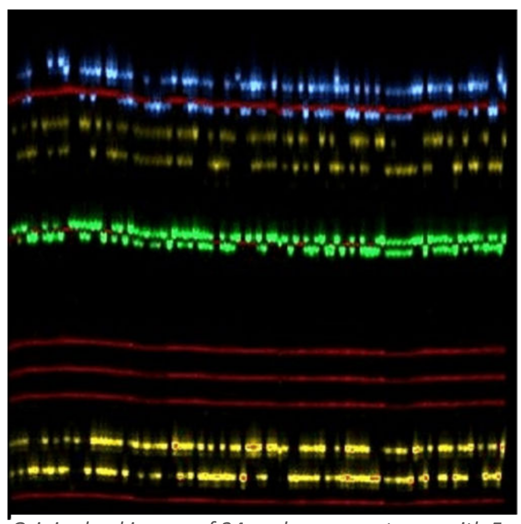
Repetitive DNA

	Repetitive	Non-repetitive
Genes	✓	✓
Non genes	✓	✓

Arrangements

Flavell, 1980

Tandem



Original gel image of 24 soybean genotypes with 5 fluorescent-labeled SSR loci. **Akkaya et al., 1992**

NOR

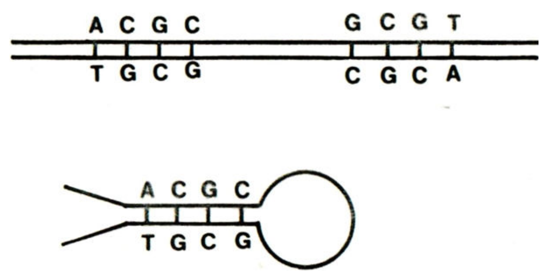
Microsatellites

Zietkiewicz et al, 1993

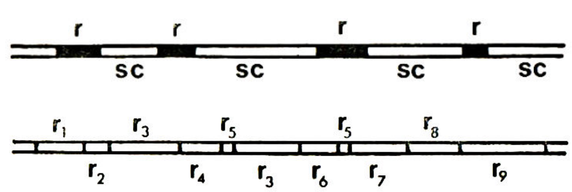
Minisatellites

Schmidt et al., 2000

Reverse or inverted

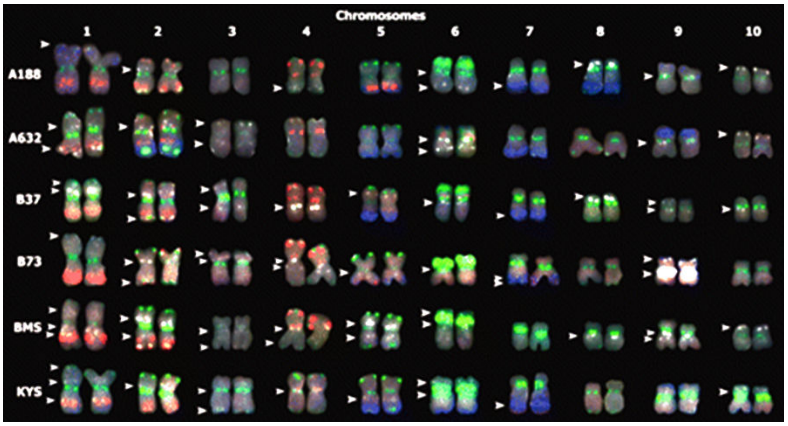


Interspersed



Mitochondrial DNA

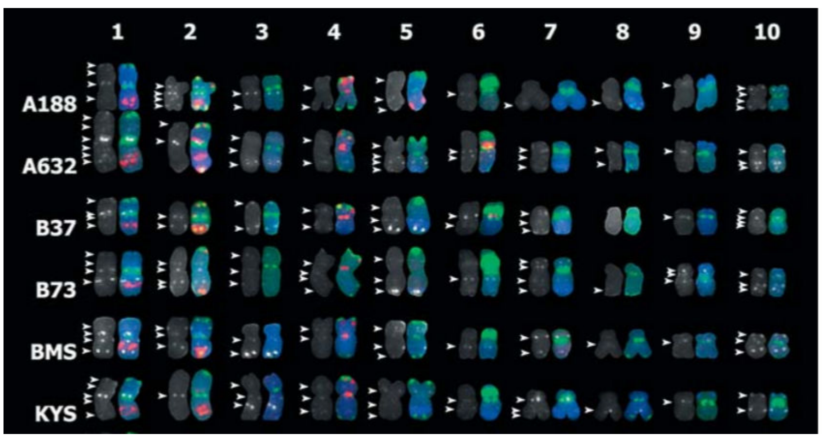
Lough et al, 2008 (Birchler lab)



Arrowheads indicated mitochondrial DNA that has been integrated into the genome.

Chloroplast DNA

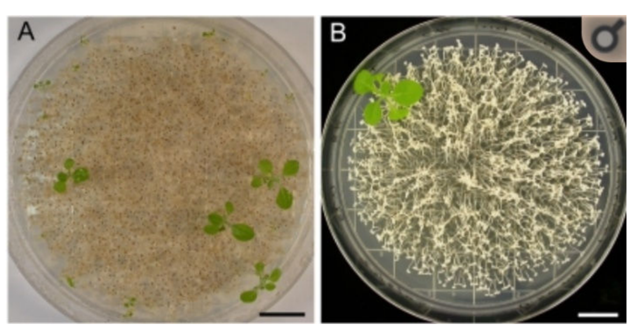
Roark et al, 2010 (Birchler lab)



Movement of organellar DNA to the nucleus

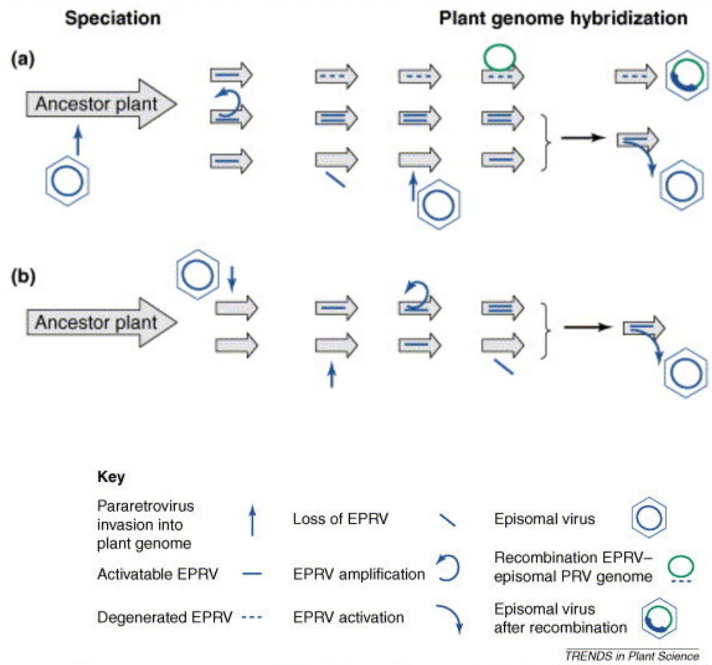
Huang et al, 2003; 2004; Sheppard et al, 2008

- 6 to 22 kb fragments
    - 1 event per 16,000 pollen grains
- KanR+ transgene in chloroplast with nuclear promoter
    - 1 per 11,231 plants via male gametes
- GUS transgene
    - Somatic transfer 1 per 18,000 leaf cells



Pararetroviruses

Staginnus & Richert-Pöggeler, 2006



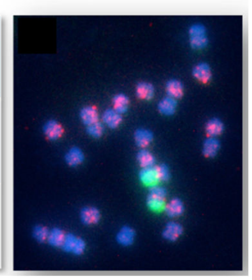
Stagginus et al, 2007; Liu et al, 2012

https://www.le.ac.uk/biology/phh4/prv.htm#eprvs

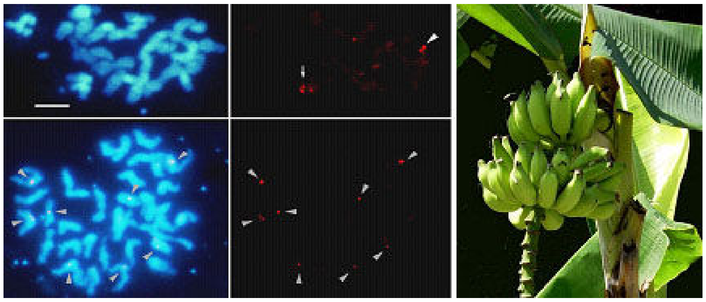
Transient integration

Stable integration

Tomato

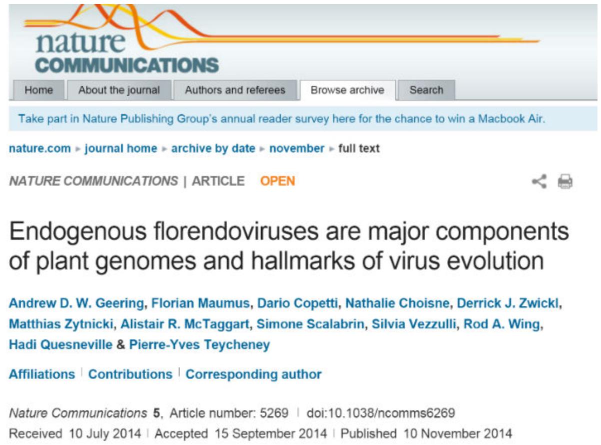


	Viral insert number	Virus
Rice, Indica (93-11)	74	rice tungro bacilliform
Rice, Japonica (Nipponbare)	88	rice tungro bacilliform



Banana Streak Virus

Geering et al, 2014



NATURE COMMUNICATIONS | ARTICLE OPEN

Endogenous florendoviruses are major components of plant genomes and hallmarks of virus evolution

