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Genetically Modified Crops – Introduction and Status

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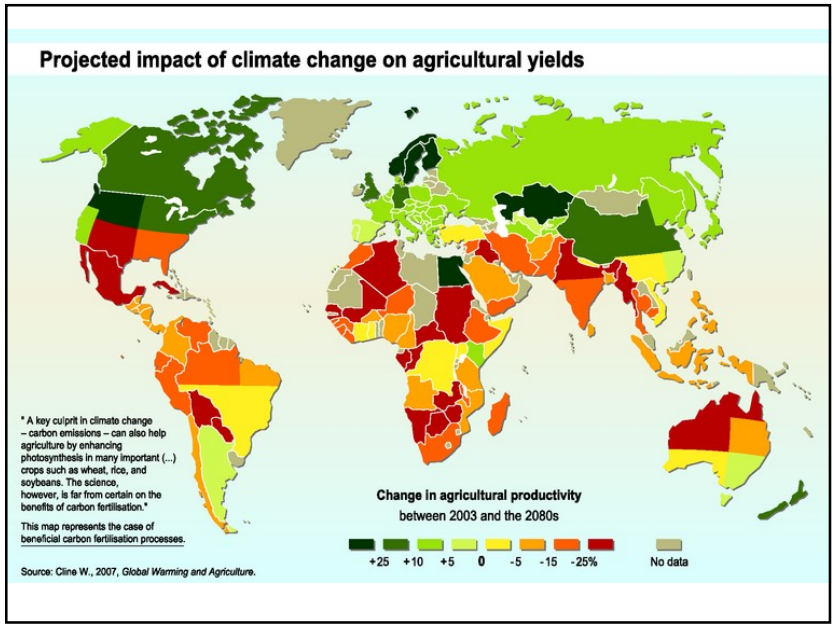
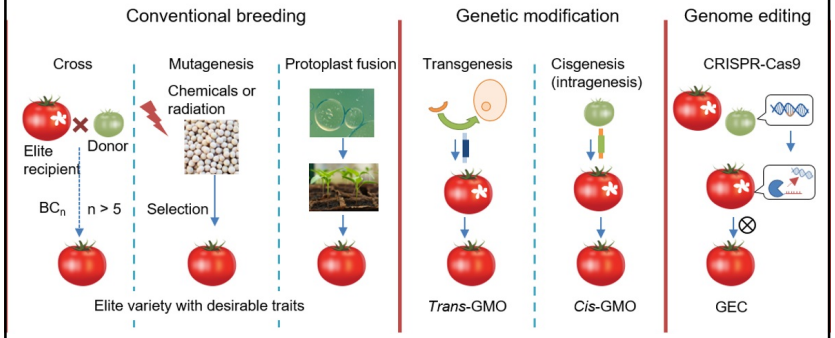
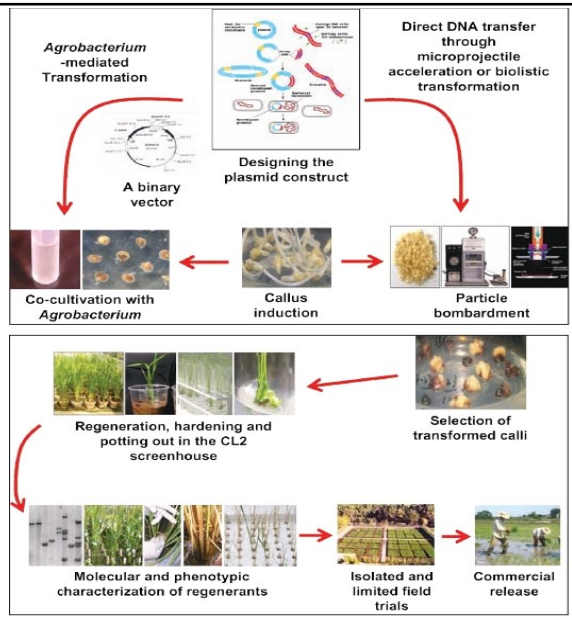
Creating a Sustainable Food Future by 2050
How do we feed 10 billion people...
...without using more land...
...while lowering emissions?
WE WILL NEED
56% more food
2010
2050
TO FEED NEARLY
10B people in 2050
2050
2010
WE NEED TO PREVENT AGRICULTURE FROM EXPANDING
we currently use ~50% of the world's vegetated land for agriculture
TO SAVE AN AREA OF FORESTS NEARLY 2X the size of India
WE CAN LOWER EMISSIONS
12 Gt CO2e
-67%
4 Gt CO2e
2010
2050
WITH INNOVATIVE TECHNOLOGY LIKE
burp
Improved feeds
Plant-based burgers
Resilient crop breeds
Source: wri.org/sustfoodfuture
WORLD RESOURCES INSTITUTE


