Transformação genética de plantas e suas aplicações em pesquisa e biotecnologia
2018

BIB0143 - Recursos Econômicos Vegetais

Bruno Silvestre Lira

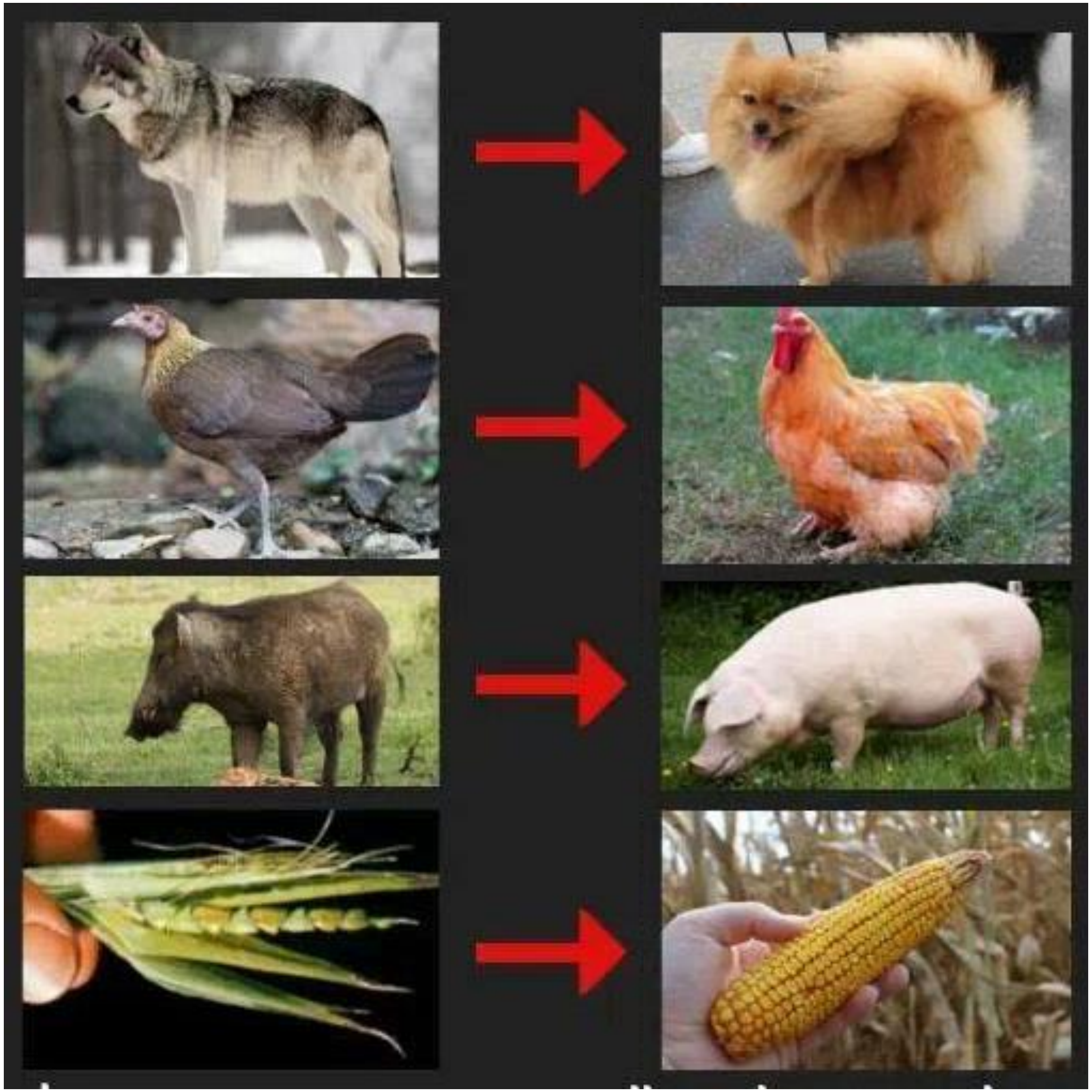
O que é um OGM (organismo geneticamente modificado)?

É a mesma coisa que um organismo transgênico?

O que é um OGM (organismo geneticamente modificados)?

Toda entidade biológica cujo material genético (ADN/ARN) foi alterado por meio de qualquer técnica de engenharia genética, de uma maneira que não ocorreria naturalmente.

Ministério da Agricultura: http://www.agricultura.gov.br/vegetal/organismos-geneticamente-modificados



?

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Organismos manipulados geneticamente, de modo a favorecer características desejadas, como a cor, tamanho etc. Os OGMs possuem alteração em trecho(s) do genoma realizadas através da tecnologia do RNA/DNA recombinante ou engenharia genética. Na maior parte das vezes, quando se fala em OGMs, trata-se de organismos transgênicos. Mas OGMs e transgênicos não são sinônimos: todo transgênico é um organismo geneticamente modificado, mas nem todo OGM é um transgênico.

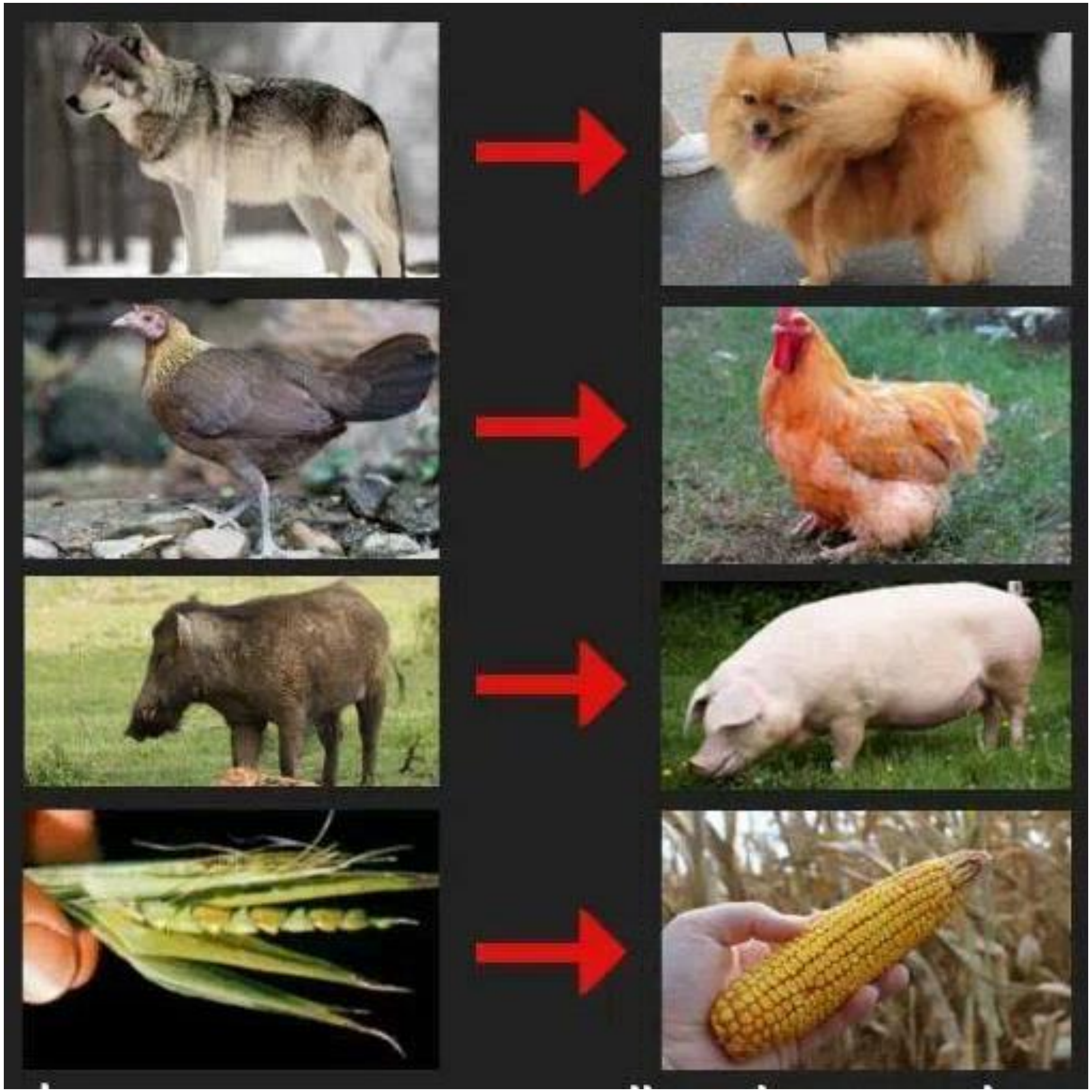
Wikipédia: https://pt.wikipedia.org/wiki/Organismos_geneticamente_modificados

O que é um OGM (organismo geneticamente modificados)?

"Living modified organism" as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (Cartagena Protocol on Biosafety, 2003)

application of in vitro nucleic acid techniques, or fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and <u>are not techniques used in traditional breeding and selection</u>

Como aconteceu esta modificação?



?

AKSENOVA NATALYA/SHUTTERSTOCK

VIKTAR MALYSHCHYTS/SHUTTERSTOCK

MAKS NARODENKO/SHUTTERSTOCK

Tabela 1.1 Domesticação de algumas espécies de animais e de plantas

Espécie domesticada	Espécie ancestral	Época da domesticação (anos atrás)	Local
Ovelha	Ovelha selvagem (*Ovis ammon*)	12.000	Iraque
Cão	Lobo (*Canis lupus*)	12.000	Palestina-Irã
Cabra	Cabra selvagem (*Capra aegagrus*)	10.000	Irã
Gato	Gato selvagem (*Felis caffra*)	9.500	Chipre ou Egito
Porco	Porco selvagem europeu (*Sus scrofa*)	10.000	Europa-Ásia
Cavalo	Cavalo selvagem (*Equus przevalski*)	8.000	Irã
Marreco	Marreco selvagem comum (*Anas platyrhynchus*)	6.000	China
Camelo	Camelo selvagem (*Camelus bactrianus*)	6.000-5.000	Egito
Jumento	Jumento selvagem (*Equus asinus atlanticus*)	7.000	Egito
Abelha	Abelha (*Apis mellifera*)	4.500	Egito
Bicho-da-seda	Bicho-da-seda (*Bombyx mori*)	3.500	China
Coelho	Coelho selvagem (*Oryctolagus cuniculus*)	2.200	Roma
Arroz	Arroz selvagem asiático (*Oryza sativa*)	15.900	China central
Abóbora	Abóbora (*Cucurbita pepo*)	12.000-10.000	Equador
Trigo	Trigo selvagem (*Triticum monococcum*)	9.800-9.500	Turquia
Milho	Milho selvagem (*Zea mays*)	8.000-7.000	América
Linho	Linho selvagem (*Linum usitatissimum*)	7.000	Curdistão
Lentilha	Lentilha selvagem (*Lens culinaris*)	6.000	Egito
Azeitona	Azeitona (*Olea europaea*)	6.000	Oriente Médio
Feijão	Feijão (*Phaseolus* spp.)	5.000-4.000	Américas Central e do Sul
Soja	Soja (*Glycine max*)	4.000	China

Fonte: <http://www.clt.astate.edu/aromero/histbio04.heredityIprmendel.ppt>. Acesso em: abr. 2010.

Trigo

17 Gbp
Hexaploide = 42 cromossomos

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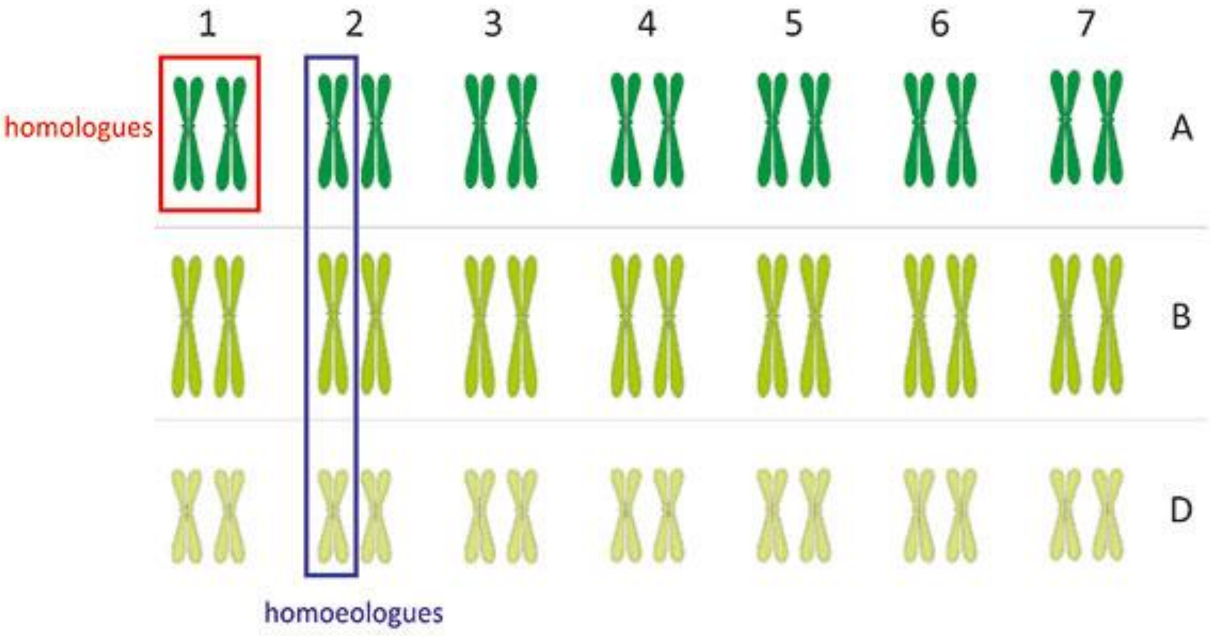
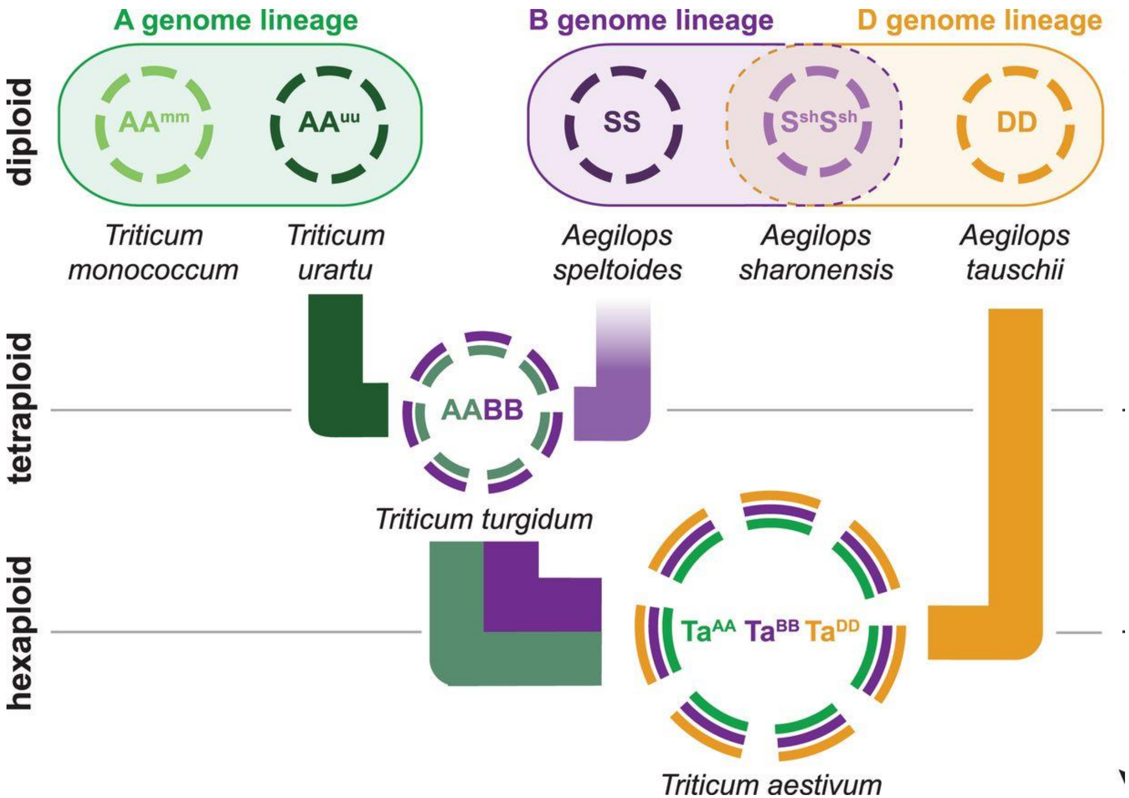
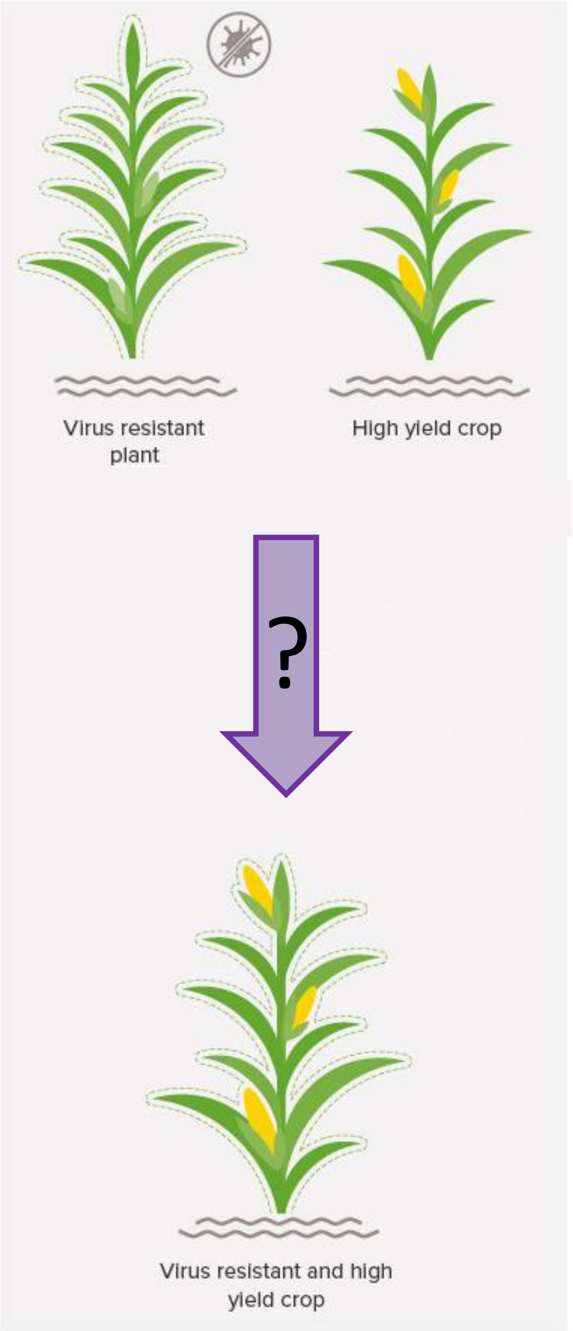
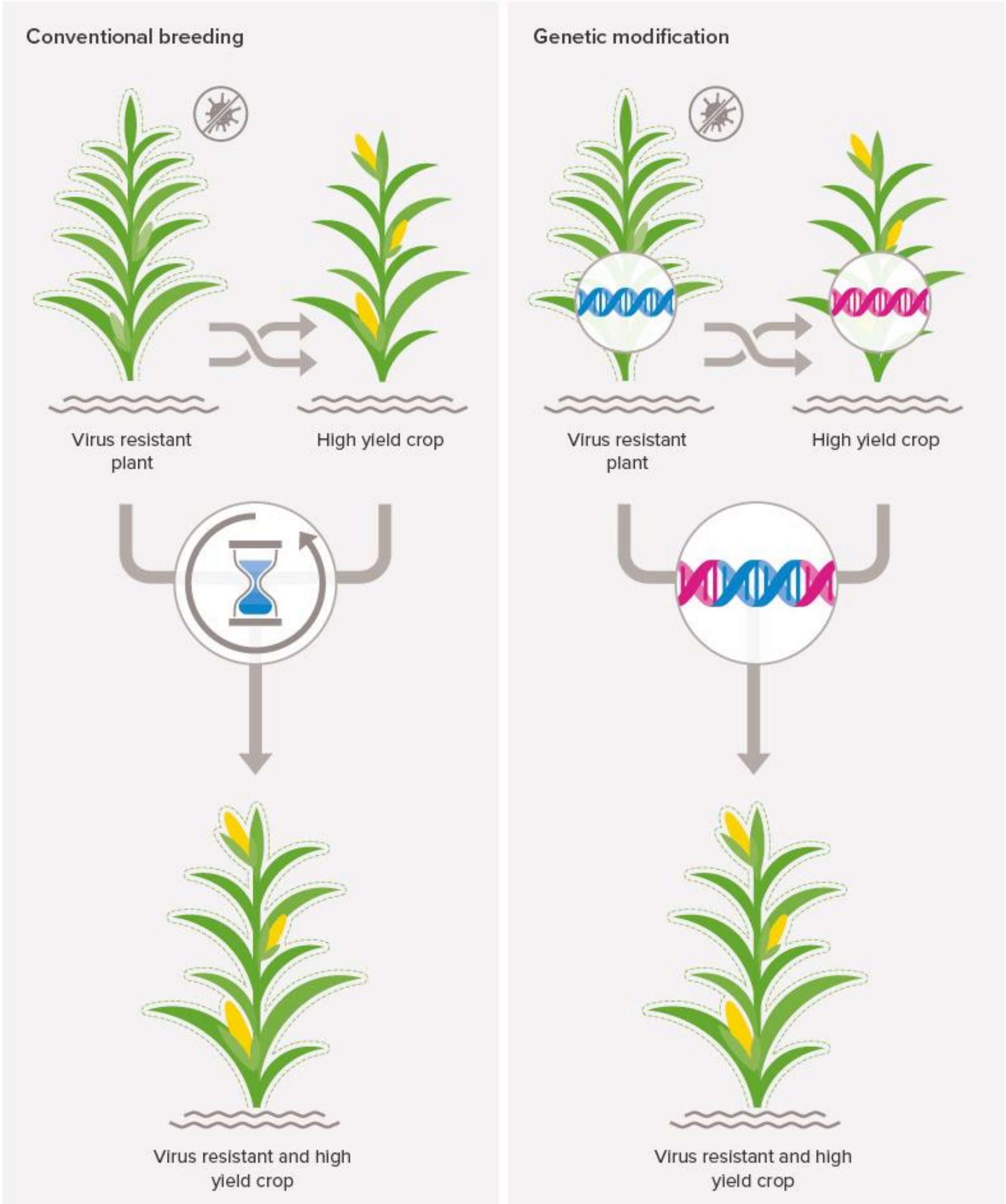


