Amazing Germplasm

Traditional Genetics

International Collaboration

DNA-Based Technologies

Cultivar Development Pipeline

Genomics Research Advances

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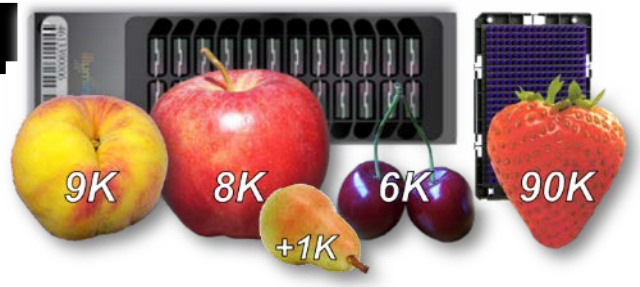


Cameron Peace, Nahla Bassil, Michael Coe, Chad Finn, Ksenija Gasic, Stan Hokanson, Jim Luby, Dorrie Main, Jim McFerson, Jay Norelli, Mercy Olmstead, Vance Whitaker, Chengyan Yue, and Amy Iezzoni

Outline of Presentation

United States Department of Agriculture

National Institute of Food and Agriculture

1. Amazing Germplasm × Traditional Genetics
2. International Collaboration × DNA-Based Technologies
3. Cultivar Development Pipeline × Genomics Research Advances

RosBREED

DISEASE RESISTANCE × HORTICULTURAL QUALITY → SUPERIOR CULTIVARS

WWW.ROSBREED.ORG

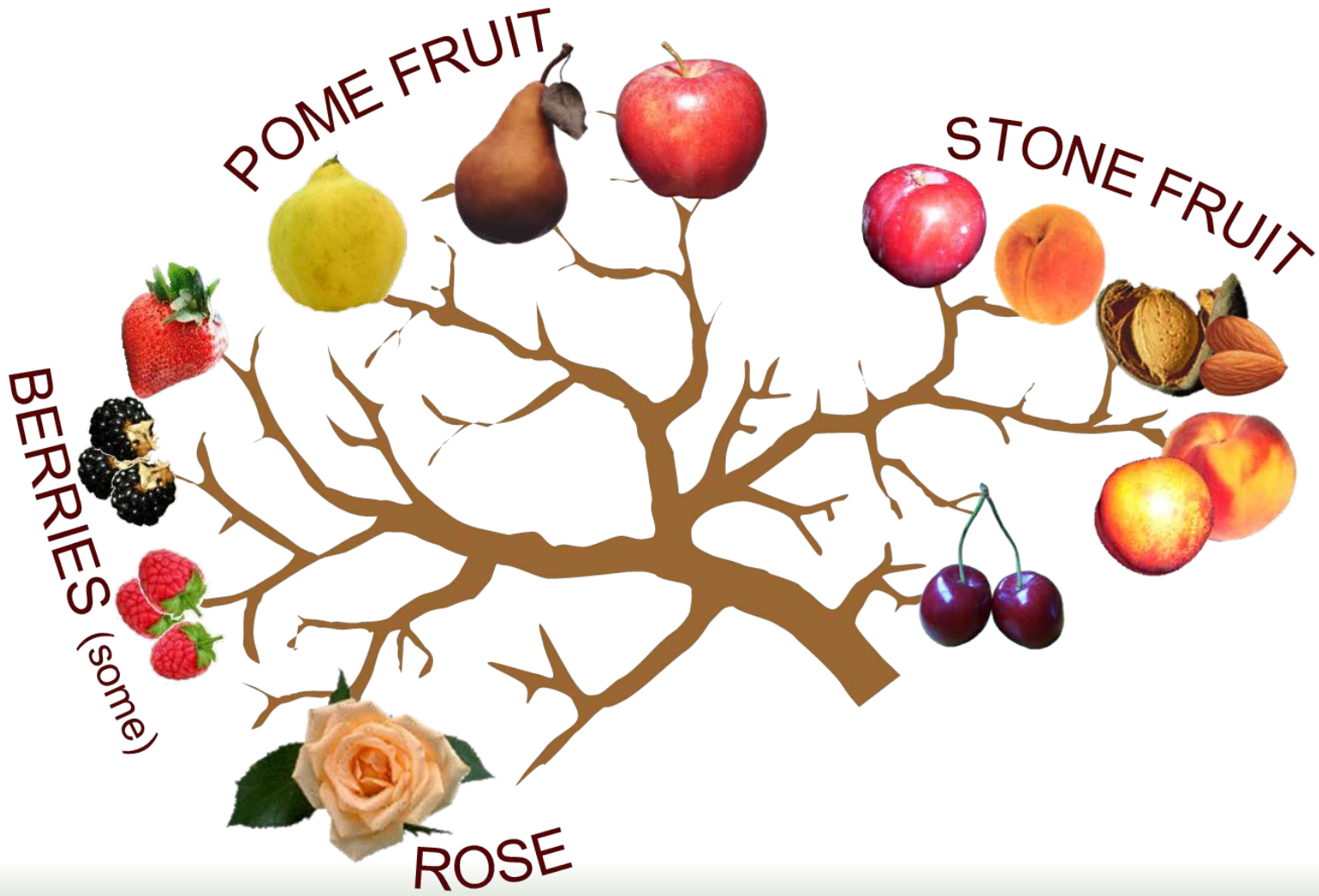
1

Amazing Germplasm

Traditional Genetics

Cultivar Development Pipeline

The Rosaceae Family



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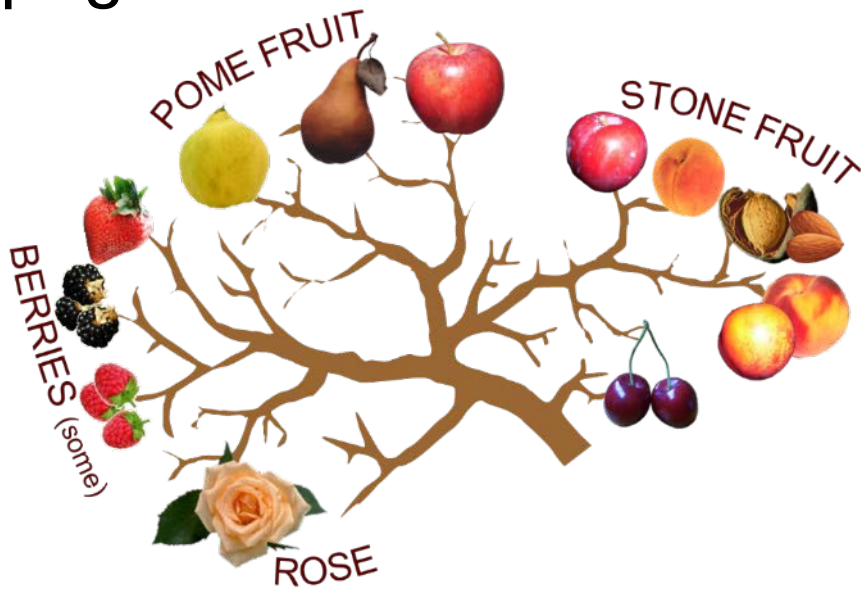
DISEASE RESISTANCE + HORTICULTURAL QUALITY

Amazing Germplasm!

Features of Rosaceous Crops

- Product quality is paramount
- Clonally propagated
- Perennial



- Often long juvenility
- Often obligate outcrossers
- Often high heterozygosity
- Sometimes polyploid

- Few generations in cultivation, much diversity in primary genepools
  → huge genetic gains possible

Traditional Genetics

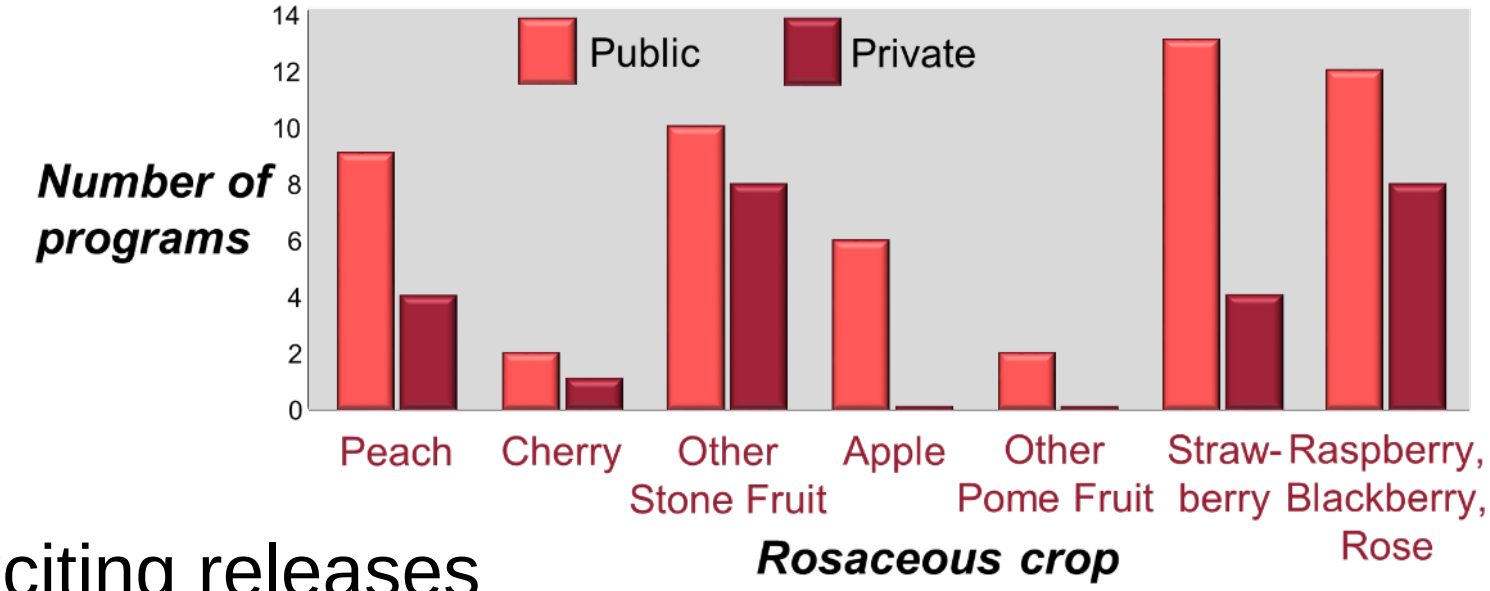
- Crossing & selecting mostly by phenotype
- Quantitative genetics rarely used
- Breeders often rely on serendipity

Challenges: large plant sizes, long juvenility, disease resistances combined with superior quality

Cosmic Crisp™ brand WA 38, an eye-catching, large, dark red apple

→ Cultivar Development Pipelines

- Need for much public breeding (some crops/regions not commercially viable?)