Projected impact of climate change on agricultural yields
* A key culprit in climate change – carbon emissions – can also help agriculture by enhancing photosynthesis in many important (...) crops such as wheat, rice, and soybeans. The science, however, is far from certain on the benefits of carbon fertilisation.*
This map represents the case of beneficial carbon fertilisation processes.
Source: Cline W., 2007, Global Warming and Agriculture.
Change in agricultural productivity between 2003 and the 2080s
+25 +10 +5 0 -5 -15 -25%
No data

How we can improve a crop?



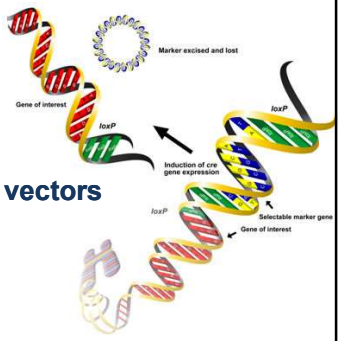
Popular Methods for Development of Transgenic Plants

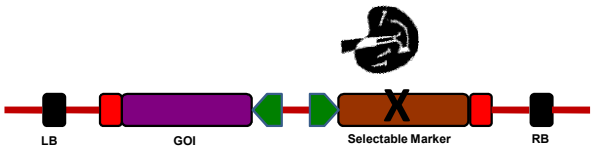


Source: Alfonso, 2007

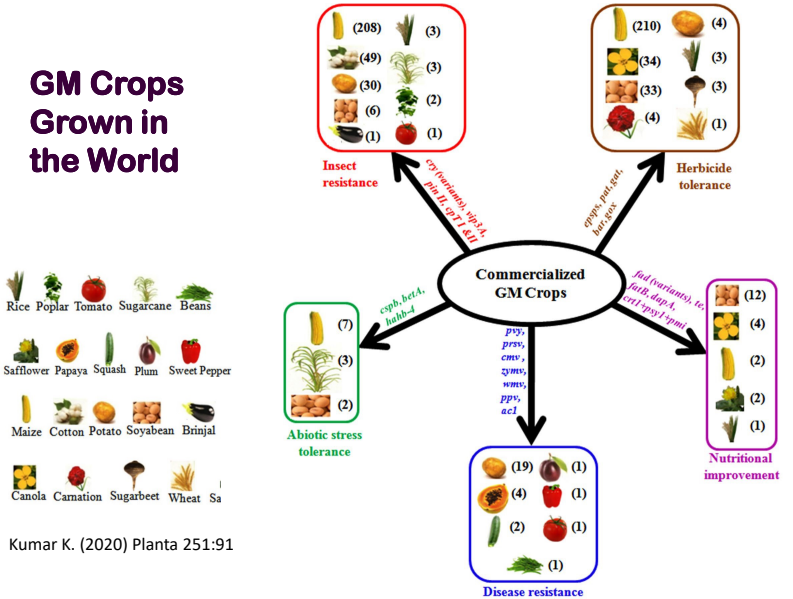
Methods to produce marker free plants

- Co-transformation
- Site-specific recombination
- Multi-autotransformation (MAT) vectors
- Transposition system
- Homologous recombination





