July 12th 2022

Classical plant breeding

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Summer Course – Plant Biotechnology

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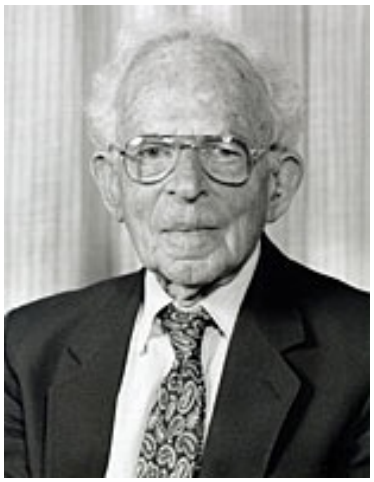
Plant breeding

"Genetic adjustment of plants at the service of humanity"

Through modifications in the DNA of the plants it is intended to obtain new characteristics of interest. Modifications can be achieved by crossbreeding or genetic manipulation

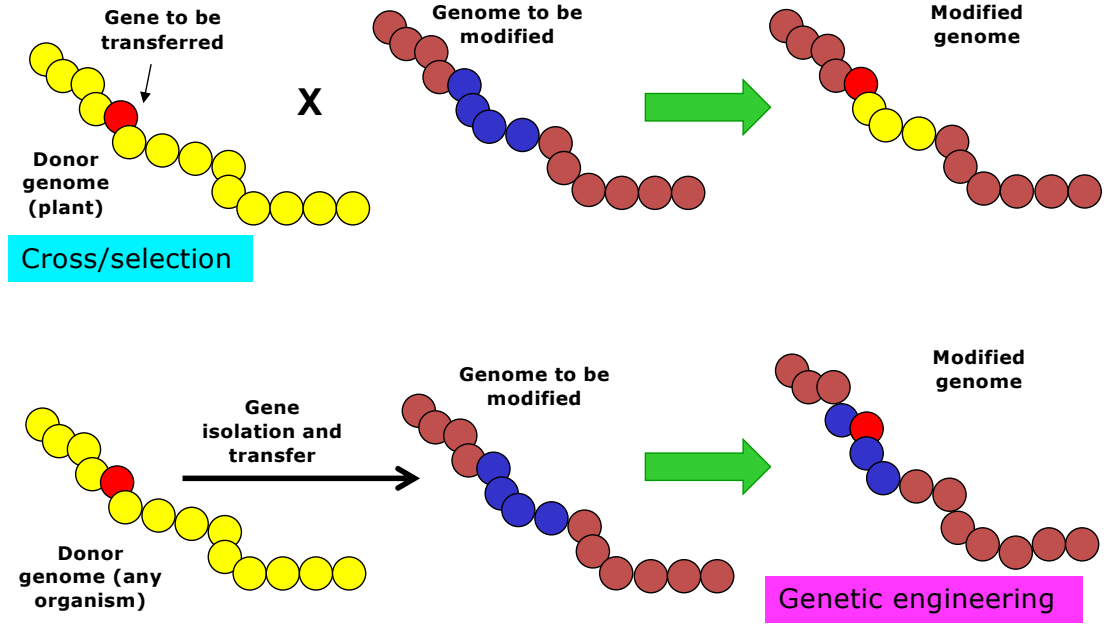
Otto Frankel



1890-1998 Áustria, Austrália

2

Plant breeding



3

Plant breeding depends on genetic variability

Solanum lycopersicum

Solanum tuberosum

4

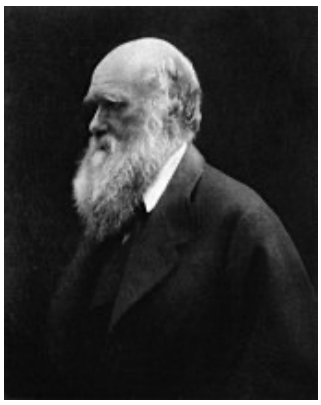
Plant breeding began with domestication

https://www.thoughtco.com/founder-crops-origins-of-agriculture-171203

5

Darwin and the artificial selection

Artificial selection is the identification by humans of desirable traits, and the steps taken to enhance and perpetuate those traits in future generations. Artificial selection works the same way as natural selection



Many plants have been improved or even created through artificial selection

Broccoli, cauliflower, and cabbage were all derived from the wild mustard plant through selective breeding

Artificial selection it is faster than natural selection and allows humans to mold organisms to their needs

https://education.nationalgeographic.org/resource/artificial-selection

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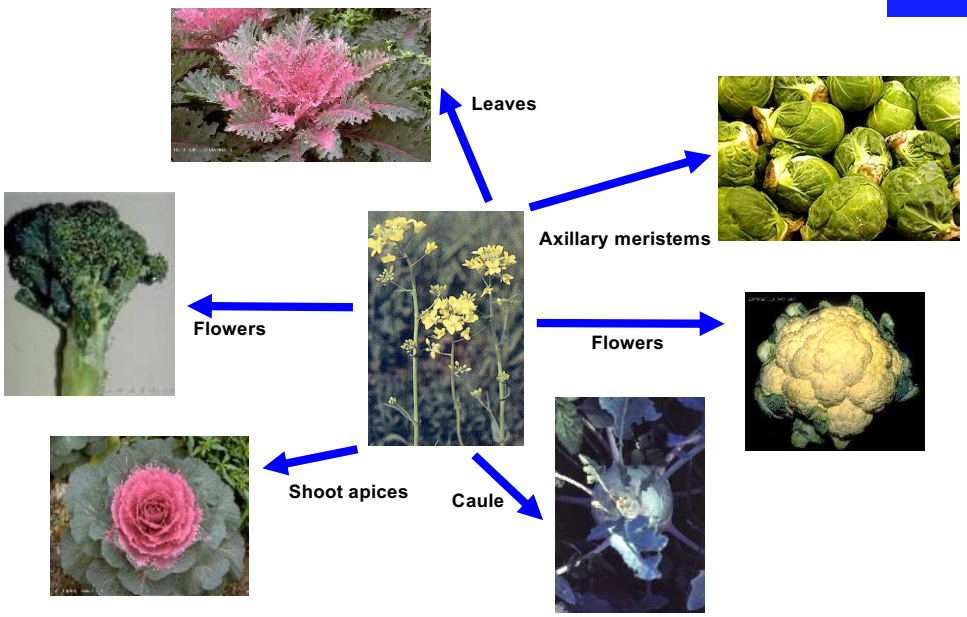
An example of artificial selection

