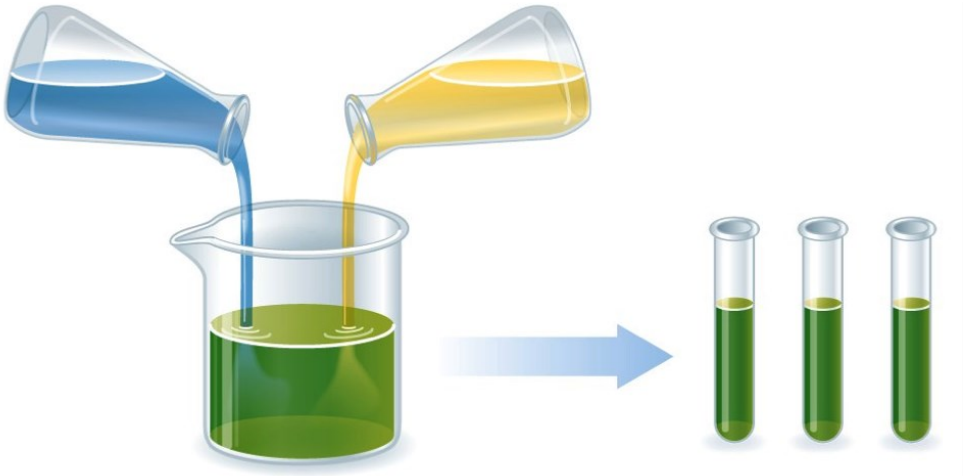
Inheritance

Inheritance

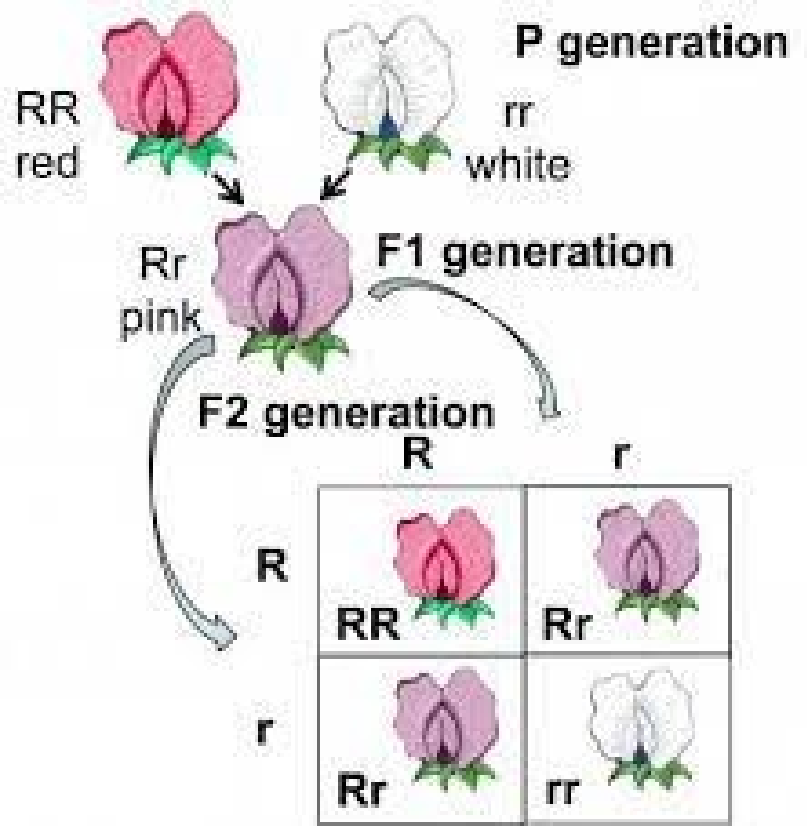
Blending inheritance

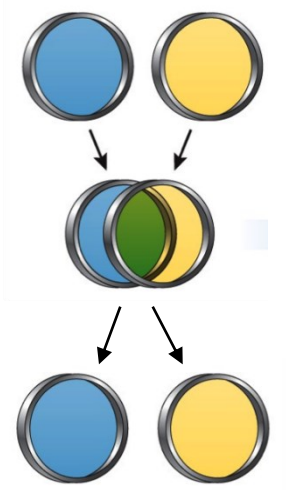


Fleeming Jenkin criticizes Darwin's theory of evolution.

Mendel's theory of inheritance (1866)

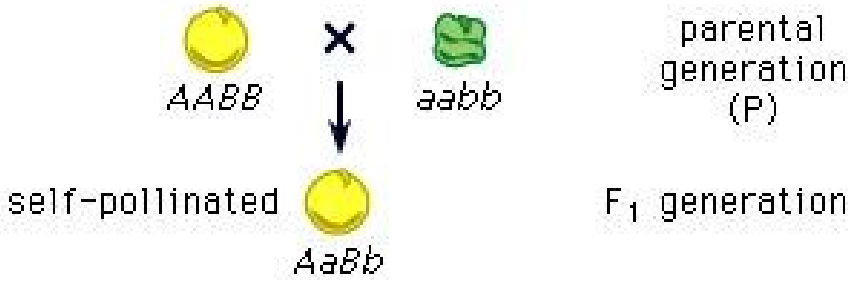
Law of segregation





Mendel's theory of inheritance

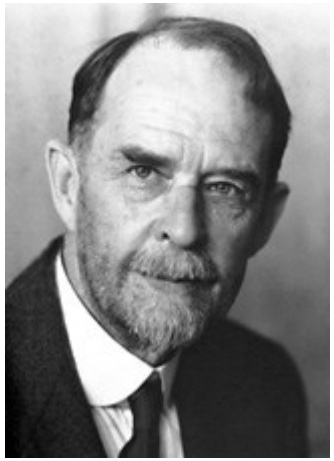
Law of independent assortment



♀ \ ♂	pollen: AB	pollen: Ab	pollen: aB	pollen: ab
ovules: AB	AABB	AABb	AaBB	AaBb
ovules: Ab	AABb	AAbb	AaBb	Aabb
ovules: aB	AaBB	AaBb	aaBB	aaBb
ovules: ab	AaBb	Aabb	aaBb	aabb

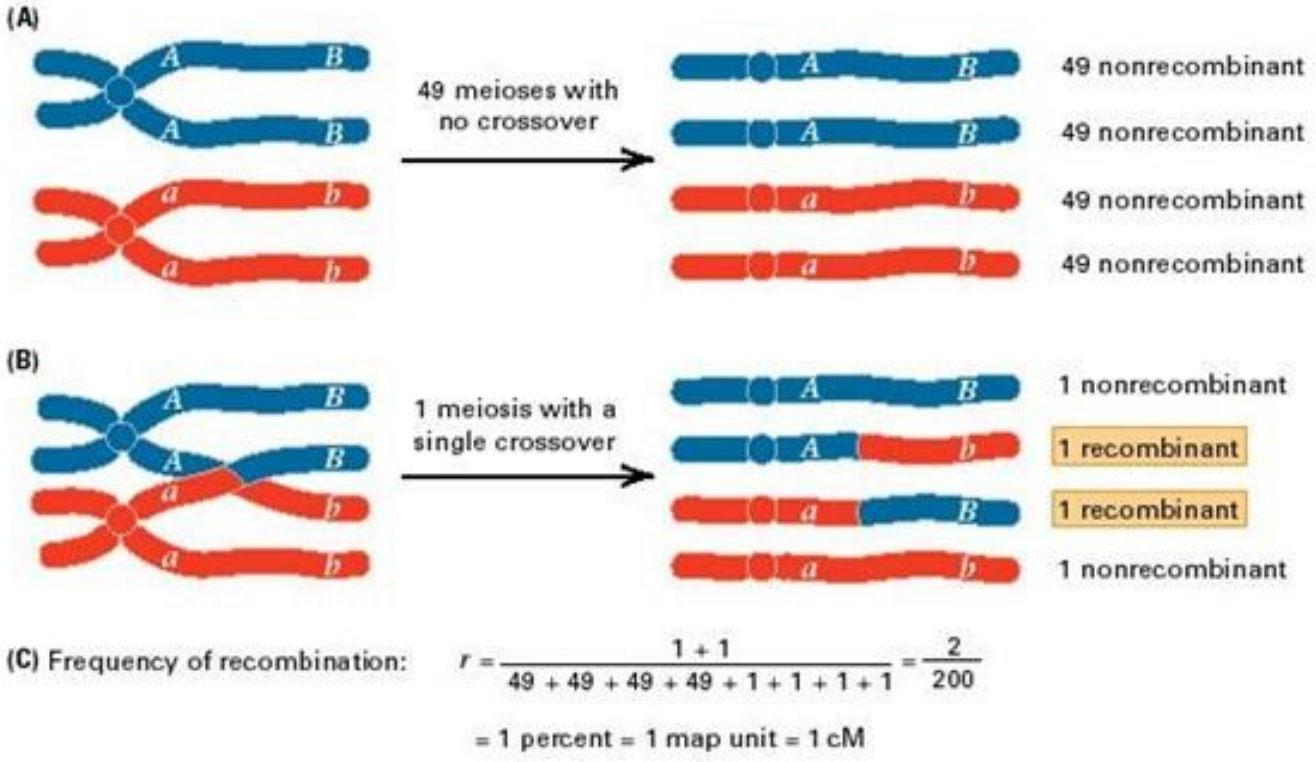
F2 generation

Chromosomal theory of inheritance and gene linkage



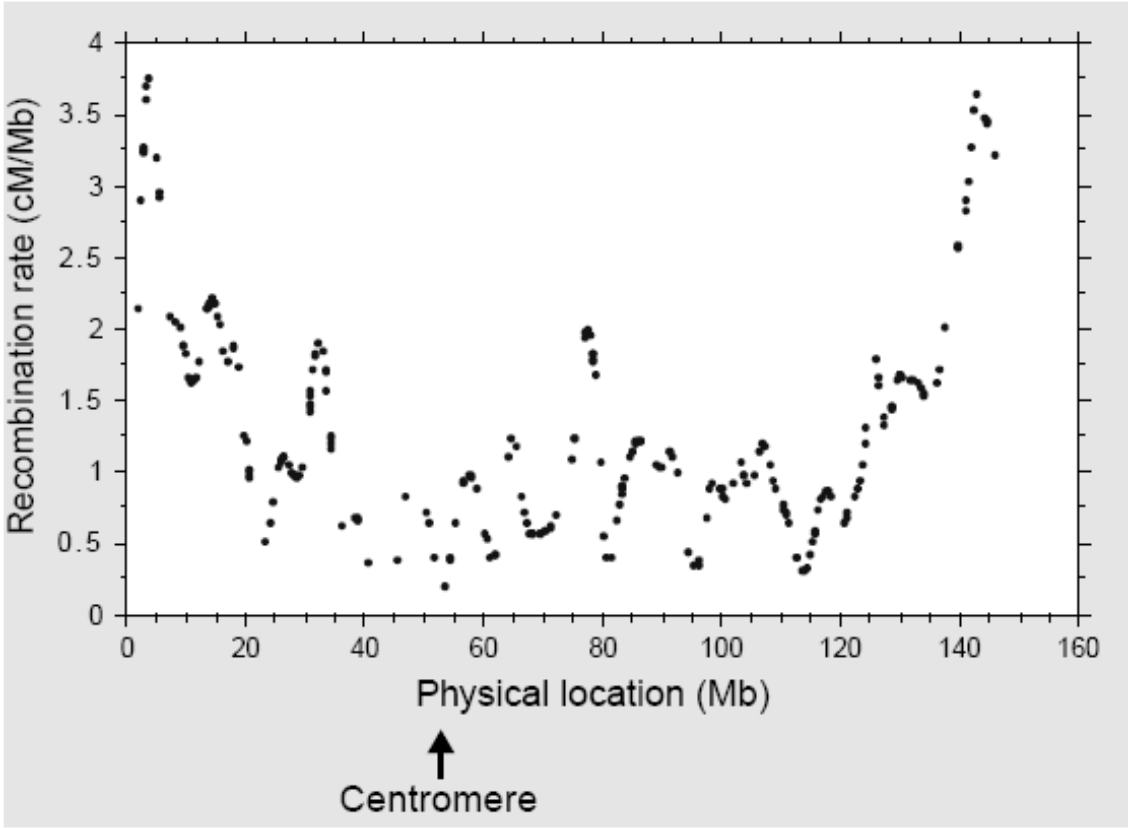
Thomas Morgan

- Aleles of different genes that are localized on the same chromosome tend to be inherited together.
- 1 cM ~ 1% recombinant genotypes



Recombination rate (r)

- Higher at the ends of chromosomes (near telomeres), lower around centromers.
- Recombination hotspots in some organisms (e.g. mammals).
- Crossing-over interference. Usually 1 crossing-over per chromosome (max. 3). Leads to higher recombination rate in smaller chromosomes.



Recombination rate (r)

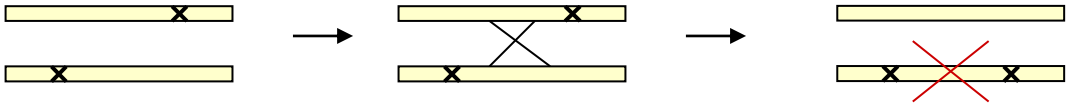
- Males usually have higher recombination rates than females.
  humans: 1,7 x ; mouse 1,3 x
- **Haldane-Huxley rule**. If one sex do not recombine, it is the heterogametic sex (např. *Drosophila*, *Bombyx*).
- Absence of recombination on non-pairing sex chromosomes (Y,W).

XY males

ZW females

Evolutionary importance of recombination

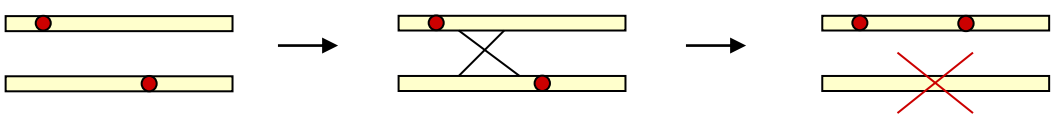
- Slows down accumulation of deleterious mutations (Muller's ratchet).

