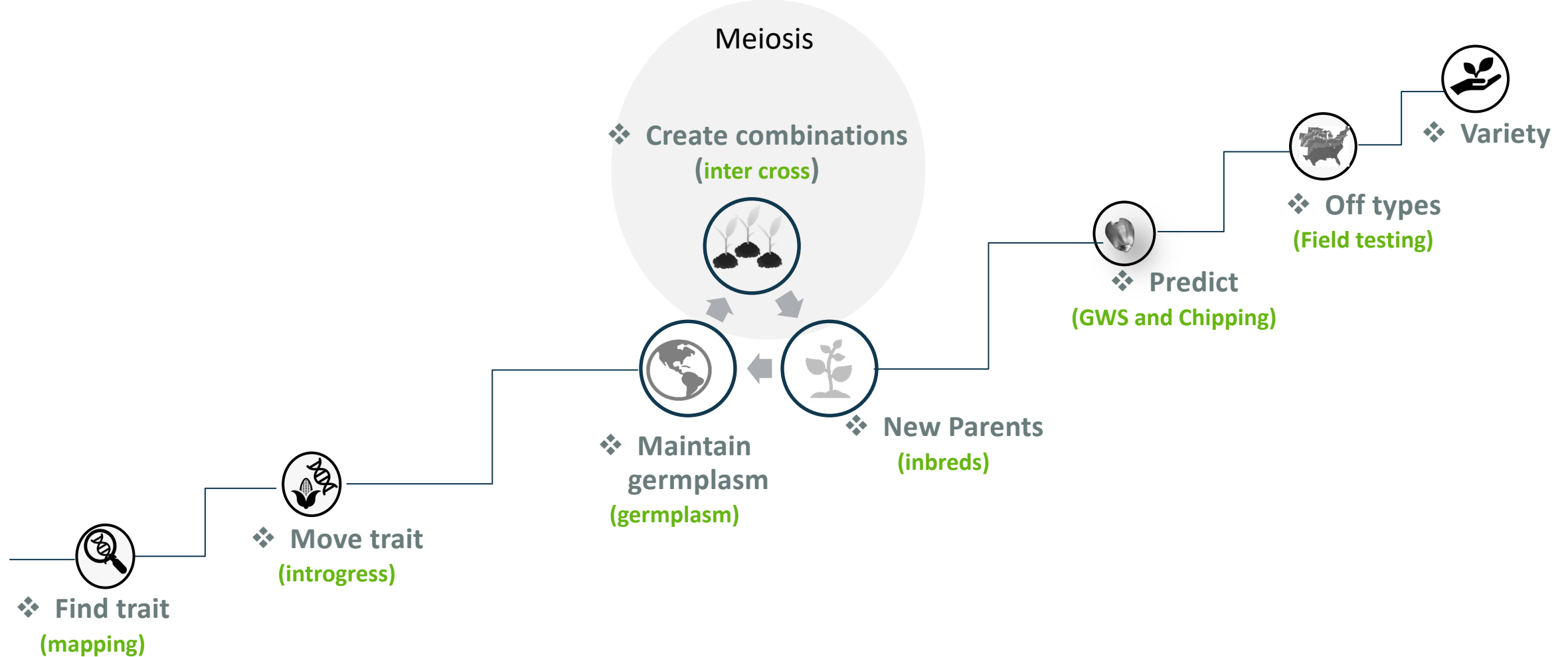
Backcrossing Relies on Cell Division To Eliminate Unwanted Effects



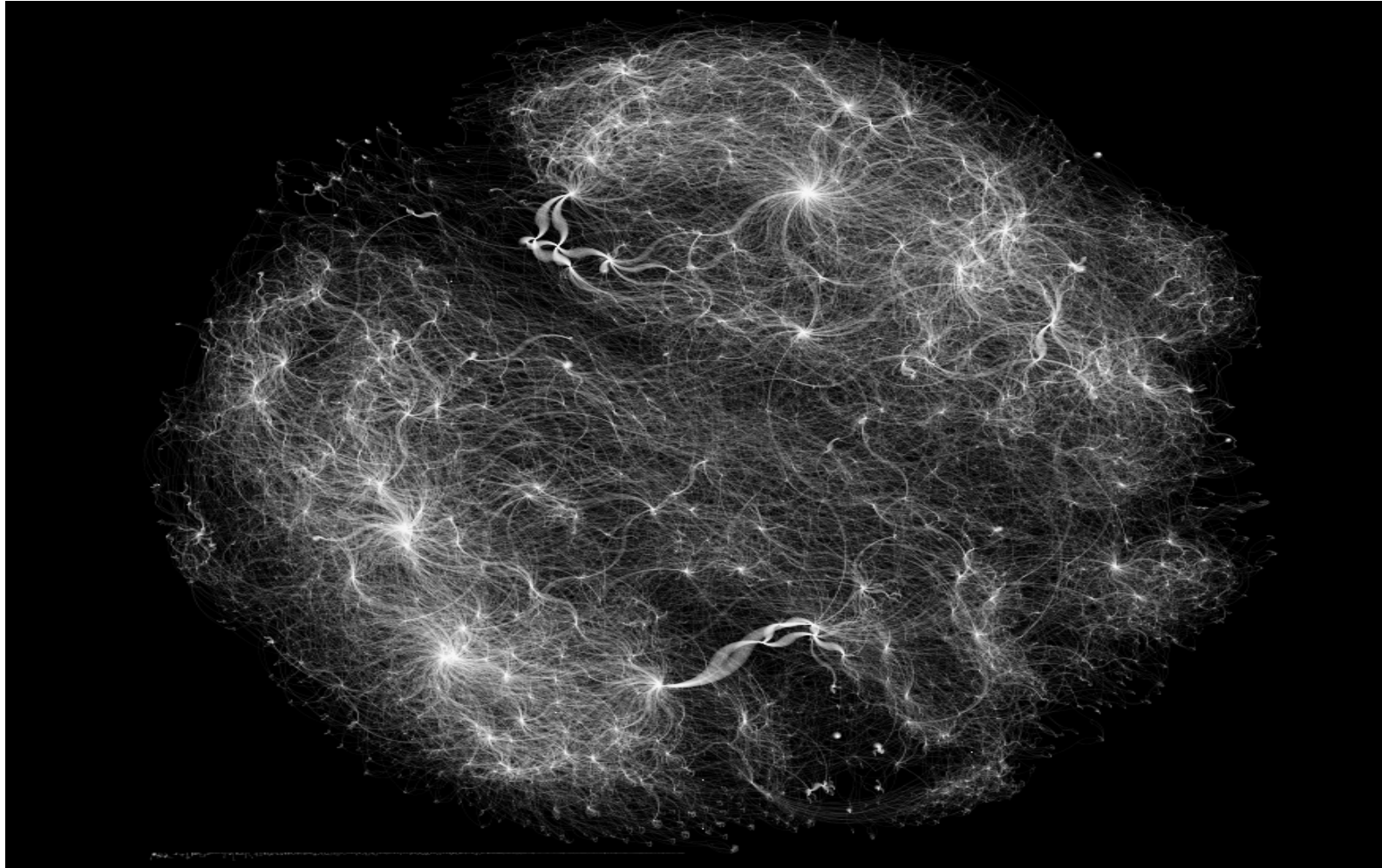
It Can Take Years of Backcrossing to Eliminate *Genetic Background Effects* and *Linkage Drag*