Variations on the same theme

Brassica oleracea



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Mendel – laws of heredity

Hugo De Vries, Carl Correns and Erich von Tschermak (1900)

Genes control the characteristics of organisms

The principles of breeding started to be understood

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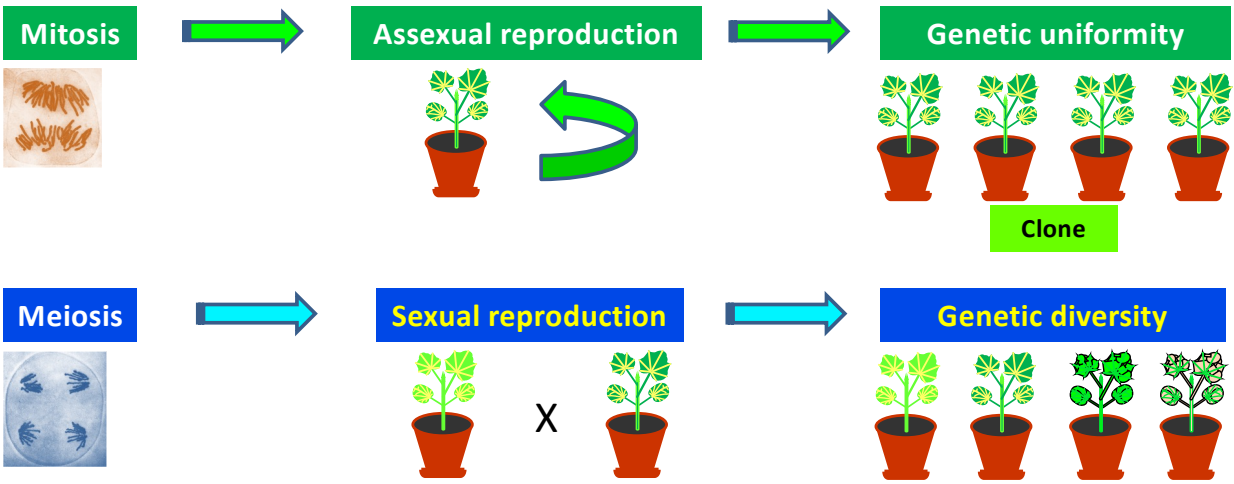
Genetic diversity is based on sexual reproduction

In turn, sexual reproduction is closely associated with meiosis



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Genetic diversity is based on sexual reproduction

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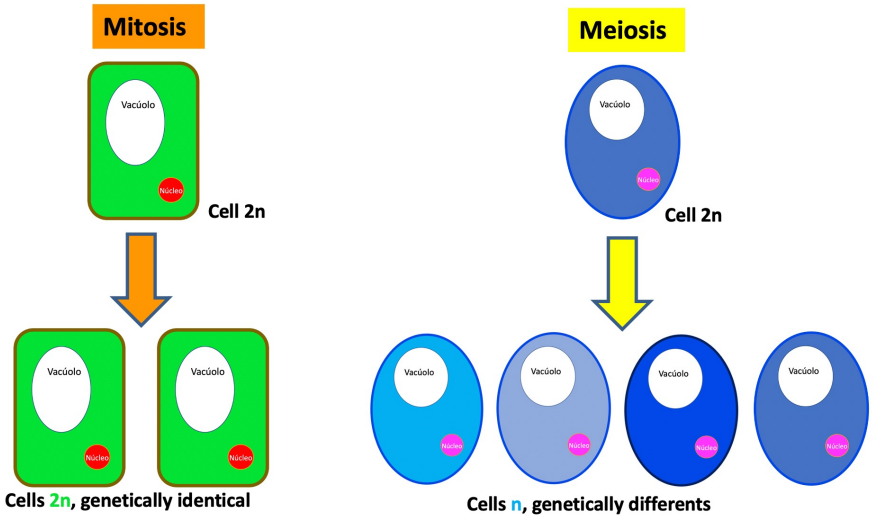

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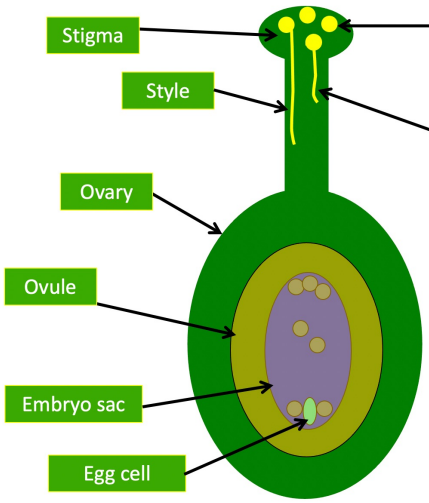
Sexual reproduction in plants