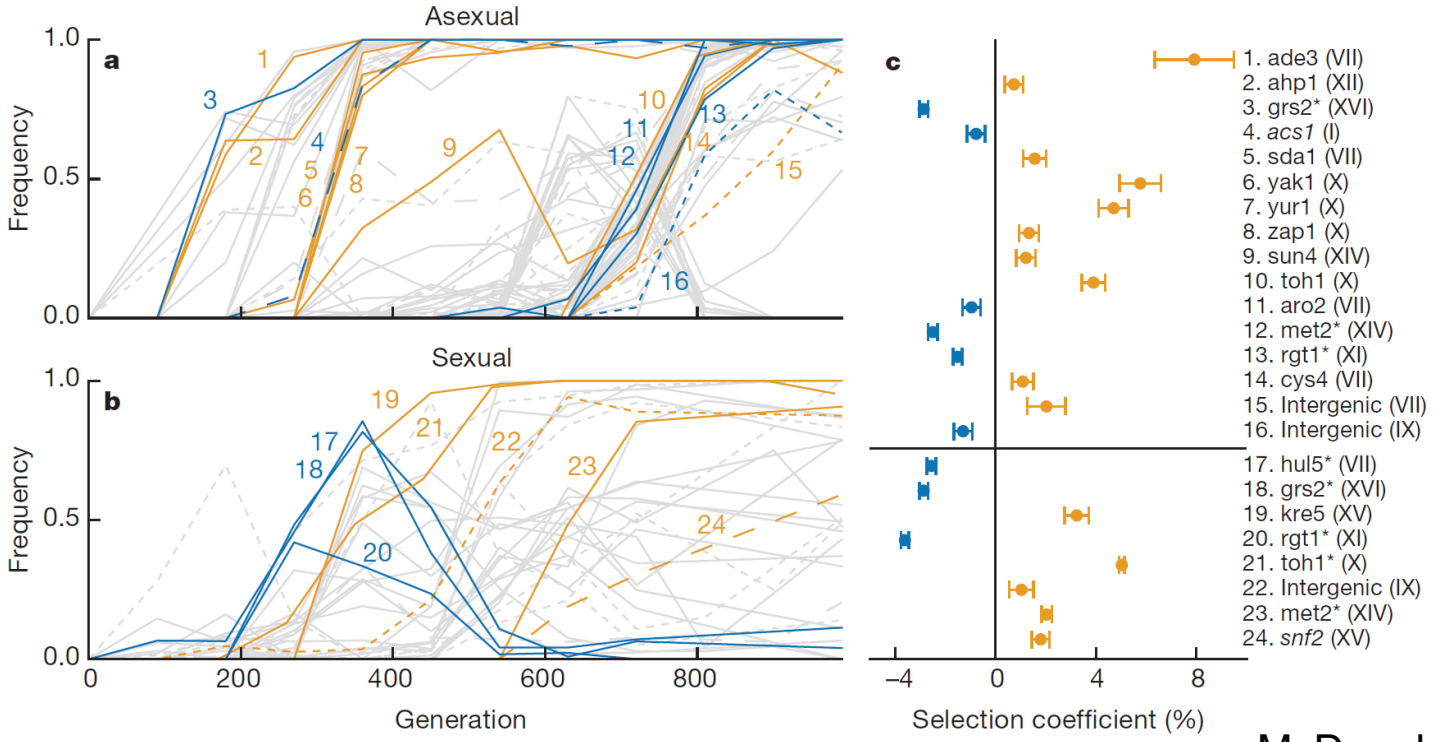


J. H. Muller

Evolutionary importance of recombination

- Allows to combine multiple advantageous mutations.
  Speed up adaptive evolution.





McDonald et al. 2016

Mendel's theory of inheritance

Law of uniformity and identity of reciprocal F1 hybrids

♀ AA × ♂ aa

↓

Aa

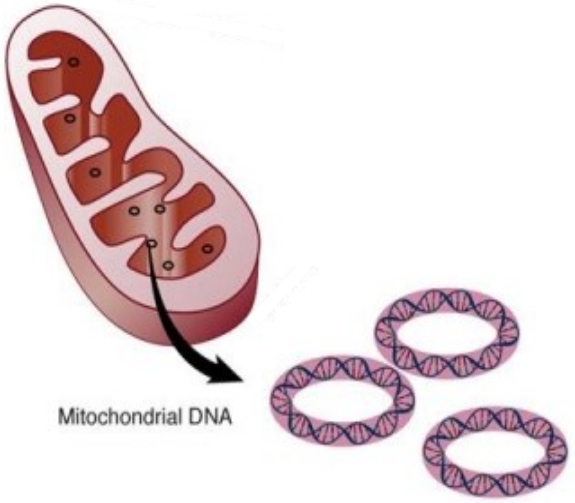
♂ AA × ♀ aa

↓

Aa

Uniparental inheritance

Mitochondrial and plastid DNA



- Mostly maternal inheritance
- „Mothers curse“
- In rare cases paternal inheritance (molluscs).
- Most genes from mitochondrial and plastid DNA moved to nukleus.

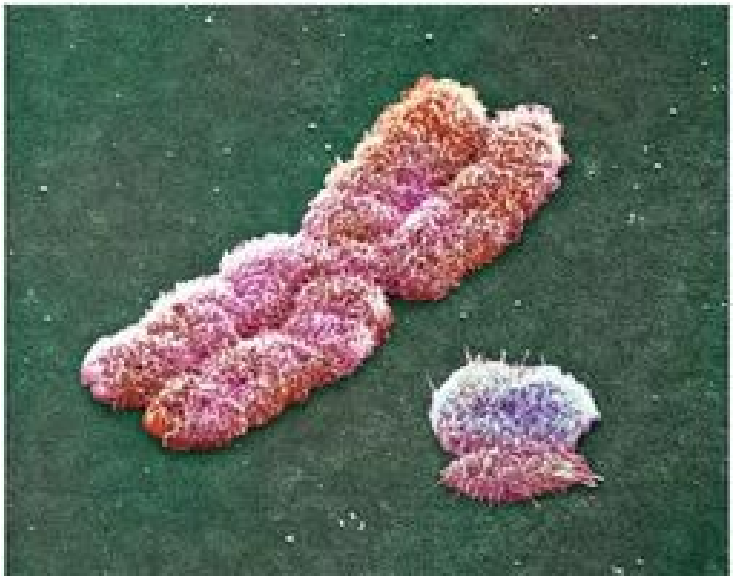
Intracelullar parazite of Arthropods

Wolbachia

- cytoplasmic incompatibility (infected males cannot reproduce with uninfected females)
- partenogenesis (infected females can reproduce without males)
- feminization of males
- killing males

Sex chromosomes

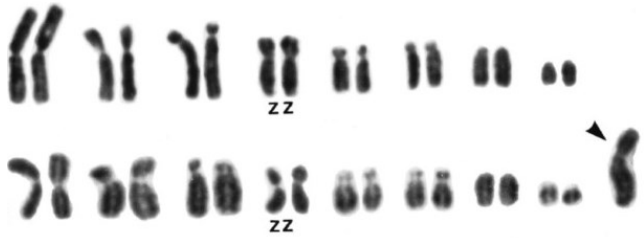
- Chromosom Y paternal inheritance.
- Chromosom W maternal inheritance.

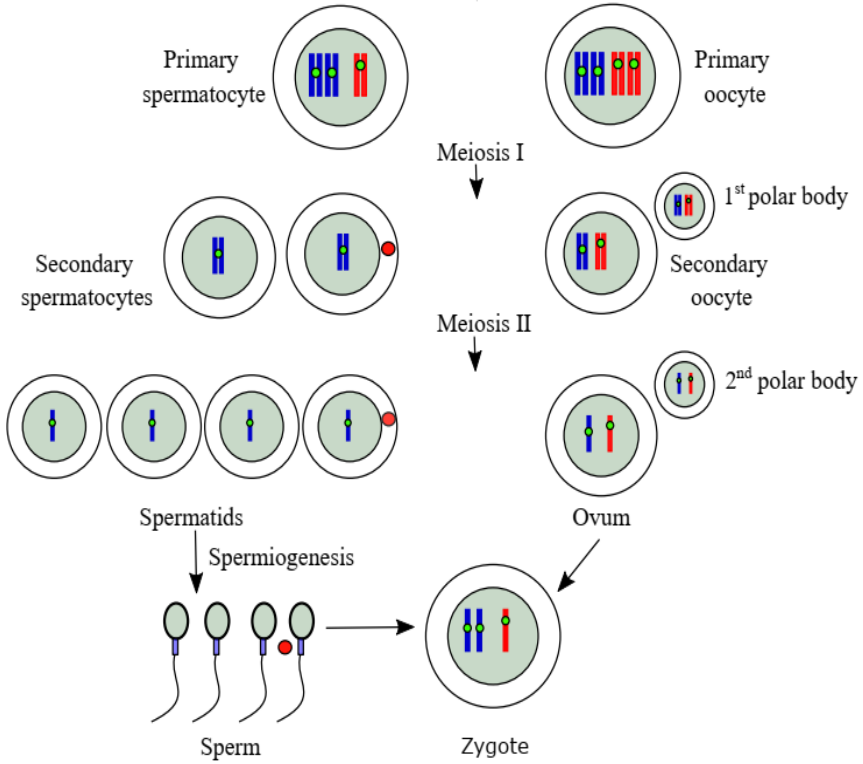


Germline-restricted chromosome

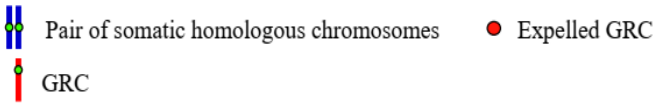
soma

testis



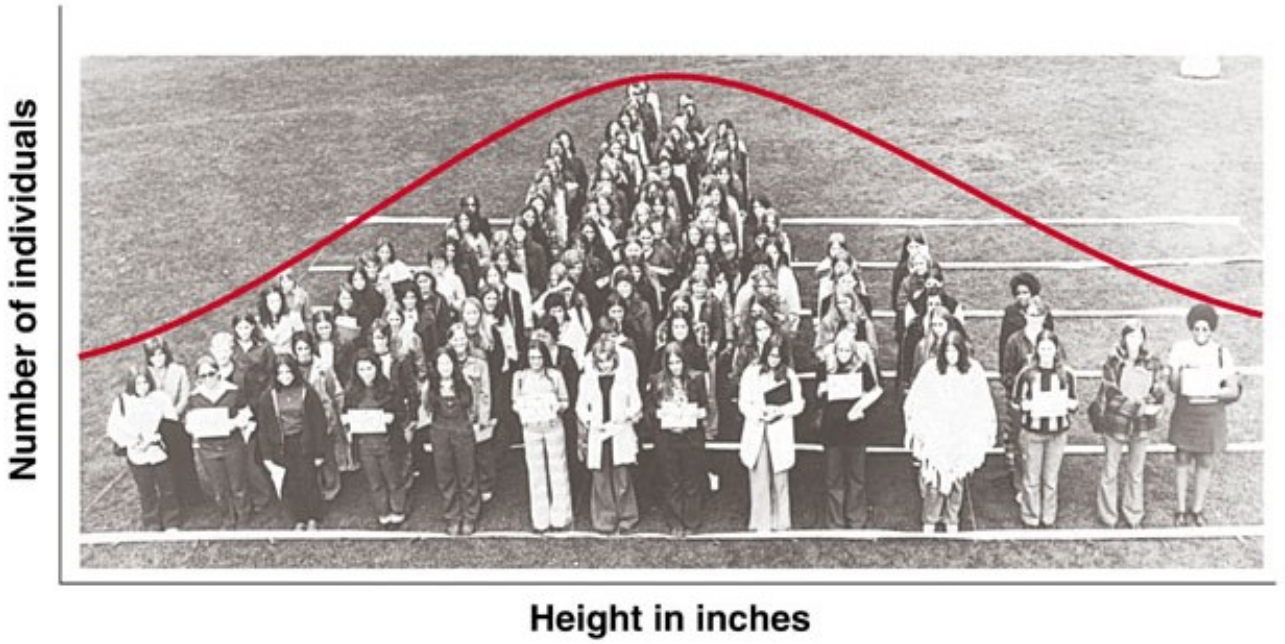


Pigozzi MI & Solari AJ (1998)



Inheritance of quantitative traits

- continuous variation of traits
- traits underlined by many genes (interactions among genes)
- traits are often affected by environment
- inheritance can be less predictable



Heritability (H^2, h^2)

- Proportion of variance in a phenotype caused by genetic factors.

