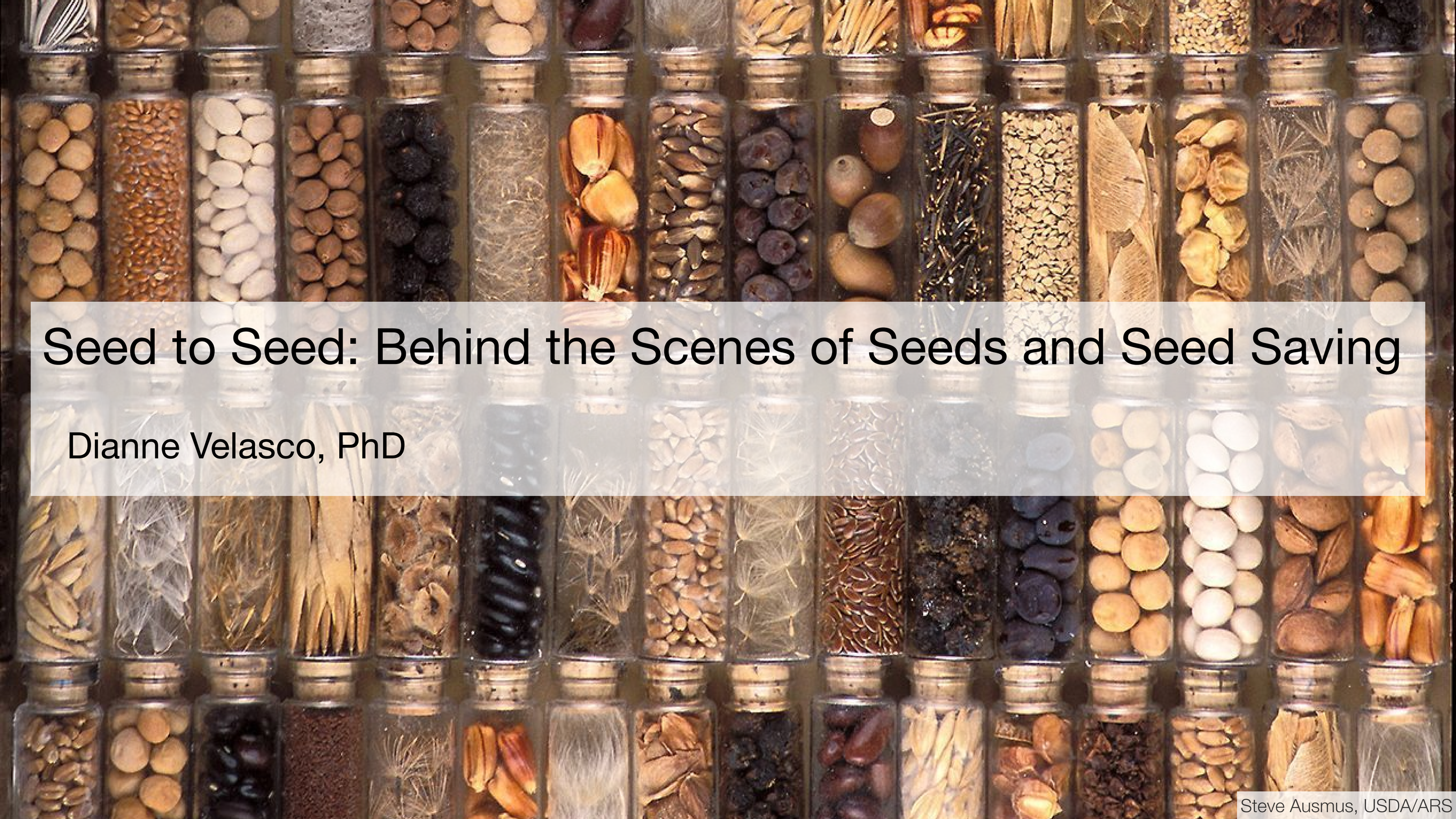
Seed to Seed: Behind the Scenes of Seeds and Seed Saving

Dianne Velasco, PhD

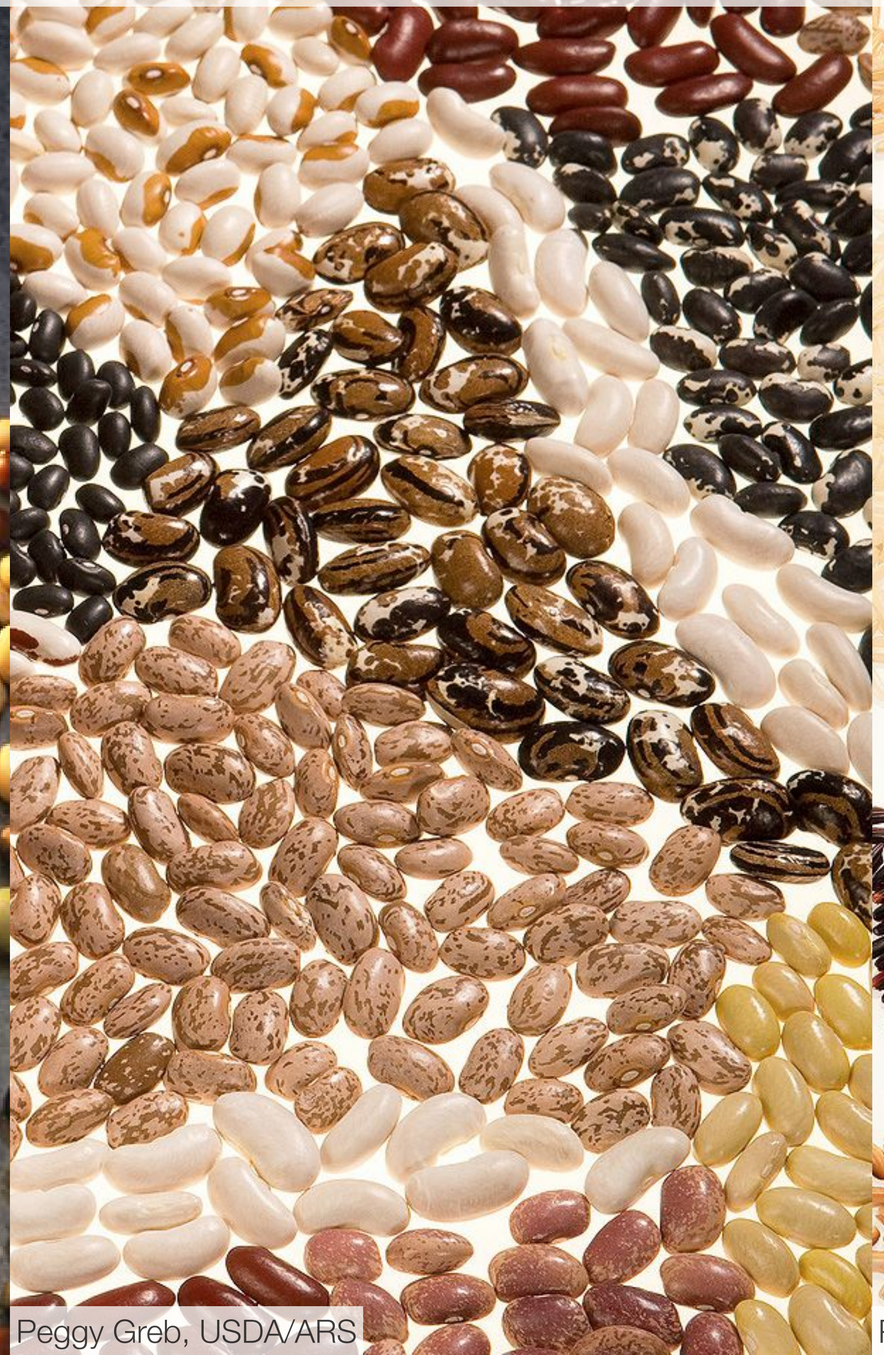


Steve Ausmus, USDA/ARS

Soybeans

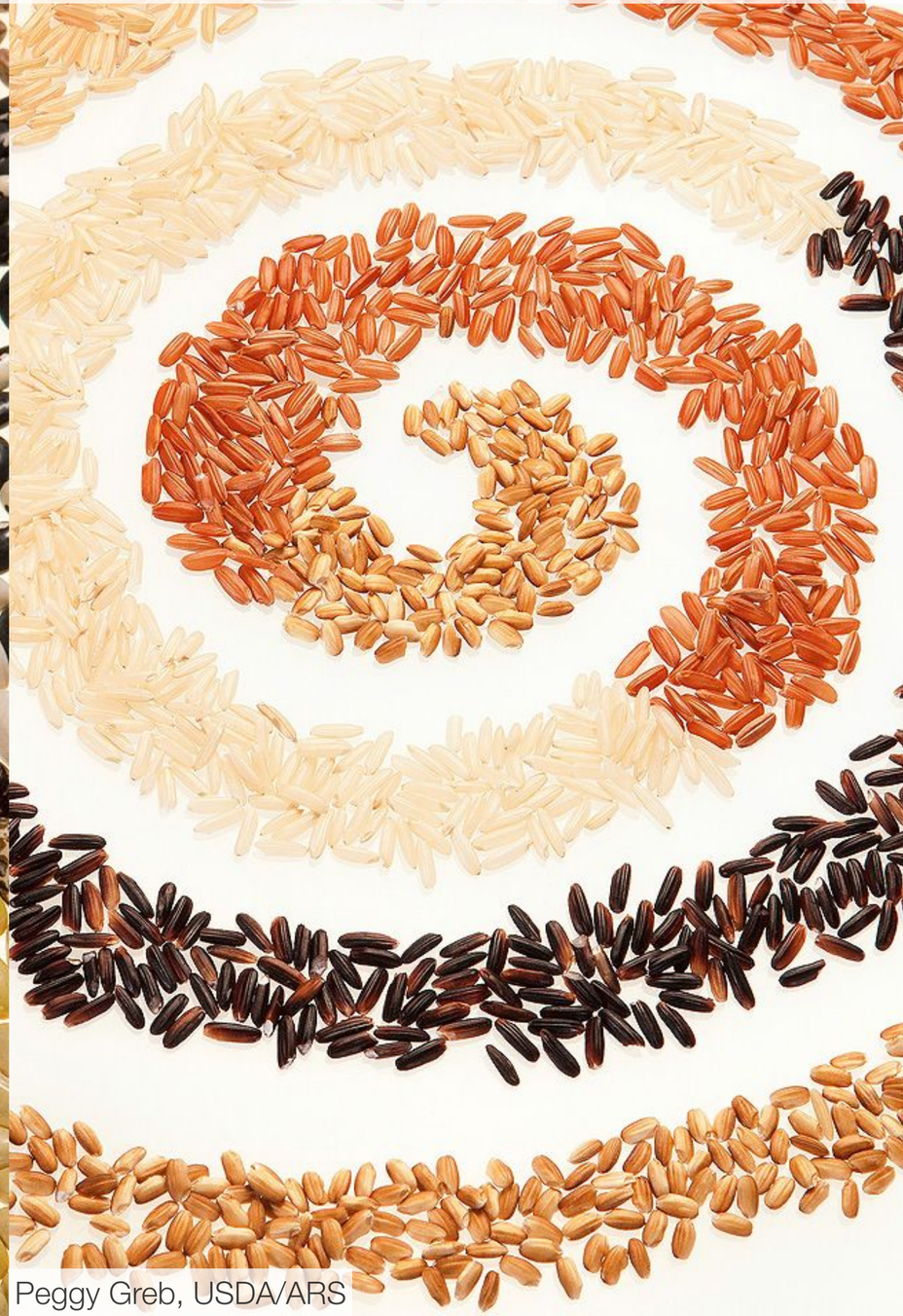
Scott Bauer, USDA/ARS

Common Beans



Peggy Greb, USDA/ARS

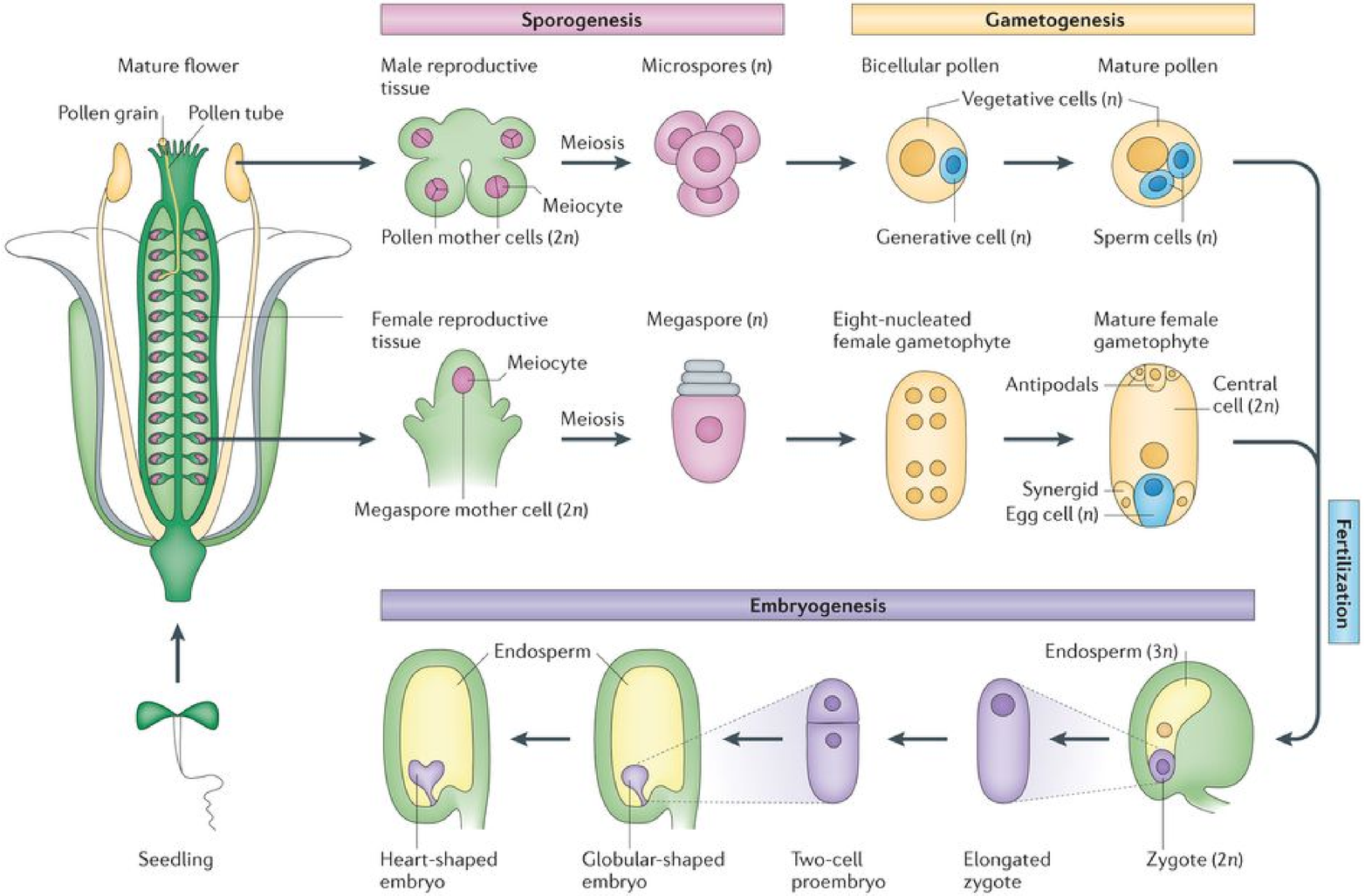
Rice



Peggy Greb, USDA/ARS

Essential Seed Saving Steps

- Grow a plant and let it reproduce
- Let the fruit and seed mature then harvest them
- Clean and store the seed