GM Crops Grown in the World



Kumar K. (2020) Planta 251:91

Top 5 countries that planted biotech crops in 2019 (area and adoption rate)

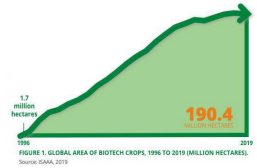
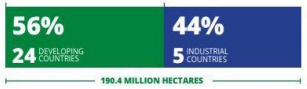
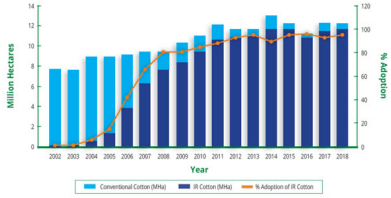
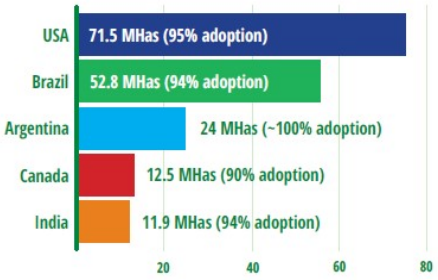


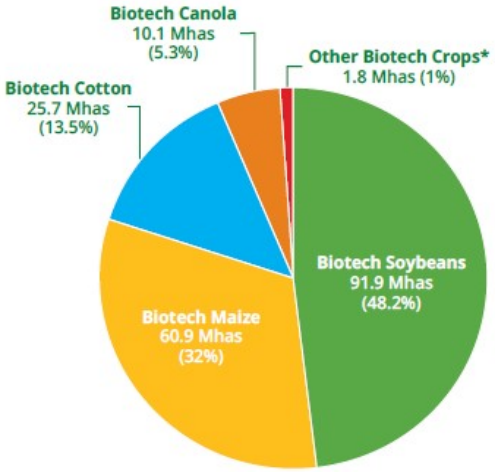
FIGURE 1. GLOBAL AREA OF BIOTECH CROPS, 1996 TO 2019 (MILLION HECTARES).
Source: ISAAA, 2019







Biotech crops in 2019 (area and adoption rate)



** Biotech sugar beets, potatoes, apples, squash, papaya, and brinjal/ eggplant.*

BIOTECH CROPS IN 2019 (AREA AND ADOPTION RATE)

Source: ISAAA, 2019

Top Ten Countries which Granted Food, Feed and Cultivation / Environment Approvals

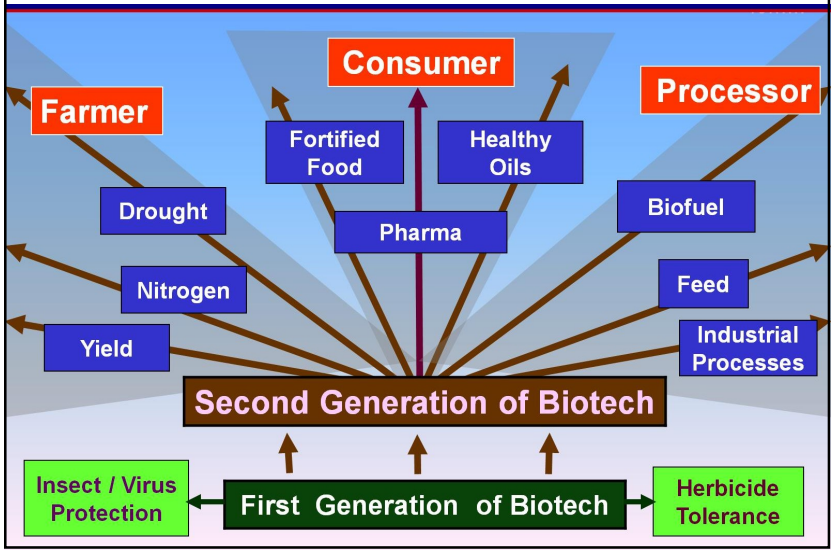
Table 2. Top Ten Countries which Granted Food, Feed and Cultivation/Environment Approvals*