Andrew D. W. Geering, Florian Maumus, Dario Copetti, Nathalie Choisne, Derrick J. Zwickl, Matthias Zytnicki, Alistair R. McTaggart, Simone Scalabrin, Silvia Vezzulli, Rod A. Wing, Hadi Quesneville & Pierre-Yves Teycheney

Affiliations | Contributions | Corresponding author

Nature Communications 5, Article number: 5269 | doi:10.1038/ncomms6269
Received 10 July 2014 | Accepted 15 September 2014 | Published 10 November 2014

Other genes from horizontal transfer

Kyndt et al, 2015

FOOD & CULTURE

Natural GMO? Sweet Potato Genetically Modified 8,000 Years Ago

ted May 5, 2015 · 2:51 PM ET

ICHAELEEN DOUCLEFF

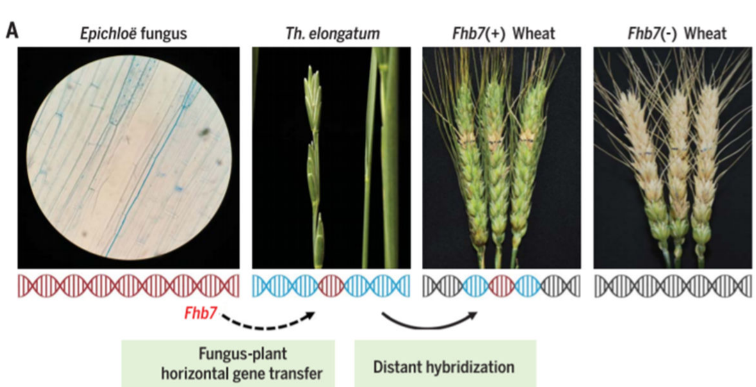
SHARE

Now that's a big root. Sweet potatoes aren't tubers, or thickened stems, like potatoes. Sweet potatoes are roots — swollen and packed with starch

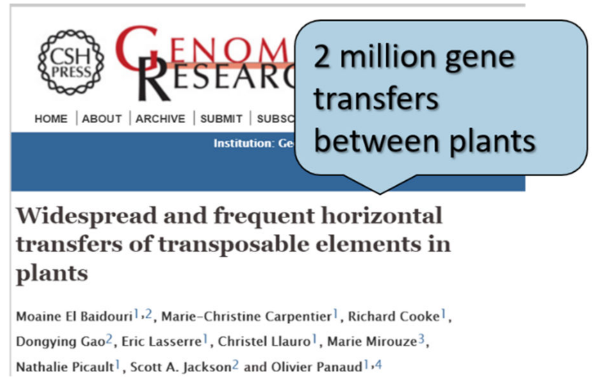
U'ichiro Murakami/Flickr.com

Stavnstrup et al, 2020

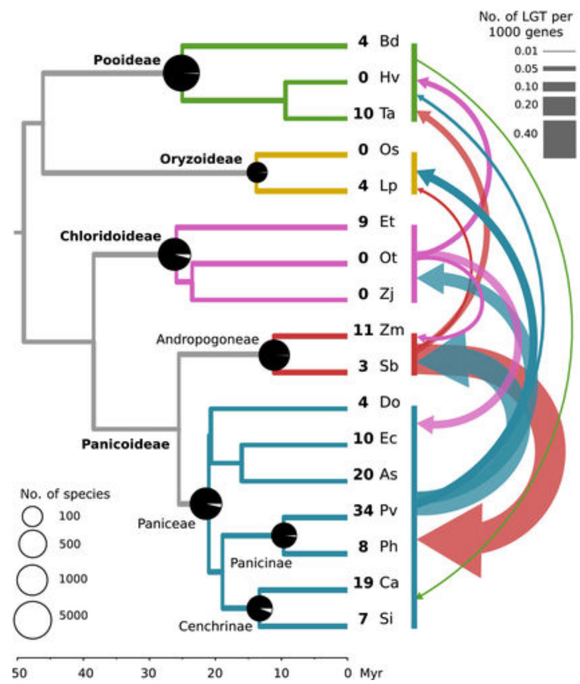
Wang et al, 2020



El Baidouri et al, 2014 (Jackson lab)

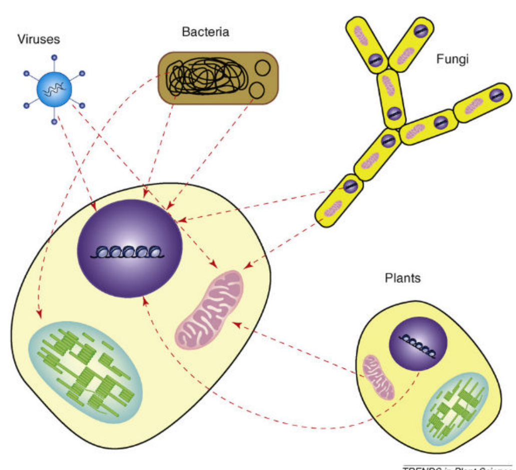


Hibdige et al, 2021



Summarizing the various sources of horizontal gene transfer

Bock 2009



Transposable Elements

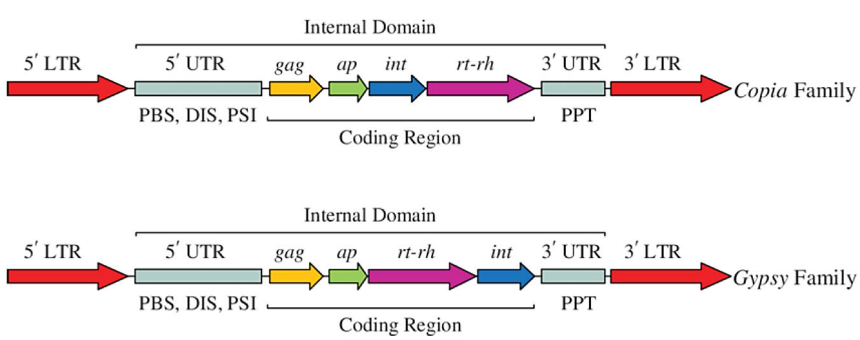
Kazazian, 2004

DNA transposons

Retrotransposons

Wessler et al., 1995; Brandes et al., 1997; Kumar & Bennetzen, 1999; Moore, 2000; Bennetzen, 2000; Kazazian, 2004; Orozco-Arias et al, 2019

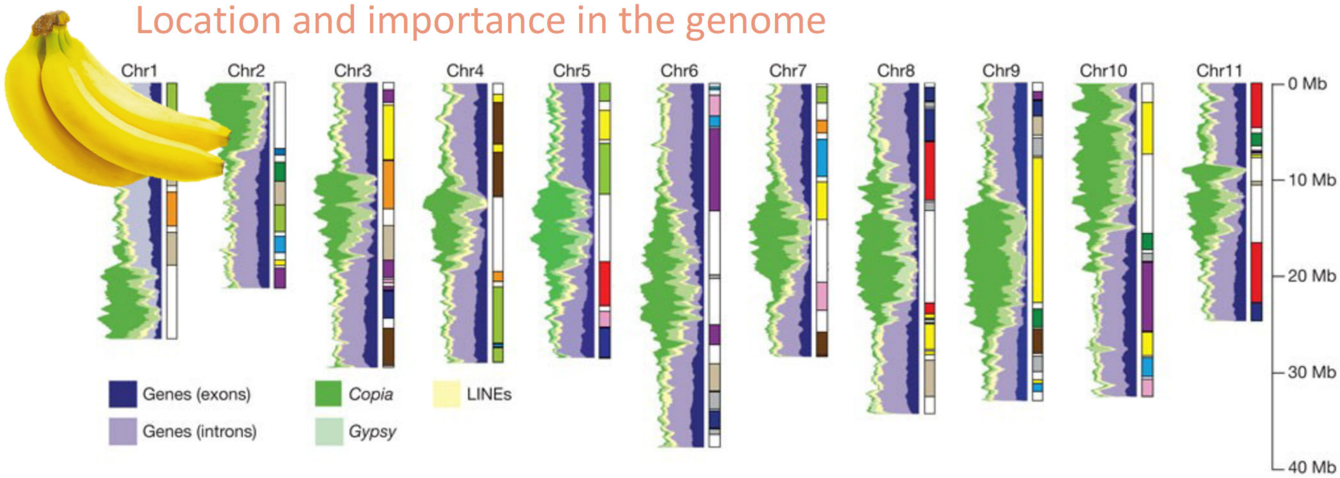
LTRs



Genes contained: gag- for intracellular packaging of the RNA; encode for viral particle coat; RH = ribonuclease H; RT = reverse transcriptase; int = integrase (to provide enzymatic activities for making cDNA from RNA and inserting it into the genome); PR = protease; EN = endonuclease

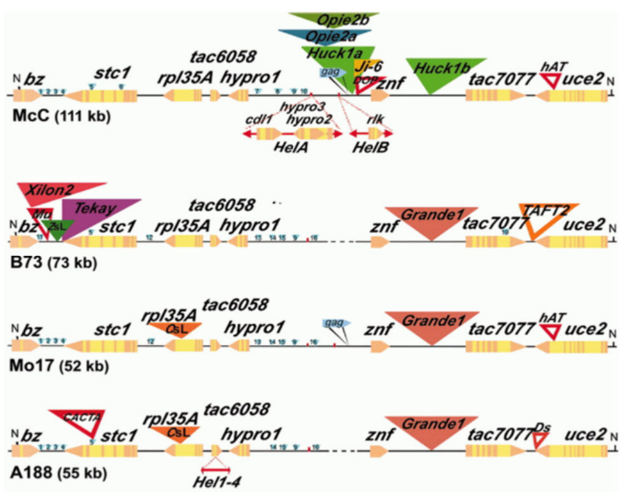
D'Hont et al, 2012

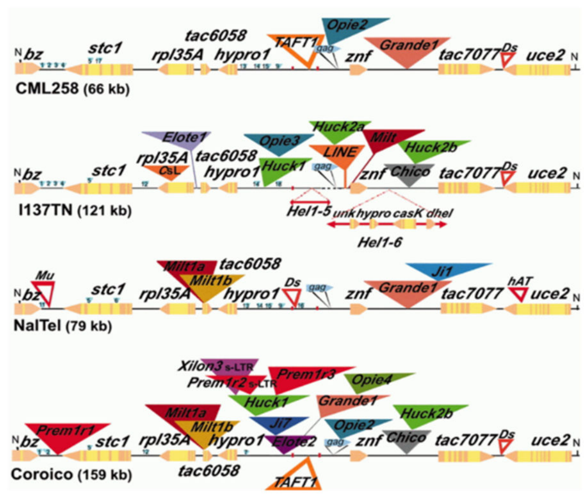
Location and importance in the genome



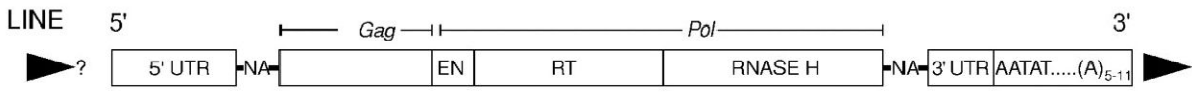
Differences in retrotransposon patterns in different inbreds of maize