Cherchez la femme

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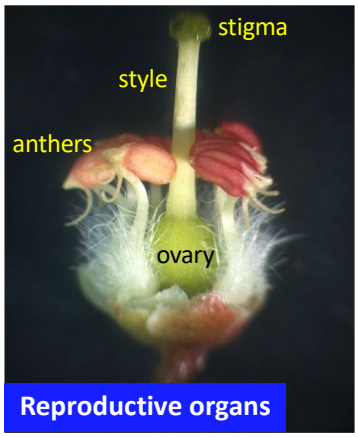
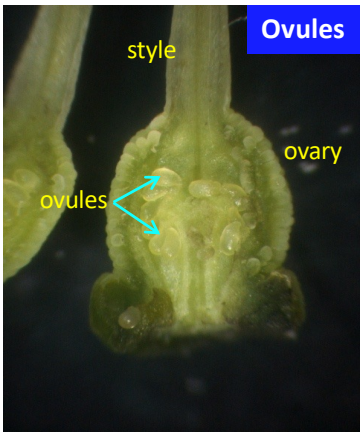
Sexual reproduction in plants

The pollen tube carries the male gametes to the ovule (embryo sac)





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Plant breeding for what?

We may nave not noticed, but around 10^7 were born last month

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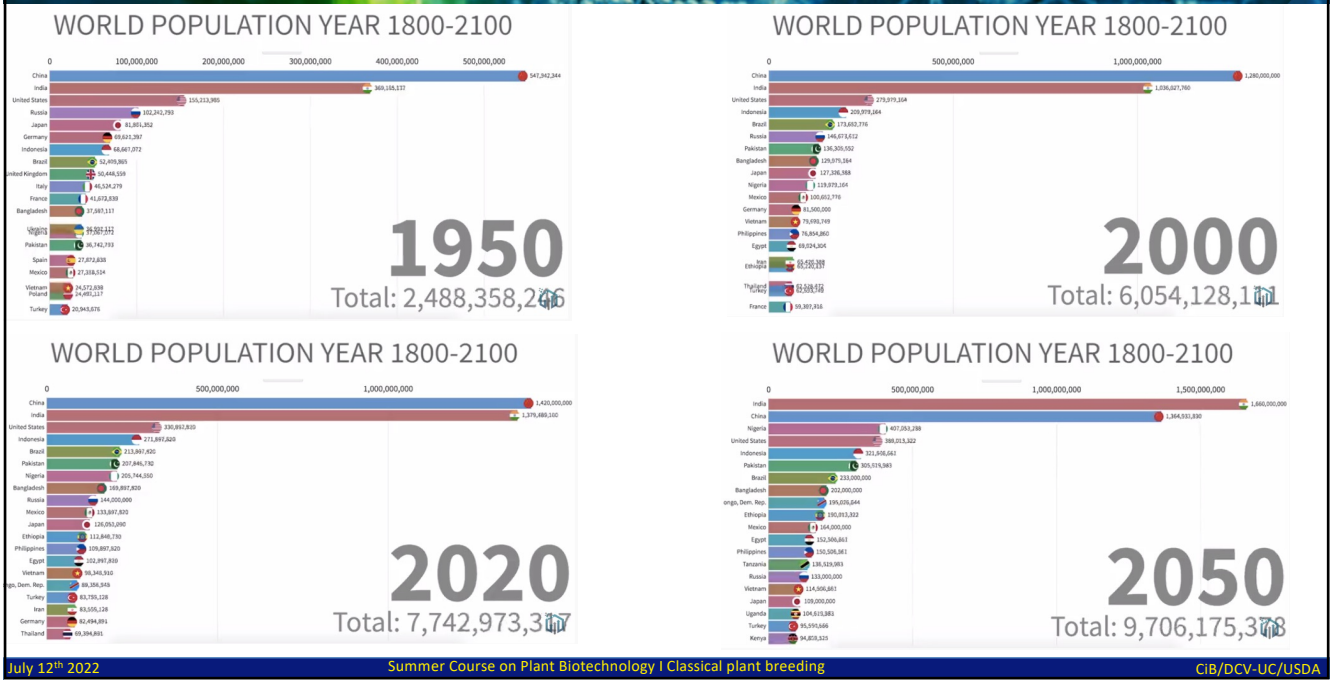
Evolution of the world population



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Pests and diseases

www.dn.pt, 6-2-2017

"Lagarta militar" ameaça agricultura africana

IRO DE 2017

:TILHAS

/IAR POR EMAIL

PUB

Já há seis países afetados e cientistas falam de

15

Climate change

Food and Agriculture Organization of the United Nations

FAO STRATEGY ON CLIMATE CHANGE

Rome, July 2017

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Losses of productivity

Insects and other small animals – 18%

Microorganisms – 16%

Weeds – 34%

Only 6% of the produced biomass is used as food

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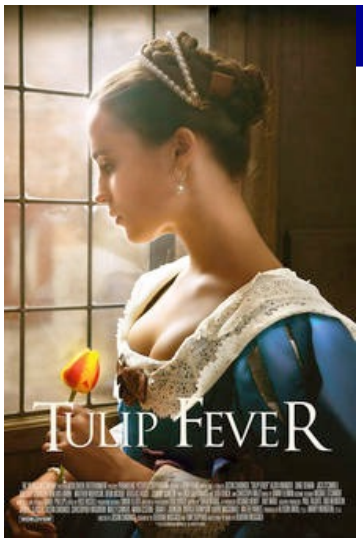
Consumers like new products