Trigo

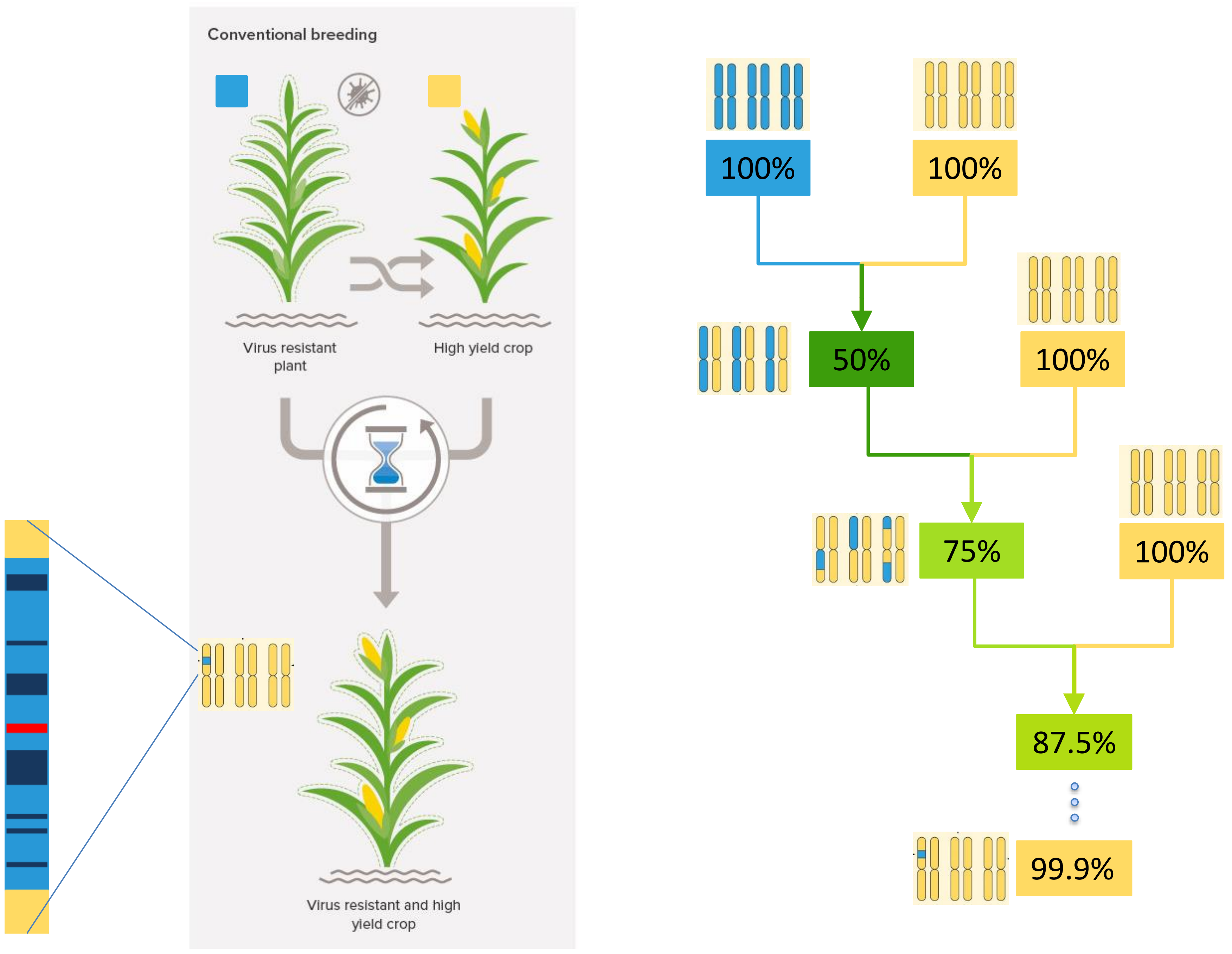
17 Gbp
Hexaploide = 42 cromossomos
3 subgenomas (A; B; D) = 2n = 14

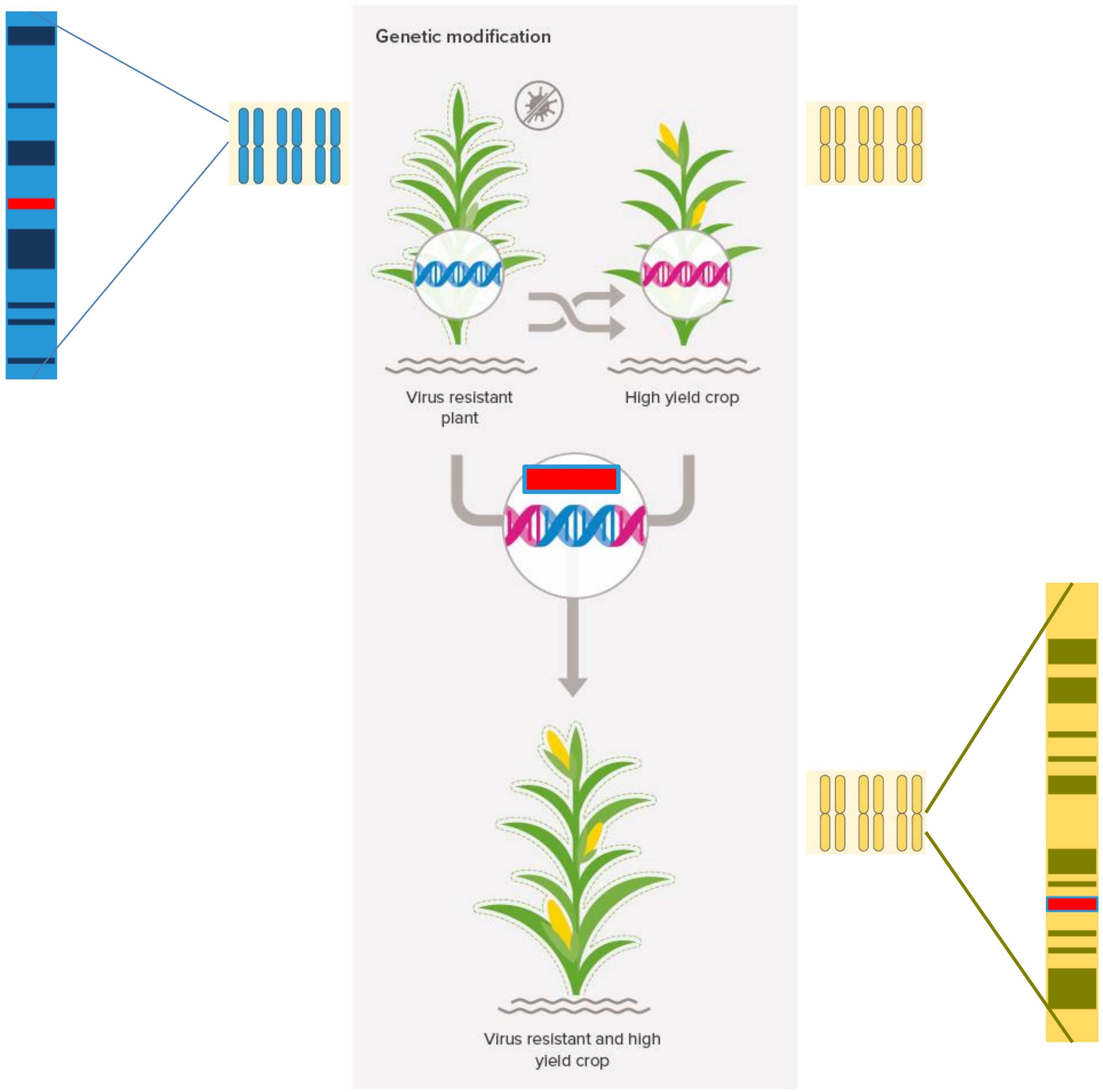



Virus resistant plant
High yield crop
?
Virus resistant and high yield crop



Conventional breeding
Virus resistant plant
High yield crop
Virus resistant and high yield crop
Genetic modification
Virus resistant plant
High yield crop
Virus resistant and high yield crop


Conventional breeding
Virus resistant plant
High yield crop
Virus resistant and high yield crop
100%
100%
50%
100%
75%
100%
87.5%
99.9%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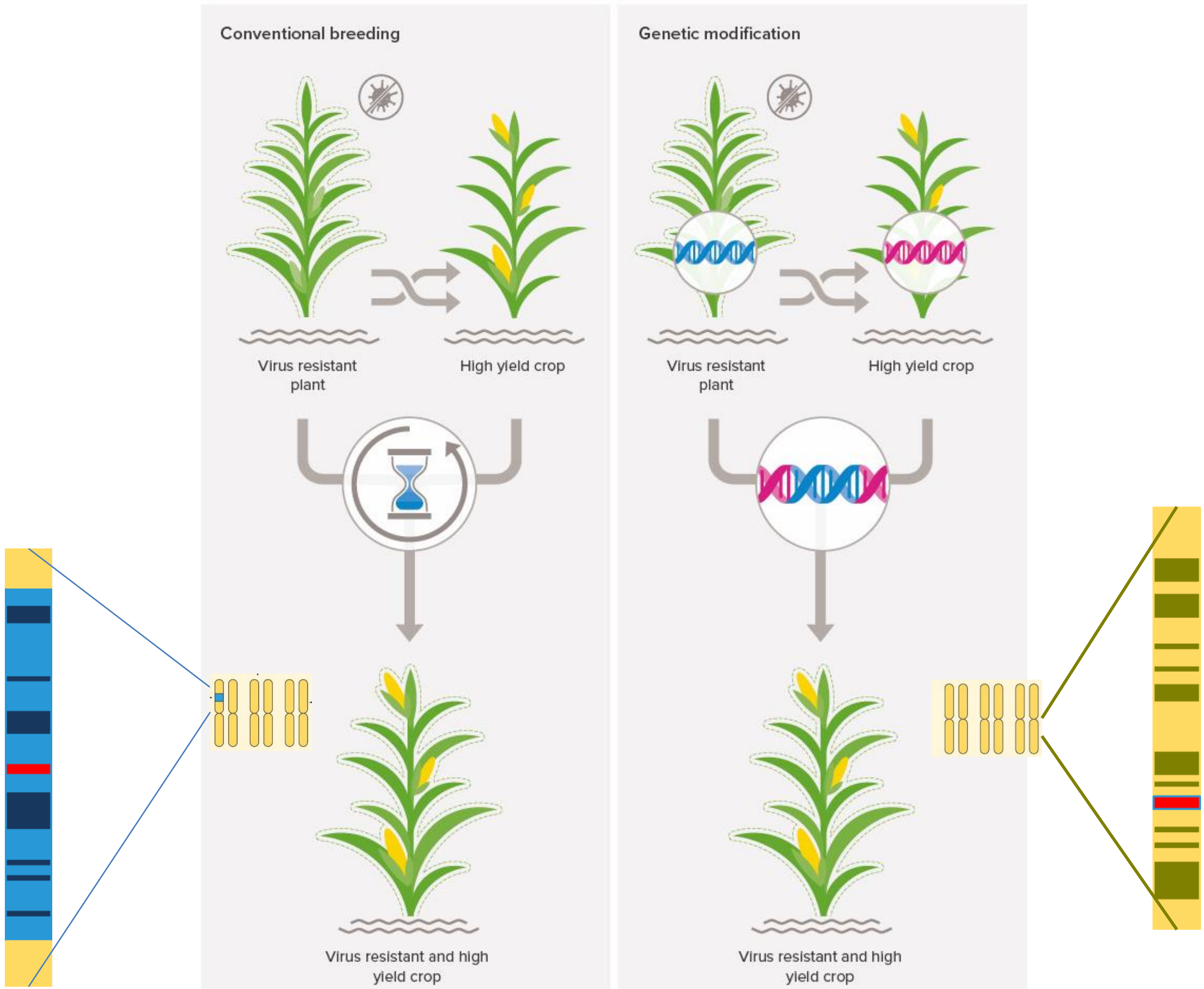
Conventional breeding
Virus resistant plant
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Virus resistant plant
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Virus resistant and high yield crop

Diferentes nomes de acordo à distância evolutiva entre o gene a ser introduzido e o organismo receptor

Table 1. Proposed categories for organisms currently designated 'transgenic' or 'genetically modified'

Categories	Source of genetic modifications	Genetic variability via conventional breeding	Genetic distance
Intragenic	Within genome[a]	Possible	Low
Famigenic	Species in the same family[b]	Possible	↓
Linegenic	Species in the same lineage[c]	Impossible	↓
Transgenic	Unrelated species[d]	Impossible	↓
Xenogenic	Laboratory-designed genes[e]	Impossible	High

[a]From directed mutations or recombinations; the extent of modification also reflects those arising in classical, selection-based breeding.
[b]Taxonomic family; the extent of modification also reflects those arising from applying cellular techniques in classical breeding.
[c]Phylogenetic lineage; recombination of genetic material beyond what can be achieved by classical breeding methods.
[d]Contains recombined DNA from unrelated organisms. Reflects the genetic composition of most GMOs commercialized today.
[e]For which no naturally evolved genetic counterpart can be found or expected (for example, synthetic genes and novel combinations of protein domains from various species).