Wang and Dooner, 2006

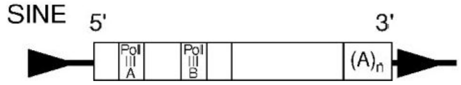




Non-LTRs



Wenke et al, 2011



Number of retrotransposons in a plant genome

Joseph et al, 1990 DOI:10.1007/BF02099941

Del 1 in Lilium spp

Leeton and Smyth,1993 DOI: 10.1007/BF00282789

Del 2 in *Lilium speciosum*

Manninen & Schulman, 1993 DOI: 10.1007/BF00027369

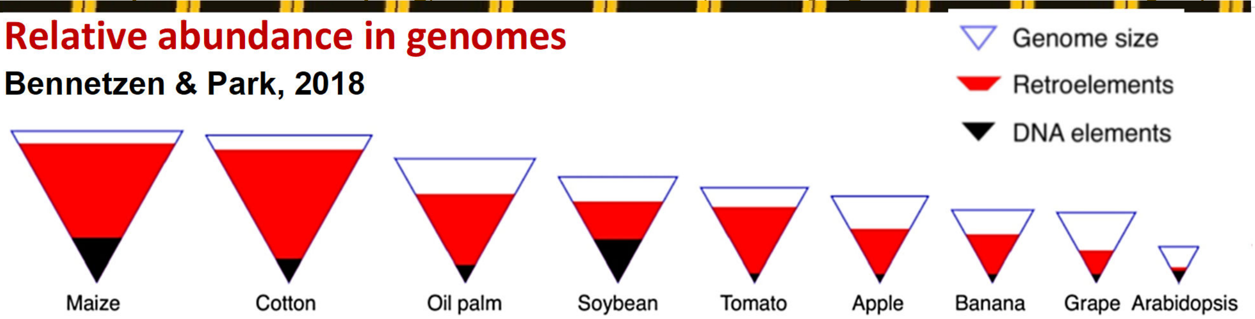
BARE1 in Barley

Moore et al, 1991 DOI: 10.1016/0888-7543(91)90334-B

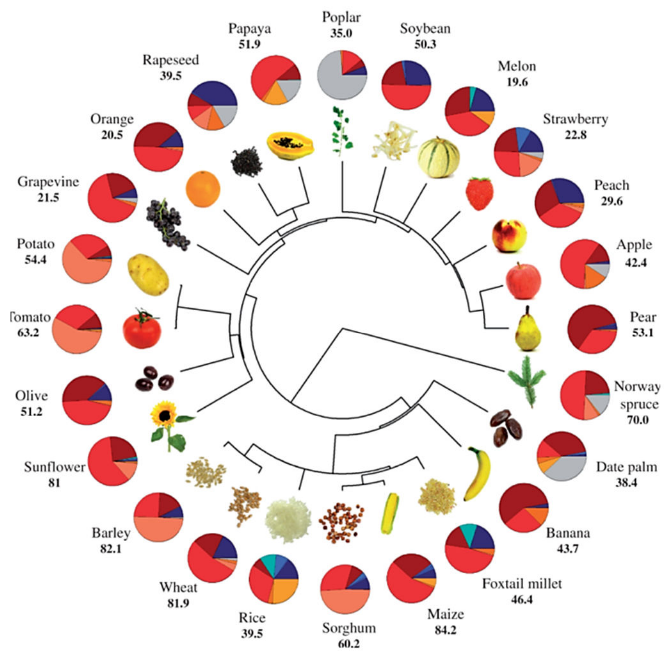
Bis-1 in wheat

Relative abundance in genomes

Bennetzen & Park, 2018



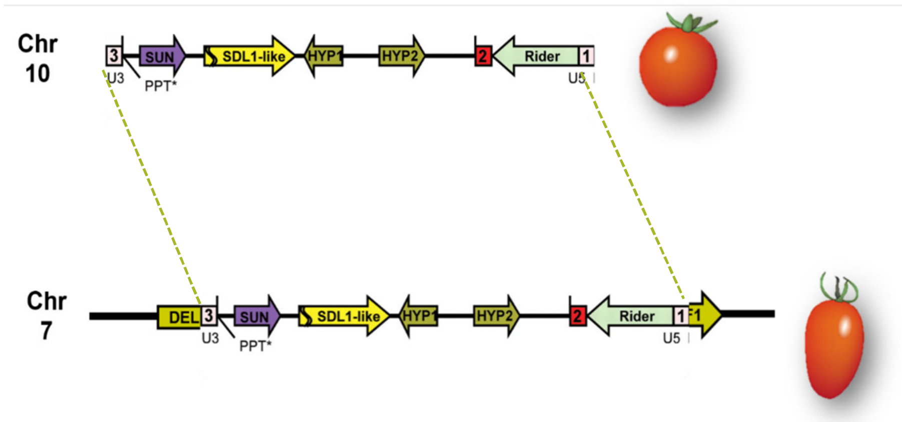
Vitte et al., 2014



Retrogenes

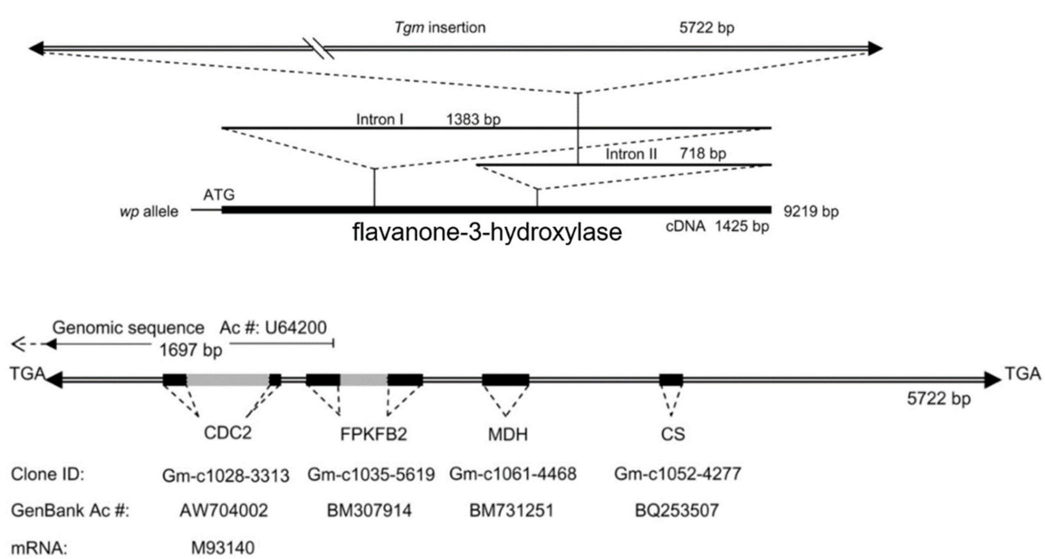
Wang et al., 2006; Elroubi and Bureau, 2010

Xiao et al, 2018 (van der Knaap lab)



Zabala and Vodkin, 2005; 2007

1987 Illinois – Wp mutation



Transposable elements & mutations

Kazazian, 2004

Allele creation

Eg, Giroux et al, 1996

Eg, Montgomery et al, 2024

-

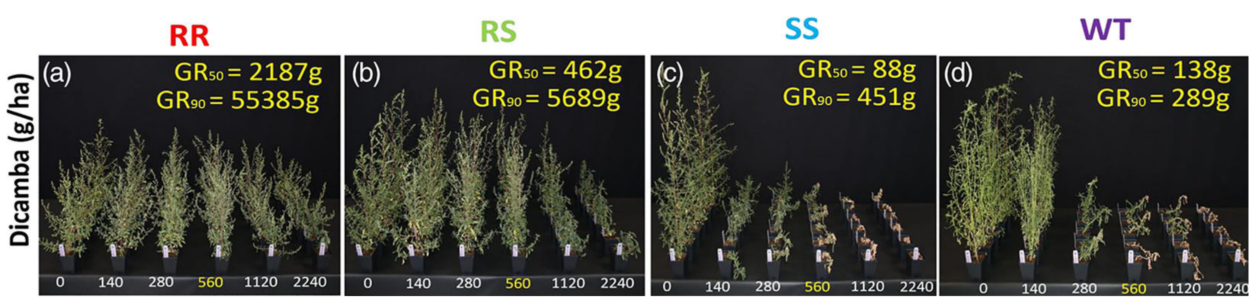
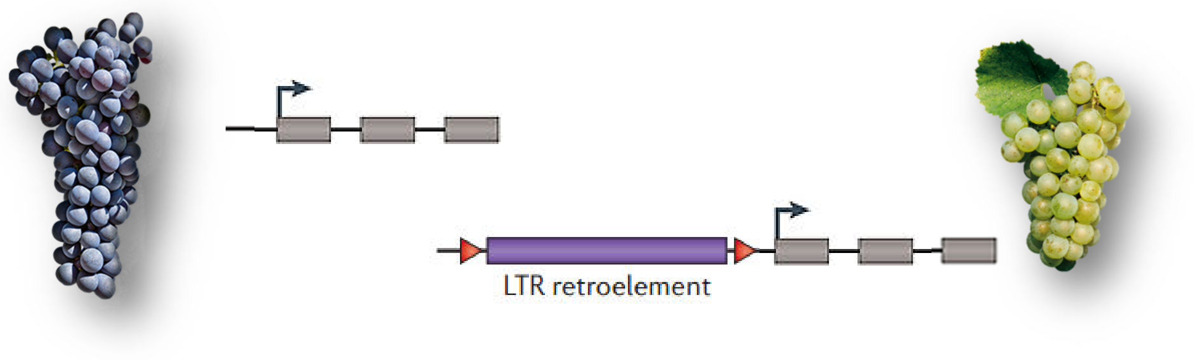