Tulips

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National and international policies

UNESCO

SDG 2015-2030

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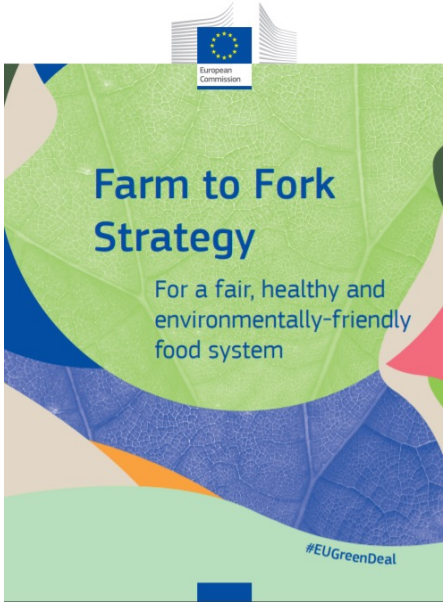
European Union strategies



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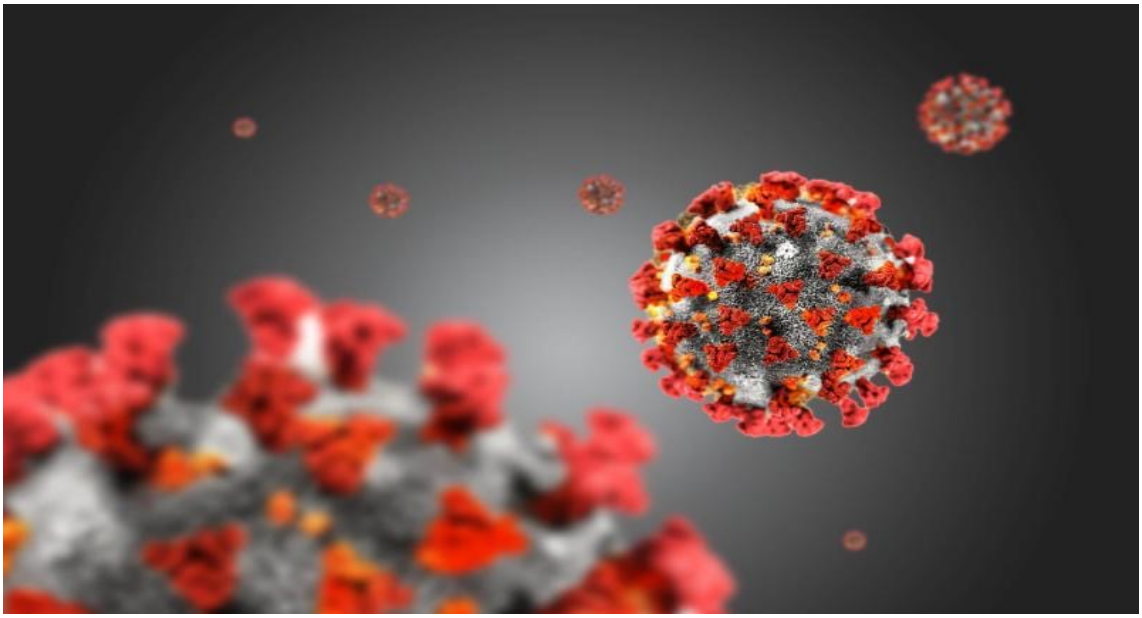
Unexpected factors



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Unexpected factors

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Food security

Limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways (USDA)

Lack of secure access to sufficient amounts of food for normal human growth and an active and healthy life. Food must be both consistently available and accessible in sufficient quantities and diversity (FAO)

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Food safety

Refers to the process of scientific organization that describes ways to deal with, manufacture, and store food through ways to prevent foodborne disease.

Try do not die when eating something!

There *is* no *food security* without *food safety*

Regulatory authorities (EFSA, FDA…)

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Food safety

E coli outbreak: German organic farm officially identified

Eat cucumbers, tomatoes and lettuce again, say German health authorities, but avoid bean sprouts

▲ The cause of the E coli outbreak has been officially linked in Germany to the consumption of bean sprouts. Photograph: Christian Charisius/EPA

Bean sprouts from an organic farm in northern Germany caused the *E coli* outbreak that has killed 31 people and infected thousands more, German officials said on Friday.

Health inspectors have identified the source of the infections after linking patients who fell ill with the bug to 26 restaurants and cafes known to have received produce from the farm in Lower Saxony.

2011

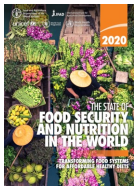
The Guardian

25

The presente situation

Chronic hunger increased 10 million people between 2018-19

Chronic hunger increased 60 million people in the last 5 years



690 million (8.9%) people were chronically hungry in 2019

840 million people will be chronically hungry in 2030

In 2019, 21.3 percent (144.0 million) of children under 5 years were estimated to be stunted

We are not on track to meet 2030 UNESCO's targets

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Potato great famine – XIX century (Ireland)

Dublin
Great Famine Memorial

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Can science feed the world?

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Can science feed the world?

Feeding this ever-growing population requires not only increasing production but also bringing other plants into our eating habits

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Orphan crops

Species that tend to be regionally important but not traded around the world and receive no attention by research networks. Used locally by communities.