Rank	Country	Number of Approvals			
		Food	Feed	Cultiva-tion	Total
1	USA**	183	178	178	539
2	Japan*	186	177	130***	493
3	Canada	147	138	144	429
4	Brazil	111	111	106	328
5	South Korea	157	148	0	305
6	Philippines	116	114	14	244
7	Mexico	188	29	14	231
8	Argentina	77	69	75	221
9	European Union	100	101	4	205
10	Australia	118	18	39	175
	Others	732	431	152	1,315
	Total	**2,115**	**1,514**	**856**	**4,485**

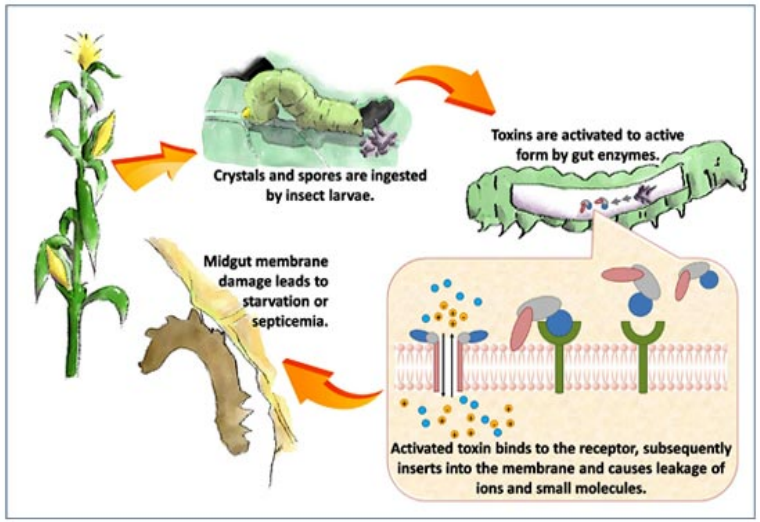
*For Japan, data is collected from Japan Biosafety Clearing House (JBCH, English and Japanese) as well as the website of the Ministry of Health, Labor and Welfare (MHLW). However, intermediate events derived from an approved pyramided event recorded in JBCH are not included in our database if they do not appear in MHLW. Also, expired approvals are included in our database from 1992 while JBCH's records starts in 2004.
**USA only approves individual events.
***While cultivation approvals are granted in Japan, there are no current GM planting done.

Source: ISAAA, 2019

Second Generation of Biotech Crops



Bt Technology against insects



Current status of Commercial BT crops

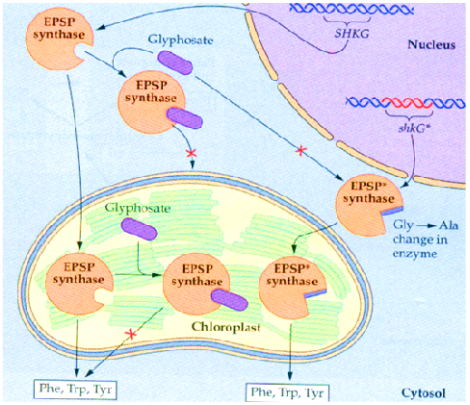
Cotton	Argentina, Australia, Brazil, Burkina Faso, Canada, China, Colombia, Costa Rica, eSwatini, Ethiopia, European Union, India, Japan, Malaysia, Mexico, Myanmar, New Zealand, Nigeria, Pakistan, Paraguay, Philippines, Singapore, South Africa, South Korea, Sudan, Taiwan,USA
Cowpea	Nigeria
Eggplant	Bangladesh
Maize	Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Egypt, EU, Honduras, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nigeria, Pakistan, Panama, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam, Zambia
Poplar	China
Potato	Australia, Canada, Japan, Mexico, New Zealand, Philippines, Russian Federation, South Korea, USA
Rice	China, Iran, USA
Soybean	Argentina, Australia, Brazil, Canada, China, Colombia, EU, India, Indonesia, Iran, Japan, Malaysia, Mexico, New Zealand, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam
Sugarcane	Brazil, Canada, USA
Tomato	Canada, USA

