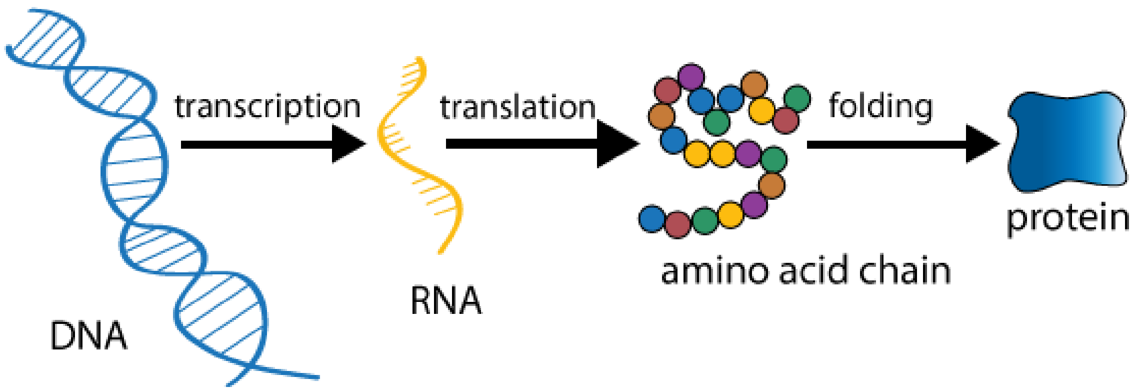
Epigenetic inheritance

genotype



phenotype

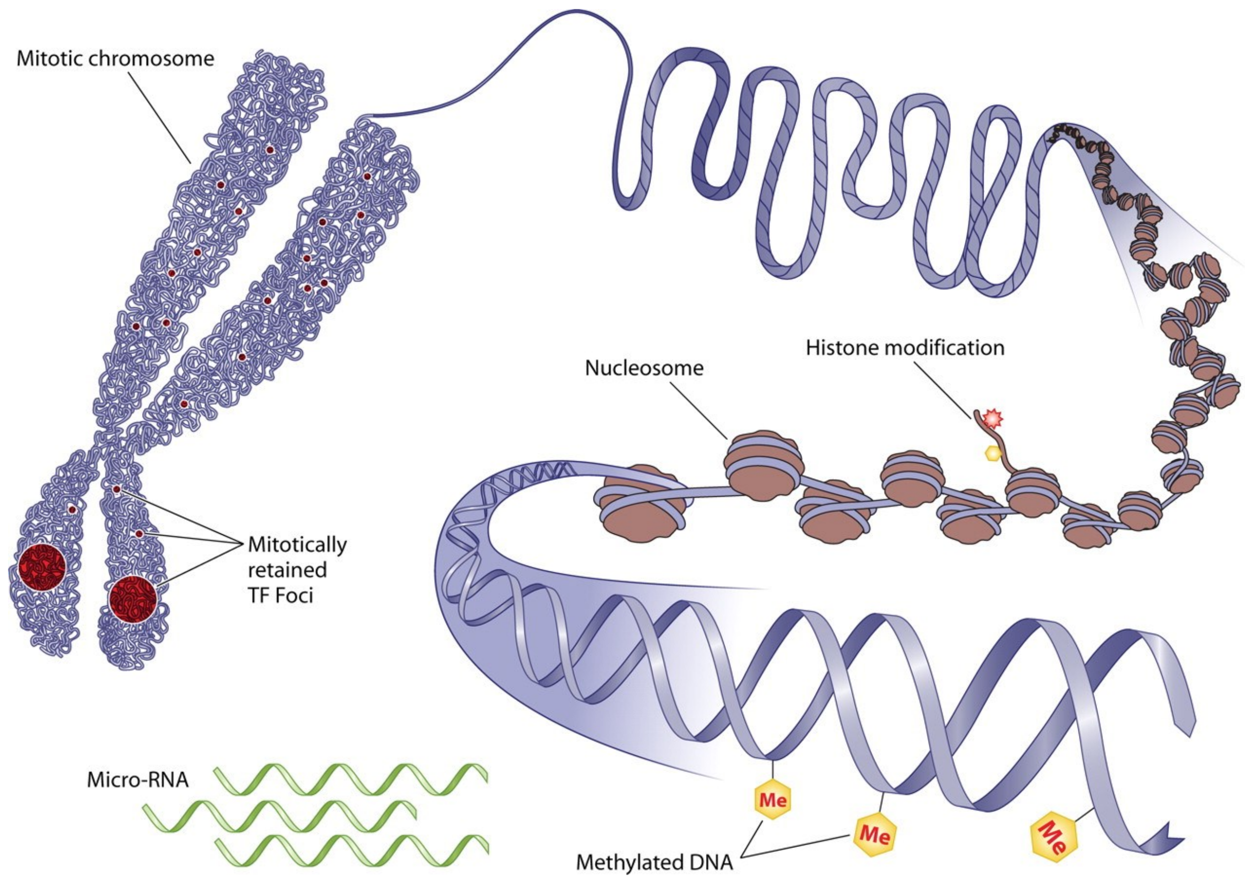
Epigenetic inheritance
= change in phenotype without the change in DNA sequence

Molecular mechanisms of epigenetic inheritance

Metylation of DNA (5mC)