Photo: Wu et al, 2020. Pest Management Science, https://doi.org/10.1002/ps.6080

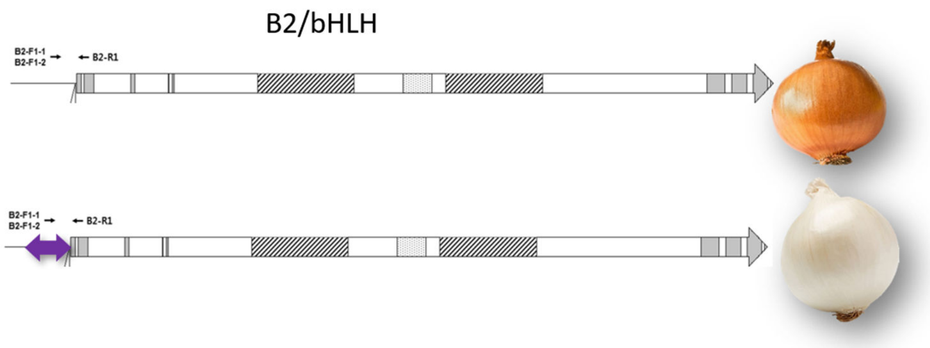
Gene knockout

Eg, Vollmann & Ruckenbauer, 1997

Kobayashi et al, 2004; Review by **Lisch, 2013**



Jo & Kim, 2020

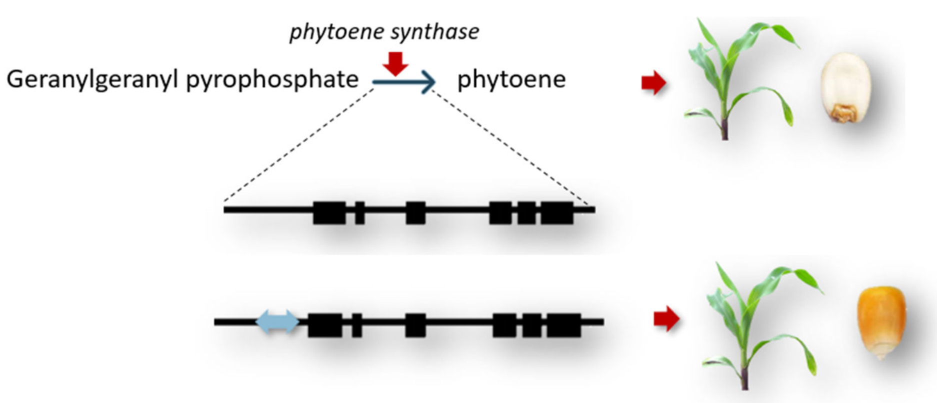


Chromosomal reconfigurations

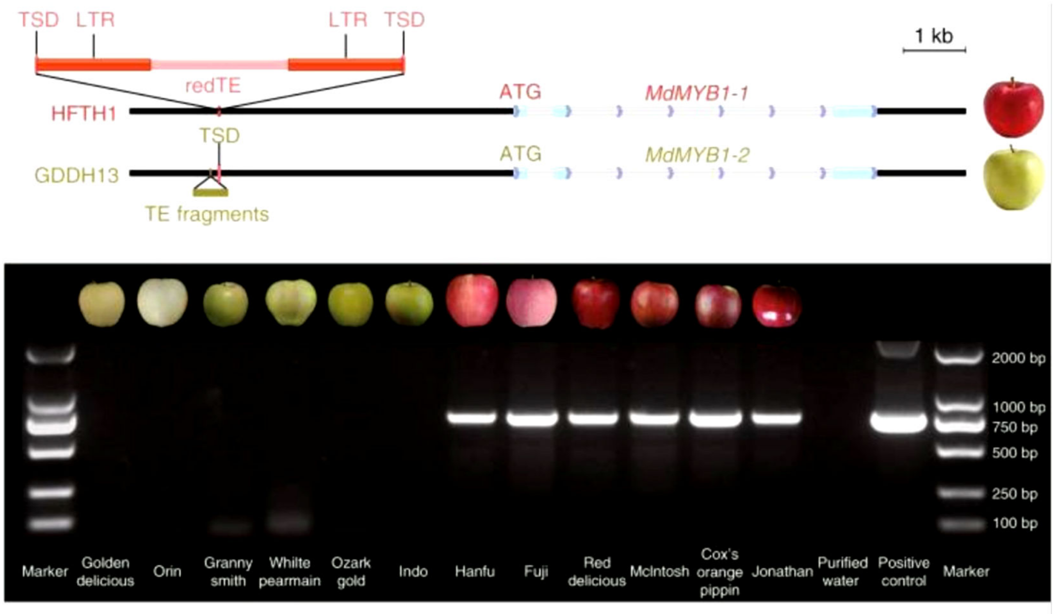
Zhang & Peterson, 1999

Change expression patterns

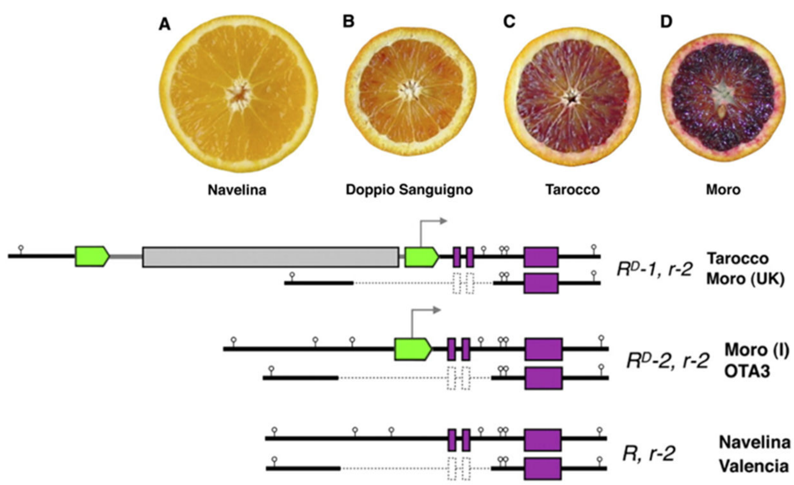
Palaisa et al, 2003 (Rafalsksi lab)