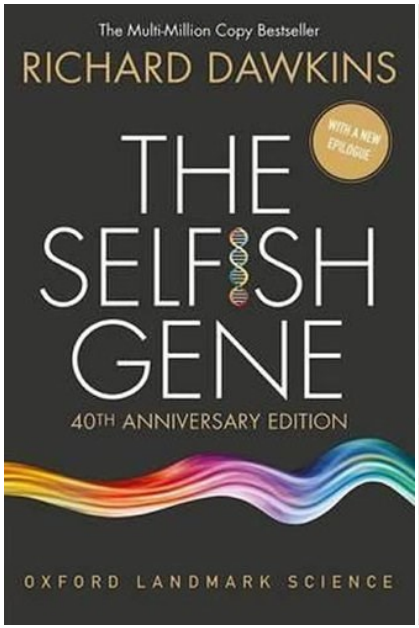
$$H^2 = V_G/V_P$$

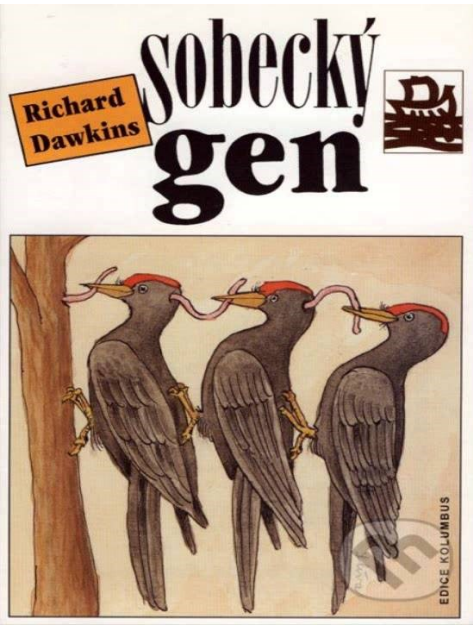
$$V_P = V_G + V_E$$

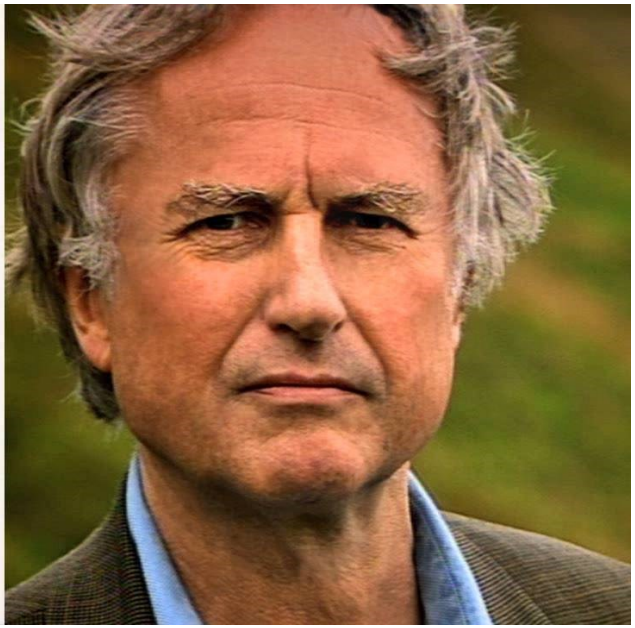
V_P - phenotype
V_G - genotype
V_E - environment

- Range between 0 and 1.
- Traits with higher heritability better respond to selection .

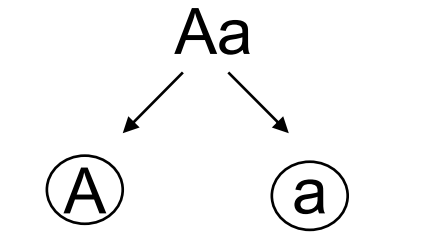
Non-Mendelian inheritance







Meiotic drive

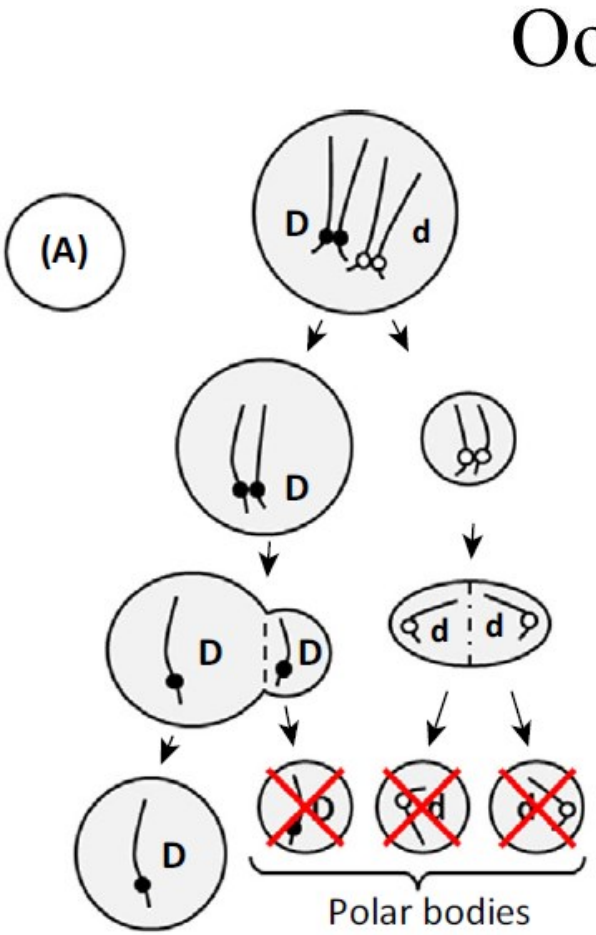


~~1 : 1~~

10 : 1

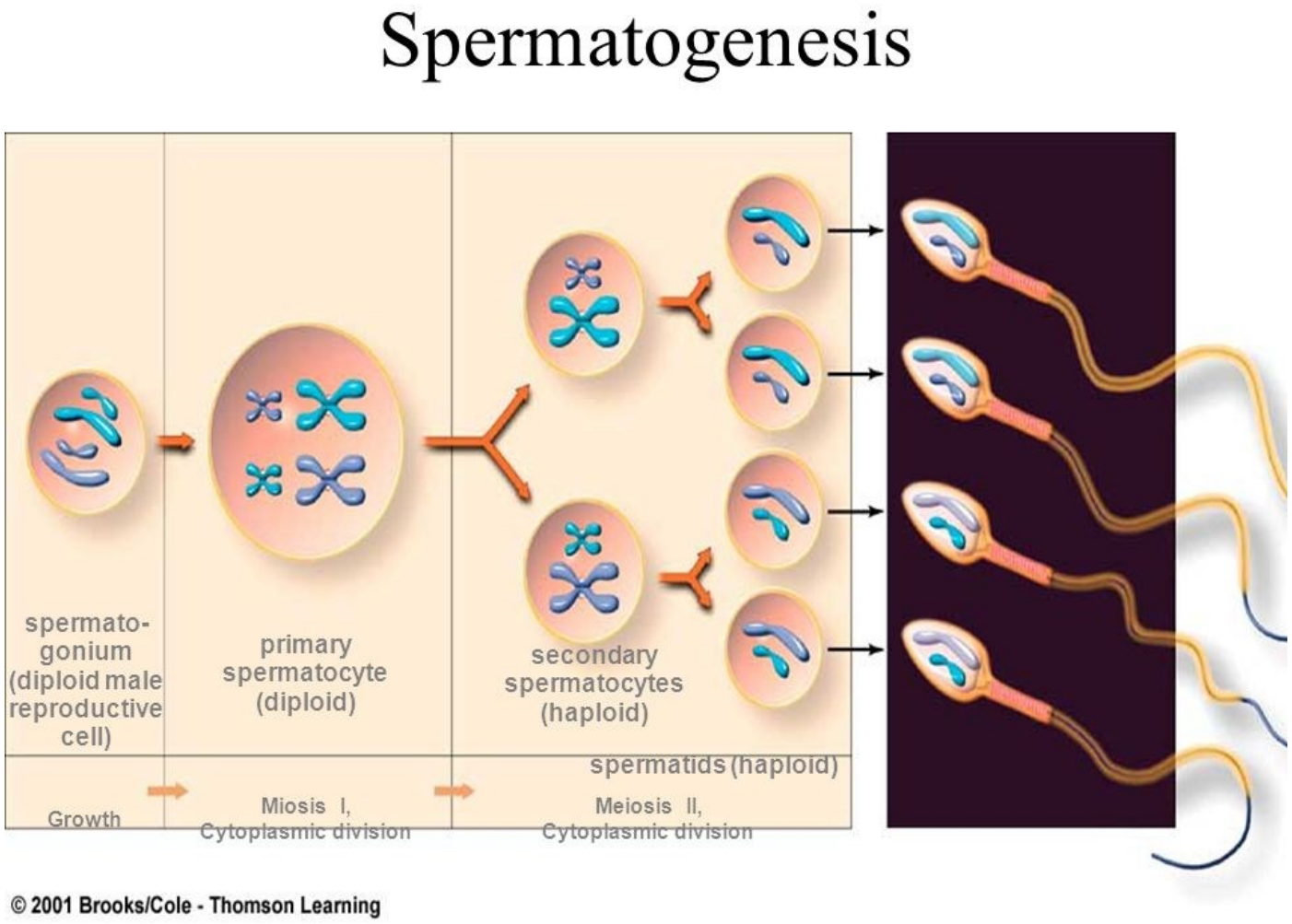
1 : 10

Female meiotic drive

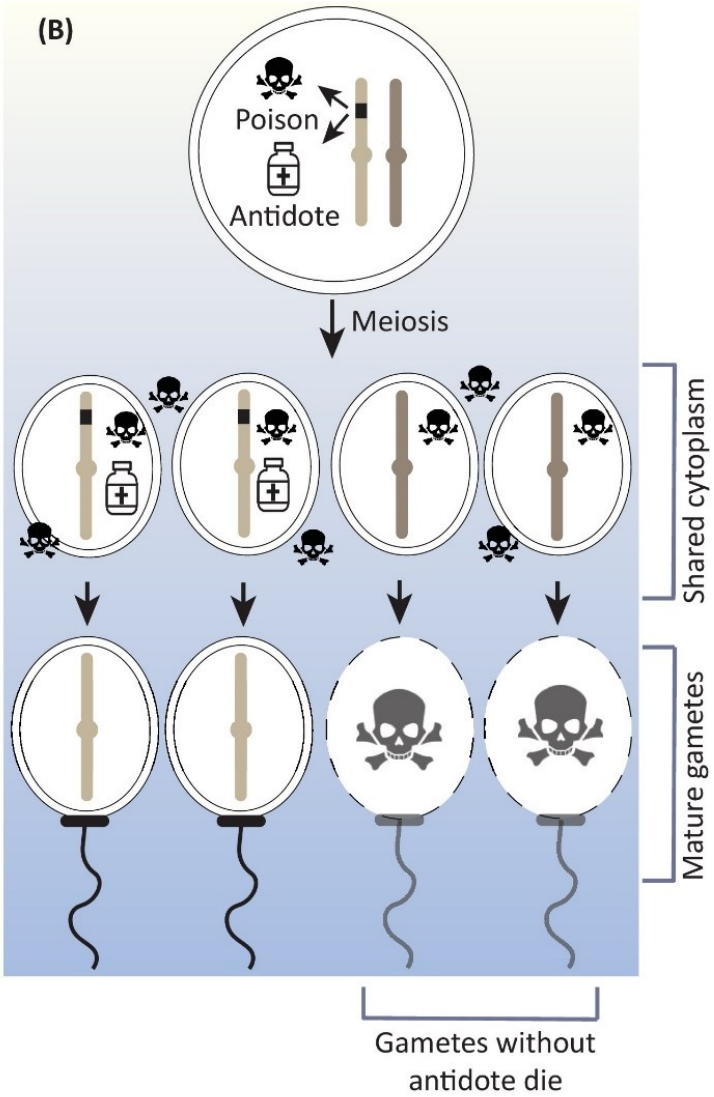


Monkey flower *(Mimulus guttatus)*

Male meiotic (gametic) drive



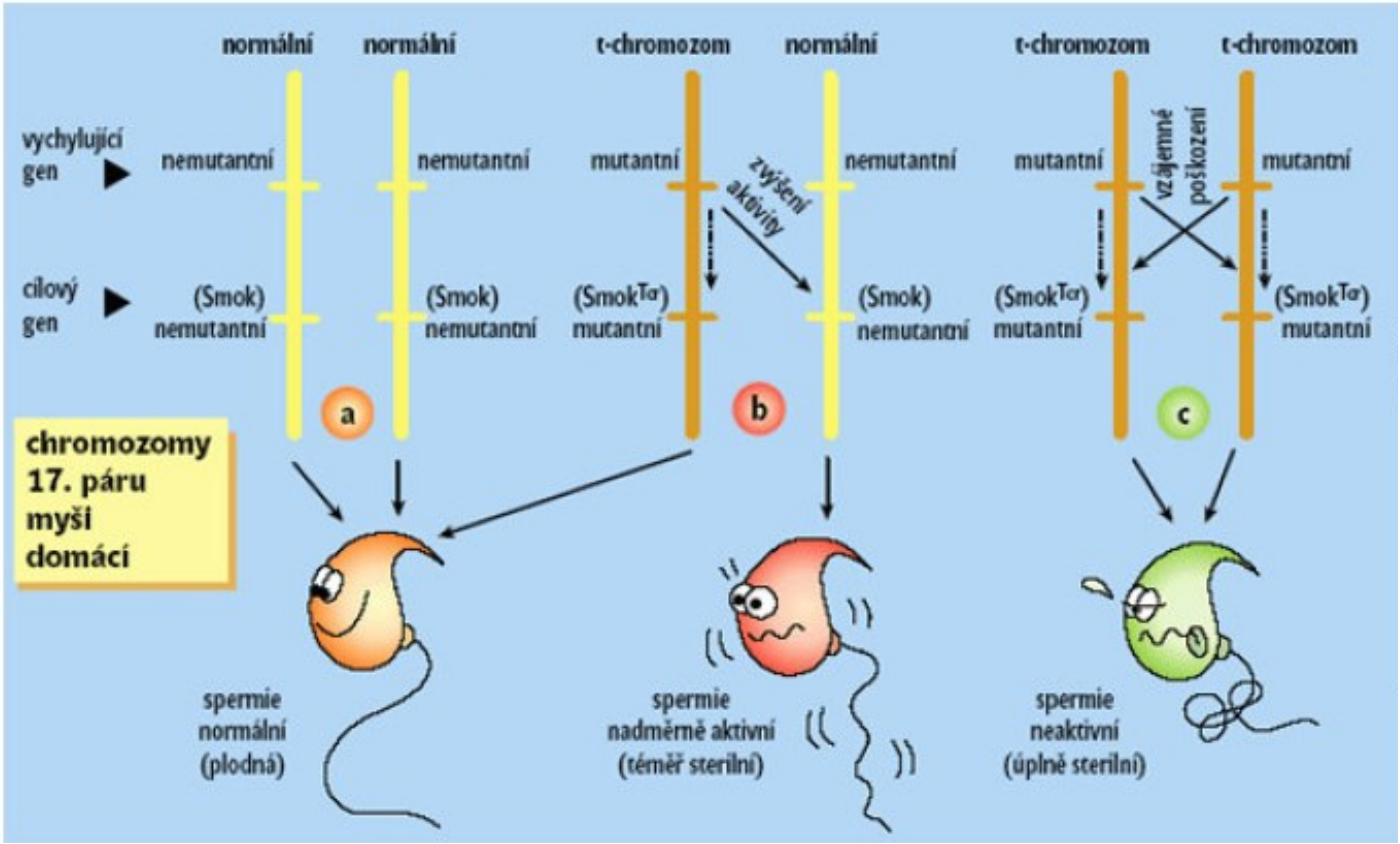
Mechanisms of male meiotic drive



Drive mostly occur in non-recombining regions (inversions)

t-haplotype

- Inversion on chromosome 17

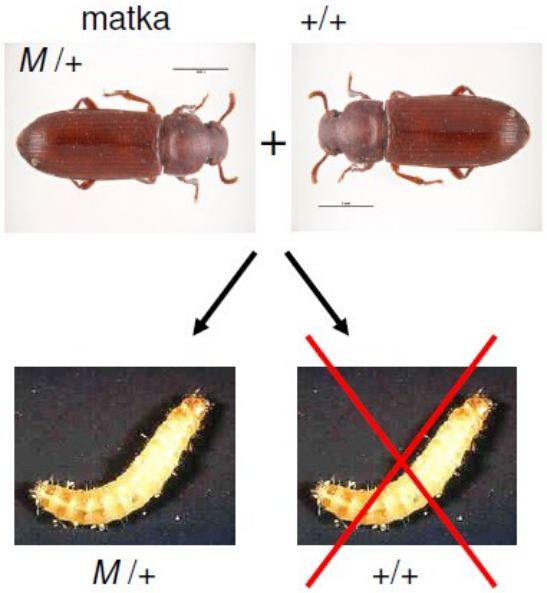


Zygotic drive

Medea (Maternal-Effect Dominant Embryonic Arrest)

