Updating Darwinian Evolution Part IV: Traces of Lamarck

Science Circle
June 8th 2024

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a.k.a. Stephen Xootfly
Researcher
Company that has nothing to do with this talk
Former University Biology Instructor

Overview

I. Darwin/NeoDarwin/Modern Synthesis

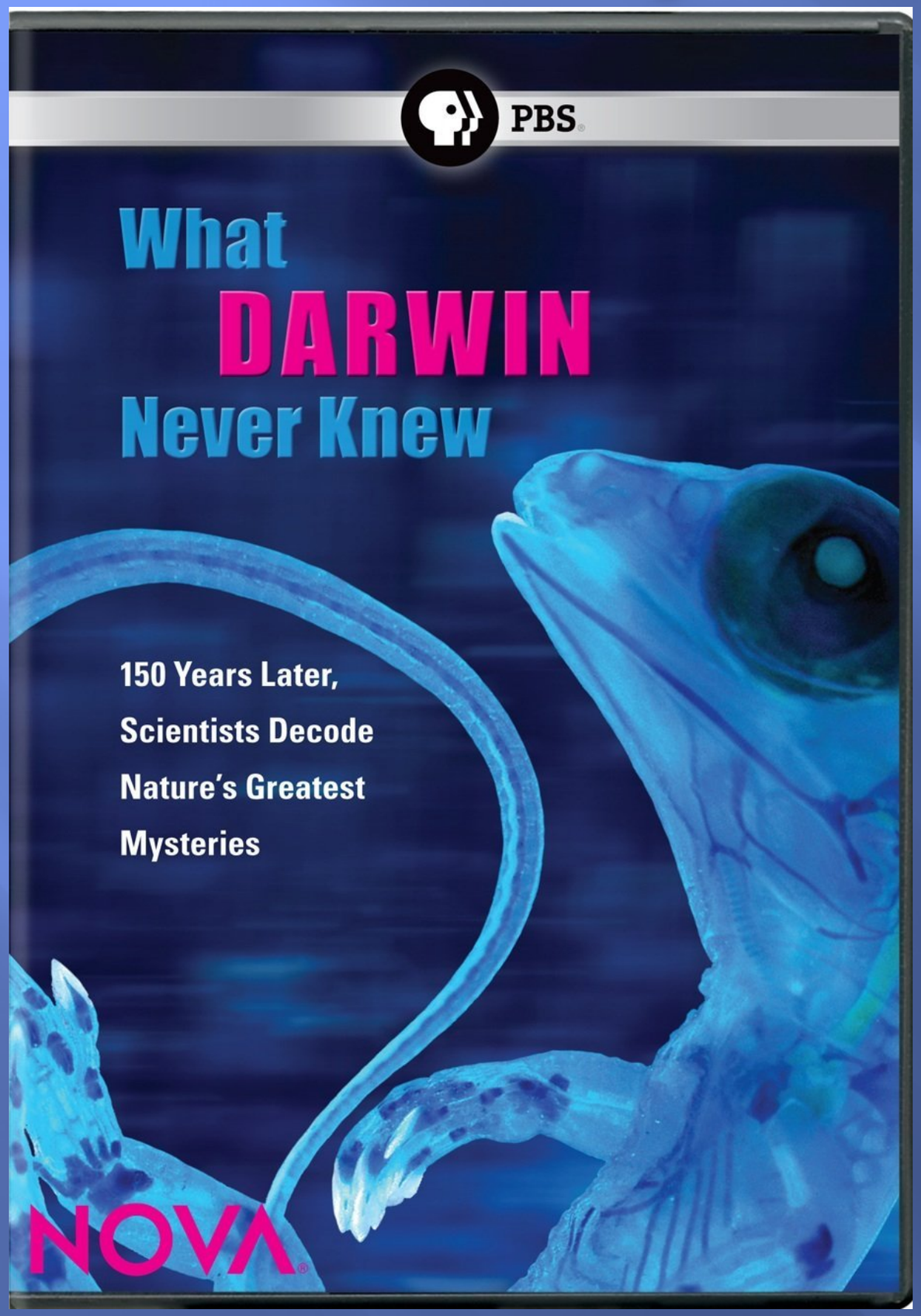
II. Mystery of Prader-Willi syndrome

III. Epigenetics/Models of Transgenerational Inheritance

IV. “Sins” of the Parents

V. Lamark Revisited

Updating Darwin



Broadcast Credits
What Darwin Never Knew
PBS Airdate: December 29, 2009

Executive Producer
Matthew Barrett

Based on the books *Endless Forms Most Beautiful* and *The Making of the Fittest* By Sean B. Carroll