- Many exciting releases

- Cultivar development pipelines are functional but inefficient

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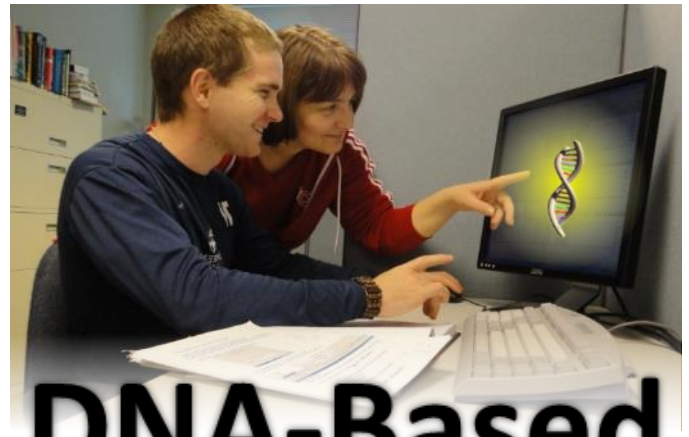
DISEASE RESISTANCE + HORTICULTURAL QUALITY

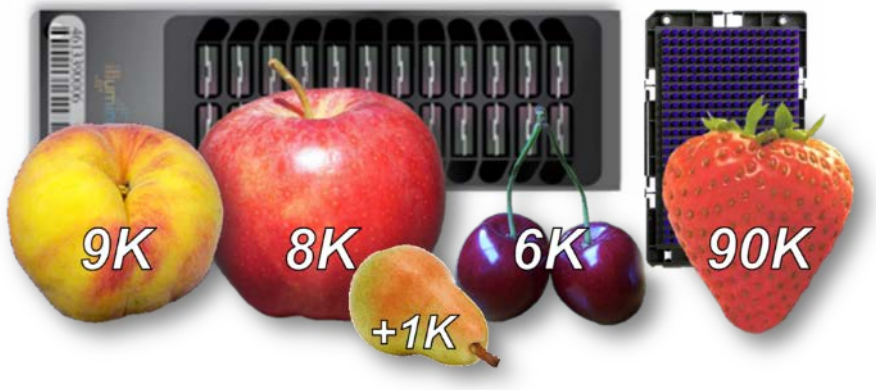
2

International Collaboration

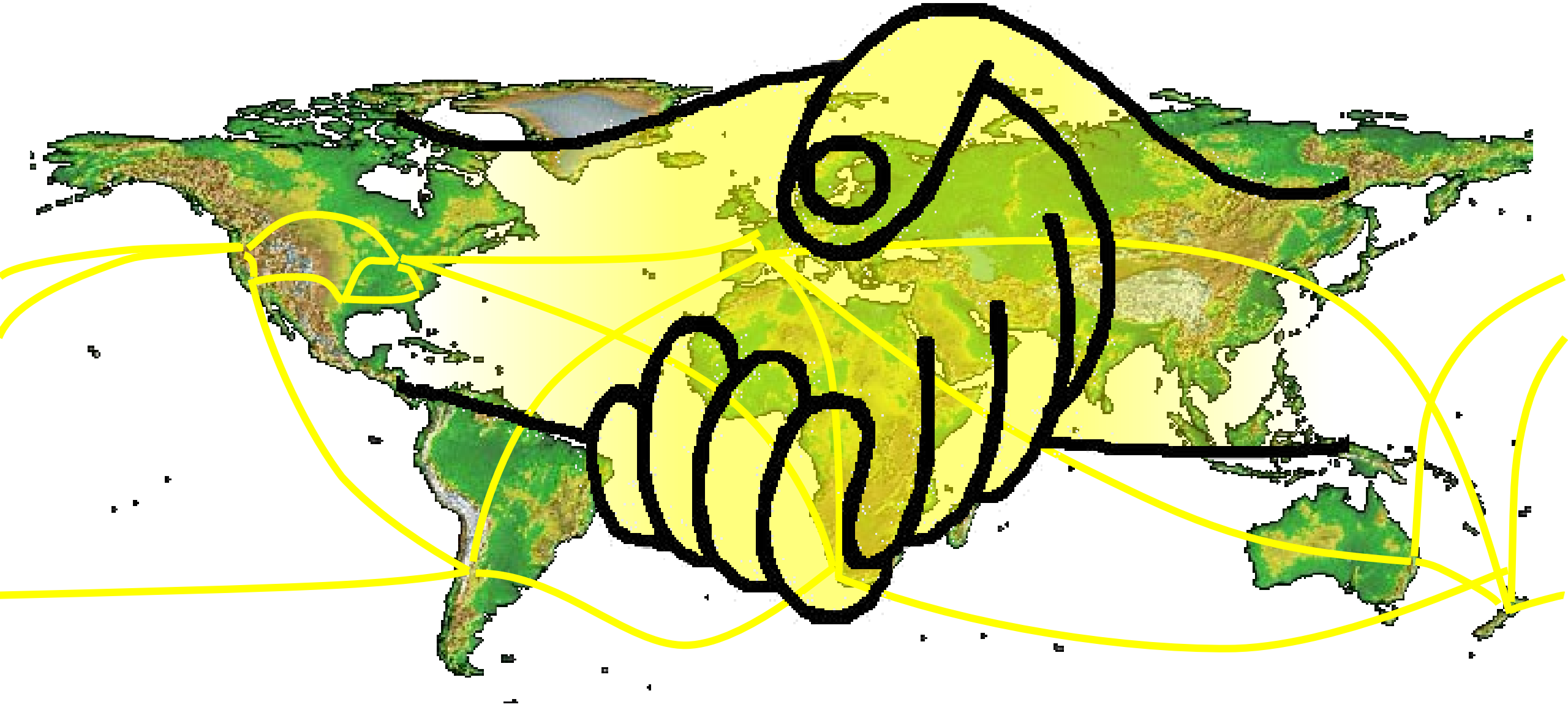


DNA-Based Technologies

Genomics Research Advances



Strong Spirit of Collaboration

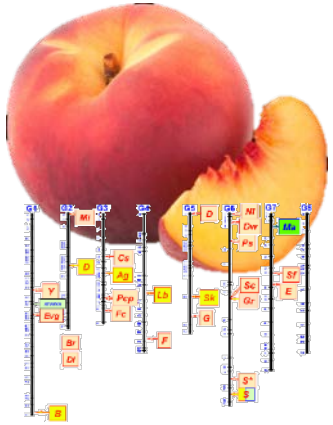


International Research Community Hub

Rosaceae Community Collaboration

2003

International Rosaceae Genomics Conferences



US–Eur Rosaceae Mapping Consortium

U.S.

RGC2

Technology Roadmap for Tree Fruit Production

GDR Genome Database for Rosaceae

2005 NEW Z'LAND

RGC3

White Paper: US Rosaceae Genomics, Genetics, & Breeding Initiative

2007 CHILE

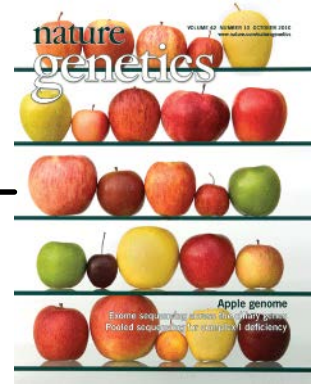
RGC4

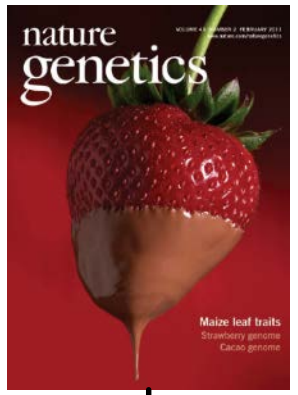
US RosEXEC

2009 S. AFRICA

RGC5

Whole genome sequences



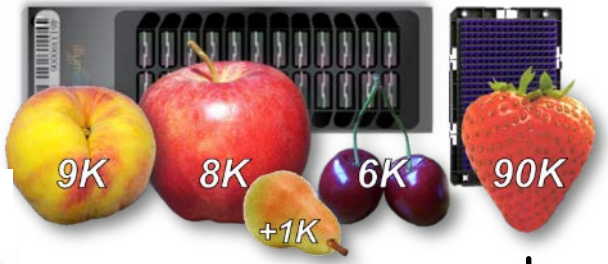


ITALY

2011

RGC 6

2013



SNP arrays

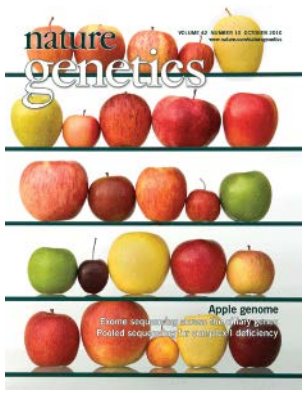
U.S.