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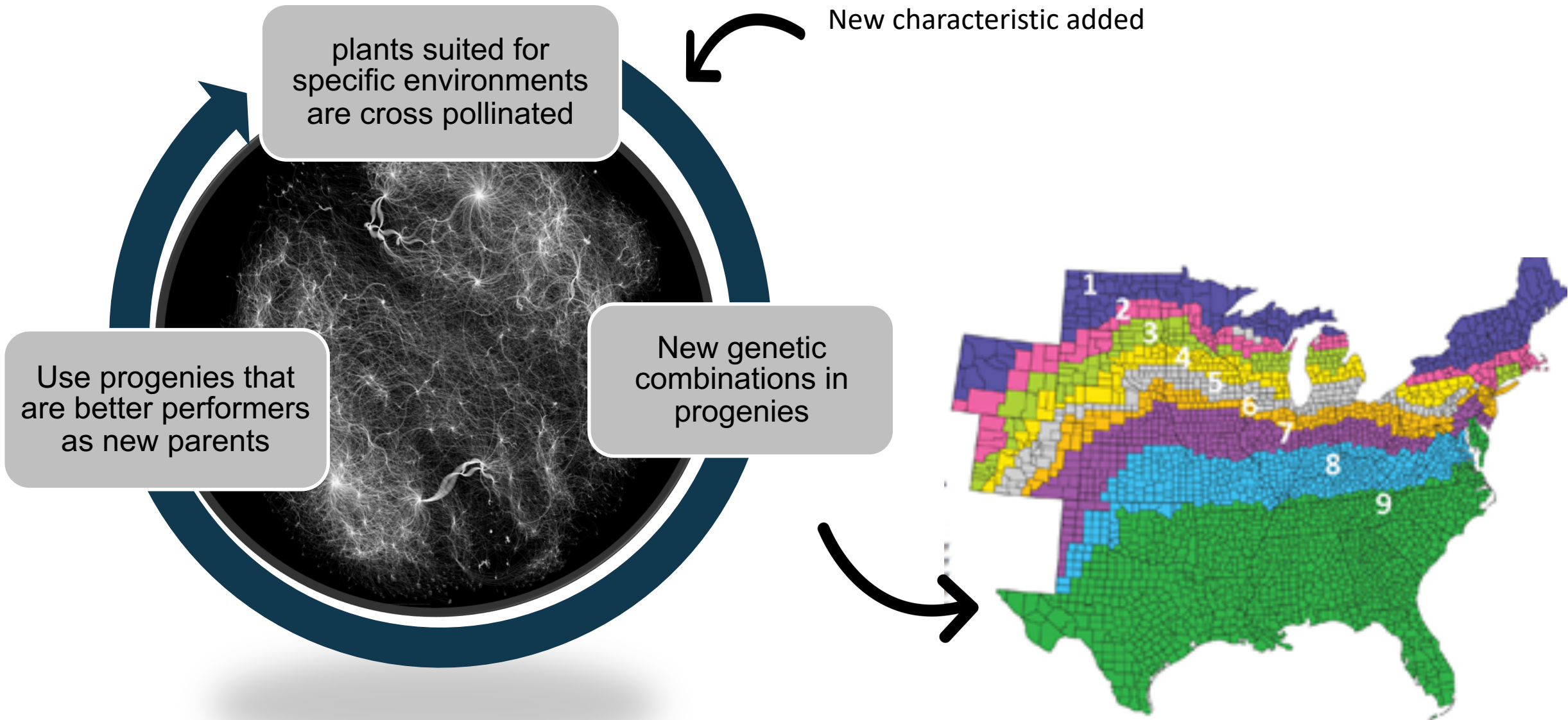


Germplasm Acts As a Reservoir for Genetic Diversity for Different Traits



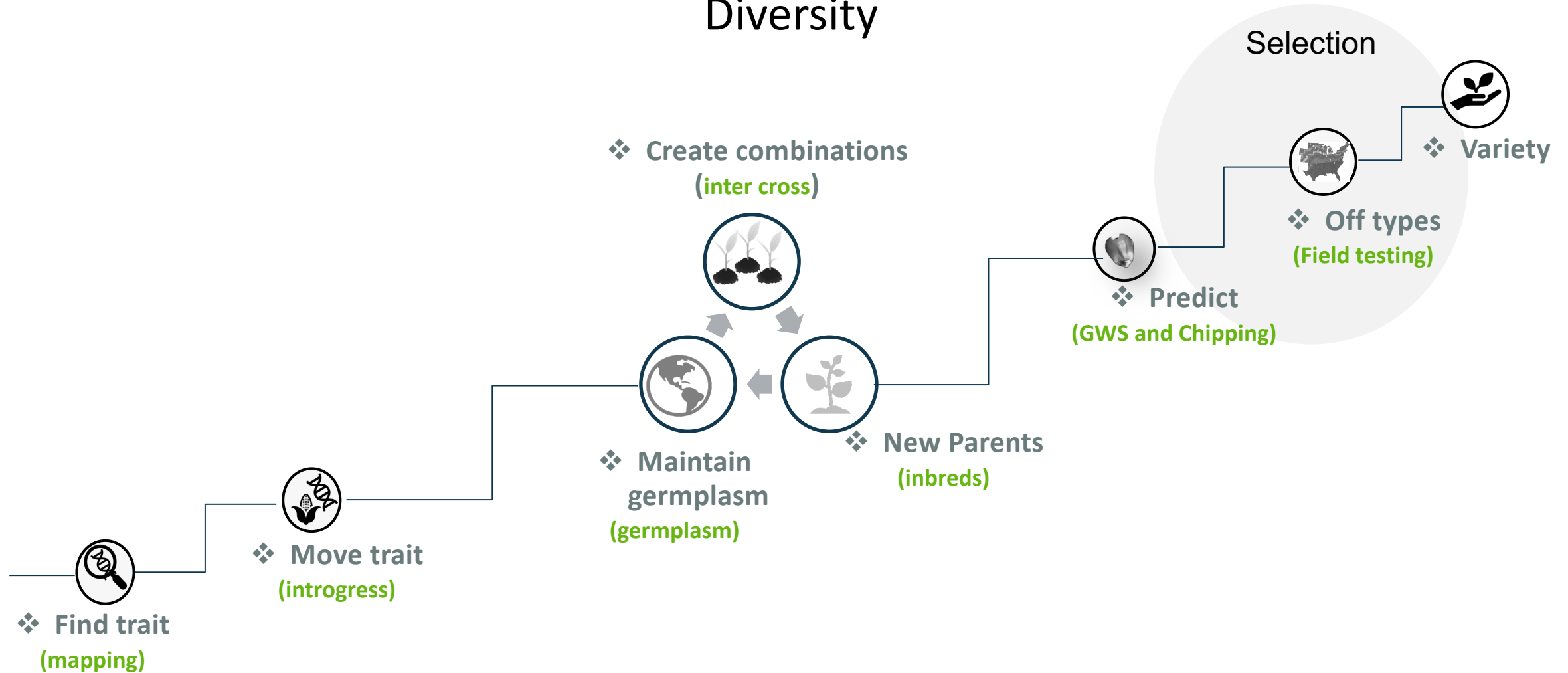
Bayer global maize germplasm uses a well characterized germplasm