Cisgenesis refers to the transfer of genetic material between sexually compatible organisms.
Transgenesis occurs between sexually incompatible organisms .
(Schouten et al., 2006).

Fonte: Nielsen, 2003.

A really useful pathogen, *Agrobacterium tumefaciens*

From common plant pathogen to useful tool in plant molecular biology and engineering

Crown gall (galha-de-coroa) disease and the tumor-inducing principle

The first written record of crown gall disease, on grape, dates from 1853

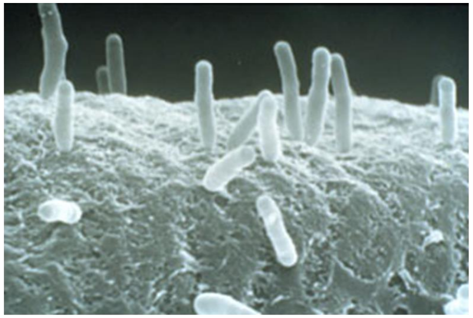
Fridiano Cavara (1897) found bacterias associated to crown gall in grape

Crown gall induces growths at wound sites and severely limits crop yields and growth vigor

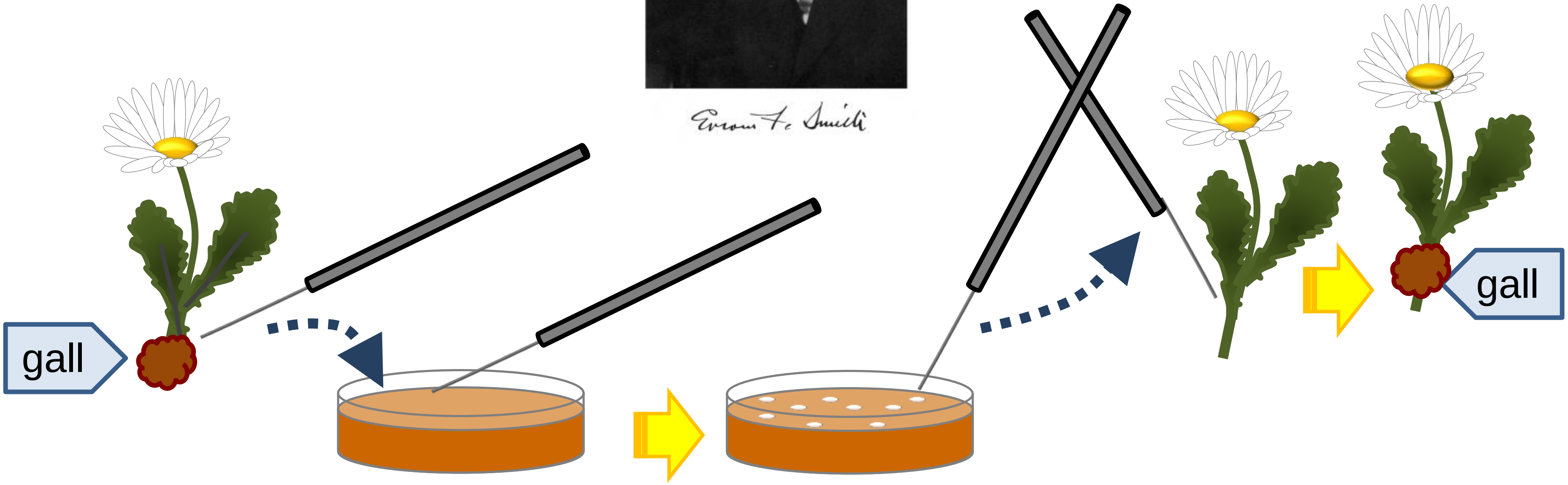
Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org; Mike Ellis, Ohio State University; University of Georgia Plant Pathology Archive, University of Georgia, Bugwood.org; Wikimedia commons

1907: Crown gall is caused by a bacterium

1907 - Erwin Smith and C.O. Townsend isolated a bacterium from galls on daisy. When inoculated onto other plants, galls were produced

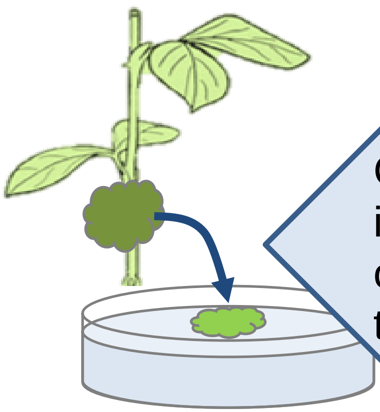


Agrobacterium tumefaciens attached to a plant cell.
Image by Martha Hawes



Smith, E.F. and Townsend, C.O. (1907). A plant-tumor of bacterial origin. Science. 25**:** [671-673](671-673).

Agrobacterium-induced galls do not require bacterial persistence



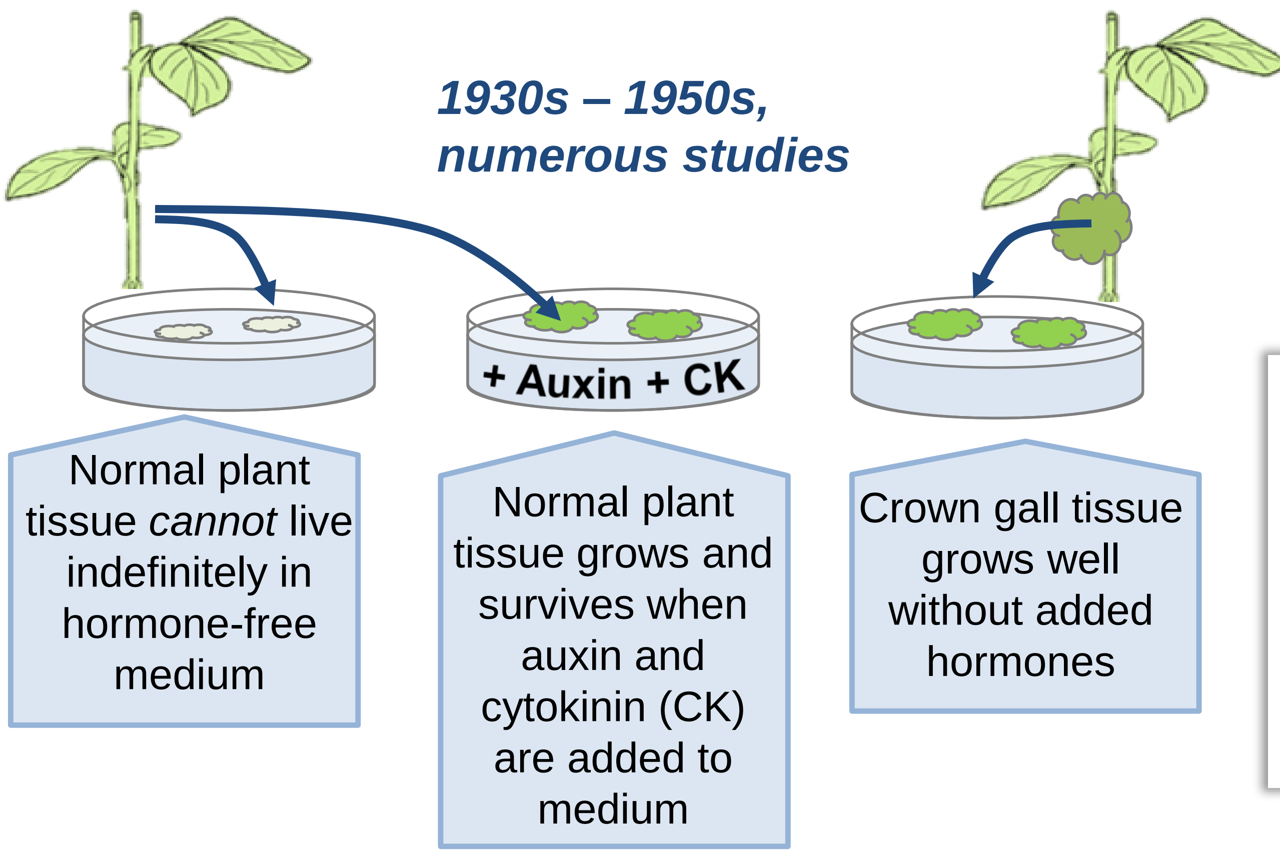
Gall tissues without any bacteria can persist indefinitely in culture, in contrast with most other pathogen-induced neoplastic growths that require the presence of the pathogen

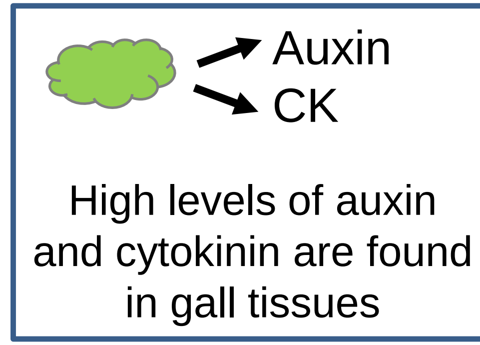
Braun made fundamental discoveries about how *Agrobacterium* transforms plant cells

Armin C. Braun
1911 - 1986

White, P.R. and Braun, A.C. (1941). Crown gall production by bacteria-free tumor tissues. Science. 94: 239-241; Photo from Wood, H.N., and Kelman, A. (1987) Phytopathology 77: 991.

Gall tissues can grow indefinitely without exogenous phytohormones



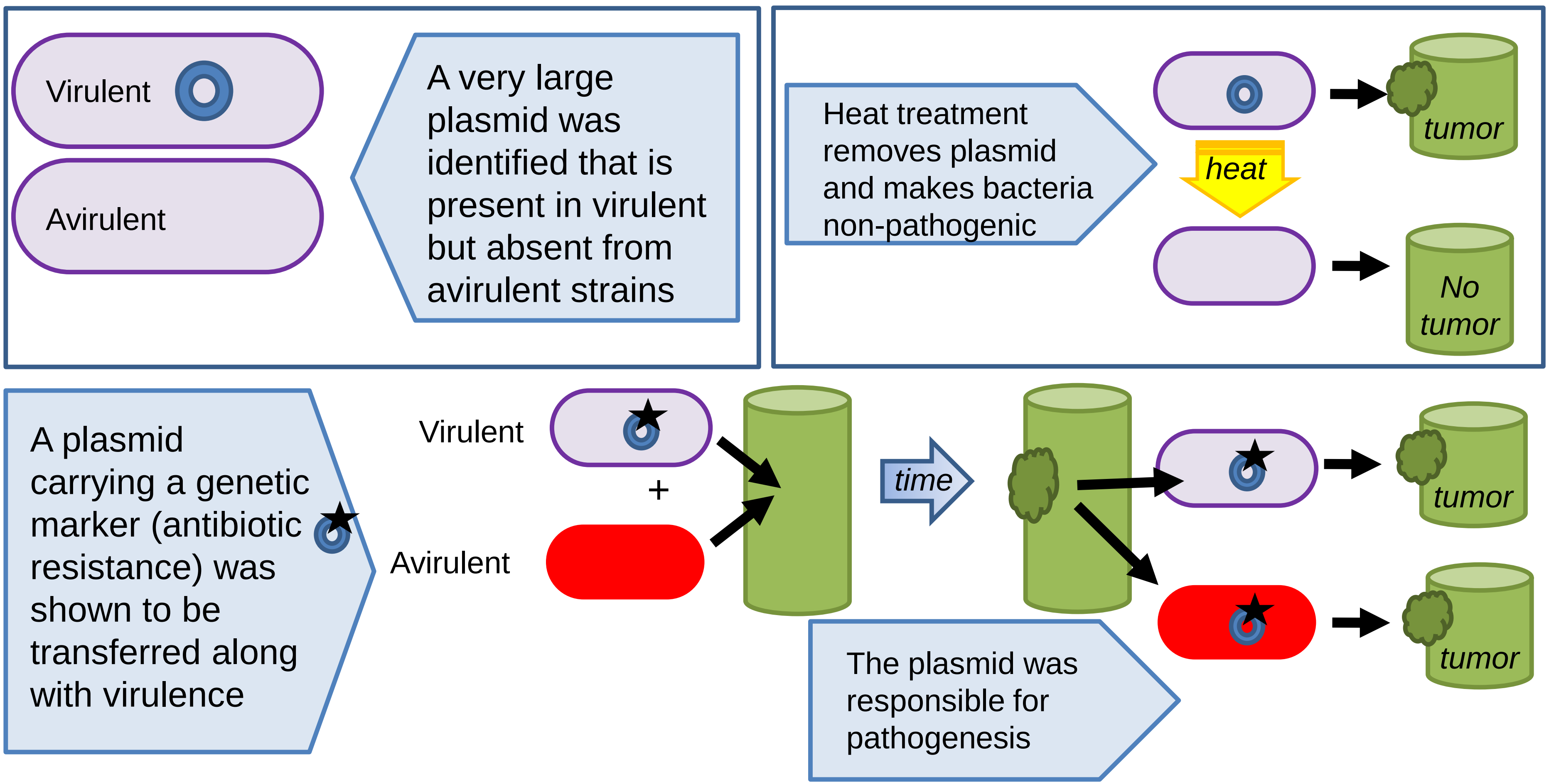


"It is possible for a cell to acquire the capacity for autonomous growth as a result of the permanent activation of growth-substance-synthesizing systems"

-AC Braun 1958

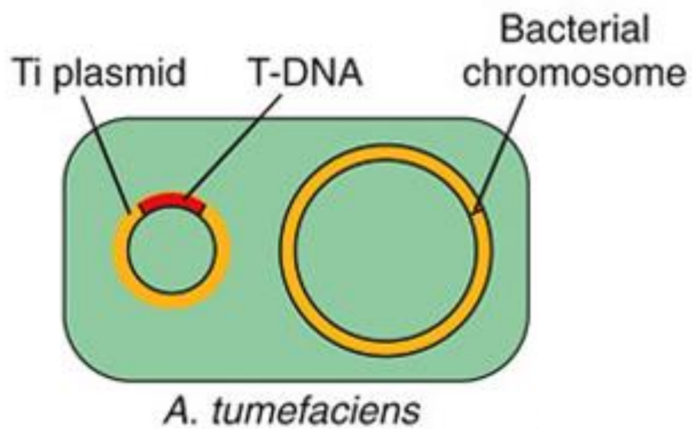
Braun, A.C. (1958) A physiological basis for autonomous growth of the crown-gall tumor cell. Proc Natl Acad Sci U S A. 44: 344–349.

A large plasmid in gall-inducing *Agrobacterium* transfers virulence



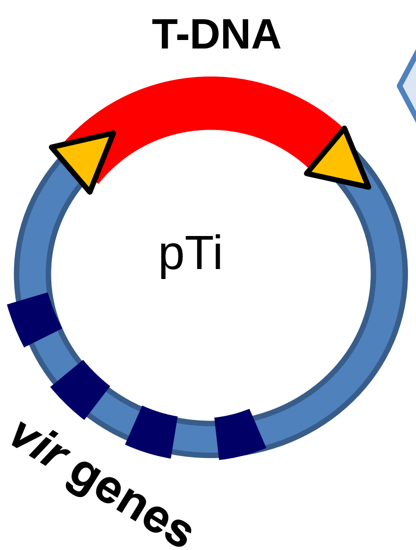
Zaenen, I., van Larebeke, N., Teuchy, H., van Montagu, M. and Schell, J. (1974). Supercoiled circular DNA in crown-gall inducing *Agrobacterium* strains. Journal of Molecular Biology. 86: 109-127. Larebeke, N.V., Engler, G., Holsters, M., Den Elsacker, S.V., Zaenen, I., Schilperoort, R.A. and Schell, J. (1974). Large plasmid in *Agrobacterium tumefaciens* essential for crown gall-inducing ability. Nature. 252: 169-170. Van Larebeke, N., Genetello, C.H., Schell, J., Schilperoort, R.A., Hermans, A.K., Hernalsteens, J.P. and Van Montagu, M. (1975). Acquisition of tumour-inducing ability by non-oncogenic agrobacteria as a result of plasmid transfer. Nature. 255: 742-743.