Source: ISAAA GM Approval Database (http://www.isaaa.org/gmapprovaldatabase/)

Engineering Glyphosate Tolerance

Glyphosate inhibits a chloroplast enzyme of essential amino acid biosynthesis: 5-enolpyruvyl-3-phosphoshikimic acid synthase (EPSPS)

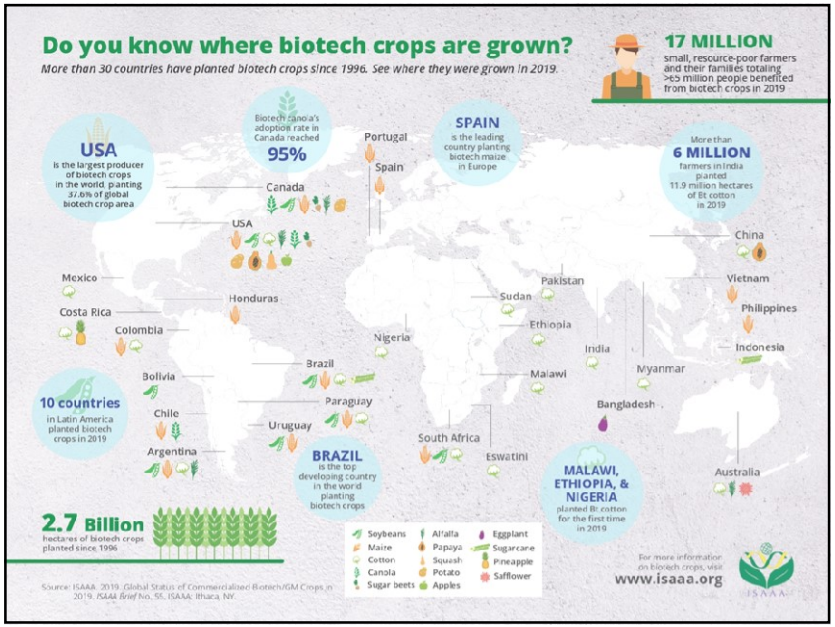
- **A mutant EPSPS gene (retaining catalytic activity but insensitive to glyphosate) has been isolated from *Agrobacterium***
- ***The Agrobacterium* gene introduced into plants confers glyphosate tolerance**