Histon modifications

Small non-coding RNAs



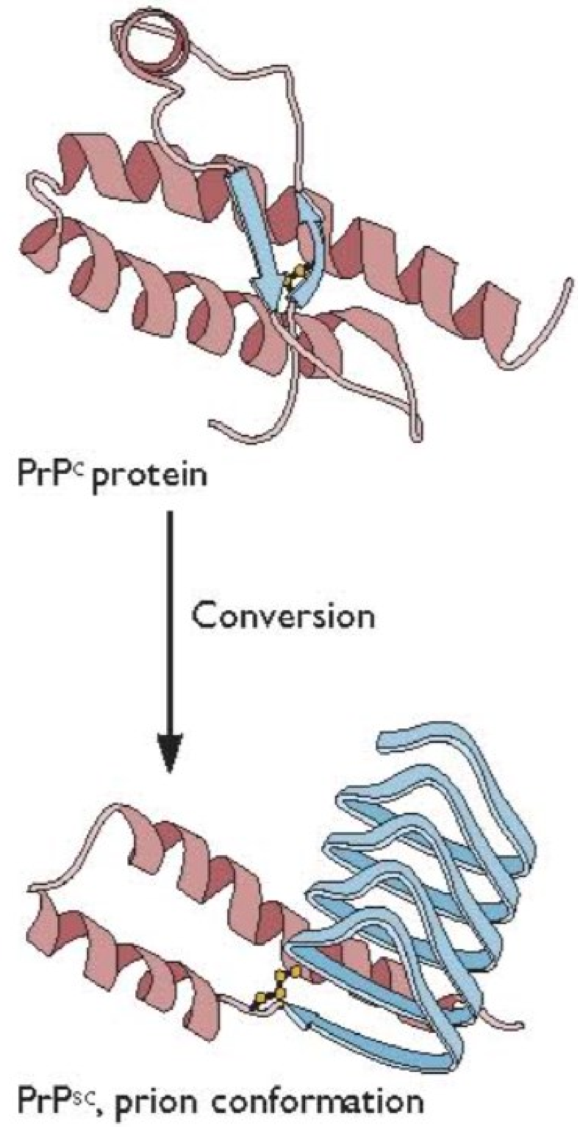
Prions

- Infectious proteins

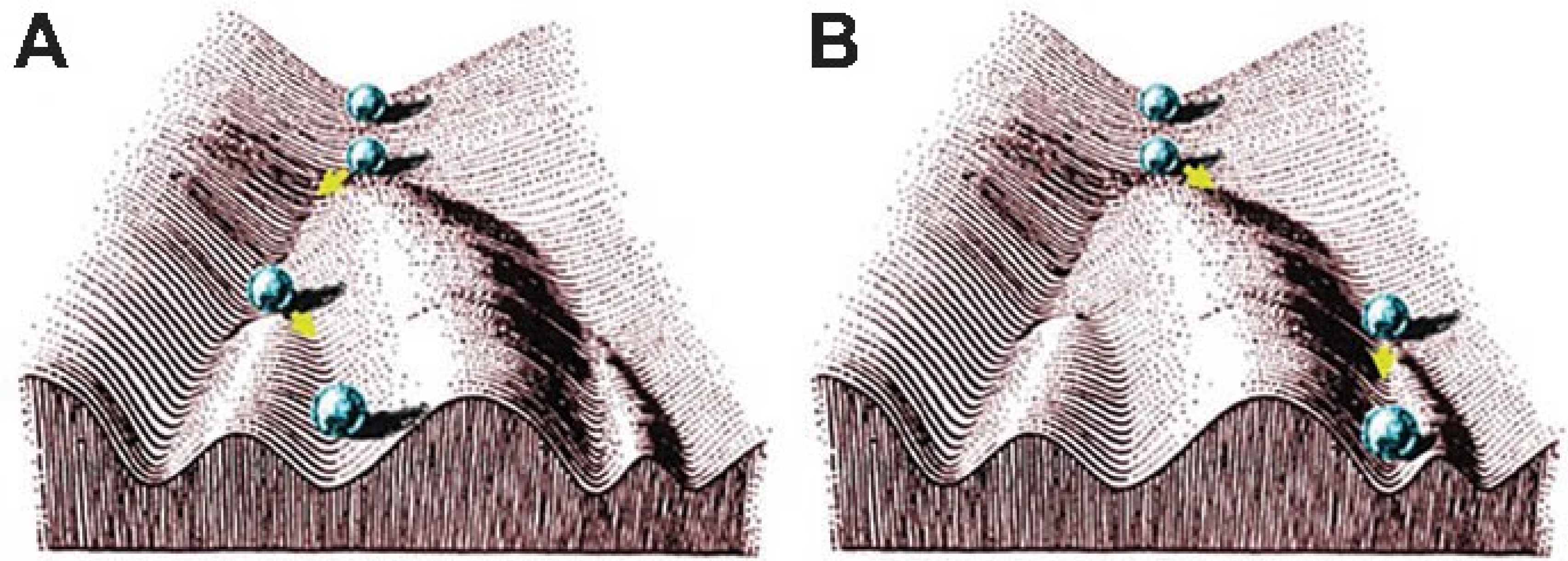
- Can cause neurodenerative diseases

  - Kuru
  - Creutzfeldt–Jakob disease
  - Bovine spongiform encephalopathy (BSE) (mad cow disease)

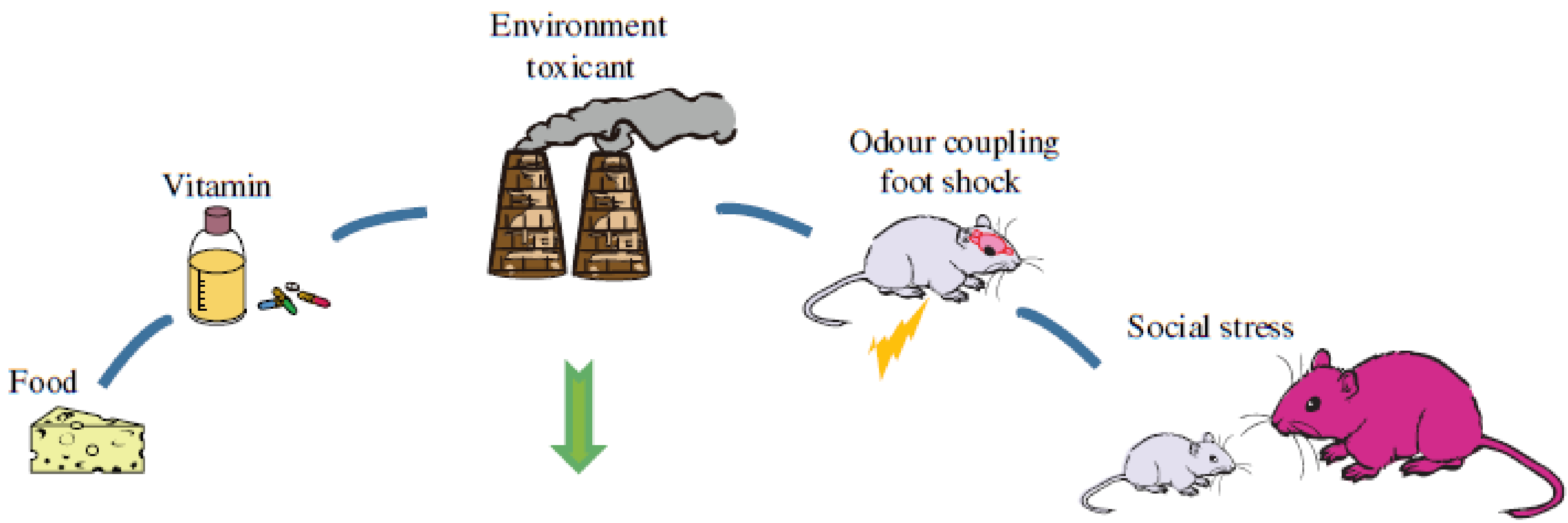
- Yeasts: [PSI+], prion of Sup35 protein. Termination of translation. Prion form leads to translation over stopcodon. Reveals hidden genetic variation.