Diversity is Created to Develop Parents With Beneficial Genetic Combinations



Germplasm Collection is Routinely Monitored and Recycled with New Genetic Combinations and Traits

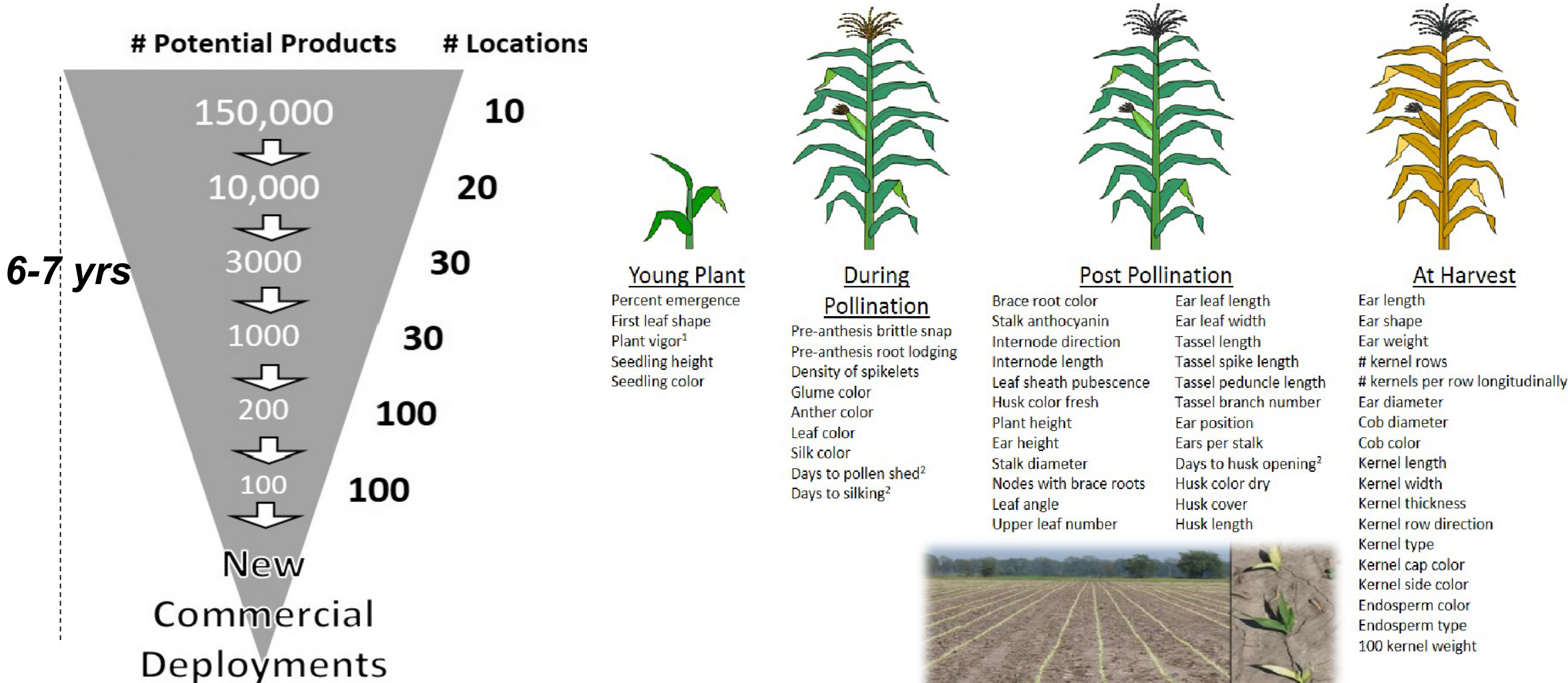
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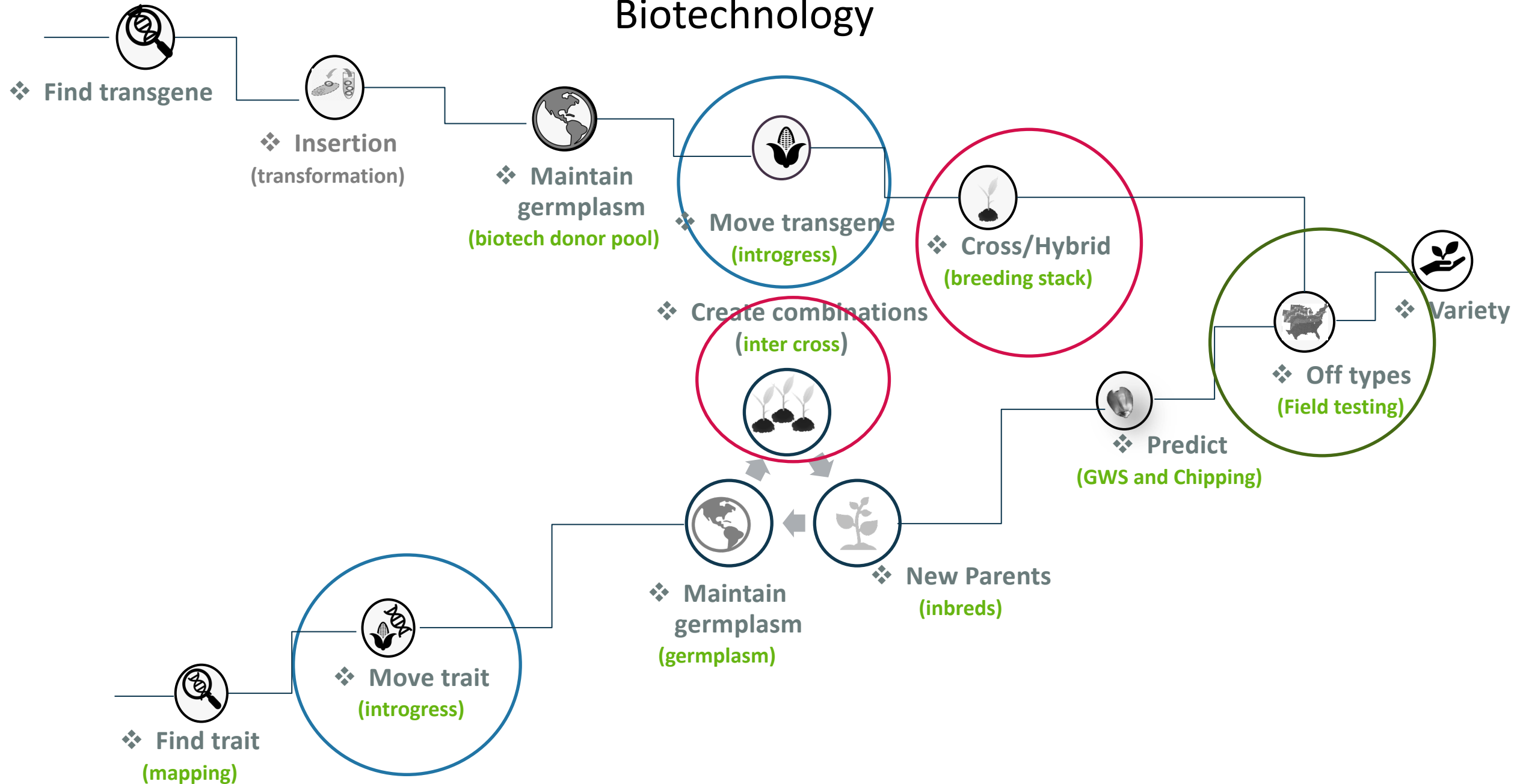
All Crops- Conventional, Biotech and Genome Edits - Go Through Intense Selection