Zhang et al, 2019

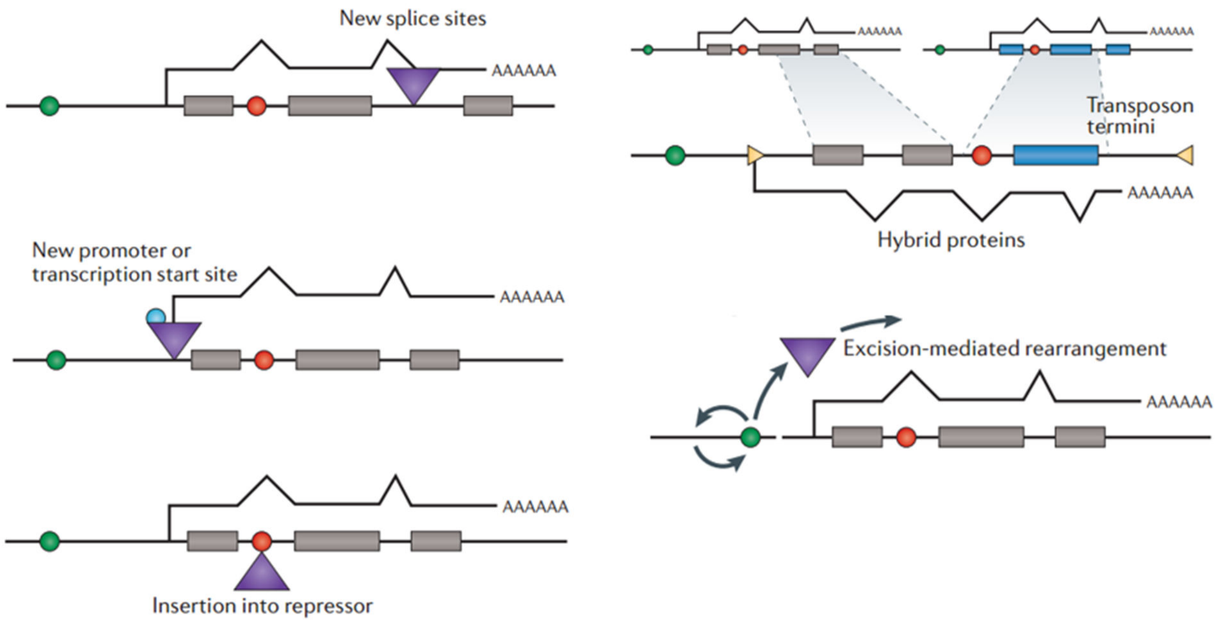


Butelli et al., 2012; Review by **Lisch, 2013**



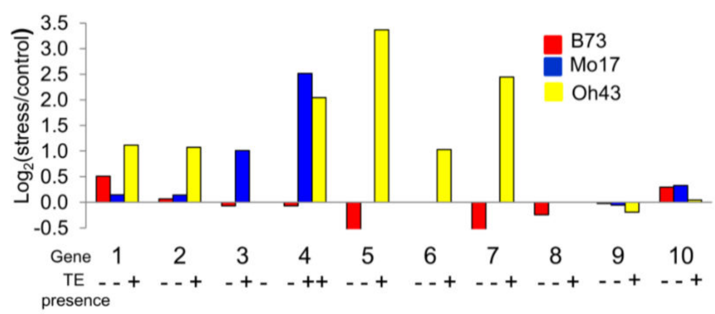
Summary of major changes

Review by **Lisch, 2013**

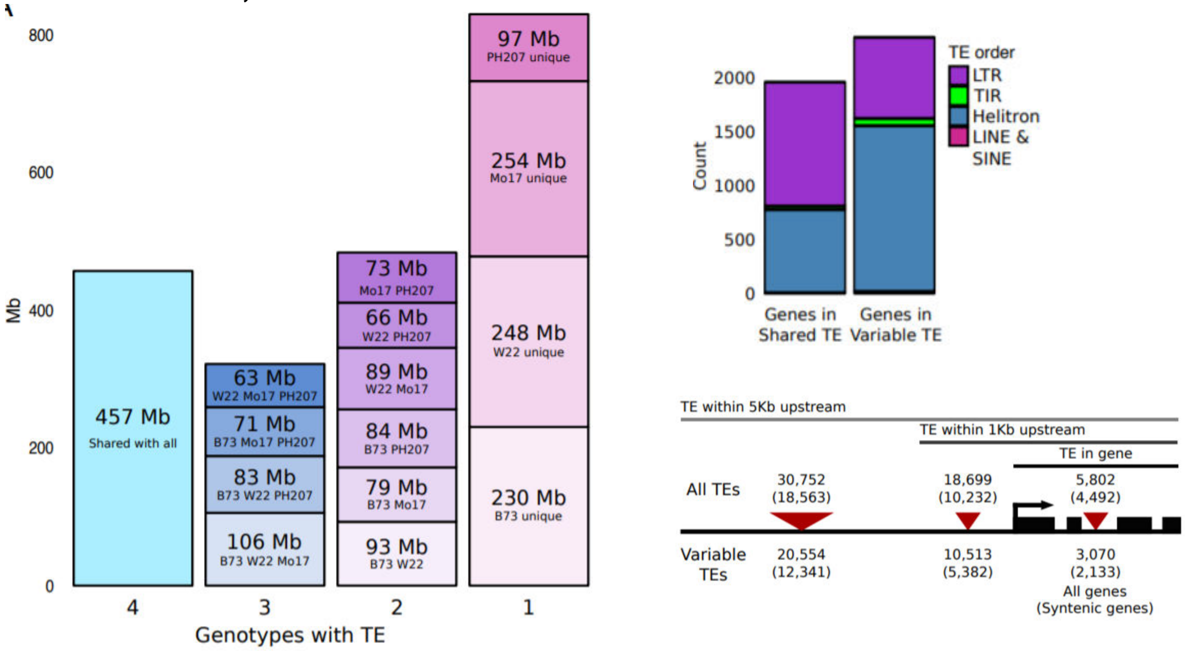


Transposons affect gene expression in the vicinity

Makarevitch et al, 2015

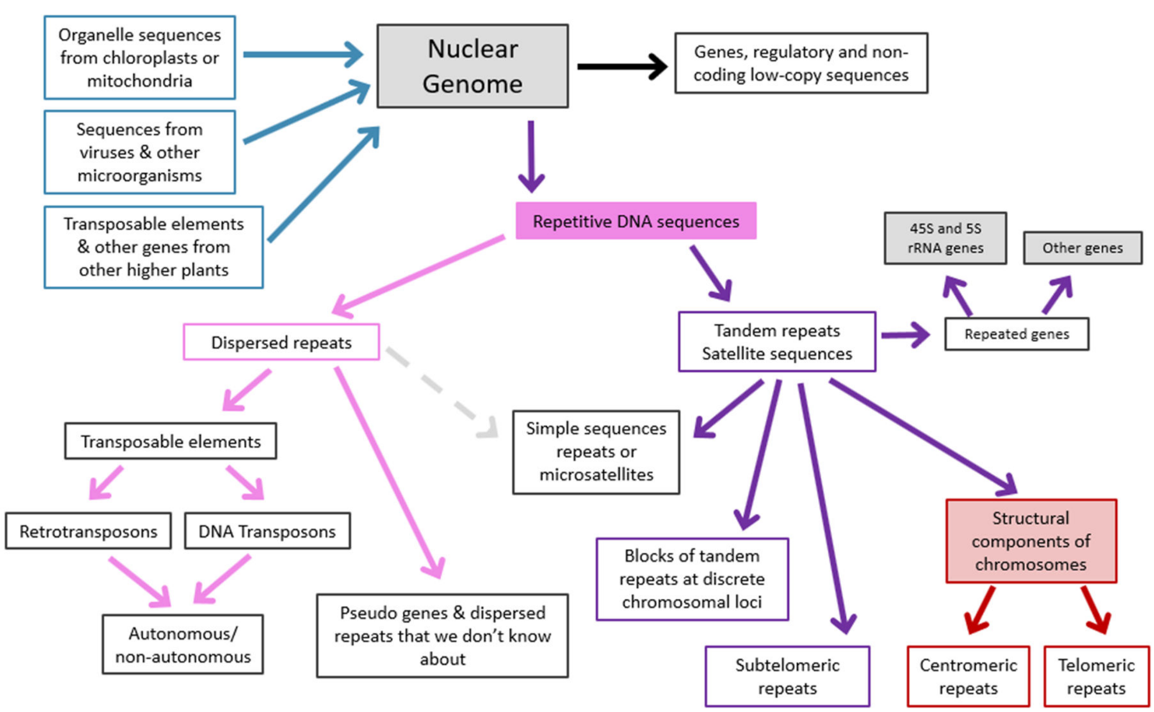


Anderson et al, 2019



Summary of repetitive DNA types

Modified from **Biscotti et al, 2015**



Movement of DNA in the plant genome

Belyanev et al., 2000

Wheat graphic from www.mpiz-koeln.mpg.de/pr/garten/schau/Triticumaestivum/wheat.html

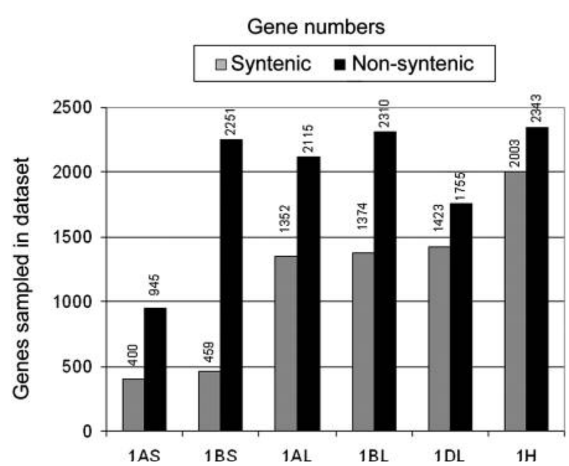
Movement by transposon capture

Malacarne et al, 2012

Movement during double strand break repair

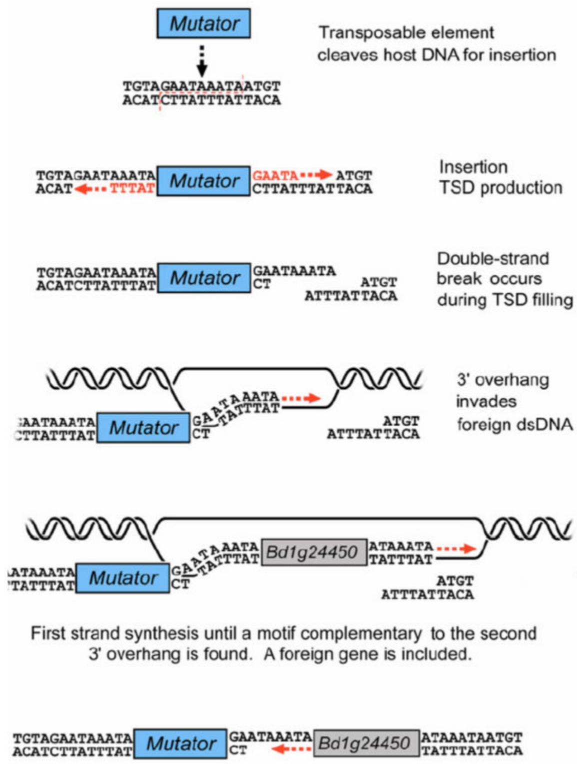
Freeling et al, 2008;

Wicker et al., 2010; 2011

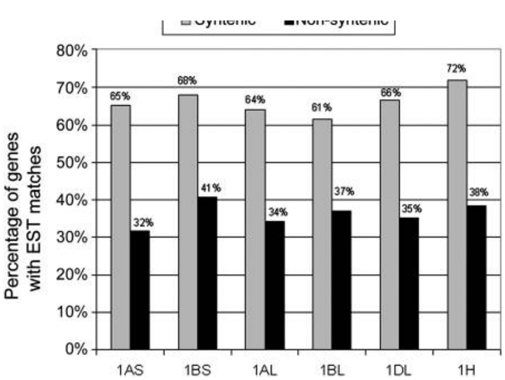


Wicker et al., 2011. Syntenic & non syntenic genes in chromosomes 1A, 1B, 1D and 1H