Lathyrus sativus **(Chícharo, Fabaceae)**

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Orphan crops

Lathyrus sativus (Chícharo, Fabaceae)

Cod fish

Soup

31

Orphan crops

Montia fontana

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Sources of variability

Sources of natural genetic diversity

Landraces

Crop wild relatives

www.seedsofdiscovery.org

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Portuguese germoplasm bank

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Crop wild relatives

***Daucus carota* subsp. *halophilus* – wild carrot**



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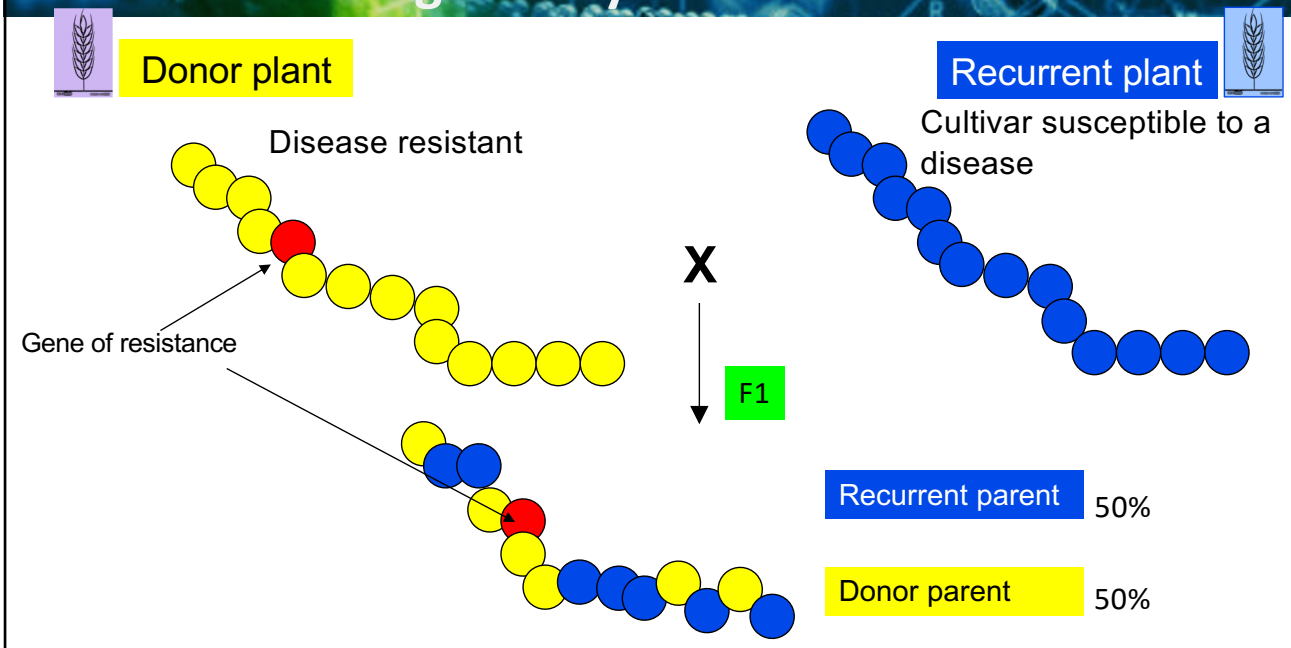
How to transfer genes by crosses?



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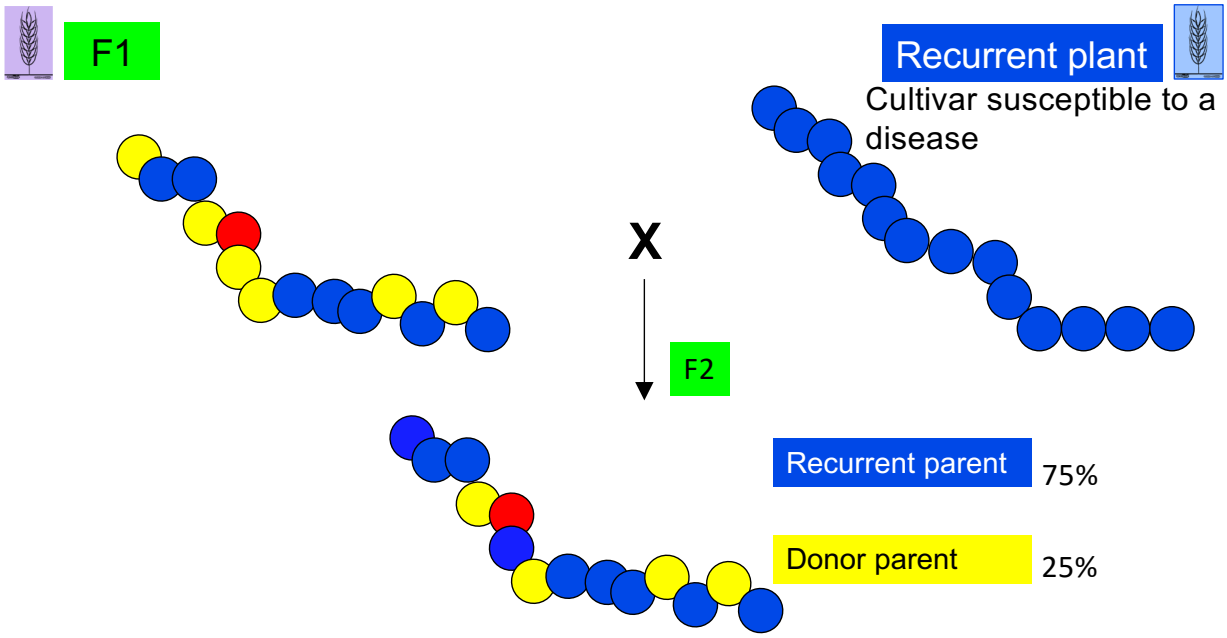
Backcrossing