Nature Reviews | Genetics

Kawashima & Berger 2014

Grafted Plants

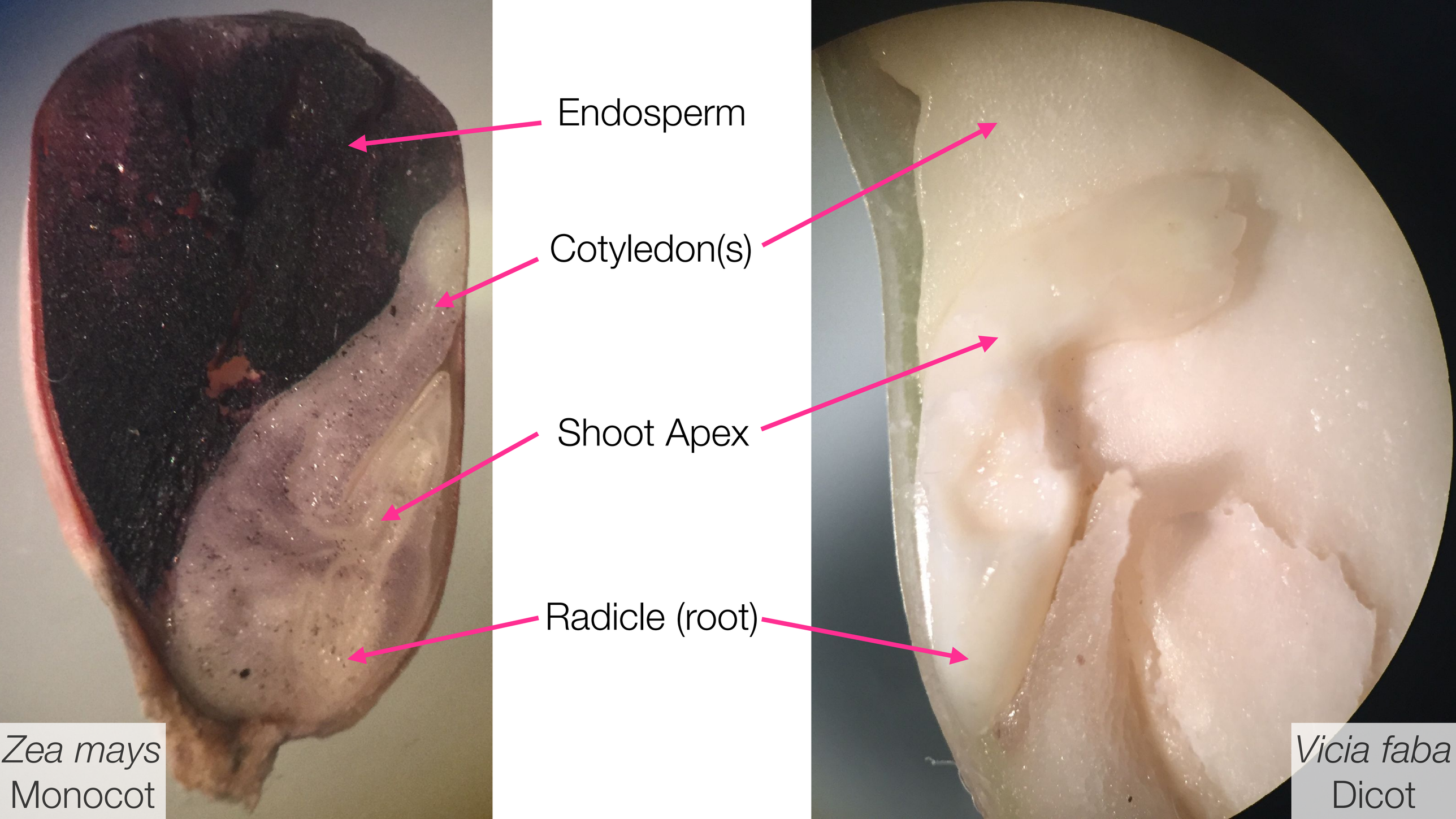
Scion

- fruiting variety
- grafted to rootstock
- fruit and seed only contain scion genetics
- typically either weak or susceptible to soilborne diseases

Rootstock

- rooting variety
- imparts vigor or resistance to soilborne diseases

What is a Seed

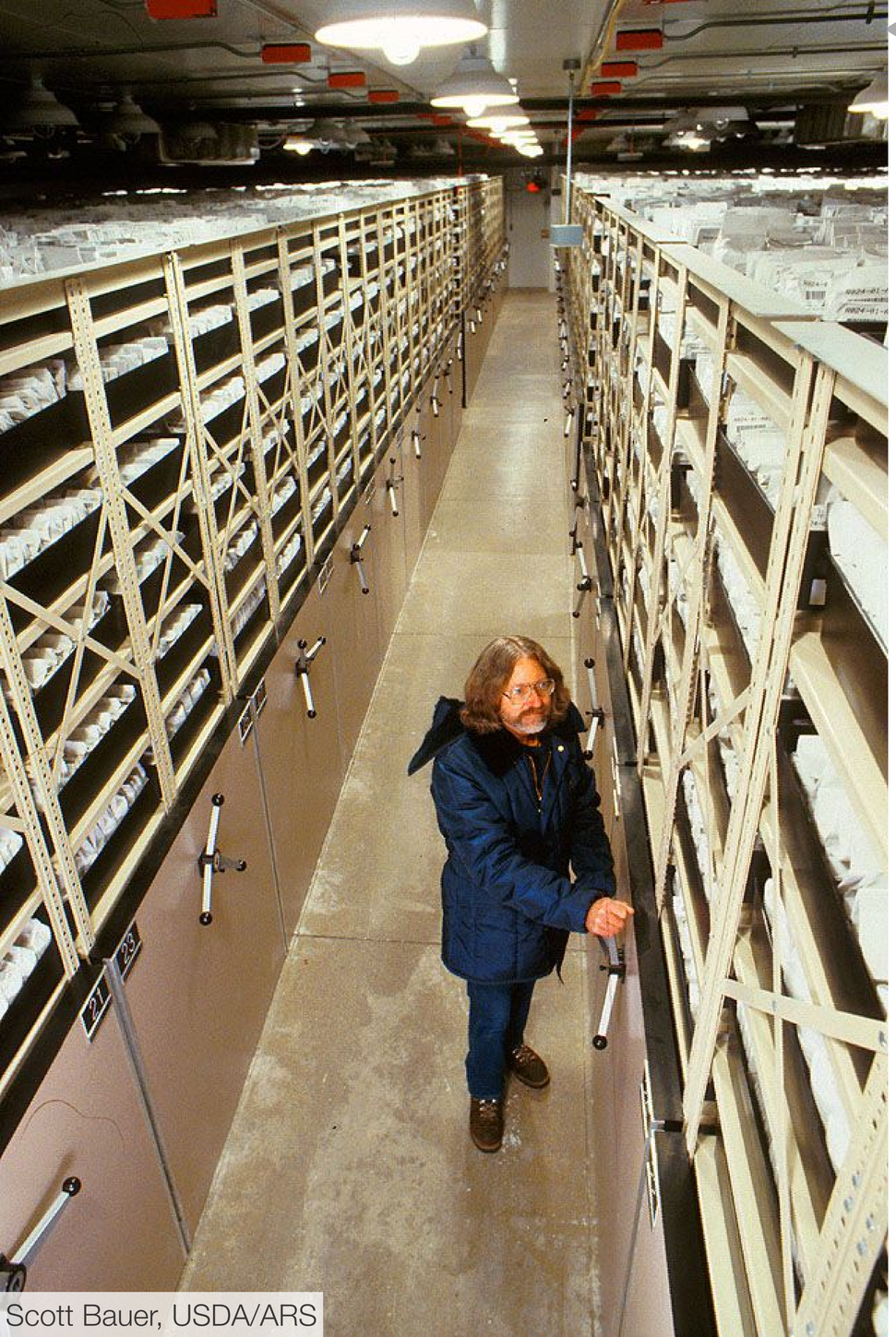

Endosperm
Cotyledon(s)
Shoot Apex
Radicle (root)
Zea mays
Monocot
Vicia faba
Dicot

Who Saves Seeds

National Governments

USDA Agricultural Research Service Germplasm Repositories

Site	Location
Arctic and Subarctic Plant Genetic Resources Unit	Palmer, Alaska
C.M. Rick Tomato Genetics Resource Center	Davis, California
Genetic Stocks - Oryza (GSOR) Collection	Stuttgart, Arkansas
Maize Cooperation Genetic Stocks	Urbana, Illinois
G.A. Marx Pea Genetic Stock Center (GSPI)	Pullman, Washington
National Arid Land Plant Genetic Resources Unit (PARL)	Parlier, California
National Clonal Germplasm Repository (COR)	Corvallis, Oregon
National Clonal Germplasm Repository for Citrus and Dates	Riverside, California
National Clonal Germplasm Repository for Tree Fruit/Nut Crops and Grapes (DAV)	Davis California
National Germplasm Resources Laboratory (NGRL)	Beltsville, Maryland
Plant and Animal Genetic Resources Preservation	Fort Collins, Colorado
National Small Grains Collection including Barley and Wheat Genetic Stocks (NSGC)	Aberdeen, Idaho
National Temperate Forage Legume Genetic Resources Unit	Prosser, Washington
North Central Regional Plant Introduction Station (NC7)	Ames, Iowa
Ornamental Plant Germplasm Center (OPGC)	Columbus, Ohio
Pecan Breeding & Genetics (BRW)	Brownwood and Somerville, Texas
Plant Genetic Resources Conservation Unit	Griffin, Georgia
Plant Genetic Resources Unit (PGR)	Geneva, New York
Soybean/Maize Germplasm, Pathology, and Genetics Research Unit	Urbana, Illinois
Subtropical Horticulture Research Station (MIA)	Miami, Florida
Tropical Agriculture Reseach Station	Mayagüez, Puerto Rico
Tropical Plant Genetic Resource Management Unit (HILO)	Hilo, Hawaii
United States Potato Genebank - NRSP-6	Sturgeon Bay, Wisconsin
Western Regional Plant Introduction Station (W6)	Pullman, Washington
Woody Landscape Plants	Washington, DC



Scott Bauer, USDA/ARS

USDA-ARS Plant and Animal Genetic Resources Preservation Unit, National Seed Storage Laboratory

Fort Collins, Colorado

USDA-ARS North Central Regional Plant Introduction Station

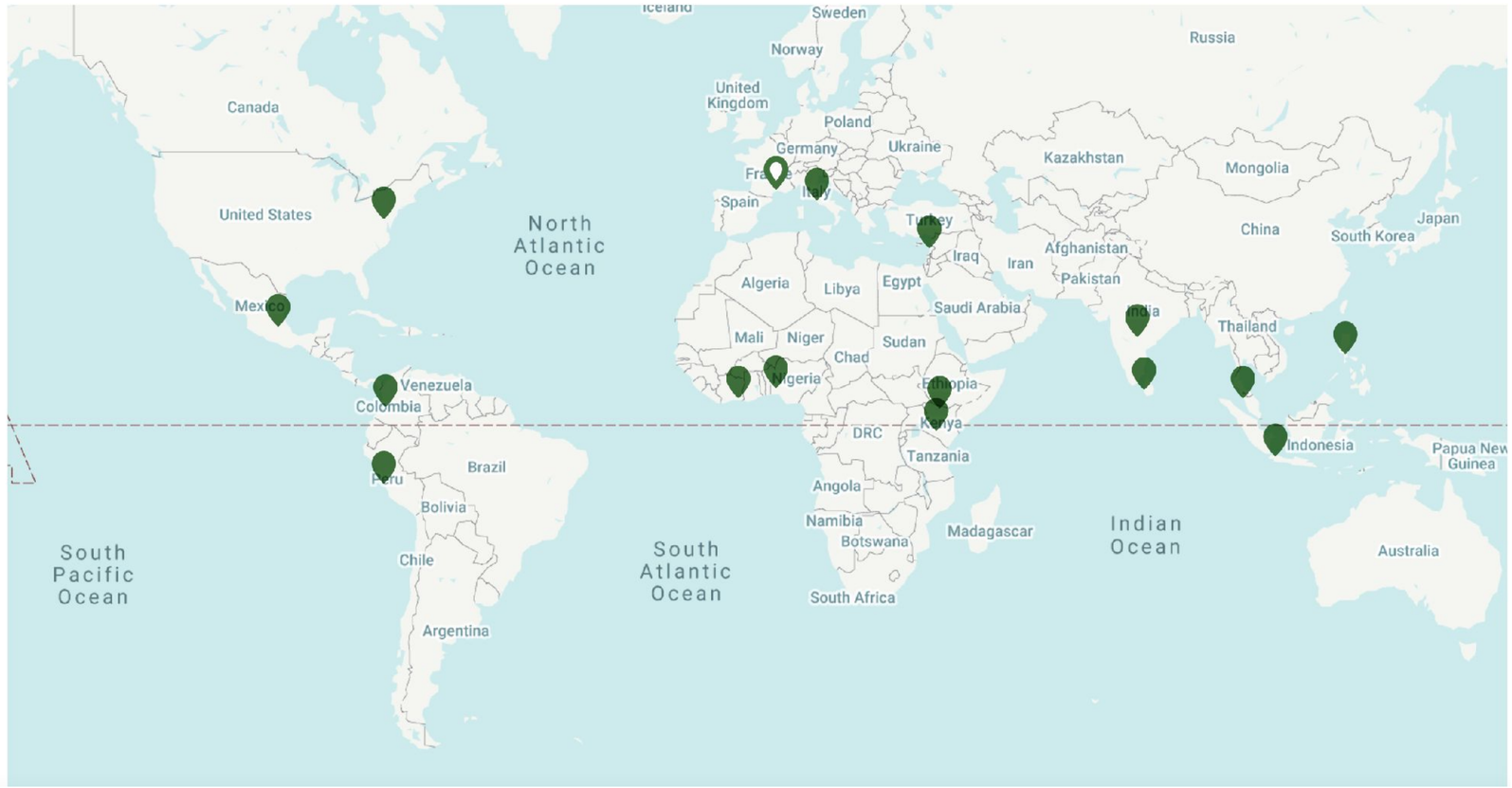
Ames, Iowa

Scott Bauer, USDA/ARS

Non-governmental Organizations

CGIAR

Our centers across the world



AfricaRice
Africa Rice Center

CIFOR
Center for International Forestry Research (CIFOR)