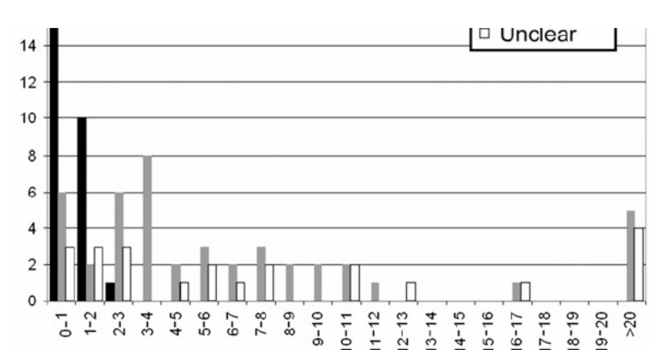
Wicker et al., 2010; 2011



Most non-syntenic genes are not expressed; i.e., they are pseudo genes

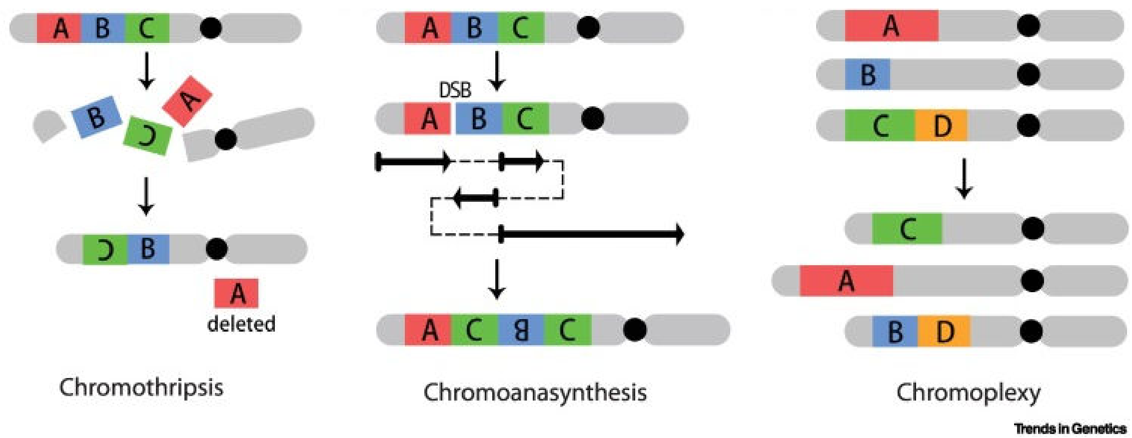


X axis is size (kb) of DNA fragments. Y axis represents the number of fragments in each size class

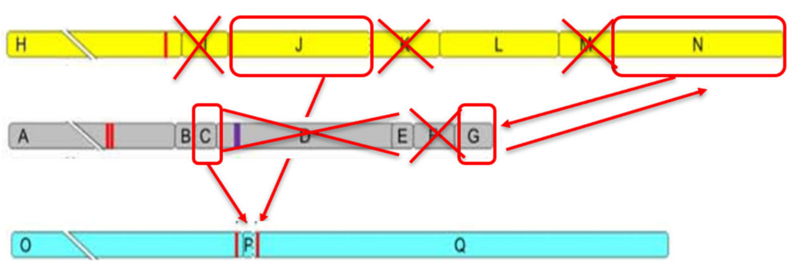


Chromothripsis, chromoanasynthesis & chromoplexy

Guo et al, 2023

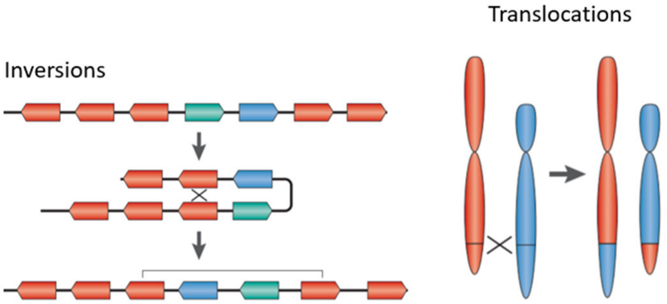


Carbonell-Bejerano et al, 2017



Repetitive DNA & chromosomal reconfigurations

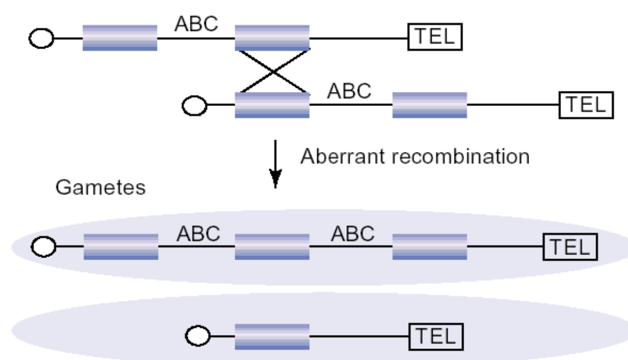
Gaut et al., 2007



Amplification and deamplification of repetitive DNA

Unequal crossing over

Flavell, 1985; Jelesko et al., 1999



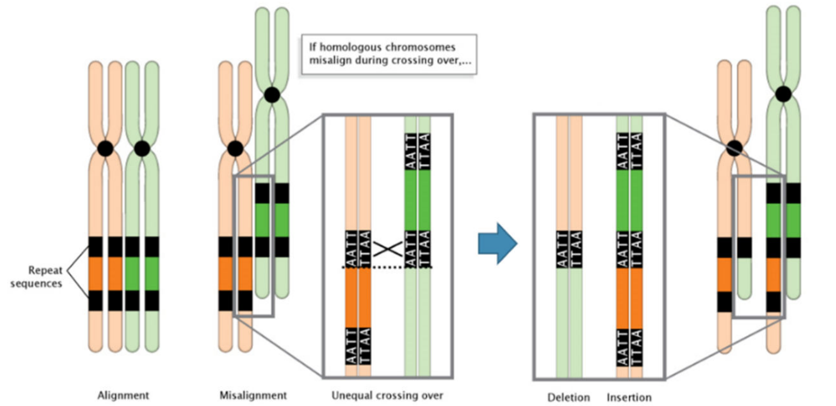
https://eichlerlab.gs.washington.edu/research.html

Unequal crossing over

Allele creation

E.g., a1 locus of maize

Yandeau-Nelson et al, 2006



https://www.nature.com/scitable/topicpage/genetic-mutation-441

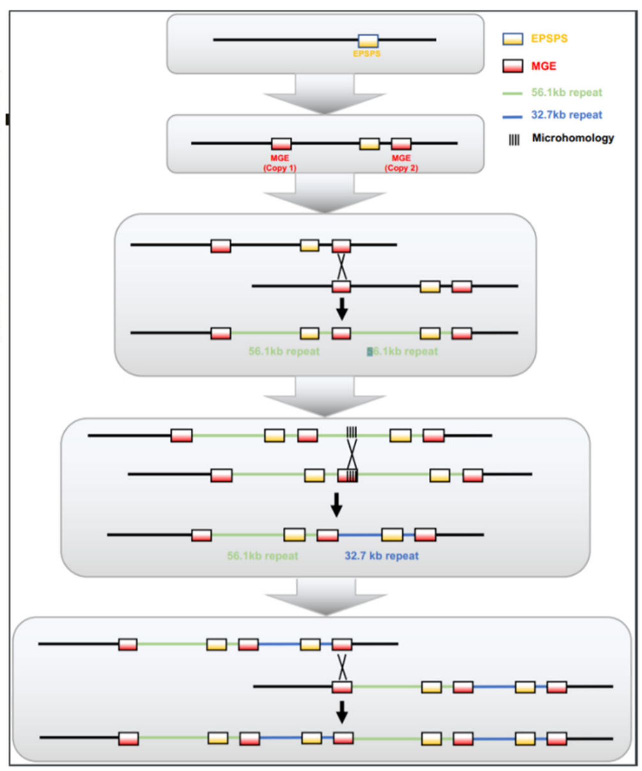
Herbicide tolerance

Patterson et al, 2019

Kochia contains saponins, alkaloids, oxalates and nitrates that can be toxic to livestock, so it must be controlled in their diet. | File photo

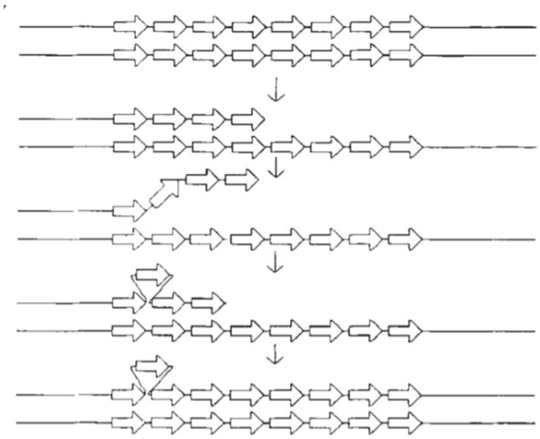
Kochia is one of the Prairies' more damaging weeds.