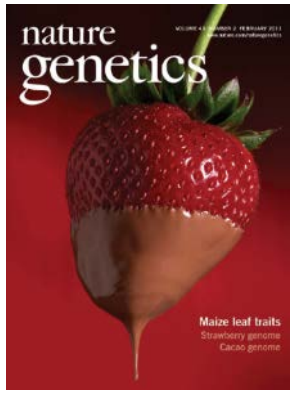
RGC7

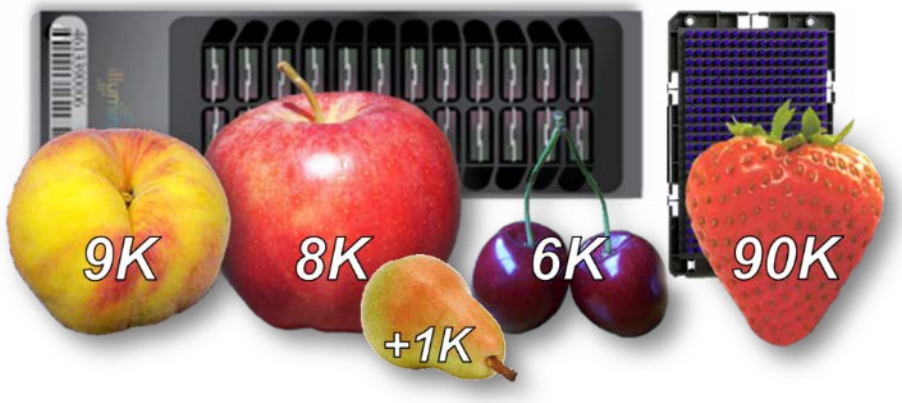
2015

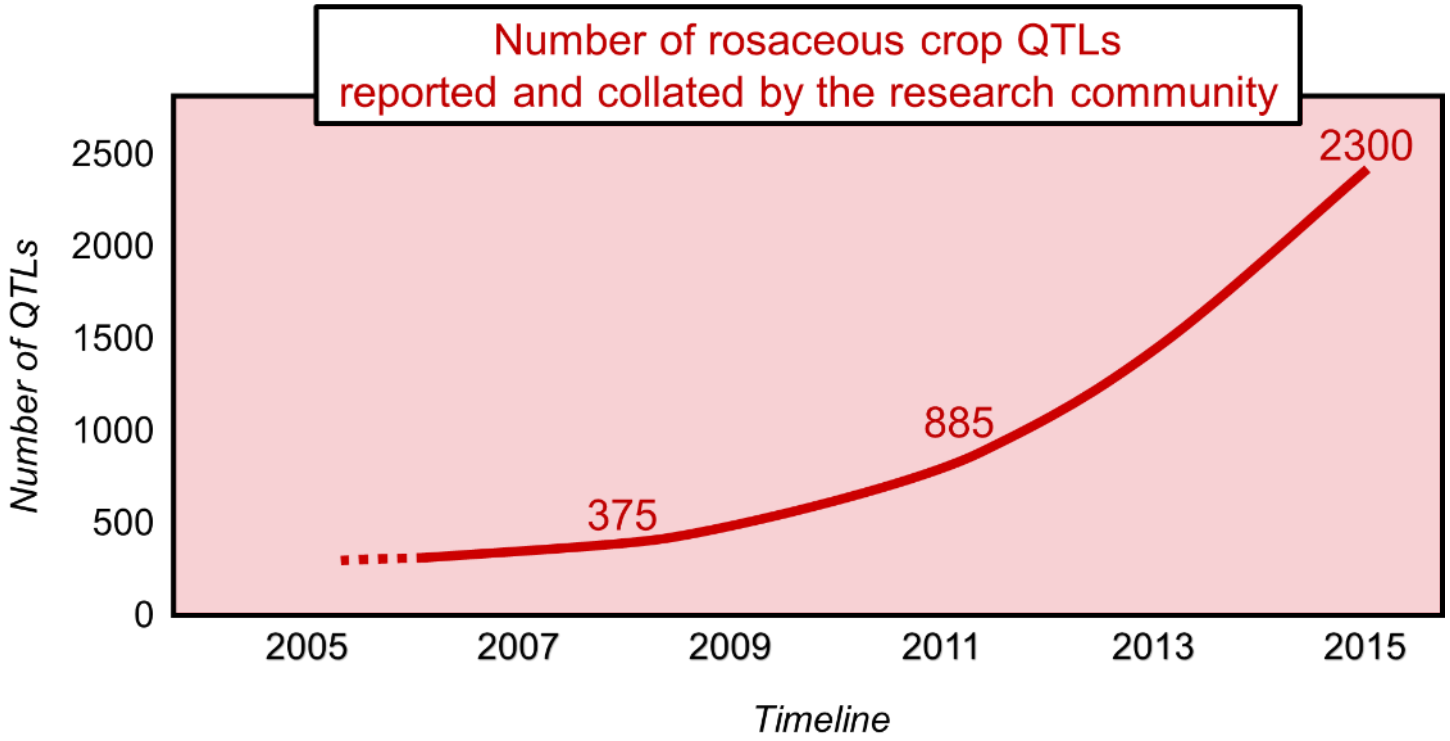
Rosaceae Specialty Crops Planning Workshop

→ Genomics Research Advances









- Powerful genomics resources and many discoveries
- Little translation to breeding application

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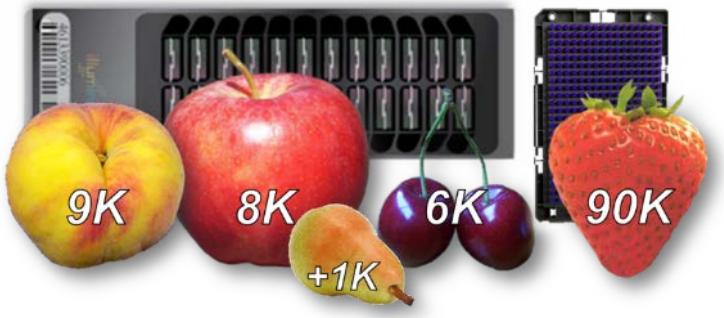
DISEASE RESISTANCE + HORTICULTURAL QUALITY

3

Cultivar Development Pipeline



Genomics Research Advances

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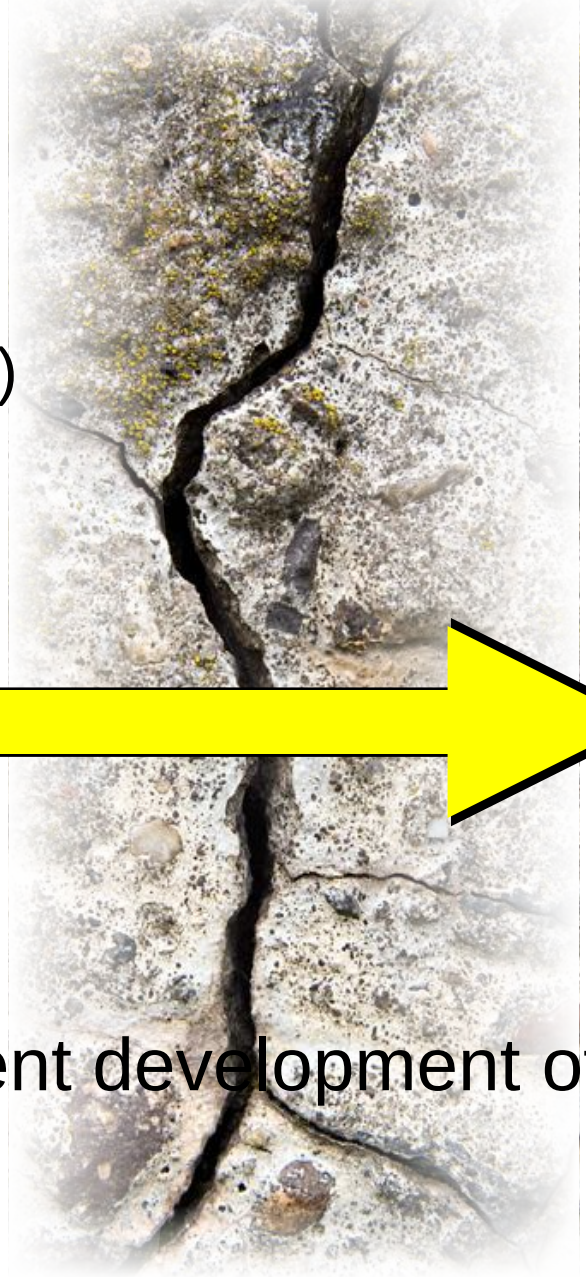
Genomics-Assisted Breeding

Genomics resources
(e.g., whole genome sequences)

