Chromosome reconfigurations

These were once known as "chromosomal aberrations." They are now recognized as intermediate steps that take place as the genome reconfigures itself.

Deficiencies

First described by Bridges in the notched wing mutants of Drosophila

Later, Mohr was first to correlate gametic loss with a cytological loss

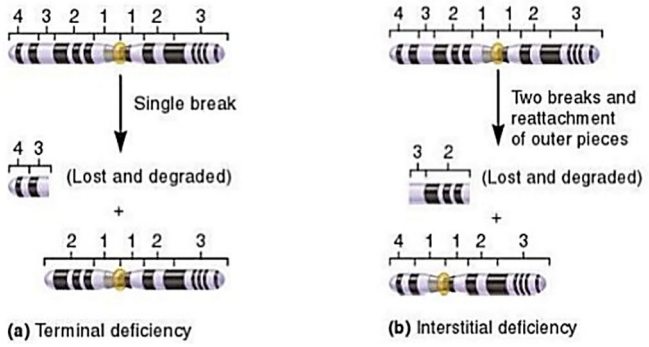


Figure 1, https://www.slideshare.net/Samchuchoo/chromosomal-aberration

McClintock, 1931

Correlated genetic loss with pachytene analysis:

- Cross female *pl/pl* × X-rayed male *Pl/Pl* → looked for F1 plants of *pl* phenotype, then did pachytene analysis
- Pseudodominance: the expression of a recessive phenotype due to a deficiency
- Other phenotypic effects
    - Male sterility (lethal in male gamete)
    - Reduced female transmission

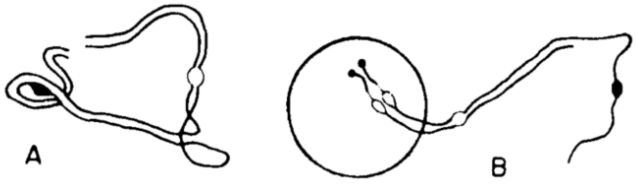


Figure 2. A: Interstitial deficiency of chromosome 7. B: Terminal deficiency of chromosome 6 (McClintock, 1931)

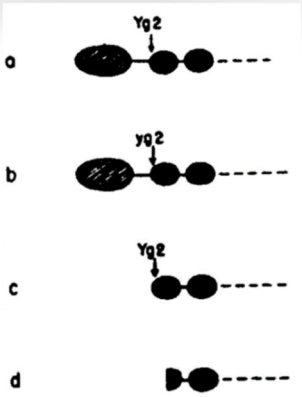
McClintock, 1944

Working with the *yg2* (yellow-green) locus, which was known to be 15 crossover units from *C* (colored endosperm) on chromosome 9

She also found *py* (pale-yellow) mutants and *w* (white) mutants that mapped to the same region. In the following crosses:

- *py* × *w* → all pale-yellow, therefore, were allelic, with *py* dominant over *w*
- *w* × *yg2* → all yellow-green, therefore, were allelic
- *py* × *yg2* → green, therefore, were not allelic, which is a discrepancy

This genetic discrepancy can be explained by cytological deficiencies:



- Normal chromosome 9, with *Yg2*
- Normal chromosome 9, with *yg2*
- Chromosome 9 missing terminal knob, but with the wild-type allele (Yg2)
- Chromosome 9 missing the *Yg2* locus altogether

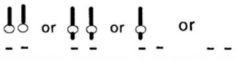
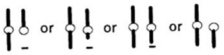
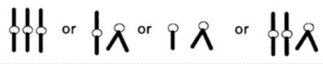
Thus:
- b + b = yellow-green seedling
- c + c = pale-yellow seedling
- d + d = white seedling
- b + c = green seedling
- b + d = yellow-green seedling
- c + d = pale-yellow seedling

- Deficiencies in plants not as frequently transmitted as in animals, as haploid gametophyte will not tolerate significant deficiencies
- Recover more aberrations through the female than the male, as the ovule around the female gametophyte serves as nurse tissue
- Alternative hypothesis: Less genes are turned on in the female
- Diploids cannot tolerate homozygous deficiencies above a certain size. Allopolyploids can.