ICARDA
Science for resilient livelihoods in dry areas
International Center for Agricultural Research in the Dry Areas (ICARDA)

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI
International Food Policy Research Institute (IFPRI)

IITA
Transforming African Agriculture
International Institute of Tropical Agriculture (IITA)

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE
International Livestock Research Institute (ILRI)

CIMMYT
International Maize and Wheat Improvement Center
International Maize and Wheat Improvement Center (CIMMYT)

CIP
INTERNATIONAL POTATO CENTER
International Potato Center (CIP)

IRRI
International Rice Research Institute (IRRI)

IWMI
International Water Management Institute
International Water Management Institute (IWMI)

Alliance
Bioversity International
CIAT
The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT)

World Agroforestry
World Agroforestry (ICRAF)

WorldFish
WorldFish

Non-governmental Organizations

Crop Trust Svalbard Global Seed Vault

- Often referred to as the Doomsday or Millennial Seed Bank/ Vault
- Home of back up collections of many public, NGO, and non-profit seed banks

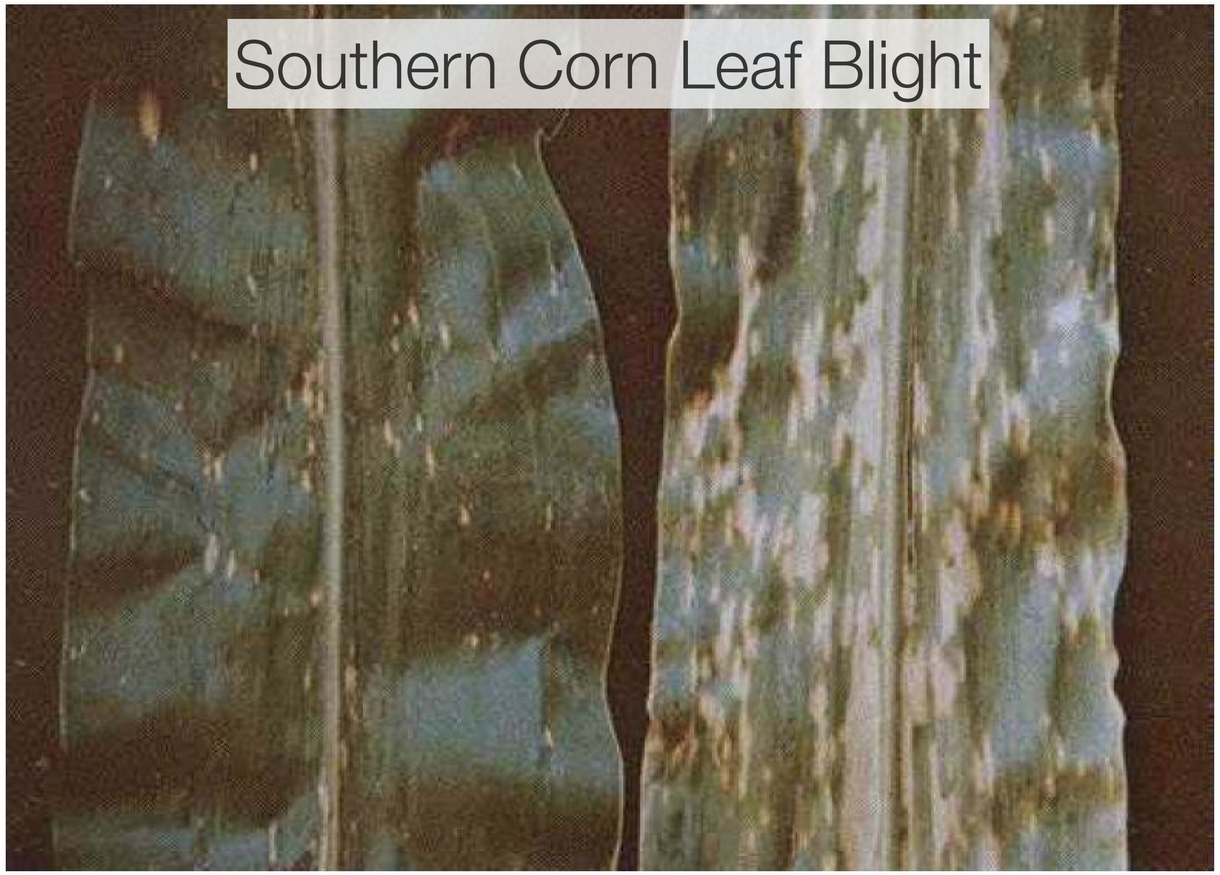
Why do these organizations save seed?

Crop Genetic Diversity

- Pest and disease resistance
- Abiotic stress tolerance
- Sources of improved nutrition, flavor
- Preserve historical varieties

Crop Wild Relatives

- Discovery
- Evolutionary studies



PLA TE 1 Leaves of a corn hybrid with "Normal" cytoplasm (left) and the same hybrid with T male-sterile cytoplasm (right) showing contrast in reaction to infection by *Helminthosporium maydis,* Race T (Photo courtesy of A. J. Ullstrup, Purdue Univ.).

National Research Council 1972

Non-profit organizations

- Seed Savers Exchange, Native Seed/SEARCH, Sandhill Preservation Center
  - heirloom, historical varieties, local varieties
  - sales support preservation efforts

Seed Savers EXCHANGE

Native Seeds S·E·A·R·C·H

For profit Organizations

Seeds of Change, Baker Creek

- preserve historic varieties
- educate

Large commercial seed companies

- maintain breeding germplasm
- develop new varieties
- maintain inbred lines (to produce F1 hybrids)

HM Clause

Why Should You Consider Saving Seeds

Maintain heirloom, family, traditional, or rare varieties

Help maintain genetic diversity

Contribute to personal or local food security

- Save money on buying seeds
- Share seeds with family, friends, and others
- Maintain fresh seed stock

Locally adapt varieties

- Select best performers
- Control growth conditions

Napa County Seed Library

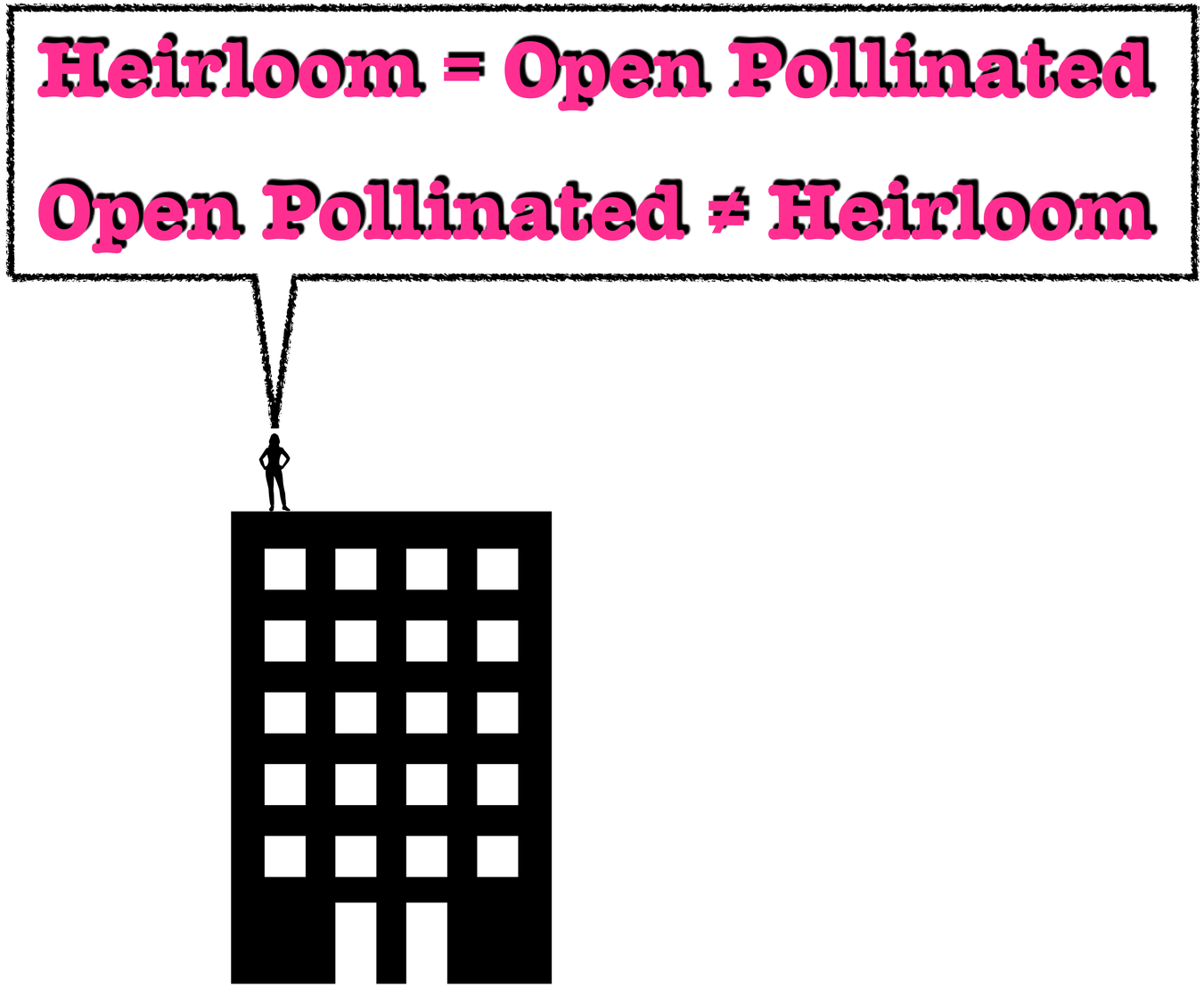
COMMUNITY SEED NETWORK

Save Uncommon Seed

General Seed Categories

Open Pollinated & Heirloom Varieties

- Think of an open pollinated variety as a population where the individuals are very similar but not identical
- Heirlooms are varieties with a story or history
- Either may be older or newer variety



	Open Pollinated	Heirloom
Reproduction	Open Pollinated	Open Pollinated
History	Old or New Variety	Typically an Older Variety Has a Story
Maintenance	• Public Seed Banks • Seed Preservation Societies • Seed Companies	• Long Term Family or Community Maintenance • Seed Preservation Societies • Public Seed Banks • Seed Companies

Hybrid (F1)

Labrador Retriever
(inbred line 1)

X

Labradoodle (F1)

Poodle
(inbred line 2)

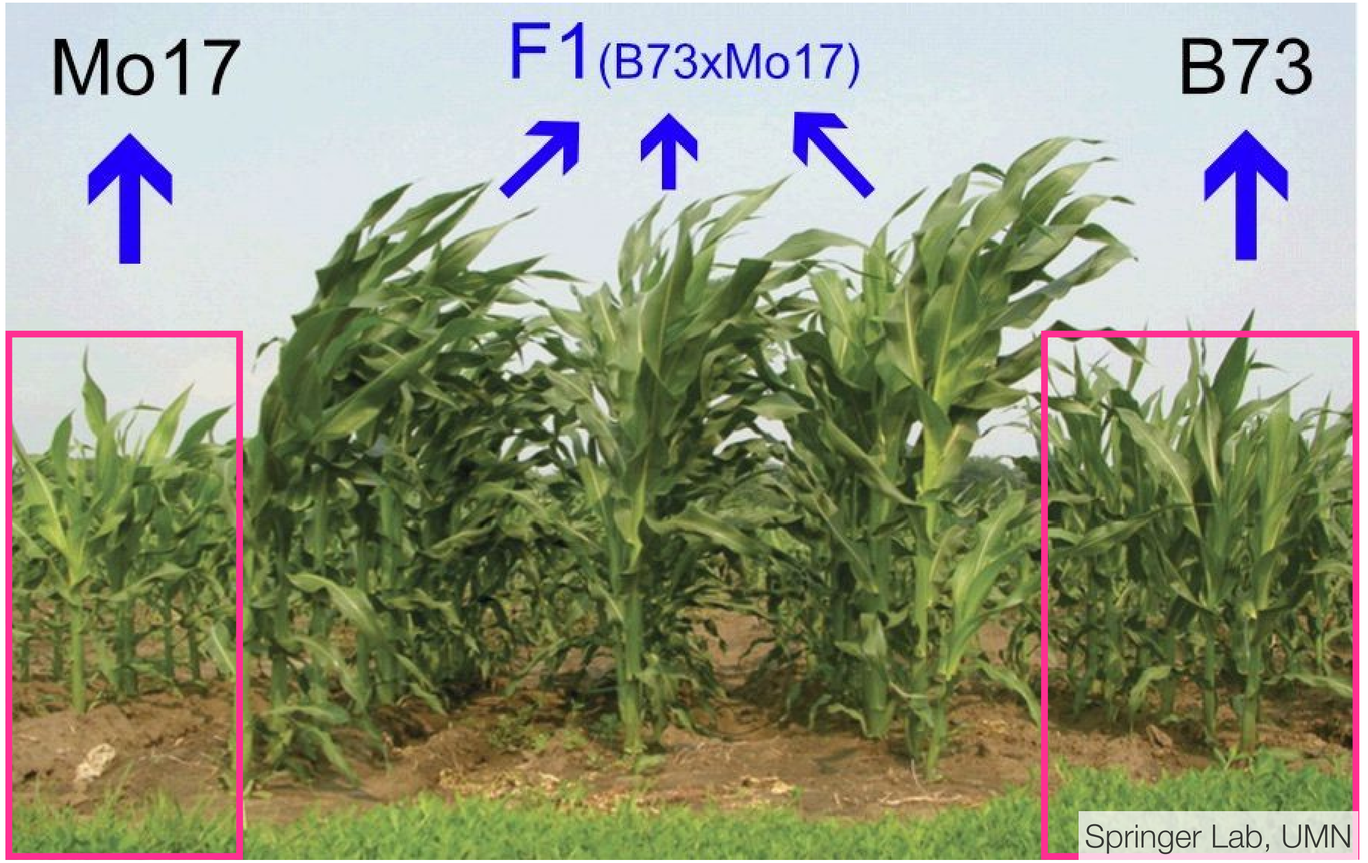
Hybrid (F1)

Why are hybrids produced?