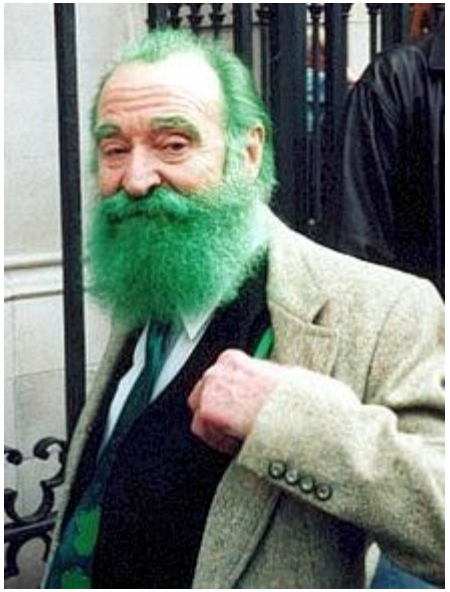
- Allele causes death of progeny that do not inherite it
- Maternally expressed poison and zygotically epressed antidote.

Tribolium castaneum



Green-beard effect

William D. Hamilton

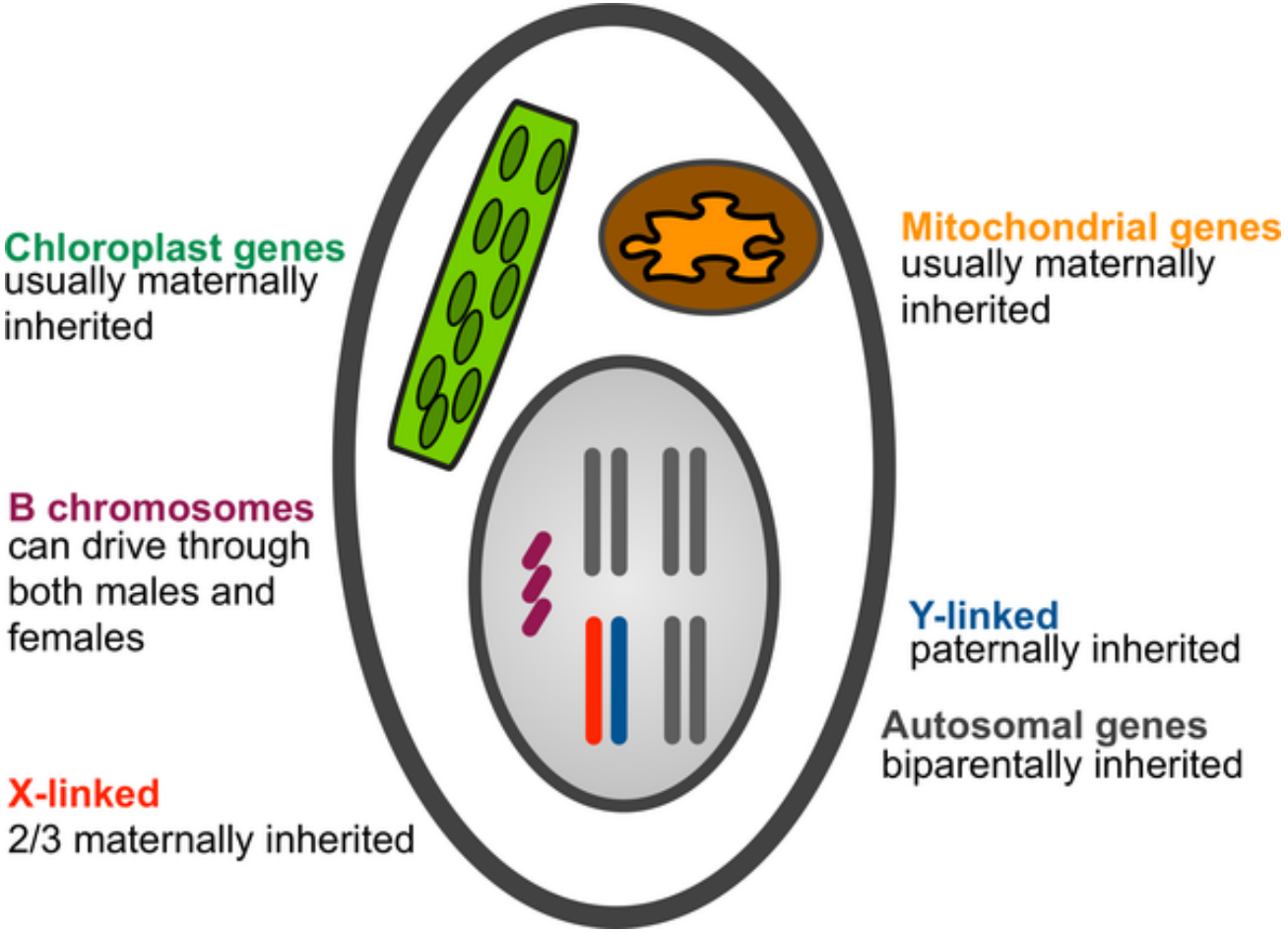


Solenopsis invicta
Supergen Gp-9
Polygynnous colonies (Bb queens) a monogynnous coloniese (BB queen).
Workers (Bb) but not workers (BB) kill BB queens when they are introduced to polygynous colonies.

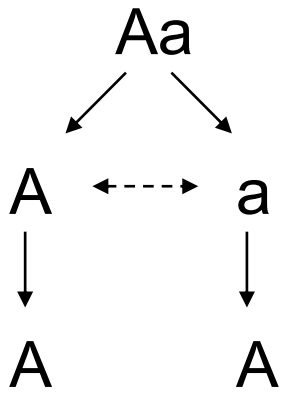
Syntetic drive

- Could be used to inroduce quickly some allele to the population.
- Possible practical applications: regulation of disseases etc.

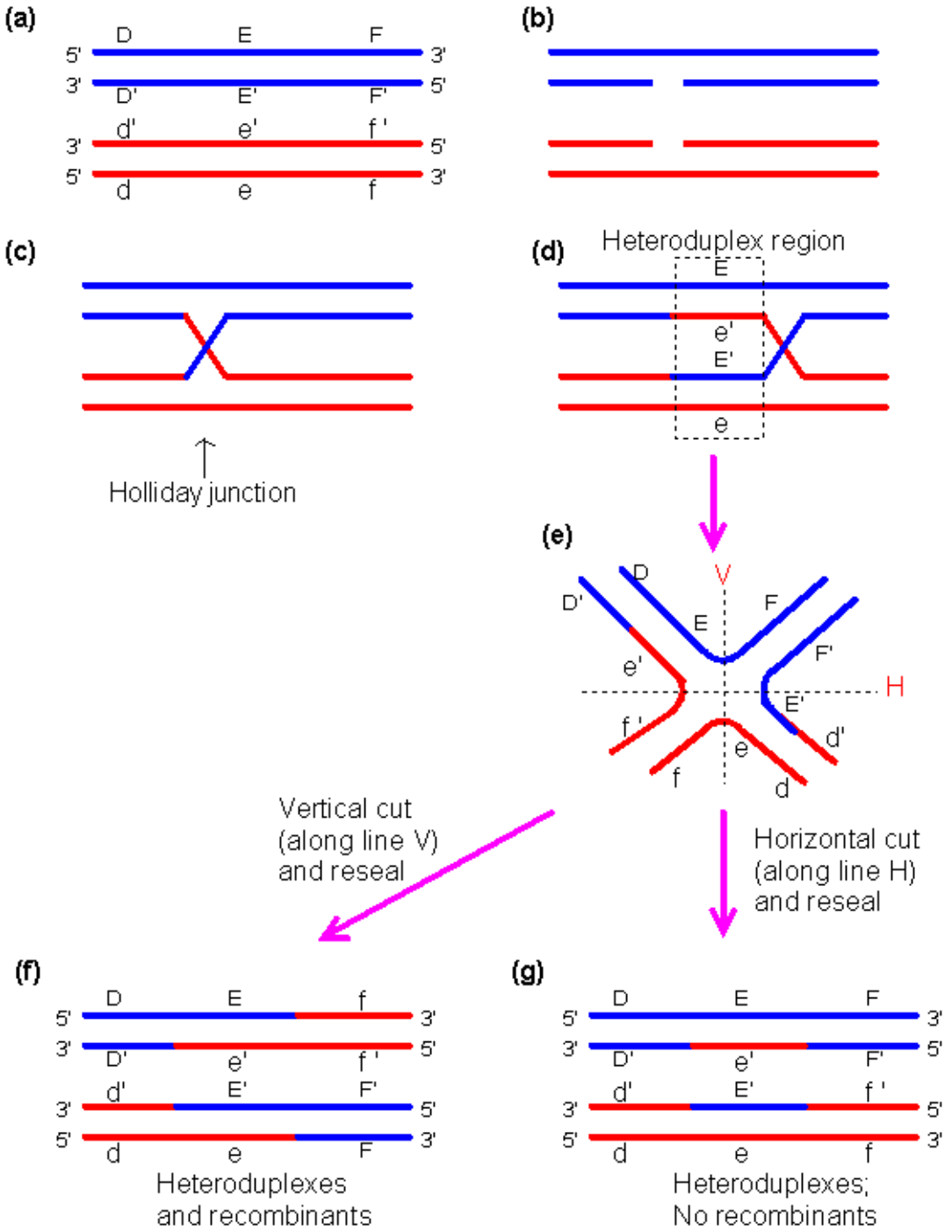
Selfish B chromosomes



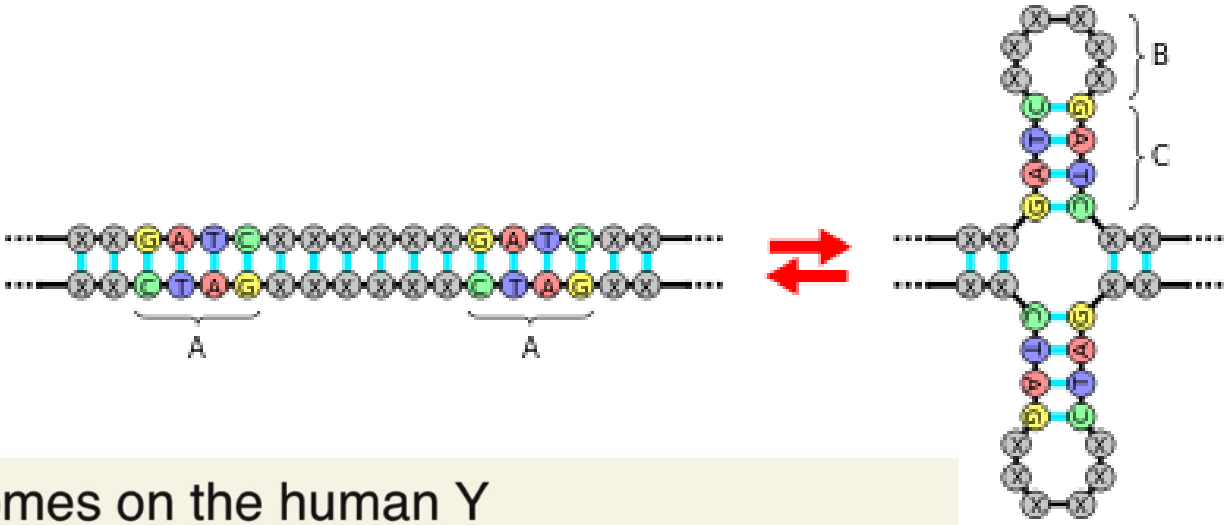
Gene conversion

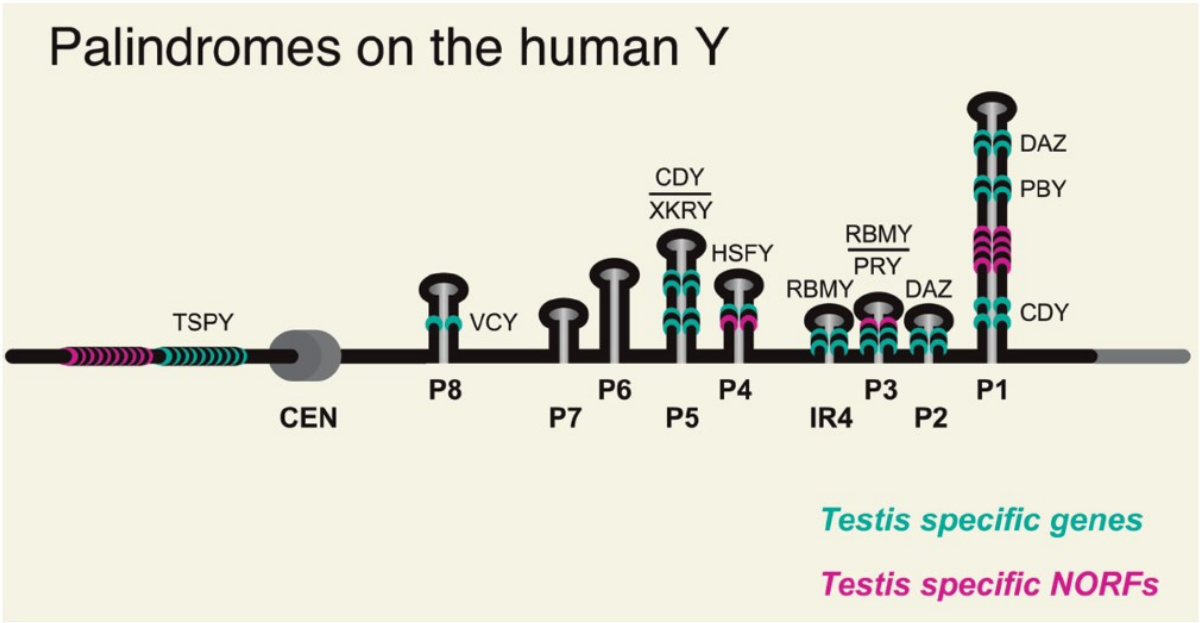


- Gene conversion during meiotic recombination.