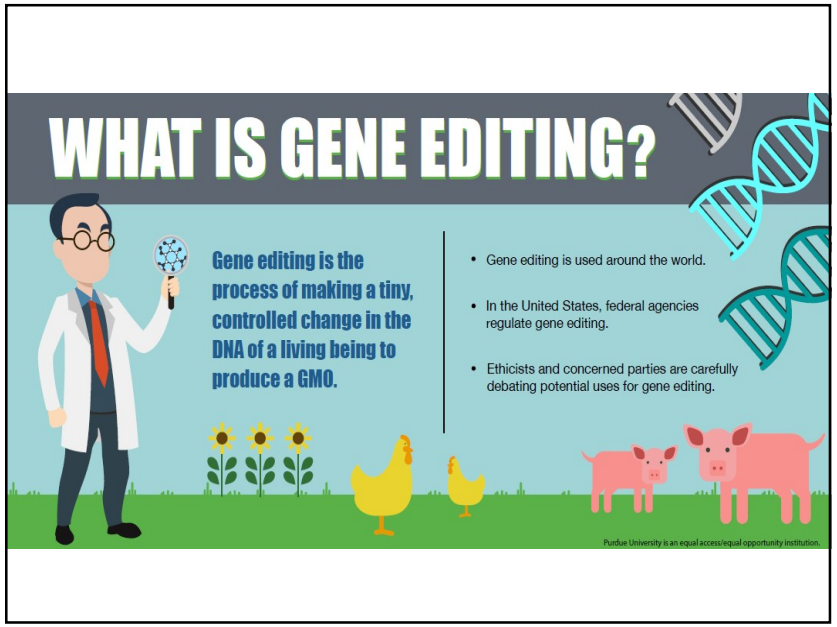


Current status of commercial HT transgenic crops

Crop	Countries
Alfalfa	*Argentina, Australia, Canada, Japan, Mexico, New Zealand, Philippines, Singapore, South Korea, USA*
Argentine Canola	*Australia, Canada, Chile, China, EU, Japan, Malaysia, Mexico, New Zealand, Philippines, Singapore, South Africa, South Korea, Taiwan, USA*
Carnation	*Australia, Colombia, EU, Japan, Malaysia*
Chicory	*USA*
Cotton	*Argentina, Australia, Brazil, Canada, China, Colombia, Costa Rica, EU, Japan, Malaysia, Mexico, New Zealand, Paraguay, Philippines, Singapore, South Africa, South Korea, Taiwan, USA*
Creeping bentgrass	*USA*
Flax, Linseed	*Canada, Colombia, USA*
Maize	*Argentina, Australia, Brazil, Canada, China, Colombia, Costa Rica, Cuba, EU, Honduras, Indonesia, Iran, Japan, Malaysia, Mexico, New Zealand, Nigeria, Pakistan, Panama, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam, Zambia*
Polish Canola	*Canada*
Potato	*Australia, Canada, Japan, Mexico, New Zealand, Philippines, South Korea, USA*
Rice	*Australia, Canada, Colombia, Honduras, Mexico, New Zealand, Philippines, Russian Federation, South Africa, USA*
Soybeans	*Argentina, Australia, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, EU, India, Indonesia, Iran, Japan, Malaysia, Mexico, New Zealand, Nigeria, Paraguay, Philippines, Russian Federation, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, Turkey, USA, Uruguay, Vietnam*
Sugar beets	*Australia, Canada, China, Colombia, EU, Japan, Mexico, New Zealand, Philippines, Russian Federation, Singapore, South Korea, Taiwan, USA*
Tobacco	*EU*
Wheat	*Australia, Colombia, New Zealand, USA*

Source: ISAAA GM Approval Database. http://www.isaaa.org/gmapprovaldatabase/

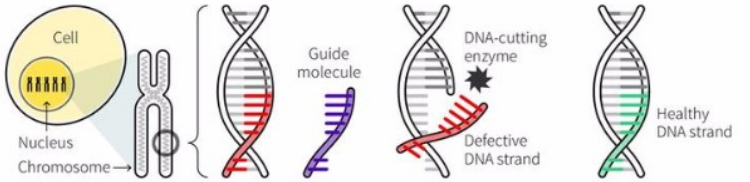

Do you know where biotech crops are grown?
More than 30 countries have planted biotech crops since 1996. See where they were grown in 2019.
17 MILLION
small, resource-poor farmers and their families totaling >65 million people benefited from biotech crops in 2019
USA
is the largest producer of biotech crops in the world, planting 37.6% of global biotech crop area
Biotech canola's adoption rate in Canada reached
95%
SPAIN
is the leading country planting biotech maize in Europe
More than
6 MILLION
farmers in India planted 11.9 million hectares of Bt cotton in 2019
10 countries
in Latin America planted biotech crops in 2019
BRAZIL
is the top developing country in the world planting biotech crops
MALAWI, ETHIOPIA, & NIGERIA
planted Bt cotton for the first time in 2019
2.7 Billion
hectares of biotech crops planted since 1996
Portugal
Spain
Canada
USA
Mexico
Honduras
Costa Rica
Colombia
Brazil
Bolivia
Paraguay
Chile
Uruguay
Argentina
Nigeria
Sudan
Pakistan
Ethiopia
India
Malawi
Myanmar
China
Vietnam
Philippines
Indonesia
Bangladesh
South Africa
Eswatini
Australia
Soybeans
Maize
Cotton
Canola
Sugar beets
Alfalfa
Papaya
Squash
Potato
Apples
Eggplant
Sugarcane
Pineapple
Safflower
For more information on biotech crops, visit
www.isaaa.org
ISAAA
Source: ISAAA. 2019. Global Status of Commercialized Biotech/GM Crops in 2019. ISAAA Brief No. 55. ISAAA: Ithaca, NY.