Written By
John Rubin

Directed By
John Rubin
Rushmore DeNooyer
Serena Davies
Sarah Holt

http://www.pbs.org/wgbh/nova/evolution/darwin-never-knew.html

Updating Darwin

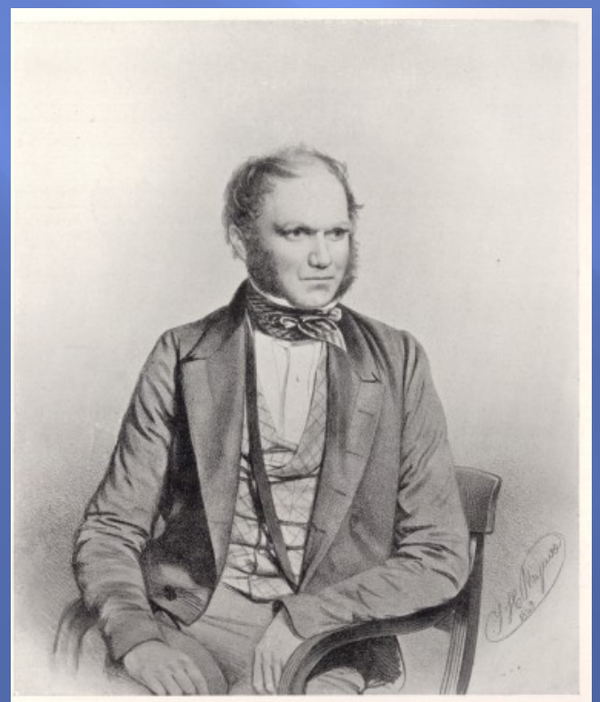
Natural Selection

Organisms within a species vary in their genes

Reproductive capacity always hits limits of environment and predation and disease remove some

Best reproducers (with their more fit genes) leave more offspring (with those fit genes)

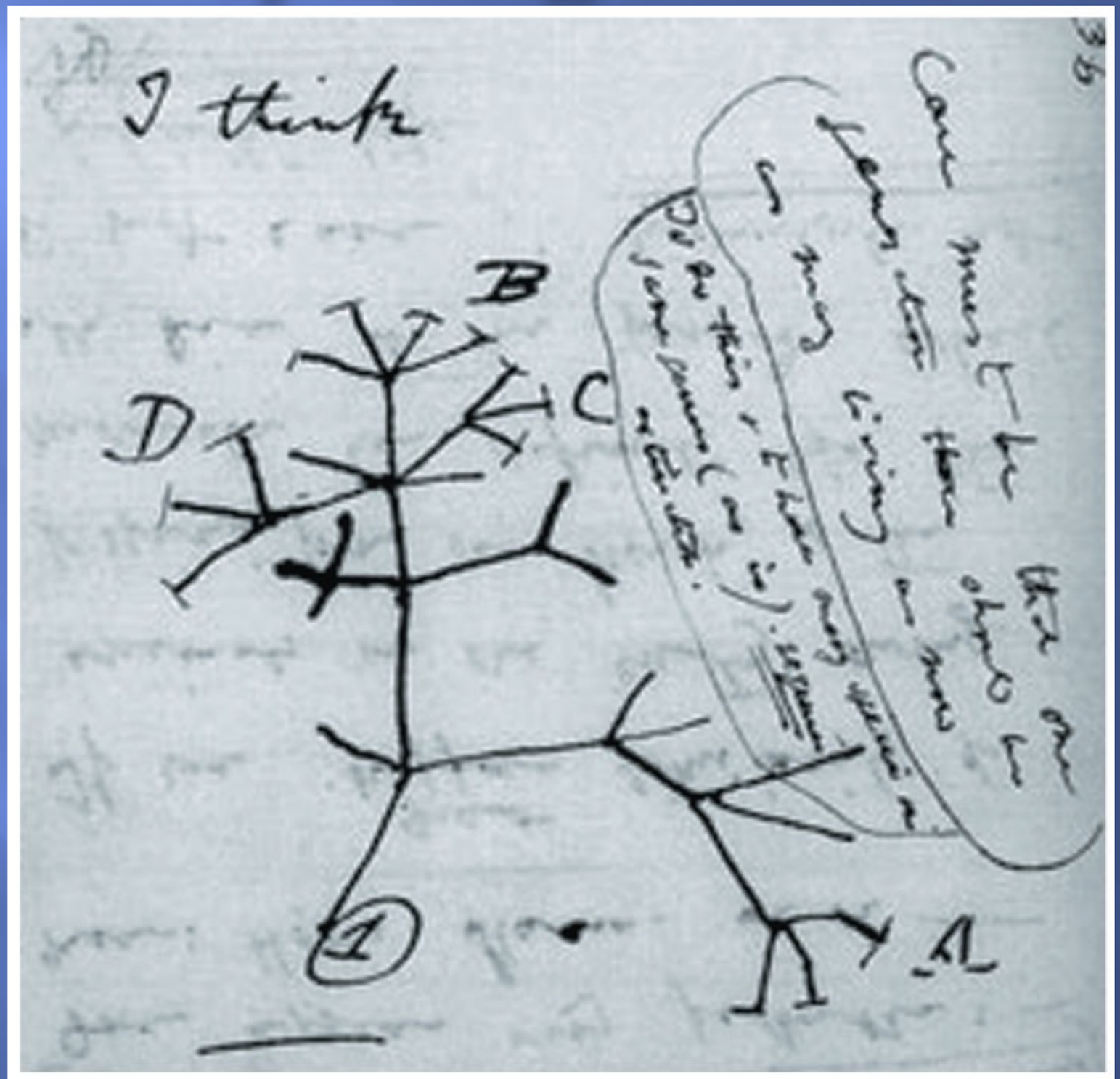
Over time, favorable traits accumulate in the population.