Some DNA from the Ti plasmid is transferred into the plant cells (1977)



http://cms.daegu.ac.kr/sgpark/microbiology/agrobacterium.jpg

Structure and function analysis of the Ti plasmid

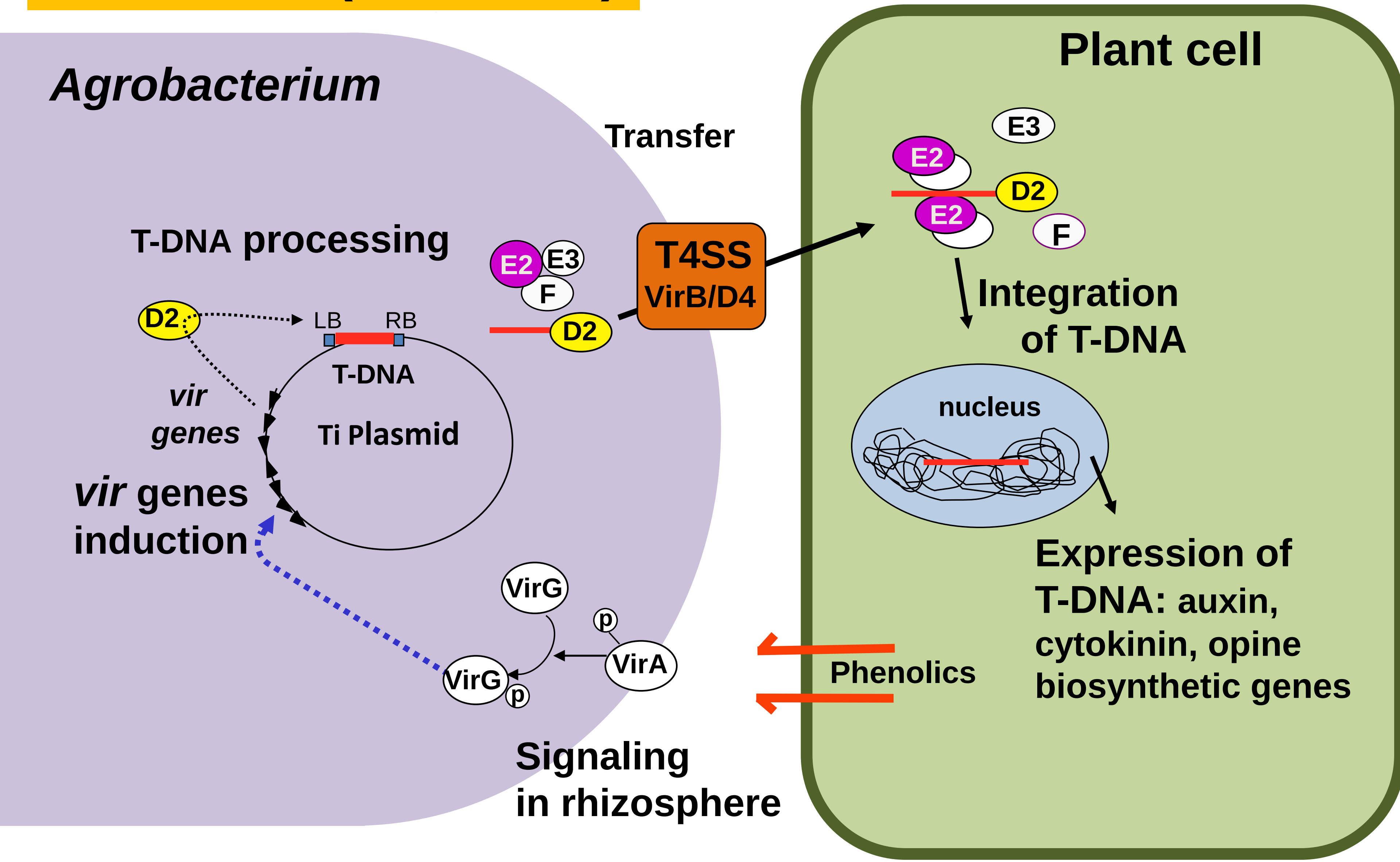


Transfer DNA (T-DNA) moves into the plant cell nucleus. It is flanked by two direct 25 bp repeat border sequences, shown as yellow triangles

The *virulence* (*vir*) genes are required for T-DNA movement into the plant cell (more on them later)

The organization of Ti plasmids varies between isolates, but all carry one or more **T-DNA region** and one ***vir* region**

SUMMARY (Animated)



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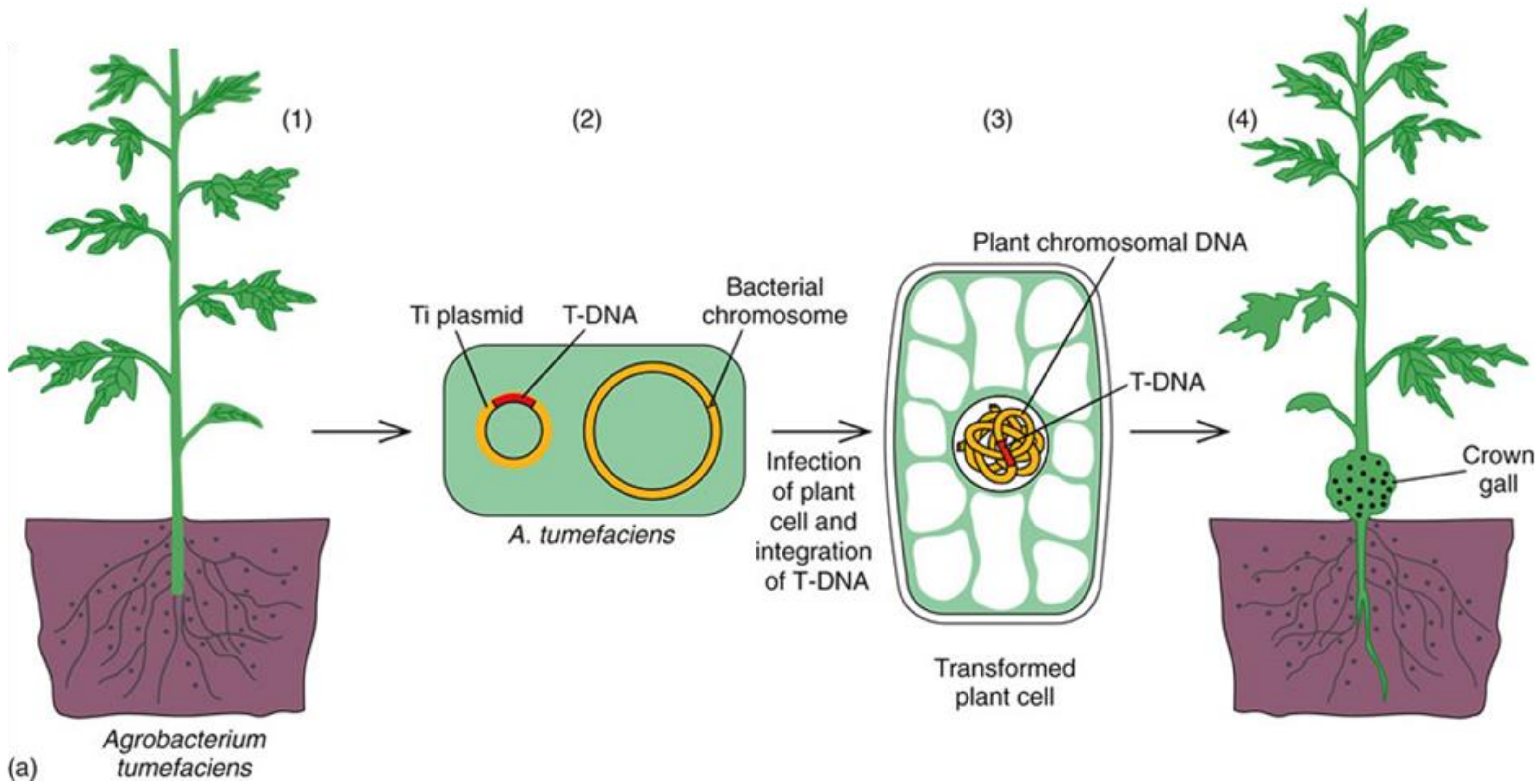
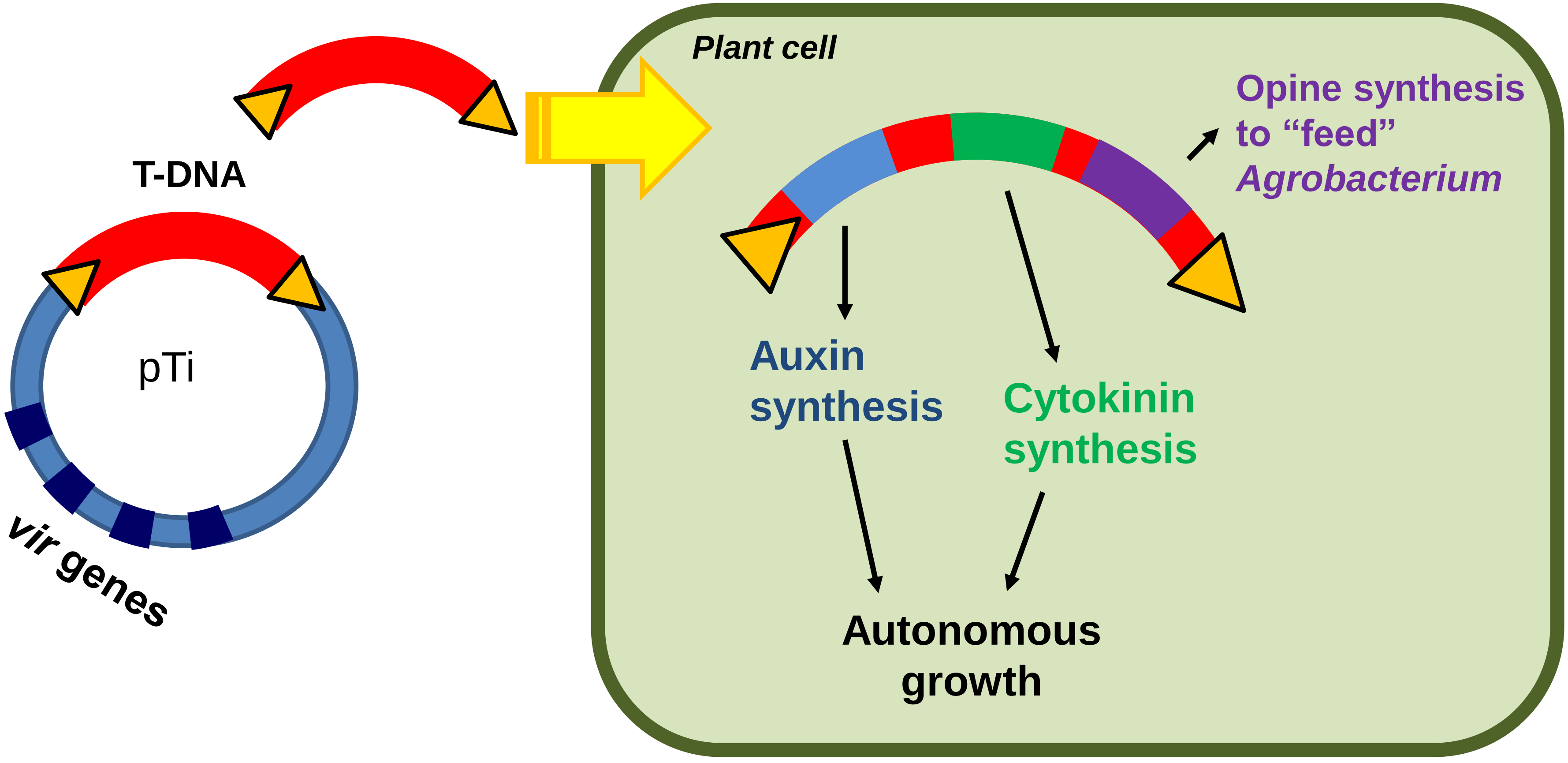
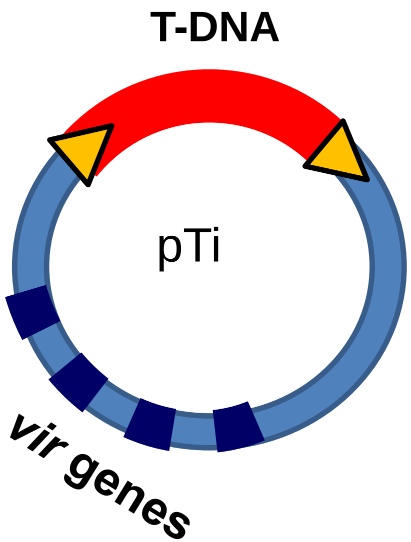


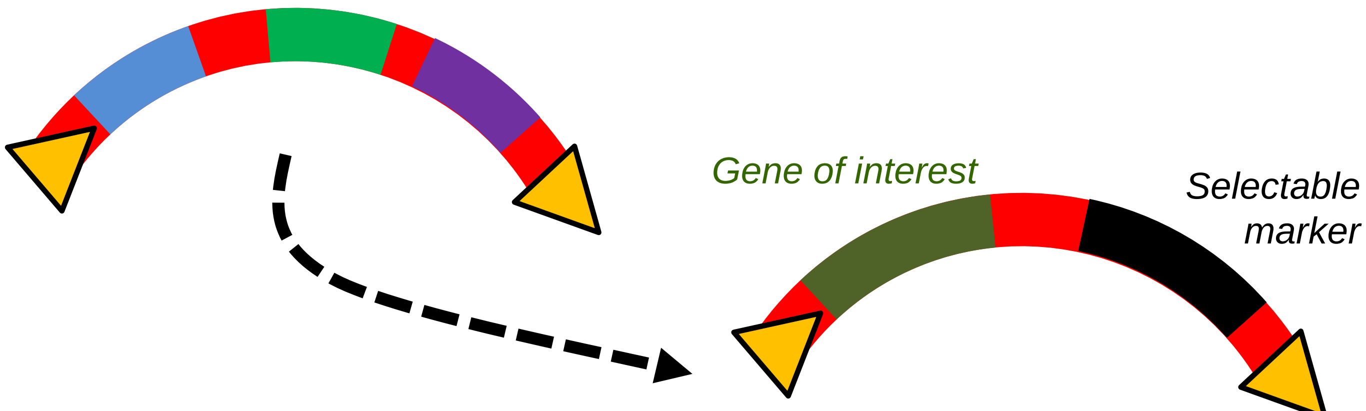
The T-DNA region: tumor-inducing genes and opine synthesis genes



The Ti plasmid can be used to introduce any gene into plants

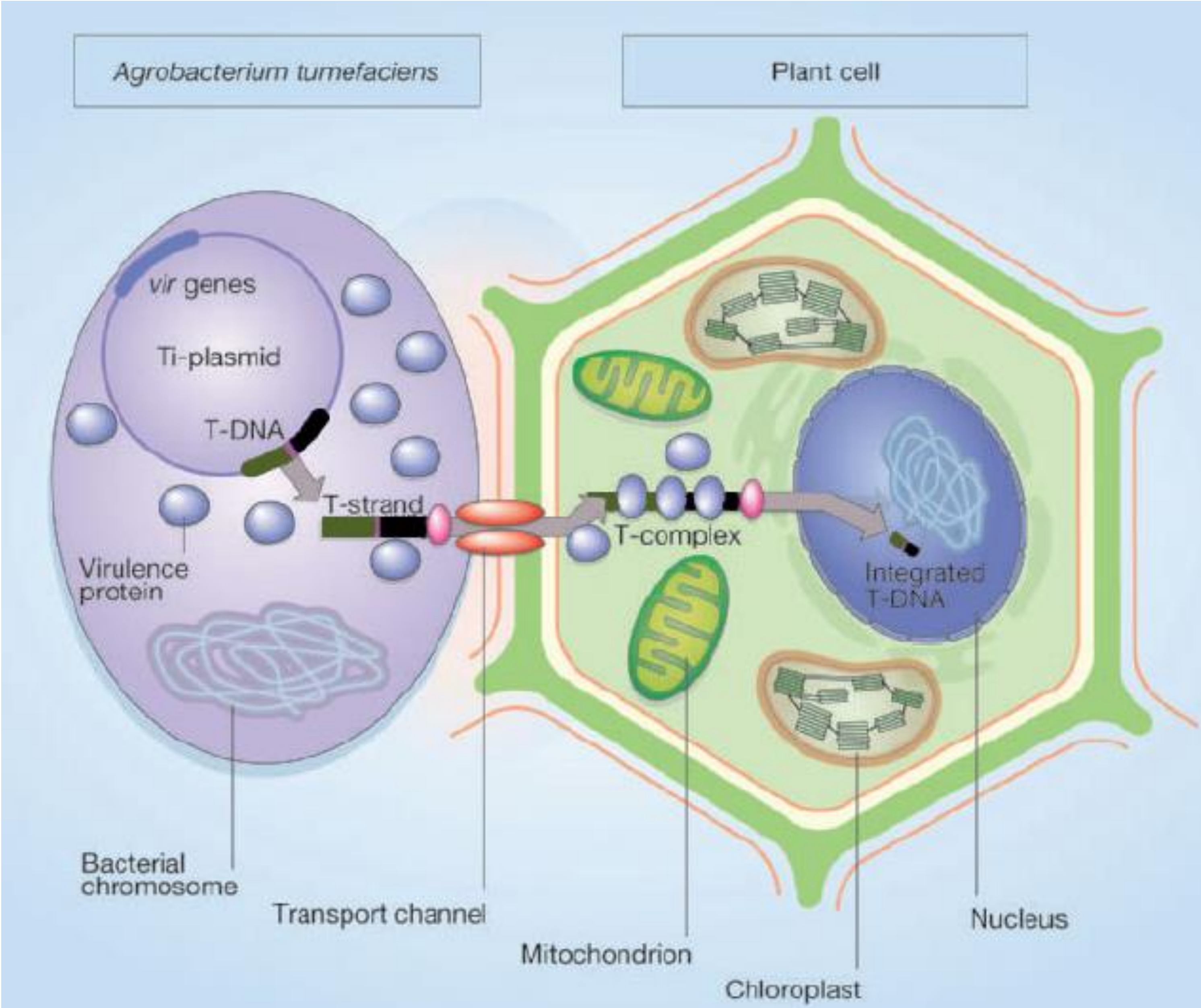
The discovery that T-DNA was inserted into the plant genome raised the possibility that "any gene" could be transferred into plants