Genomics Research

DNA information



Decision support

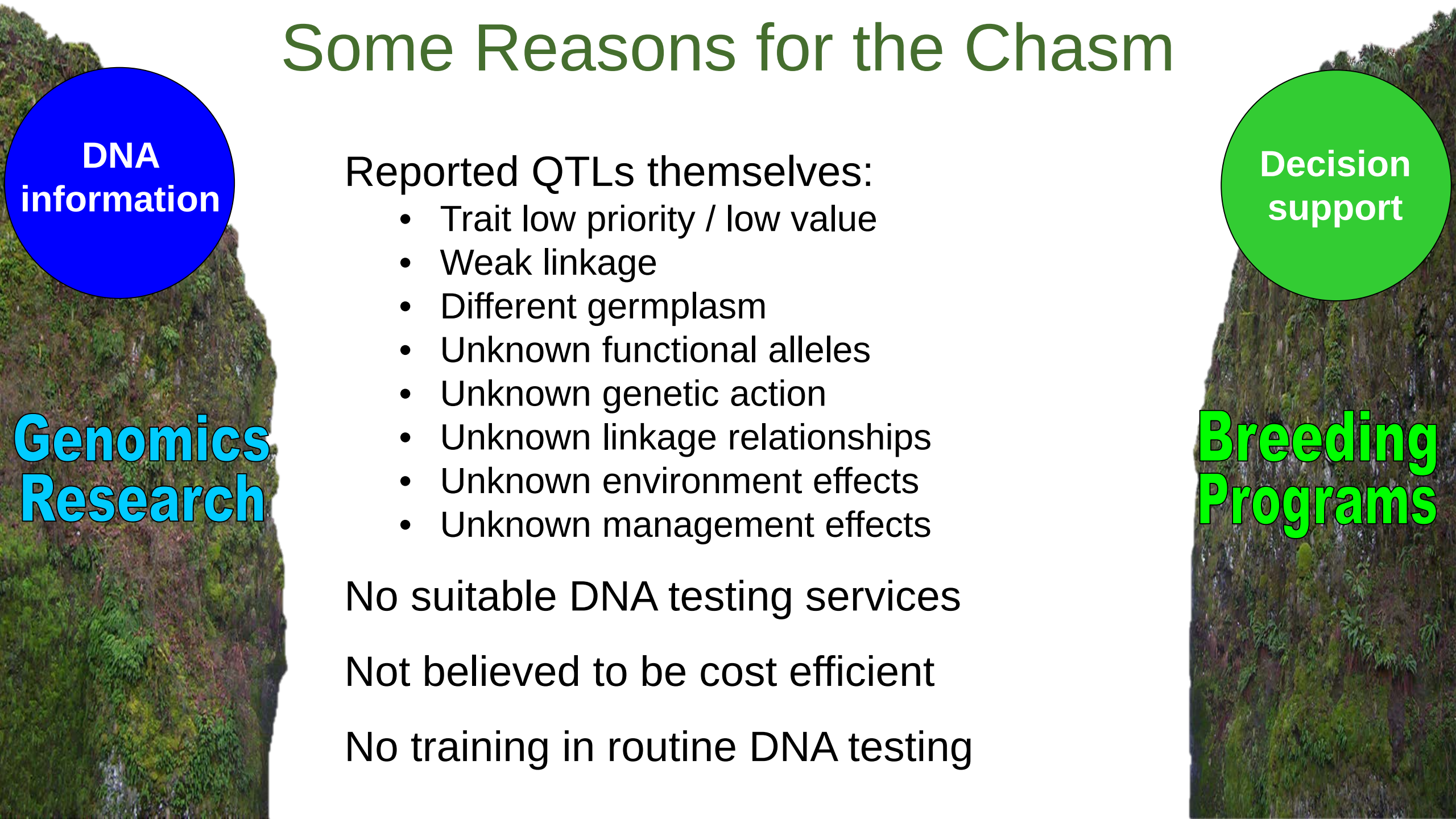
Breeding Programs

More efficient development of new cultivars

The Chasm!

DNA information
good intentions
skeptical dismissal
Decision support
Genomics Research
Breeding Programs

Some Reasons for the Chasm



Reported QTLs themselves:

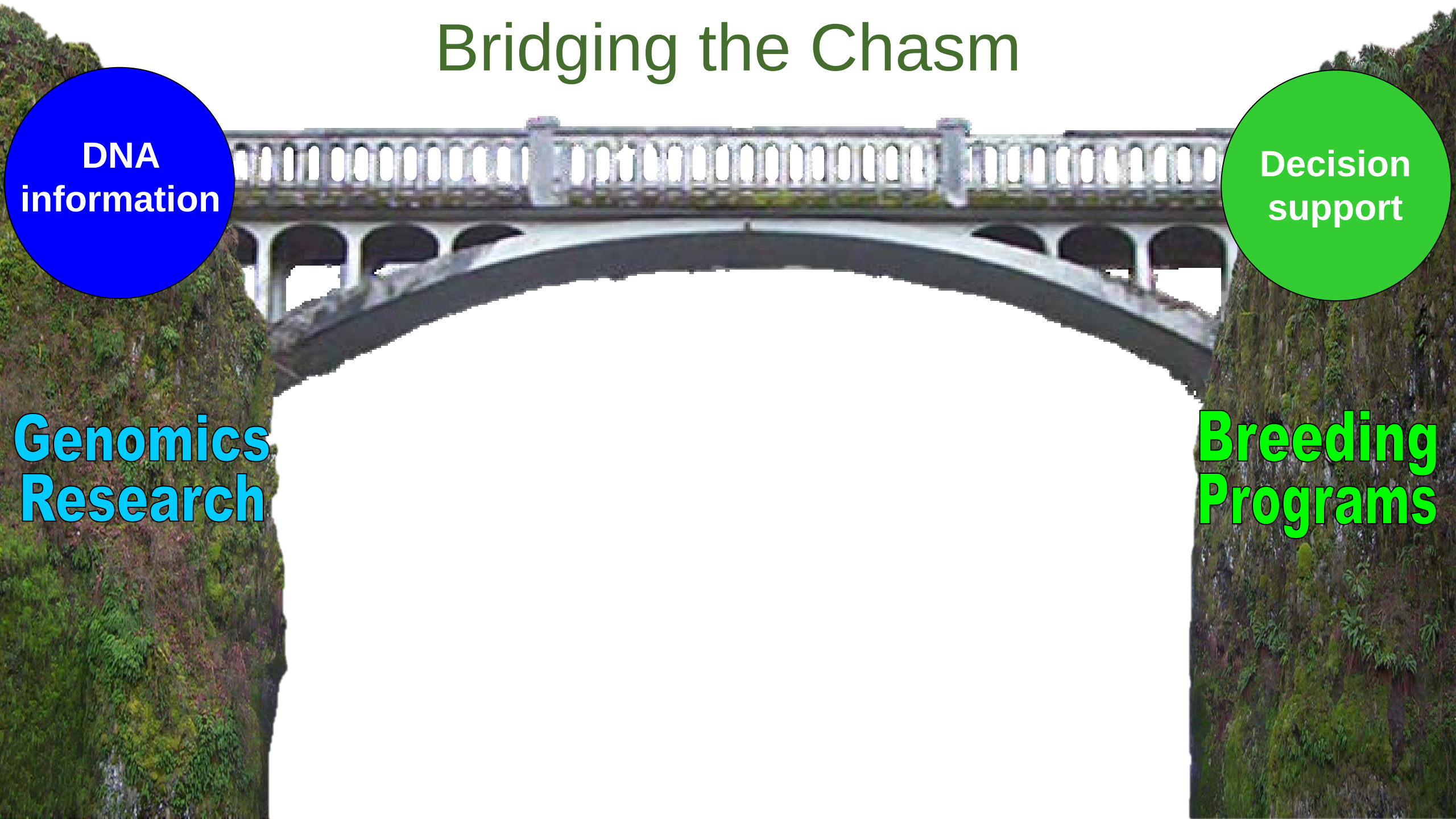
- Trait low priority / low value
- Weak linkage
- Different germplasm
- Unknown functional alleles
- Unknown genetic action
- Unknown linkage relationships
- Unknown environment effects
- Unknown management effects

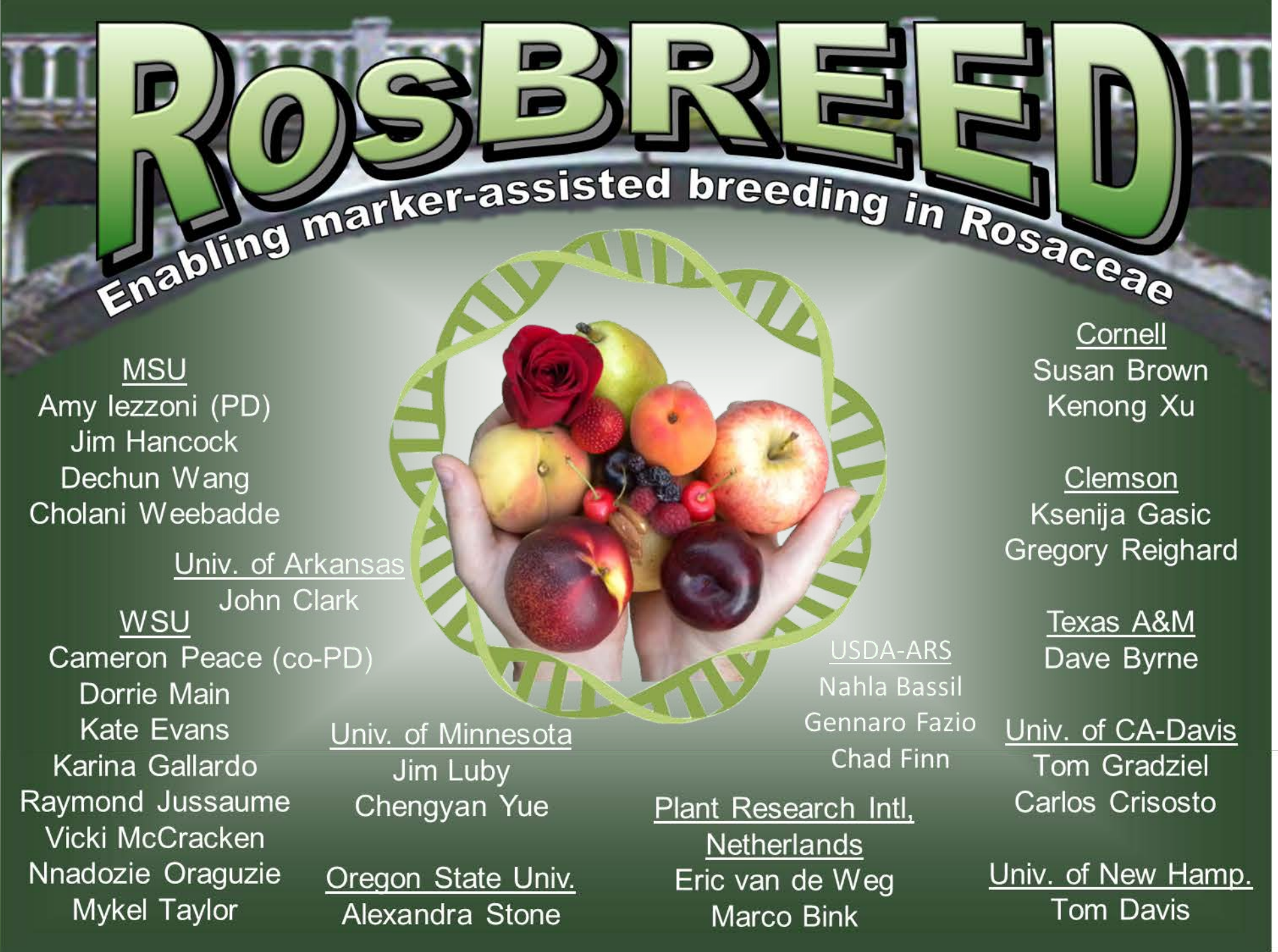
No suitable DNA testing services

Not believed to be cost efficient

No training in routine DNA testing

Bridging the Chasm





"RosBREED 1"