Ontogenetic development and Conrad Waddington's epigenetic landscape



Epigenetic changes often induced by environment

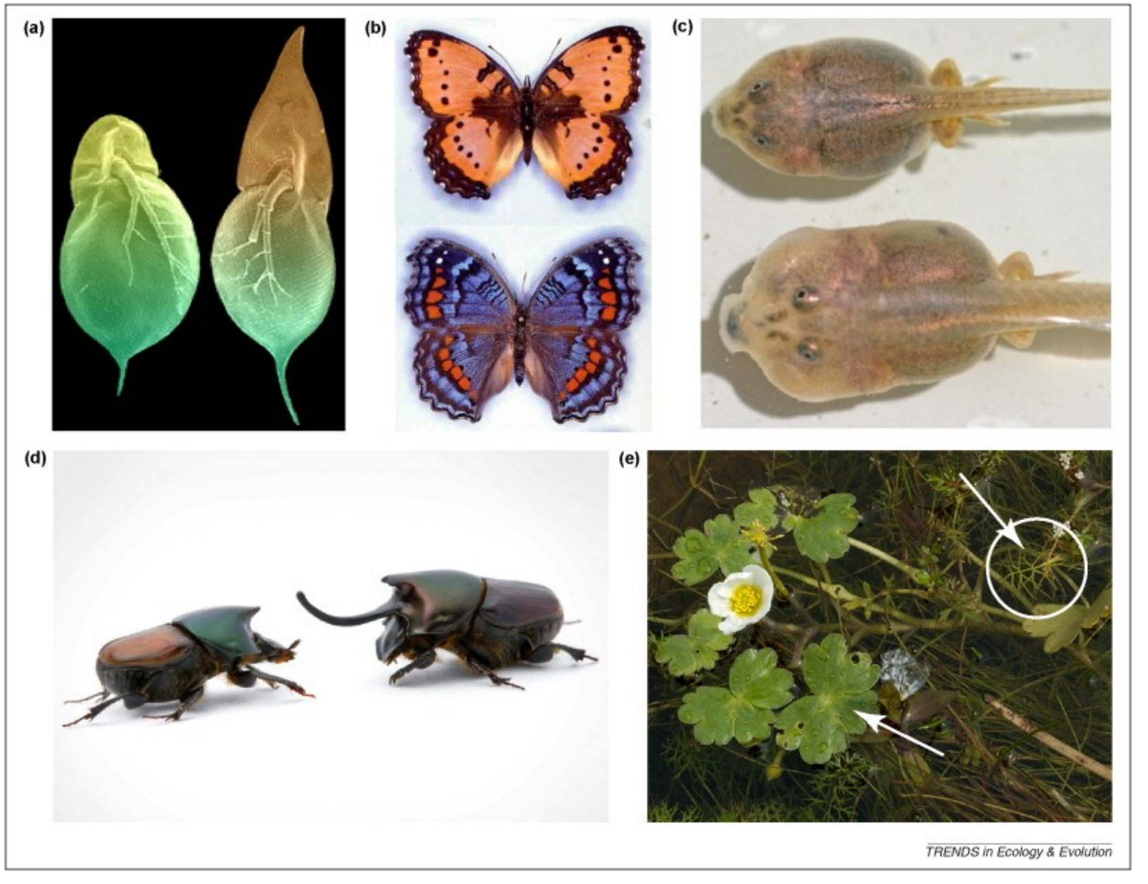


DNA methylation
histon modifications
small non-coding RNAs

Fertility, metabolism, lifespan, mental health etc.

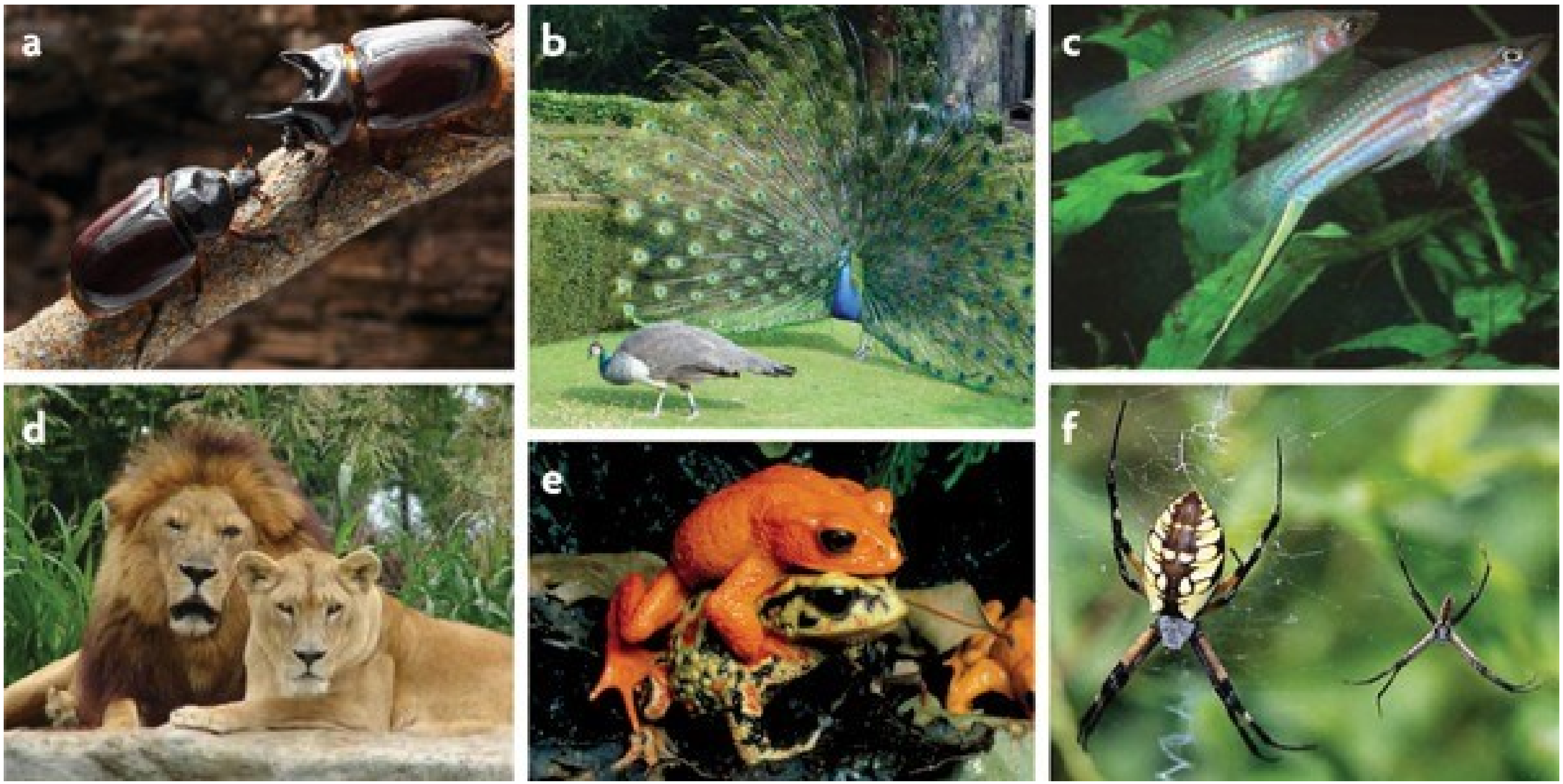
Phenotypic plasticity

- The same genotype, different phenotypes in different environments.