Criteria

0.1% plants selected; 99.9% discarded over 6-8 years of testing across 100 locations

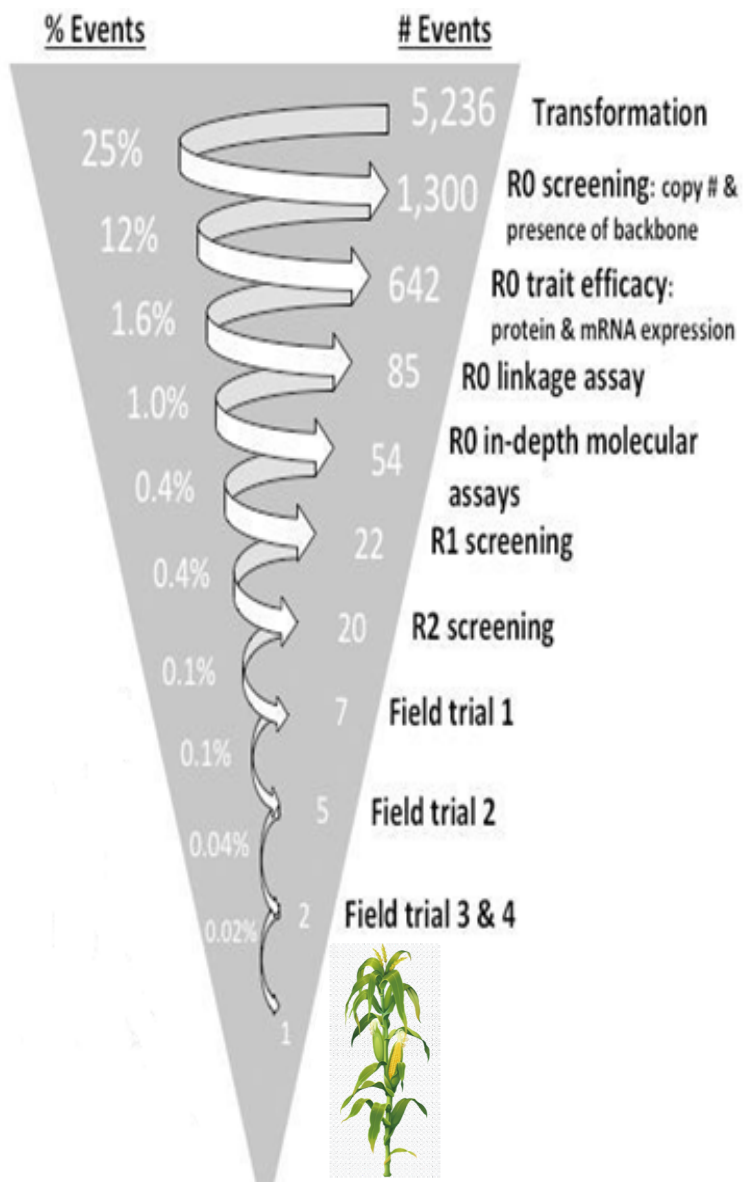


Breeding Methods- Backcrossing, Selection, Cross Pollination- Used To Incorporate Biotechnology



Selection is Used to Identify A Parent Plant To Use For Trait Introgression at The Next Stage

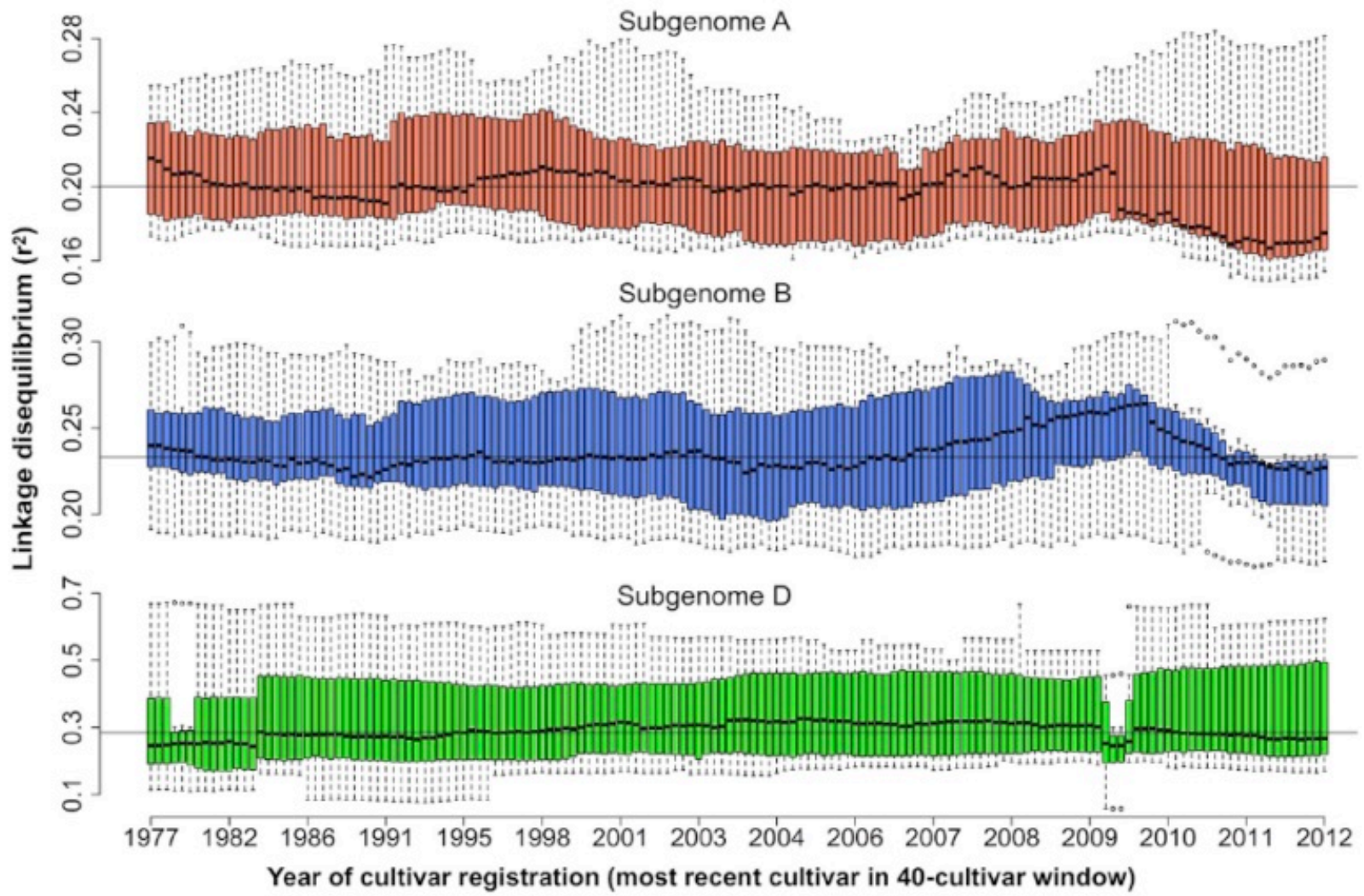
❖ **Insertion**
(transformation)