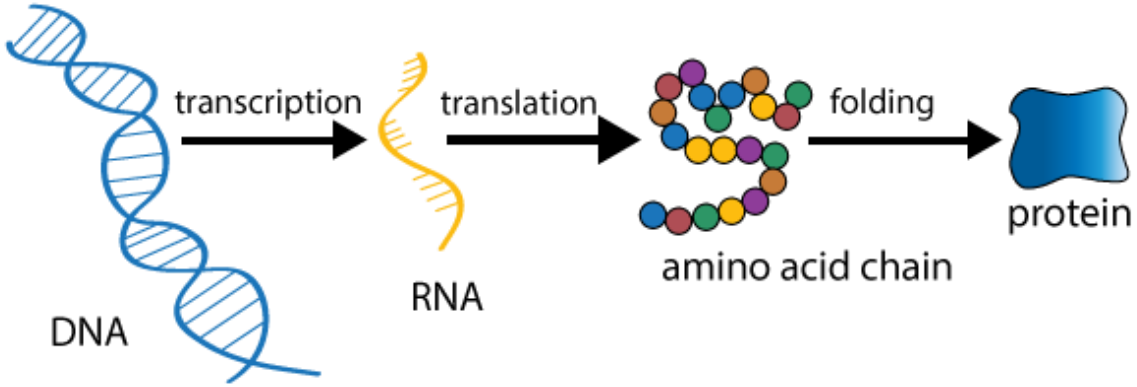
Gene conversion between paralogous sequences





Epigenetic inheritance

genotype



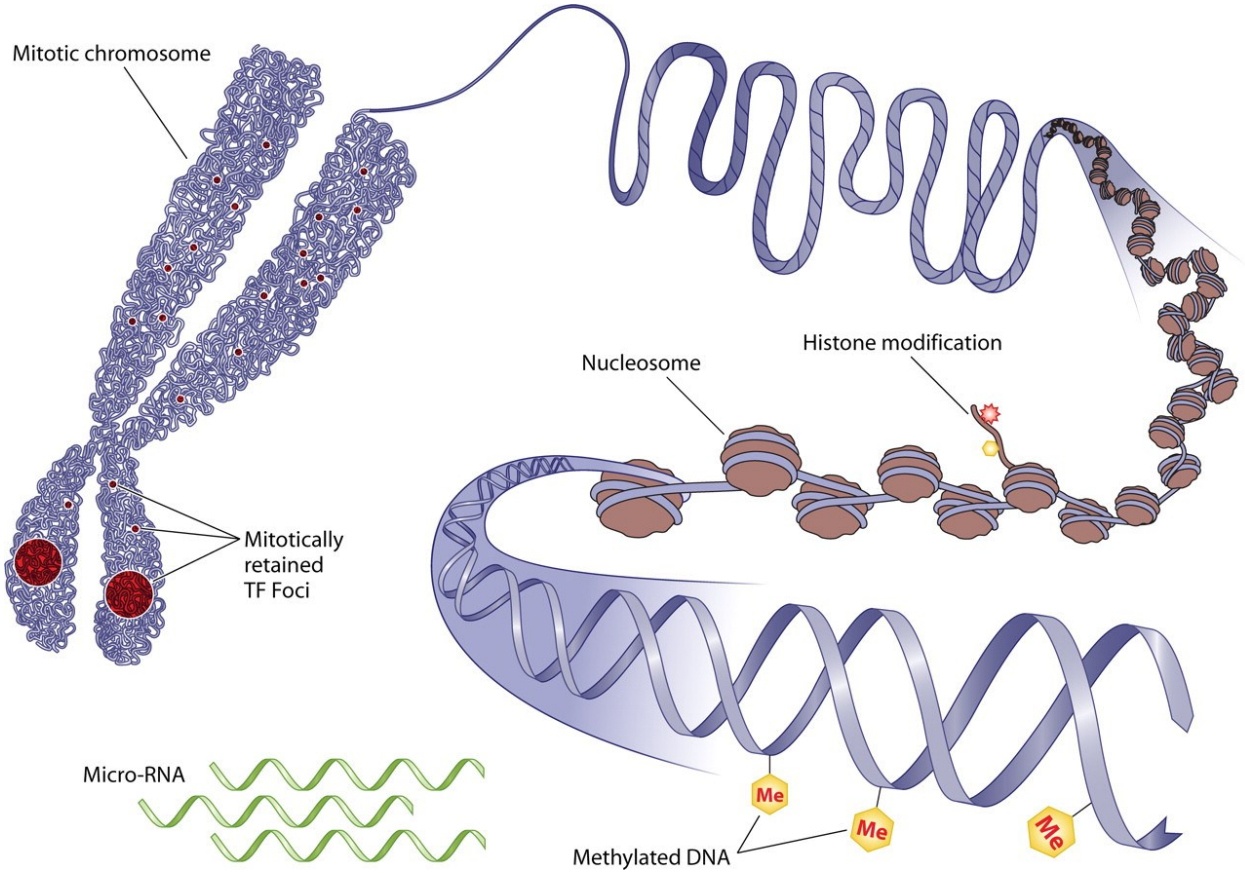
phenotype

Molecular mechanisms of epigenetic inheritance

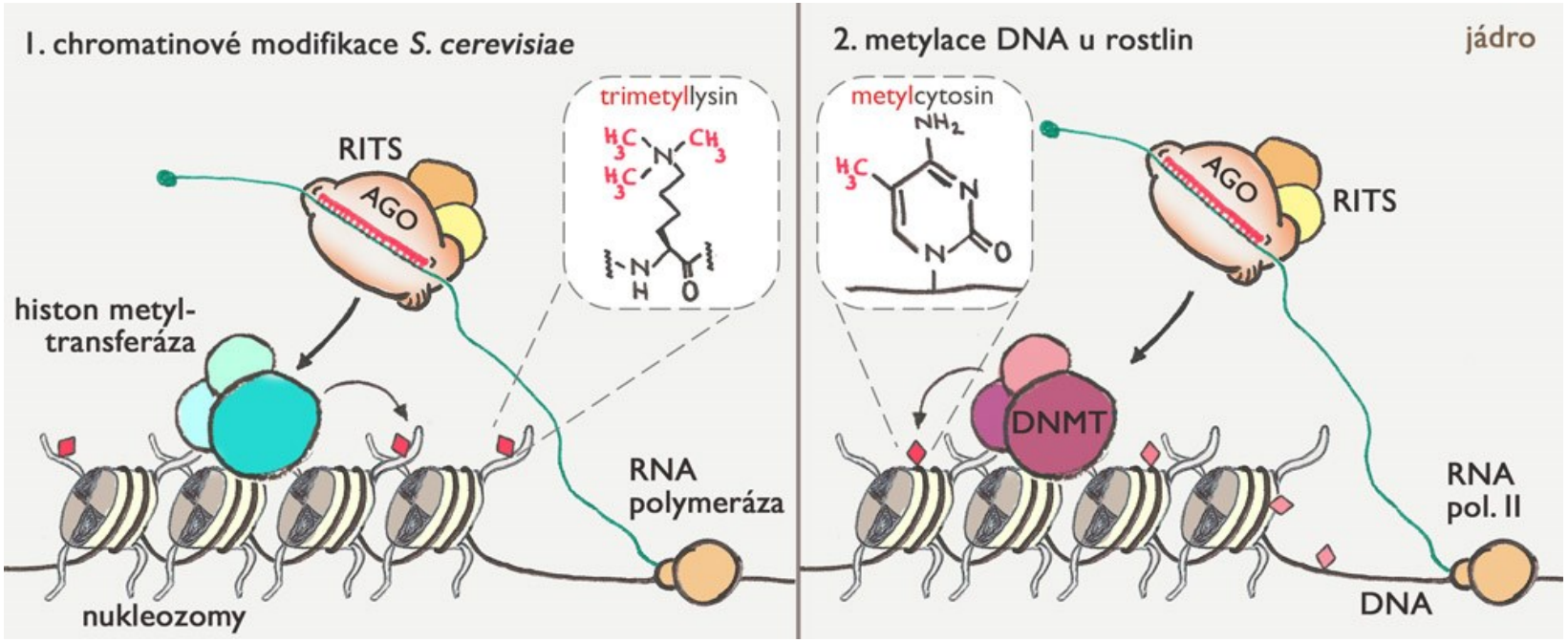
Metylation of DNA (5mC)

Histon modifications

Small non-coding RNAs



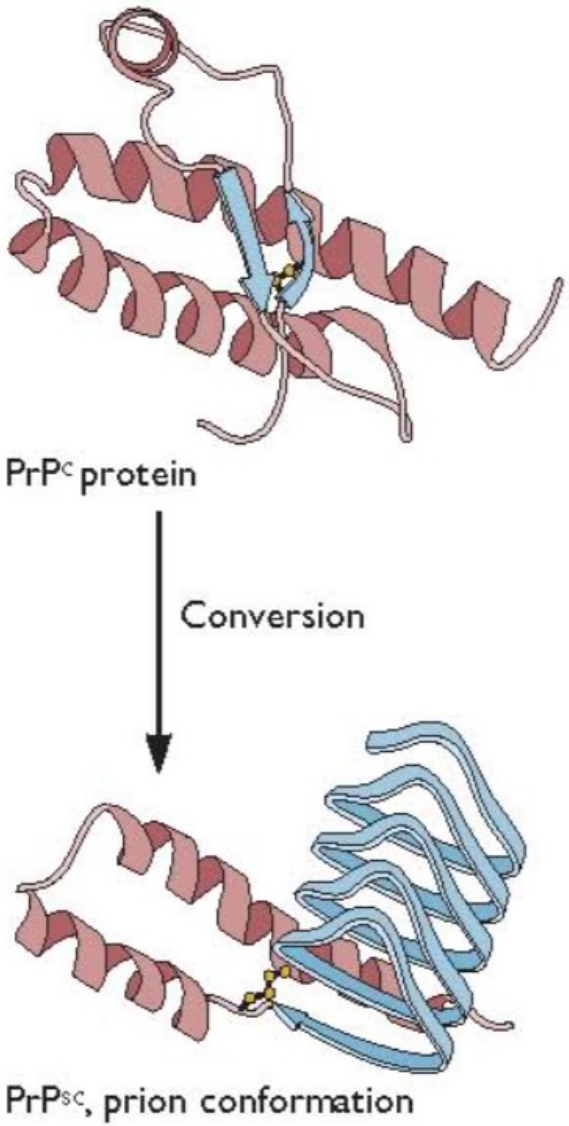
Small non-coding RNAs can induce changes of chromatin



Svoboda a Jankele, 2015, Vesmír

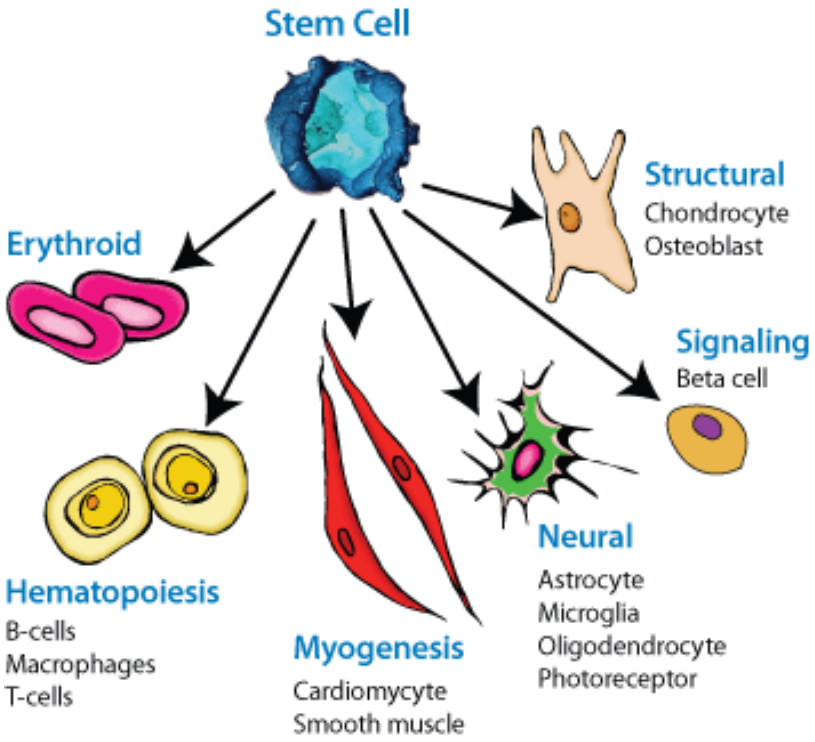
Prions

- Infectious proteins
- Can cause neurodenerative diseases
  - Kuru
  - Creutzfeldt–Jakob disease
  - Bovine spongiform encephalopathy (BSE) (mad cow disease)
- Yeasts: [PSI+], prion of Sup35 protein. Termination of translation. Prion form leads to translation over stopcodon. Reveals hidden genetic variation.