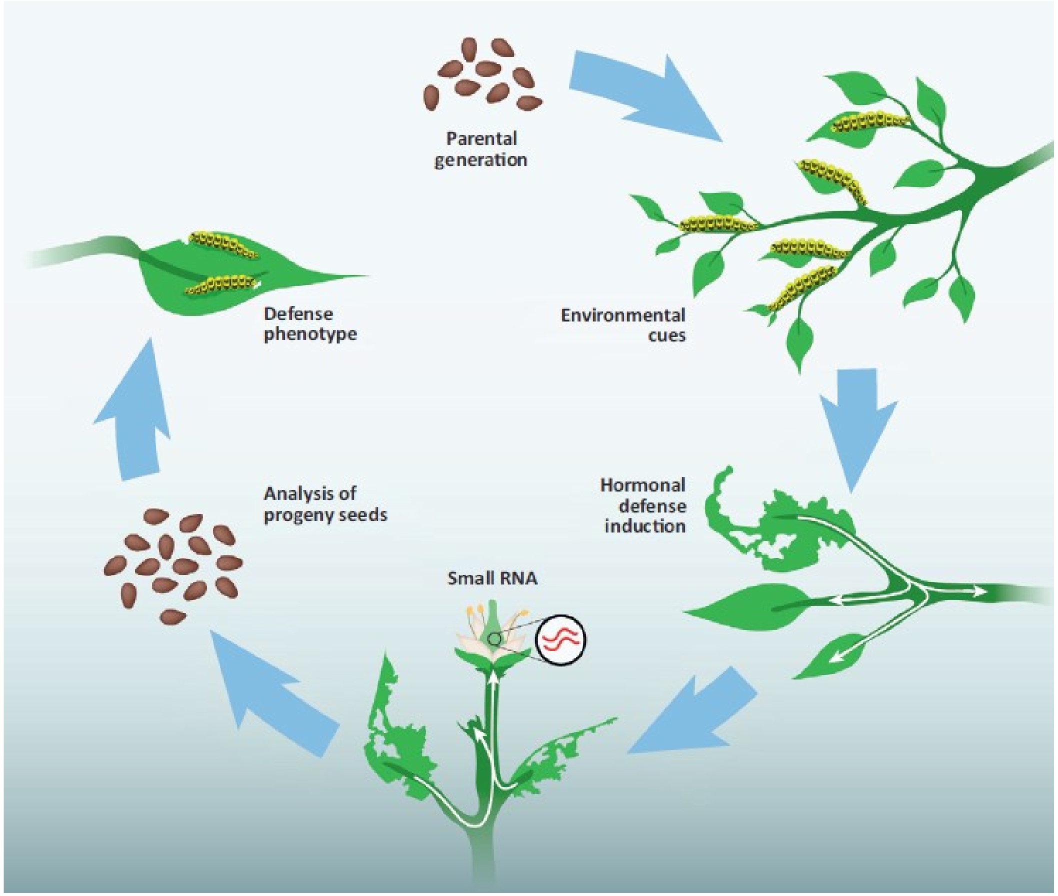
Phenotypic plasticity

Sexual dimorphism



Phenotypic plasticity

Induced resistance against herbivors and pathogens in plants

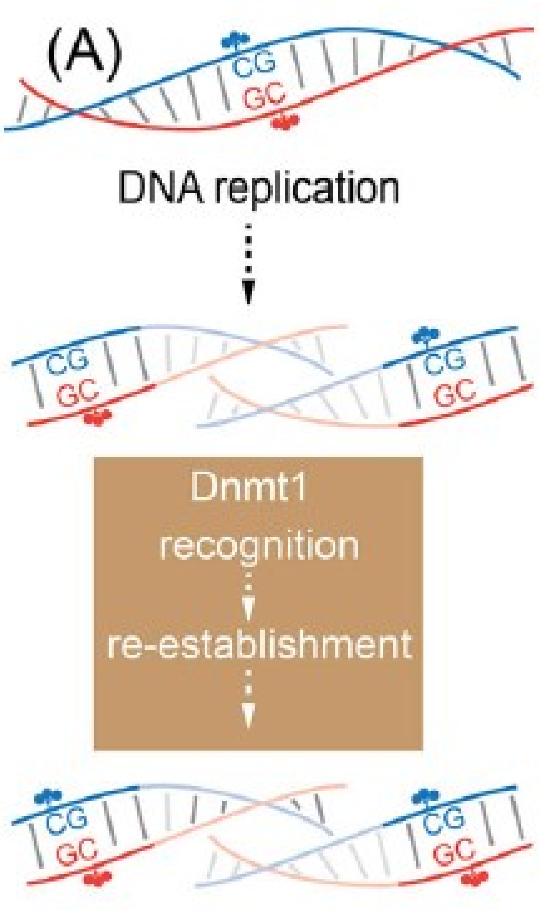


Holeski et al. (2012)

Molecular mechanisms of epigenetic inheritance

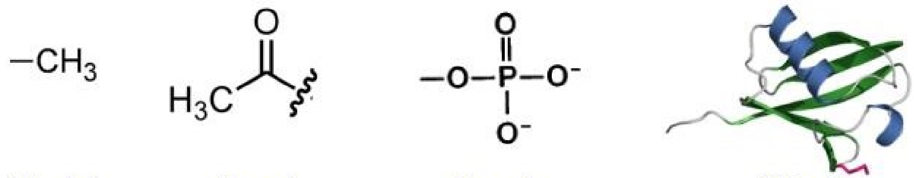
Methylation of cytosines in CG dinucleotides

Dnmt1 – DNA methyl transferase 1
Methylates cytosines in hemimethylated CG dinucleotides



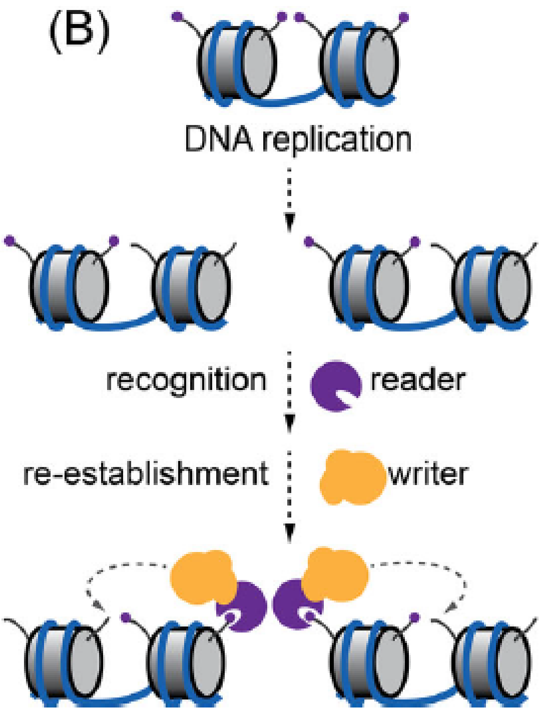
Molecular mechanisms of epigenetic inheritance

Histone modification

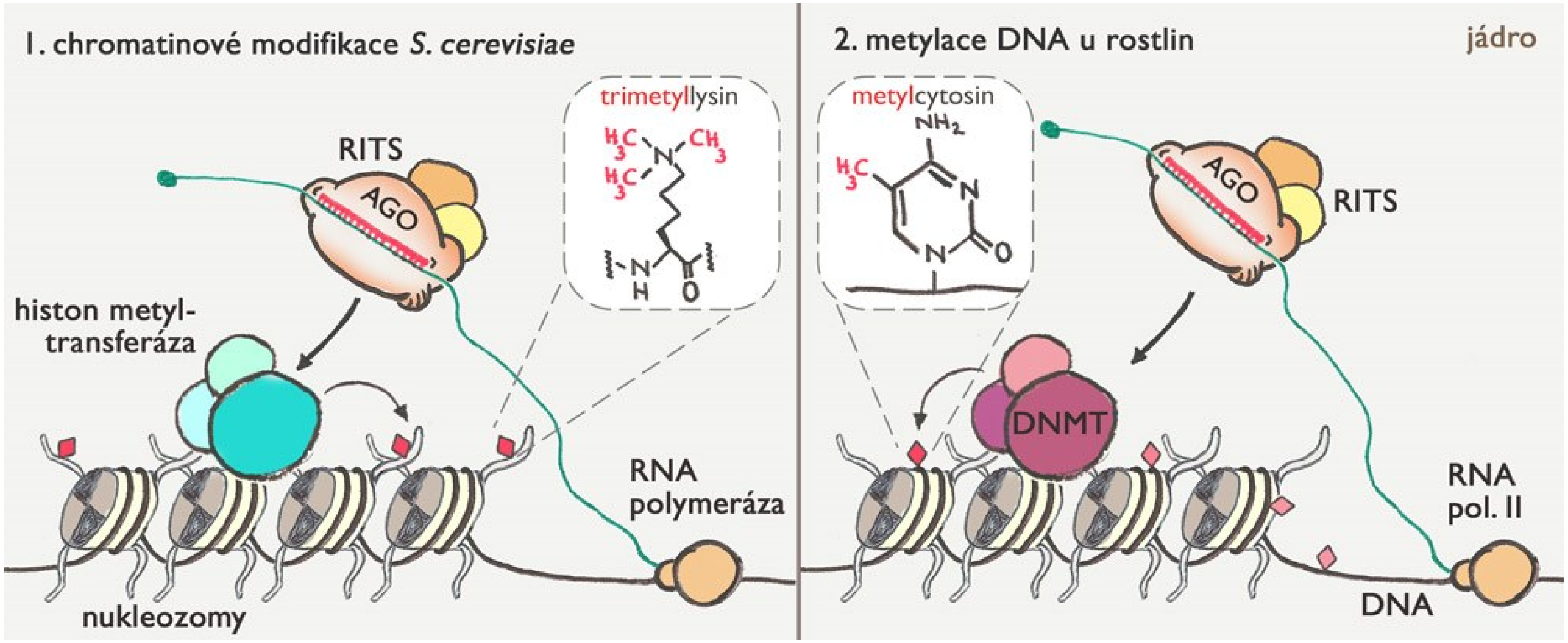


Methyl Acetyl Phospho Ubiquitin

(B)