https://www.producer.com/2015/06/weed-of-the-week-kochia/



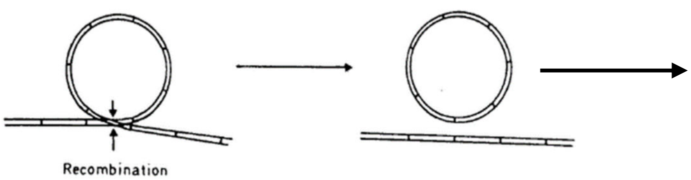
Replication slippage/ stutter

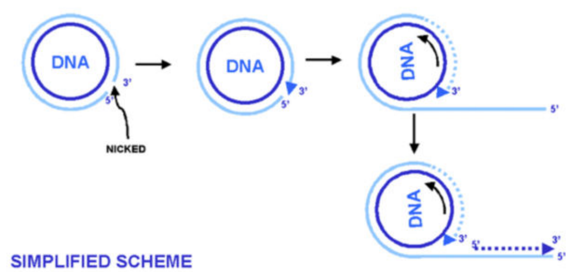
Strand et al, 1993

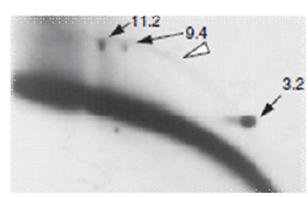


Intrastrand recombination

Flavell, 1985



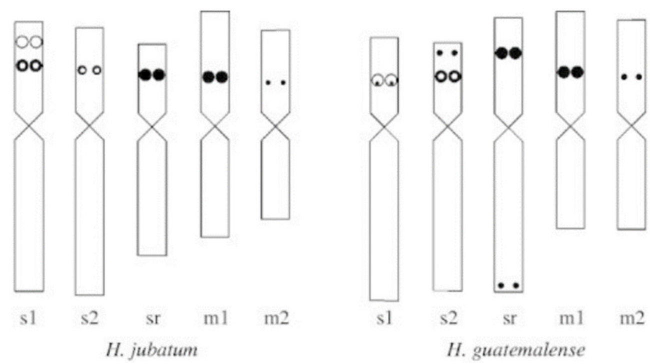




Cohen et al, 2008

Cohen et al., 2008; Navrátilová et al., 2008

Eg, Taketa et al, 2015

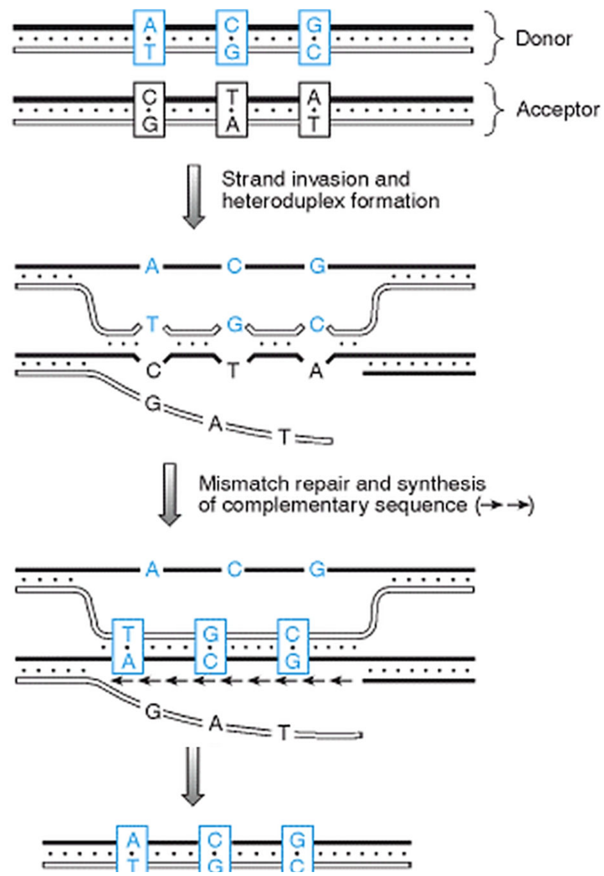


Note the 2 extra NOR sites in H. guatemalense relative to H. jubatum.

Concerted evolution

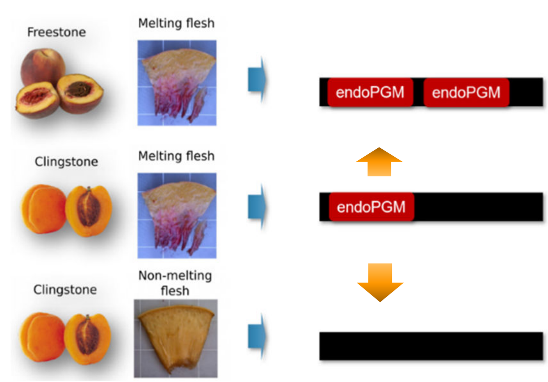
Unequal crossing over

Gene conversion



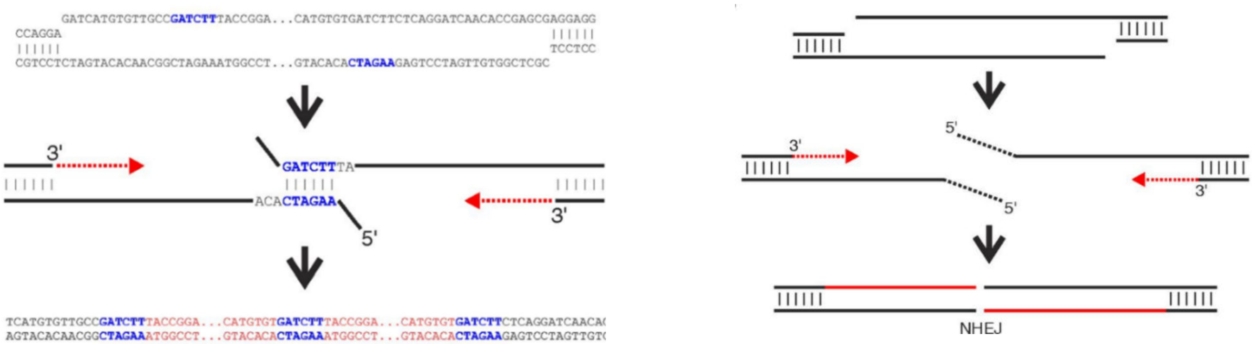
http://obiweb.bcgsc.ca/medgen/medgen520/Block6_files/image011.gif

Tandem duplications



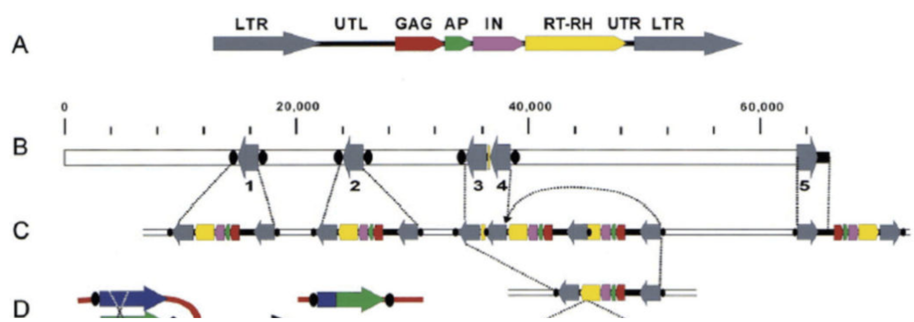
. Gu et al, 2016

Schiml et al., 2016



Genome expansion and contraction

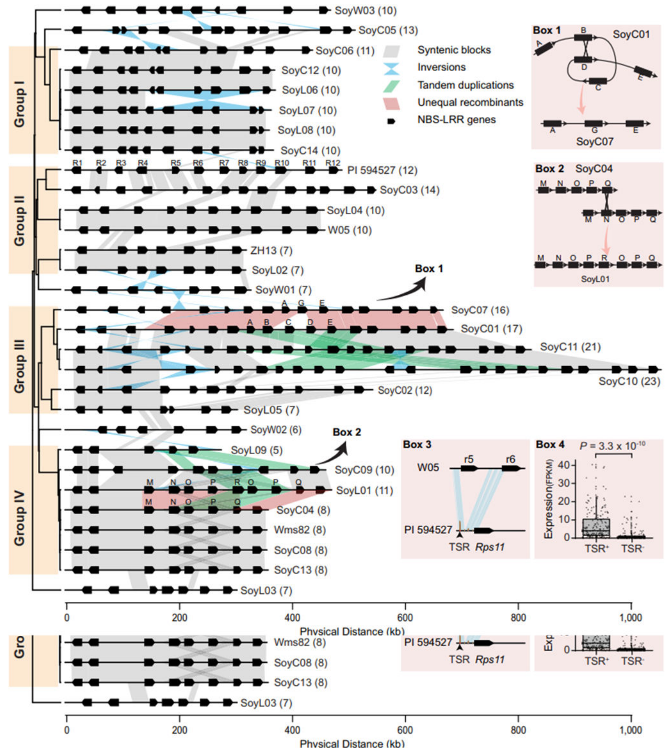
Shirasu et al., 2000
Hawkins et al., 2009



. A: Structure on an LTR retrotransposon. B: Barley DNA showing LTRs, but not the middle sequences. C: the retrotransposons that must have been there. D: A proposed mechanism for the loss of the internal sequences

Case study

Wang et al, 2021 (Ma lab)



Source of genetic variation

Eg, Rasmussen & Phillips, 1997

"Plant breeding progress and genetic diversity from de novo variation and elevated epistasis"

https://www.flickr.com/photos/53400673@N08/12921979305

Genomic shock

The significance of responses of the genome to challenge

McClintock, 1984

"In the future, attention undoubtedly will be centered on the genome, with greater appreciation of its significance as a highly sensitive organ of the cell that … senses unusual and unexpected events, *and responds to them, often by restructuring the genome*."

Activation of retrotransposons & transposons

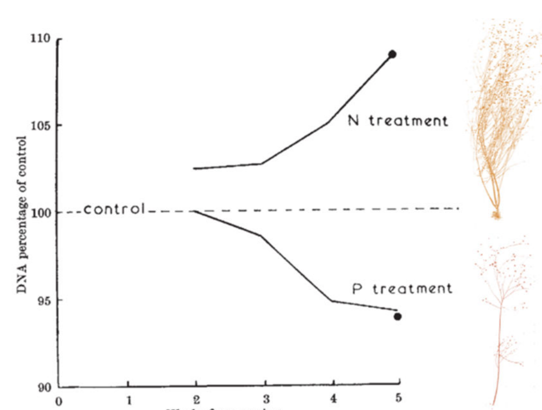
Flax genotrophs

Durant, 1962;

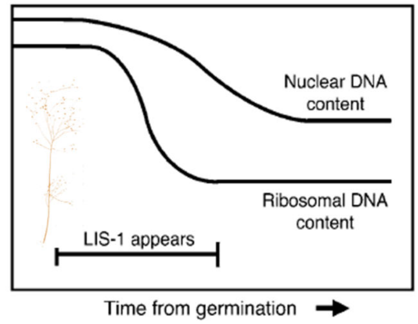
Large and Small genotrophs of flax.

