Origen, consecuencias y estudio de la poliploidía en plantas

Genética, Genómica y Mejora Vegetal

Febrero de 2023

Máster en Genética y Evolución
(Especialidad Agroalimentaria)

UNIVERSIDAD DE GRANADA

Rafael Navajas-Pérez

Una visión naif de la Genética Vegetal

Un gen, una función…

Mendel's Genes: Toward a Full Molecular Characterization

James B. Reid and John J. Ross[1]
School of Plant Science, University of Tasmania, Hobart, Tasmania 7001, Australia

Genetics, Vol. 189, 3–10 September 2011

Table 1 Seven characters of *P. sativum* examined by Mendel and a summary of the genes, phenotypes, and presumed mutations involved

Trait	Dominant phenotype	Recessive phenotype	Symbol group	Linkage group	Cloned	Gene function	Molecular nature of mutation
Seed shape	Round	Wrinkled	*R*	V	Yes	Starch branching enzyme 1	0.8-kb insertion
Stem length	Tall	Dwarf	*LE*	III	Yes	GA 3-oxidase1	G-to-A substitution
Cotyledon color	Yellow	Green	*I*	I	Yes	Stay-green gene	6-bp insertion
Seed coat/flower color	Purple	White	*A*	II	Yes	bHLH transcription factor	G-to-A at splice site
Pod color	Green	Yellow	*GP*	V	No	Chloroplast structure in pod wall	Unknown
Pod form	Inflated	Constricted	*V?*	III	No	Sclerenchyma formation in pods	Unknown
Position of flowers	Axial	Terminal	*FA*	IV	No	Meristem function	Unknown

References are given in the text.

Stay-green

ii → *Dos copias del gen Stay-green* → 

Ii → *Una copia funcional y una copia del gen Stay -green* → 

II → *Dos copias funcionales* → 

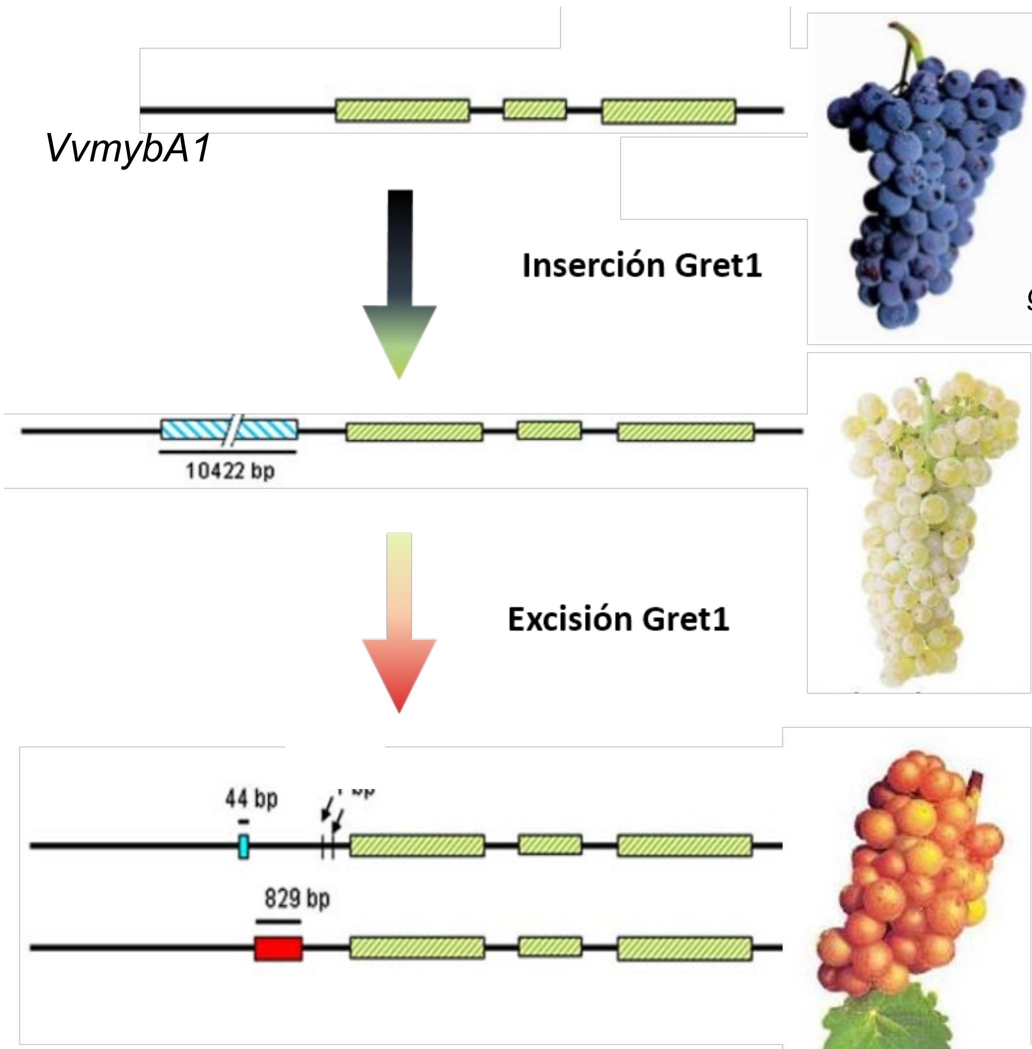
Dominancia/Recesividad

I **i**

Fuente: Fotolia

Una visión naif de la Genética Vegetal

Un gen, una función… (II)



Modificado de This et al., 2007 (Imágenes de unifeed.club)

Dos copias intactas del gen VvmybA1 → V^+V^+ *Producción normal de antocianinas*

Dos copias mutadas del gen VvmybA1 → V V *Sin producción de antocianinas*

Herencia Intermedia

Una copia mutada y otra funcional del gen VvmybA1 → V^+V *Se produce la mitad de la cantidad normal de antocianinas*

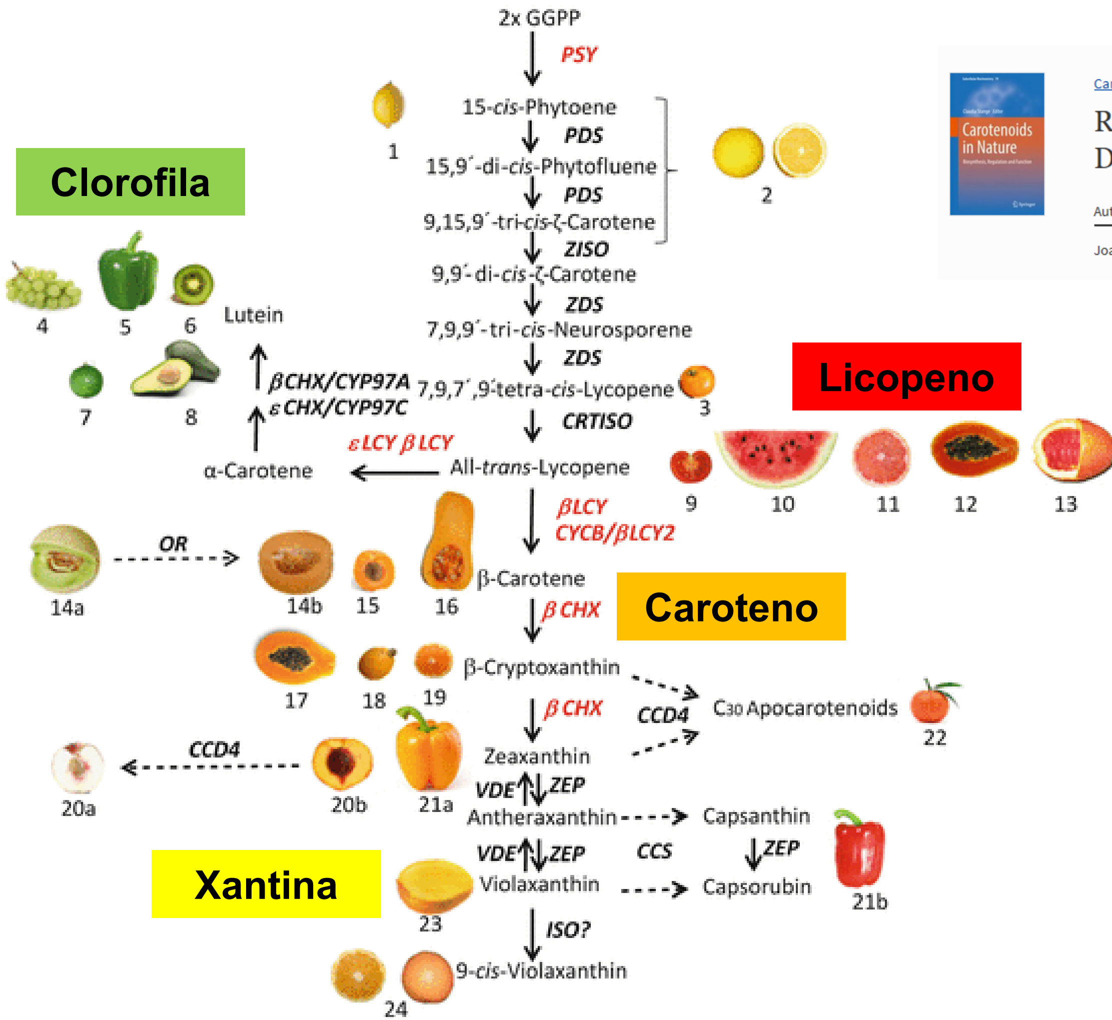
Wine grape (*Vitis vinifera* L.) color associates with allelic variation in the domestication gene *VvmybA1*

Patrice This · Thierry Lacombe · Molly Cadle-Davidson · Christopher L. Owens

Theor Appl Genet (2007) 114:723–730
DOI 10.1007/s00122-006-0472-2

Una visión naif de la Genética Vegetal

Varios genes, una función… (Interacción génica)



Carotenoids in Nature pp 161-198 | Cite as

Regulation of Carotenoid Biosynthesis During Fruit Development

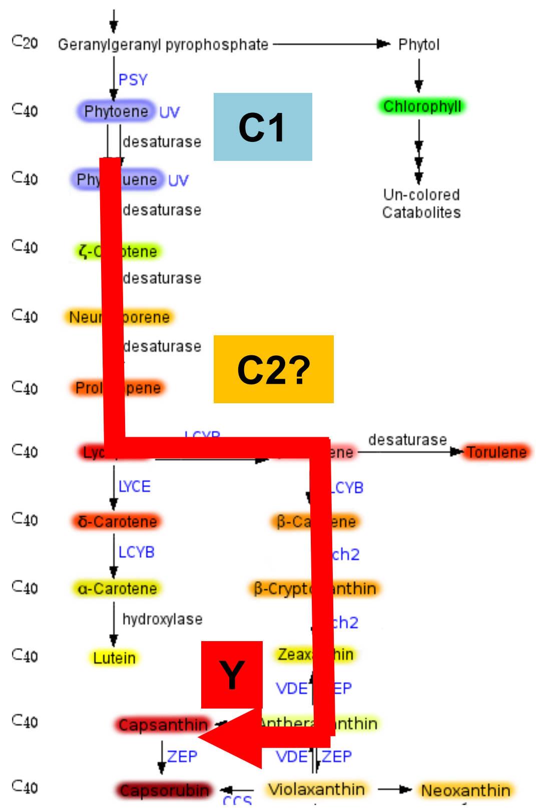
Authors | Authors and affiliations

Joanna Lado, Lorenzo Zacarías, María Jesús Rodrigo

Foto: R. Navajas

Una visión naif de la Genética Vegetal

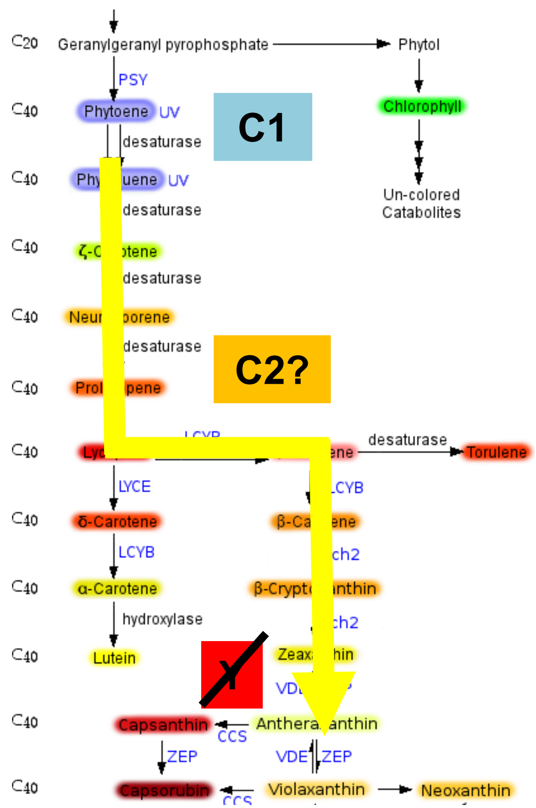
Varios genes, una función… (Interacción génica)