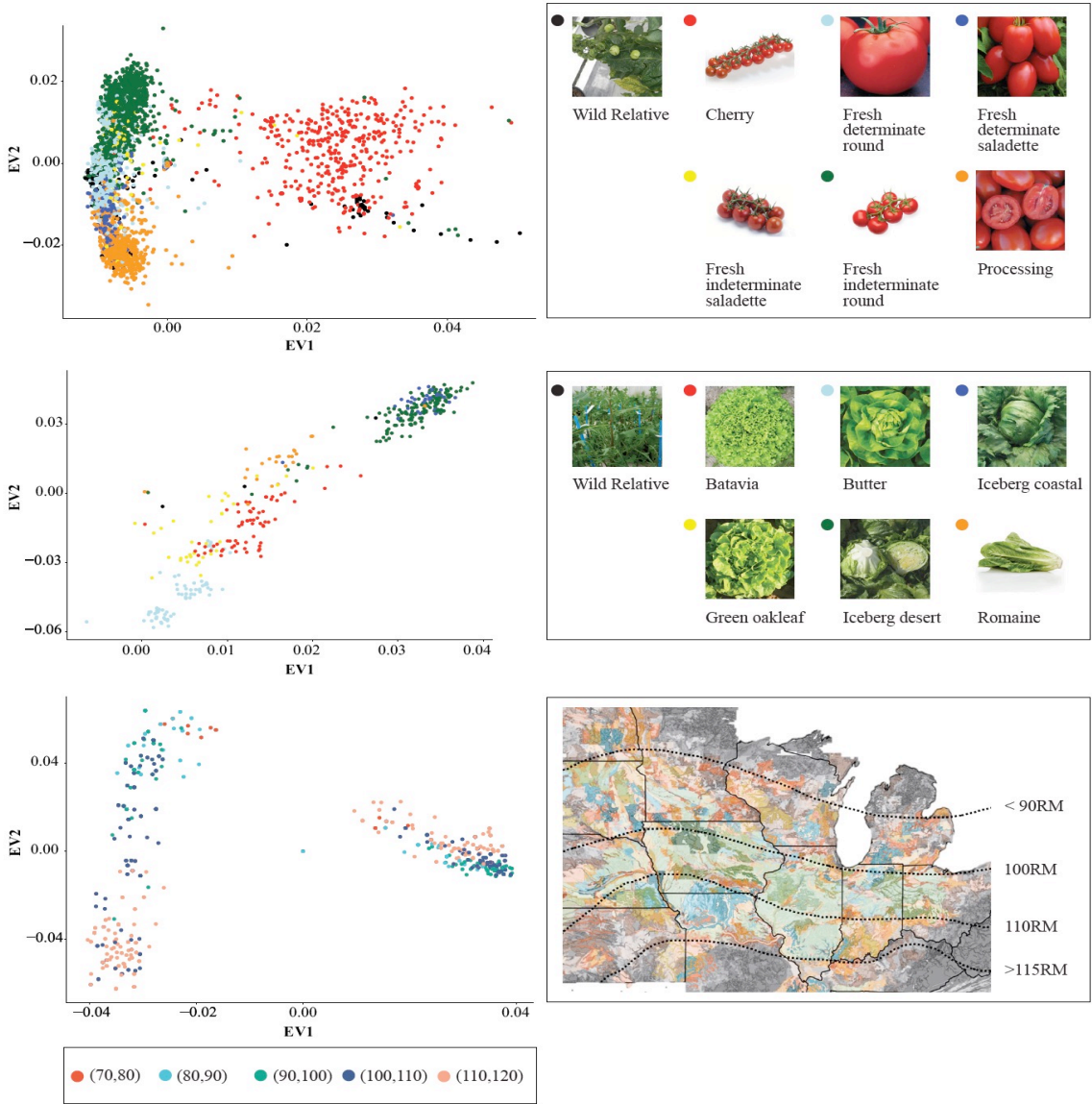
- ✓ Insertion
- ✓ Efficacy
- ✓ Genetic and environmental stability in plants

Has modern plant breeding exhausted
genetic diversity?

Genetic Diversity is Actively Maintained While Improving Performance (Wheat)



Genetic Diversity is Actively Maintained in Commercial Breeding for Desirable Consumer Traits



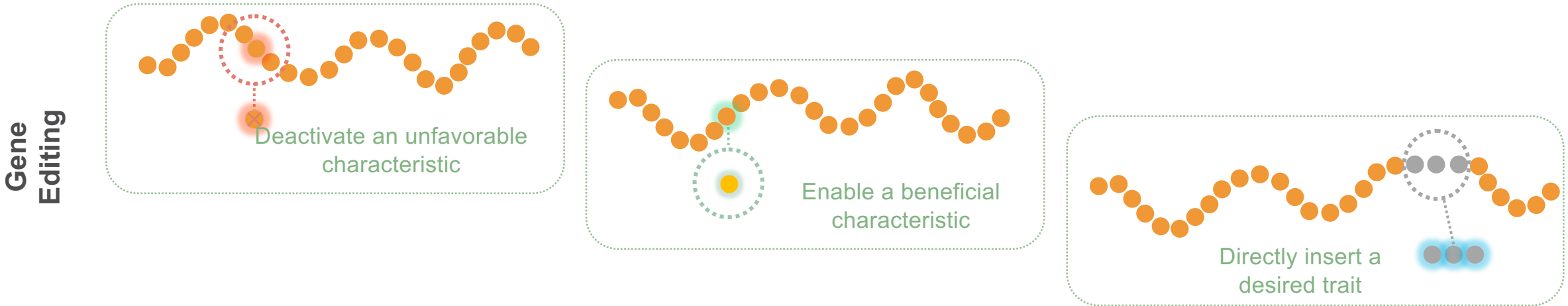
Commercial Breeding Utilize Genetic Diversity for Different Environments