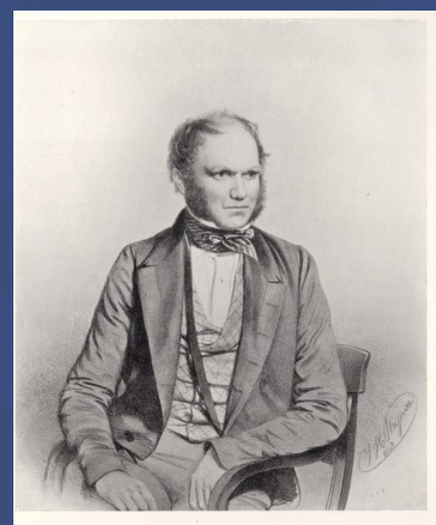


Charles Darwin, 1849

1859 *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life.* London: Murray. [1st ed.]

Updating Darwin



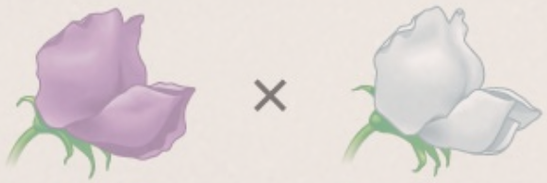


Charles Darwin, 1849

Theory a construct of observation and thought

Mendel

P Generation



Appearance: Purple flowers × White flowers

Genetic makeup: *PP* × *pp*

Gametes: *P* and *p*

F_1 Generation

Appearance: Purple flowers

Genetic makeup: *Pp*

Gametes: 1/2 *P* and 1/2 *p*

Sperm from F_1 (*Pp*) plant

F_2 Generation

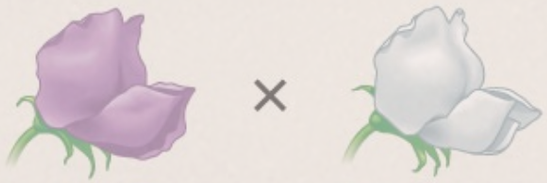
Eggs from F_1 (*Pp*) plant

	P	*p*
P	*PP*	*Pp*
p	*Pp*	*pp*

3 : 1

Mendel

P Generation



Appearance: Purple flowers × White flowers

Genetic makeup: *PP* × *pp*

Gametes: *P* and *p*

F_1 Generation

Appearance: Purple flowers

Genetic makeup: *Pp*

Gametes: 1/2 *P*, 1/2 *p*

Sperm from F_1 (*Pp*) plant

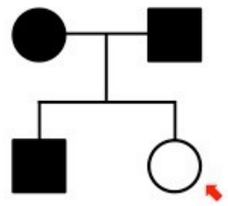
F_2 Generation

Eggs from F_1 (*Pp*) plant

	P	*p*
P	*PP*	*Pp*
p	*Pp*	*pp*

3 : 1

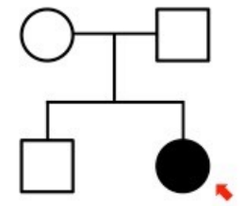
AUTOSOMAL DOMINANT



Cannot be recessive as two affected parents could **not** have an unaffected offspring

Parents MUST be heterozygous

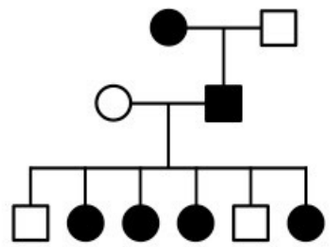
AUTOSOMAL RECESSIVE



Cannot be dominant as two unaffected parents could **not** have an affected offspring