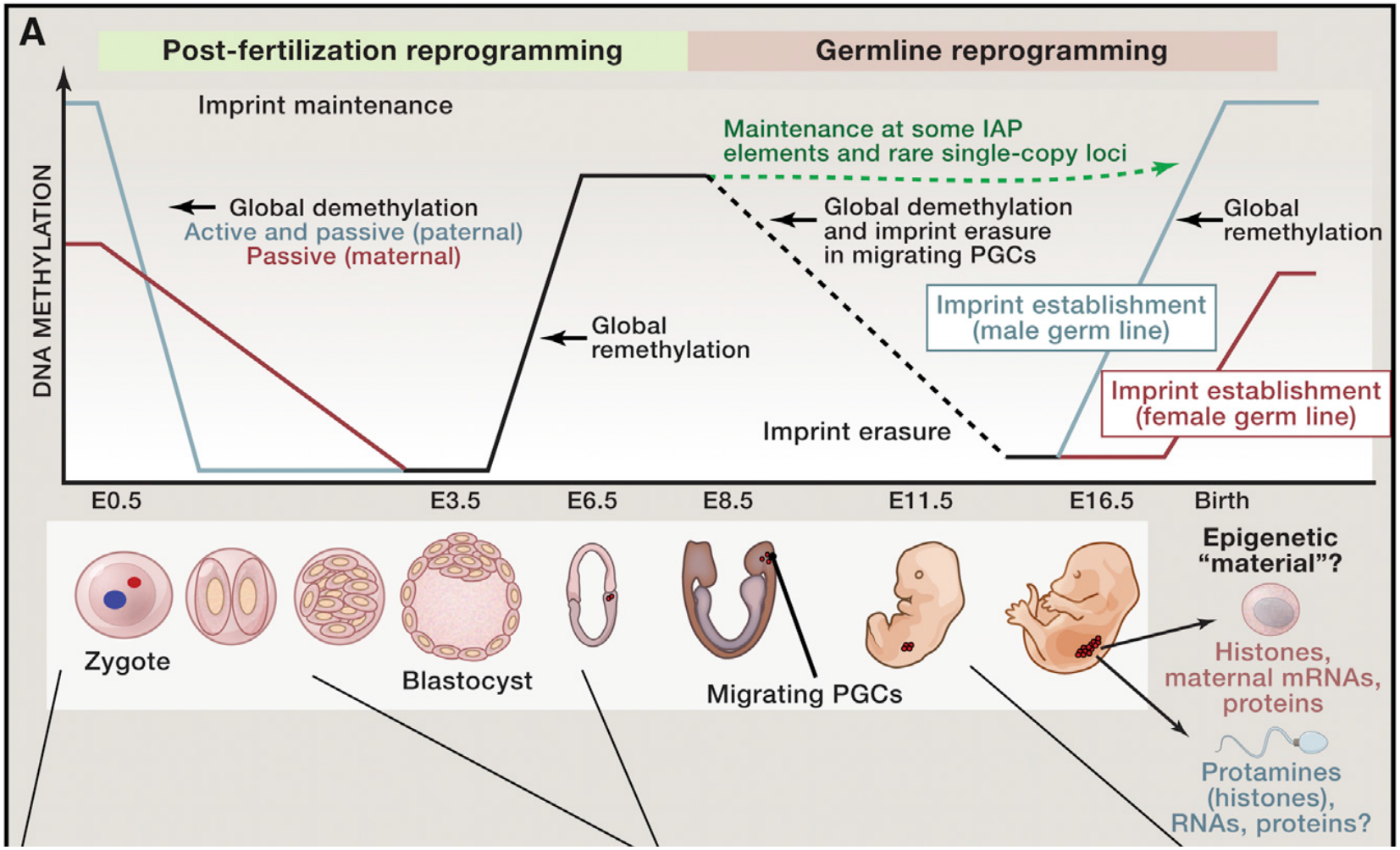
Epigenetics

Originally discipline about cell differentiation during ontogeny



Transgeneration epigenetic inheritance?

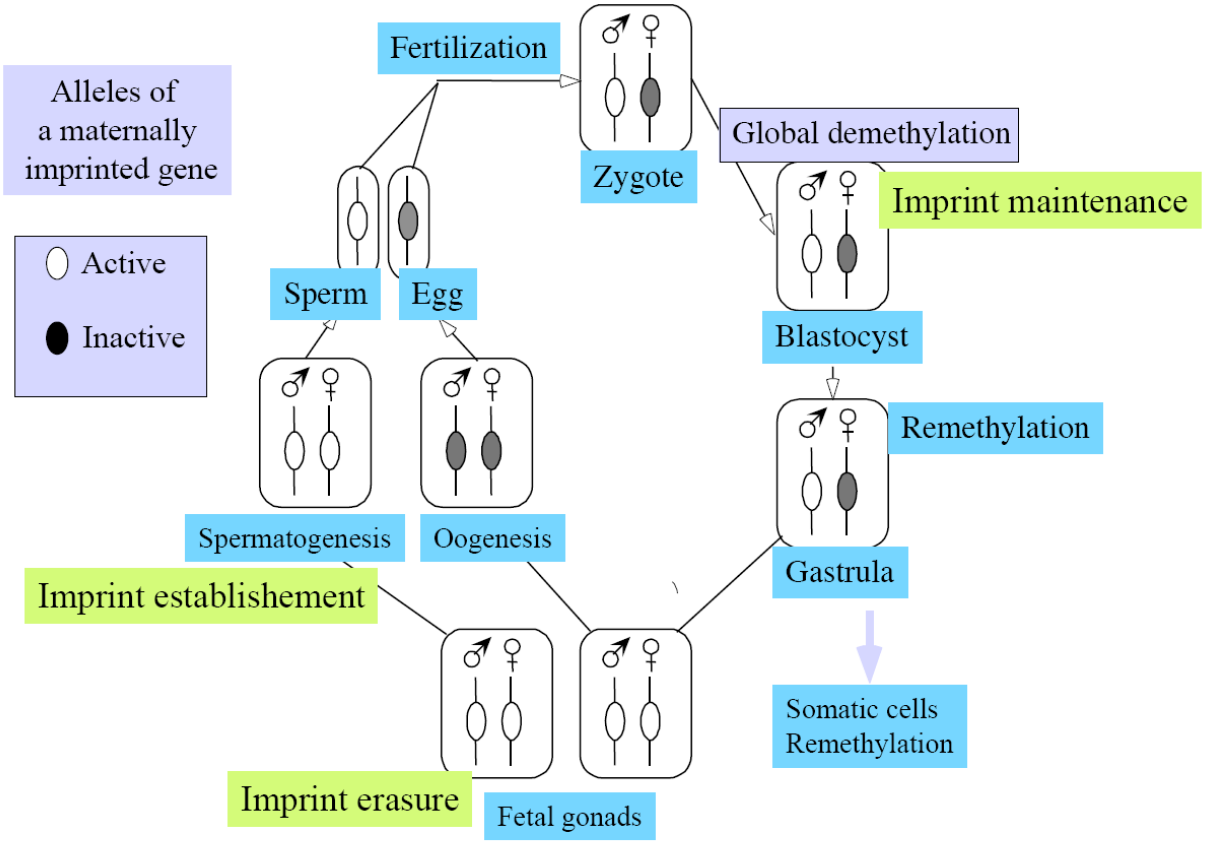
Epigenetic reprogramming of DNA



- Not complete. Some genes can escape reprogramming (e.g. imprinted genes in mammals, retrotransposons).

Genomic imprinting

- Expression only from a maternal or paternal allele
- Epigenetic marks are established in the germline of parents and are inherited to offspring.



Genomic imprinting

Theory of parental conflict
(David Haigh, 1991)

Paternally expressed genes (e.g. Igf2): support prenatal growth
Maternally expressed genes (e.g. Igf2r): inhibit prenatal growth

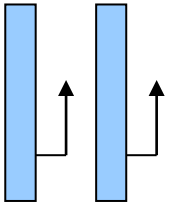
Mammals, angiosperms (endosperm)