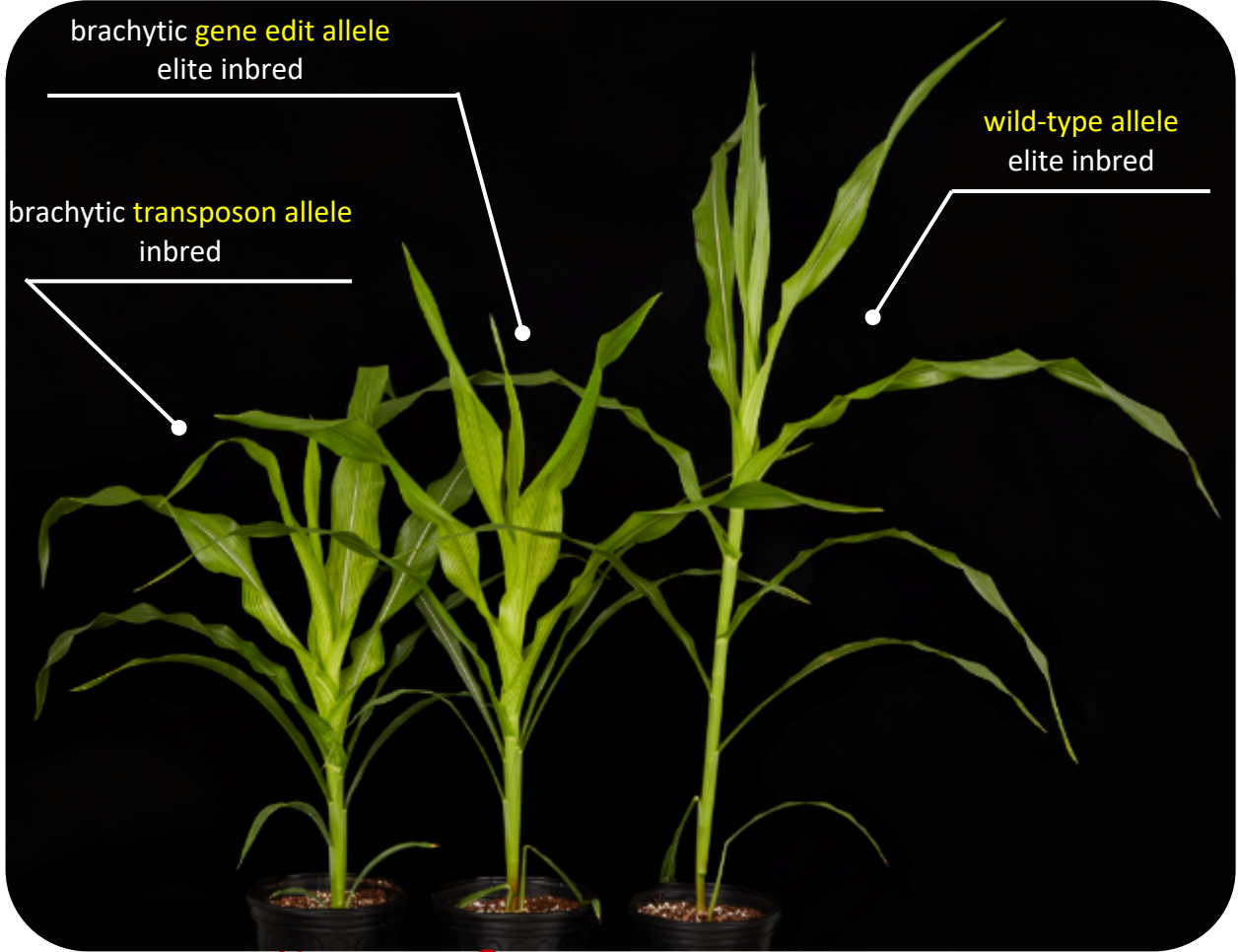
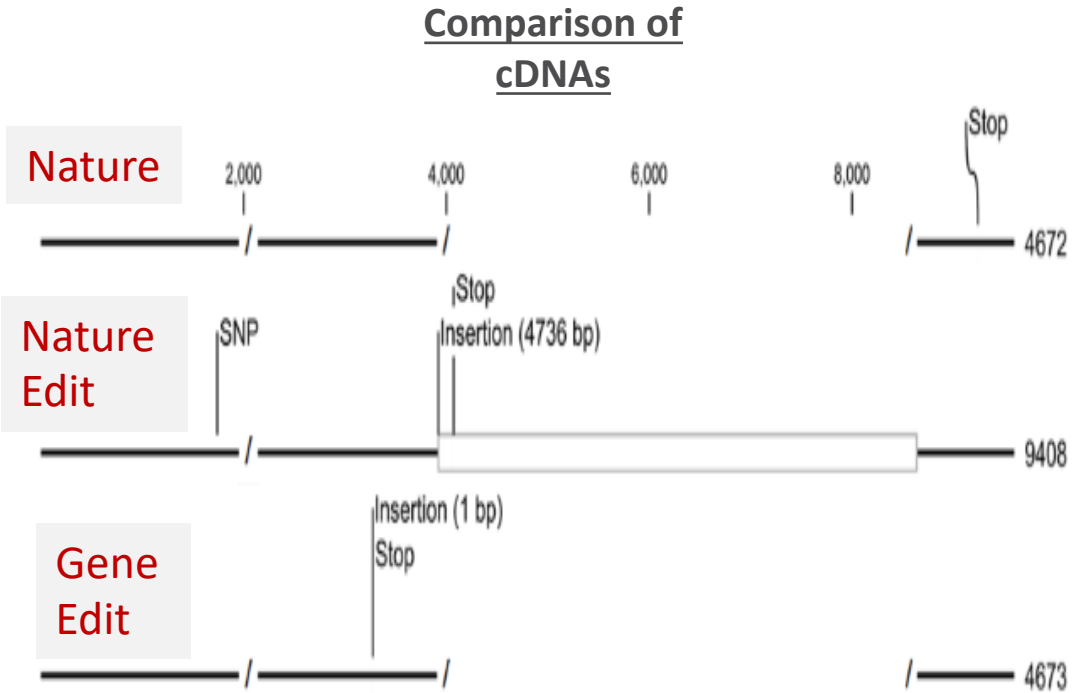
How Can Genome Editing Be Used in Plant Breeding?