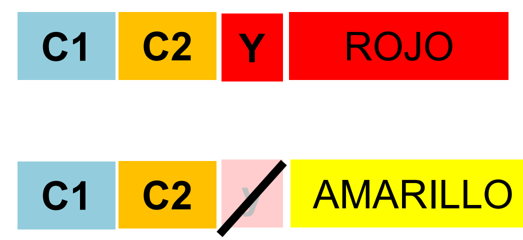


C1 | C2 | Y | ROJO

Una visión naif de la Genética Vegetal

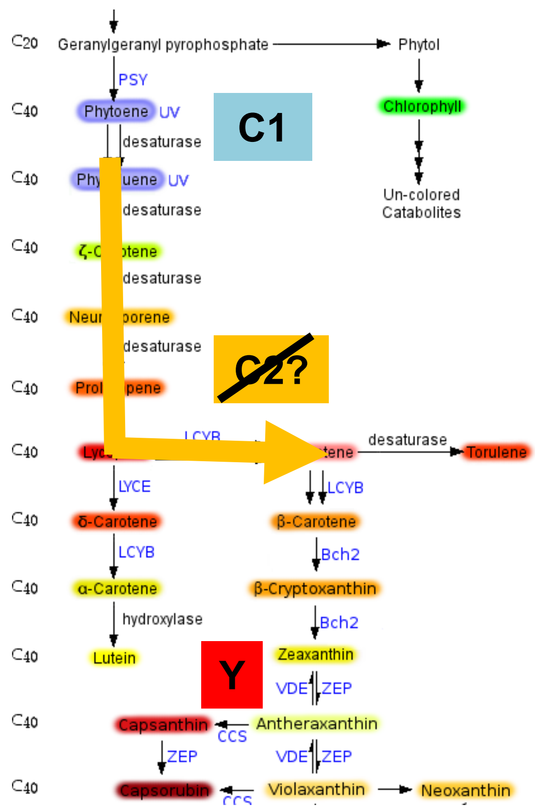
Varios genes, una función… (Interacción génica)

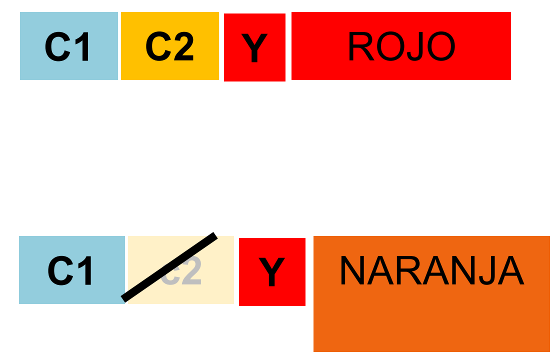




Una visión naif de la Genética Vegetal

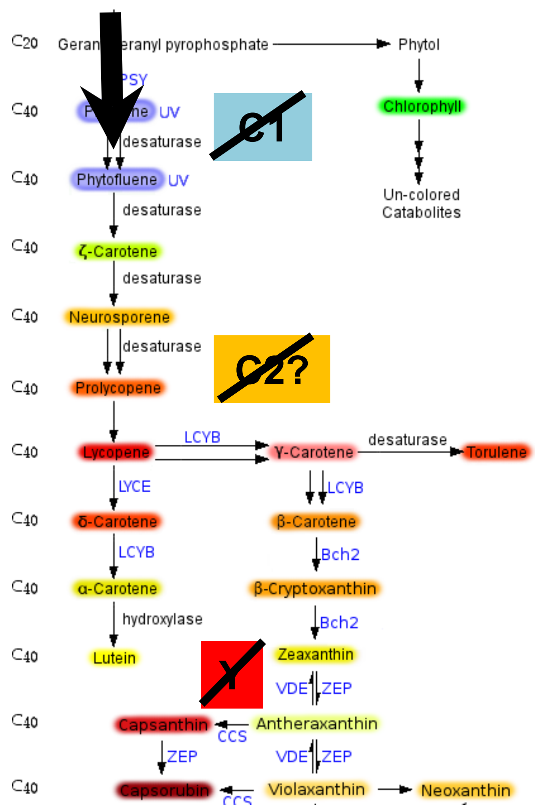
Varios genes, una función… (Interacción génica)





Una visión naif de la Genética Vegetal

Varios genes, una función… (Interacción génica)

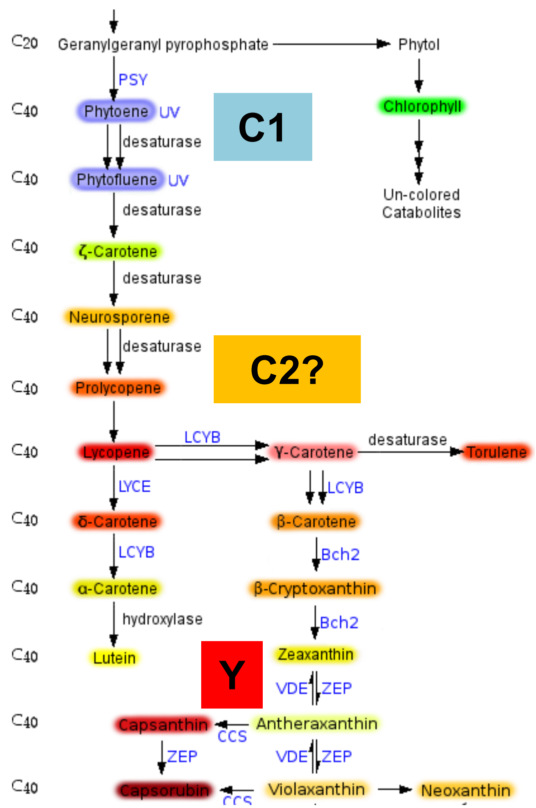


C1 C2 Y ROJO

~~c1~~ ~~c2~~ ~~y~~ BLANCO

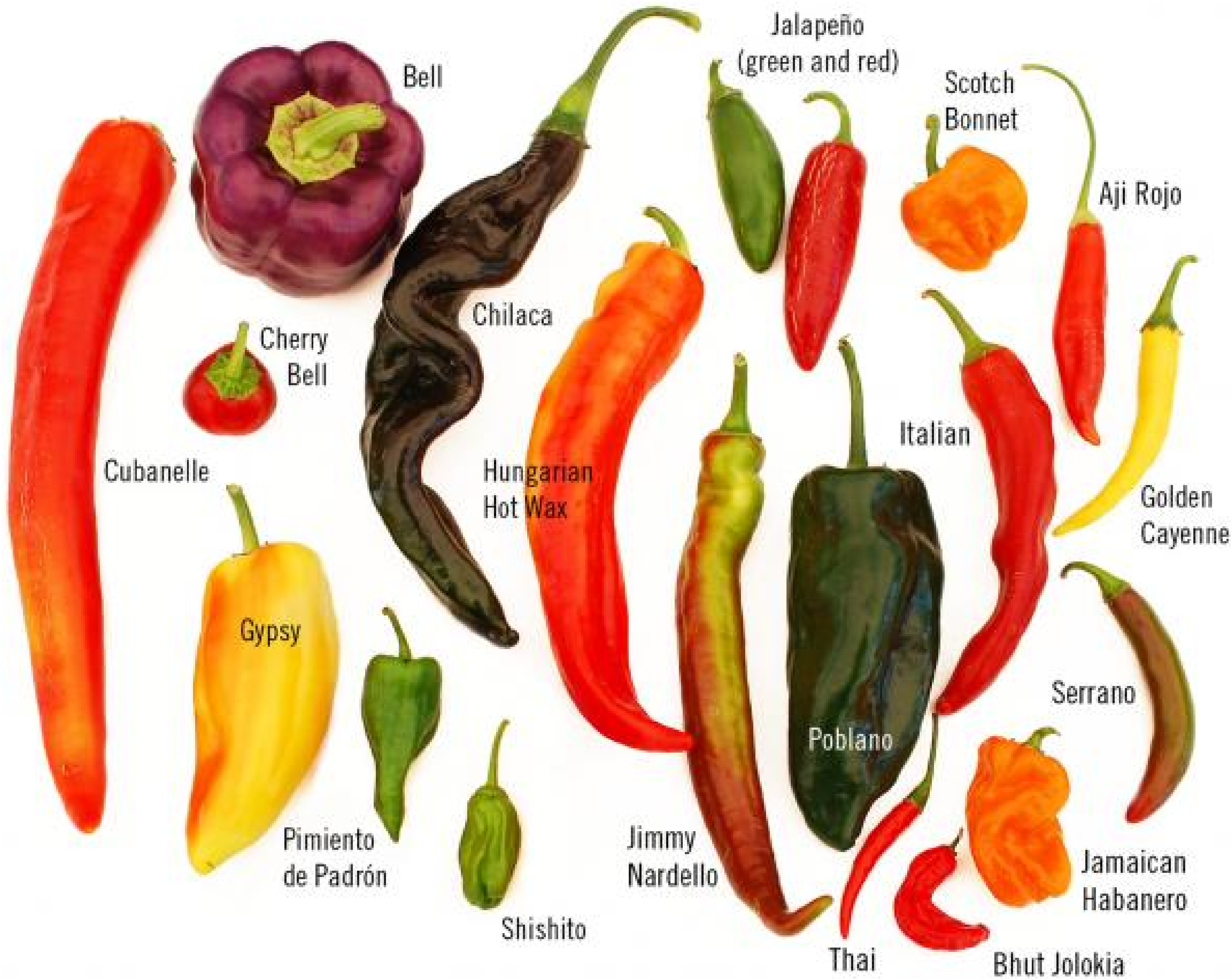
Una visión naif de la Genética Vegetal

Varios genes, una función… (Interacción génica)



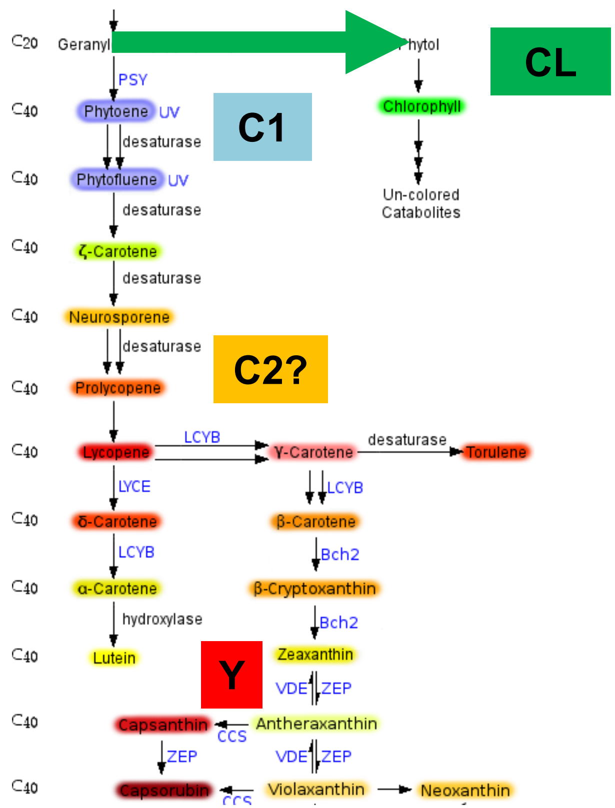
C1	C2	Y	ROJO
C1	C2	y	AMARILLO
C1	c2	Y	NARANJA
c1	c2	y	BLANCO

CUESA's GUIDE to SWEET AND HOT PEPPERS



Una visión naif de la Genética Vegetal

Varios genes, una función… (Interacción génica)

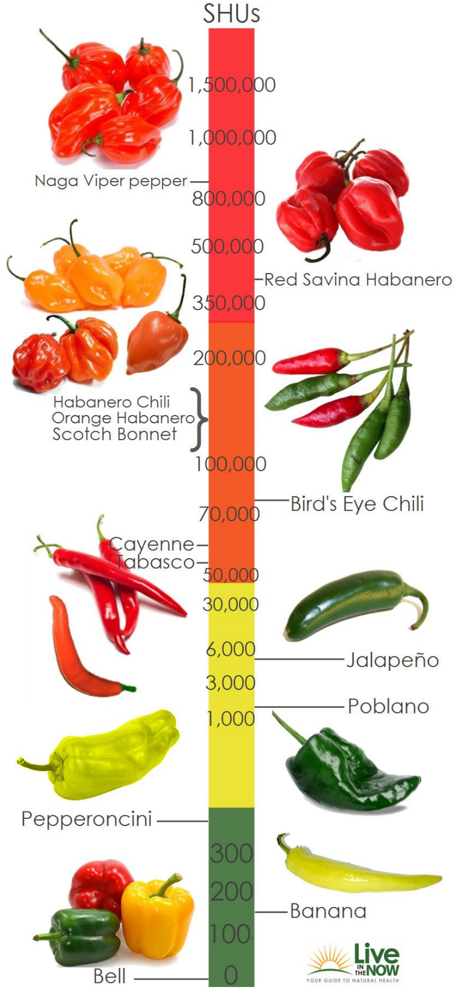


C1 | C2 | Y | ROJO

CL | VERDE

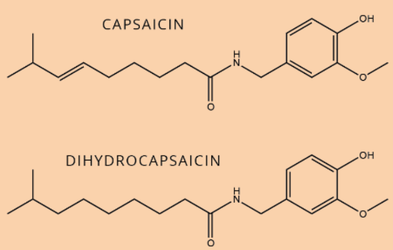
Pssst... Capsaicin benefits heart health! So,

HOW SPICY IS THAT PEPPER?