- Funded by USDA Specialty Crop Research Initiative
- $7.2 M federal
- Sep 2009 – Aug 2014
- Project Directors:
  Amy Iezzoni
  Cameron Peace

RosBREED 1 Outcomes

- Socio-economic values for levels of breeding traits
- Genomics resources and DNA information:
  SNP array genome scans, QTLs

RosBREED 1 Outcomes

- Practical tools for breeding use:
  DNA tests for many breeding-relevant traits

- DNA information about breeding germplasm:
  genetic potential of parents, seedlings, selections, cultivars

DNA Tests in 2009

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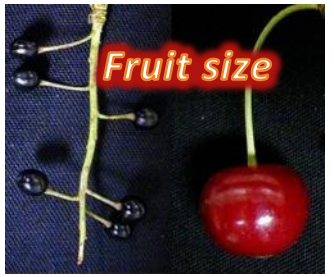
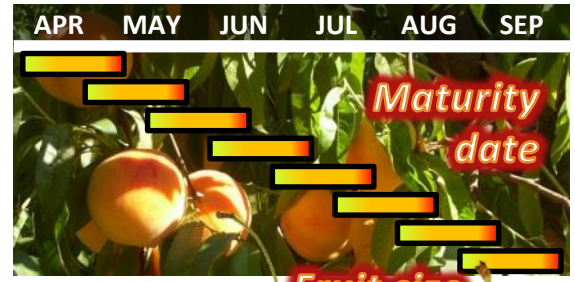
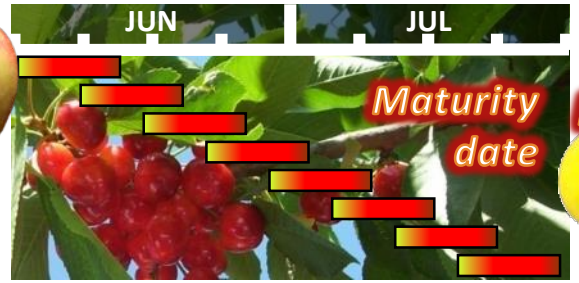
DISEASE RESISTANCE + HORTICULTURAL QUALITY

DNA Tests Now







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DISEASE RESISTANCE + HORTICULTURAL QUALITY

RosBREED 1 Outcomes

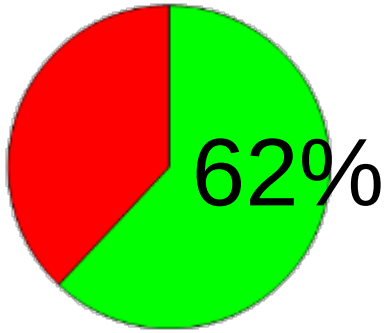
- Trained the next generation of breeders!

… and many of the current generation

RosBREED 1 Outcomes

- DNA-informed breeding is now conventional!

U.S.-wide survey of Rosaceae breeders (early 2014):



Agree that “Genetic marker information will be included in 2014 in how my organization addresses plant breeding & selection”

RosBREED

COMBINING DISEASE RESISTANCE WITH HORTICULTURAL QUALITY IN NEW ROSACEOUS CULTIVARS

MSU
Amy Iezzoni (PD)
Jim Hancock
Bill Shane

Cornell Univ
Susan Brown

Univ New Hampshire
Tom Davis

WSU
Cameron Peace (coPD)
Lisa DeVetter
Kate Evans
Karina Gallardo
Des Layne
Dorrie Main
Vicki McCracken
Pat Moore
Nnadozie Oraguzie

Univ Minnesota
Rex Bernardo
Stan Hokanson
Jim Luby
Chengyan Yue

Cal Poly State
Kelly Ivors

Univ Queensland
Craig Hardner

USDA-ARS
Nahla Bassil
Richard Bell
Chad Finn
Jay Norelli

Univ Florida
Mercy Olmstead
Vance Whitaker

Univ Arkansas
John Clark

Clemson Univ
Ksenija Gasic
Steve Kresovich
Amy Lawton-Rauh
Gregory Reighard
Chris Saski
Guido Schnabel

Texas A&M
Dave Byrne

Univ CA-Davis
Tom Gradziel
Carlos Crisosto

"RosBREED 2"

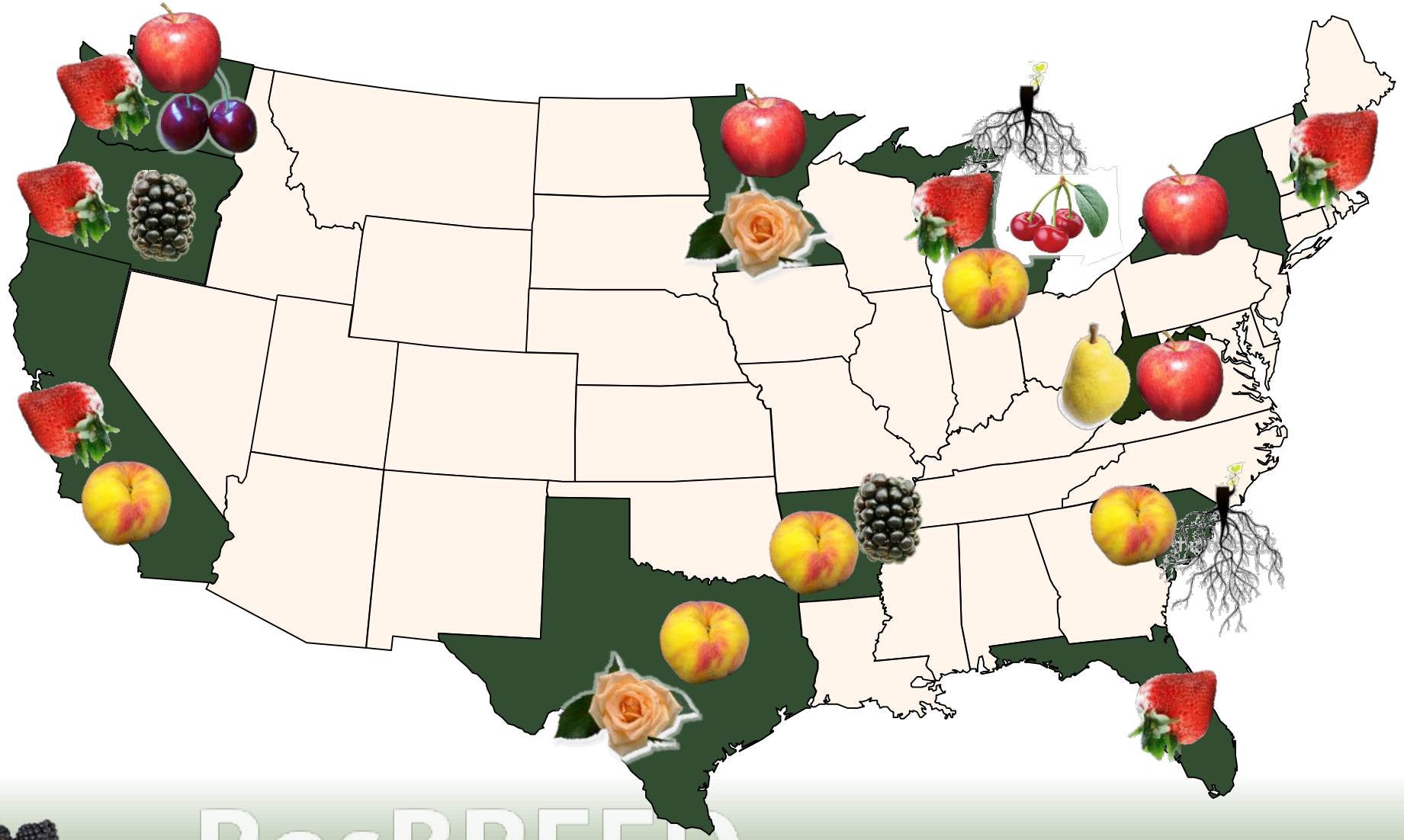
- Funded by USDA Specialty Crop Research Initiative
- $10.0 M federal
- Sep 2014 – Aug 2019
- Project Directors: *Amy Iezzoni* *Cameron Peace*

RosBREED 2 Vision

U.S. rosaceous crop breeding programs
will exploit genetic resources,
applying modern genomics tools
to efficiently, accurately, creatively, and rapidly deliver
new cultivars with market-essential horticultural quality
and producer-required disease resistances
to enhance consumer demand
and mitigate stakeholder risk
for rosaceous fruit, nut, and floral products.