Genome Editing Sits at the Interface of Breeding and Genetic Modification

Genome Editing is the Latest Tool in the Breeder's Toolkit

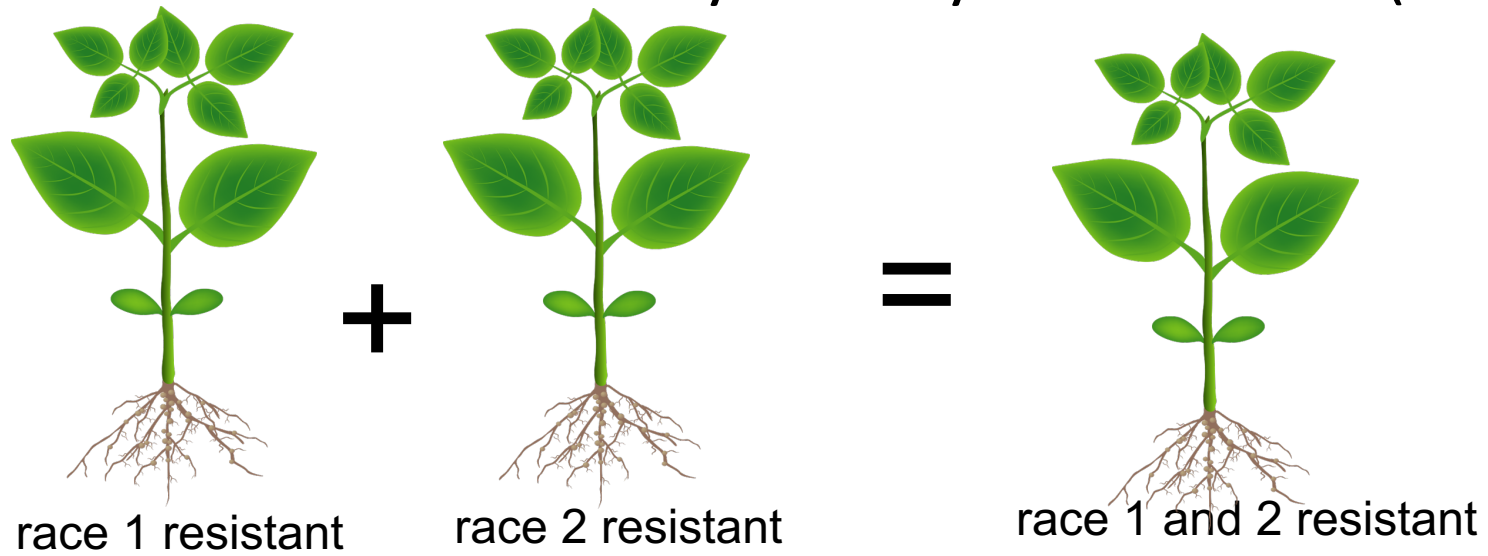


Genome Editing Can Make Precise Changes Mimicking Natural Changes

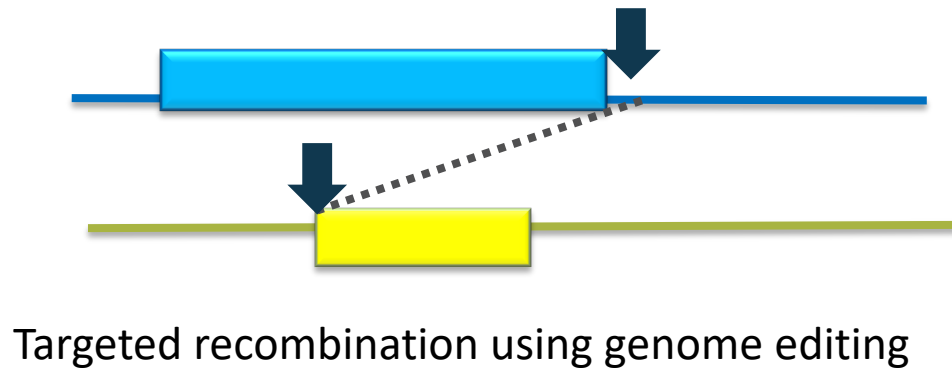
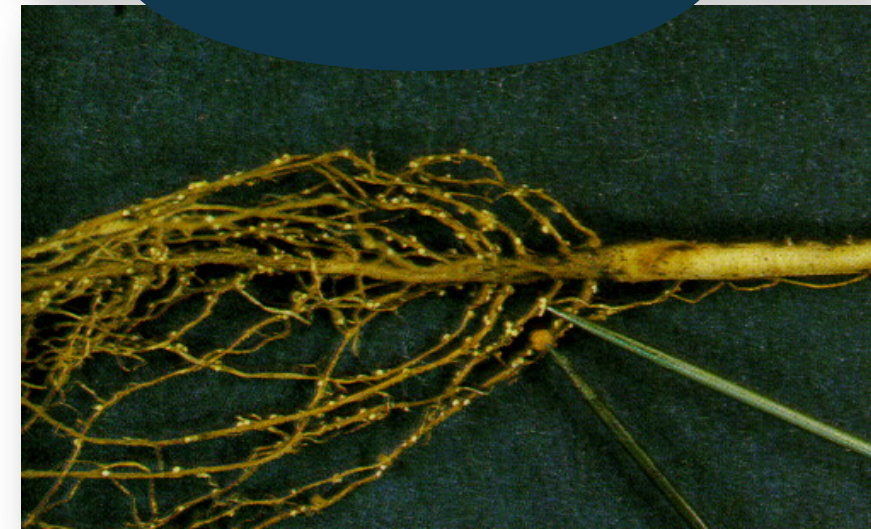


Nature Edit Gene Edit Nature

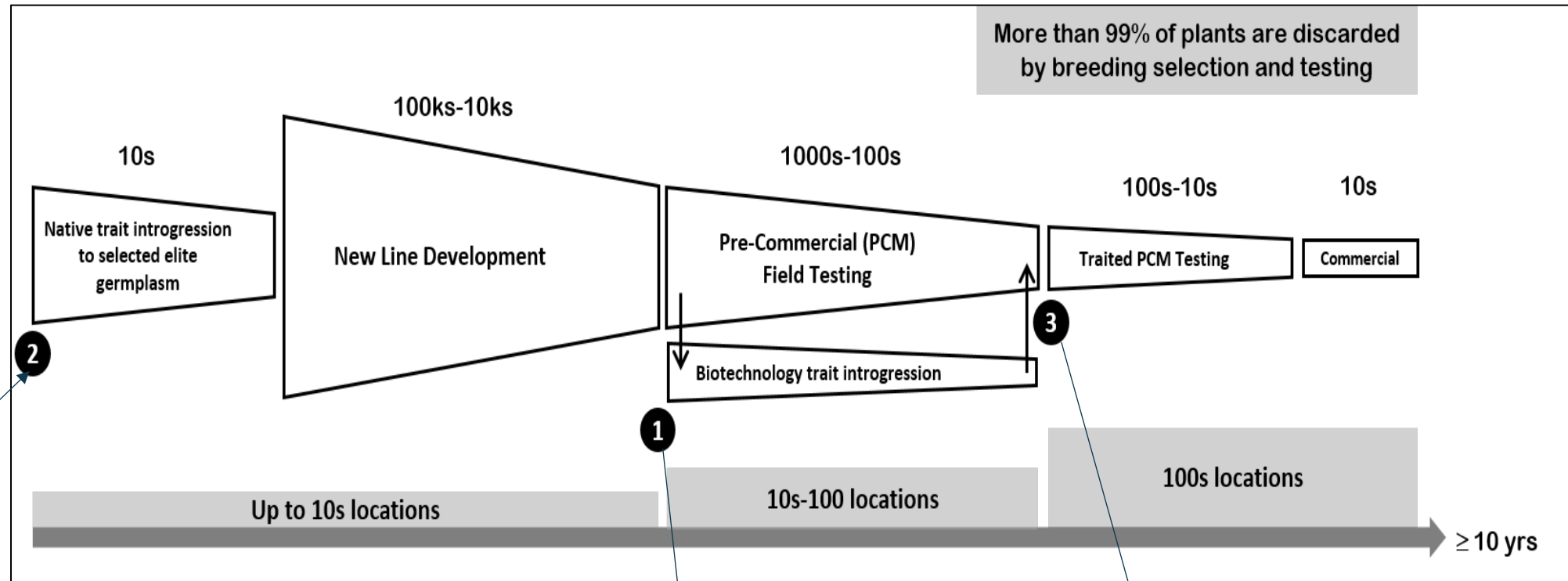
Genome Editing Can Overcome Limitations of Conventional Breeding Approach: Soybean Cyst Nematode (SCN) Disease