THE CHEMISTRY OF A CHILLI

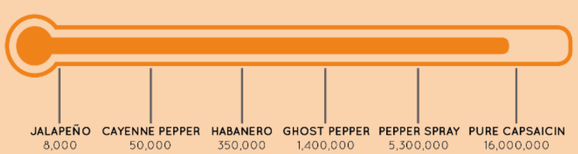
CAPSAICINOIDS



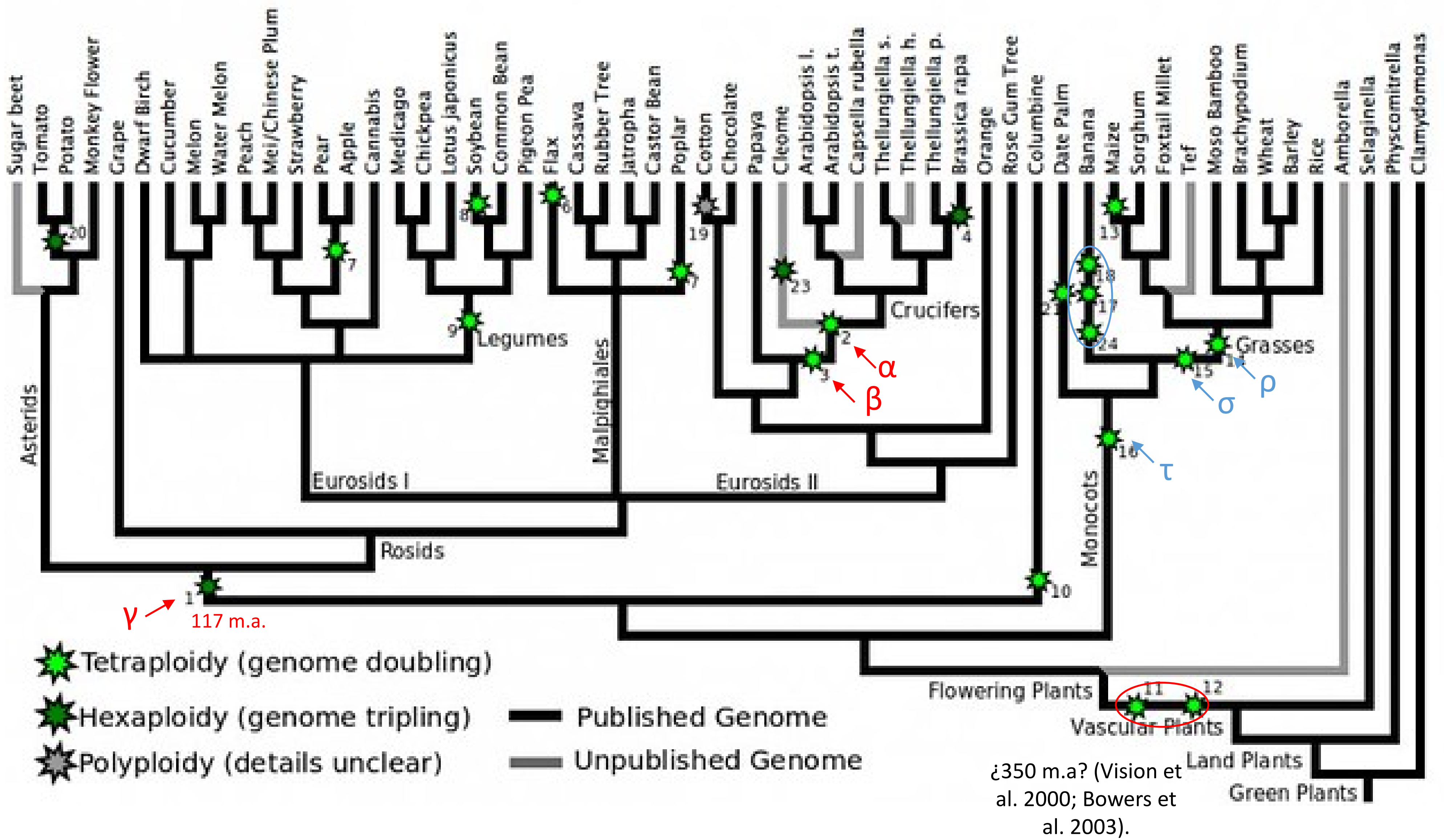
The spiciness of chillis is due to the presence of compounds called capsaicinoids. The two compounds above are the main capsaicinoids in chilli peppers. They cause a burning sensation when they come into contact with mucous membranes, due to their interaction with pain and heat sensing neurons.

Capsaicin is also used in some brands of pepper spray, and studies have shown it may be capable of killing prostate and lung cancer cells. It is toxic in large quantities.

THE SCOVILLE HEAT INDEX



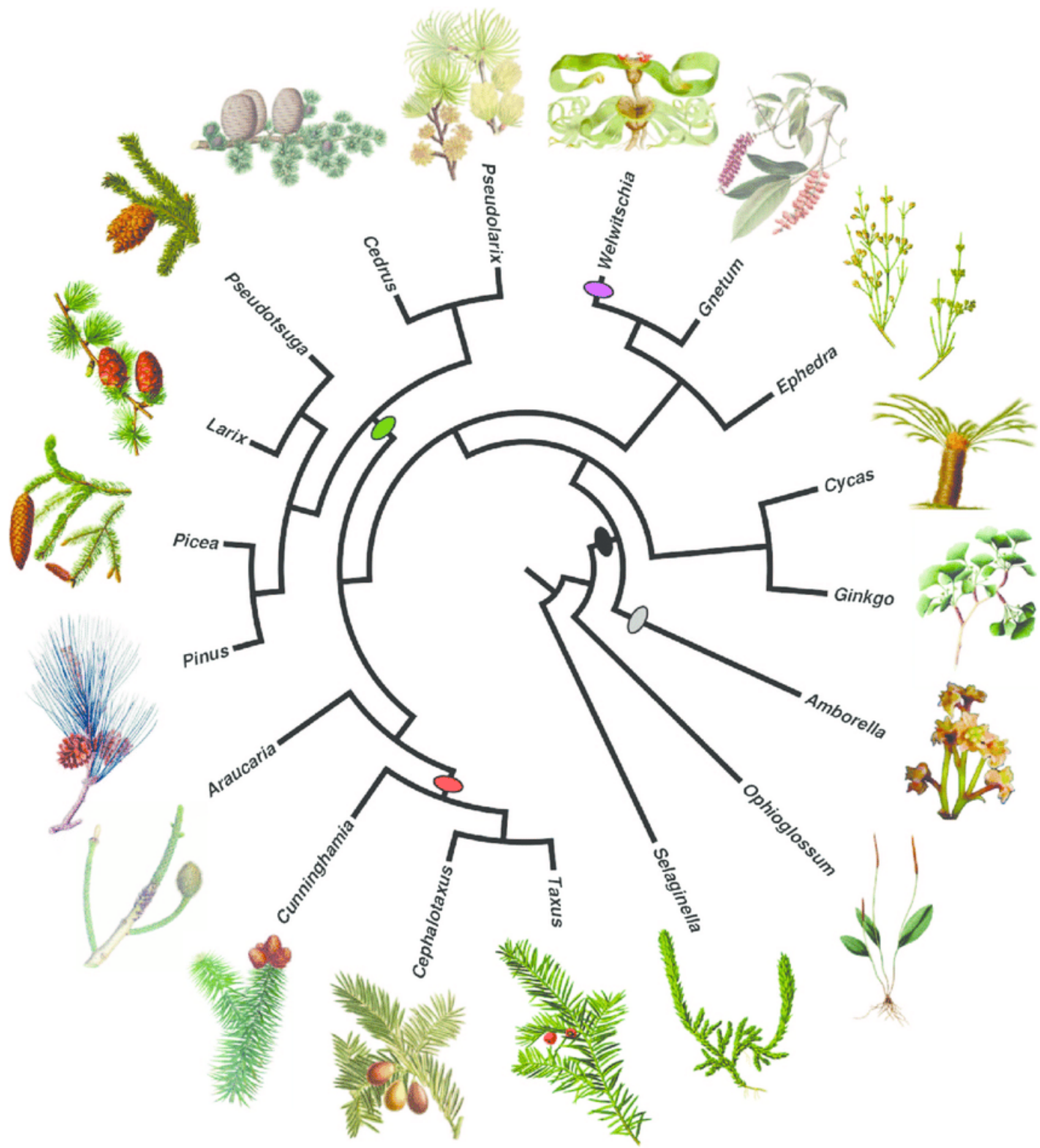
The Scoville scale is a taste detection based method for rating the heat of chilli peppers. A measured amount of pepper extract has sugar added to it incrementally until the heat is undetectable through taste. Though it is an imprecise method, it has been estimated that 1 unit corresponds to 18μM.


Sugar beet
Tomato
Potato
Monkey Flower
Grape
Dwarf Birch
Cucumber
Melon
Water Melon
Peach
Mei/Chinese Plum
Strawberry
Pear
Apple
Cannabis
Medicago
Chickpea
Lotus japonicus
Soybean
Common Bean
Pigeon Pea
Flax
Cassava
Rubber Tree
Jatropha
Castor Bean
Poplar
Cotton
Chocolate
Papaya
Cleome
Arabidopsis l.
Arabidopsis t.
Capsella rubella
Thellungiella s.
Thellungiella h.
Thellungiella p.
Brassica rapa
Orange
Rose Gum Tree
Columbine
Date Palm
Banana
Maize
Sorghum
Foxtail Millet
Tef
Moso Bamboo
Brachypodium
Wheat
Barley
Rice
Amborella
Selaginella
Physcomitrella
Clamydomonas
Asterids
Legumes
Malpighiales
Crucifers
Grasses
Eurosids I
Eurosids II
Rosids
Monocots
Flowering Plants
Vascular Plants
Land Plants
Green Plants
α
β
γ
ρ
σ
τ
117 m.a.
¿350 m.a? (Vision et al. 2000; Bowers et al. 2003).
Tetraploidy (genome doubling)
Hexaploidy (genome tripling)
Polyploidy (details unclear)
Published Genome
Unpublished Genome

Early genome duplications in conifers and other seed plants

Zheng Li,[1] Anthony E. Baniaga,[1] Emily B. Sessa,[2] Moira Scascitelli,[3] Sean W. Graham,[3]
Loren H. Rieseberg,[3,4] Michael S. Barker[1]*

Li *et al.* Sci. Adv. 2015;1:e1501084 20 November 2015



Large-Scale Gene Relocations following an Ancient Genome Triplication Associated with the Diversification of Core Eudicots

Citation: Wang Y, Ficklin SP, Wang X, Feltus FA, Paterson AH (2016) Large-Scale Gene Relocations following an Ancient Genome Triplication Associated with the Diversification of Core Eudicots. PLoS ONE 11(5): e0155637. doi:10.1371/journal.pone.0155637

Yupeng Wang[1], Stephen P. Ficklin[2], Xiyin Wang[1], F. Alex Feltus[3], Andrew H. Paterson[1]*

- **Eudicotas basales**:
  - Buxales
  - Proteales
  - Ranunculales
  - Trochodendrales

- **Eudicotas centrales**:
  - Clados
    - Superasterids
    - Superrosids
  - Órdenes
    - Berberidopsidales
    - Caryophyllales
    - Dilleniales
    - Gunnerales
    - Santalales
    - Saxifragales

La mayoría de los paleopoliploides son consecuencia de duplicaciones, excepto algunos que conservan **triplicaciones e incluso quintuplicaciones**:

A genome triplication associated with early diversification of the core eudicots

Yuannian Jiao[1,2], Jim Leebens-Mack[3], Saravanaraj Ayyampalayam[3], John E Bowers[3], Michael R McKain[3], Joel McNeal[3,4], Megan Rolf[5], Daniel R Ruzicka[5], Eric Wafula[2], Norman J Wickett[2,6], Xiaolei Wu[7], Yong Zhang[7], Jun Wang[7,8], Yeting Zhang[2,9], Eric J Carpenter[10], Michael K Deyholos[10], Toni M Kutchan[5], Andre S Chanderbali[11,12], Pamela S Soltis[11], Dennis W Stevenson[13], Richard McCombie[14], J Chris Pires[15], Gane Ka-Shu Wong[7,16], Douglas E Soltis[12] and Claude W dePamphilis[1,2*]

Jiao *et al. Genome Biology* 2012, **13**:R3
http://genomebiology.com/2012/13/1/R3

Received 23 Oct 2013 | Accepted 22 Apr 2014 | Published 23 May 2014 DOI: 10.1038/ncomms4930 OPEN

nature COMMUNICATIONS

The *Brassica oleracea* genome reveals the asymmetrical evolution of polyploid genomes

doi:10.1038/nature11119

The tomato genome sequence provides insights into fleshy fruit evolution

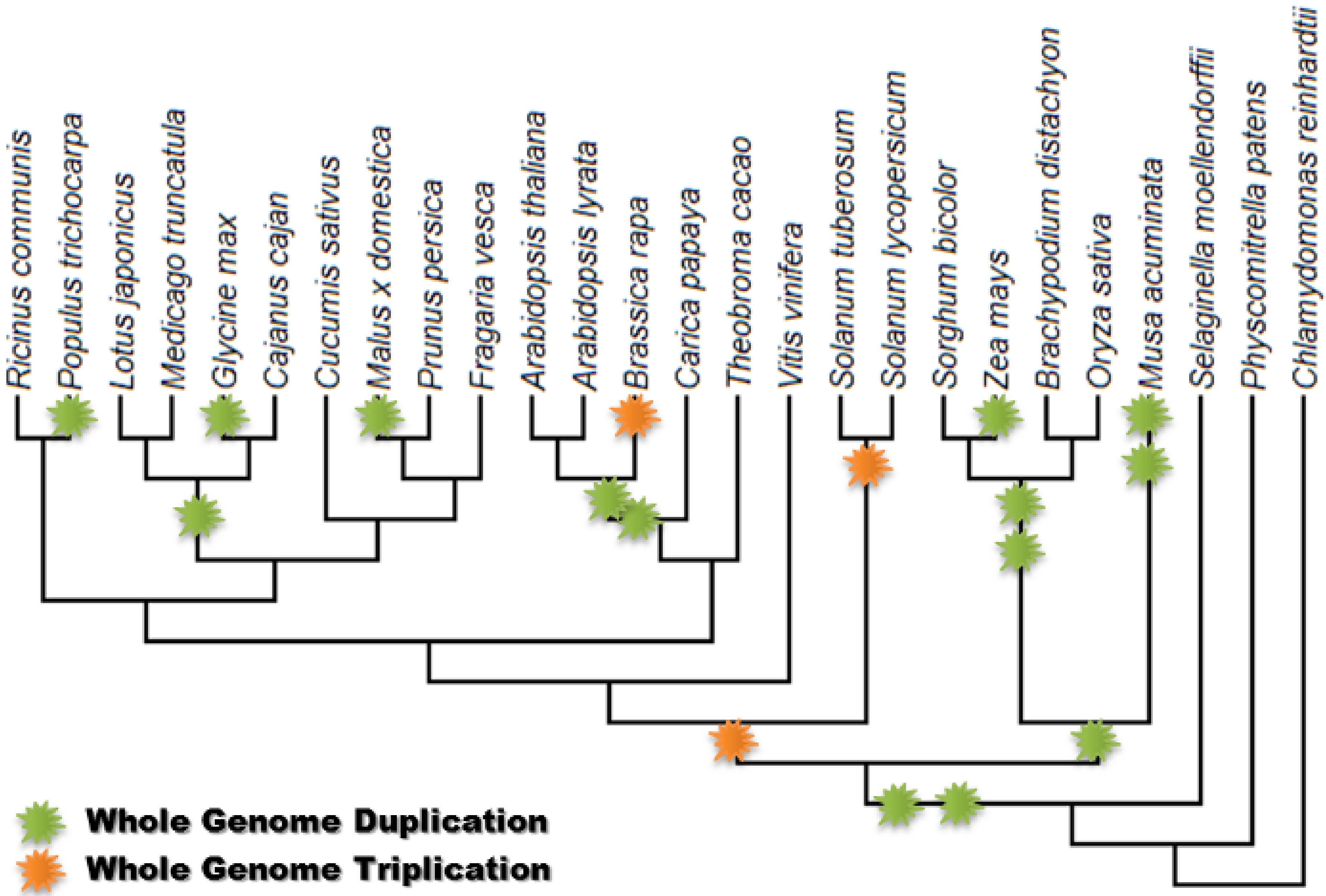
31 MAY 2012 | VOL 485 | NATURE | 635

The Tomato Genome Consortium*

Comparative genomic de-convolution of the cotton genome revealed a decaploid ancestor and widespread chromosomal fractionation