- Uniformity
  - important for farmers; not always beneficial for home gardeners
- Relative ease of combining of disease resistance traits

Other commercial considerations

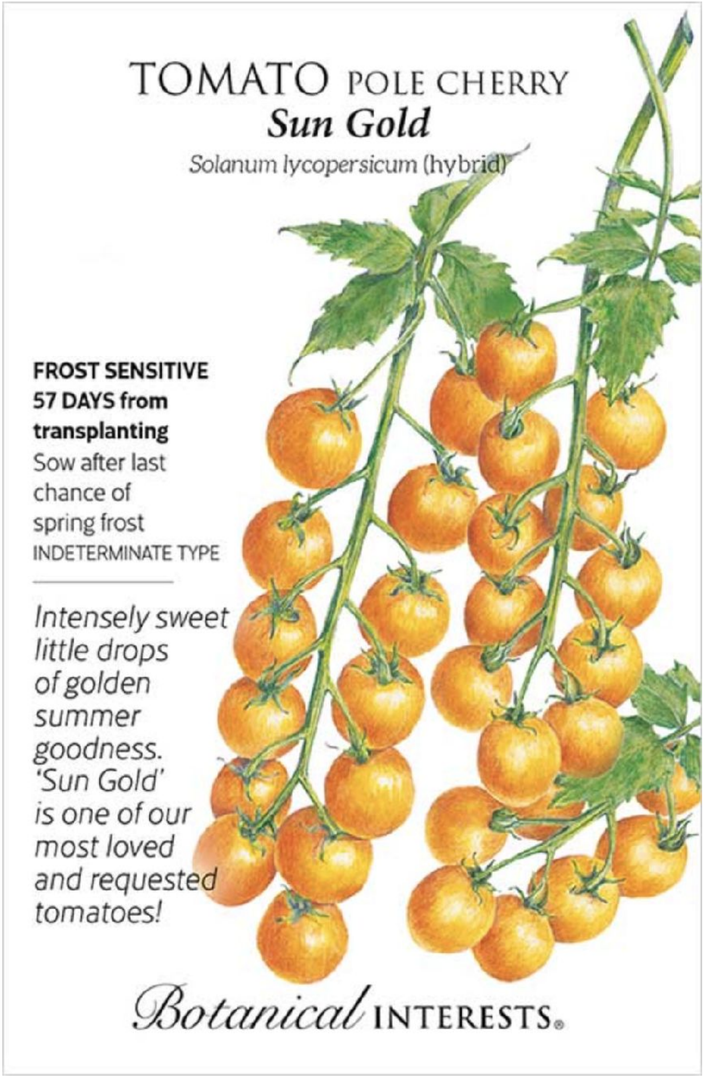
- ~10-20 years for development and testing
- Cannot protect hybrids directly
- Can protect inbred lines for 20 years



Hybrid (F1)

Can you save seeds from hybrid plants?

- Often misunderstood that they cannot be saved
- Plants grown from hybrid derived seed will still likely result in something edible or useful



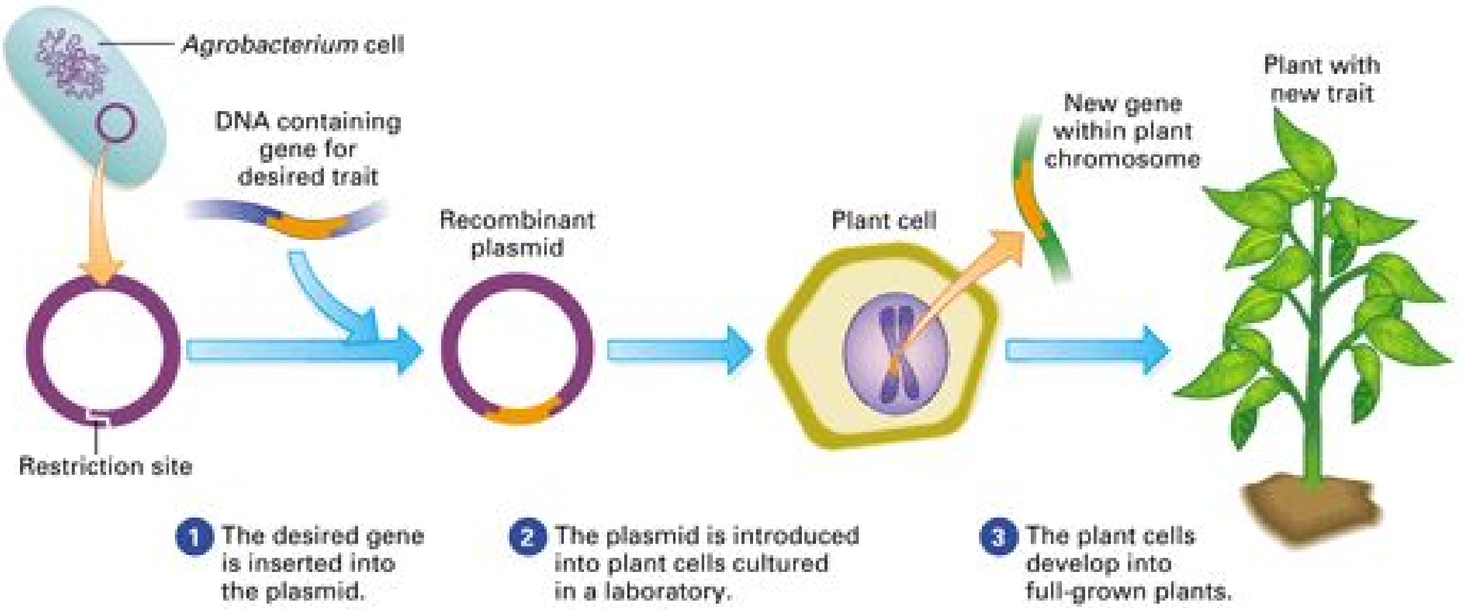
Genetically Engineered (GE)

GE crops are often referred to as Genetically Modified Organisms (GMOs)

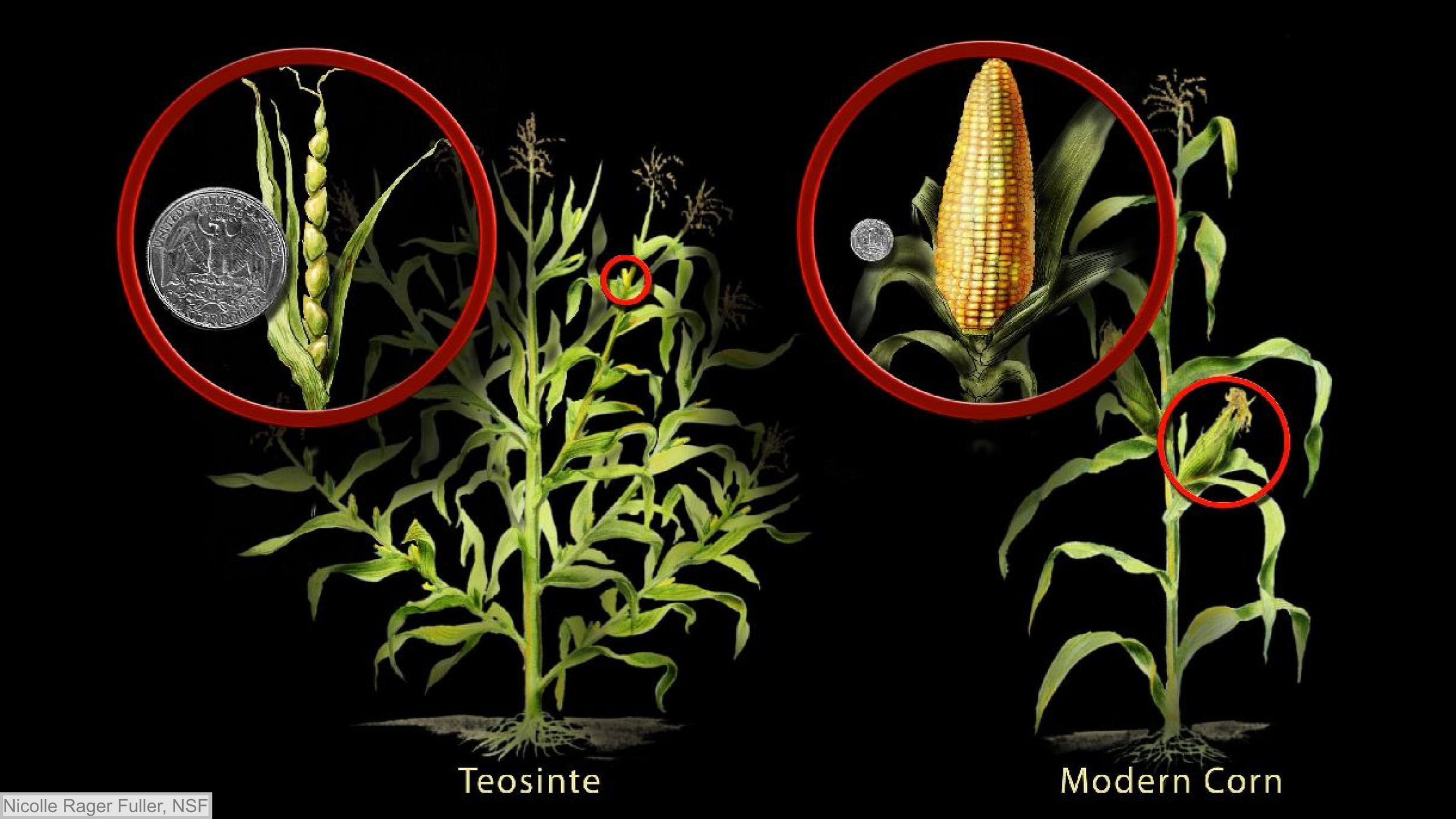
- No single scientific definition of genetically modified

Regulation in US is jointly overseen by EPA, FDA, and USDA

- Primarily plants developed with genetic engineering (GE) are currently regulated in the US
- The EU is beginning to regulate varieties produced by other methods, such as genetic editing

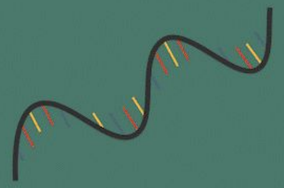
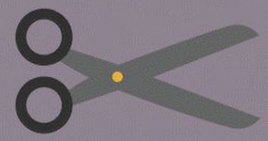


Bodell, Meridian Technical Charter HS



Nicolle Rager Fuller, NSF

How Crops are Genetically Modified

Traditional Breeding	Mutagenesis	RNA Interference	Transgenics	Gene Editing
Crossing plants and selecting offspring	Exposing seeds to chemicals or radiation	Switching off selected genes with RNA	Inserting selected genes using recombinant DNA methods	When used to delete genes using engineered nucleases (CRISPR, TALENs, ZFNs, etc.)
				
Desired gene(s) inserted with other genetic material	Random changes in genome, usually unpredictable	Targeted gene(s) switched off or 'silenced'	Only gene(s) inserted at desired locations selected	Desired gene(s) deleted only at known locations
Almost all crops				
Number of genes affected: few genes to whole genomes	**100s - 1,000s**	**1 – dozens**	**1 – 8**	**1 or more**
No safety testing required; **Unregulated**	No safety testing required; **Unregulated**	Safety testing required; **Highly regulated**	Safety testing required; **Highly regulated**	Safety testing required depending on jurisdiction; **Mixed regulations**

Undesirable, unintended effects rarely occur in the final product of any crop, regardless which process is used.

GE Crops and Home Gardeners

- Genetically engineered crops are not currently available to home gardeners
  - Possession of GE seed requires permits from regulatory agencies
  - Seed companies producing and selling GE seed establish contracts with buyers
  - Generally high per seed cost
- Norfolk Plant Sciences is working on having seeds for their Big Purple tomato approved for purchase by home gardeners

Norfolk Plant Sciences

“So those pledges in seed catalogs promising they contain no GMO seeds are technically true, but also pretty meaningless. So if you are worried about accidentally getting a GMO variety, don’t be.”

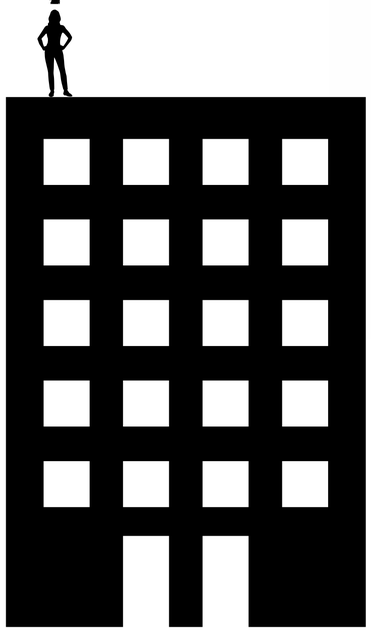
– Joseph Tychonievich

Review of Seed Categories

- Open Pollinated
  - Includes heirlooms
- F1 hybrids
- Genetically Engineered
  - Not currently available to home gardeners

Heirloom = Open Pollinated

Open Pollinated ≠ Heirloom



Labradoodle (F1)

Considerations for Saving Seeds

Key Concepts

- Intellectual Property Rights
- Species Considerations
- Maintaining Genetic Identity
- Maintaining Genetic Diversity
  - Population Size
- Seed Longevity & Storage
- Germination Testing

Peggy Greb, USDA/ARS

Intellectual Property Rights

Patent and Trademark Office (PTO), Plant Patent (PP)

- “asexually reproduced…distinct and new variety of plant, other than a tuber propagated plant or a plant found in an uncultivated state”
- 20 years

Plant Variety Protection Office (PVPO), Plant Variety Protection (PVP)

- “new, distinct, uniform, and stable varieties of sexually reproduced, tuber propagated, or asexually reproduced plants”
- 20 years; 25 years for trees and vines

Species Considerations

- Seeds that can be dried and stored (orthodox) or not (recalcitrant)

- Are there distinct varieties within the same species?