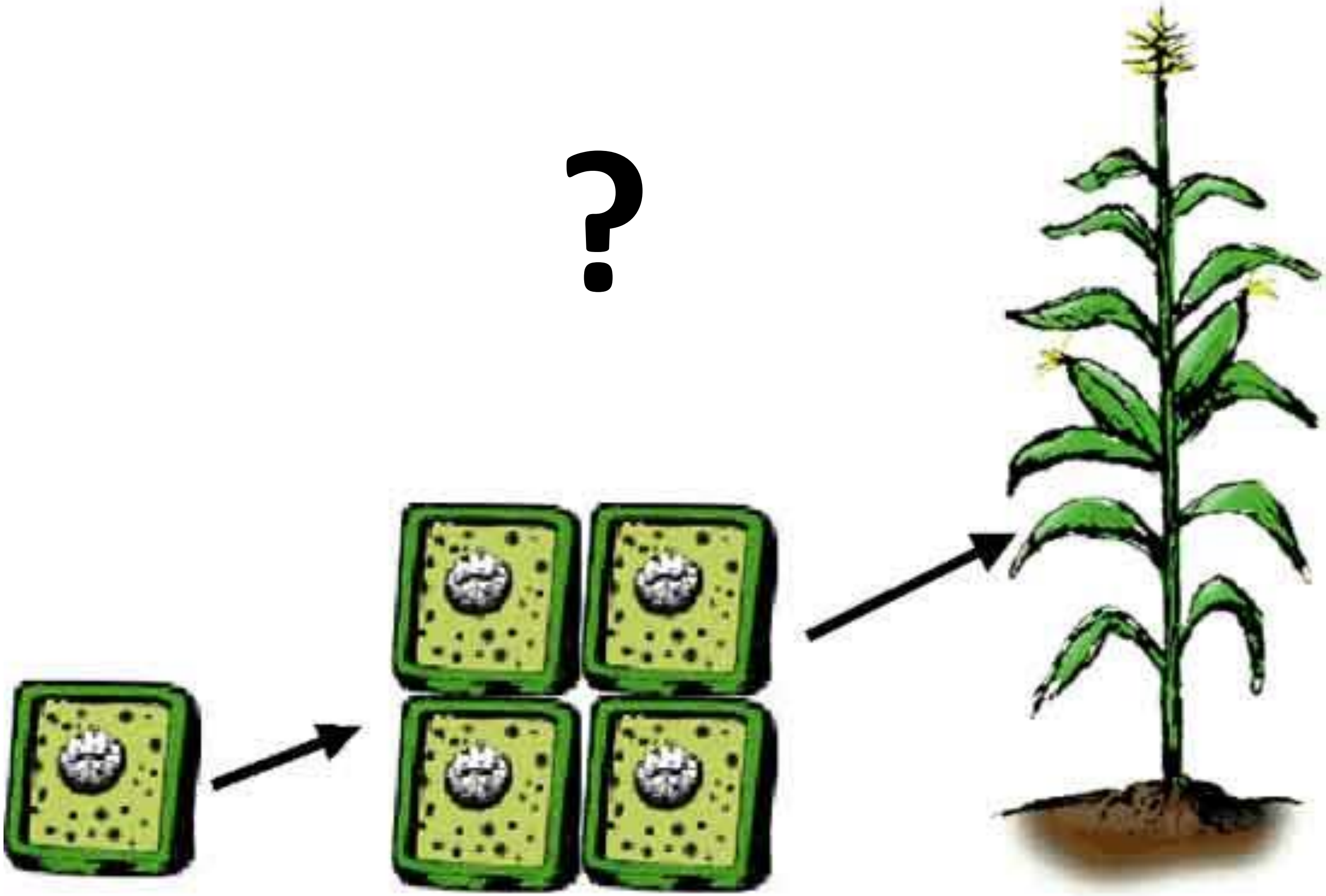
Tumor-inducing and opine synthesis genes on T-DNA can be replaced by a "gene of interest" and selectable marker

Hoekema, A., Hirsch, P.R., Hooykaas, P.J.J. and Schilperoort, R.A. (1983). A binary plant vector strategy based on separation of vir- and T-region of the *Agrobacterium tumefaciens* Ti-plasmid. Nature. 303: 179-180.



ONE transformed plant cell

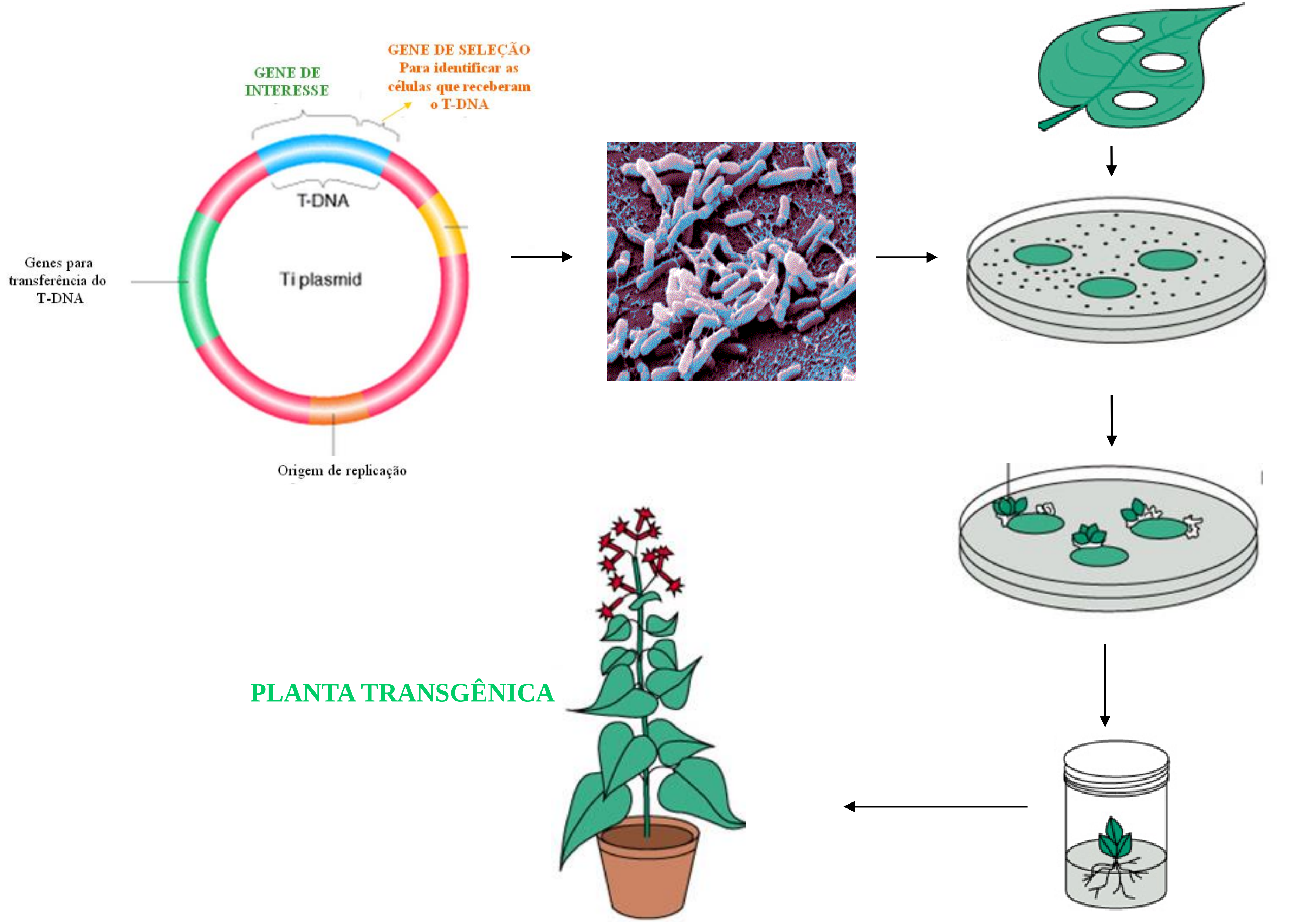
http://www.nature.com/nature/journal/v433/n7026/images/433583a-f2.2.jpg



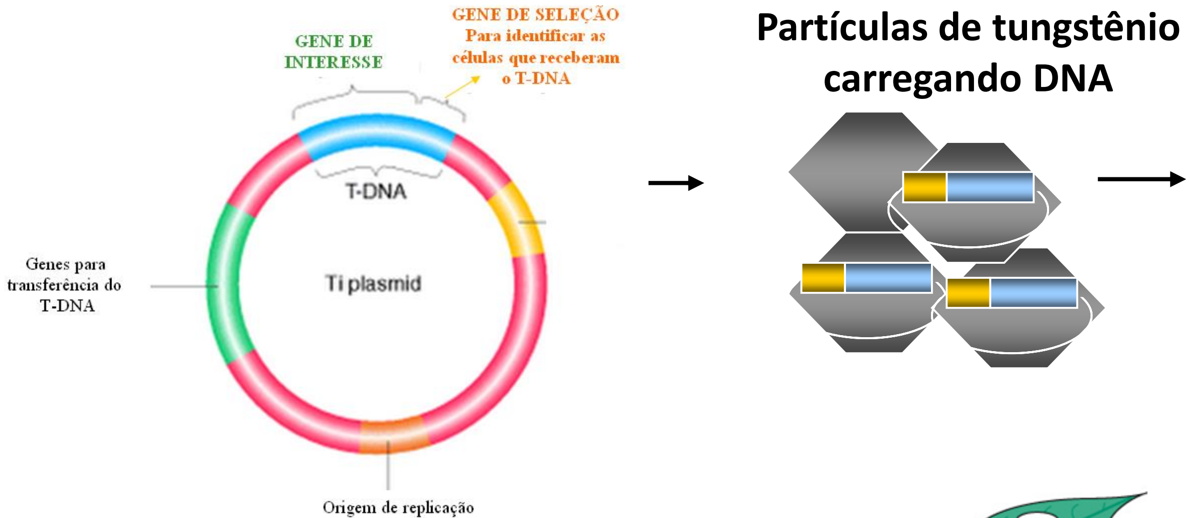
http://passel.unl.edu/Image/siteImages/CelltopltLG.jpg

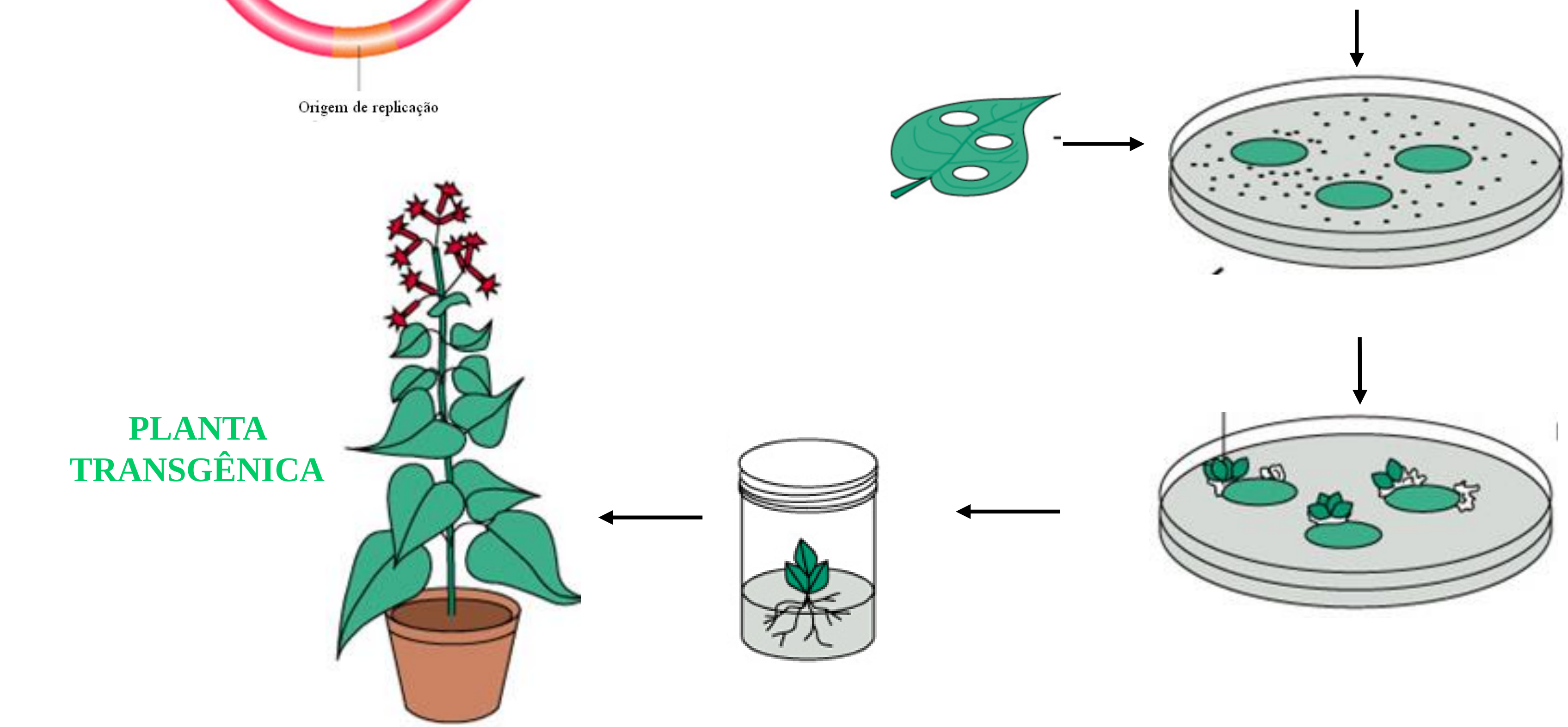
Mexendo *in vitro* na composição do meio de cultura posso diferenciar qualquer tecido...

Transformação *via Agrobacterium*

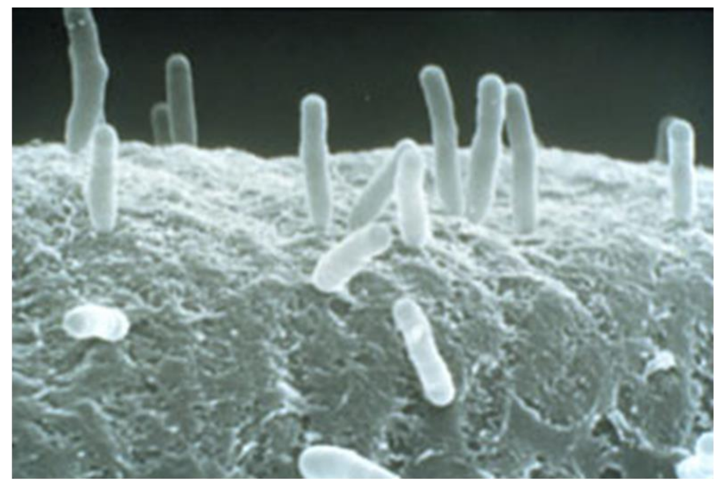


Transformação via bombardeamento: canhão gênico





A. tumefaciens

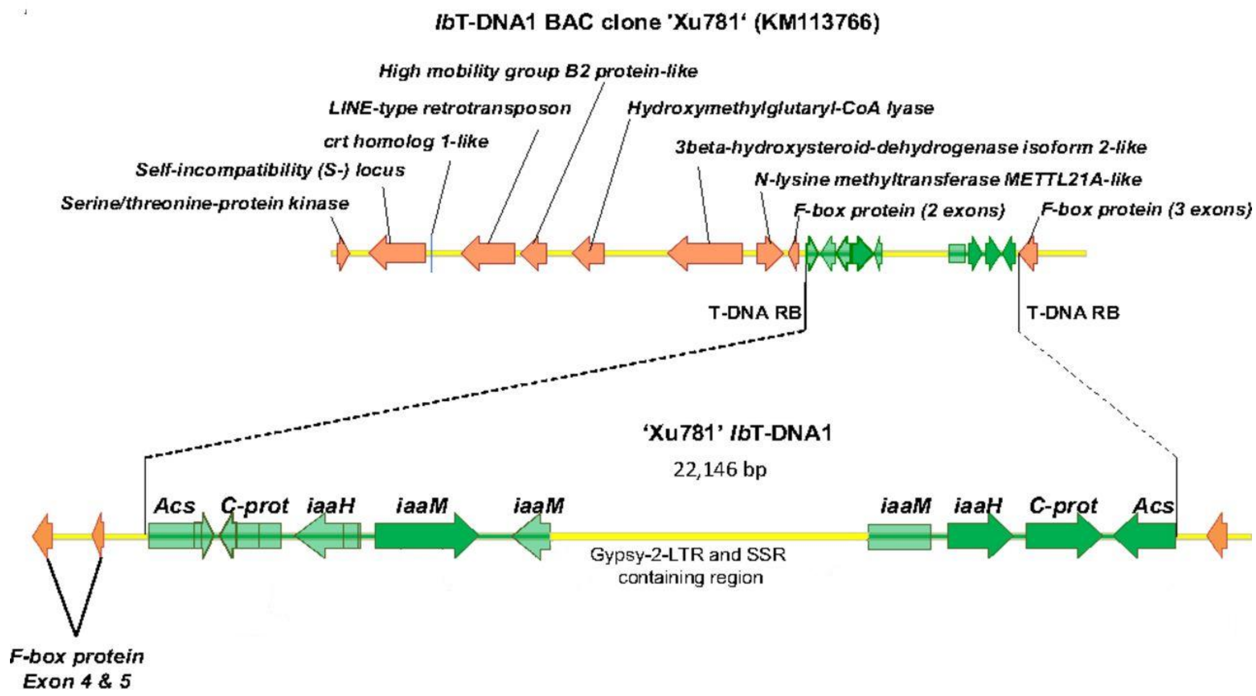


Agrobacterium tumefaciens attached to a plant cell.
Image by Martha Hawes

A. tumefaciens

291 acessos testados

iaa = biossíntese auxina
acs = biossíntese opina
C-prot = função desconhecida



Adaptado de Kyndt, T., Quispe, D., Zhai, H., Jarret, R., Ghislain, M., Liu, Q., ... & Kreuze, J. F. (2015). The genome of cultivated sweet potato contains Agrobacterium T-DNAs with expressed genes: an example of a naturally transgenic food crop. Proceedings of the National Academy of Sciences, 112(18), 5844-5849.