New Phytologist (2016) **209:** 1252–1263
doi: 10.1111/nph.13689

Xiyin Wang[1,2,3], Hui Guo[1,4], Jinpeng Wang[2,3], Tianyu Lei[2,5], Tao Liu[2,5], Zhenyi Wang[2,3], Yuxian Li[2,3], Tae-Ho Lee[1], Jingping Li[1], Haibao Tang[6,7,8], Dianchuan Jin[2,5] and Andrew H. Paterson[1,4]



http://chibba.pgml.uga.edu/duplication/index/home

POLIPLOIDÍA EN MEJORA GENÉTICA

- Gran parte de las **plantas cultivadas son poliploides** (alfalfa, algodón, patata, café, fresas, trigo, etc…).

- En algunos casos, se observa una correlación entre la poliploidía y el **proceso de domesticación**.

- Hay poliploides **naturales e inducidos** (colchicina).

POLIPLOIDÍA EN MEJORA GENÉTICA

Mejora de plantas **autógamas**

[Selección de **caracteres de interés**]

Mejora de plantas **alógamas**

[Obtención de **híbridos**]

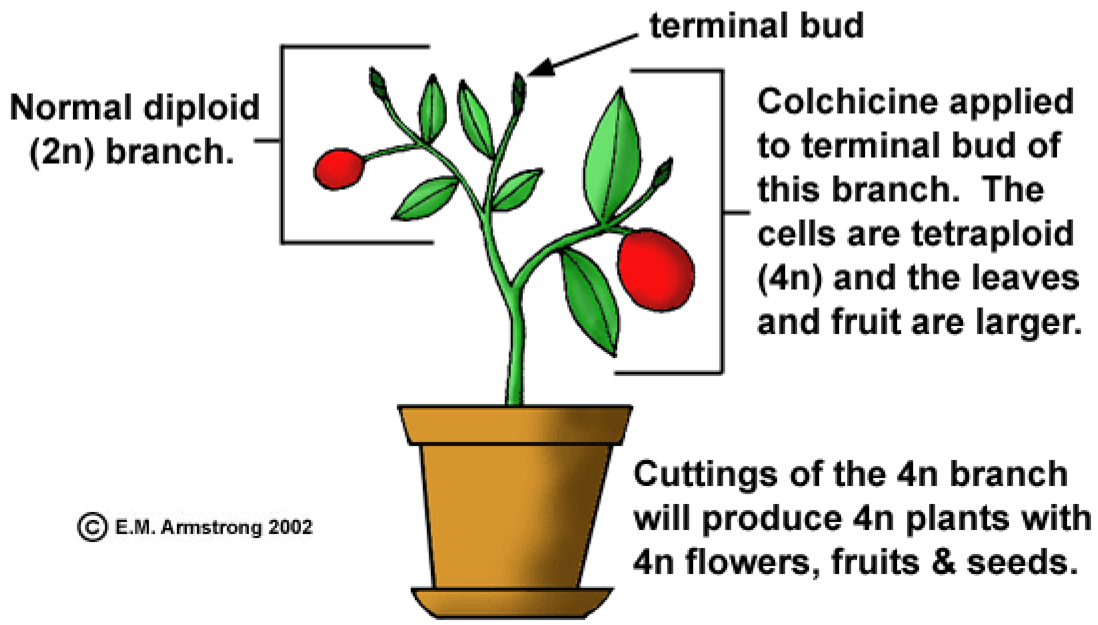
POLIPLOIDÍA EN MEJORA GENÉTICA

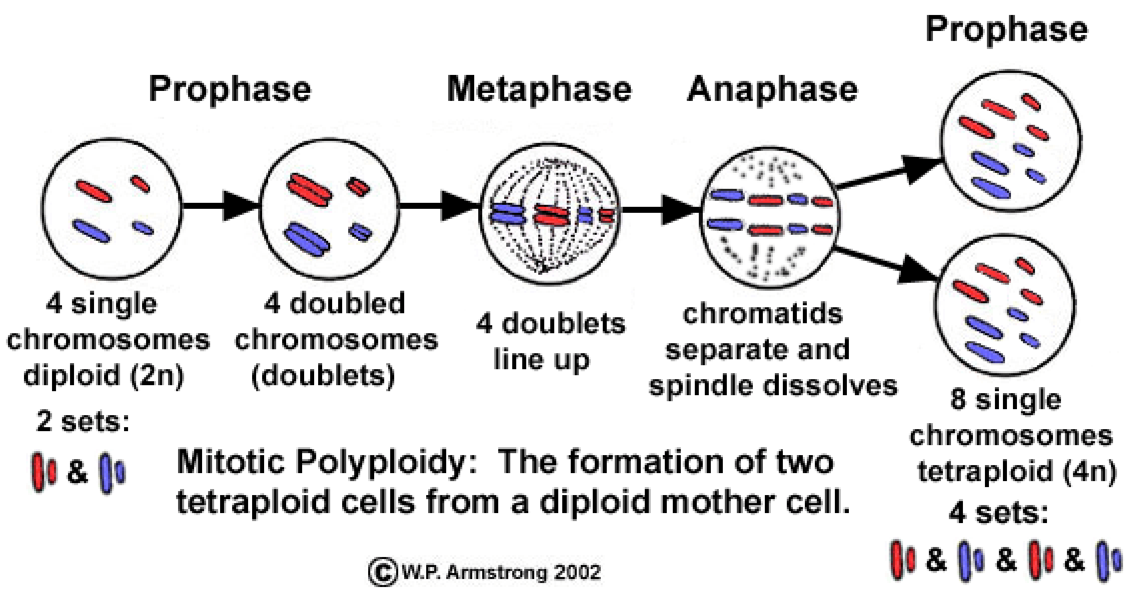
- La poliploidía podría dar lugar a nuevos **rasgos con interés productivo** (fenotipo gigas).

- Se puede usar (o no) para recuperar la **fertilidad de híbridos**.

- Como vector para la **transferencia de genes** de unas especies/variedades a otras.