RosBREED
DISEASE RESISTANCE + HORTICULTURAL QUALITY

RosBREED 2 Breeding Programs



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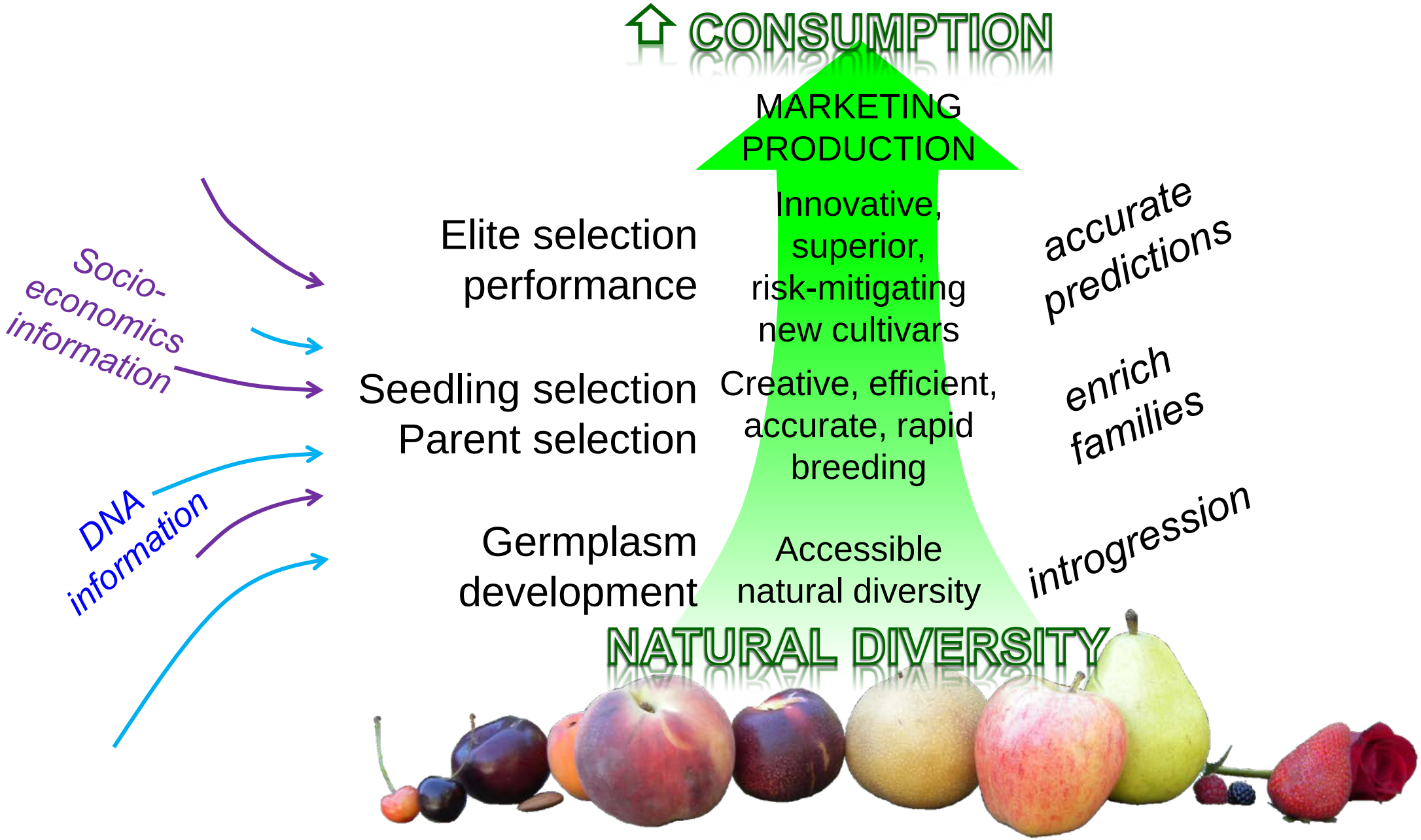
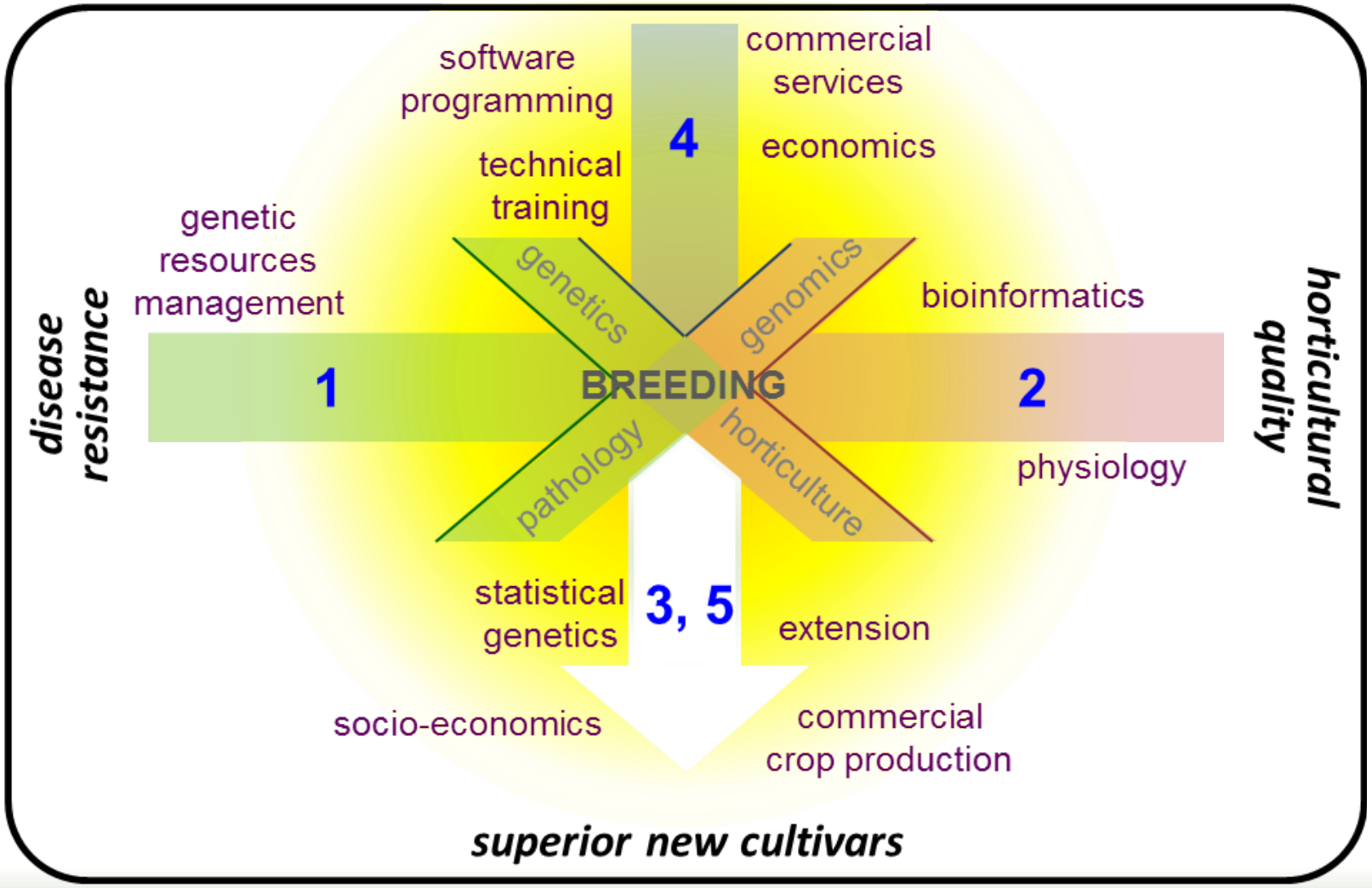
DISEASE RESISTANCE + HORTICULTURAL QUALITY