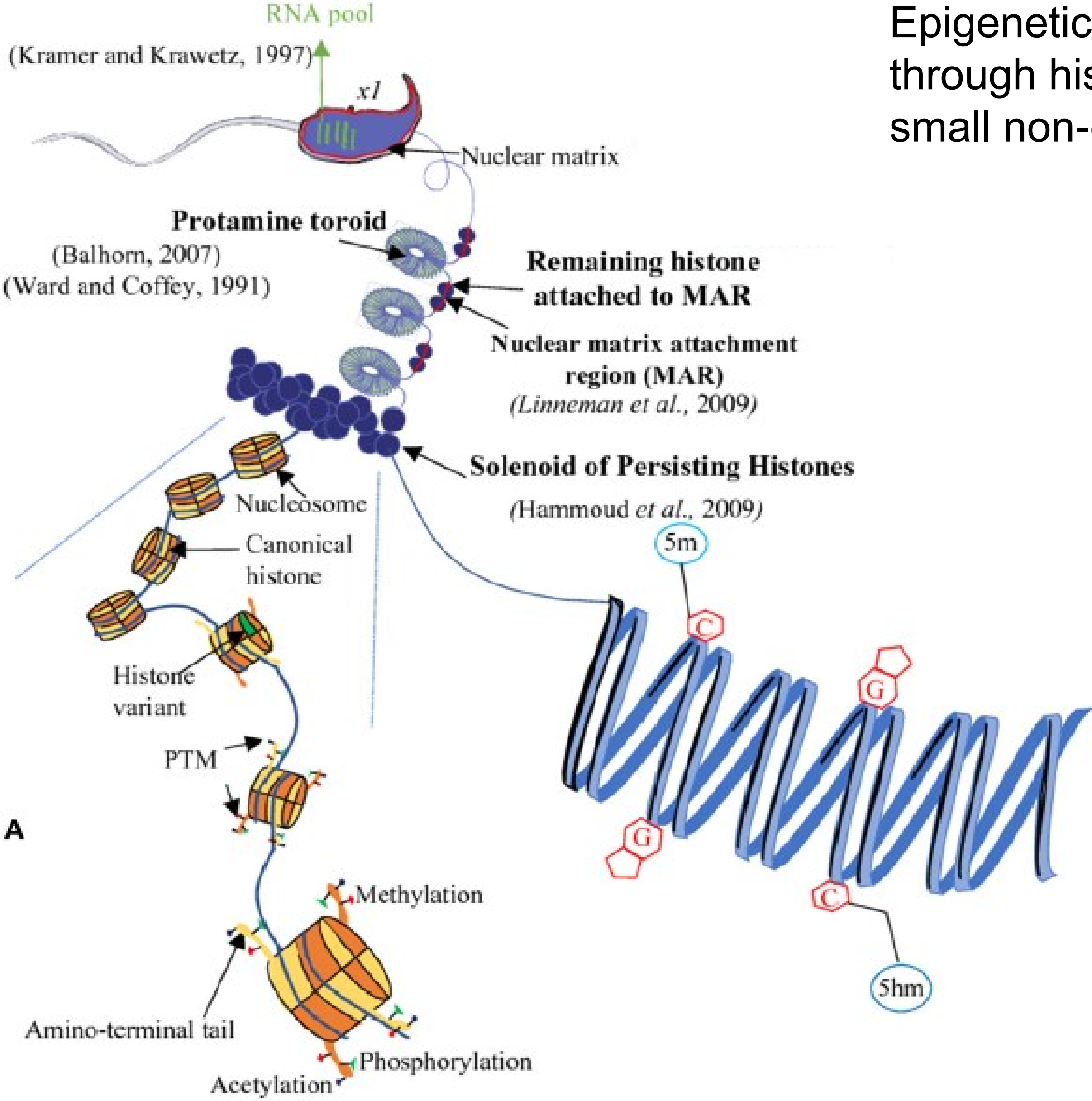


Small non-coding RNAs can induce changes of chromatin



Svoboda a Jankele, 2015, Vesmír

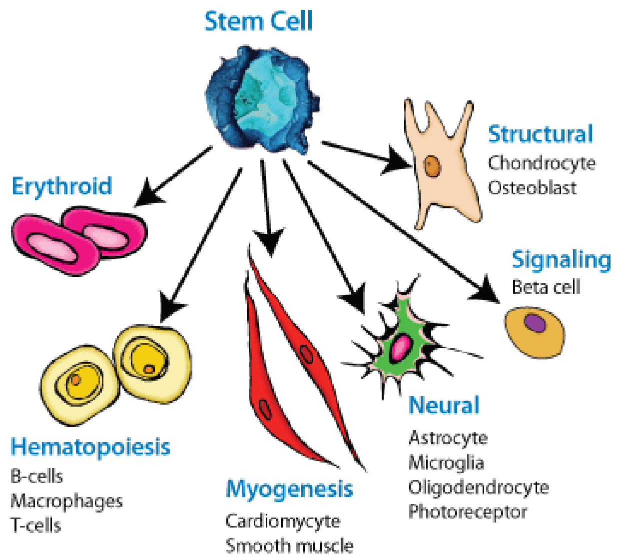
Epigenetic inheritance mediated through histon modifications and small non-coding RNAs.