5A deficiencies in wheat and oat (2n = 6x = 42):

Occasionally get off-types that resemble related wild species

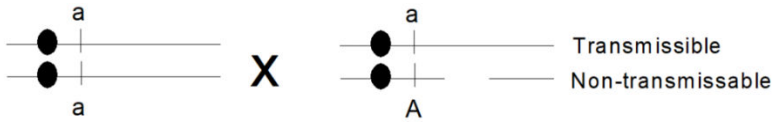
- Due to addition/deletion of chromosome 5A

Oat	Wheat	
Fatoid	Speltoid	
	Het speltoid	
	Subnormal	
Steriloid	Subcompactoid	
	Compactoid	

Speltoid, normal, subcompactoid, and compactoid heads of wheat

Mapping deficiencies

In the example below, the chromosome carrying the "A" allele is not transmissible through a gamete because of the deficiency:



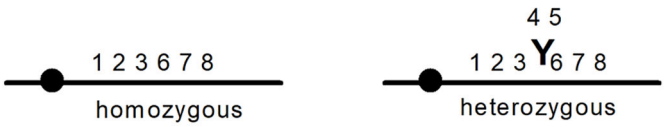
However, "A" can still be recovered if there is a crossover between "A" and the deficiency, allowing "A" to be mapped relative to the junction. E.g.:

- If out of 179 progenies, 146 are "a" and 33 are "A", then the distance between "A" and the junction is:

$$\frac{A}{a+A}=\frac{33}{179}=0.184$$

- which = the % of dominant progeny
- In this case, every CO gives 1 dominant progeny, as compared to the normal situation where 1 CO gives a 50% recombination rate.

Effect of deficiencies on linkage maps



If the deficiency is viable, a homozygous map would simply be missing all the loci in the deficiency, while a heterozygous map would have all the loci in the deficient region map to one point.

Uses of deficiencies

- Make knockouts
- Cytological mapping via pseudodominance- **Khush & Rick, 1968**
- Studies of pairing specificity
- Gene cloning through genomic subtraction
- Reverse genetics
- Determine function of the chromosomal region

- Fine genetic mapping of mutations and markers
    - Eg., Merlino et al., 2012 - Associate loss of proteins from 2D gels with specific deletions
    - Missing protein means the deletion has the coding gene or a regulatory gene

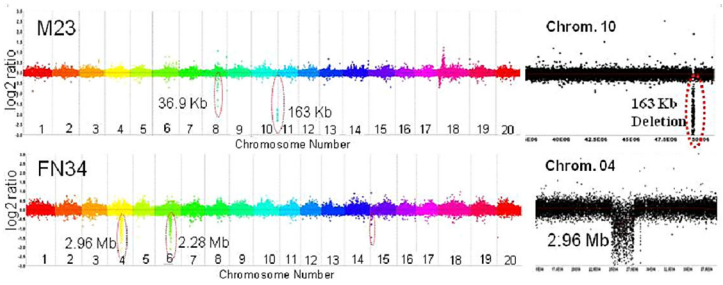
Merlino et al., 2012

Dectection

Comparative Genomic Hybridization (CGH)

Makes it much easier to ID region where deficiency is, and thus assign phenotype to gene.

An array is made of single copy DNA in linear order as is found in the chromosomes



- Reference and deletion genomes are both labeled
- When DNA from both is present, the labels cancel each other out
- If a deletion is present, there is no counter label, making the deletion obvious

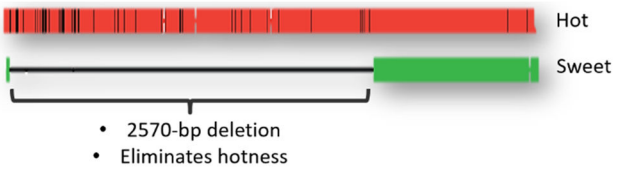
Structural variants: Indels

It is also possible to get smaller indels.

- These do not affect fertility, but can affect the phenotype
- 3 examples are:

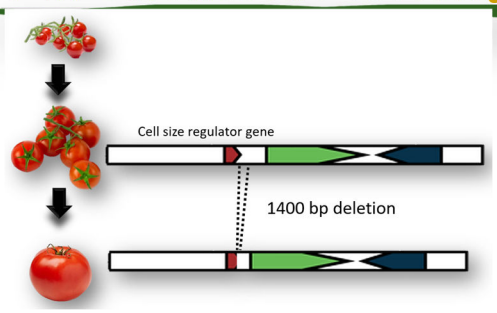
Non-pungent chili peppers

Stewart et al., 2005; Hulse-Kemp et al., 2018



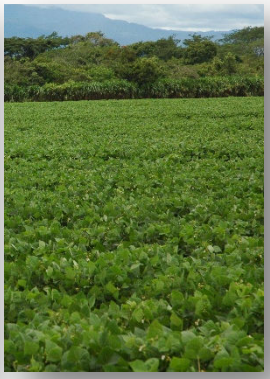
Tomato fruit size

Mu et al., 2017

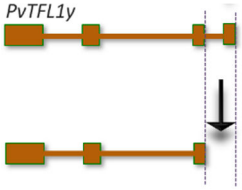


Determinancy in bean

Kwak et al., 2012

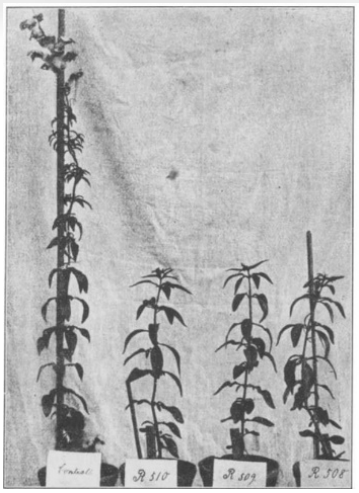


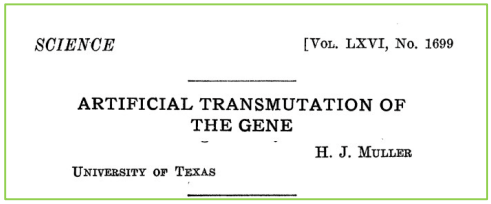
A deficiency leads to loss of function, and plants go from viny indeterminate to bush-type determinate



Ionizing radiation creates deficiencies

Although Muller is recognized as the discoverer of radiation-induced mutations in 1927, for which he received the Nobel Prize, radiation mutagenesis actually traces back to Emmy Stein in 1921



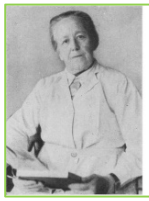


SCIENCE [Vol. LXVI, No. 1699

ARTIFICIAL TRANSMUTATION OF THE GENE

H. J. Muller

University of Texas



Über den Einfluß von Radiumbestrahlung auf Antirrhinum.

(Vorläufige Mitteilung.)

Von **Emmy Stein.**

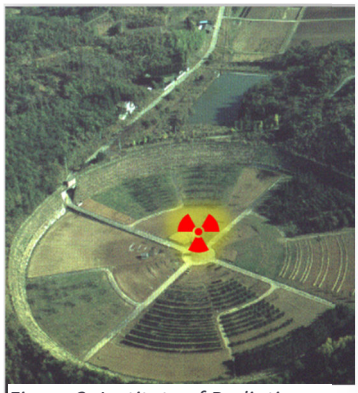
(Eingegangen 22. August 1921.)

Die auf der Versammlung der deutschen Gesellschaft für Vererbungswissenschaft demonstrierten Antirrhinum sind der Anlaß zu einigen vorläufigen Worten über die mit Radium angestellten Versuche.

Structural variants: Mutation breeding

When the needed mutation is not found in nature, it can be obtained by inducing structural variation, usually with ionizing radiations, which induce:

- Indels 4 bp - 8kb
- Inversions up to 1.5 kb
- Frame shift mutations
- Premature stop codons



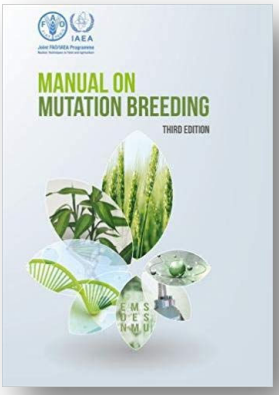


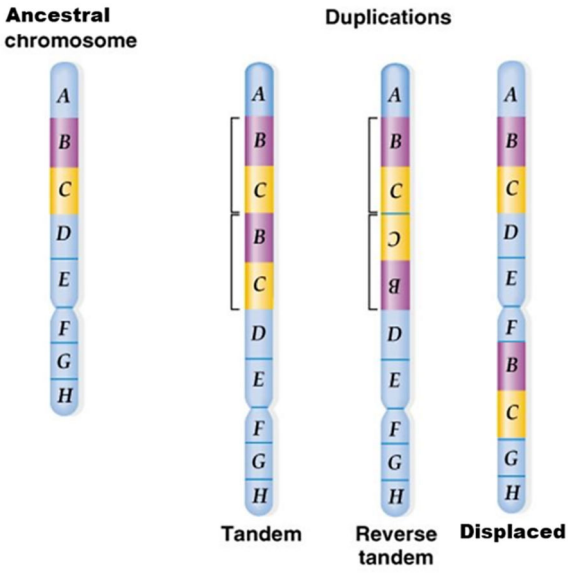
Figure 3. Institute of Radiation Breeding, Ibaraki-ken, JAPAN