  - *Brassica oleracea* (dog of plants): cabbage, kale, cauliflower, broccoli, etc.

  - *Beta vulgaris*: beets, chard

  - *Zea mays*: sweet corn, popcorn, dent corn, flint corn, decorative corn

Species Considerations

Trait	Considerations
Reproduction	Annual, Biennial, Perennial
Pollination	Animal, Wind
Flower Anatomy	Perfect, Imperfect
Plant Sex	Monoecious, Dioecious
Mating System	Self-Pollinating, Outcrossing
Fruit Maturity	Market Ready, Beyond Market Ready
Population	Open Pollinated, F1 Hybrid
Post-Harvest	Fermentation, None

Fermentation: Processing Tomato Seeds

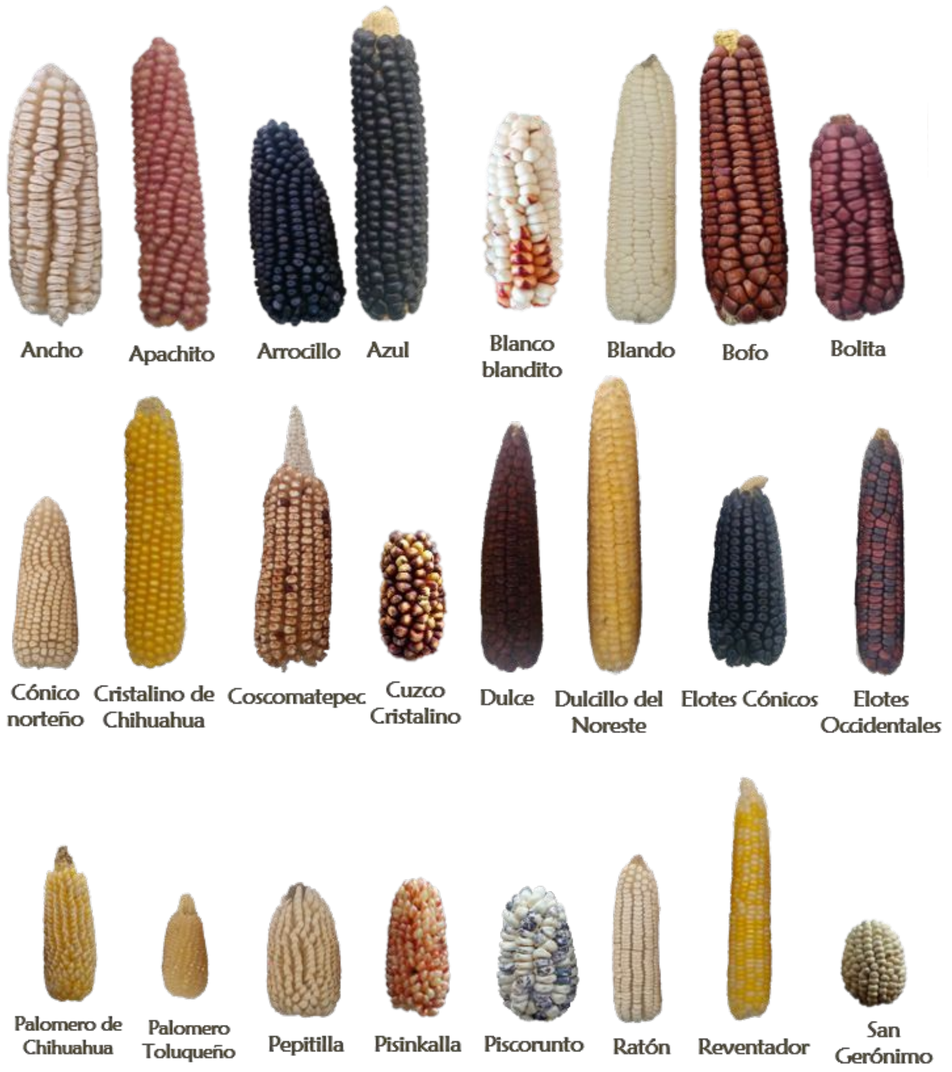
Maintaining Genetic Identity

What is genetic identity?

- “the **sharing of certain biological characteristics** between people, families or species” (Goekoop et al. 2020)

Important factors for maintaining genetic identity

- Understand the mating system
- Isolation minimums and methods



Maintaining Genetic Identity

Seed Savers EXCHANGE

SEED SAVING GUIDE

Crops	Species	Family	Life Cycle	Primary Pollination Method	Recommended Isolation Distance for Seed Saving	Population Size (Number of plants)		
						Viable Seeds	Variety Maintenance	Genetic Preservation
adzuki bean	*Vigna angularis*	Fabaceae	annual	self	10–20 feet (3–6 m)	1	10–25	50+
amaranth	*Amaranthus spp.*	Amaranthaceae	annual	wind	650–1,300 feet	1	5–25	50+
Armenian cucumber	*Cucumis melo*	Cucurbitaceae	annual	insect	800 feet–1/2 mile (244–805 m)	1	5–10	25+
artichoke	*Cynara cardunculus*	Asteraceae	perennial	insect	800 feet–1/2 mile (244–805 m)	5	20–50	80+
arugula (rocket)	*Eruca sativa*	Brassicaceae	annual	insect	800 feet–1/2 mile (244–805 m)	5	20–50	80+
asparagus	*Asparagus officinalis*	Asparagaceae	perennial	wind	800 feet–1/2 mile (244–805 m)	2 (1 male, 1 female)	20–50	80+
barley	*Hordeum vulgare*	Poaceae	annual	self	10–20 feet (3–6 m)	1	5–10	20+
bean (common bean)	*Phaseolus vulgaris*	Fabaceae	annual	self or insect	10–20 feet (3–6 m)	1	5–10	20+
beet	*Beta vulgaris*	Amaranthaceae	biennial	wind	800 feet–1 mile (244 m–1.6 km)	5	20–50	80+
Belgian endive	*Cichorium intybus*	Asteraceae	biennial	insect	800 feet–1/2 mile (244–805 m)	5	20–50	80+
broccoli	*Brassica oleracea*	Brassicaceae	biennial	insect	800 feet–1/2 mile (244–805 m)	5	20–50	80+

Maintaining Genetic Identity

Options to isolation by distance (**<u>up to 1 mile!!!</u>**)

- Insect barriers, useful for insect pollinated species
  - Tents and mosquito netting, blossom bags
- Pollinator distractions
  - Dense plantings of other flowering species to reduce unwanted crosses; Not foolproof
- Isolation by Timing
  - Plantings staggered to ensure non-overlapping bloom
- Hand Pollination
  - Pretend to be a pollinator! (Borrow a bee costume?)
  - Make like the wind and spread pollen (selectively)

Seed Savers Exchange

Seed Savers Exchange

Peggy Greb, USDA/ARS

Special Considerations

- Brassicas, particularly *Brassica oleracea* but also *Brassica rapa*
- Squash (*Cucurbita* spp.)
  - Species: *C. argyrosperma*, *C. maxima*, *C. moschata*, *C. pepo*
  - Hybrids between species may occur, hand pollination recommended
- Biennials
- Saving Seeds from F1 Hybrids

Brassica oleracea AKA “The Dog of Plants”

var. *acephala*

var. *gongylodes*

var. *alboglabra*

var. *medullosa*

var. *longata*

var. *botrytis*

var. *botrytis*

var. *ramosa*

var. *sabellica*

var. *palmifolia*

var. *gemmifera*

var. *italica*

var. *capitata*
f. *sabauda*

var *capitata*
f. *acuta*

var. *viridis*

var. *costata*

@Andi_Kur_

Brassica oleracea

Selection for terminal buds	Selection for lateral buds	Selection for stem	Selection for leaves	Selection for stems and flowers	Selection for flower clusters
					
Cabbage	Brussels sprouts	Kohlrabi	Kale	Broccoli	Cauliflower

modified from vox.com & @Andi_Kur_

Squash (*Cucurbita* spp.)

C. argyrosperma

- cushaw, silver-seeded types

C. maxima

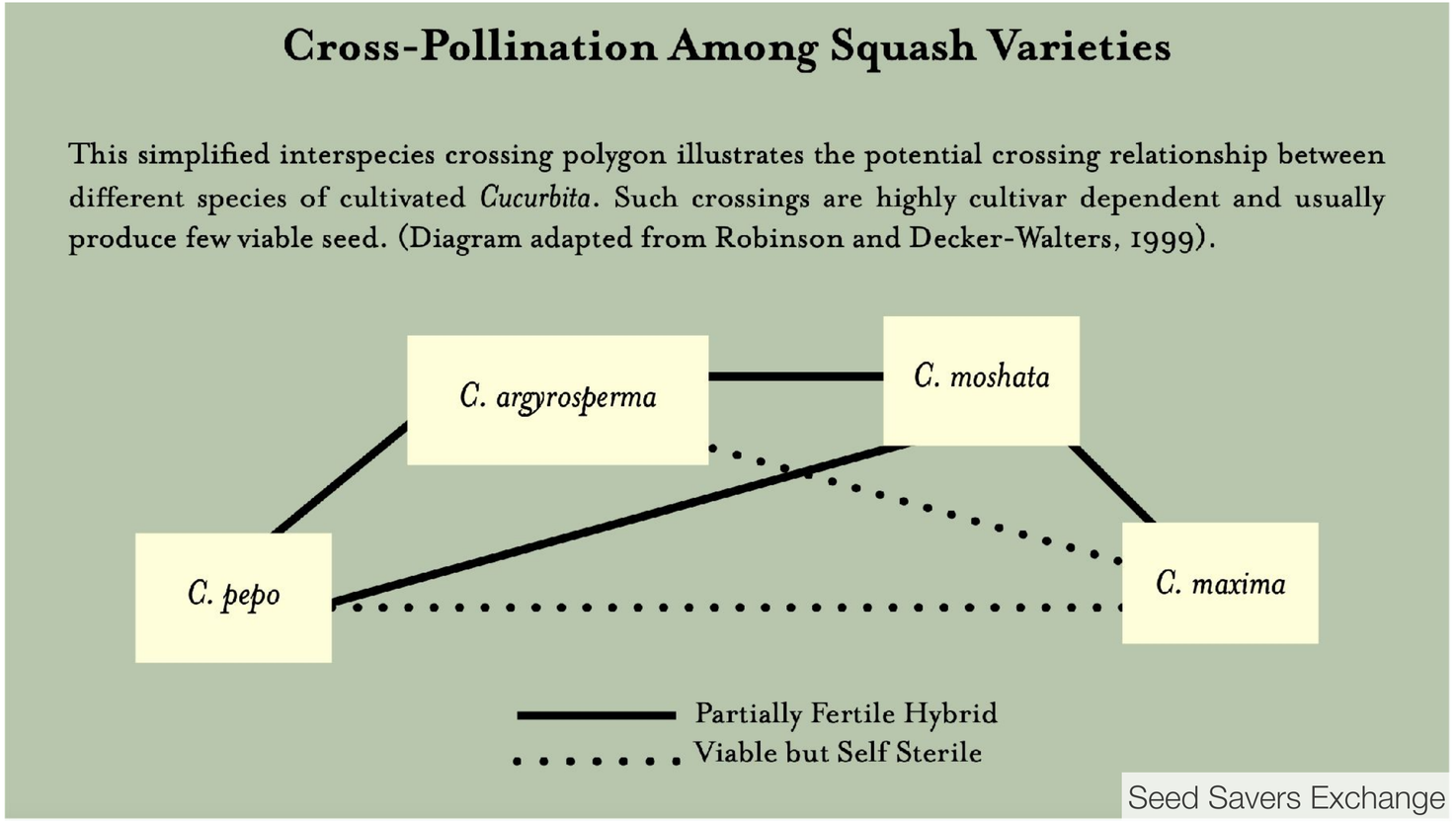
- banana, buttercup, hubbard, turban, kabocha, most pumpkins

C. moschata

- butternut, cheese types

C. pepo

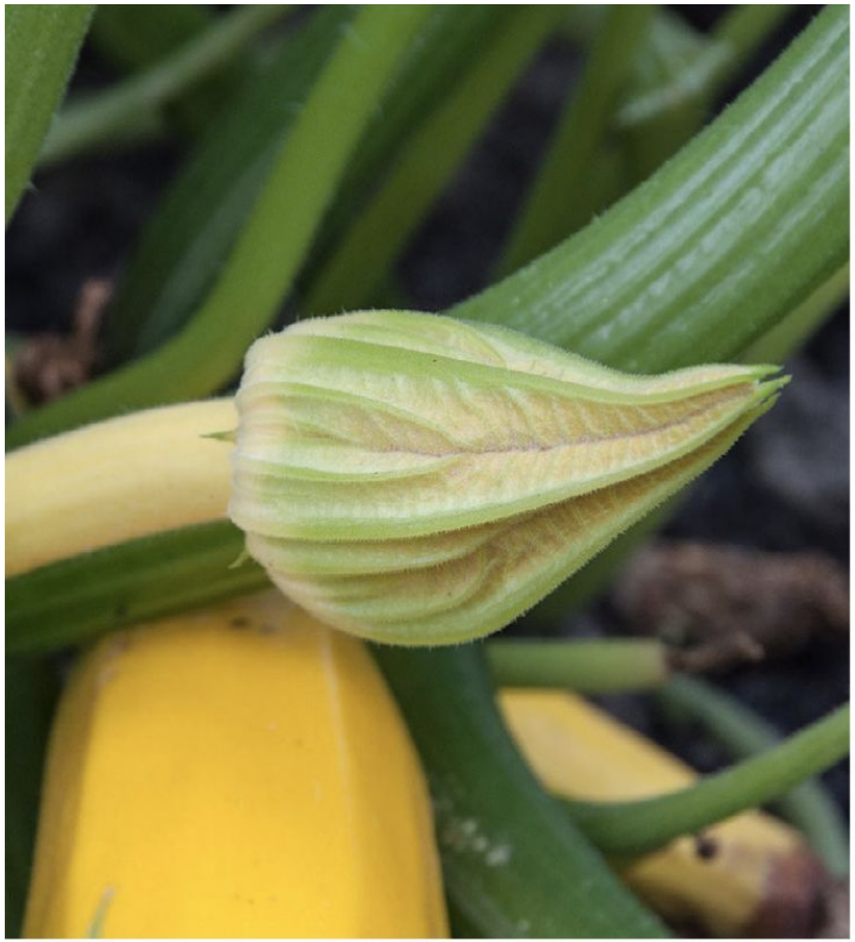
- acorn, scallop, spaghetti, crookneck, zucchini, delicata



Squash (*Cucurbita* sp.)