RosBREED 2 Breedging Germplasm Levels



RosBREED 2 Transdisciplinary Approach

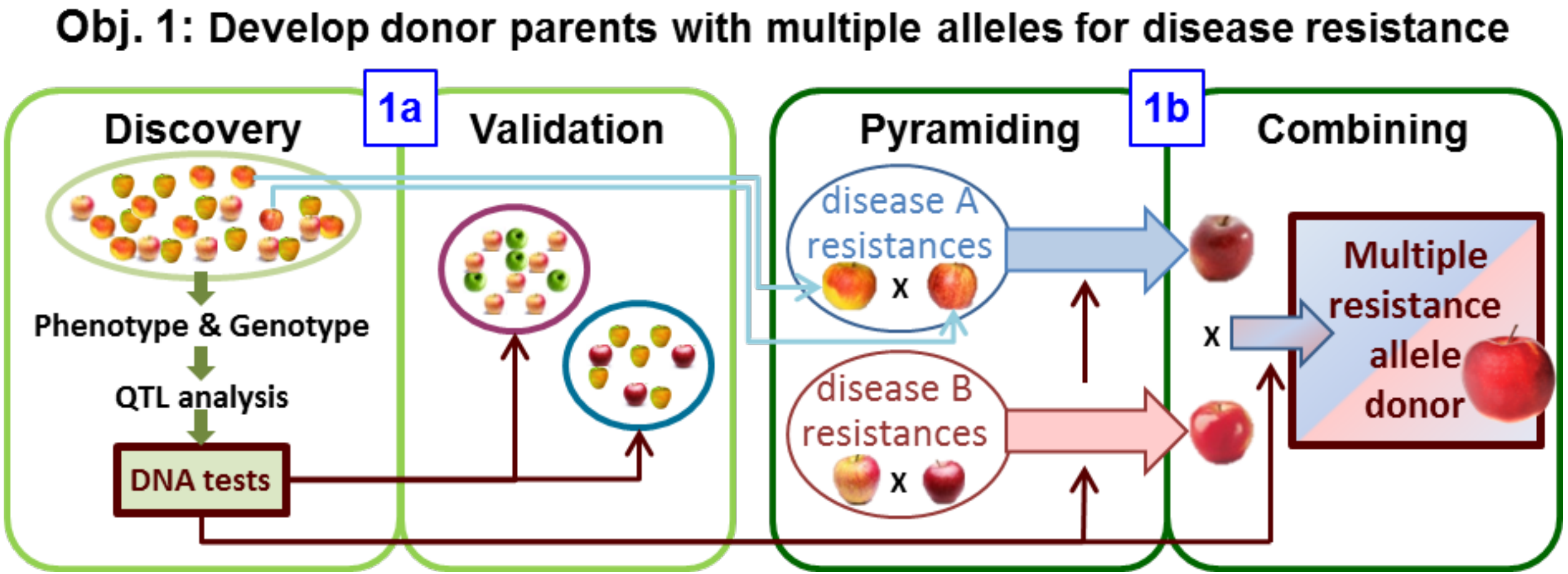


Objectives

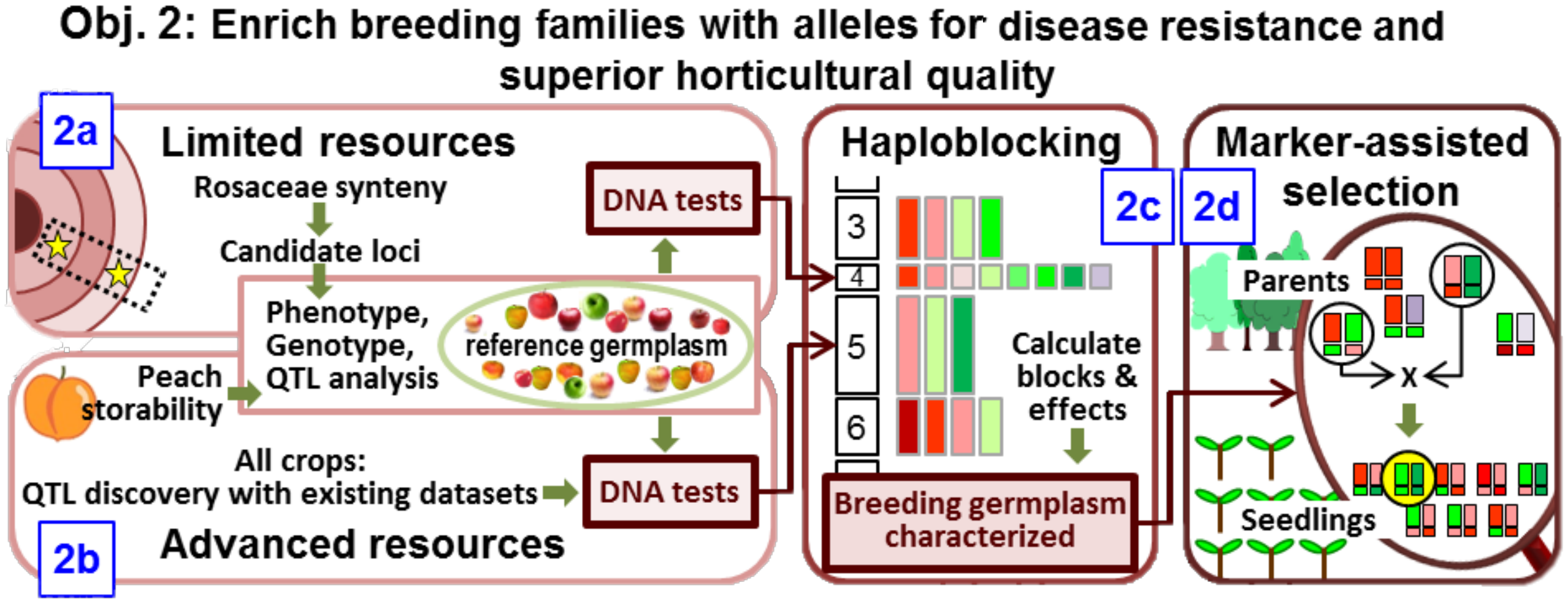
RosBREED

DISEASE RESISTANCE + HORTICULTURAL QUALITY

Objective 1


Obj. 1: Develop donor parents with multiple alleles for disease resistance
1a
1b
Discovery
Validation
Pyramiding
Combining
Phenotype & Genotype
QTL analysis
DNA tests
disease A resistances
x
disease B resistances
x
x
Multiple resistance allele donor

Objective 2



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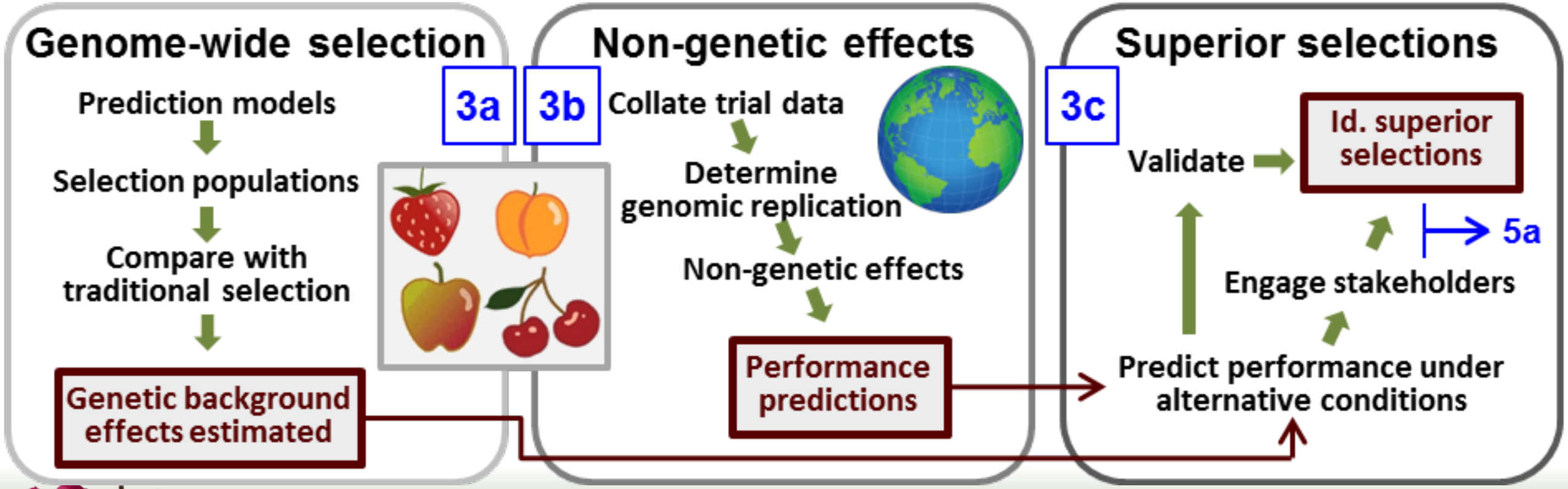
DISEASE RESISTANCE + HORTICULTURAL QUALITY

Objective 3

Obj. 3: Advance selections with alleles for superior horticultural quality and disease resistance with improved confidence



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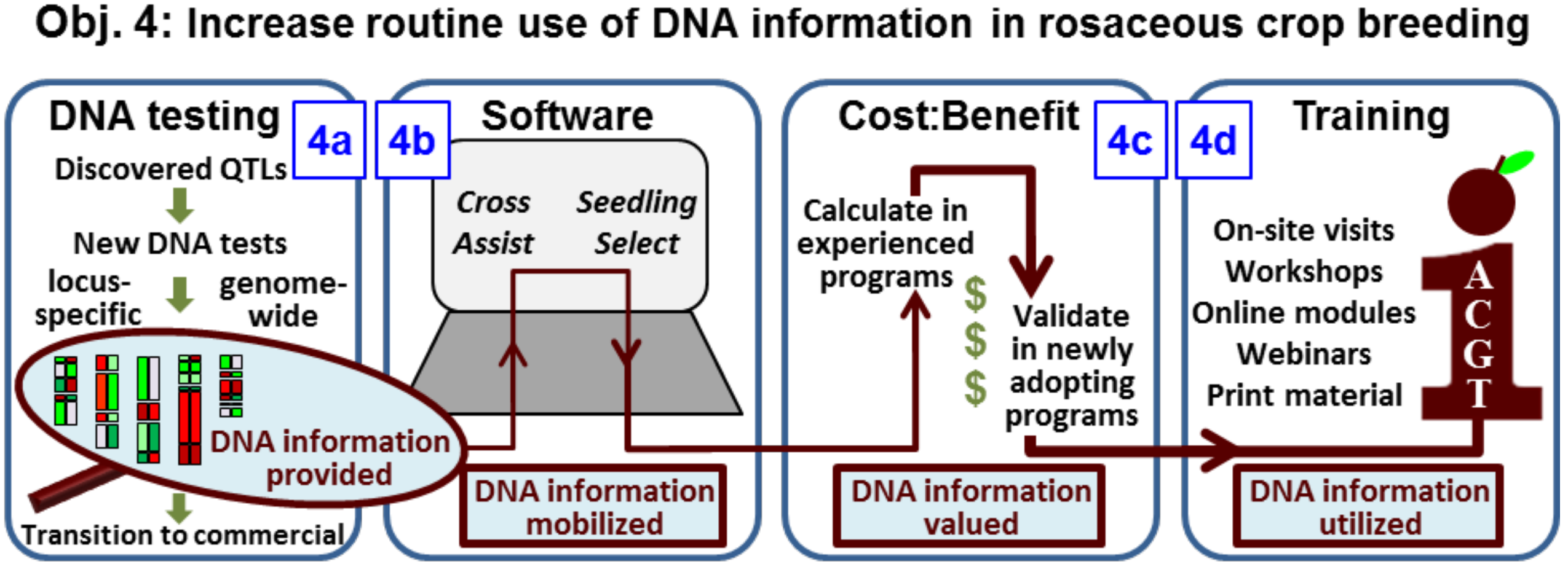
DISEASE RESISTANCE + HORTICULTURAL QUALITY

Objective 4



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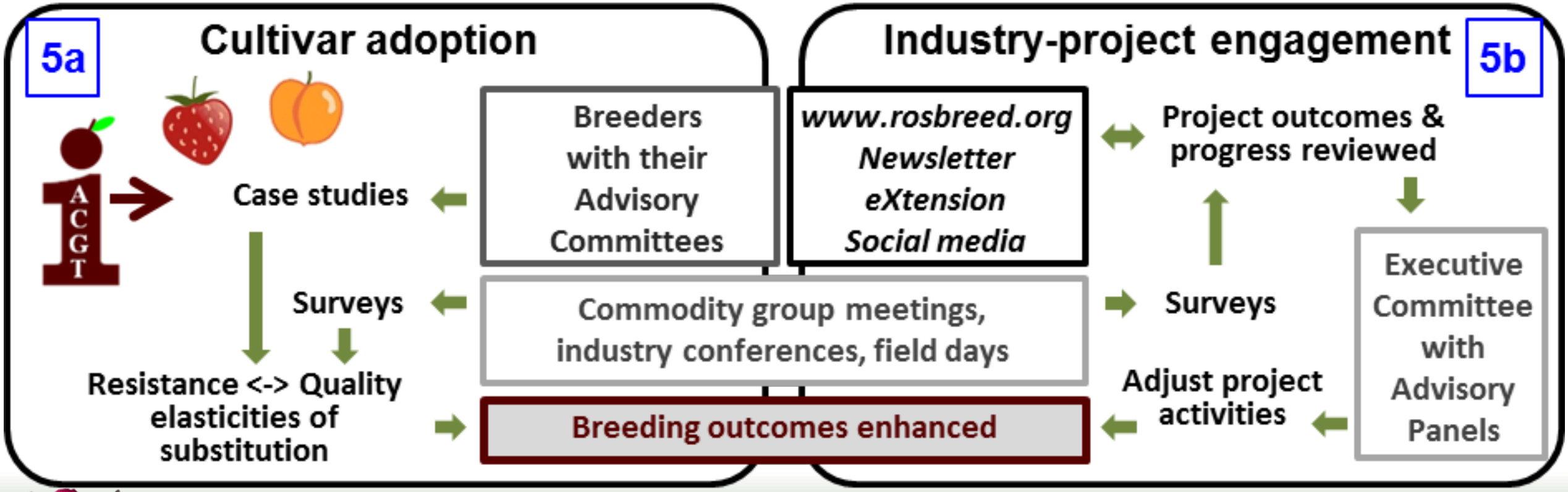
DISEASE RESISTANCE + HORTICULTURAL QUALITY