Heterosis o vigor híbrido





POLIPLOIDÍA EN MEJORA GENÉTICA

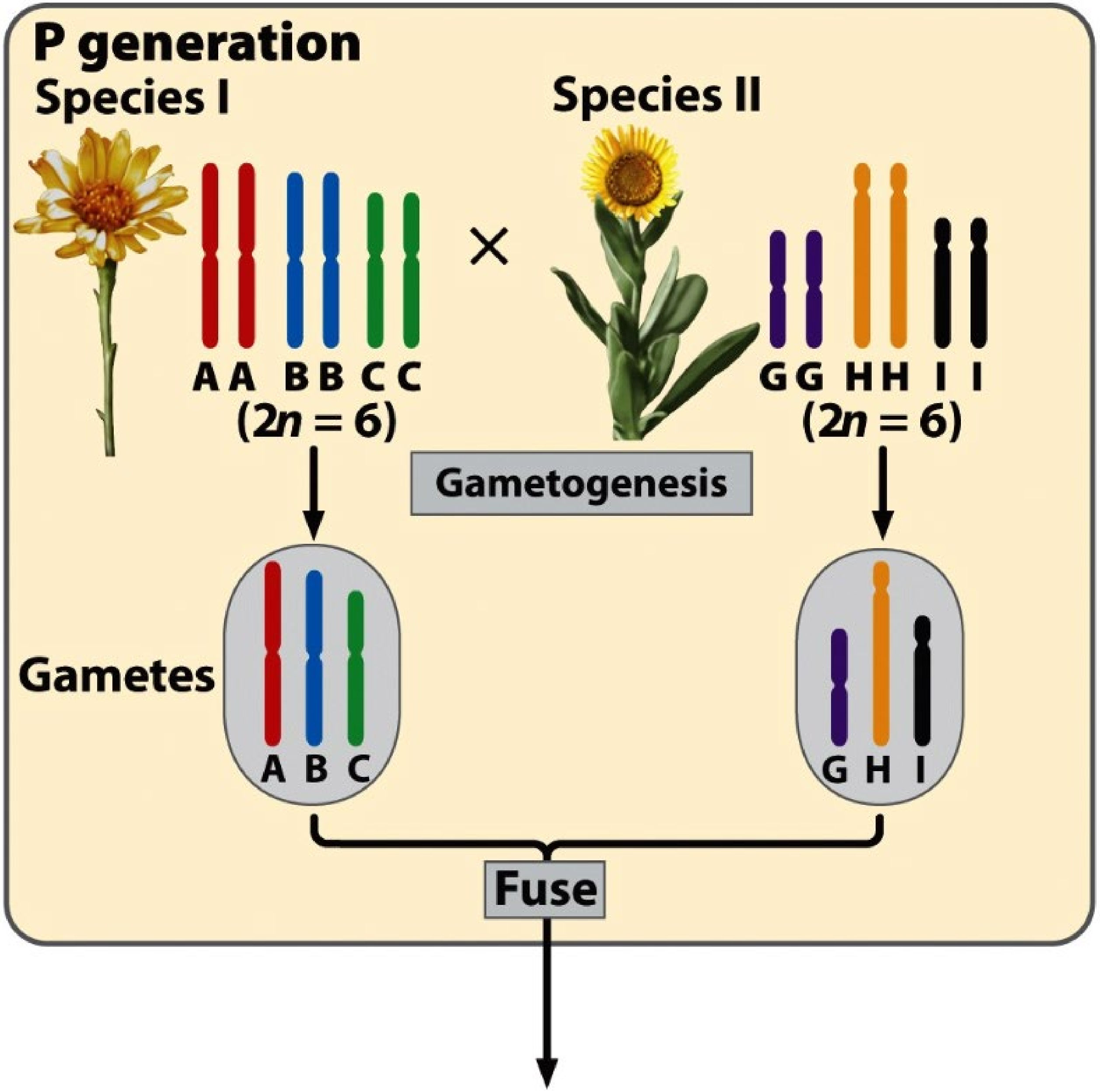


Figure 9-28 part 1
Genetics: A Conceptual Approach, Third Edition

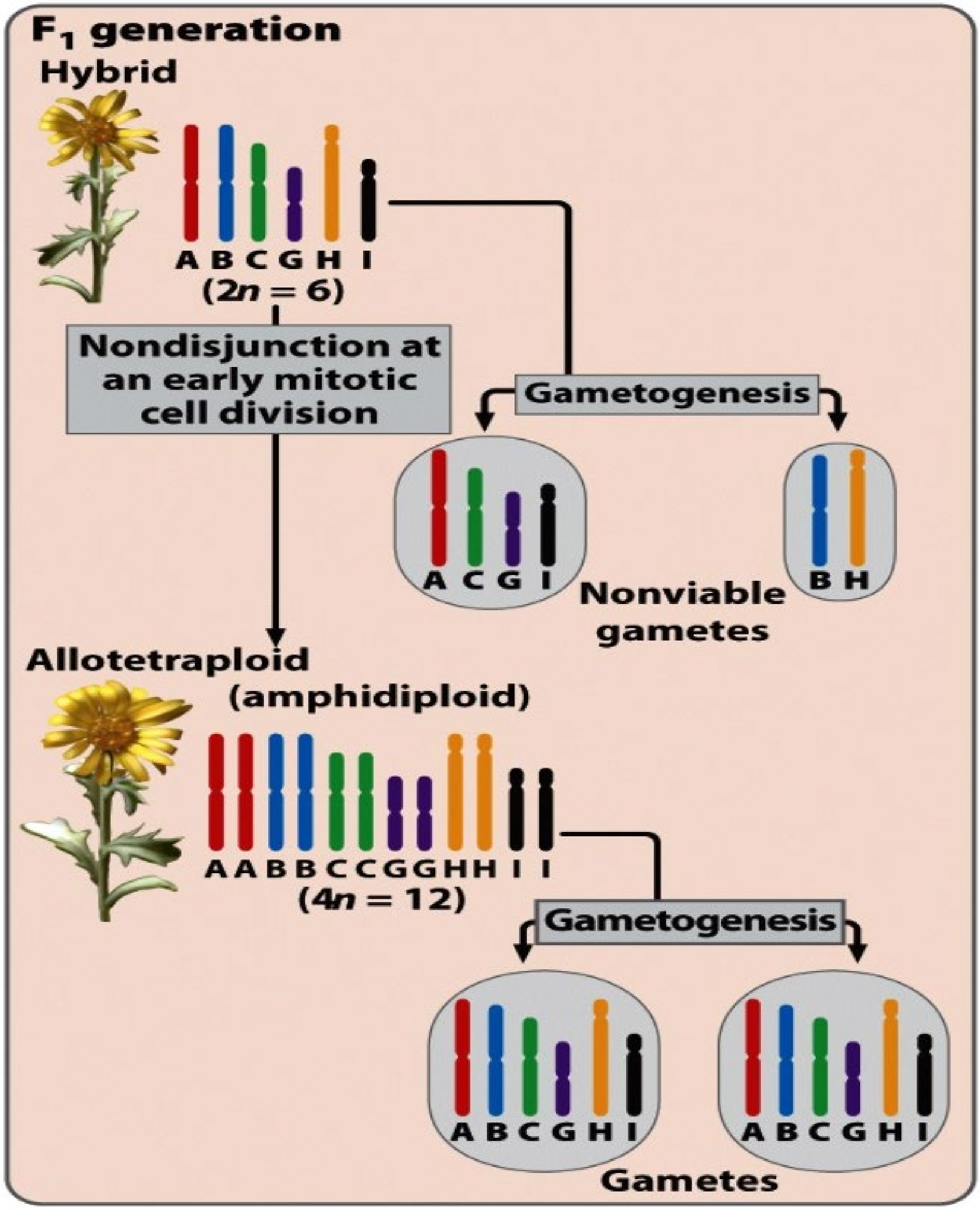
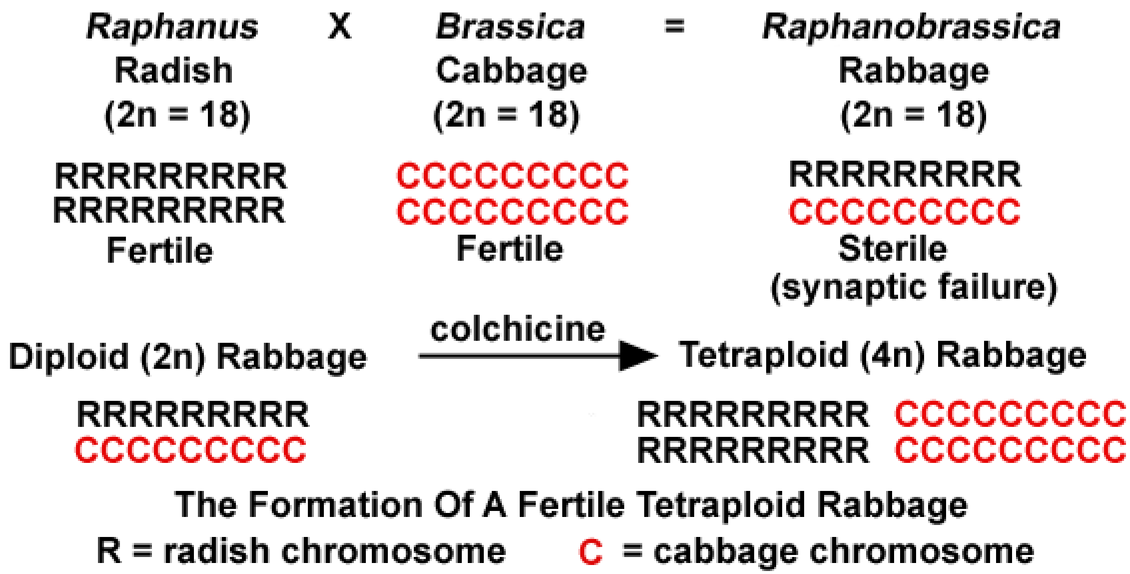
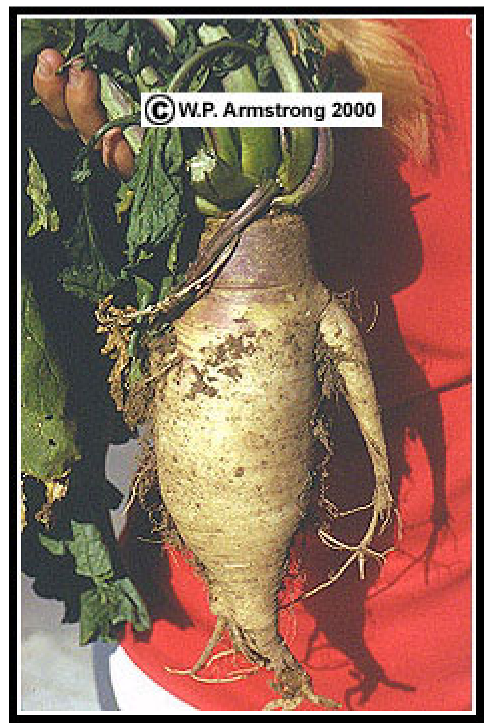


Figure 9-28 part 2

Genetics: A Conceptual Approach, Third Edition



(Rábano x Col) + Poliploidización

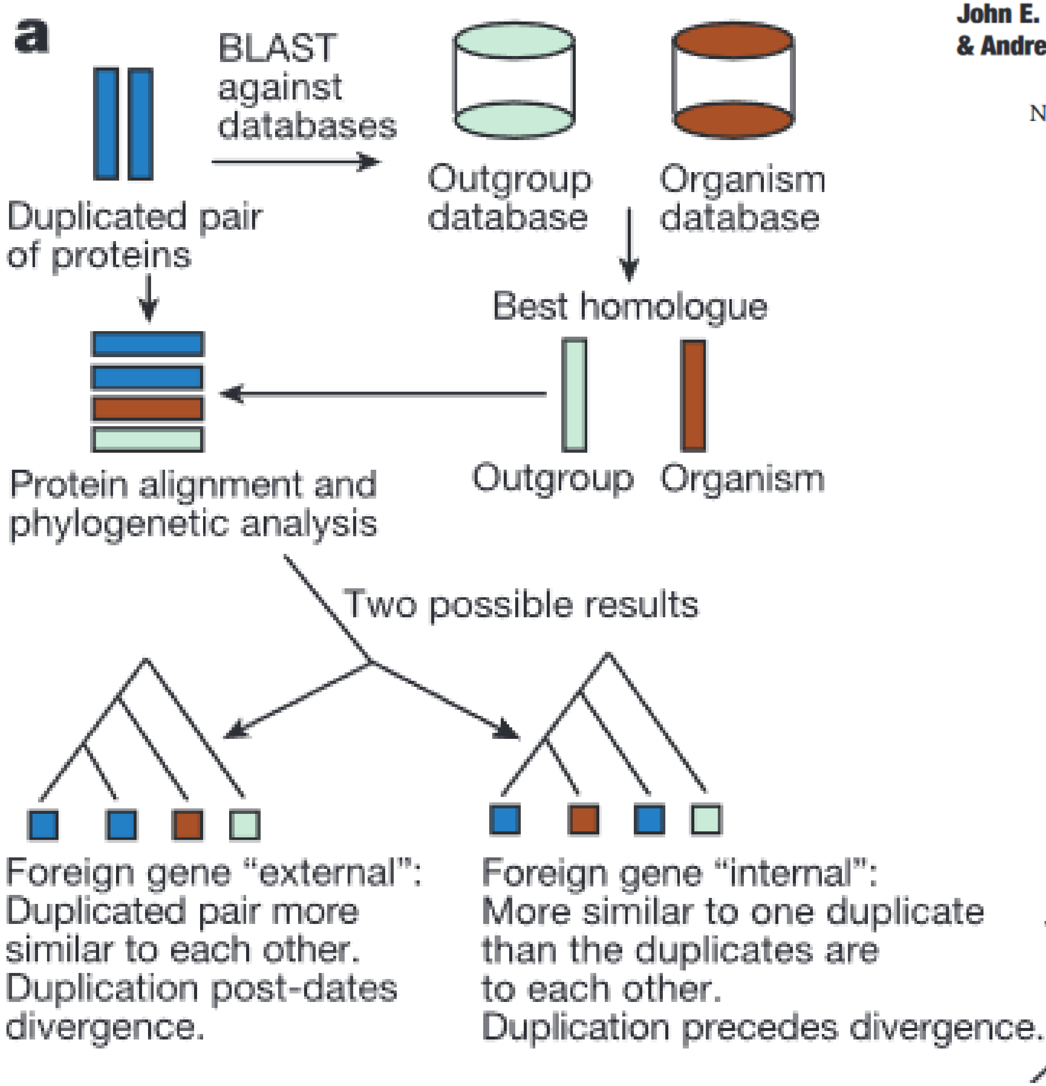


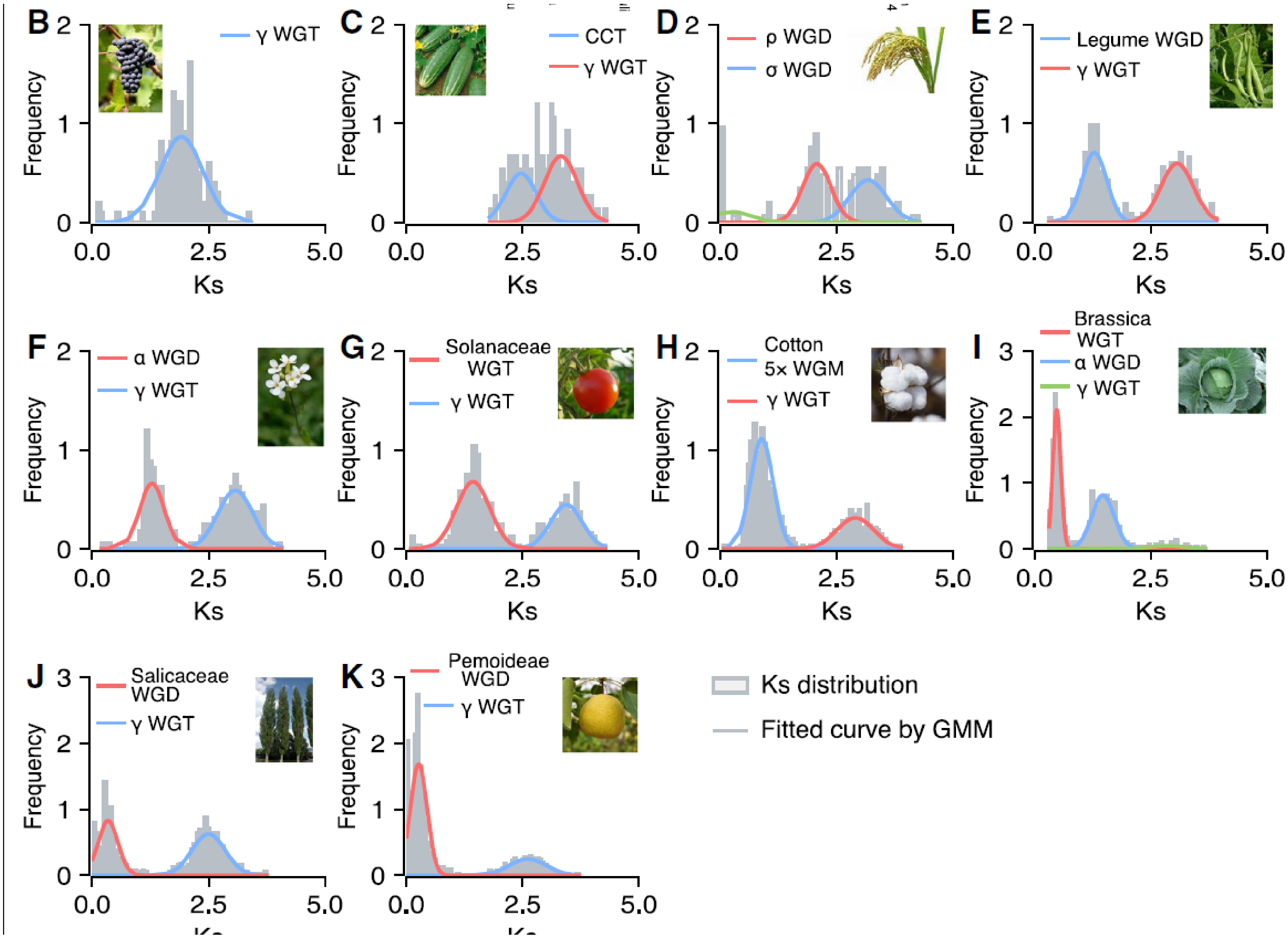
Raphanus sativus

Unravelling angiosperm genome evolution by phylogenetic analysis of chromosomal duplication events

John E. Bowers*, Brad A. Chapman*, Junkang Rong & Andrew H. Paterson

NATURE | VOL 422 | 27 MARCH 2003 | www.nature.com/nature



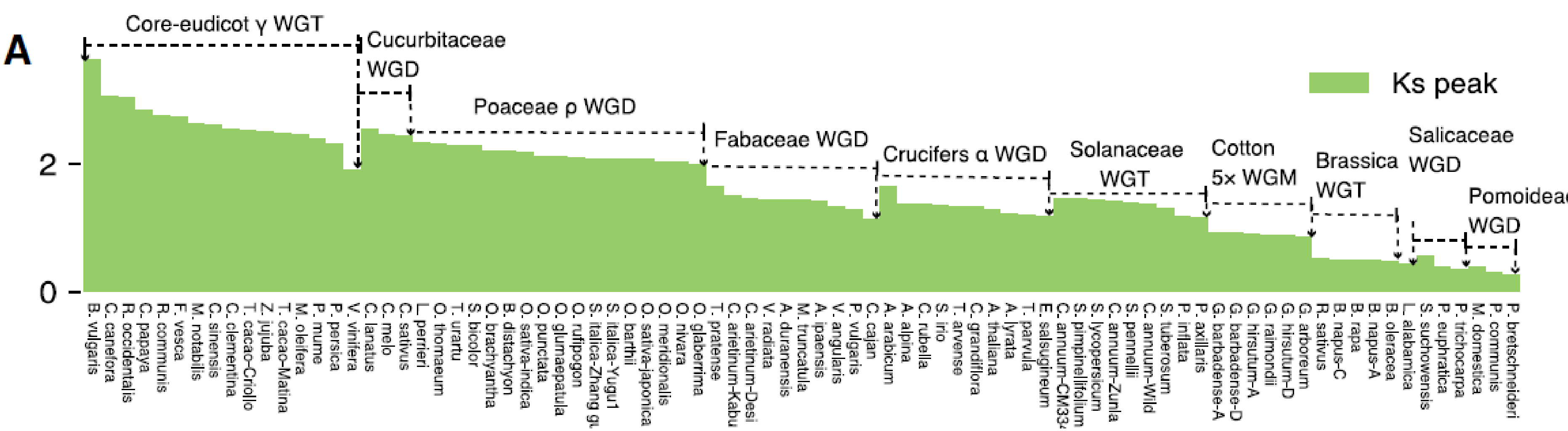

B
γ WGT
C
CCT
γ WGT
D
ρ WGD
σ WGD
E
Legume WGD
γ WGT
F
α WGD
γ WGT
G
Solanaceae WGT
γ WGT
H
Cotton 5× WGM
γ WGT
I
Brassica WGT
α WGD
γ WGT
J
Salicaceae WGD
γ WGT
K
Pemoideae WGD
γ WGT
Frequency
Ks
Ks distribution
Fitted curve by GMM