\$1B loss per year



Genome Edits, Just Like Biotech and Conventionally Bred Crops, Go Through Rigorous Field Testing

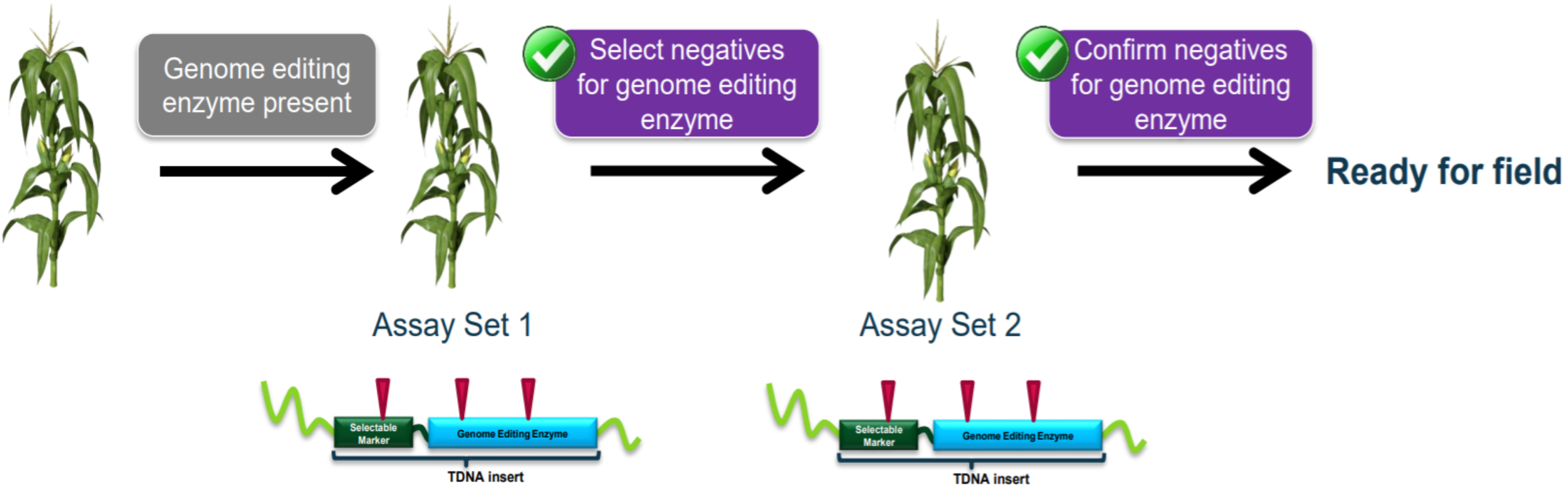


✓ Create Diversity

✓ Make edits in the elite plants directly replacing backcrossing

Make edits in after biotech trait introgression

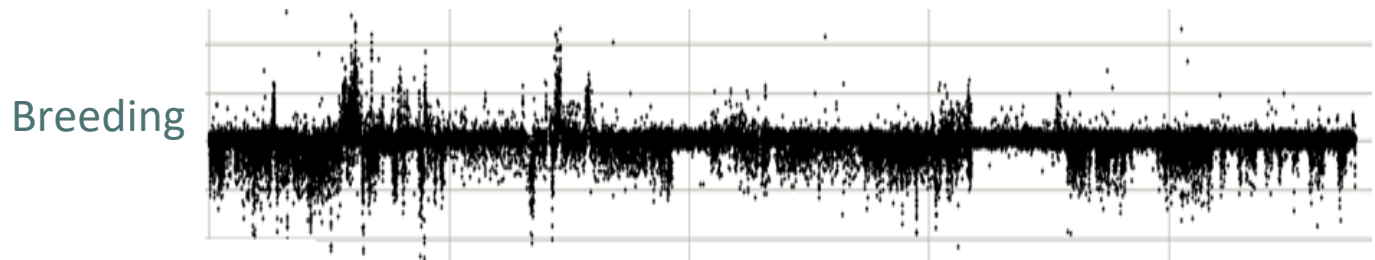
Gene Editing Screening Assays Ensures Clean Edit For Field Testing



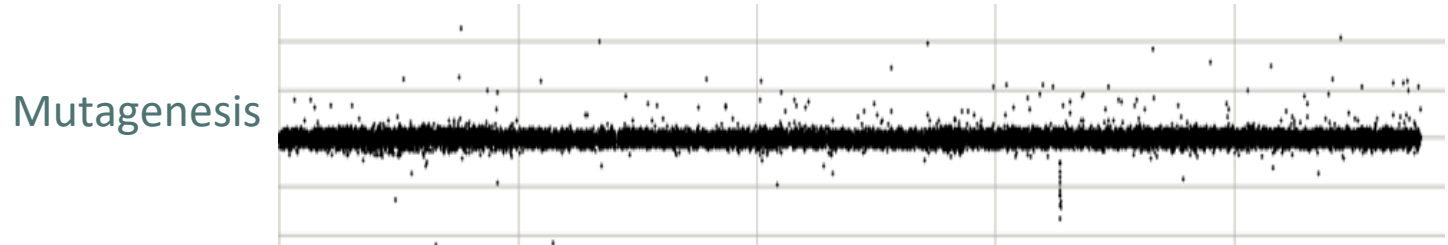
Before Field Testing

- Unintended effects: develop edit-specific assay
- Potential human error: add selection step between assay points
- Prevent cross pollination: perform selection before flowering

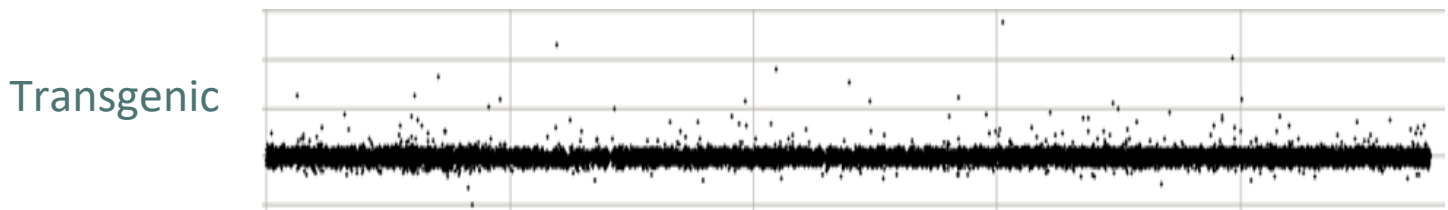
Contribution of Technologies to Genomic Stability and Variation is Negligible



✓ Safe

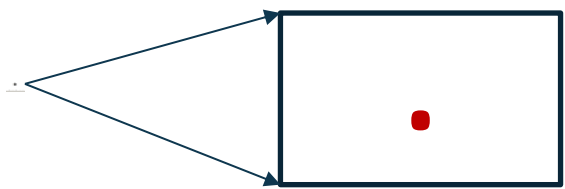


✓ Safe



✓ Safe

Genome Editing



✓ Safe

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Thank You!