Cullis, 2005

Evans et al, 1966; Cullis, 1974

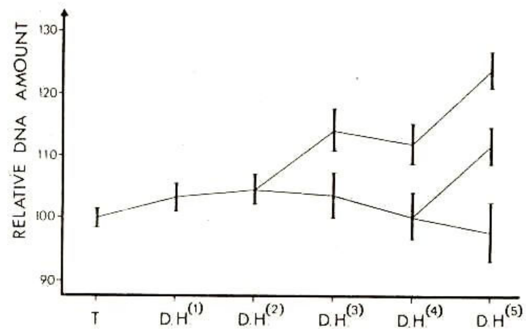


Chen et al, 2005; Henikoff, 2005



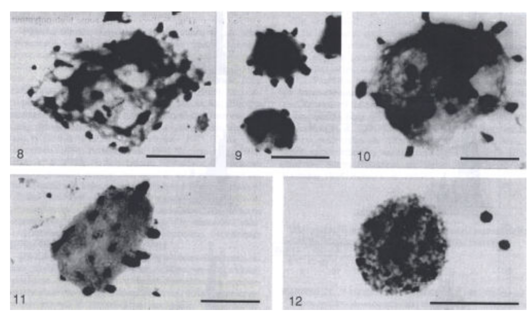
Effect of Tissue Culture

DePaepe et al., 1982

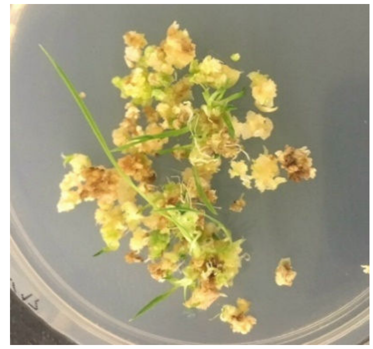


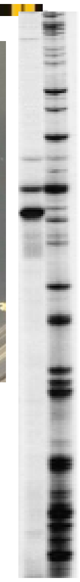
DNA content of doubled haploids of tobacco

Joachimiak and Ilnicki, 2003



Grandbastien, 1998

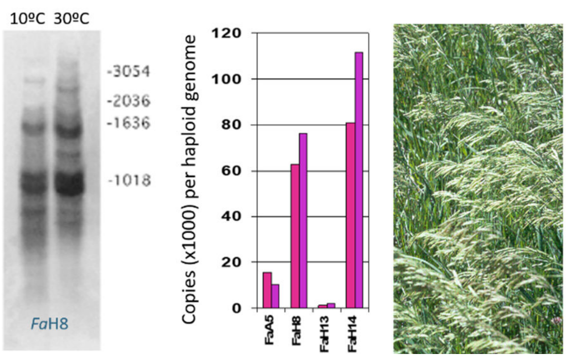




Amplification of pong elements in rice C5924 before (L) and after (R) cell culture. Jiang et al., 2003

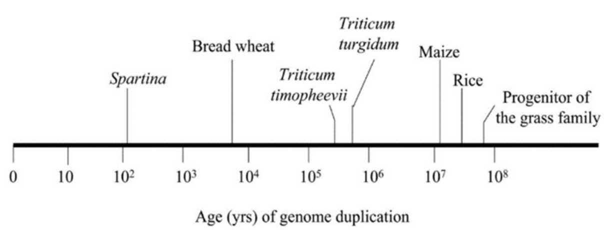
Adverse environments

Ceccarelli et al, 1992



Effect of germination temperature on tall fescue

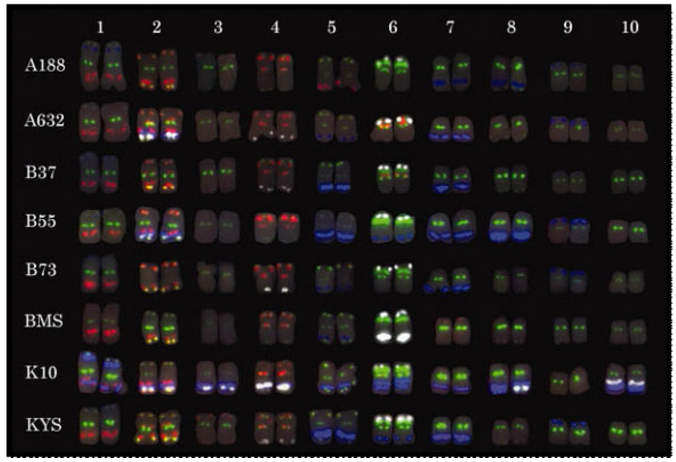
Polyploidy as a trigger of instability



Grass family includes young and old polyploids. Levy and Feldman, 2002

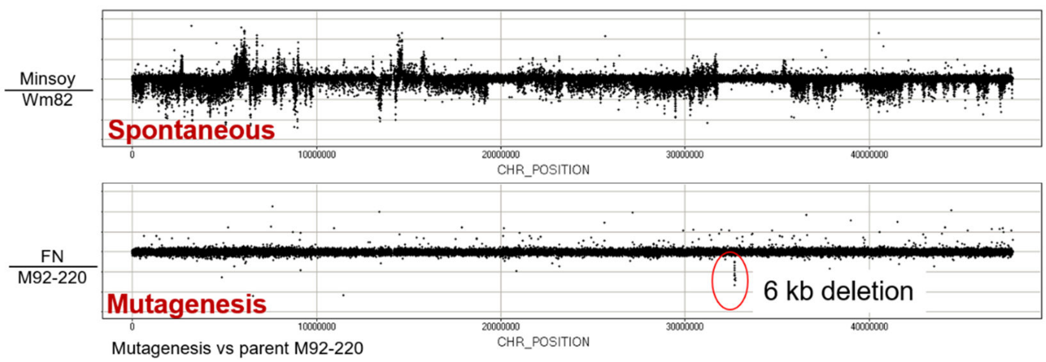
DNA plasticity and species divergence

Kato et al, 2004 (Birchler lab)



Standing variation

Anderson et al, 2016 (Stupar lab)



Shen et al, 2018

- > 250,000 structure variations
  - 1,404 translocations
  - 161 inversions
  - 1,233 translocation & inversions
  - 505,506 indels (1-99 bp)
  - 17,409 insertions (>=100 bp)

Williams 82

- 641 unique genes

Zhonghuang 13

- 1,365 unique genes
- 52.75% of genome is transposable elements
- 46.13 Mb > Williams 82

Ohtsubo et al., 1991

355 bp repeat in rice

Genome	Copies/haploid
O. sativa cv. C5924	2000-3000
cv. Sasanishiki	700-900
cv. Koshihikari	3400-4300
cv. Nipponbare	4600-6000
O. glaberrina	540-680
Setaria italica foxtail millet	-0-

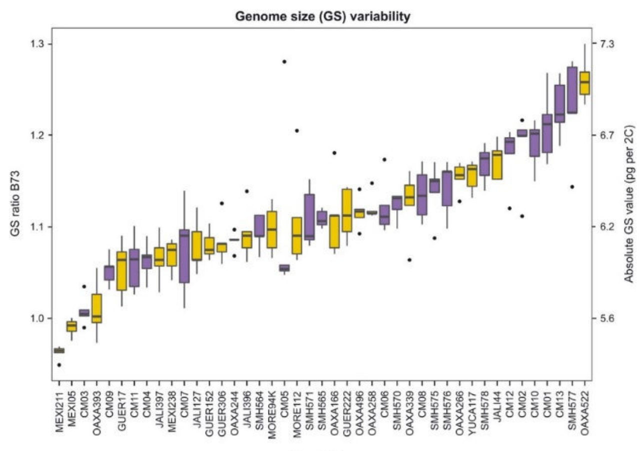
Cumulative effects of DNA flux leads to large effects

e.g., maize (**Rayburn et al., 1989**)

Inbred	pg DNA/4C nucleous
Va35, pop. 1	10.31
Va35, pop. 2	10.06
Gaspe Flint	10.06
KYS	11.46
Zapolote Chico	14.35

-red pepper (**Mukherjee & Sharma, 1990**)

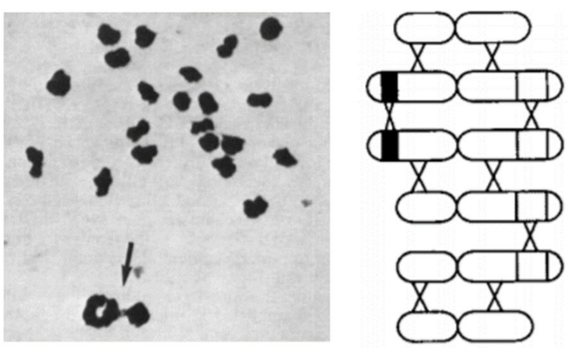
Cultivar	pg DNA/4C nucleous
69/33	18.38
K-2553	19.30
6C-173358	20.58
U8-45	21.34
BDJ/NKG-297	22.98



Díez et al, 2013. Genome size in Mexican maizes relative to B73. Median + ¼ and -³/₄. Yellow = maize; purple = teosinte.

Effect of DNA amplification on chromosome pairing

Reed and Burns, 1989; Reed et al., 1992



Interpretive drawing of multivalent in photo

A cell with 21 II and 1 VI in semiclosed configuration.

Role of repetitive DNA in speciation

Repeated DNAs hybridized together	pg DNA	% *L. hirsutus* repeated DNA hybridized
hirsutus + hirsutus	20.3	100
hirsutus + tingitanus	17.9	50
hirsutus + odoratus	17.2	62
hirsutus + sphaericus	14.2	17
hirsutus + clymenum	13.8	14
hirsutus + articulatus	12.5	44
hirsutus + angulatus	9.2	21