Objective 5

Obj. 5: Engage industry stakeholders in project outcomes, evaluation, and adjustment



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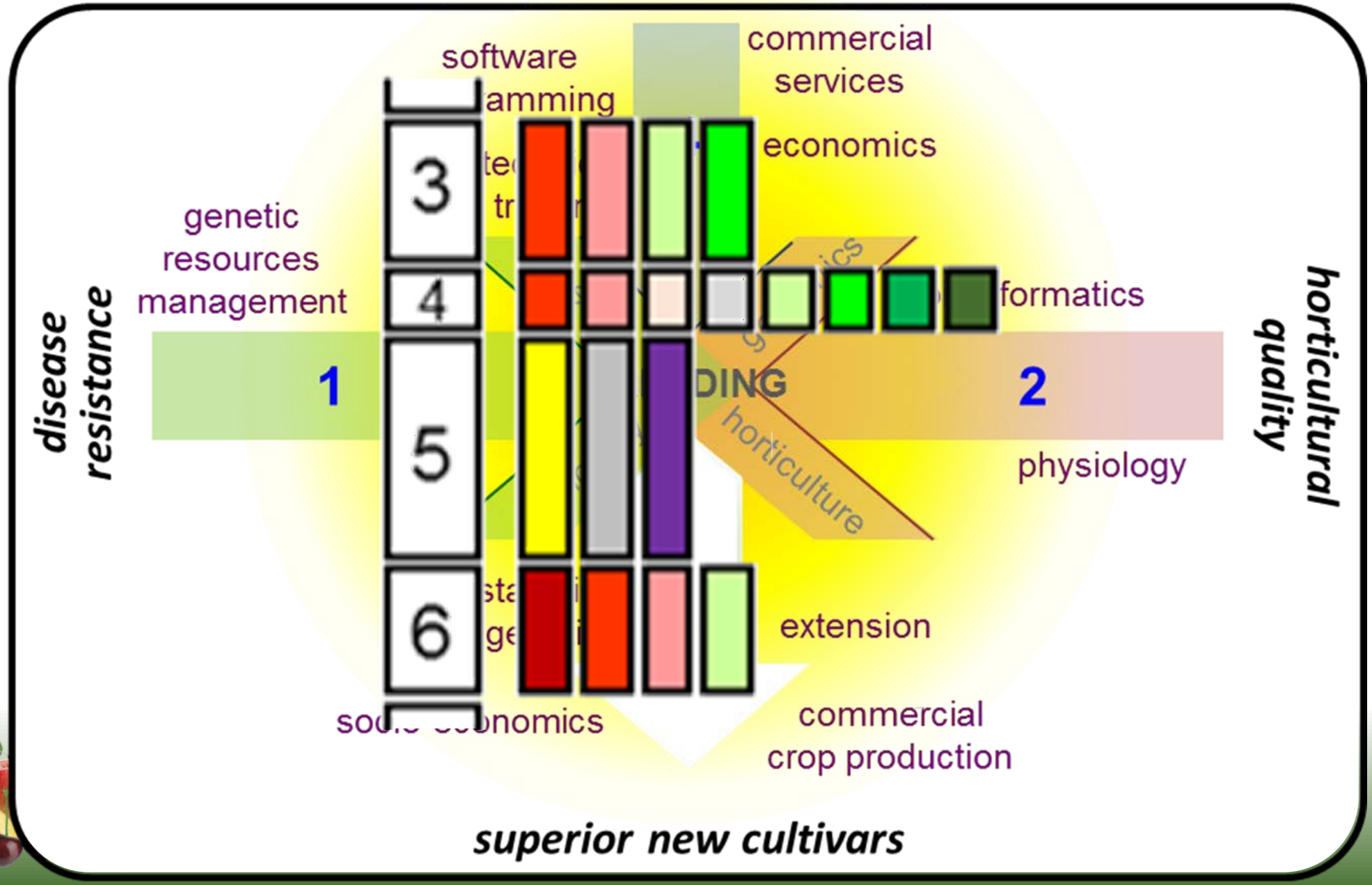
DISEASE RESISTANCE + HORTICULTURAL QUALITY

Haploblocking

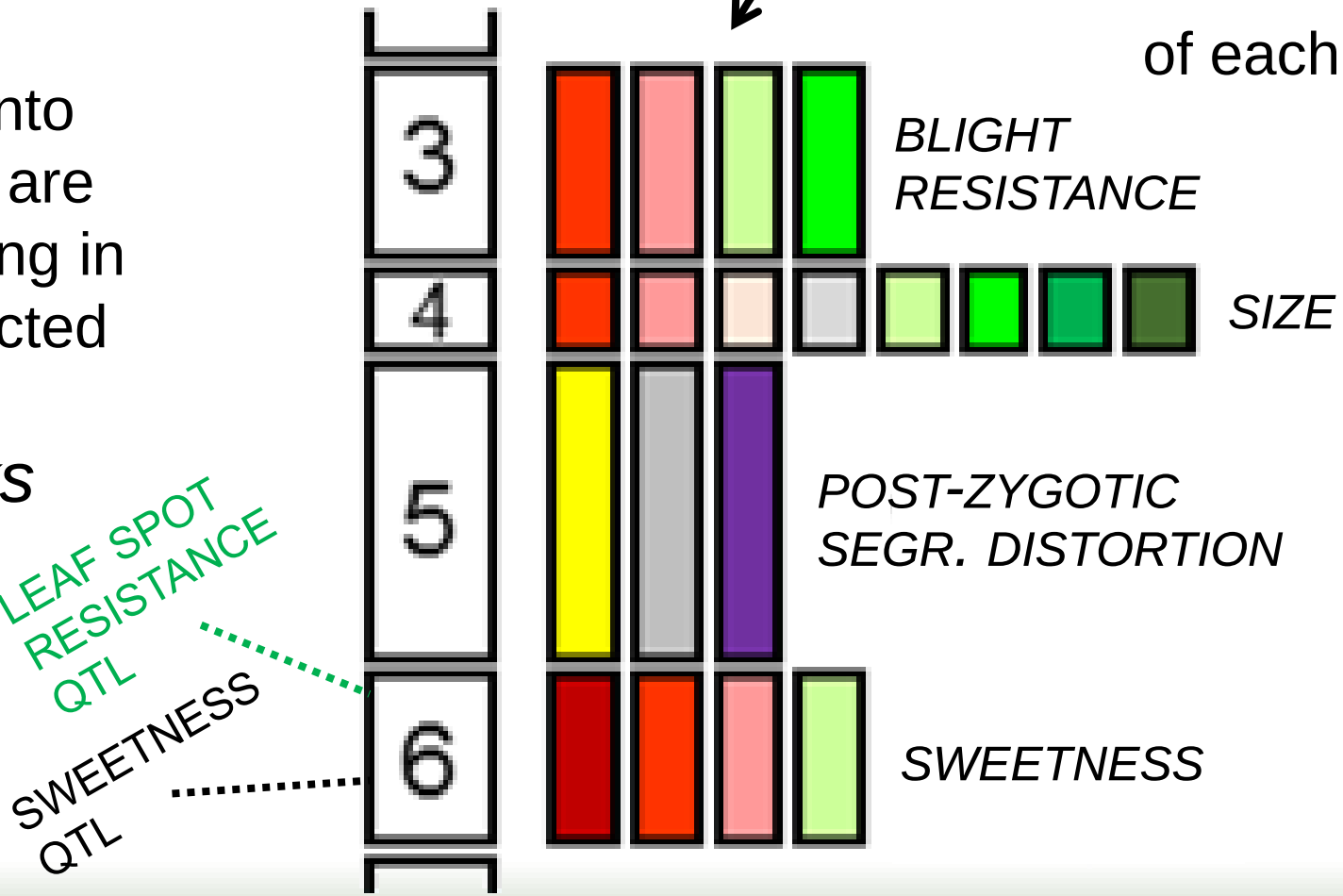


Haploblocking

Divide each chromosome into segments that are non-recombining in historical, selected germplasm – *haploblocks*

Target tight linkages to break, if desired

Characterize effects and ancestry of each variant – *haplotypes*



- extremely positive
- strongly positive
- positive
- mildly positive
- neutral
- mildly negative
- negative
- strongly negative
- extremely negative

- over-represented
- neutral
- under-represented

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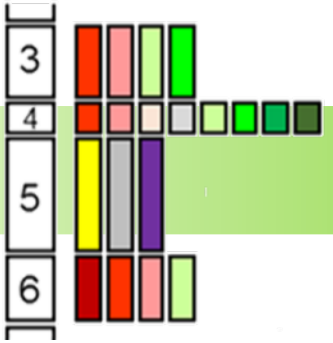
DISEASE RESISTANCE + HORTICULTURAL QUALITY

The Pedigree of RosBREED

Amazing Germplasm + *Traditional Genetics* → *Cultivar Development Pipeline*

International Collaboration + DNA-Based Technologies → Genomics Research Advances



RosBREED

→ Enhanced breeding *efficiency*, *accuracy*, *speed*, & *creativity*

The Children of RosBREED

Amazing Germplasm

Traditional Genetics

International Collaboration

DNA-Based Technologies

Cultivar Development Pipeline

Genomics Research Advances

RosBREED

Acknowledgements

RosBREED is supported by the USDA-NIFA-Specialty Crop Research Initiative by a combination of federal and matching funds (grant number 2014-51181-22378).

Questions?

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DISEASE RESISTANCE + HORTICULTURAL QUALITY

USDA United States Department of Agriculture National Institute of Food and Agriculture