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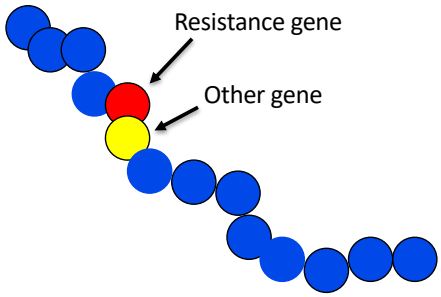
Backcrossing

A new cultivar is obtained similar to the recurrent parent but with a "new" gene conferring resistance to a pathogen



After 7-8 backcrosses

Recurrent parent 99.9%

Donor parent 0.01%

A genetic transformation was achieved without gene manipulation in the lab

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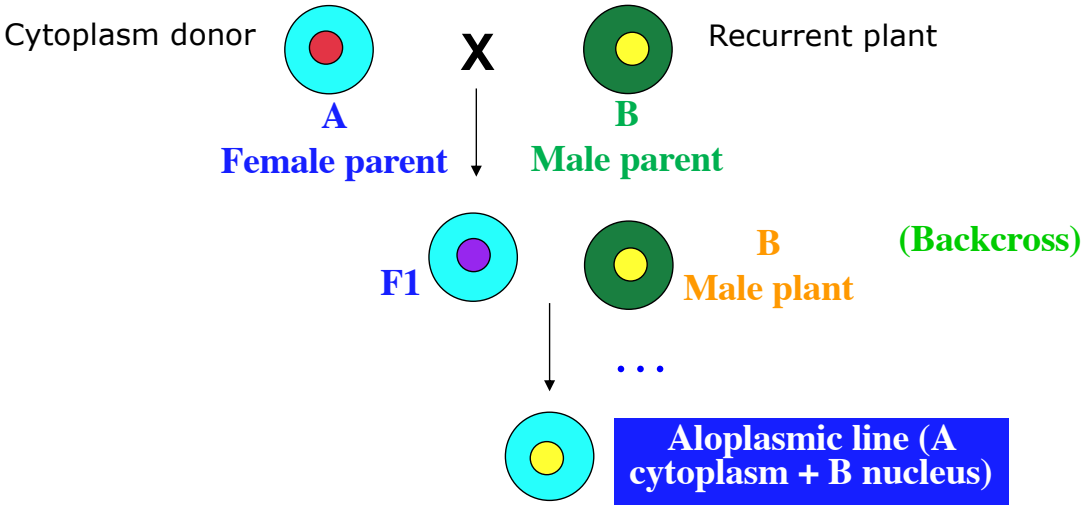
Cytoplasmic genes can also be changed - aloplasmia



Aloplasmic lines often display cytoplasmic male sterility which make them "female" plants

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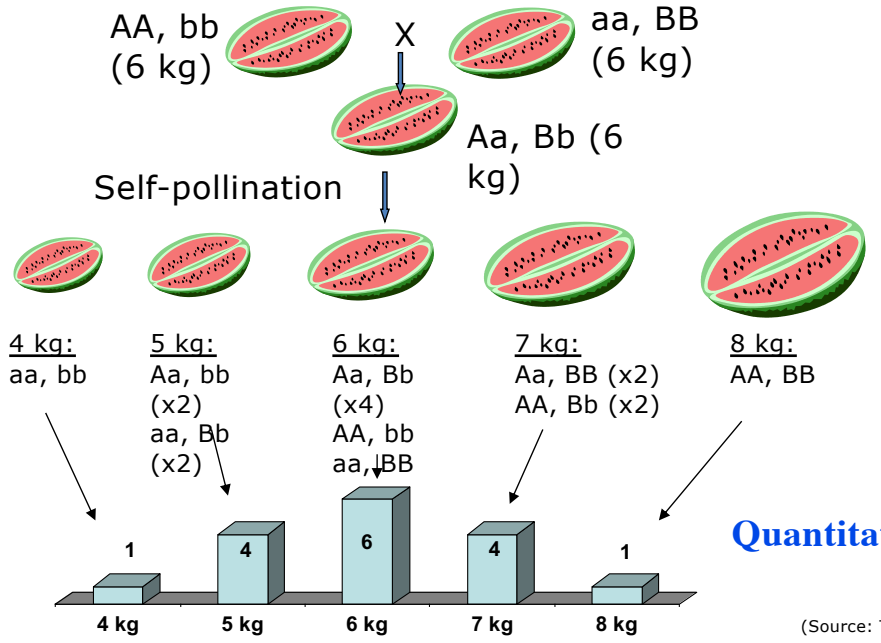
Interesting features are usually polygenic

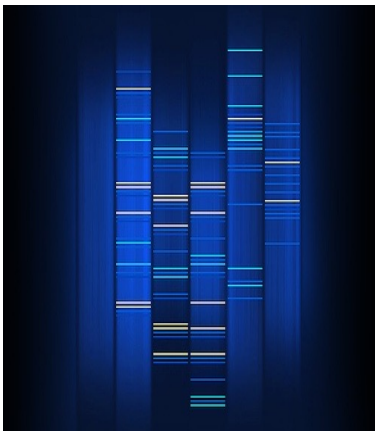


Quantitative traits

(Source: Tinker, 2008)

40

To select polygenic traits, MAS selection is used



QTLs – *quantitative trait loci*
MAS – Markers-assisted selection

Based on the identification of molecular markers associated to QTLs

Selection is carried out using molecular tools and not phenotypic characteristics