Transformação Genética:

- ***Auxiliar no estudo da biologia vegetal***

- ***Biotecnologia (melhoramento genético)***

Cisgeneses ou transgeneses- Estratégias:

- ***Expressão de gene***

(que não estava antes nesse organismo e de origens diversas)

- ***Silenciamento de gene***

(reduzir a quantidade de mRNA e consequentemente de proteína)

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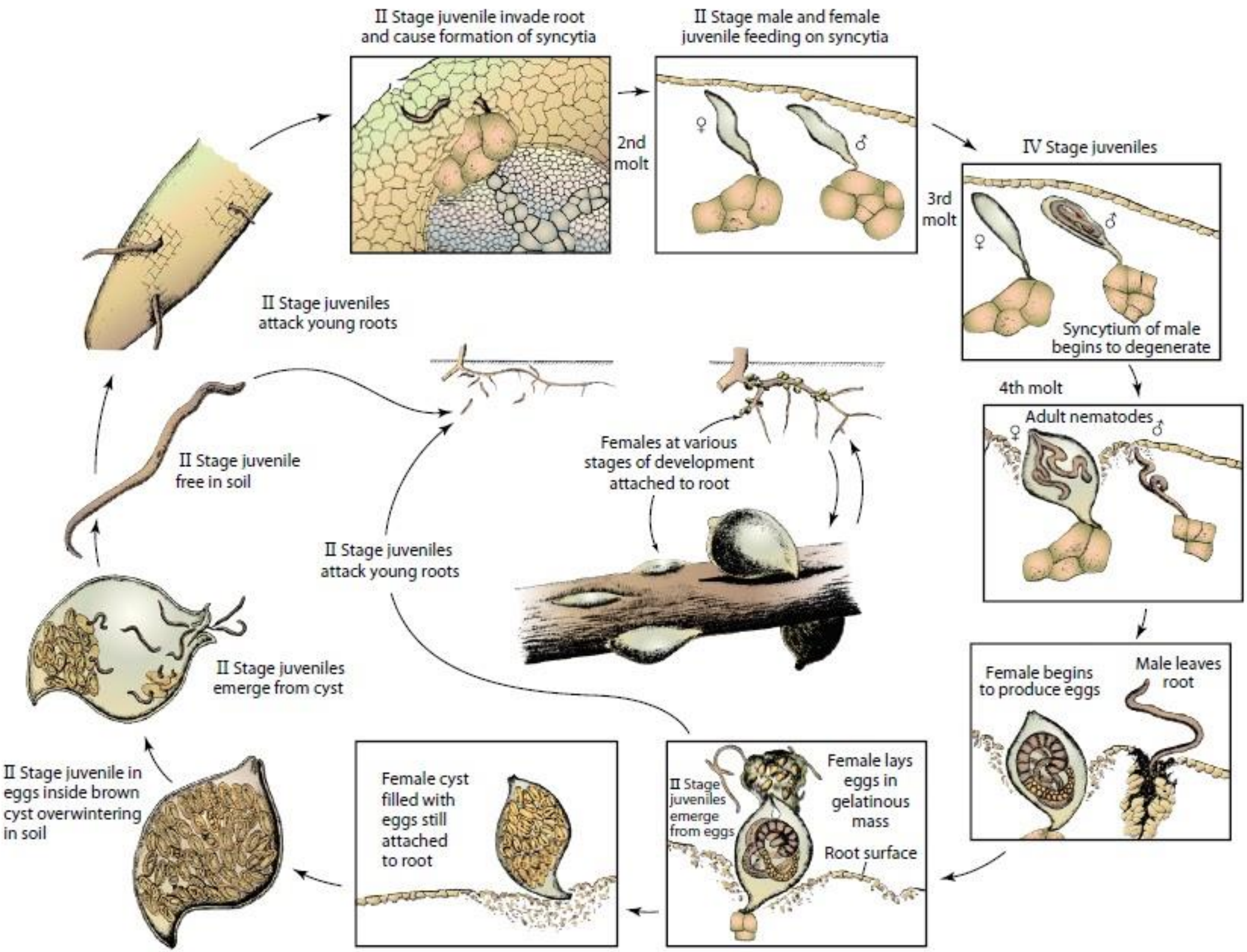
Resistência a nemátodos: gene *Mi* de *Solanum peruvianum*



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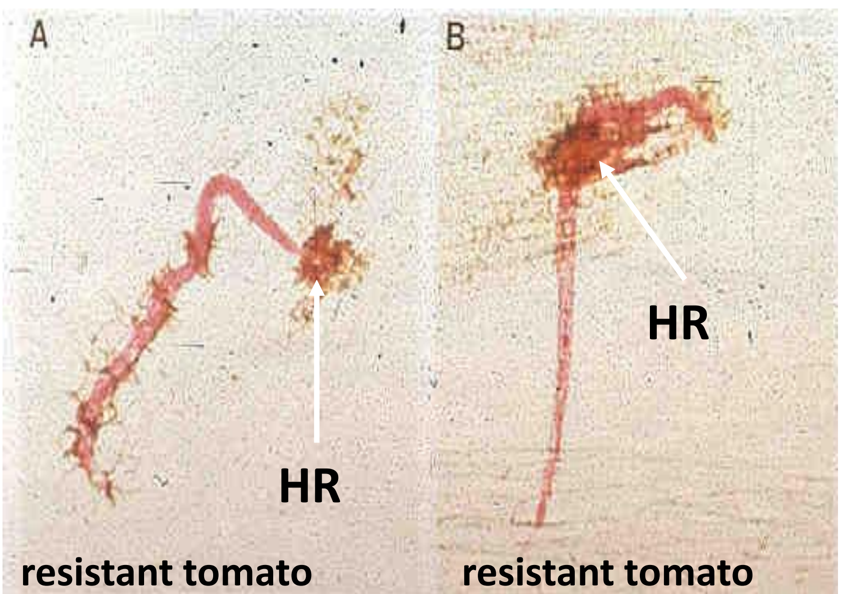

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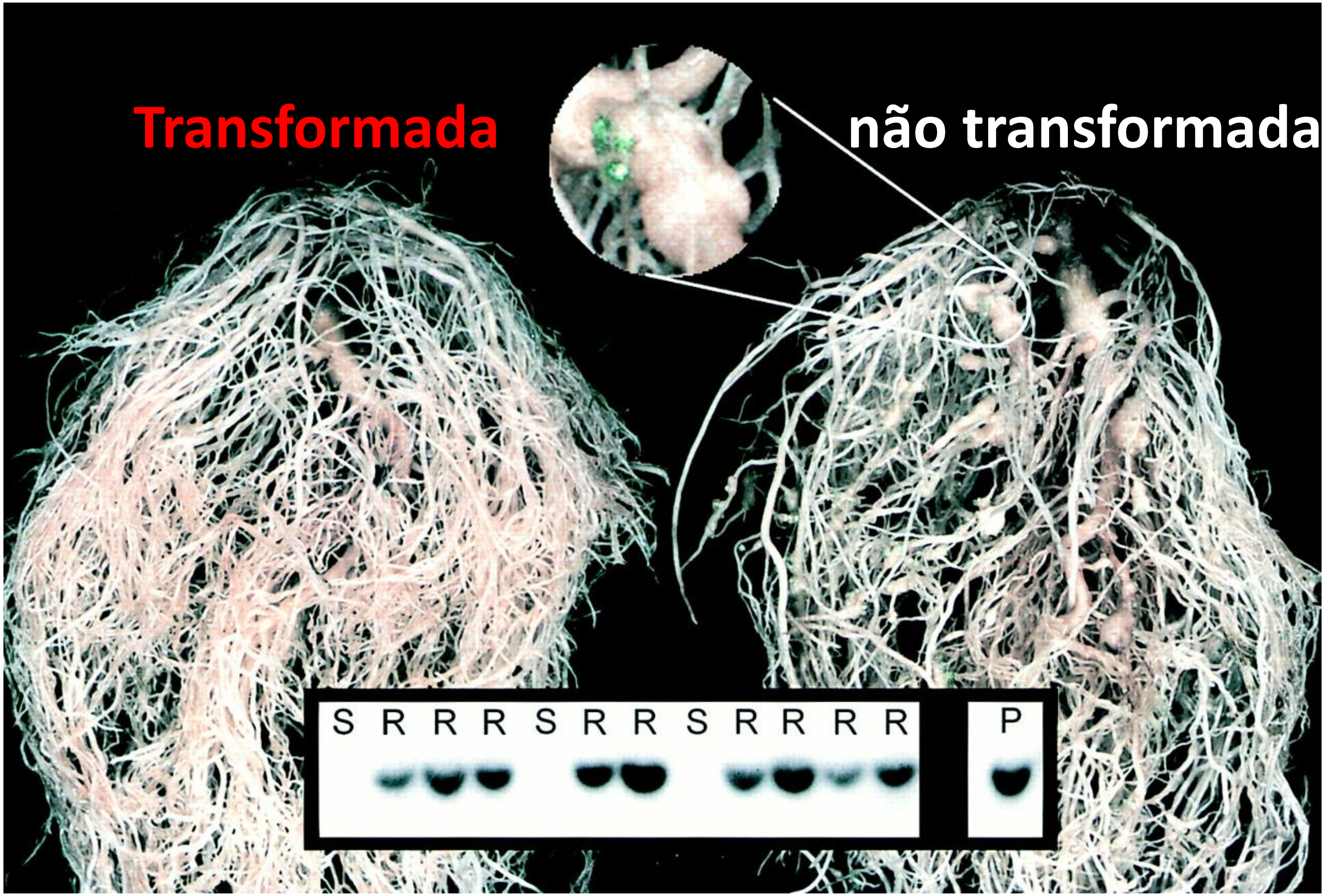
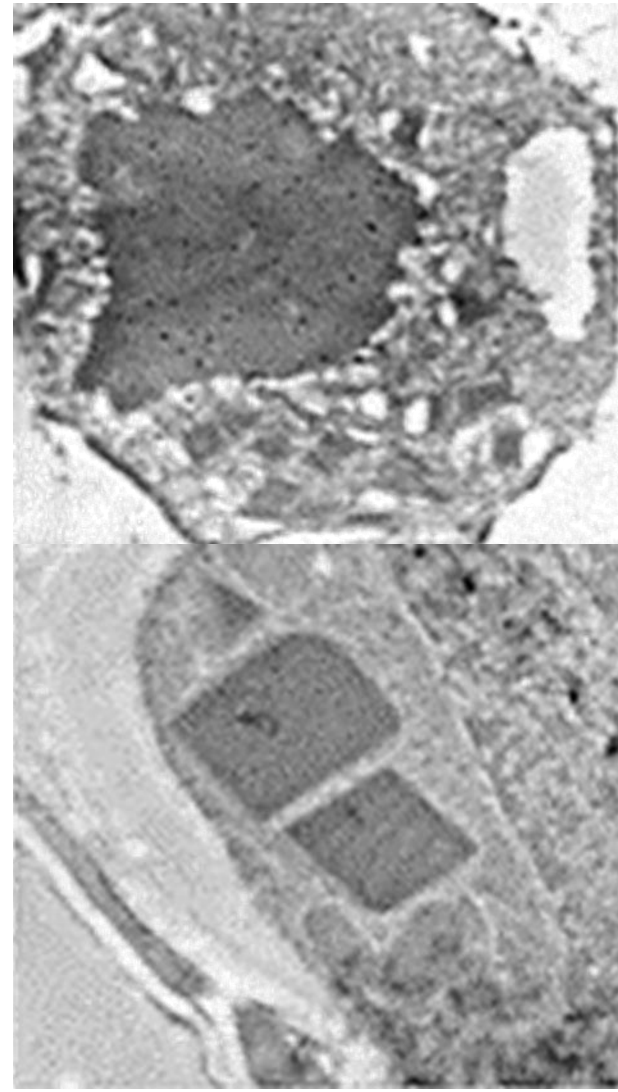


Resistência a insetos: genes *Bt* de *Bacilus turingensis* (transgênico)



Country	Insecticide reduction	Increase in effective yield	Increase in gross margin	References
	—— % ——		US$ ha⁻¹	
Argentina	47	33	23	Qaim and de Janvry, 2005
Australia	48	0	66	Fitt, 2003
China	65	24	470	Pray *et al.*, 2002
India	41	37	135	Subramanian and Qaim, 2009
Mexico	77	9	295	Traxler *et al.*, 2003
USA	36	10	58	Carpenter *et al.*, 2002

Aumentar a qualidade nutricional das culturas: Arroz com pro-vitamina A (carotenoides)

Vitamin A Deficiency and Rice

The problem :

Rice as major staple does not contain any pro-vitamin A.

The consequences:

400 million rice-eating poor suffer from vitamin A deficiency.
6,000 die per day, 500,000 become blind every year.

The transgenic concept:

Introduce, under endosperm-specific regulation, all genes necessary to establish the biochemical pathway.

Why genetic engineering in addition to the traditional interventions?

The genetic basis in the rice gene pool does not offer a basis for a conventional approach.

Golden Rice 2nd generation (trangênico)

Phytoene desaturase (*CRTI*) from *Erwinia uredovora*

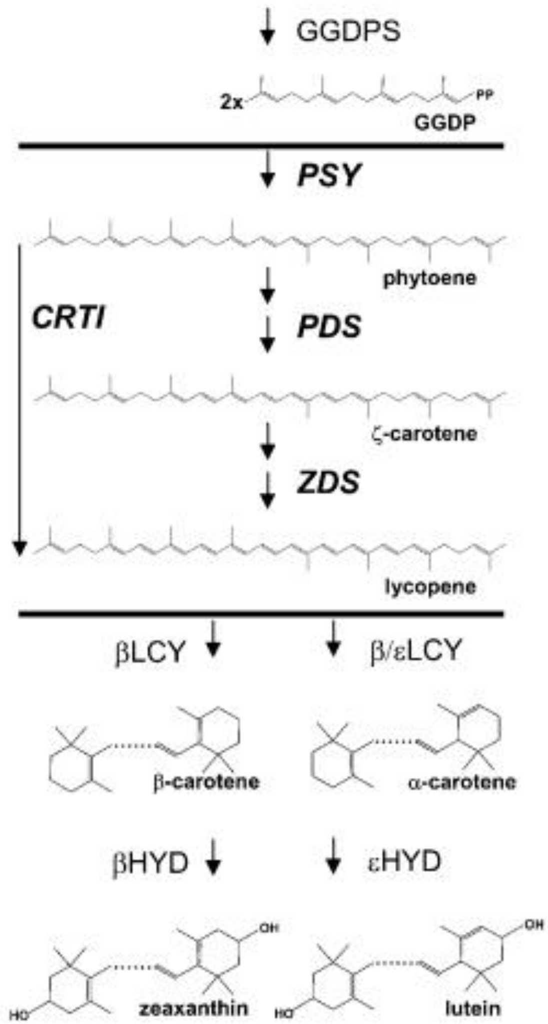
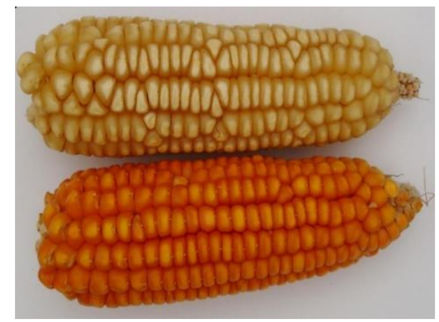


Figure 1. Carotenoid biosynthesis in transgenic rice endosperm. The precursor molecule geranylgeranyl-diphosphate (GGDP) is synthesized in wild-type endosperm. The enzymatic activities between horizontal bars are supplemented by transformation. This can be done either by using the two plant-type desaturases, PDS and ZDS, or by using the bacterial carotene desaturase, CrtI. However, lycopene does not appear as a product; instead, the carotenoids shown below the bottom bar are found in transgenic endosperm, among which *β*-carotene is predominant.