A

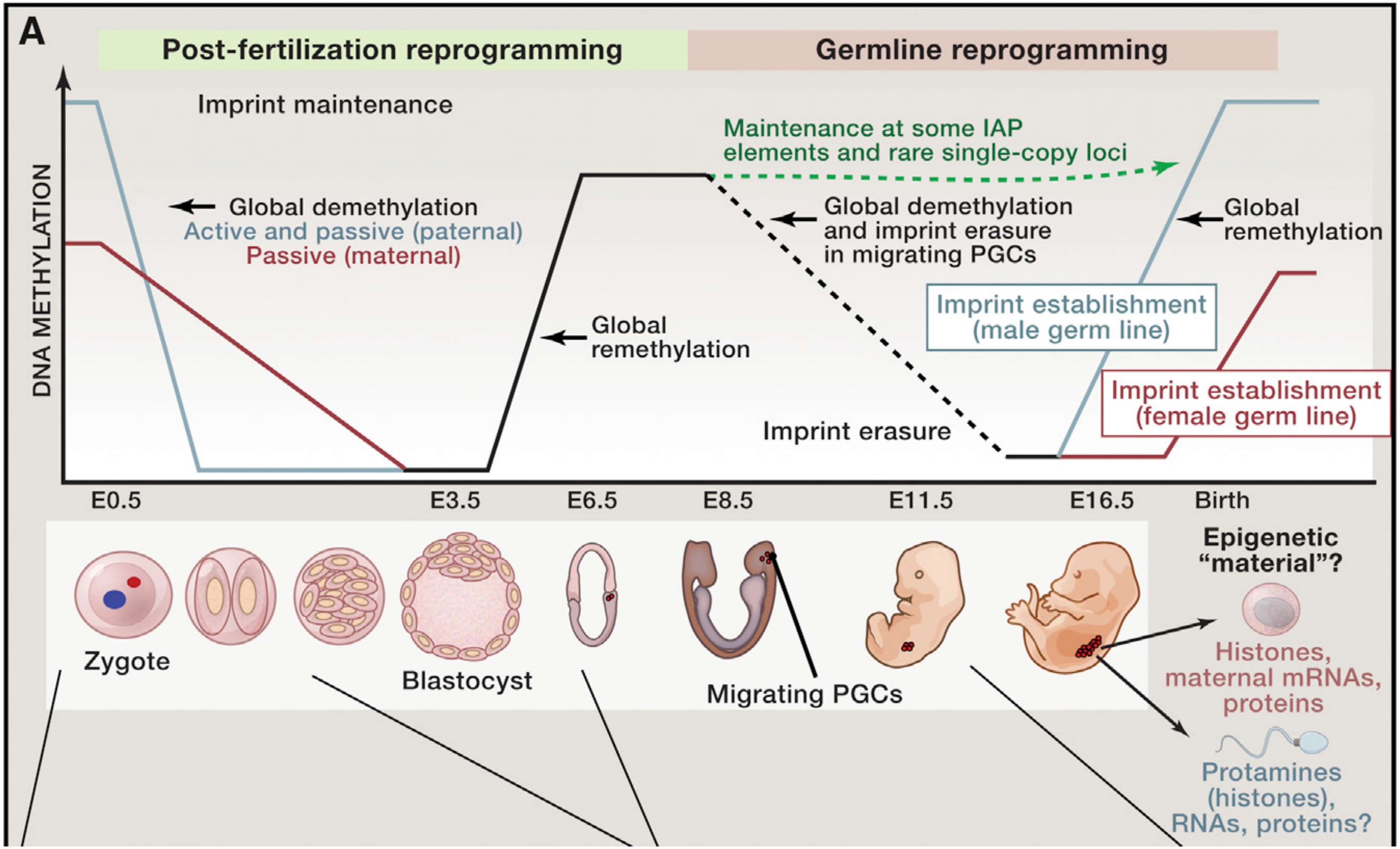
Epigenetics

Originally discipline about cell differentiation during ontogeny



Transgeneration epigenetic inheritance?

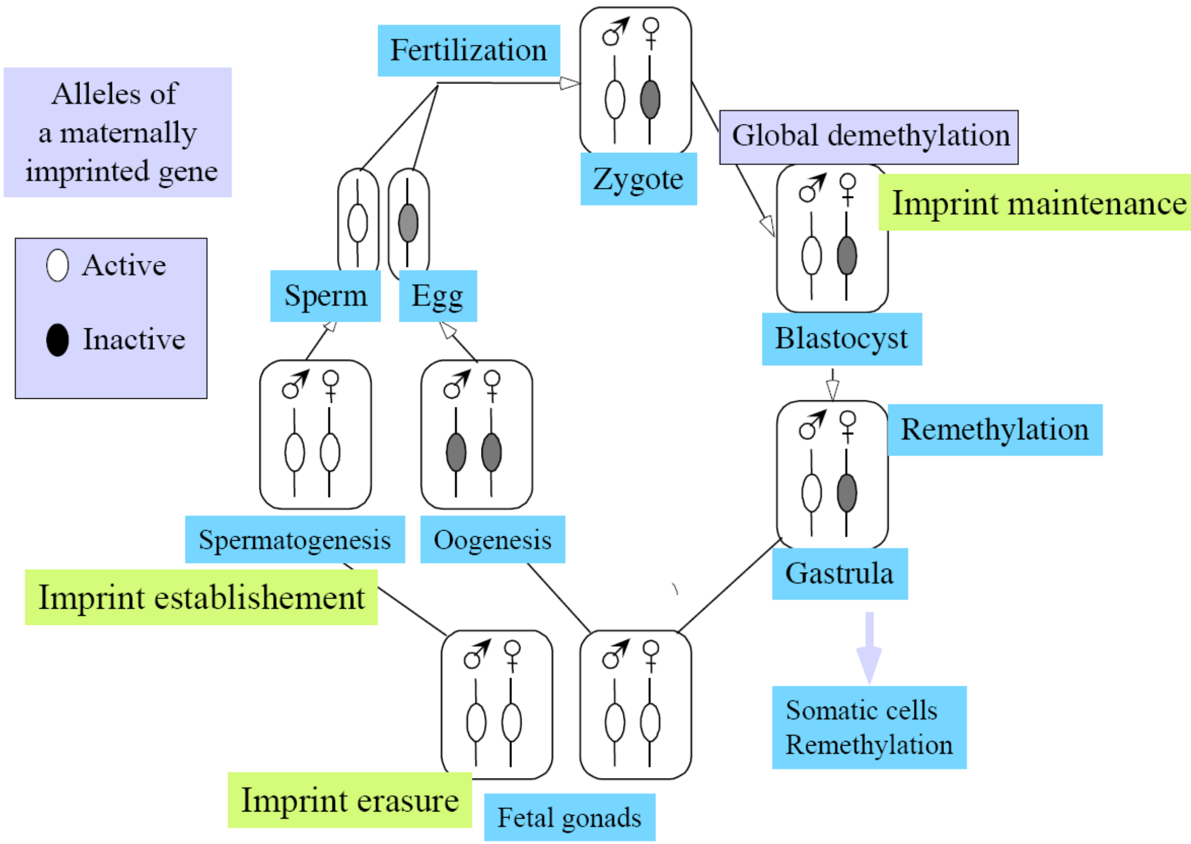
Epigenetic reprogramming of DNA



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

Genomic imprinting

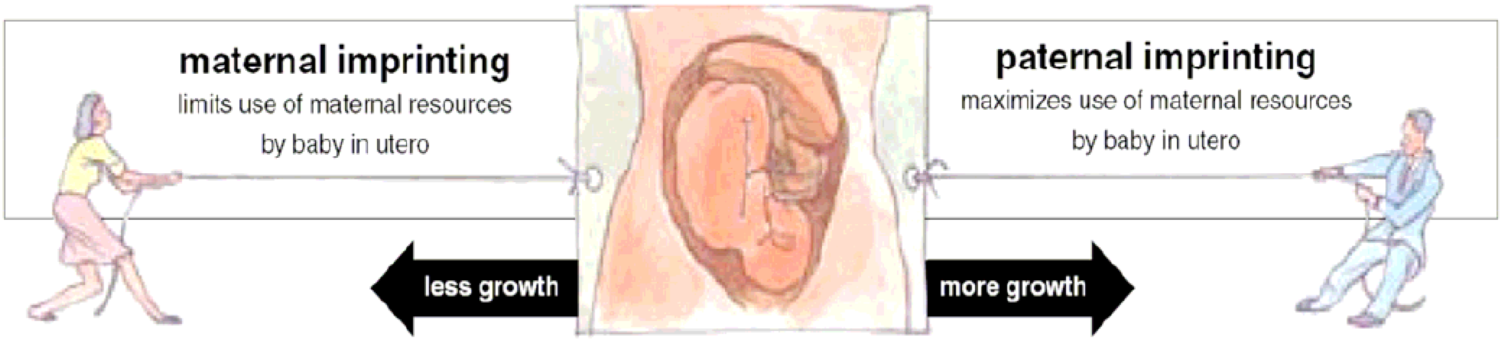
- Expression only from a maternal or paternal allele
- Epigenetic marks are established in the germline of parents and are inherited to offspring.



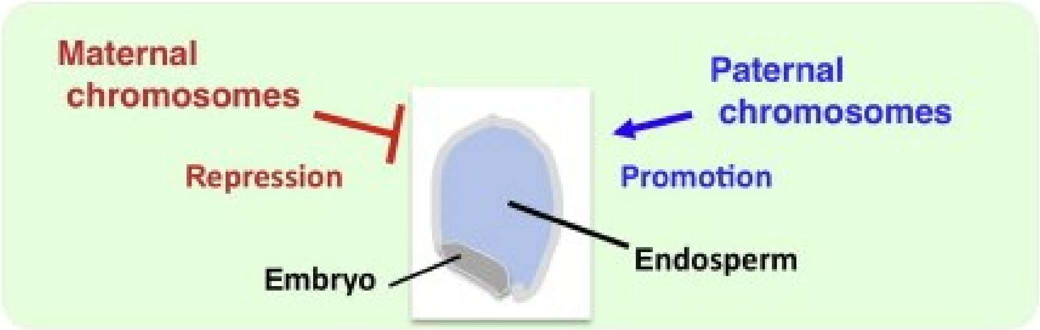
Genomic imprinting

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



Genomic imprinting in angiosperms (endosperm)