Duplications

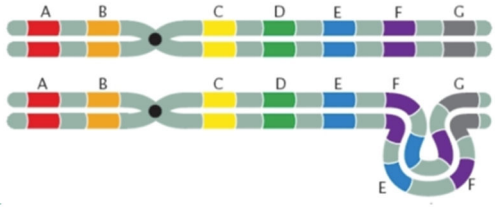
Types: Tandem, Reversed, & Displaced

Displaced can be:

- Fragment with centromere
- To another chromosome
- To another location on the same chromosome



Modified from Randall, PJ. iGenetics, Pearson Education Inc, published as Benjamin Cummings



Nature Education Adapted from Pierce, Benjamin. Genetics: A Conceptual Approach, 2nd ed

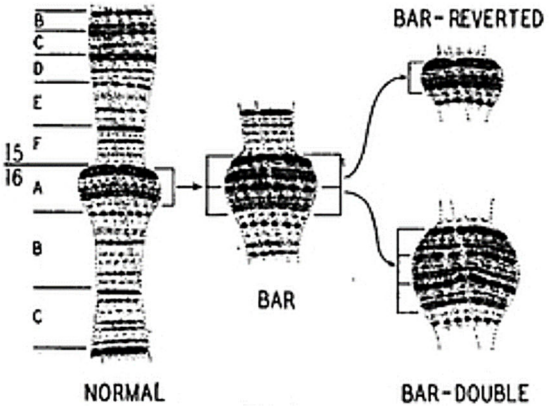
- First found by Bridges in Drosophila

Behavior of duplications

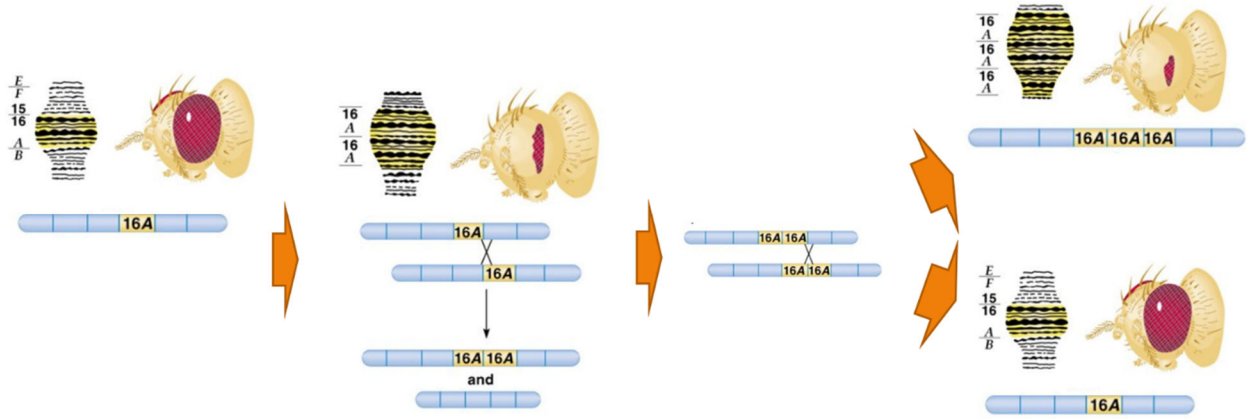
Bridges 1936

Bar eye, a sex-linked dominant trait

- In female flies, bar would mutate to double bar or back to normal
- Studying salivary gland chromosomes, found that bar was a duplication of bands 1-7 in the 16A chromosomal region.



Duplications prone to unequal crossover



Modified from https://slideplayer.com/slide/10755099/

- This illustrates one of the principal properties of duplications -- their propensity for unequal crossing over
- Duplications provide a way of adding genetic material
- Increase copy number of a gene
- 2 genes, identical by duplication, can then diverge by mutation to achieve different functions

Uses

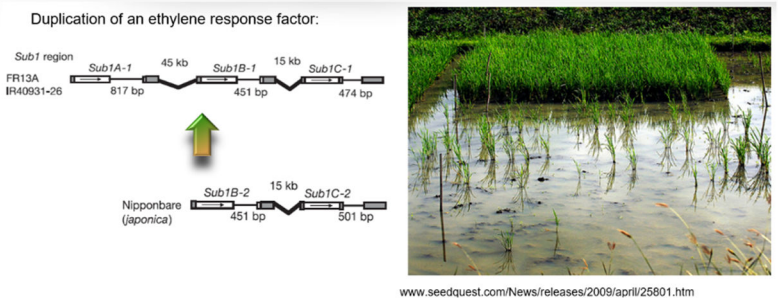
Study effect of gene dosage
Increase amount of desired gene product without resorting to polyploidy