WHAT IS GENE EDITING?
Gene editing is the process of making a tiny, controlled change in the DNA of a living being to produce a GMO.
• Gene editing is used around the world.
• In the United States, federal agencies regulate gene editing.
• Ethicists and concerned parties are carefully debating potential uses for gene editing.
Purdue University is an equal access/equal opportunity institution.

DNA editing

A DNA editing technique, called CRISPR/Cas9, works like a biological version of a word-processing programme's "find and replace" function.

HOW THE TECHNIQUE WORKS



A cell is transfected with an enzyme complex containing:
- Guide molecule
- Healthy DNA copy
- DNA-cutting enzyme

A specially designed synthetic guide molecule finds the target DNA strand.

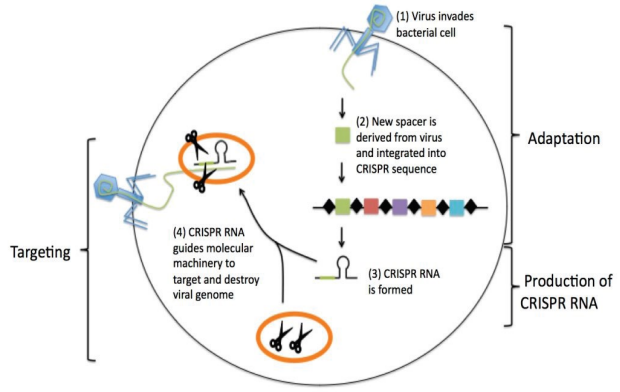
An enzyme cuts off the target DNA strand.

The defective DNA strand is replaced with a healthy copy.

Sources: Reuters; Nature; Massachusetts Institute of Technology

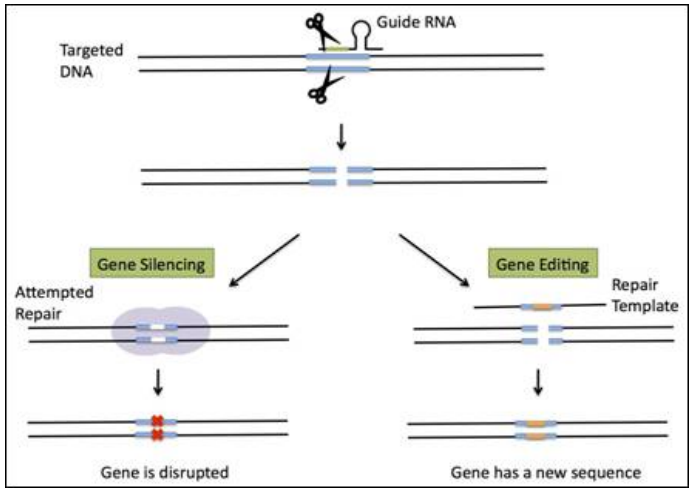
CRISPER for Gene Editing

- CRISPR, or Clustered Regularly Interspaced Short Palindromic Repeats, is an integral part of a bacterial defense system and basis of the CRISPR-Cas9 system.
- The CRISPR molecule includes CRISPR-associated genes, or Cas genes encode proteins that unwind and cut DNA, called helicases and nucleases, respectively.
- The CRISPR immune system protects the bacteria from repeated virus attacks.