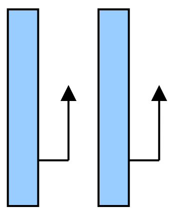


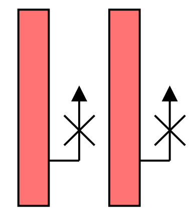
Aberrant genomic imprinting

Angelman syndrom

Prader-Willi syndrom

paternal disomy



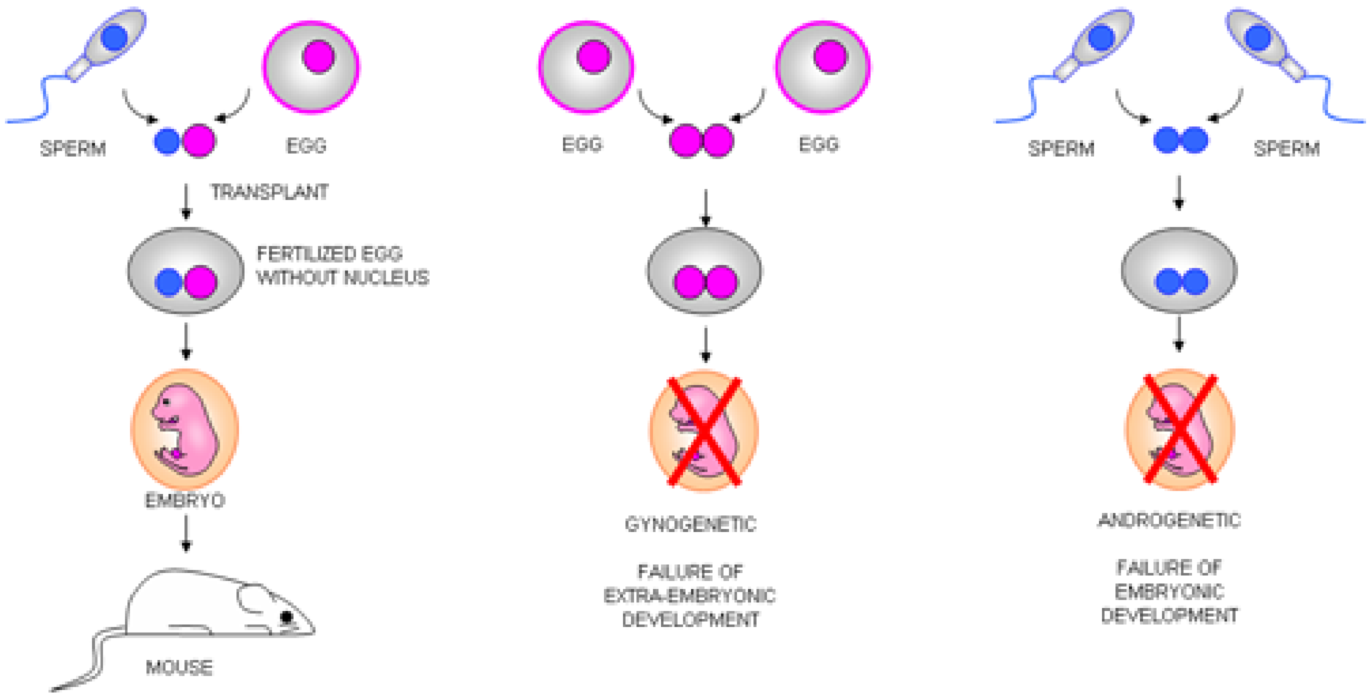


maternal disomy

uniparental disomy chr 15

Genomic imprinting is responsible for the inviability of mammalian uniparental embryos

1984: Davor Solter a Azim Surani



Linaria vulgaris

peloric form

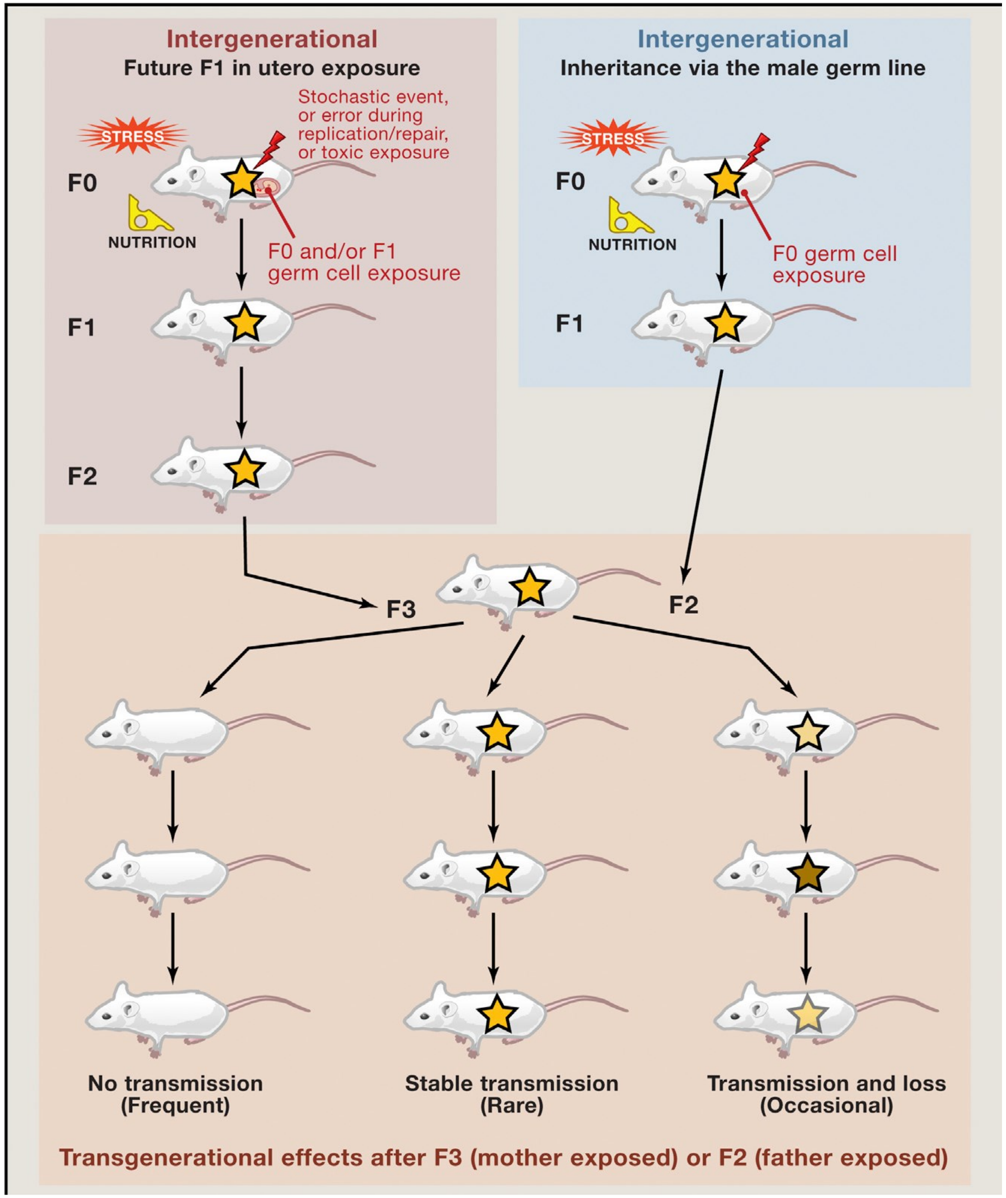
normal form

Live specimen of *Peloria*

Normal *Linaria* (toadflax)

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

Transgenerational epigenetic inheritance vs. maternal effect



Maternal effect in

Agouti viable yellow (A^{vy})

A^{vy}/a mice

- 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.