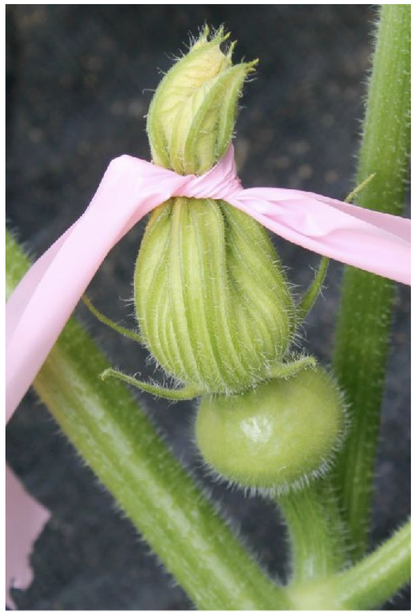
Male

Female



Squash (*Cucurbita* sp.)

Keep flowers closed



The flowers are ready to use for pollination when they are mature enough to open normally.

At this time remove all the petals from the male flower and the petal ends of the female flower.

Squash (*Cucurbita* sp.)

Using the male flower cover stigma with pollen.

Carefully close pollinated female flower before any pollinators visit. Flag to indicate the flower was hand pollinated.

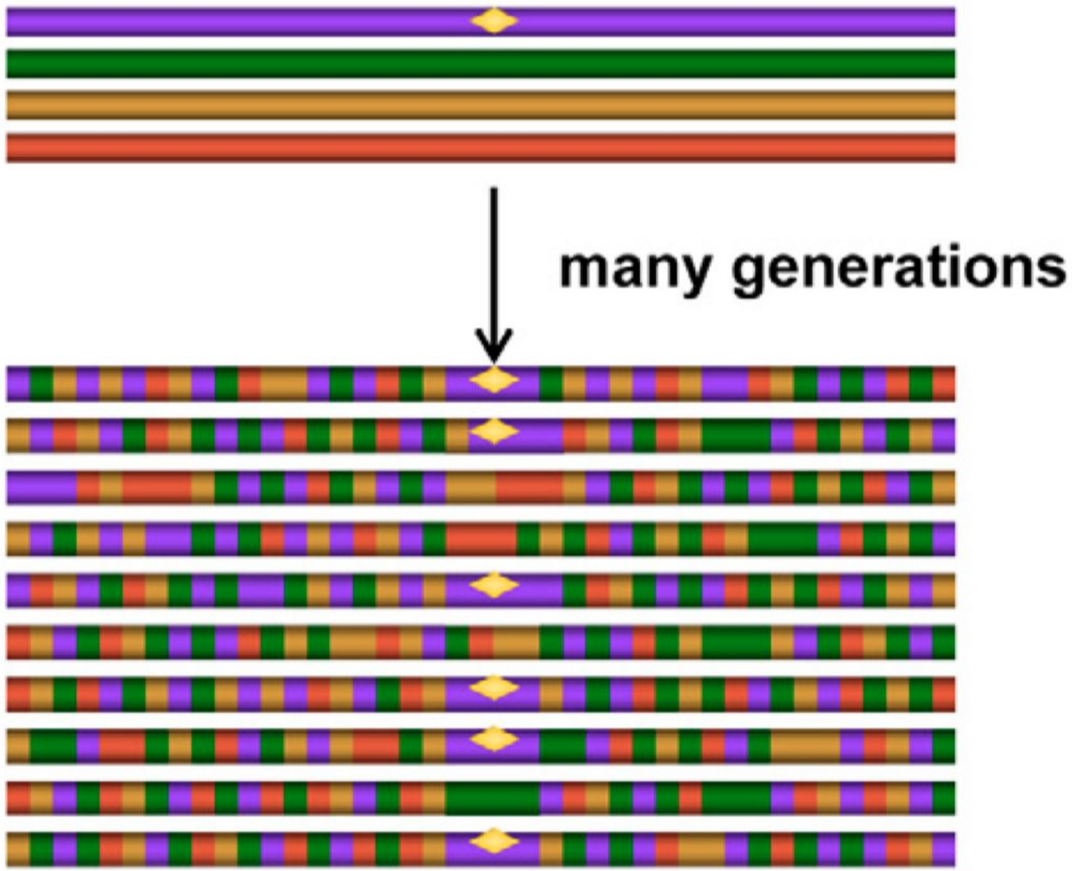
Biennials

- Pull biennial root crops to evaluate
  - replant in fall or spring
- Temporally separate biennials by saving only one variety of the same species per year
  - only overwinter or replant one variety to flower in the spring

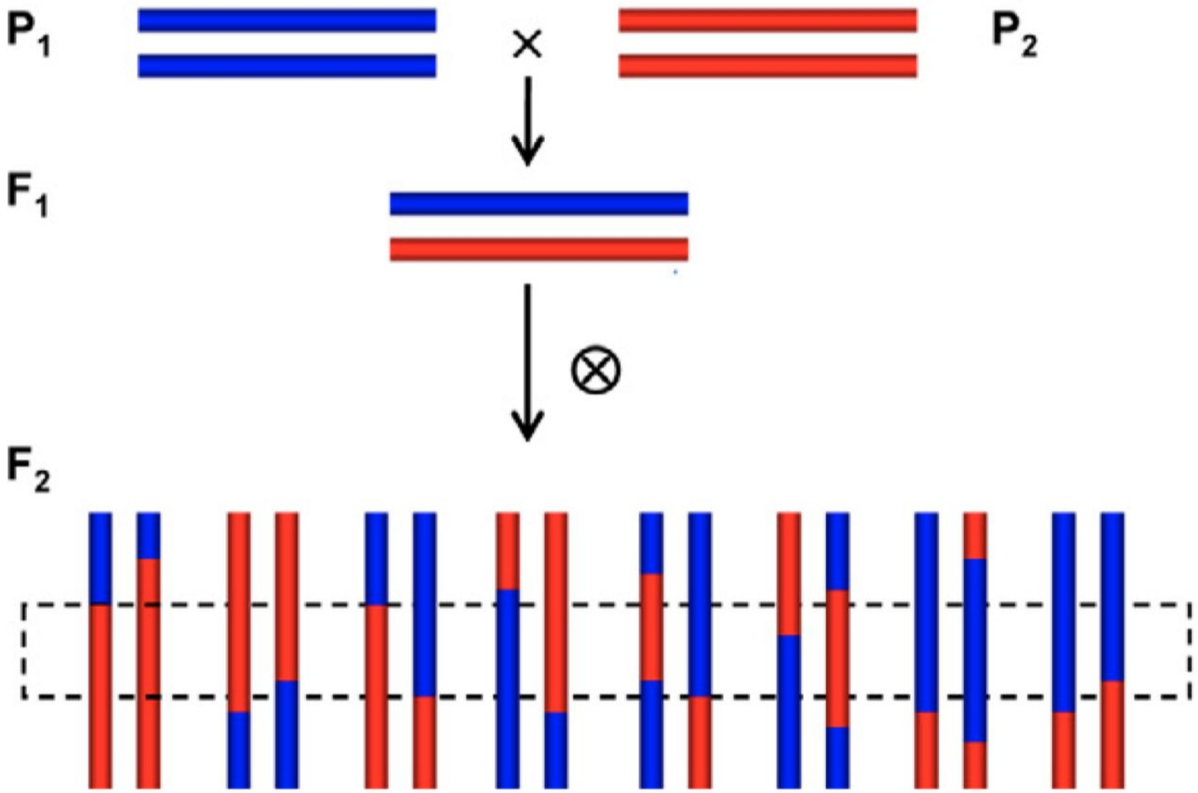
Steve Ausmus, USDA/ARS

Saving Seed From F1 Hybrids

Open Pollinated



Hybrid



Zhu et al. 2008

Saving Seed From F1 Hybrids

Pro	Con
Will Still Grow Something Useful	**Cannot Maintain Genetic Identity, Will Likely Never Recreate the Original F1**
Interesting Experimentation	Limited Genetics
Some Parental Lines are Highly Similar and Offspring of Hybrids May Reflect This	May Not Retain All Traits Without Growing Hundreds or Thousands of Individuals
With Care May Develop Into An Inbred or Open Pollinated Variety	Unpredictable Levels of Variation in Later Generations

Maintaining Genetic Diversity

Seed Savers EXCHANGE

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Population Size

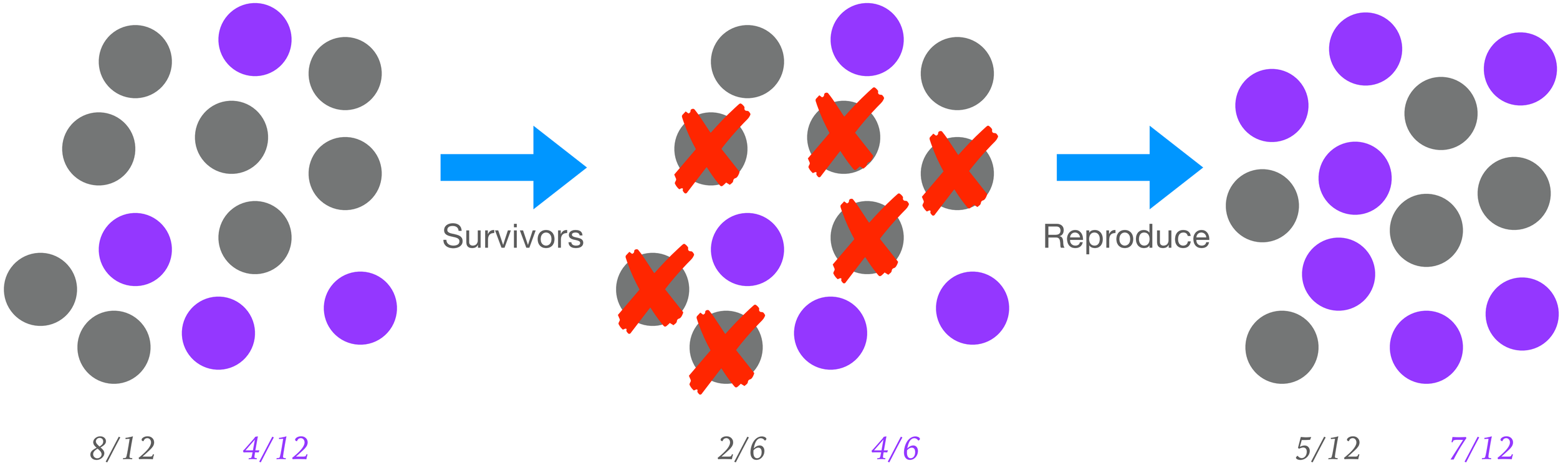
Why are the population sizes so much different depending on if you just want seed vs maintaining a variety vs genetic preservation?

- Selection
- Bottleneck/Founder Effect
- Genetic Drift
- Inbreeding Depression
- Migration

Crops	Primary Pollination Method	Population Size (Number of plants)		
		Viable Seeds	Variety Maintenance	Genetic Preservation
adzuki bean	self	1	10–25	50+
amaranth	wind	1	5–25	50+
Armenian cucumber	insect	1	5–10	25+
artichoke	insect	5	20–50	80+
arugula (rocket)	insect	5	20–50	80+
asparagus	wind	2 (1 male, 1 female)	20–50	80+
barley	self	1	5–10	20+
bean (common bean)	self or insect	1	5–10	20+
beet	wind	5	20–50	80+
Belgian endive	insect	5	20–50	80+
broccoli	insect	5	20–50	80+

Selection

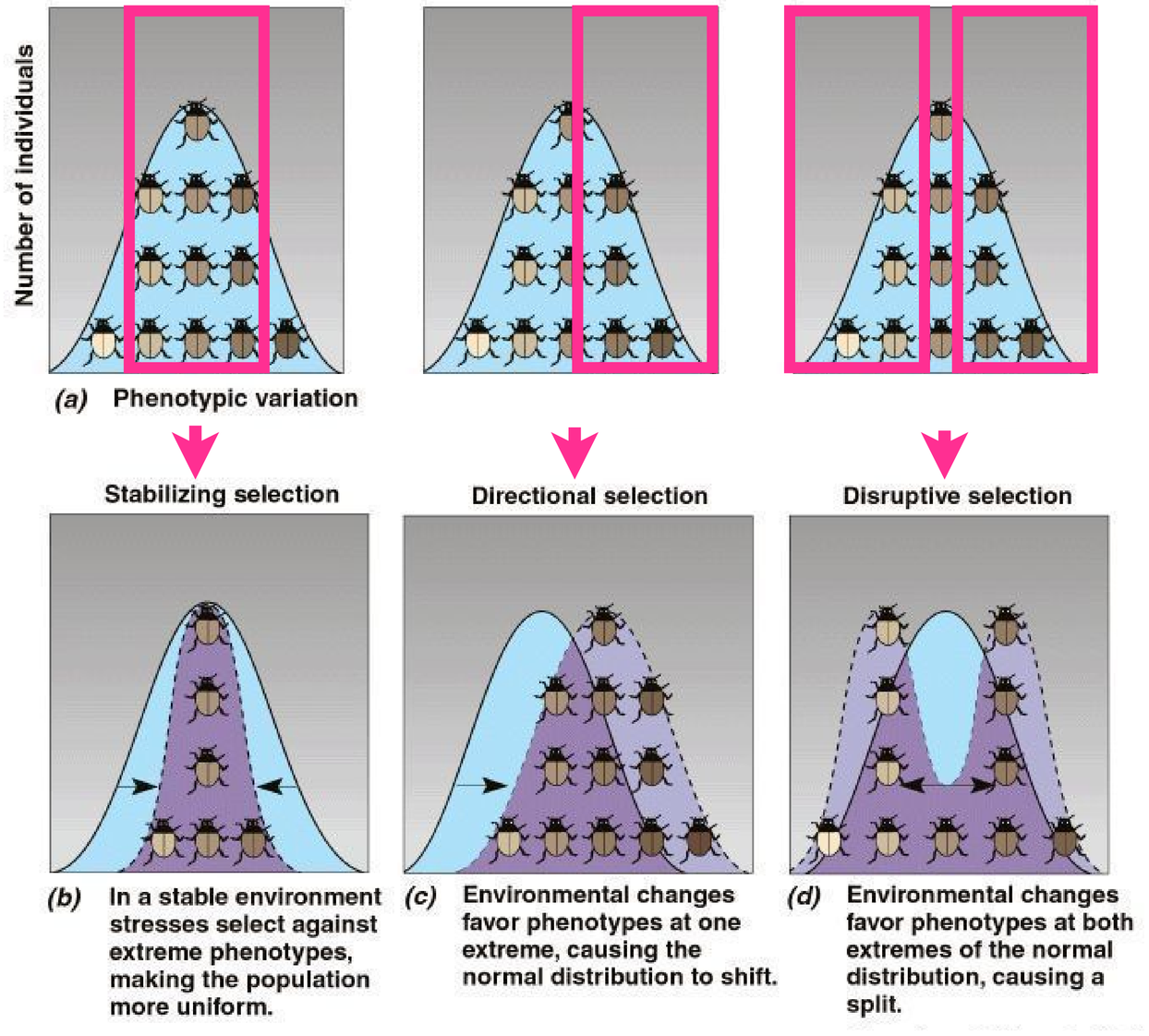
Natural selection is the higher survivorship and reproduction of more fit individuals, thus increasing their genetic contribution to the next generation