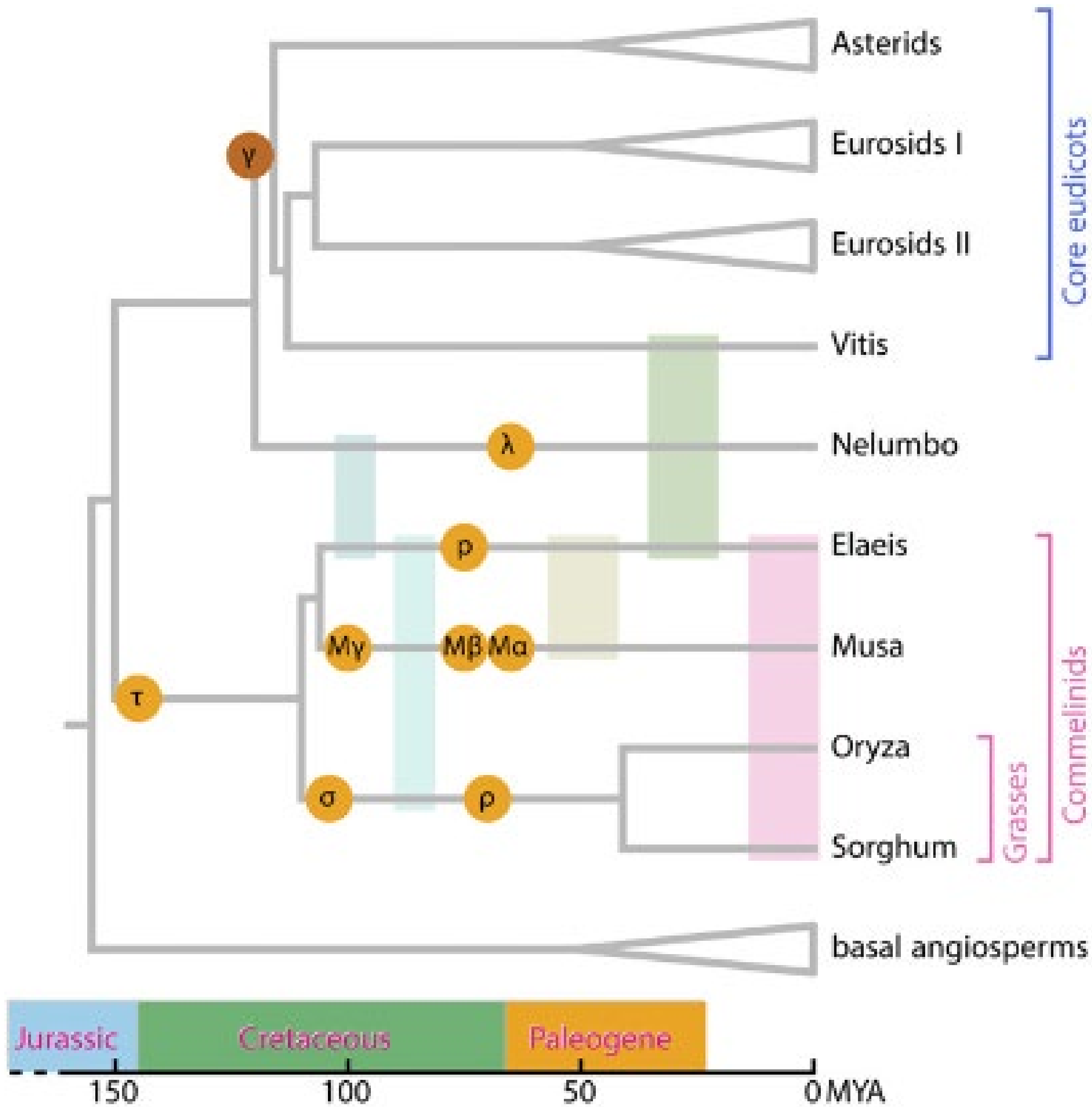
RESEARCH Open Access

Gene duplication and evolution in recurring polyploidization–diploidization cycles in plants

Xin Qiao[1], Qionghou Li[1], Hao Yin[1], Kaijie Qi[1], Leiting Li[1], Runze Wang[1], Shaoling Zhang[1*]
and Andrew H. Paterson[2*]

Qiao et al. Genome Biology (2019) 20:38
https://doi.org/10.1186/s13059-019-1650-2





Asterids
Eurosids I
Eurosids II
Vitis
Nelumbo
Elaeis
Musa
Oryza
Sorghum
basal angiosperms
Core eudicots
Commelinids
Grasses
γ
λ
ρ
Mγ
Mβ
Mα
τ
σ
ρ
Jurassic
Cretaceous
Paleogene
150
100
50
0 MYA

The transcriptional landscape of polyploid wheat

R. H. Ramírez-González[1,*], P. Borrill[1,*,†], D. Lang[2], S. A. Harrington[1], J. Brinton[1], L. Venturini[3], M. Davey[4], J. Jacobs[4], F. van...

+ See all authors and affiliations

Science 17 Aug 2018:
Vol. 361, Issue 6403, eaar6089
DOI: 10.1126/science.aar6089

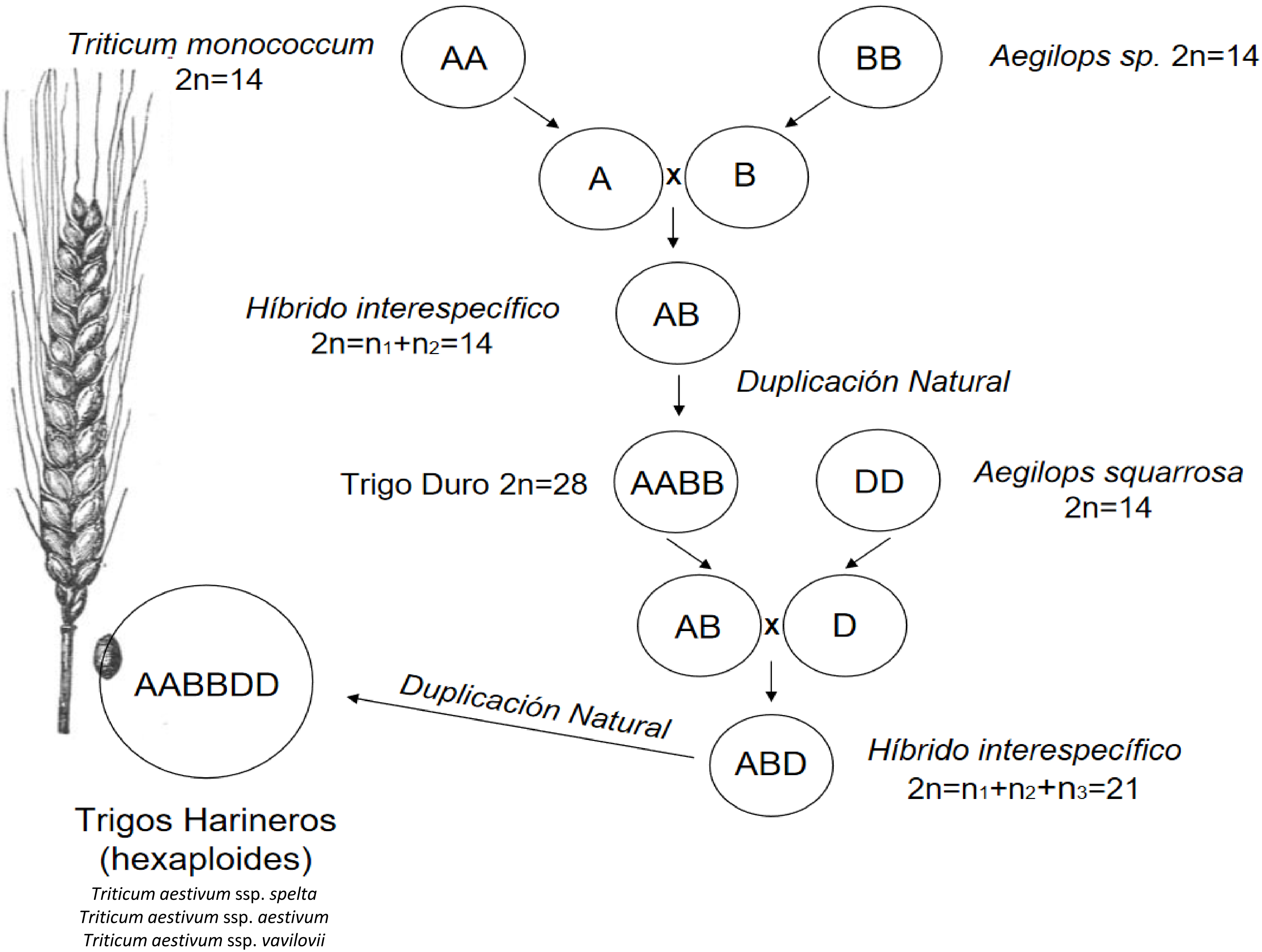

Triticum monococcum
2n=14
AA
BB
Aegilops sp. 2n=14
A
x
B
Híbrido interespecífico
$2n=n_1+n_2=14$
AB
Duplicación Natural
Trigo Duro 2n=28
AABB
DD
Aegilops squarrosa
2n=14
AB
x
D
AABBDD
Duplicación Natural
ABD
Híbrido interespecífico
$2n=n_1+n_2+n_3=21$
Trigos Harineros
(hexaploides)
Triticum aestivum ssp. *spelta*
Triticum aestivum ssp. *aestivum*
Triticum aestivum ssp. *vavilovii*

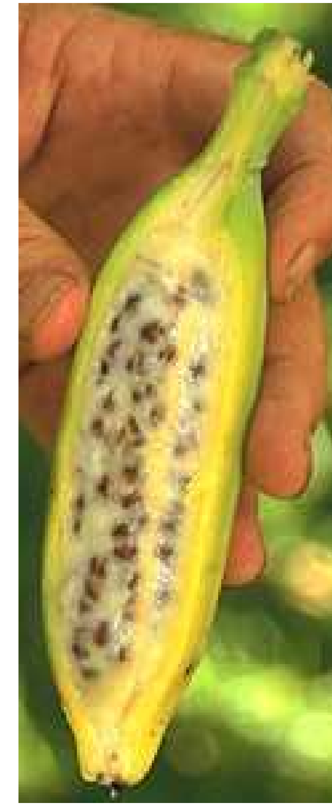
Table 5.1 Economically important polyploids

Taxa	Natural/synthetic	Ploidy auto/allo
Wheat (*Triticum aestivum*)	Synthetic	6X: Allopolyploid
Maize (*Zea mays*)	Synthetic	4X: Autopolyploid
Oats (*Avena sativa*)	Natural	6X: Allopolyploid
Alfalfa (*Medicago sativa*)	Natural	4X: Autopolyploid
Sugarcane (*Saccharum officinale*)	Natural	8X: Autopolyploid
Potato (*Solanum tuberosum*)	Natural	4X: Autopolyploid
Sweet potato (*Ipomoea batatas*)	Natural	6X:Autopolyploid
Banana (*Musa sapientum*)	Natural	2X, 3X: Autopolyploid
Cotton (*Gossypium hirsutum*)	Natural	4X: Allopolyploid
Tobacco (*Nicotiana tabacum*)	Natural	4X: Allopolyploid
Coffee (*Coffea arabica*)	Natural	4X: Allopolyploid
Apple (*Malus domestica*)	Natural	2X, 3X: Allopolyploid
Pear (*Pyrus communis*)	Natural	2X, 3X: Allopolyploid
Strawberry (*Fragaria cascadensis*)	Synthetic	10X: Allopolyploid
Peanut (*Arachis hypogaea*)	Natural	4X: Allopolyploid
Watermelon (*Citrullus lanatus*)	Synthetic	3X: Autopolyploid
Plum (*Prunus domestica*)	Natural	6X: Allotetraploid
Rapeseed (*Brassica napus*)	Synthetic	4X: Allotetraploid
Soybean (*Glycine max*)	Natural	4X: Allopolyploid
Lime (*Citrus aurantifolia*)	Natural	3X: Allopolyploid

Effect of paleopolyploidy and allopolyploidy on gene expression in banana

Alberto Cenci[1*], Yann Hueber[1], Yasmin Zorrilla-Fontanesi[2], Jelle van Wesemael[2], Ewaut Kissel[2], Marie Gislard[3], Julie Sardos[1], Rony Swennen[2,4,5], Nicolas Roux[1], Sebastien Christian Carpentier[2,4] and Mathieu Rouard[1*]

Cenci *et al. BMC Genomics* (2019) 20:244
https://doi.org/10.1186/s12864-019-5618-0



AAA: *Musa acuminata*. Cavendish

AAB: *Musa acuminata* and one by *Musa balbisiana*. Silk

ABB: *Musa acuminata* and two by *Musa balbisiana*. Bluggoe subgroup

Table 5.1 Economically important polyploids

Taxa	Natural/synthetic	Ploidy auto/allo
Wheat (*Triticum aestivum*)	Synthetic	6X: Allopolyploid
Maize (*Zea mays*)	Synthetic	4X: Autopolyploid
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Sugarcane (*Saccharum officinale*)	Natural	8X: Autopolyploid
Potato (*Solanum tuberosum*)	Natural	4X: Autopolyploid
Sweet potato (*Ipomoea batatas*)	Natural	6X:Autopolyploid
Banana (*Musa sapientum*)	Natural	2X, 3X: Autopolyploid
Cotton (*Gossypium hirsutum*)	Natural	4X: Allopolyploid
Tobacco (*Nicotiana tabacum*)	Natural	4X: Allopolyploid
Coffee (*Coffea arabica*)	Natural	4X: Allopolyploid
Apple (*Malus domestica*)	Natural	2X, 3X: Allopolyploid
Pear (*Pyrus communis*)	Natural	2X, 3X: Allopolyploid
Strawberry (*Fragaria cascadensis*)	Synthetic	10X: Allopolyploid
Peanut (*Arachis hypogaea*)	Natural	4X: Allopolyploid
Watermelon (*Citrullus lanatus*)	Synthetic	3X: Autopolyploid
Plum (*Prunus domestica*)	Natural	6X: Allotetraploid
Rapeseed (*Brassica napus*)	Synthetic	4X: Allotetraploid
Soybean (*Glycine max*)	Natural	4X: Allopolyploid
Lime (*Citrus aurantifolia*)	Natural	3X: Allopolyploid

The genome of the pear (*Pyrus bretschneideri* Rehd.)