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.

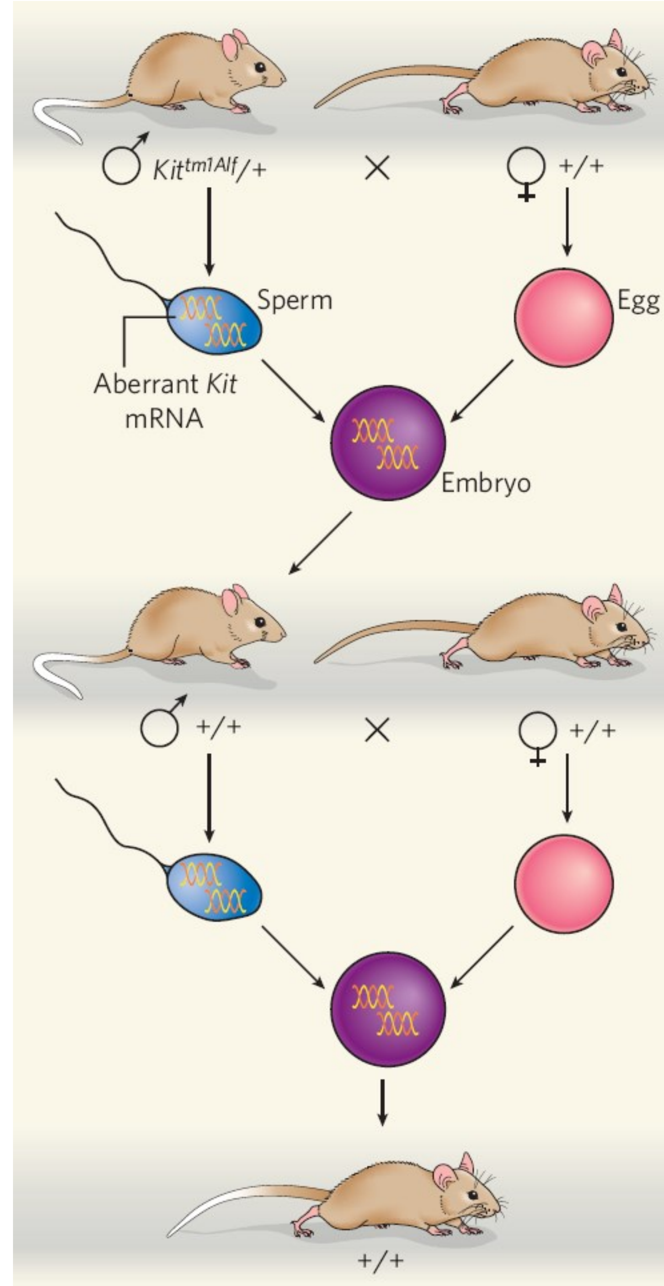
Inheritance of metabolic diseases induced by lack of food or smoking

- 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)

Paramutation

- 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

Transformation of wild-type petunia (left) with a transgene encoding a pigment protein can lead to loss of pigment (white areas) owing to cosuppression of the transgene and homologous endogenous plant gene.

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.

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PERSPECTIVE

Epigenetic inheritance in adaptive evolution

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Abstract

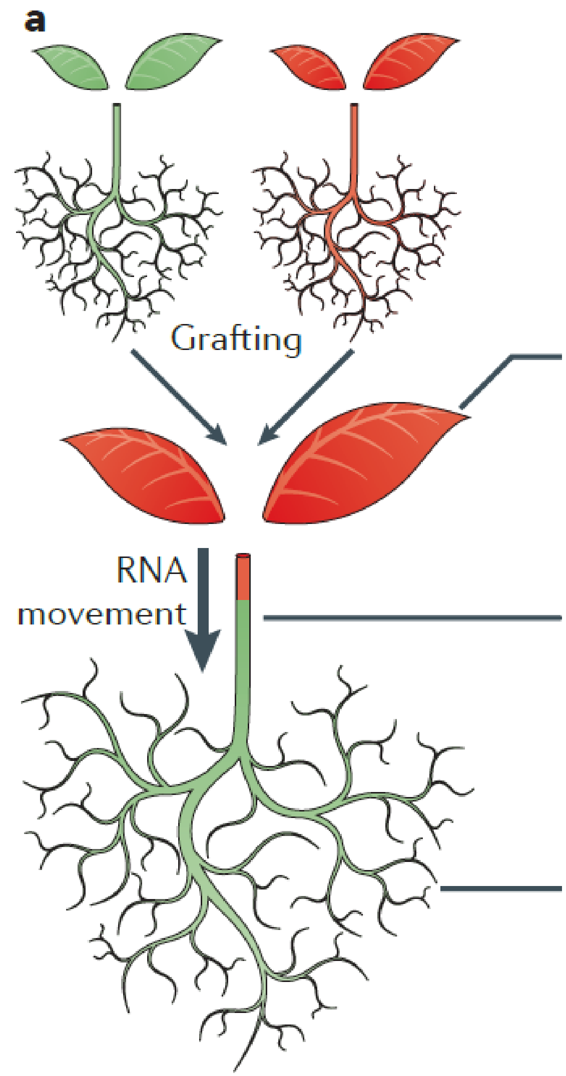
Since the Modern Synthesis, our ideas of evolution have mostly centered on the information encoded in the DNA molecule and their mechanisms of heredity. Increasing evidence, however, suggests that epigenetic mechanisms have the potential to perpetuate gene activity states in the context of the same DNA sequence. Here, we discuss recent compelling evidence showing that epigenetic signals triggered by environmental stress can persist over very long timeframes, contributing to phenotypic changes in relevant traits upon which selection could act. We argue that epigenetic inheritance plays an important role in fast phenotypic adaptation to fluctuating environments, ensuring the survival of the organisms of a population under environmental stress in the short term while maintaining a "bet-hedging" strategy of reverting to the original state if the environment returns to standard conditions. These examples call for a reevaluation of the role of nongenetic information in adaptive evolution, raising questions about its broader relevance in nature.

KEYWORDS
adaptation, assimilation, environmental change, epigenetic inheritance, genetic, Waddington

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

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)

Epigenetic inheritance and lamarckism

Inheritance of acquired characters

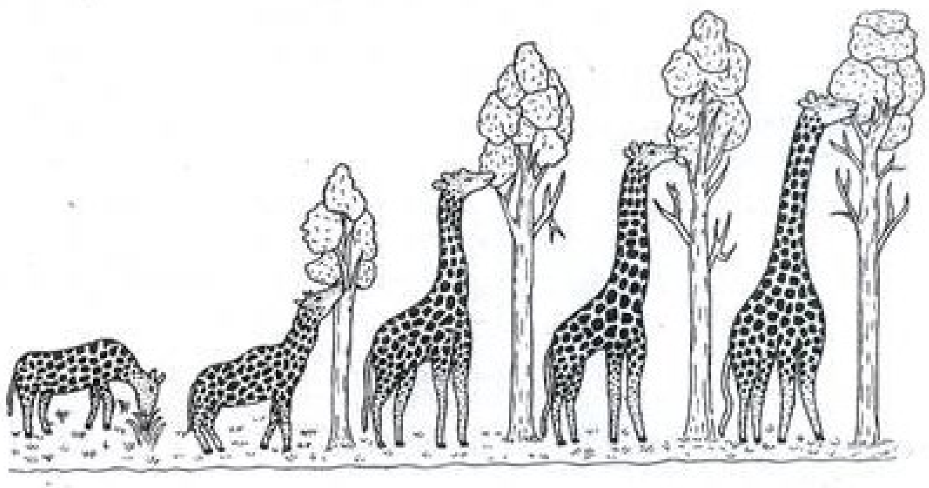


Diagram showing elongation of neck in giraffe according to Lamarck.


Jean Baptiste Lamarck