Structural variants: Duplications

Structural variant duplications – affect the phenotype, but too small to affect fertility. They are prone to rearrangements that affect the phenotype (Sub 1 rice; Sorghum) or trigger RNAi (soybean, maize, rice examples)

Sub1 rice

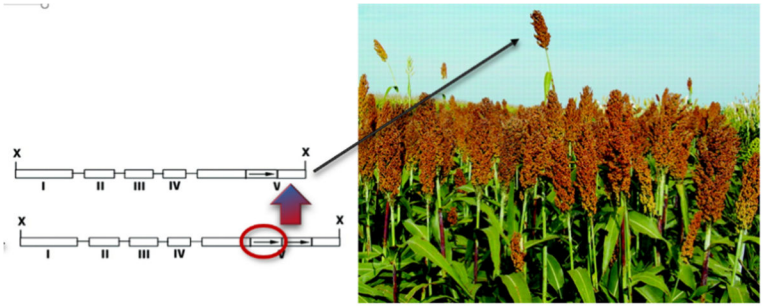
Xu et al., 2006



Soybean Vodkin seed coat color eg is missing here and in handout

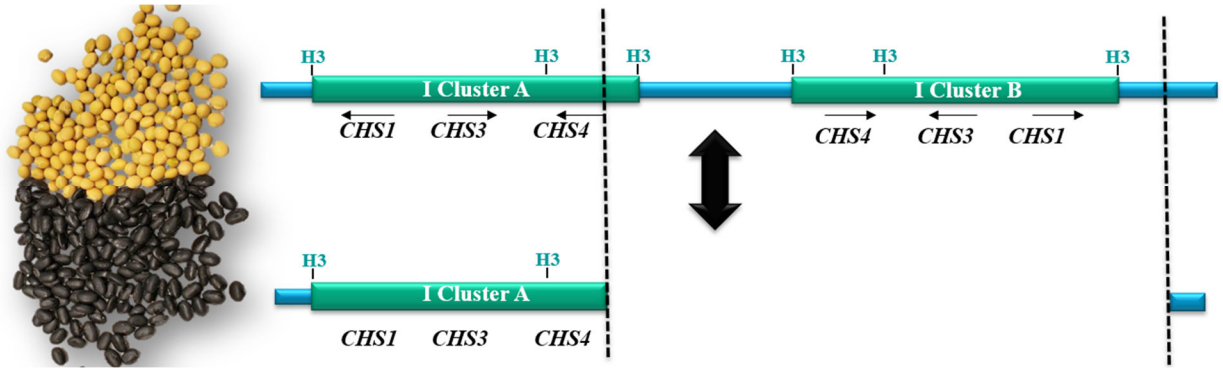
Sorghum dwarfism

Multani et al., 2003



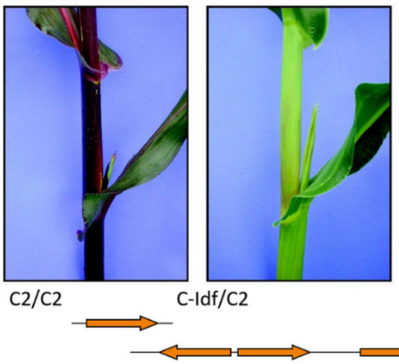
Seed coat color in soybean

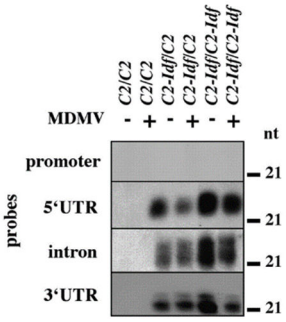
Tuteja et al, 2004



C-Idf green stalks in corn

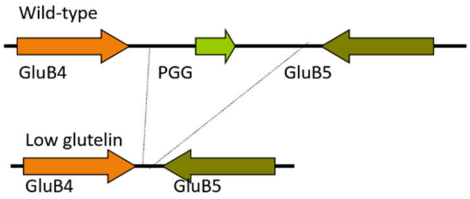
Della Vedova et al., 2005

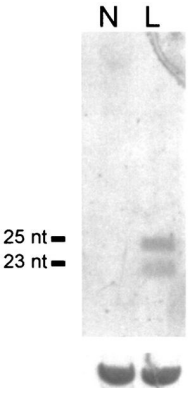




Low glutelin rice

Kusaba et al., 2003





Sunflower goes high-oleic

Lacombe et al., 2009

- High-oleic comes from what is known as the Pervenets sunflower.
- It was derived using dimethyl sulphate (DMS) on 'Vniimk 8931' in the 1970s.
- The partial gene duplication leads to siRNA.