Jun Wu,[1,11] Zhiwen Wang,[2,11] Zebin Shi,[3,11] Shu Zhang,[2,11] Ray Ming,[4,11] Shilin Zhu,[2,11] M. Awais Khan,[5] Shutian Tao,[1] Schuyler S. Korban,[5] Hao Wang,[6] Nancy J. Chen,[7] Takeshi Nishio,[8] Xun Xu,[2] Lin Cong,[2] Kaijie Qi,[1] Xiaosan Huang,[1] Yingtao Wang,[1] Xiang Zhao,[2] Juyou Wu,[1] Cao Deng,[2] Caiyun Gou,[2] Weili Zhou,[2] Hao Yin,[1] Gaihua Qin,[1] Yuhui Sha,[2] Ye Tao,[2] Hui Chen,[1] Yanan Yang,[1] Yue Song,[1] Dongliang Zhan,[2] Juan Wang,[2] Leiting Li,[1,4] Meisong Dai,[3] Chao Gu,[1] Yuezhi Wang,[3] Daihu Shi,[2] Xiaowei Wang,[2] Huping Zhang,[1] Liang Zeng,[2] Danman Zheng,[5] Chunlei Wang,[8] Maoshan Chen,[2] Guangbiao Wang,[2] Lin Xie,[2] Valpuri Sovero,[9] Shoufeng Sha,[1] Wenjiang Huang,[1] Shujun Zhang,[3] Mingyue Zhang,[1] Jiangmei Sun,[1] Linlin Xu,[1] Yuan Li,[1] Xing Liu,[1] Qingsong Li,[1] Jiahui Shen,[1] Junyi Wang,[2] Robert E. Paull,[7] Jeffrey L. Bennetzen,[6] Jun Wang,[2,10,12] and Shaoling Zhang[1,12]

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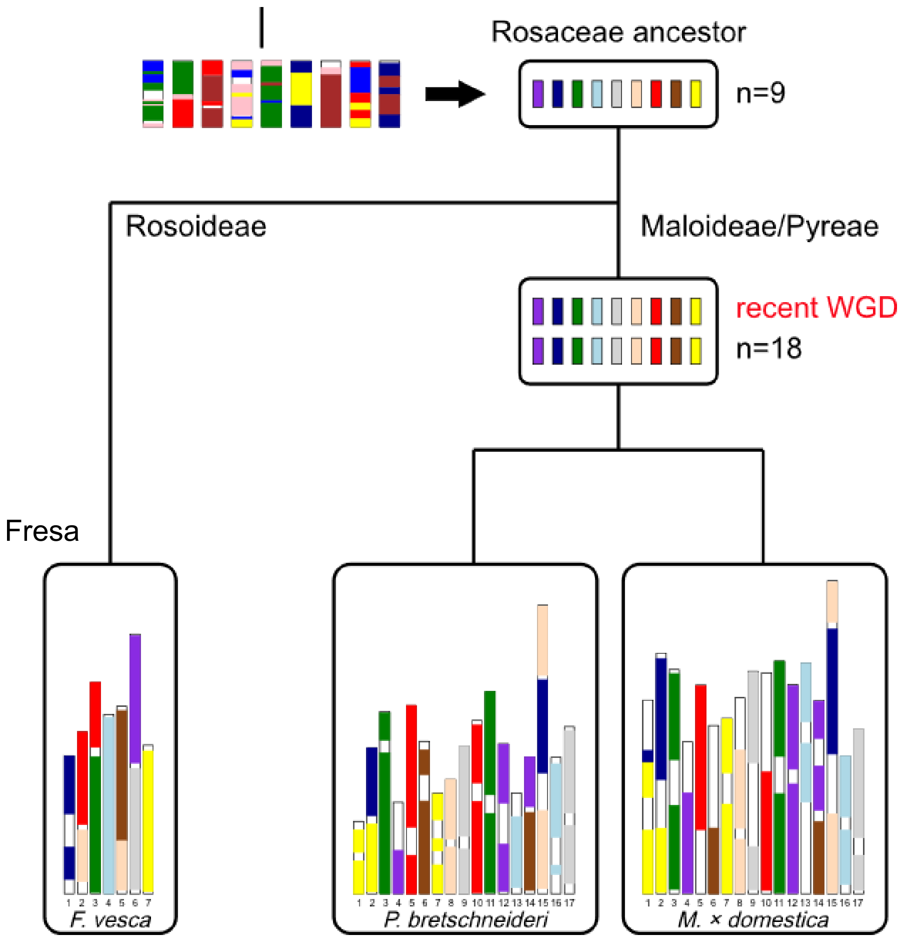
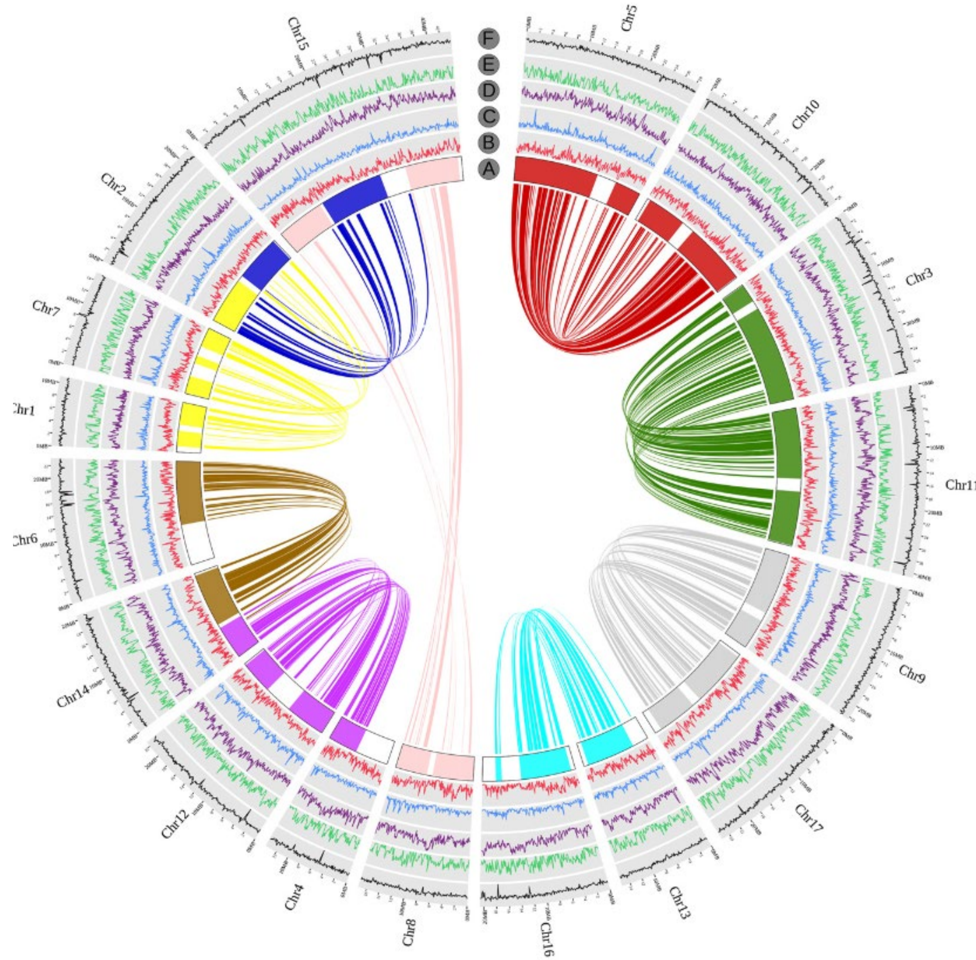




Pera y manzana
comparten una WGD ocurrida hace unos 30-45 m.a.

Table 5.1 Economically important polyploids

Taxa	Natural/synthetic	Ploidy auto/allo
Wheat (*Triticum aestivum*)	Synthetic	6X: Allopolyploid
Maize (*Zea mays*)	Synthetic	4X: Autopolyploid
Oats (*Avena sativa*)	Natural	6X: Allopolyploid
Alfalfa (*Medicago sativa*)	Natural	4X: Autopolyploid
Sugarcane (*Saccharum officinale*)	Natural	8X: Autopolyploid
Potato (*Solanum tuberosum*)	Natural	4X: Autopolyploid
Sweet potato (*Ipomoea batatas*)	Natural	6X:Autopolyploid
Banana (*Musa sapientum*)	Natural	2X, 3X: Autopolyploid
Cotton (*Gossypium hirsutum*)	Natural	4X: Allopolyploid
Tobacco (*Nicotiana tabacum*)	Natural	4X: Allopolyploid
Coffee (*Coffea arabica*)	Natural	4X: Allopolyploid
Apple (*Malus domestica*)	Natural	2X, 3X: Allopolyploid
Pear (*Pyrus communis*)	Natural	2X, 3X: Allopolyploid
Strawberry (*Fragaria cascadensis*)	Synthetic	10X: Allopolyploid
Peanut (*Arachis hypogaea*)	Natural	4X: Allopolyploid
Watermelon (*Citrullus lanatus*)	Synthetic	3X: Autopolyploid
Plum (*Prunus domestica*)	Natural	6X: Allotetraploid
Rapeseed (*Brassica napus*)	Synthetic	4X: Allotetraploid
Soybean (*Glycine max*)	Natural	4X: Allopolyploid
Lime (*Citrus aurantifolia*)	Natural	3X: Allopolyploid