PSY from maize (*Zea mays*)



Provitamin A-contribution from a typical daily diet:

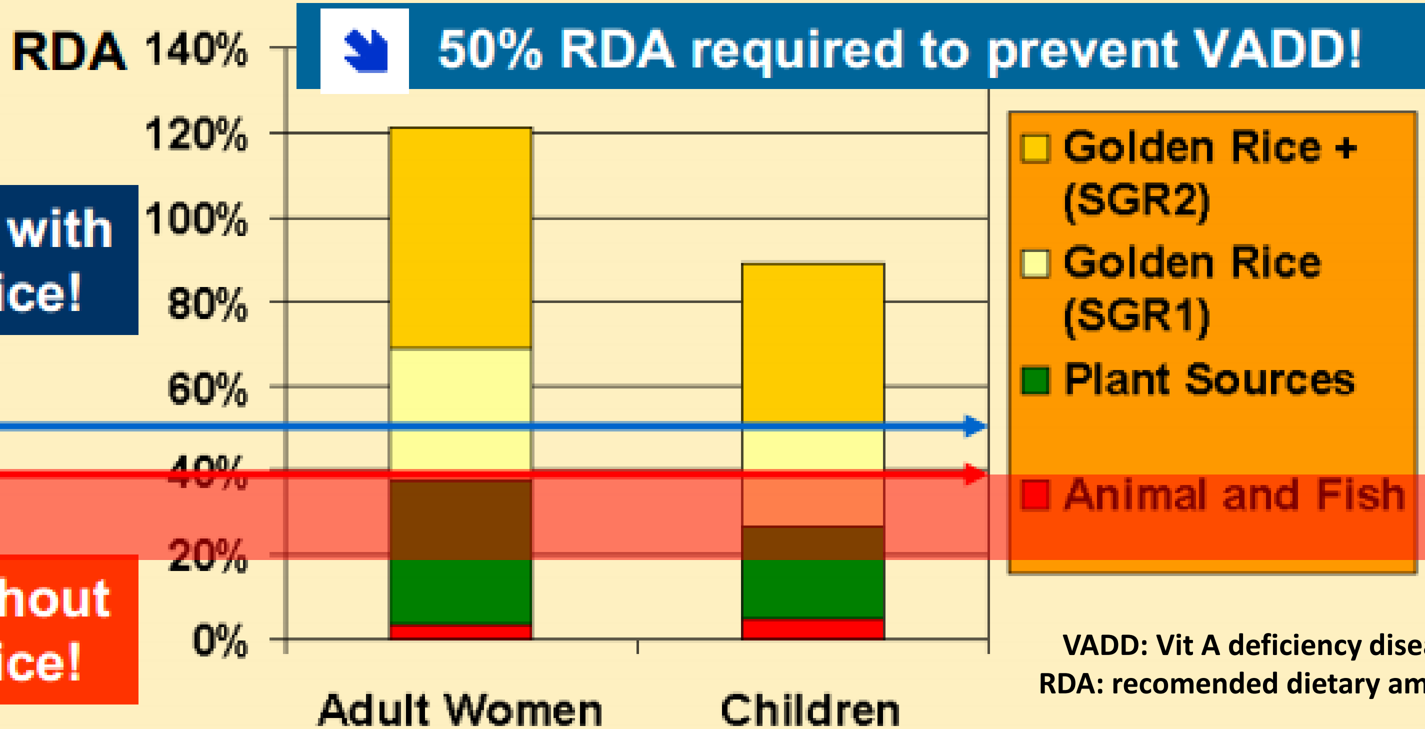
Calculation from the

International Food Policy Research Institute: **(2) Vitamin A contribution from nutrient intake.**

50% RDA required to prevent VADD!

No VADD with Golden Rice!

VADD without Golden Rice!



VADD: Vit A deficiency disease
RDA: recomended dietary amount

A typical daily diet would prevent vitamin A-deficiency, ...

... but GMO-regulation prevents, so far, use of Golden Rice.

Cisgeneses ou transgeneses- Estratégias:

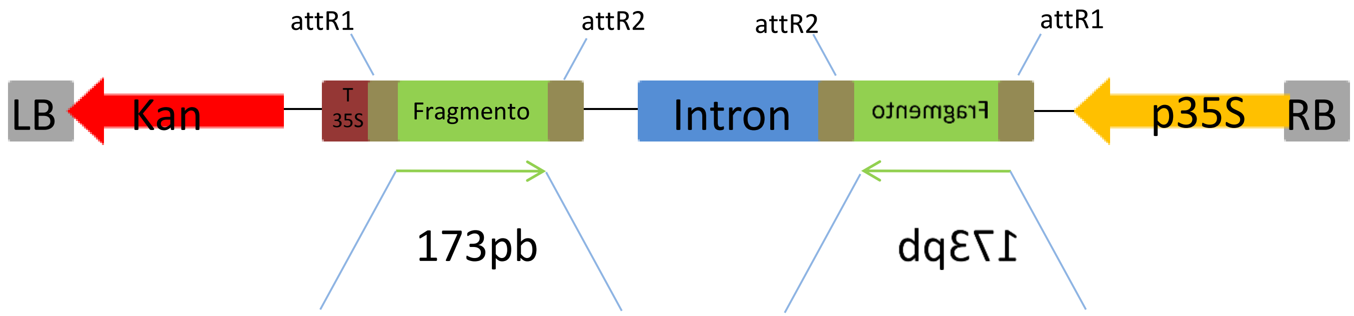
- ***Expressão de gene***

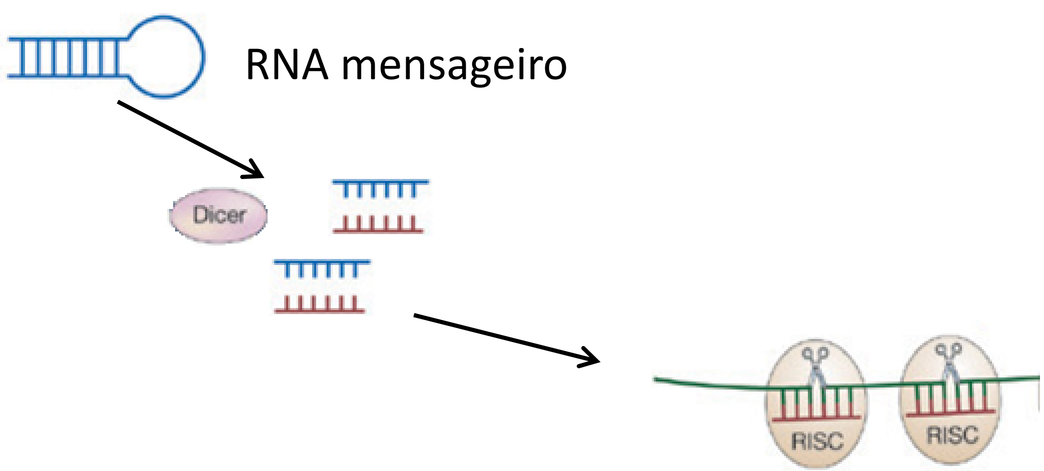
(que não estava antes nesse organismo e de origens diversas)

- ***Silenciamento de gene***

(reduzir a quantidade de mRNA e consequentemente de proteína)

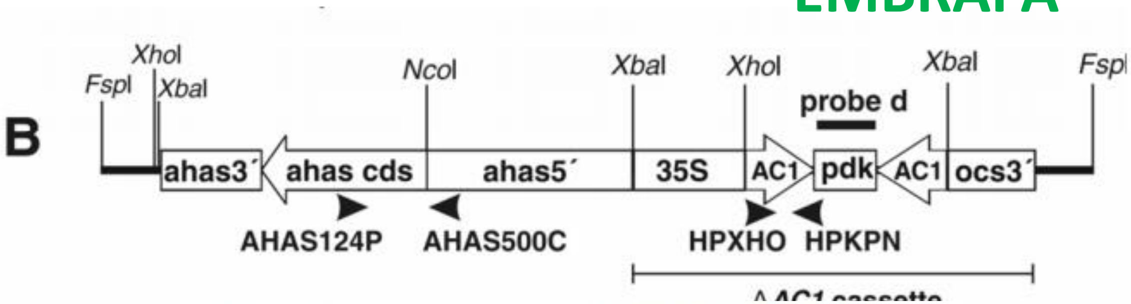
Estratégia para expressar um RNA mensageiro que forma uma estrutura de grampo (hairpin)

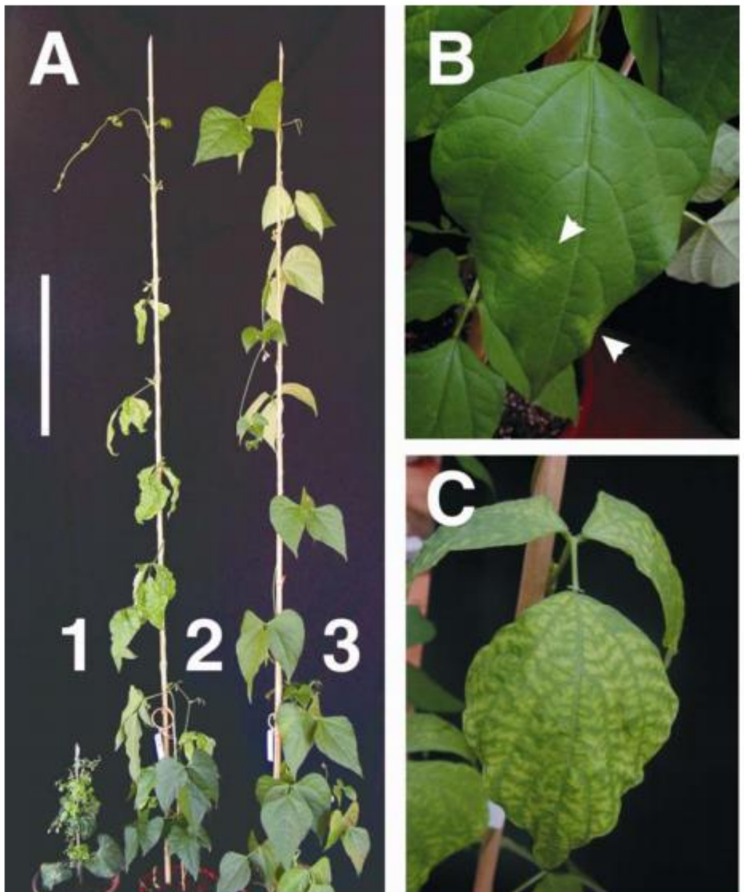




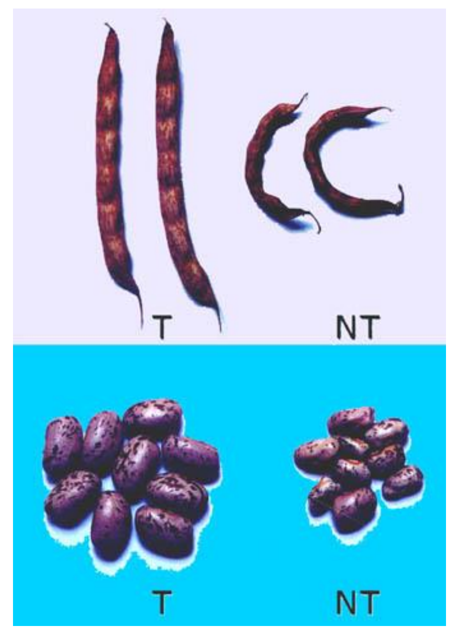
RNAm de gene alvo é DEGRADADO!!!!! E NÃO HÁ PRODUÇÃO DE PROTEÍNA!

RNAi-Mediated Resistance to Bean golden mosaic virus in Genetically Engineered Common Bean (*Phaseolus vulgaris*)- EMBRAPA





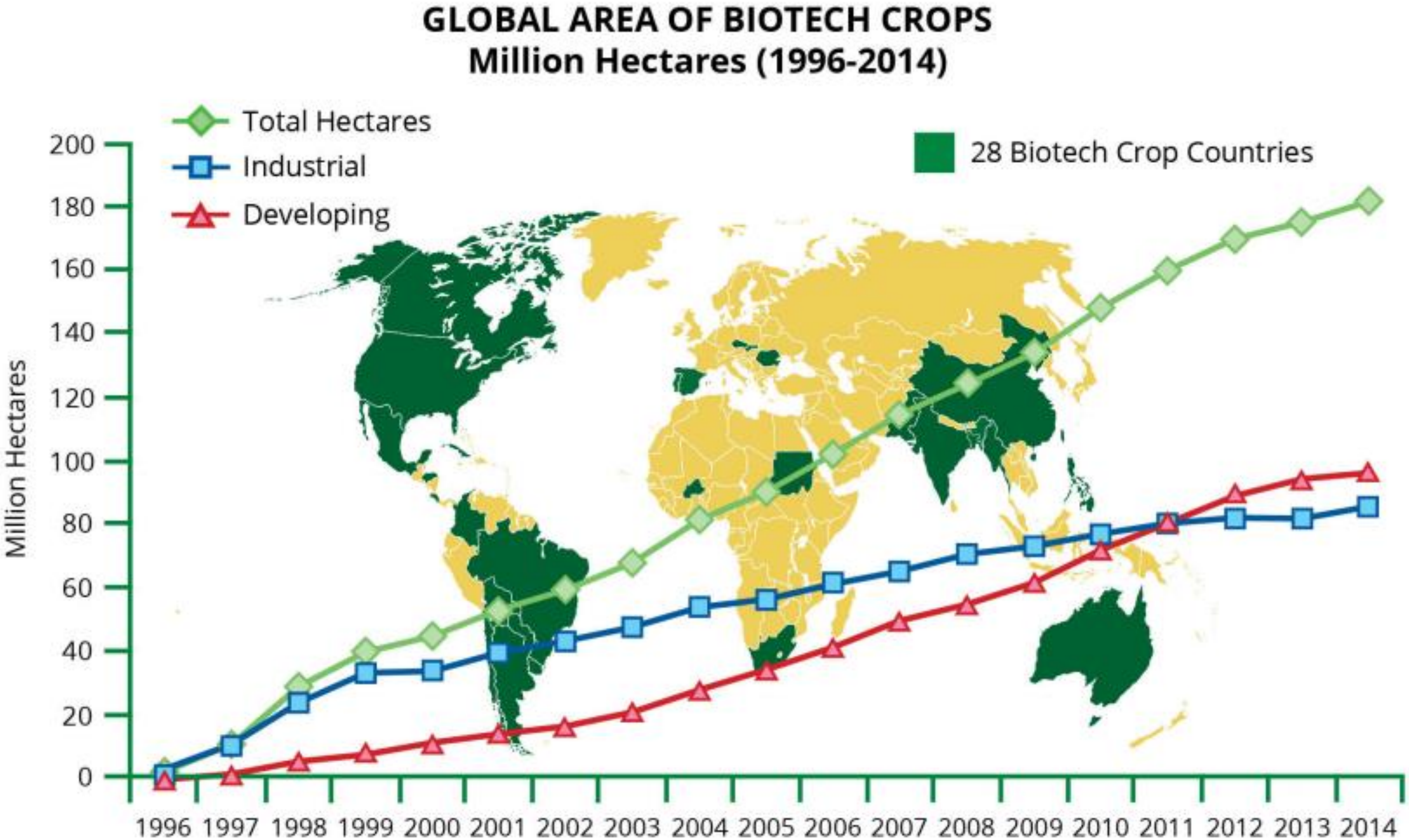
Expressa um mRNA em forma de grampo que da origem a um RNA dupla fita com um fragmento do gene da replicase viral (AC1)



Biotech Crop Countries and Mega-Countries*, 2014

*19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

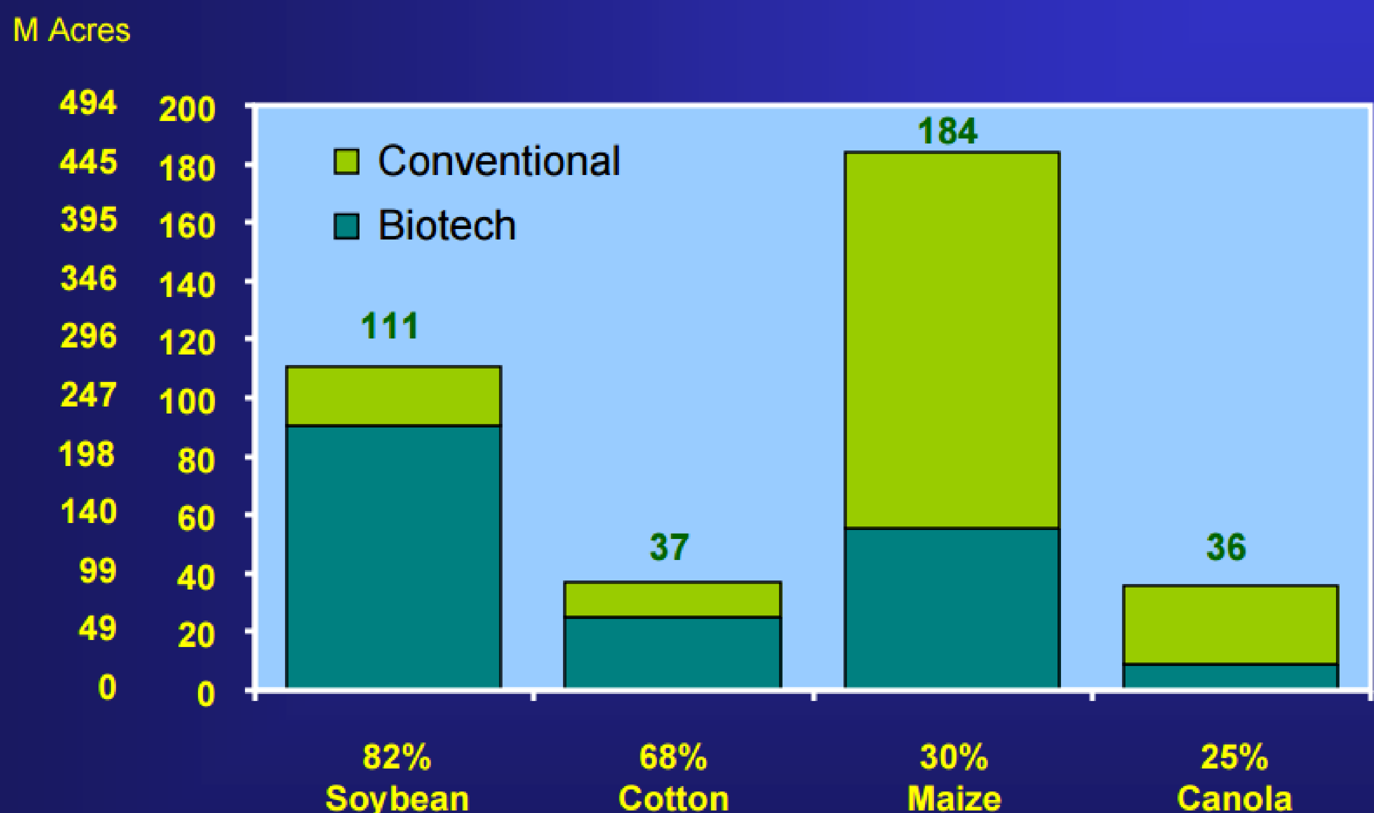
Source: Clive James, 2014.