Selection

Applications to seed saving

- adaptation is selecting the best performing individuals under local environmental conditions
- seeds of the same variety saved by different gardeners will vary, depending on the selection criteria imposed

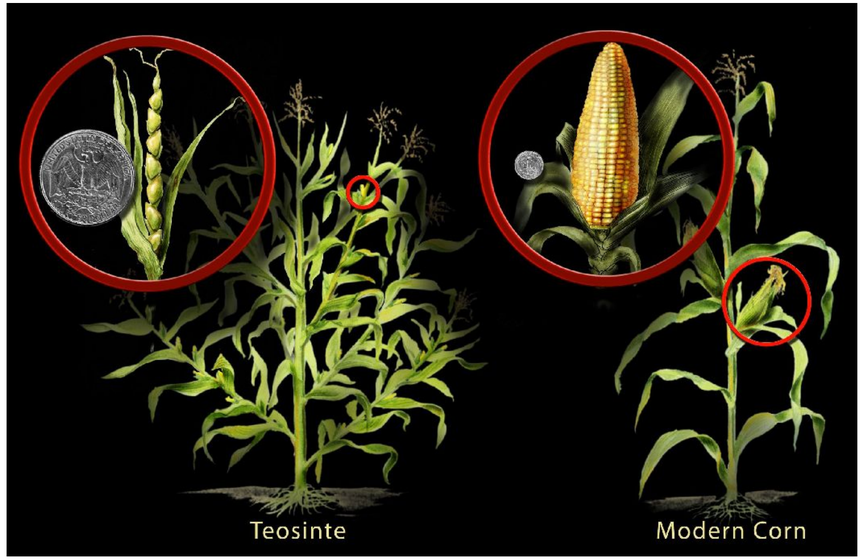


Modified from: Solomon: Biology, 5/e
Figure 18.5
Saunders College Publishing

Bottleneck / Founder Effect

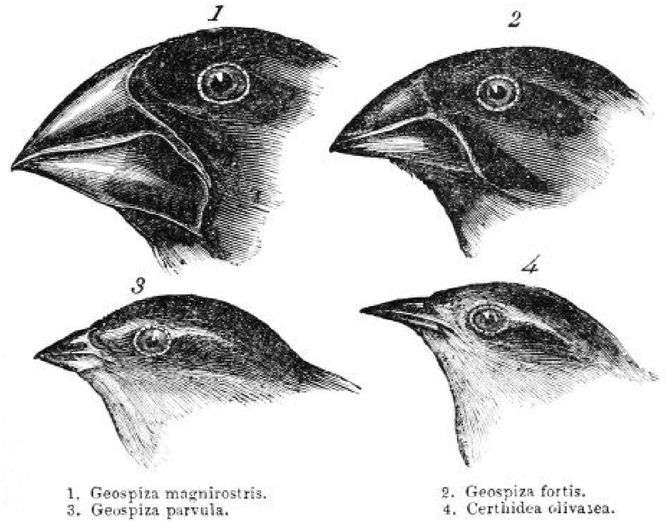
Bottleneck

- extreme population reduction (natural disaster, domestication, etc.)
- maize domestication, cheetahs



Founder effect

- small number of individuals found a new population
- Galapagos Islands



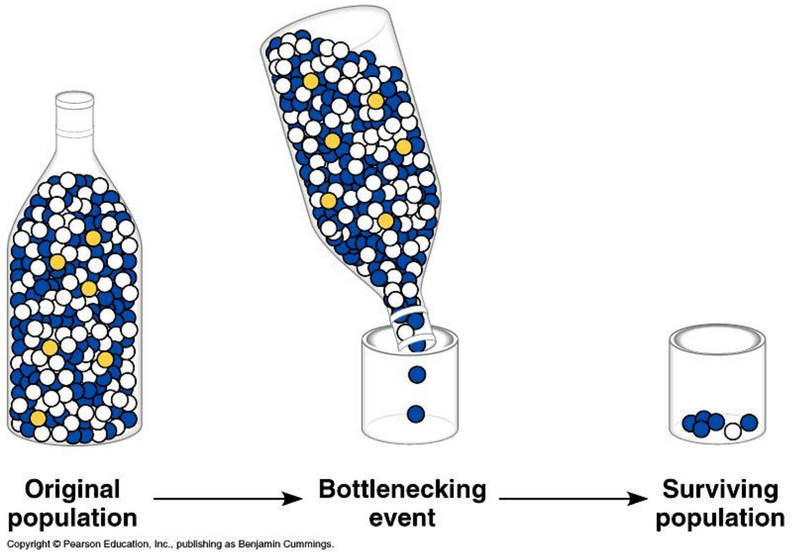
Bottleneck / Founder Effect

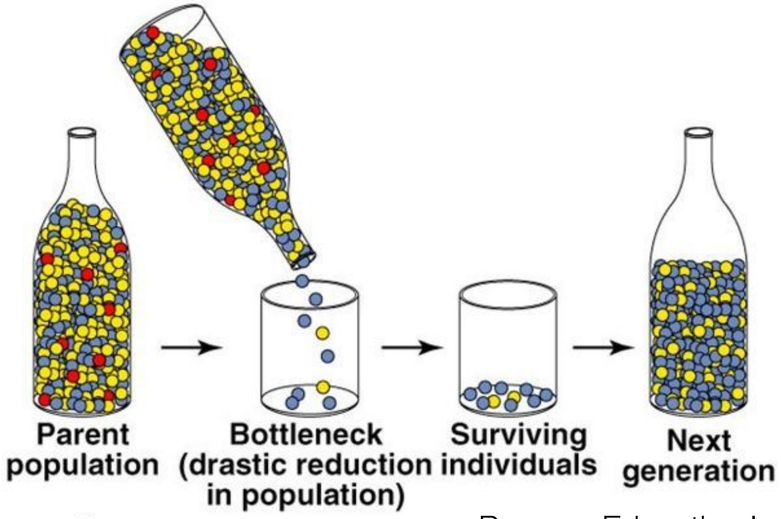
Bottleneck

- A drastic population reduction by natural or artificial means

Founder effect

- A new population founded by a small group of individuals





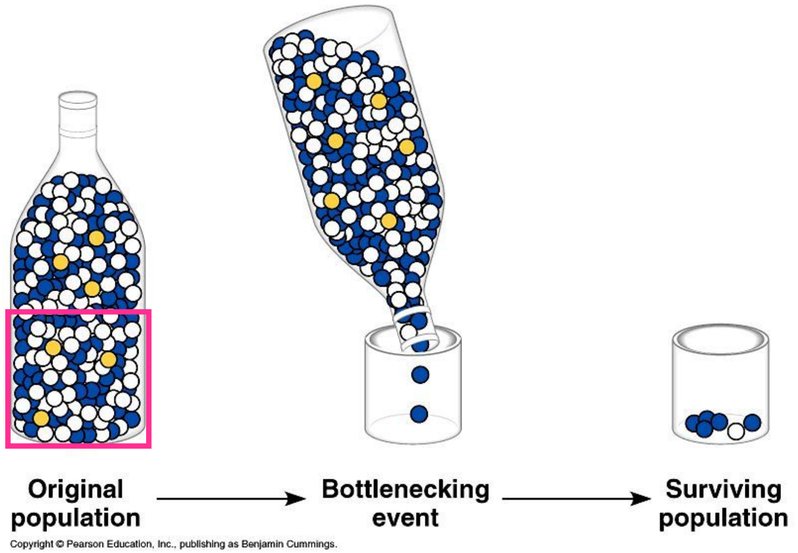
Pearson Education Inc.

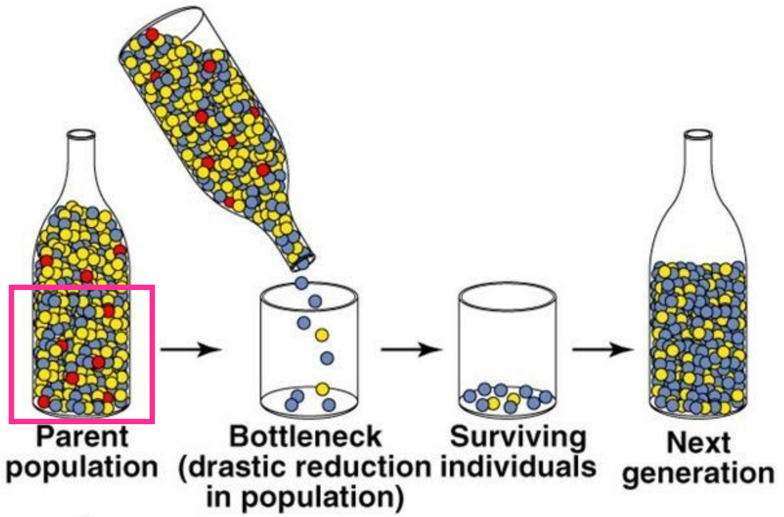
Both hypothetical populations undergo drastic reductions in size. The top population loses its ***yellow*** **individuals** while the bottom population loses its ***red*** **individuals**.

The top population may lose its ***white*** **individuals** in the next few generations if they are not as reproductively fit as the ***blue*** **individuals**.

Genetic Drift

- Reduction of genetic variation due to random chance
- More likely to impact rare variants
  - likelihood is they may disappear over time
  - there is also a chance that they may increase in frequency
- Larger populations are more likely to retain rare genetic variants

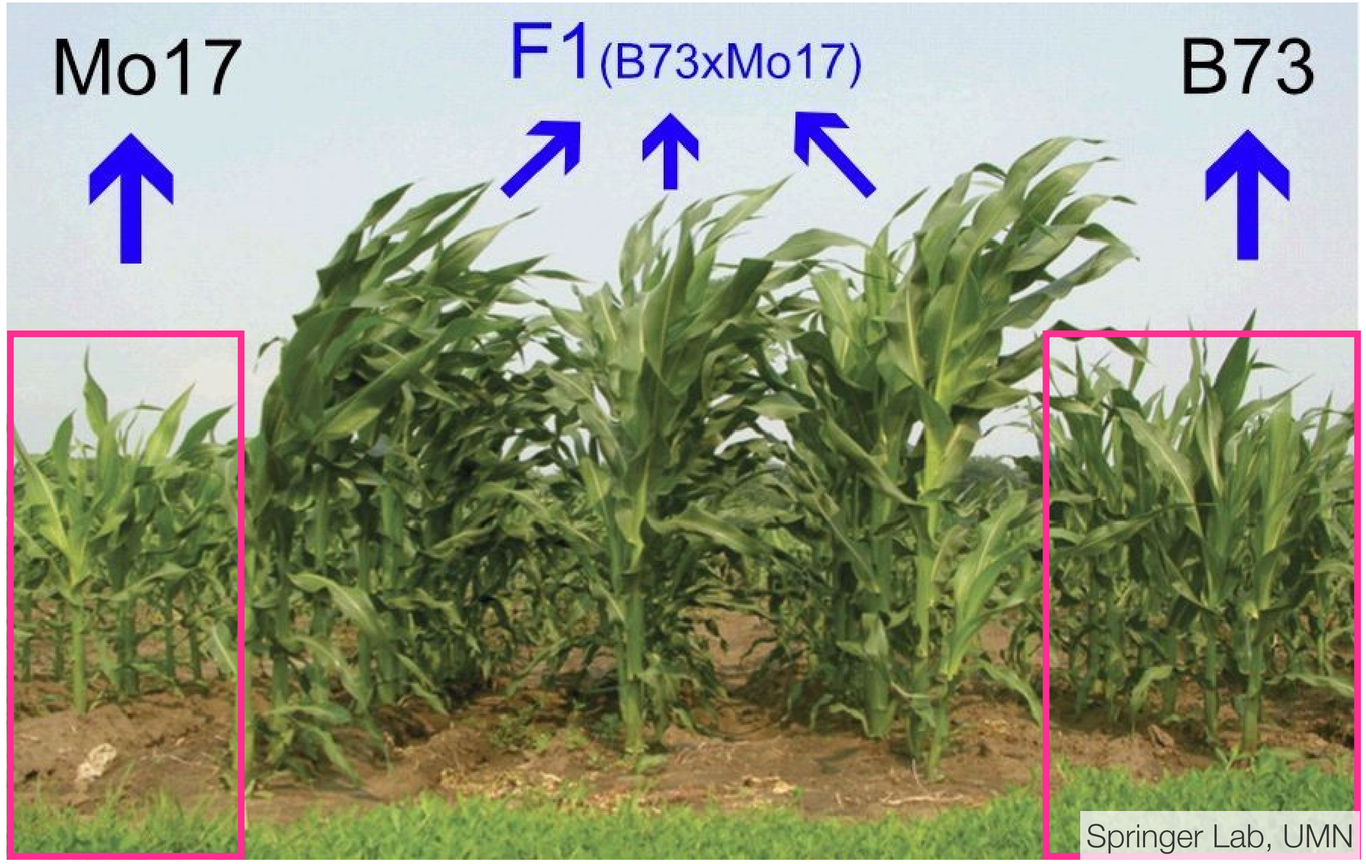




Pearson Education Inc.