Hybridisation is a tool to obtain new species

Tangerina x Toranja

C. reticulata x C paradisi

Tângera

C. reticulata x paradisi

Hybrid cultivars

Zea mays

Arabidopsis thaliana

When two inbred lines are crossed the F1 show better performances

This is called heterosis or hybrid vigor or outbreeding enhancement

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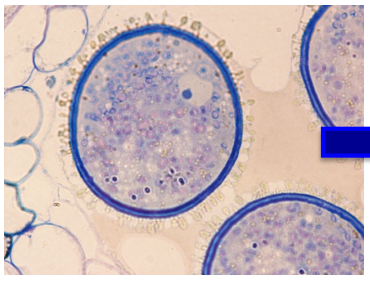
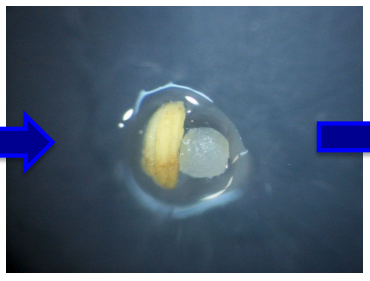
Inbred lines

Inbred lines can be obtained by successive self-pollinations or, more easily through chromosome duplication of haploid plants



Micrósporo (n)



Calo

Planta n

44

Chromosome doubling

Planta n

Colchicine

Planta 2n

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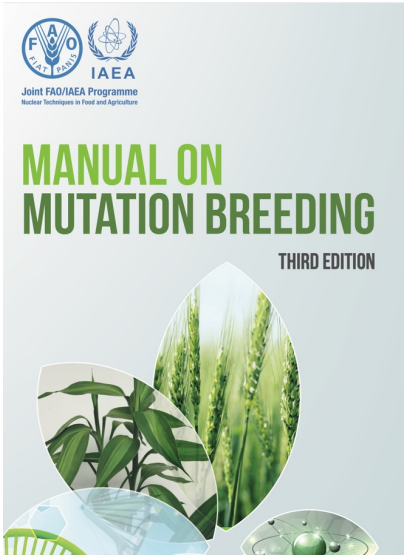
Induced variability

Mutagenesis has long been used in plant breeding

Spencer-Lopes, M.M.
Forster, B.P.
Jankuloski, L.

2018



https://www.fao.org/3/i9285en/I9285EN.pdf

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Mutagenesis occurs in natural conditions

Esteva – *Cistus ladanifer*

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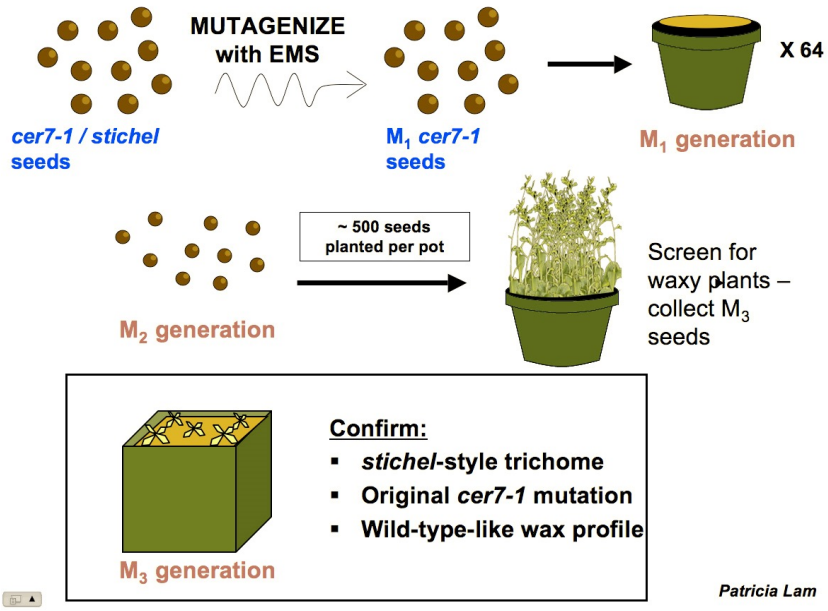
Induction of mutagenesis



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Every year new cultuvars based on mutagenesis appear

www.iaea.org

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Joint FAO/IAEA Division of Nuclear Techniques in Agriculture

Plant Breeding and Genetics Subprogramme

Welcome to the Joint FAO/IAEA Mutant Variety Database

Search Varieties

Most Recent Varieties

Variety Name	Latin Name
Binadhan-19	Oryza sativa L.
Binamasur-11	Lens culinaris Medik.
Binamoog-9	Vigna radiata (L.) Wil.
CBC5	Vigna unguiculata Walp.
DT2010	Glycine max L.

Background

The application of mutation techniques has generated a vast amount of genetic variability and is playing a significant role in plant breeding and genetics and advanced genomics studies. The widespread use of mutation techniques in plant breeding programmes throughout the world has generated thousands of novel crop varieties in hundreds of crop species, and billions of dollars in additional revenue.

The FAO/IAEA Mutant Variety Database or MVD collects information on plant mutant varieties (cultivars) released officially or commercially worldwide. Data on the mutagen and dose used, the characters improved, and agronomic data if available are among the information provided. The purpose of the database is to demonstrate the significance of mutation breeding as an efficient tool for preserving and enhancing global food security, to serve as a platform for breeders to showcase their varieties to a global audience, and to stimulate germplasm transfer for cultivation, breeding or genomics studies.