A record 18 million farmers, in 28 countries, planted 181.5 million hectares (448 million acres) in 2014, a sustained increase of 3 to 4% or 6.3 million hectares (~16 million acres) over 2013.

Source: Clive James, 2014.

Global Adoption Rates (%) for Principal Biotech Crops (Million Hectares, Million Acres), 2014



Source: Clive James, 2014
Hectarage based on FAO Preliminary Data for 2012.

Os transgênicos estão presente

2. Na saúde

A engenharia genética contribui para grandes avanços da medicina

Há muito tempo, a medicina faz uso da biotecnologia como uma ferramenta fundamental para realizar diagnósticos mais rápidos e precisos de muitas doenças e para encontrar a cura ou prevenir enfermidades cujos tratamentos são custosos.

Como tudo começou

Uma das primeiras aplicações comerciais da biotecnologia na saúde é também uma das mais úteis: a produção da insulina humana com base em micro-organismos transgênicos. Até a década de 80, ela era extraída de bois e porcos, e, frequentemente, causava alergias. De lá pra cá, diabéticos do mundo inteiro se beneficiam dessa tecnologia, que tornou a insulina mais segura e aumentou a eficiência dos tratamentos.

"A engenharia genética foi responsável por avanços na saúde, nos processos industriais e na alimentação, e tornou a vida das pessoas mais confortável"

Alda Lerayer,
Diretora-Executiva do CIB

Hormônio do crescimento, vitamina C e vacina contra hepatite B são algumas das 400 aplicações da biotecnologia na saúde

Presente

- Mais de 400 medicamentos são produzidos por meio da aplicação da biotecnologia, entre eles, vitaminas, anticorpos e remédios para o combate à AIDS.
- A biotecnologia já contribui para a fabricação de kits para diagnósticos de doenças.
- É transgênico o hormônio do crescimento (hGH), contra o nanismo, que afeta 10 mil crianças brasileiras.
- O Instituto Butantan produz, anualmente, cerca de 50 milhões de doses da vacina contra a hepatite B, desenvolvida por meio da engenharia genética.

Futuro

- A terapia gênica é uma técnica já em testes que pode alterar a função de células humanas e tratar desde doenças cardíacas até o

Biotecnologia na calça jeans?

Há alguns anos, era comum colocar a calça jeans nova com pedras e ácido em máquinas para obter um efeito "desbotado" e aumentar a maciez do tecido, num processo conhecido como *stonewashing*. Graças à biotecnologia, foram desenvolvidos micro-organismos transgênicos capazes de dar ao jeans as mesmas características, eliminando-se, assim, um processo altamente poluidor do meio ambiente.

Micro-organismos transgênicos são usados para dar maciez ao jeans

Ministério da Ciência, Tecnologia e Inovação
Comissão Técnica Nacional de Biossegurança
Resumo Geral de Plantas Geneticamente modificadas aprovadas para Comercialização

Produto	Nome Comercial	Identificador único	Eventos	Organismo Doador	Característica	Proteína	Requerente	Ano de aprovação
Soja	Roundup Ready	MON-Ø4032-6	GTS-40-3-2	*Agrobacterium tumefaciens*	Tolerante a Herbicida	CP4-EPSPS	Monsanto	1998
	Cultivance	BPS-CV127-9	BPS-CV-127-9	*Arabidopsis thaliana*	Tolerante a Herbicida	Csr-1-2	BASF & Embrapa	2009
	Liberty Link ™	ACS-GMØØ5-3	A2704-12	*Streptomyces viridochromogenes*	Tolerante a Herbicida	PAT	Bayer	2010
	Liberty Link ™	ACS-GMØØ6-4	A5547-127	*Streptomyces viridochromogenes*	Tolerante a Herbicida	PAT	Bayer	2010
	Intacta RR2 PRO	MON-87701-2 x MON-89788-1	MON87701 & MON89788	*Agrobacterium tumefaciens/Bacillus thuringiensis*	Tolerante a Herbicida e Resistência a insetos	CP4-EPSPS Cry1Ac	Monsanto	2010
	***	***	DAS-68416-4	*Delftia acidovorans Streptomyces viridochromogenes*	Tolerante a herbicidas	aad12 pat	Dow Agrosciences	2015
Milho	Yield Gard	MON-ØØ810-6	MON810	*Bacillus thuringiensis*	Resistente a insetos	Cry1Ab	Monsanto	2007
	Liberty Link	ACS-ZMØØ3-2	T25	*Streptomyces viridochromogenes*	Tolerante a Herbicida	PAT	Bayer	2007
	TL	SYN-BTØ11-1	Bt	*Bacillus thuringiensis/Streptomyces viridochromogenes*	Resistente a insetos e Tolerante a herbicidas	Cry1Ab PAT	Syngenta	2007
	Roundup Ready 2	MON-ØØ6Ø3-6	NK603	*Agrobacterium tumefaciens*	Tolerante a Herbicida	CP4-EPSPS	Monsanto	2008
	TG	MON-ØØØ21-9	GA21	*Zea mays*	Tolerante a Herbicida	mEPSPS	Syngenta	2008
	Herculex	DAS-Ø15Ø7-1	TC1507	*Bacillus thuringiensis/Streptomyces viridochromogenes*	Resistente a insetos e Tolerante a herbicida	Cry1F PAT	Du Pont & DowAgroScience	2008
	YR YieldGard/RR2	MON-ØØ6Ø3-6 MON-ØØ810-6	NK603 & MON810	*Agrobacterium tumefaciens/Bacillus thuringiensis*	Tolerante a Herbicida e Resistência a insetos	CP4-EPSPS Cry1Ab	Monsanto	2009
	TL/TG	SYN-BTØ11-1 MON-ØØØ21-9	Bt11 & GA21	*Bacillus thuringiensis/Streptomyces viridochromogenes/Zea Mays*	Tolerante a Herbicida e Resistência a insetos	Cry1Ab PAT mEPSPS	Syngenta	2009
	Viptera-MIR162	SYN-IR162-4	MIR162	*Bacillus thuringiensis*	Resistente a Insetos	VIP3Aa20	Syngenta	2009
	HR Herculex/RR2	DAS-Ø1507-1 MON-ØØ6Ø3-6	TC1507 & NK603	*Bacillus thuringiensis/Strepomyces viridrochromogenes/Agrobacterium tumefaciens*	Resistente a Inseto e Tolerante a Herbicida	Cry1F PAT CP4-EPSPS	Du Pont	2009
	Pro	MON-89Ø34	MON89034	*Bacillus thuringiensis*	Resistente a insetos	Cry1A.105 Cry2Ab2	Monsanto	2009
	TL TG Viptera	SYN-BTØ11-1 SYN-IR162-4 MON-ØØØ21-9	Bt11 & MIR162 & GA21	*Bacillus thuringiensis/Streptomyces viridochromogenes/Zea Mays*	Resistente a insetos e Tolerante a herbicida	Cry1Ab VIP3Aa20 mEPSPS	Syngenta	2010
	PRO2	MON-89Ø34-3 MON-ØØ6Ø3-6	MON89034 7 NK603	*Bacillus thuringiensis/Agrobacterium tumefaciens*	Resistente a insetos e Tolerante a herbicida	Cry1A.105 Cry2Ab2 CP4-EPSPS	Monsanto	2010
	Yield Gard VT	MON-88Ø17-3	MON88017	*Agrobacterium tumefaciens/Bacillus thuringiensis*	Tolerante a Herbicida e Resistência a insetos	CP4-EPSPS Cry3Bb1	Monsanto	2010
	Power Core PW/Dow	MON-89Ø34-3 DAS-Ø15Ø7-1 MON-ØØ6Ø3-6	MON89034 & TC1507 & NK603	*Bacillus thuringiensis/Streptomyces viridochromogenes/Agrobacterium tumefaciens*	Resistente a insetos e Tolerante a herbicida	Cry1A.105 Cry2Ab2 Cry1F PAT CP4-EPSPS	Monsanto e Dow Agrosciences	2010
	HX YG RR2	MON-ØØ810-6 DAS-Ø15Ø7-1 MON-ØØ6Ø3-6	MON810 & TC1507 &NK603	*Bacillus thuringiensis/Streptomyces viridochromogenes/Agrobacterium tumefaciens*	Tolerante a Herbicida e Resistência a insetos	cry1Ab Cry1F PAT CP4EPSPS	Du Pont	2011
	TC1507xMON810	DAS-Ø1507 & MON810	TC1507 & MON810	*Bacillus thuringiensis/Streptomyces viridochromogenes*	Tolerante a Herbicida e Resistente a insetos	Cry1F Cry1Ab PAT	Du Pont	2011
	MON89034 x MON88017	MON-89Ø34-3 MON-88Ø17-3	MON89034 & MON88017	*Bacillus thuringiensis/Agrobacterium tumefaciens*	Tolerante a Herbicida e Resistente a insetos	Cry1A.105 Cry2Ab2 Cry3Bb1 CP4-EPSPS	Monsanto	2011
	Herculex XTRA™ maize	DAS-Ø15Ø7-1 DAS-59122-7	TC1507 x DAS-59122-7	*Bacillus thuringiensis/Streptomyces viridochromogenes*	Tolerante a Herbicida e Resistente a insetos	Cry1F PAT cry34Ab1 cry35Ab1	Du Pont & DowAgroScience	2013
	Viptera4	SYN-BTØ11-1 SYN-IR162-4 SYN-IR6Ø4-5 MON-ØØØ21-9	Bt11xMIR162xMIR604xGA21	*Bacillus thuringiensis/Streptomyces viridochromogenes/Zea mays*	Tolerante a Herbicida e Resistente a insetos	Cry1Ab PAT VIP3Aa20 mcry3A mEPSPS	Syngenta	2014

	MIR 604	SYN-IR6Ø4	MIR604	*Bacillus thuringiensis*	Resistente a insetos	mcry3A	Syngenta	2014
	***	***	DAS-40278-9	*Sphingobium herbicidorovans*	Tolerante a herbicida	*aad-1v3*	Dow Agrosciences	2015
	***	MON-ØØ6Ø3-6 ACS-ZMØØ3-2	NK603 x T25	*Agrobacterium tumefaciens Streptomyces viridocromogenes*	Tolerante a herbicida	*CP4-EPSPS PAT*	Monsanto	2015
	***	DAS-Ø15Ø7-1 MON-ØØ810-6 SYN-IR162-4 MON-ØØ6Ø3-6	TC15Ø7 x MON81Ø x MIR162 x NK6Ø3	*Bacillus thuringiensis Streptomyces viridochromogenes Agrobacterium tumefaciens*	Tolerante a herbicida & resistência a insetos	*cry1F cry1Ab PAT VIP3Aa20 CP4-EPSPS*	Du Pont	2015
	***	DAS-Ø15Ø7-1 SYN-IR162-4 MON-ØØ6Ø3-6	TC1507xMIR162xNK603	*Bacillus thuringiensis Streptomyces viridochromogenes Agrobacterium tumefaciens*	Tolerancia a herbicida & resistência a insetos	*cry1F PAT VIP3Aa20 CP4-EPSPS*	Du Pont (RN15)	2015
	***	DAS-Ø15Ø7-1 SYN-IR162-4	TC1507xMIR162	*Bacillus thuringiensis Streptomyces viridochromogenes Bacillus thuringiensis*	Tolerância a herbicidas & resistência a insetos	*cry1F PAT VIP3Aa20*	Du Pont (RN15)	2015
	***	SYN-IR162-4 MON-ØØ6Ø3-6	MIR162xNK603	*Bacillus thuringiensis Agrobacterium tumefaciens*	Tolerância a herbicidas & resistência a insetos	*VIP3Aa20 CP4-EPSPS*	Du Pont (RN15)	2015
	***	MON-ØØ810-6 SYN-IR162-4	MON810xMIR162	*Bacillus thuringiensis*	Resistência a insetos	*Cry1Ab VIP3Aa20*	Du Pont (RN15)	2015
	***	DAS-Ø15Ø7-1 MON-ØØ810-6 SYN-IR162-4	TC1507 x MON810 x MIR162	*Bacillus thuringiensis Streptomyces viridochromogenes*	Tolerância a herbicidas & resistência a insetos	*Cry1F pat VIP3Aa20 cry1Ab*	Du Pont	2015
	Bolgard I	MON-ØØ531-6	MON531	*Bacillus thuringiensis*	Resistente a insetos	Cry1Ac	Monsanto	2005
	Roundup Ready	MON-Ø1445-2	MON1445	*Agrobacterium tumefaciens*	Tolerante a Herbicida	CP4-EPSPS	Monsanto	2008
	Liberty Link	ACS-GHØØ1-3	LLCotton25	*Streptomyces viridochromogenes*	Tolerante a Herbicida	PAT	Bayer	2008
	Bolgard I Roundup Ready	MON-ØØ531-6 MON-Ø1445-2	MON531&MON1445	*Bacillus thuringiensis/Agrobacterium tumefaciens*	Tolerante a herbicida & resistência a insetos	Cry1Ac CP4-EPSPS	Monsanto	2009
	Widestrike	DAS-24236-5 DAS-21Ø23-5	281-24-236 & 3006-210-23	*Bacillus thuringiensis/Streptomyces viridochromogenes*	Tolerante a herbicida & resistência a insetos	Cry1Ac Cry1F PAT	Dow Agrosciences	2009
	Bolgard II	MON-15985-7	MON15985	*Bacillus thuringiensis*	Resistente a Insetos	Cry2Ab2 Cry1Ac	Monsanto	2009
	GlyTol	BCS-GHØØ2-5	GHB614	*Zea mays*	Tolerante a herbicida	2mEPSPS	Bayer	2010

Algodão	TwinLink	BCS-GHØØ4-7 BCS-GHØØ5-8	T304-40 & GHB119	*Bacillus thuringiensis/Streptomyces hygroscopicus*	Resistente a insetos e Tolerante a herbicidas	Cry1Ab Cry2Ae PAT	Bayer	2011
	MON88913	MON-88913-8	MON88913	*Agrobacterium tumefaciens*	Tolerante a Herbicida	CP4-EPSPS	Monsanto	2011
	GlytolxTwinLink	BCS-GHØØ2-5 BCS-GHØØ4-7 BCS-GHØØ5-8	GHB614 x T304-40 x GHB 119	*Zea may/Bacillus thuringiensis/Streptomyces higroscopicus*	Tolerante a herbicida e reistência a insetos	Cry1Ab, cry2Ae,2mepsps	Bayer	2012
	GTxLL	BCS-GHØØ2-5 ACS-GHØØ1-3	GHB614 x LLCotton25	*Zea mays/Streptomyces viridochromogenes*	Tolerante a Herbicida	2mepsps, bar	Bayer	2012
	BolgardII Roundup Ready Flex	MON 15985-7 x MON 88913-8	MON 15985 x MON 88913	*Bacillus thuringiensis/Agrobacterium tumefaciens*	Tolerante a Herbicida e Resistente a insetos	cry1Ac e cry2Ab2 e CP4-EPSPS	Monsanto	2012
Feijão	Embrapa 5.1	BEM-PVØ51-1	Embrapa 5.1	*BGMV - Bean Golden Mosaic Virus*	Resistente ao Vírus do Mosaico dourado do feijoeiro	não se aplica	Embrapa	2011
Eucalipto	***	***	H421	*Arabdopsis thaliana*	aumento volumétrico de madeira	cell1	Futuragene	2015

*** Aguardam denomicações

- Conselho de Informações sobre Biotecnologia (http://www.cib.org.br)

  (info geral)

- Comissão Técnica Nacional de Biossegurança (http://www.ctnbio.gov.br)

  (legislação)

- International Service for the Adquisition of Agri-Biotech Applications (http://www.isaaa.org)

  (números globais)

- Center of Environmenta Risk Assessment (www.cera-gmc.org)

  (detalhes dos eventos)