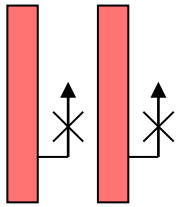
Aberrant genomic imprinting

Angelman syndrom

Prader-Willi syndrom

paternal disomy



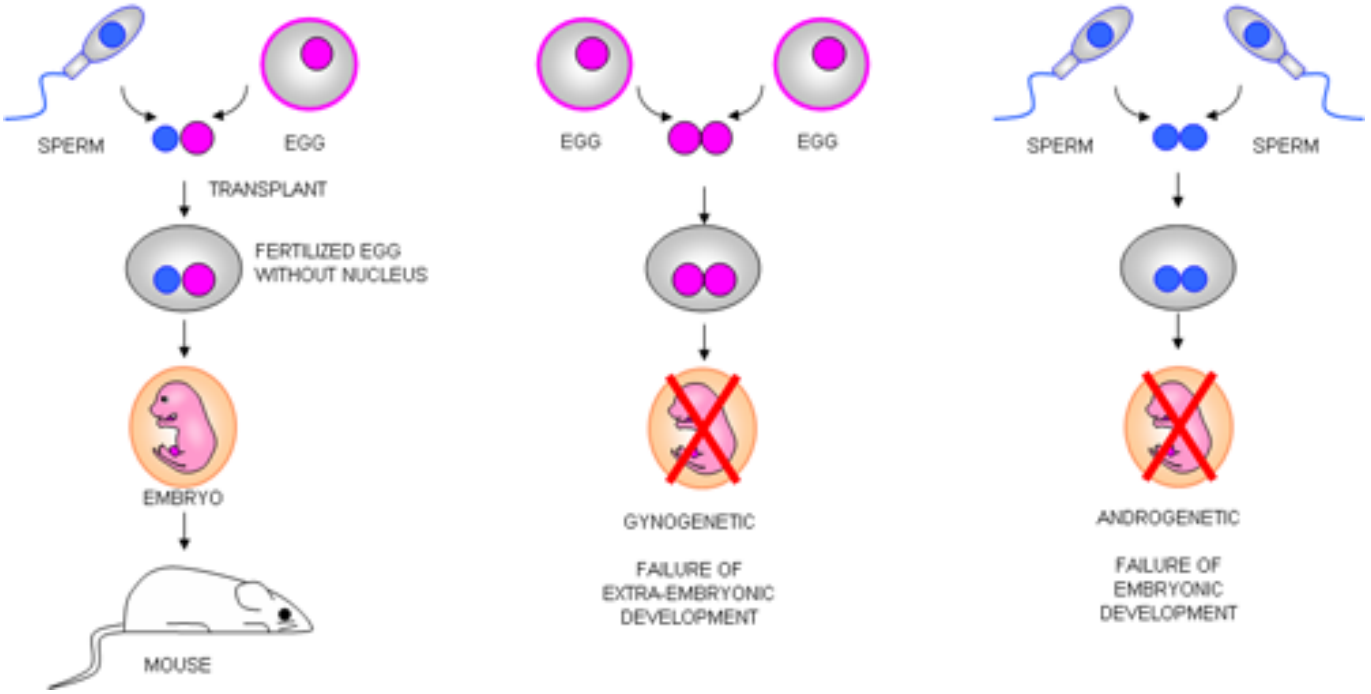


maternal disomy

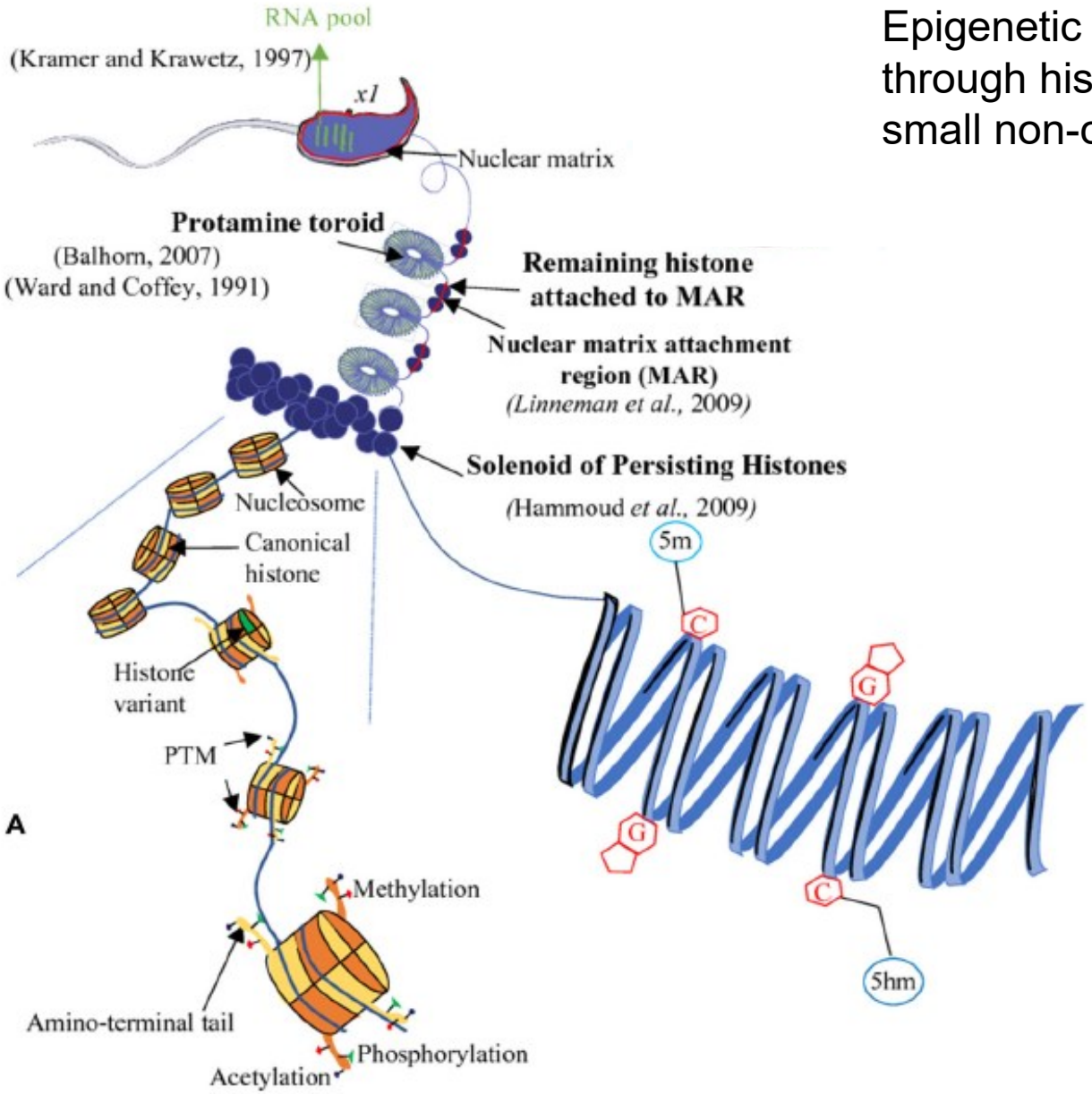
uniparental disomy chr 15

Genomic imprinting is responsible for the inviability of mammalian uniparental embryos

1984: Davor Solter a Azim Surani

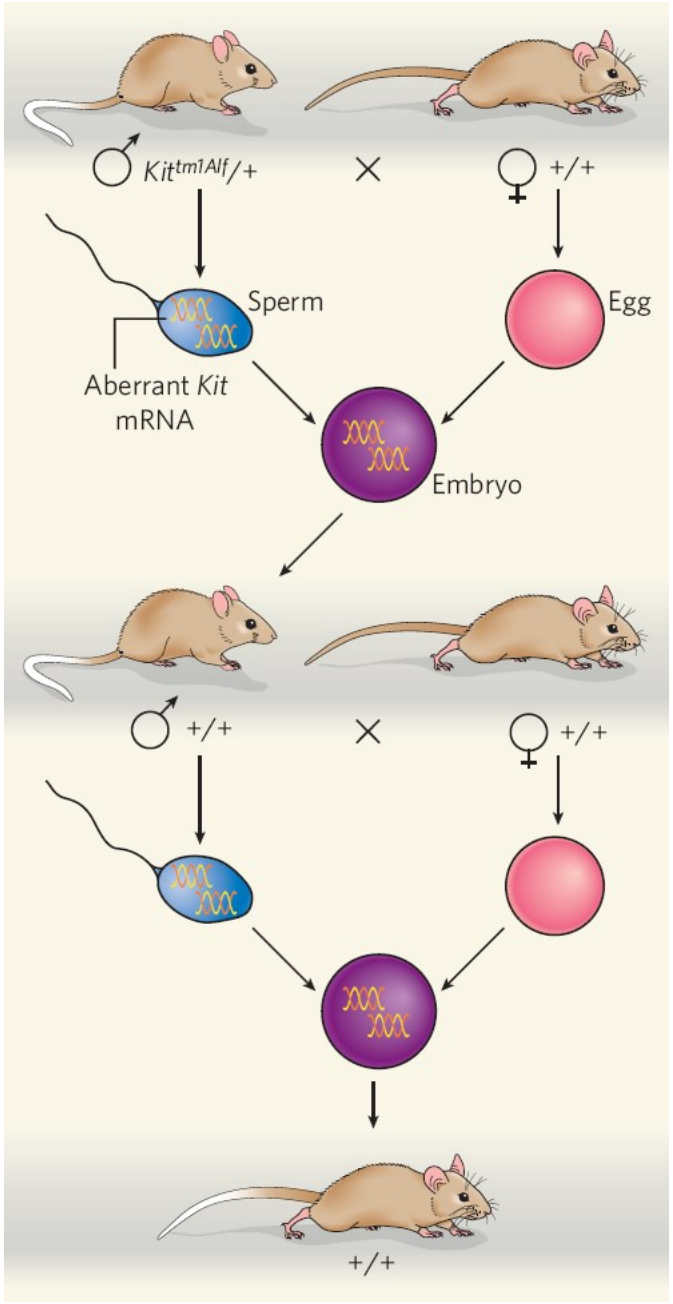


Epigenetic inheritance mediated through histon modifications and small non-coding RNAs.



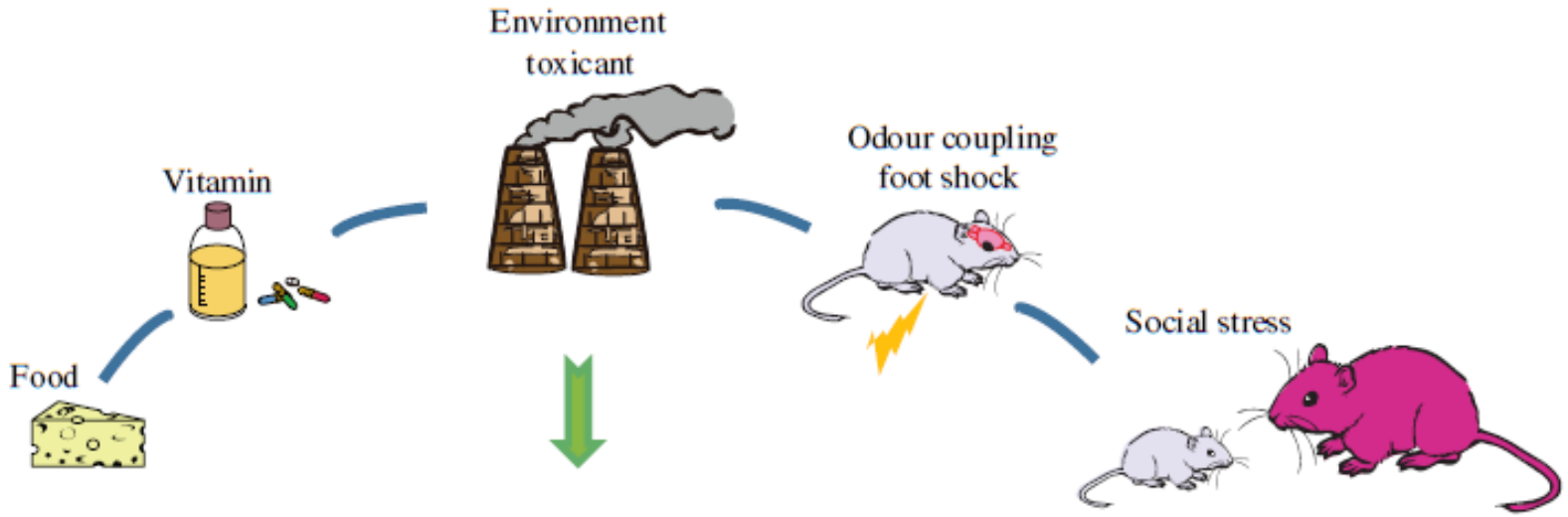
Paramutation in Kit allele

- Paramutation = the epigenetic transfer of information from one allele of a gene to another allele
- Paramutation mediated by small RNAs expressed from Kit allele affect expression from the second allele.
- Small RNAs are inherited through gametes to next generation.
- Injection of these RNAs to embryos cause the Kit phenotype (white tails).



Rassoulzadegan, Nature 2006

Epigenetic changes often induced by environment



DNA methylation
histon modifications
small non-coding RNAs

Fertility, metabolism, lifespan, mental health etc.

Agouti viable yellow (A^{vy})

- A^{vy} alele of the gene agouti originated by insertion of retroelement.
- A^{vy} alely uses the promoter of the retroelement and its activity depends on the level of the retroelement methylation. This is affected by diet of the mother (folic acid, vit B12).
- Levels of methylation and coat color to some degree inherited through generations.

A^{vy}/a mice

Inheritance of metabolic diseases induced by lack of food or smoking

- Lack of food in childhood or during pregnancy
  → lipid metabolism disorder, diabetes in childs as well as grandchild.
- Smoking or chewing of betel
  → obezity, metabolic syndrom in children.

Famine in Holland (1944-1945)

stress

Lack of maternal care, separation of progeny from the mother, social stress, trauma

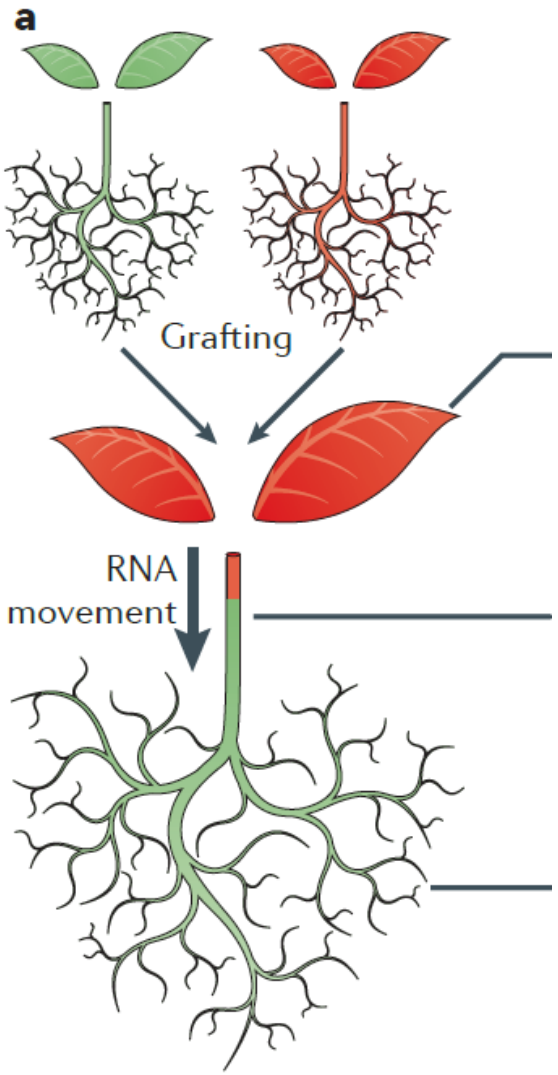
Behavioral defects in progeny (psychological problems, depression, anxiety, risky behaviors).

Changes in DNA methylation and histon modifications in genes expressed in brain.

Can be inherited through multiple generations.

Transgenerational epigenetic inheritance in plants

- Plants do not have separated germ and somatic line (**Weisman barier**).
- Global epigenetic reprogramming is not so substantial as in animals.
- Small non-coding RNAs can spread through the plant using vascular tissues



Sarkies and Miska (2014)

Linaria vulgaris

peloric form

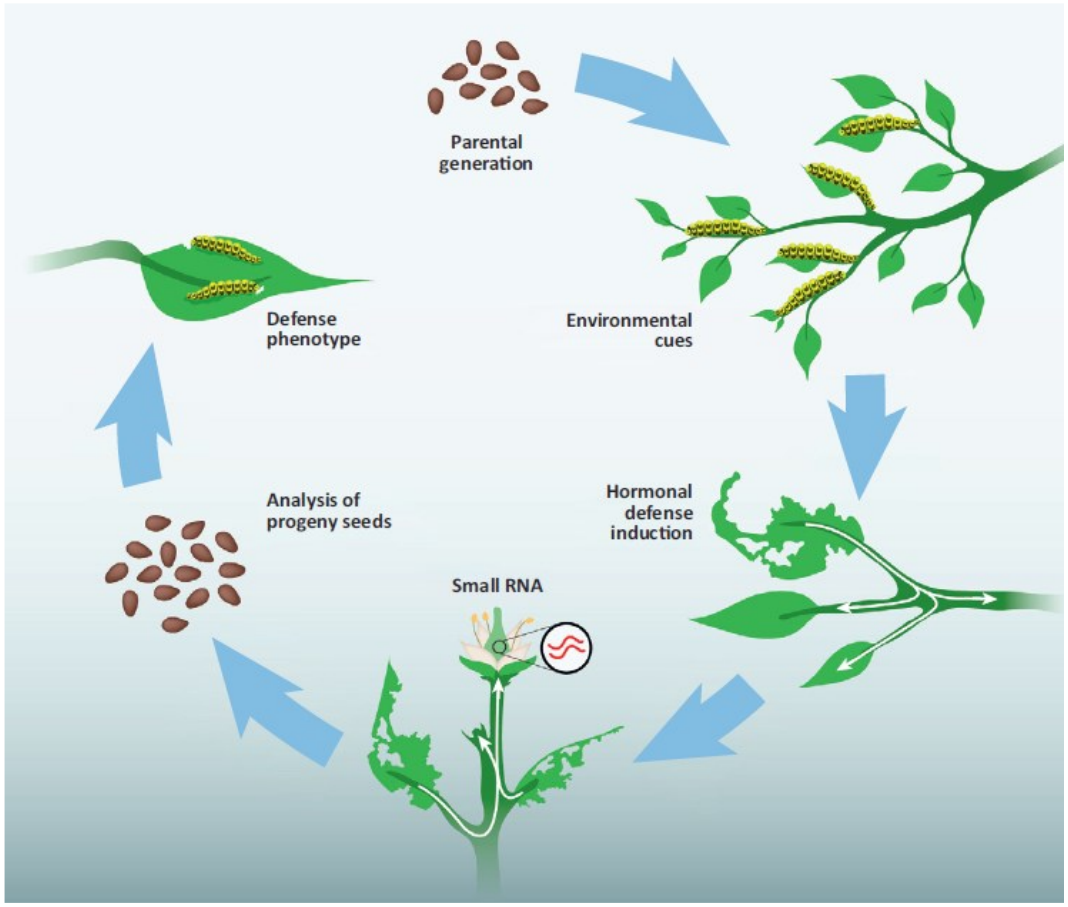
normal form

Live specimen of *Peloria*

Normal *Linaria* (toadflax)

- Peloric form caused by methylation of the *Lcyc* gene
- Stable inheritance through many generations.