2n=18

Yemas terminales

Inflorescencias

Yemas laterales

Tallos y flores

Tallo

Hojas

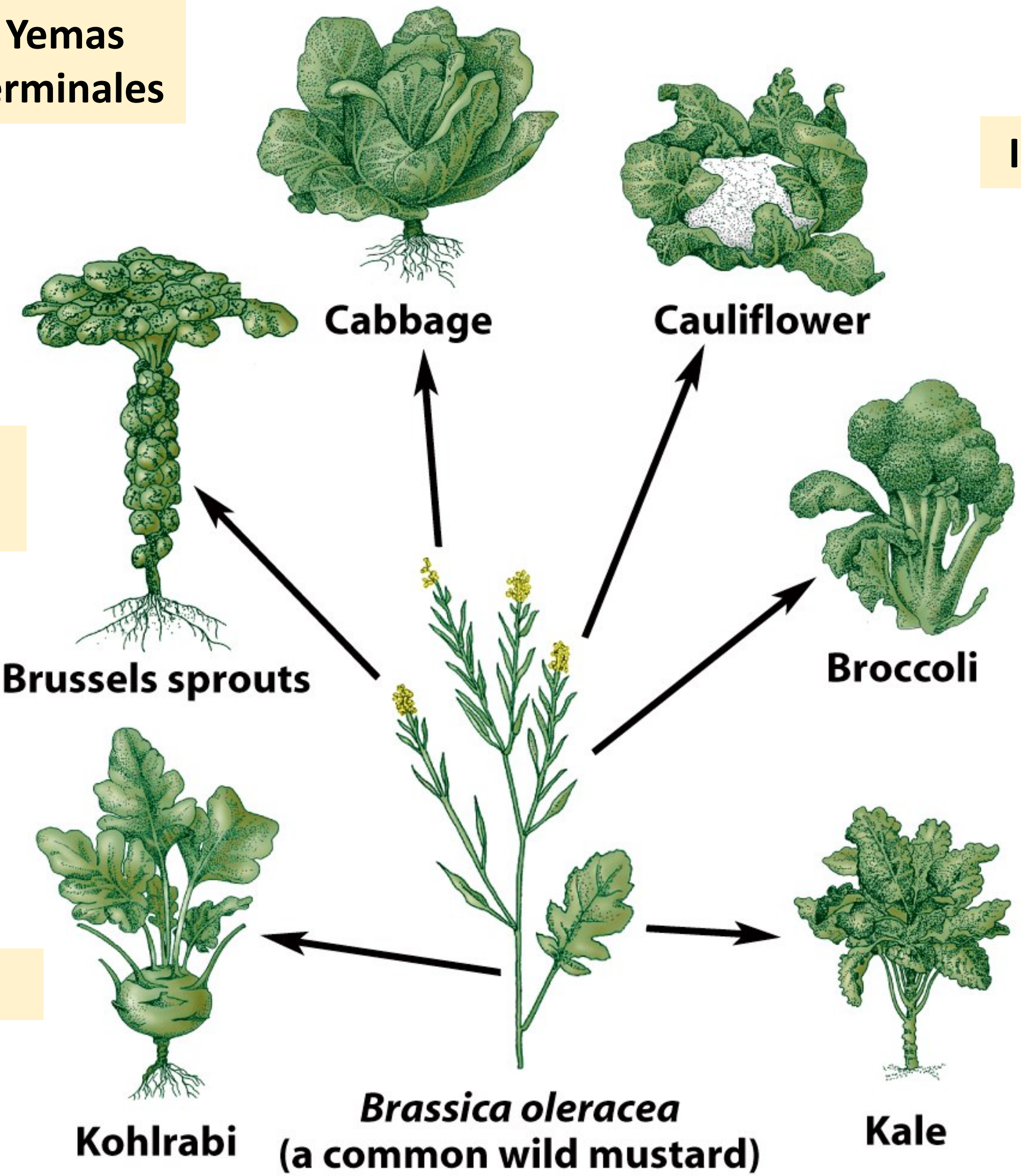
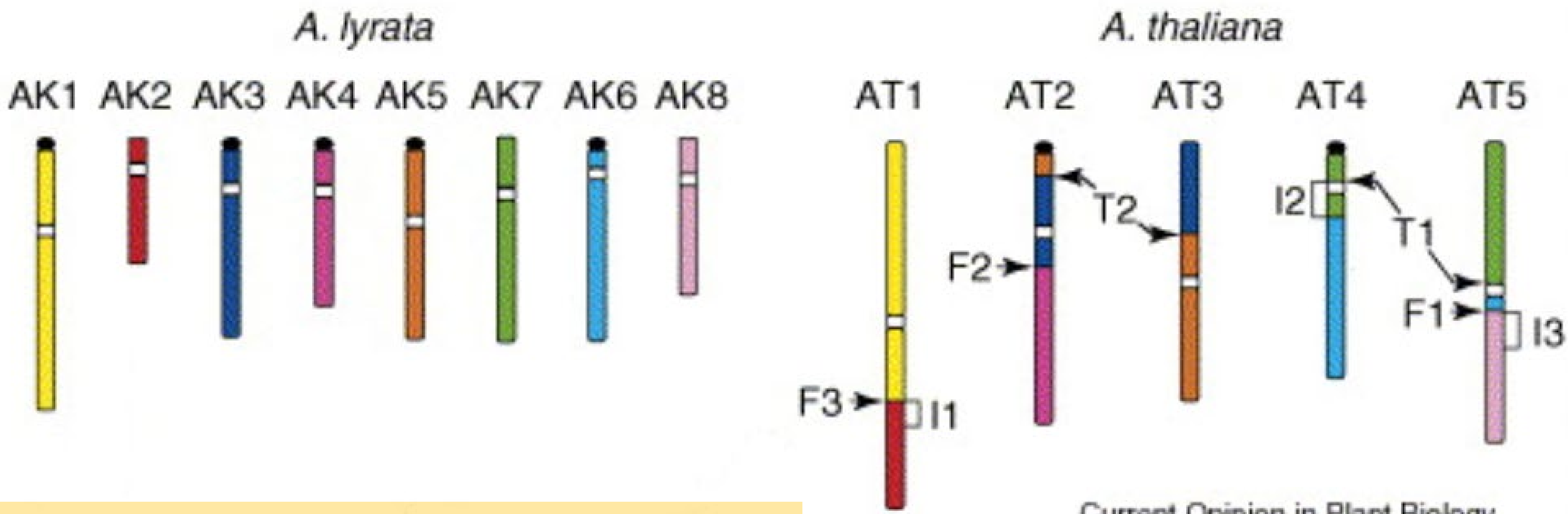
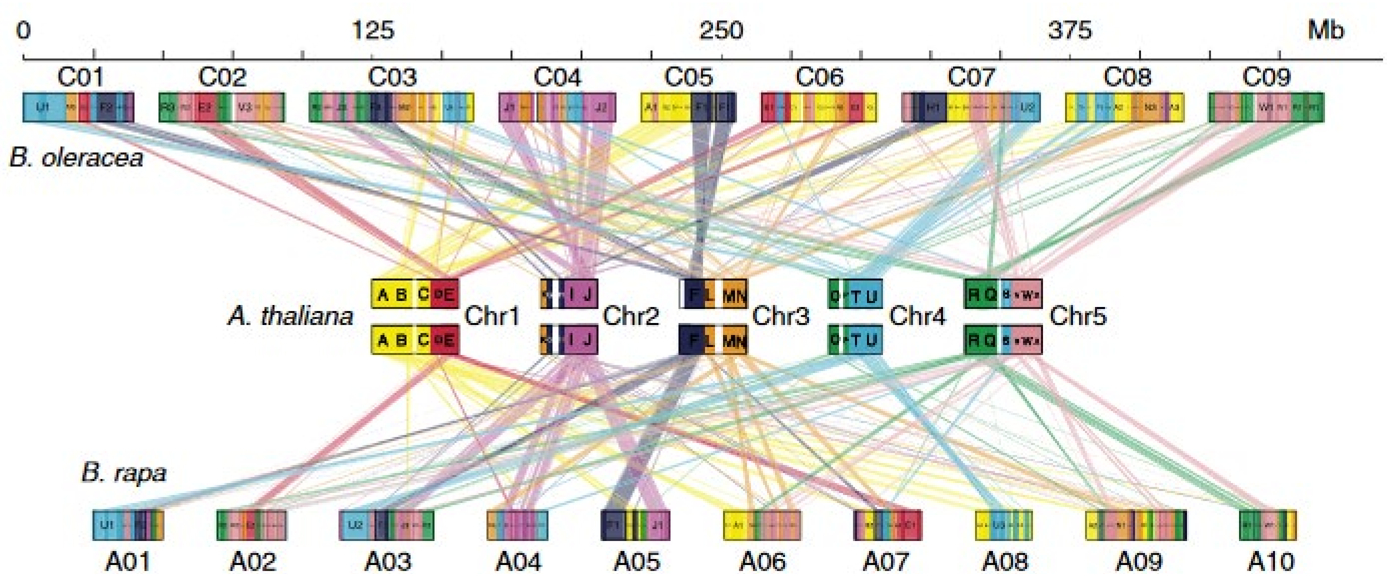


Figure 16-9 Discover Biology 3/e



Current Opinion in Plant Biology

Brassica napus multiplicación 72× (3×2×2×3×2) (Hace entre >100 m.a. a ~10,000 a.)



nature COMMUNICATIONS

Alopoliploidía

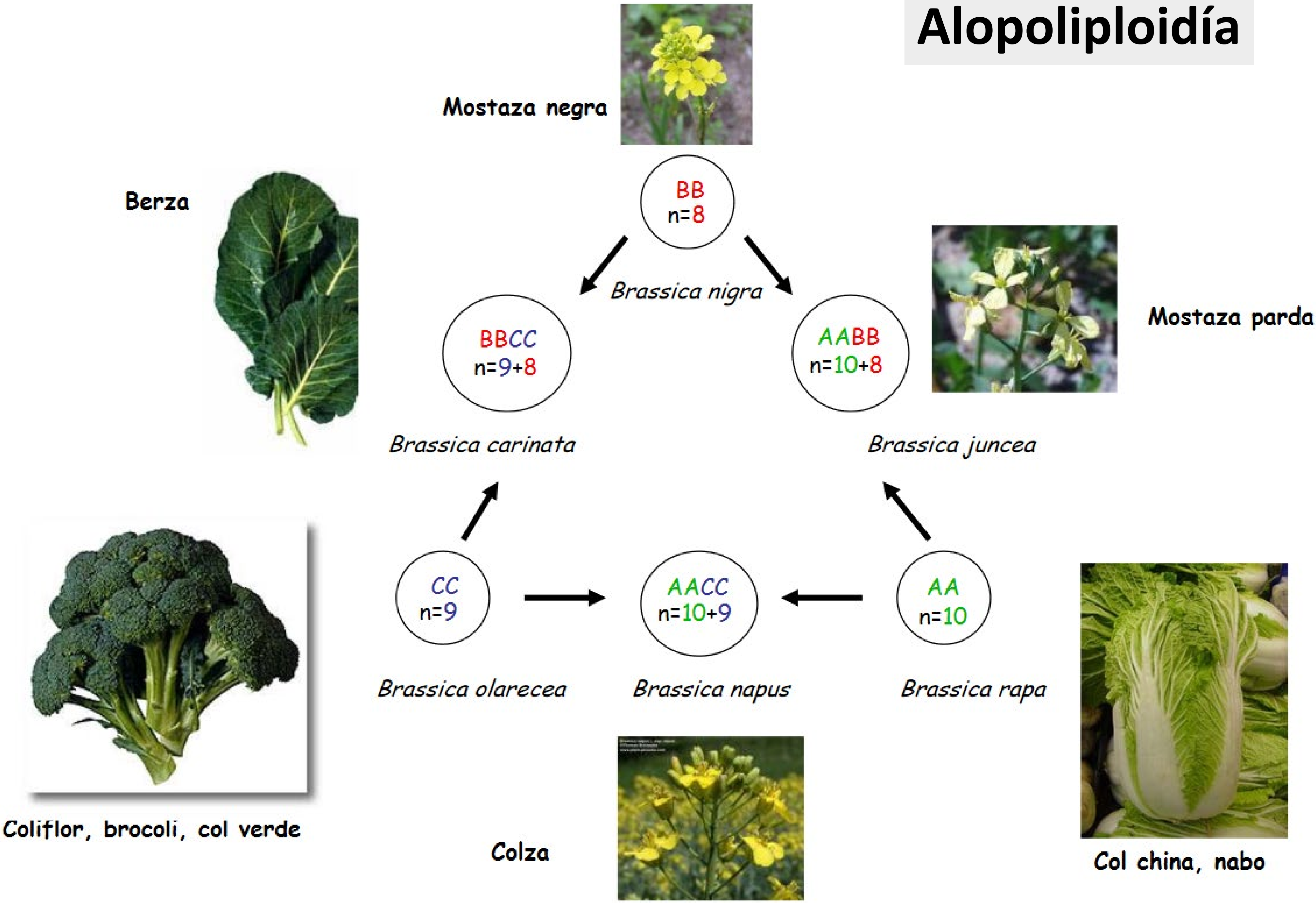


Table 5.1 Economically important polyploids

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Soybean (*Glycine max*)	Natural	4X: Allopolyploid
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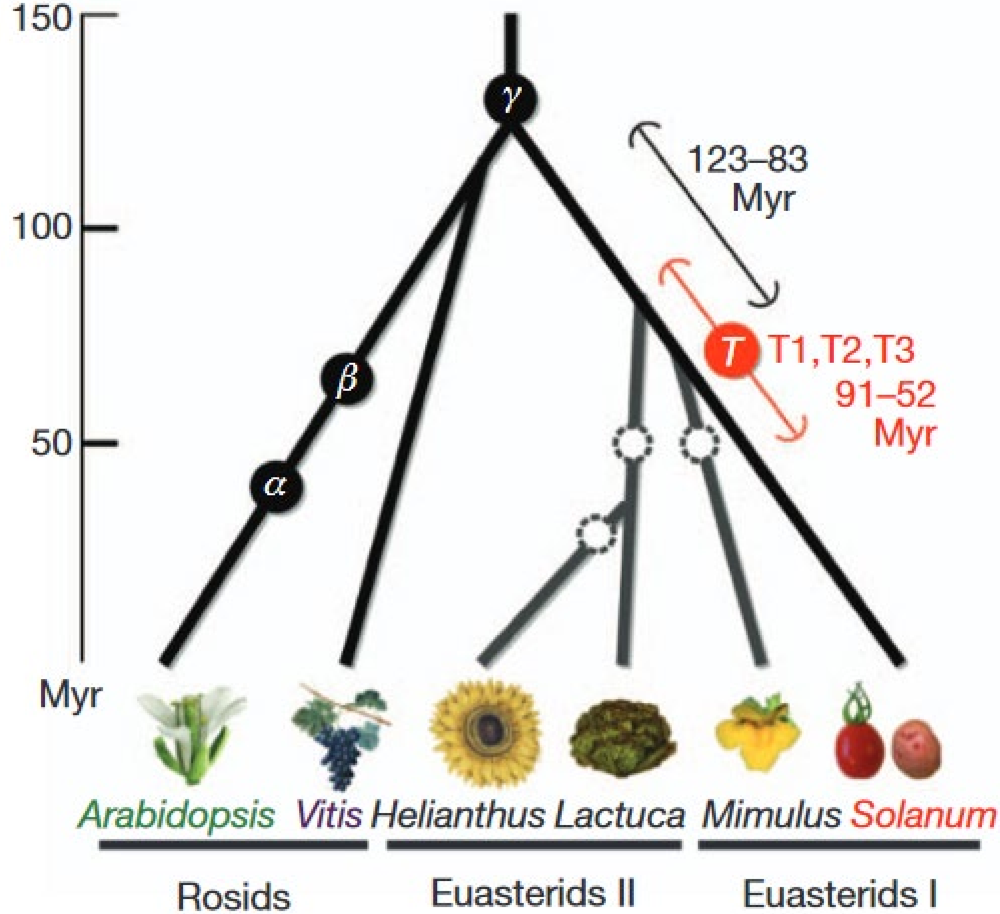

150
100
50
Myr
γ
β
α
123–83
Myr
T
T1,T2,T3
91–52
Myr
Arabidopsis
Vitis
Helianthus
Lactuca
Mimulus
Solanum
Rosids
Euasterids II
Euasterids I