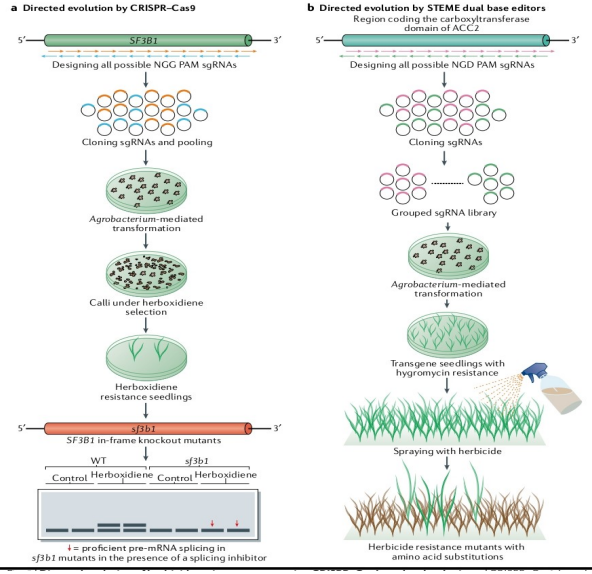
https://www.isaaa.org/resources/publications/pocketk/54/default.asp

Mechanism of Gene Editing of CRISPR/Cas96



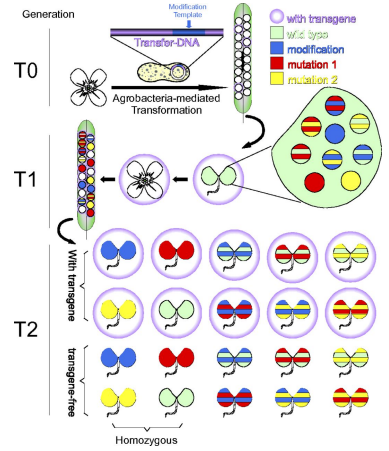
https://www.isaaa.org/resources/publications/pocketk/54/default.asp

Directed evolution of herbicide resistance through CRISPR



Zhu et al. 2020

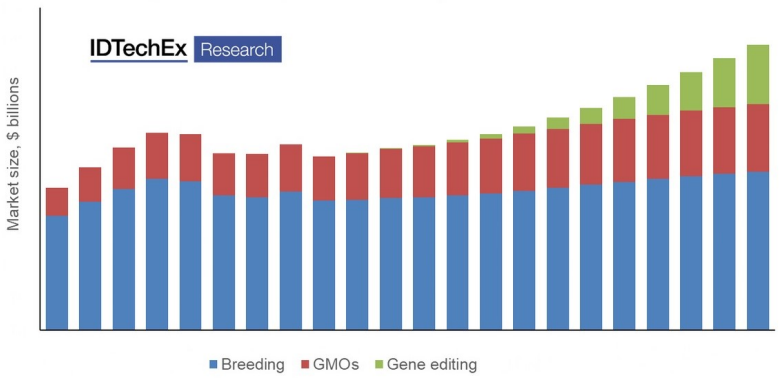
Efficient production of transgene-free Arabidopsis plants with desired modifications at the targeted loci.



Yangbin Gao and Yunde Zhao PNAS 2014;111:12:4357-4358

PNAS

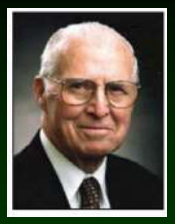
Global crop biotech seed market by method 2010-31



Epilogue

- Conventional Breeding
- Molecular breeding aided speed breeding
- Marker-free transgenic plants
- Gene editing
- Case-wise consideration

www.doublehelix.too.it



Human kind in the 21st century will need to bring about a "Blue Revolution" to complement the so-called Green Revolution of the 20th century. In the new Blue Revolution, water-use productivity must be wedded to land-use productivity. New science and technology must lead the way.

Norman Borlaug, Nobel Peace Prize