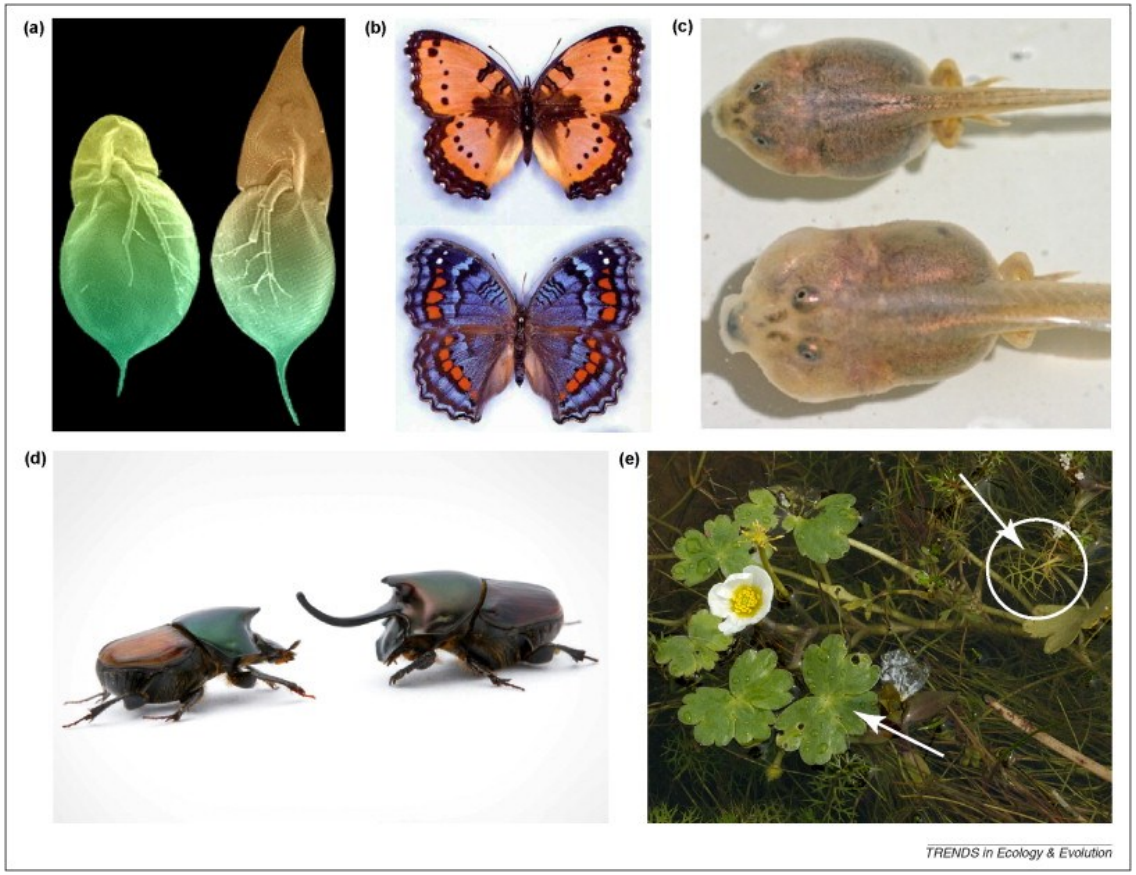
Induced resistance against herbivors and pathogens in plants



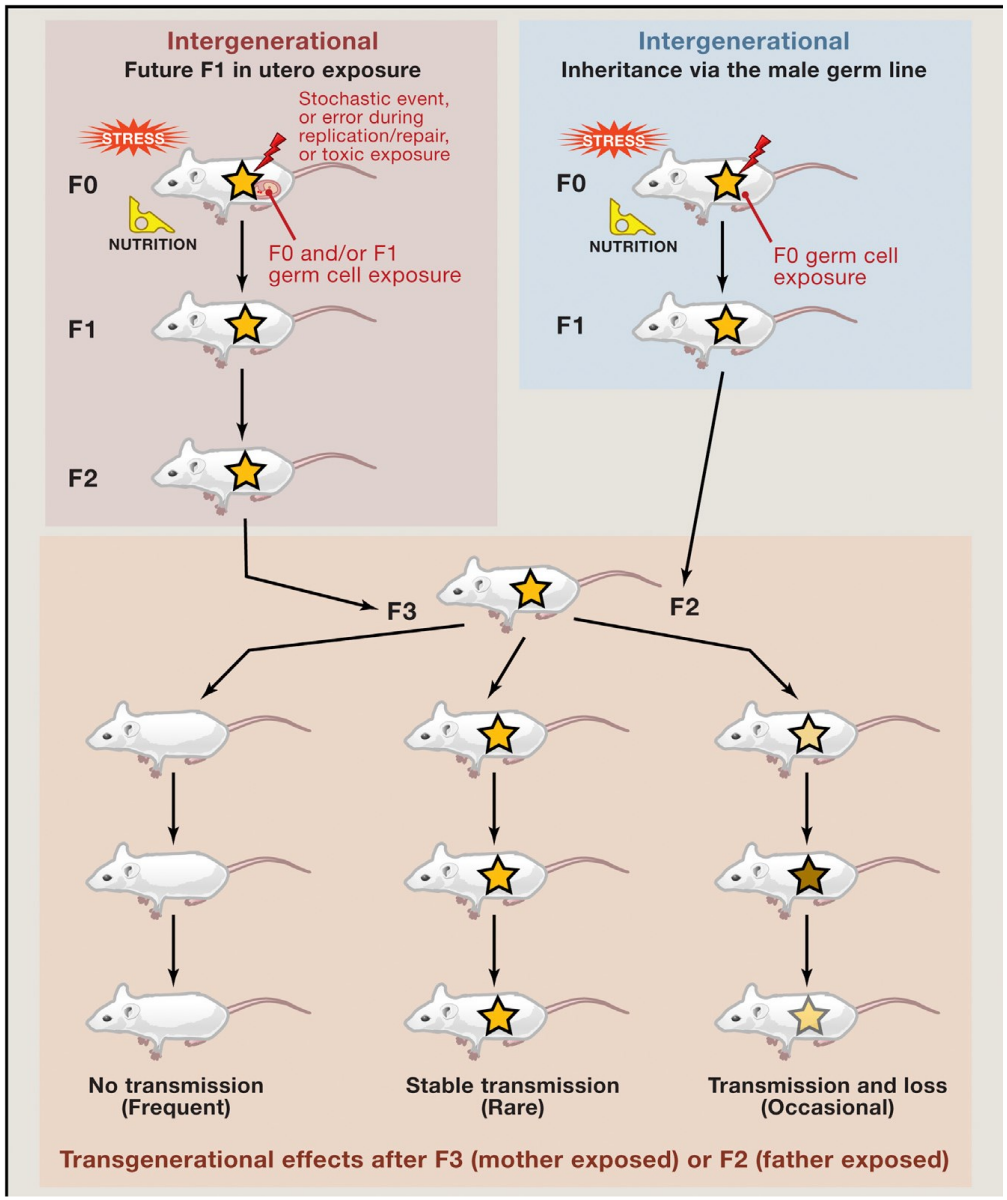
Holeski et al. (2012)

(Adaptive) phenotypic plasticity

- The same genotype, different phenotypes in different environments.



Transgenerational epigenetic inheritance vs. maternal effect



Epigenetic inheritance and lamarckism

Inheritance of acquired characters

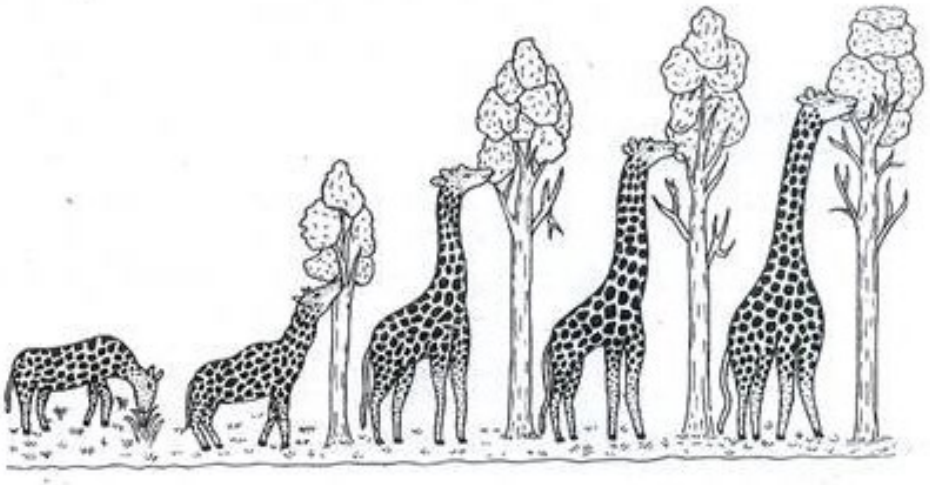


Diagram showing elongation of neck in giraffe according to Lamarck.

Jean Baptiste Lamarck

Epigenetic changes and evolution

- Epigenetic changes represent an important source of phenotypic variability.
- Are often induced by changes of environment (periodic and predictable changes can lead to evolution of adaptive phenotypic plasticity).

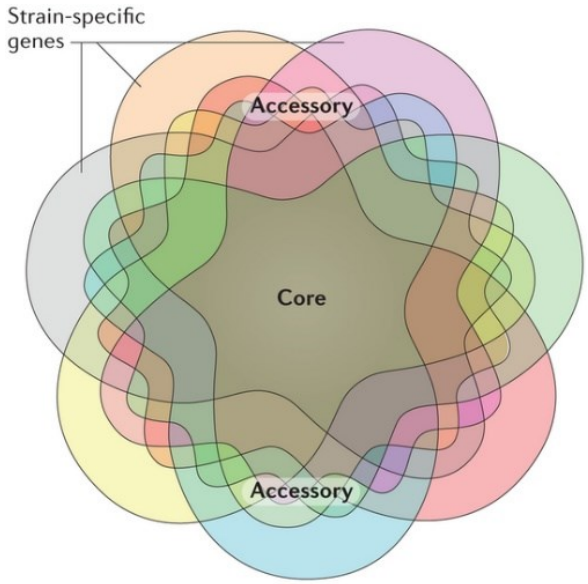
- Are reversible.

- Can affect the mutation rate. Fixation of originally epigenetic phenotype by genetic change. **Genetic assimilation**.

- Epigenetic inheritance can be important especially in sessile organisms (plants), where progeny is exposed to the same environment as parents.

Horizontal gene transfer

- Widespread in prokaryotes
- pangenom = set of all genes of the given taxonomical group



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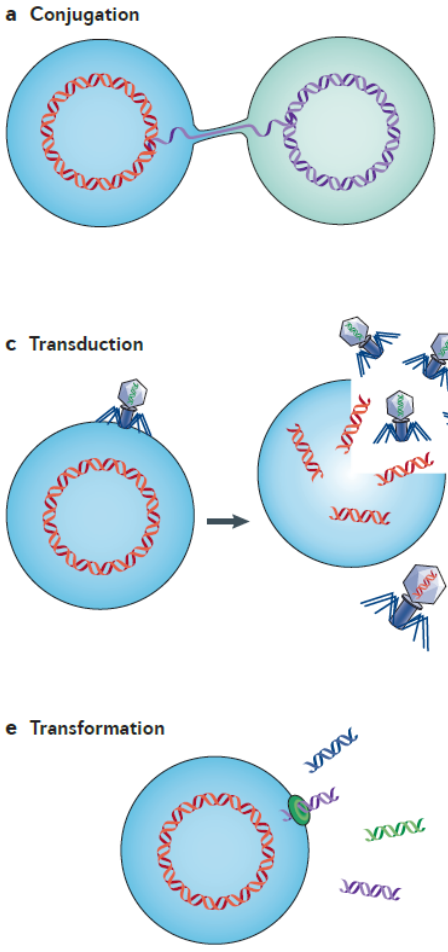


Horizontal gene transfer

- Less frequent in multicellular organisms.
- Movement of genes from mtDNA to nucleus.
- Transfer of genes from endosymbionts to the host.

Wolbachia → hmyz (např. *Drosophila*), hlístice

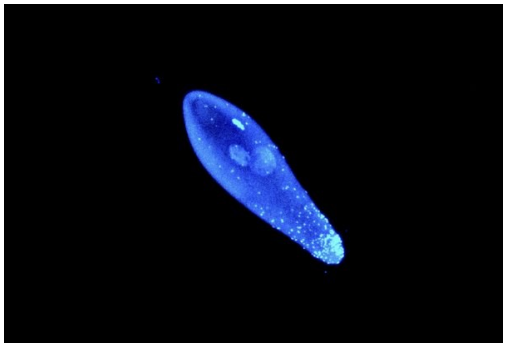
Elysia chlorotica

Acyrthosiphon pisum (aj.) – syntéza karotenoidů (původ: houby)

Sex determination in *Armadillidium*

- *Wolbachia,* can cause feminization of males.
- Horizontal gene transfer from Wolbachia to Armadillidium.
  The transferred Wolbachia genes determine female sex in Armadillidium..

Svinka obecná
Armadillidium vulgare



Wolbachia