In the context of MVD a mutant variety is a new plant variety that is bred through:

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Mutagenesis-based cultivar

Binadhan-19

Mutant Variety ID	4465
Latin Name	Oryza sativa L.
Common Name	Rice
Country	Bangladesh
Contact	Md. Abul Kalam Azad
Description	Seeds of NERICA-10 variety of rice were irradiated with 40 Gy carbon ion beams from Japan Atomic Energy Agency in 2013. A plant found in M1 generation with erect, shorter height, long and slender grains with golden yellow color unlike the parent NERICA-10. These mutated traits remained almost unchanged in the following generations. The pedigree of the mutant was N10-40(C)-1-5 which was tested two seasons in a year for yield, duration and other important yield attributes and was released 3 years and 3 months after mutation induction (irradiation).
Character Improvement	1. Shorter height, shorter duration, uniform plant growth 2. Long and slender grains with golden color 3. Higher yield (Average yield 3.84 t/ha and maximum 5.0 t/ha)
Miscellaneous	Binadhan-19 is suitable for both Aus and Aman seasons. It can be grown under rainfed condition following direct seeding (Dibbling) in line. This variety does not need seedling raising and also puddle the soil. Plant height ranges 80-90 cm and does not lodge. During severe drought the plants almost stop growing but when there is rain the plants start growing vigorously and give almost equal yield like favorable condition. It matures in 90-105 days, thousand grain weight is 23 g. Dehulled grains are white, long and slender. Grains contain 7.32% protein, 23.8% amylose.
Development Type	Direct use of an induced mutant

Carbon ion beams, 40Gy

Mutagenis is also random but very effective

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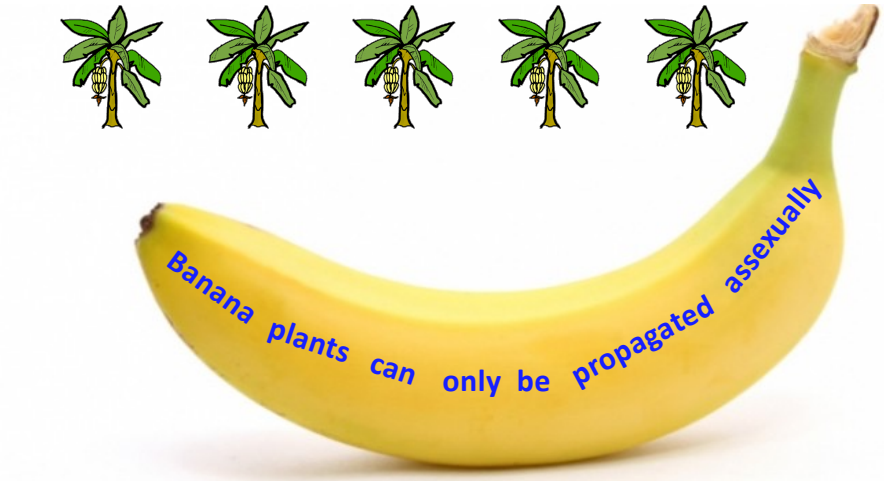
Some species are difficult to breed



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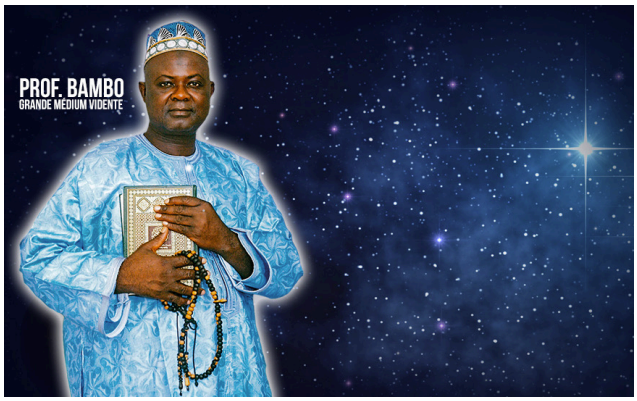
A plant breeder must have some guessing skills



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Norman Borlaug

1914 - 2009, Peace Nobel Prize in 1970

"You can't build peace on empty stomachs"

"Green revolution"

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Conventional breeding has many limitations

Time-consuming

Random

Other genes beyond the interesting gene can be transferred

Genetic incompatibility barriers

But... keep crucial to obtain new cultivars

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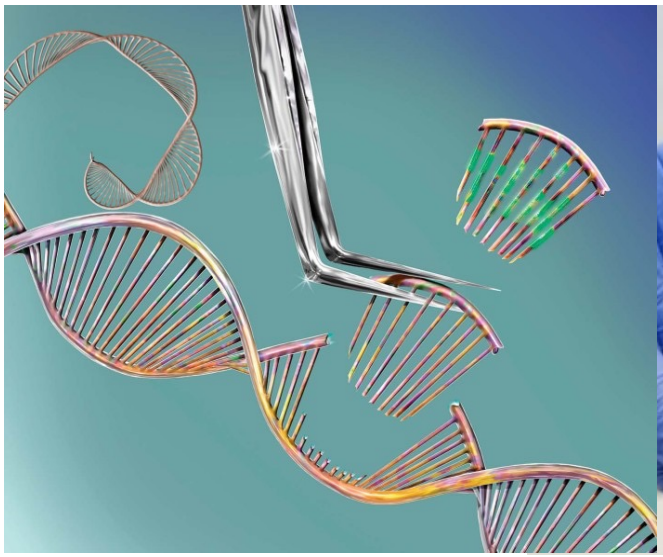
Genetic engineering, genome editing...



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July 12th 2022

Obrigado

Before I came here I was confused about this subject.

Having listened to your lecture I am still confused. But on a higher level.

Enrico Fermi

CENTRE FOR FUNCTIONAL ECOLOGY

USDA

CiB