Inbreeding Depression

- Reduced survival and fertility (fitness) of offspring of related individuals
- Often attributed to increased expression of recessive deleterious variants in the population (unmasking)

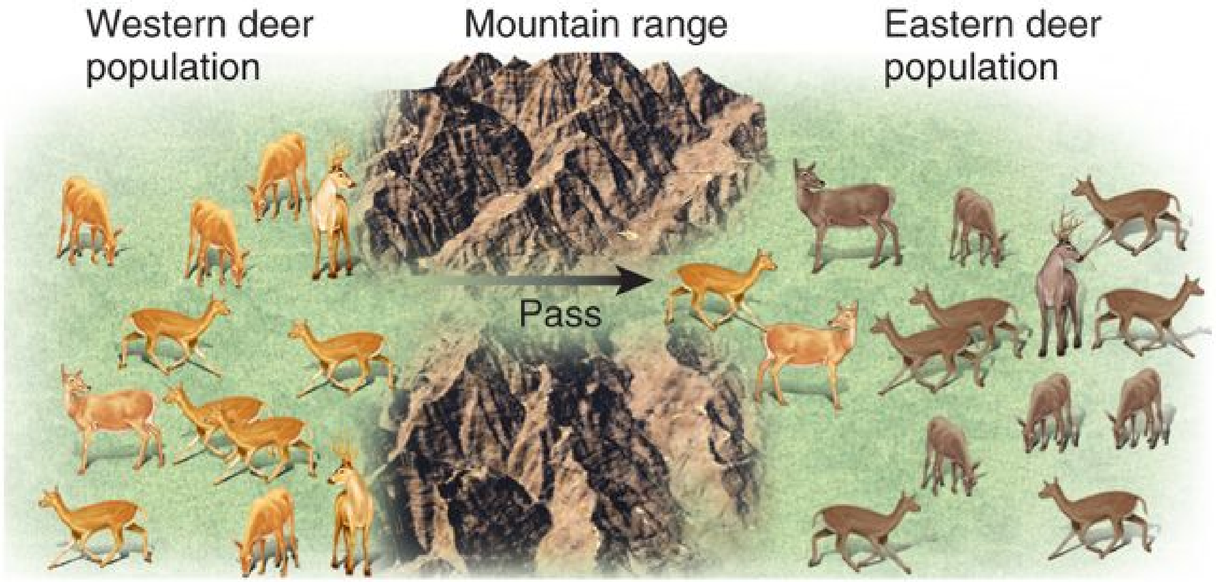


Migration

Genetic contribution from one population to another

- Only considers migrants that contribute to the next generation in the recipient population after migration

- Migrants can maintain genetic diversity of the recipient population(s) thus reducing or eliminating genetic differentiation between populations



The McGraw-Hill Companies

Seed Longevity

Seeds of some species remain viable for an exceptionally long time

- natural weed seed banks
- germination of old to ancient seeds

How is such longevity possible?

- combination of factors: species, moisture, temperature, oxygen
- most easily controlled at home are seed moisture (relative humidity) and temperature

DASonnenfeld CC BY-SA 4.0

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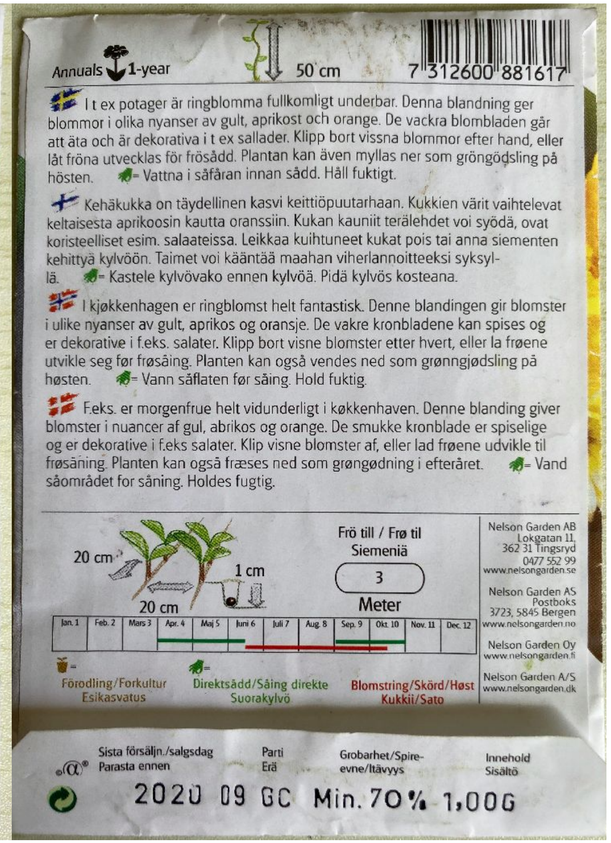
Top: Judean Date Palm, ~2000 yo seed, germinated 2005

Left: Sacred Lotus, ~1300 yo seed, germinated 1995

Seed Packet Information

Scandinavian/EU Packaging



US Packaging

Seed Longevity Charts

Seed	Relative storability index
FIELD CROP SEEDS—con.	
Wheatgrass—Con.	
Pubescent	2
Slender	2
Standard crested	2
Tall	2
Western	2
Wild rye:	
Canada	2
Russian	2
Zoysia (see Japanese lawngrass and manilagrass)	
VEGETABLE SEEDS	
Artichoke	1
Asparagus	1
Bean:	
Garden	1
Lima	1
Beet	3
Broadbean or horsebean	2
Broccoli	2
Brussels sprouts	2
Cabbage	2
Cardoon	1
Carrot	2
Cauliflower	2
Celeriac	2
Celery	2
Chicory	2
Collards	2
Corn, sweet	2
Cowpea	2

USDA Principles and Practices of Seed Storage

VEGETABLE CROP SEED STORAGE CHART

TYPE	AVG STORAGE LIFE (YRS)
Artichoke & Cardoon	1–4
Arugula	6
Asian Greens	3
Asparagus	3–4
Beans	2–4
Beets	2–5

HERB CROP SEED STORAGE CHART

TYPE	AVG STORAGE LIFE (YRS)
Angelica	2
Anise	1–3
Basil, sweet	3–5
Borage	1–4
Caraway	1–2
Catnip	3

FLOWER CROP SEED STORAGE CHART

TYPE	AVG STORAGE LIFE (YRS)
Ageratum	3–5
Agrostemma	3
Alyssum	3–5
Ammi	2
Amaranthus	4–5
Aquilegia (Columbine)	1–2
Artemisia	1–5

Johnny's Selected Seeds

Seed Storage

Relative Humidity (RH)

- dried seeds have a moisture content <20%
- airtight containers maintain a stable RH

Combined Storage Conditions

- Long term storage -18±3 °C (-0.4±5.4 °F), RH 15±3%
- Medium term storage 5-10 °C (41-50 °F), RH 15±3%

Home Storage

- refrigerators are generally set to 40 °F or below
- airtight containers

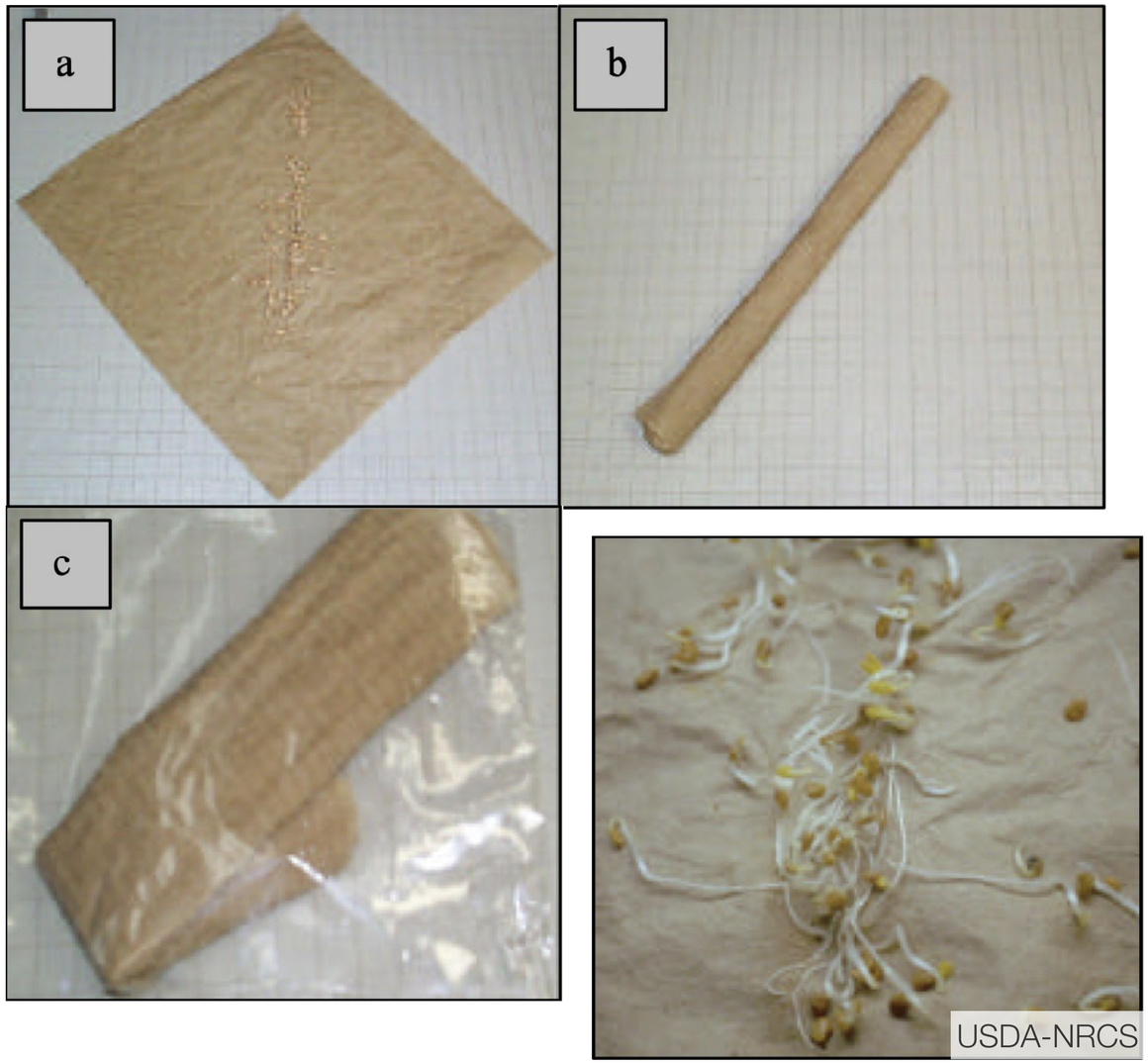
Scott Bauer, USDA/ARS

Germination Testing

Germination testing provides information on seed **longevity <u>given your storage conditions</u>** and **timing for regenerating seed stock**

Germination Testing

- 10-100 seeds placed in a moist paper towel
- roll into a tube, fold in half then place into a plastic bag and seal it
- keep at 30 °C (85 °F); room temperature (21 °C/ 70 °F) works too but may take longer
- count the number of germinated seeds at 4 days and repeat after 3-4 more days
- calculate the percent germination



Species-specific Germination Testing

An important note regarding our germination test methods:

Our methods are dynamic. We may begin with rules listed in standardized germination tests, but we are always trying to improve the accuracy of the results. Consequently, these methods may change over time and in the overwhelming majority of cases will not reflect what are listed in seed germination handbooks or manuals. The germination test methods are provided to let you know how we obtained the percent germination, dormancy, and overall viability as listed on the seed packet sent to you.

Quick Locators:

- Crop Names (Genus or general group names)
- Evaluation Numbers (ENOs)

Crop Names first letter

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

	ENO	Group	Curator info
A			
Actaea	493243	Ornamentals	curator
Agastache	493218	Ornamentals	curator
Alcea	493226	Ornamentals	curator
Alliaria	493335	Oilseeds	curator

ENO: 493218 Agastache		
Duration	Temperature	Fluorescent Lights
12 hours	25 ?C	ON
12 hours	15 ?C	OFF

Seeds are placed on 3 blotter papers (2 blue, 1 white - in contact with seeds) moistened with tap water in plastic boxes (5" x 5-1/4") and kept at room temperature overnight. Transfer to germinator alternating between 25 ?C with light for 12 hours and 15 ?C in darkness for 12 hours per 24 hour cycle. Replication and sample size: 4 reps of 50 seed each for a total of 200 seeds. Germination counts occur 8 and 16 days after start of test.

ENO: 178 Brassica (carinata, napus, rapa)		
Duration	Temperature	Fluorescent Lights
12 hours	25 ?C	ON
12 hours	15?C	OFF

Seeds are placed between blotter papers moistened with 0.1% KNO_3 in plastic boxes (5" x 5-1/4") with the following arrangement:

(top) 1 blue paper
seeds
1 white paper
(bottom) 1 blue paper

Let seeds imbibe overnight at room temperature; prechill at 4 ?C for 14 days. Transfer to germinator with temperatures alternating alternating between 25 ?C with light for 12 hours and 15 ?C in darkness for 12 hours per 24 hour cycle. Replication and sample size: 4 reps of 50 seed each for a total of 200 seeds. (Alternatively, 2 reps of 100 seeds.) The first germination count occurs between 3 and 7 days and the last count is on the 14^{th} day after start of test.

Summary

Many organizations save seeds and SO CAN YOU!

Seed Categories

- Open Pollinated & Heirloom
- F1 Hybrids
- ~~Genetically Engineered~~

Considerations for Seed Saving and Storage

Germination Testing

HAVE FUN!


Questions?

Resources

USDA Principles and Practices of Seed Storage https://naldc.nal.usda.gov/download/CAT87208646/PDF

USDA Ragdoll Test to Estimate Field Germination https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_021607.pdf

USDA Ames Plant Introduction Research, Ames, IA https://www.ars.usda.gov/midwest-area/ames/plant-introduction-research/home/germination-test-methods/page-1/

FAO Genebank Standards for Plant Genetic Resources for Food and Agriculture

- Section 4, Genebank Standards for Orthodox Seed, includes germination testing; https://www.fao.org/3/i3704e/i3704e.pdf

Resources

Seed Savers Exchange (several good resources)

- Seed Saving Information https://www.seedsavers.org/learn#seed-saving
- Seed Saving Guide https://www.seedsavers.org/site/pdf/Seed%20Saving%20Guide_2017.pdf
- Germination Testing https://www.seedsavers.org/site/pdf/HomeGermTests_LAFrevised.pdf

Johnny's Selected Seeds Seed Storage and Longevity Guides

- https://www.johnnyseeds.com/on/demandware.static/-/Library-Sites-JSSSharedLibrary/default/dw913ac4d0/assets/information/seed-storage-guide.pdf
- https://www.johnnyseeds.com/growers-library/methods-tools-supplies/harvesting-handling-storage/seed-storage-guidelines.html

Tomato Grafting

- https://horticulture.ucdavis.edu/information/tomato-grafting-guide