Parents MUST be heterozygous

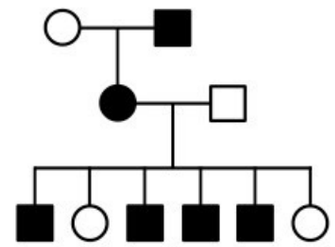
X-LINKED DOMINANT



Sex linkage cannot be confirmed

100% incidence of affected daughters from an affected father *suggests* X-linked dominance

X-LINKED RECESSIVE



Sex linkage cannot be confirmed

100% incidence of affected sons from an affected mother *suggests* X-linked recessive

Prader-Willi Syndrome

Genetic disorder that occurs in approximately one out of every 15,000 births.

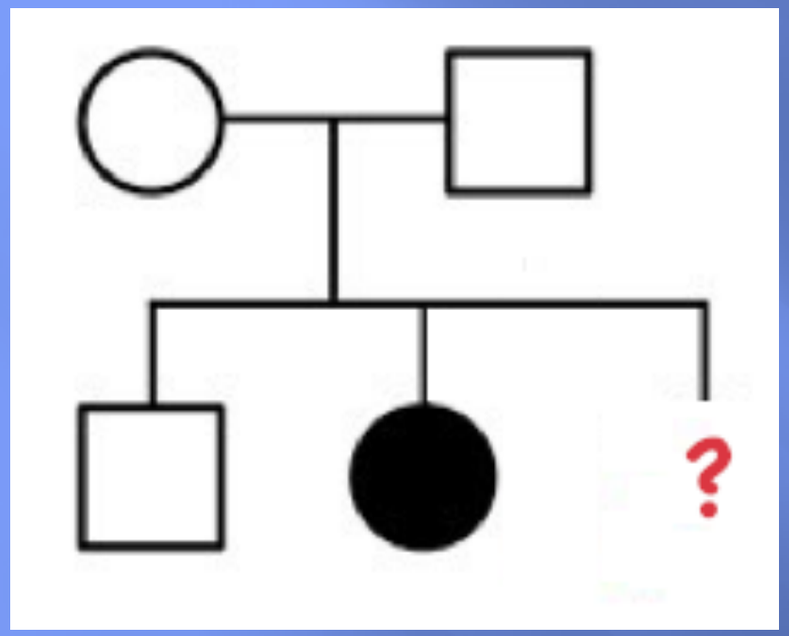
affects males and females with equal frequency and affects all races and ethnicities

PWS is recognized as the most common genetic cause of life-threatening childhood obesity.

common characteristics defined in the initial report included small hands and feet, abnormal growth and body composition (small stature, very low lean body mass, and early-onset childhood obesity), hypotonia (weak muscles) at birth, insatiable hunger, extreme obesity, and intellectual disability.

https://www.fpwr.org/what-is-prader-willi-syndrome

Prader-Willi Syndrome



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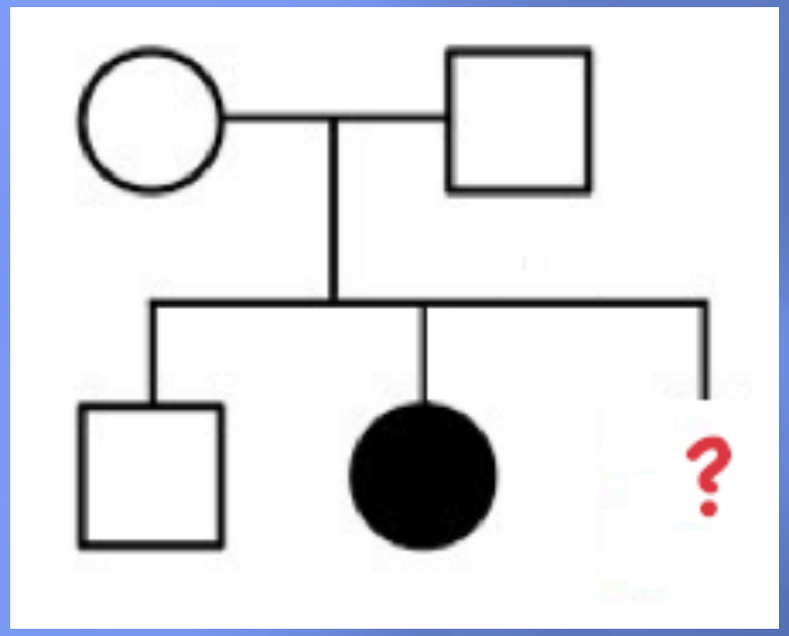
Prader-Willi Syndrome



<1%

chromosome 15

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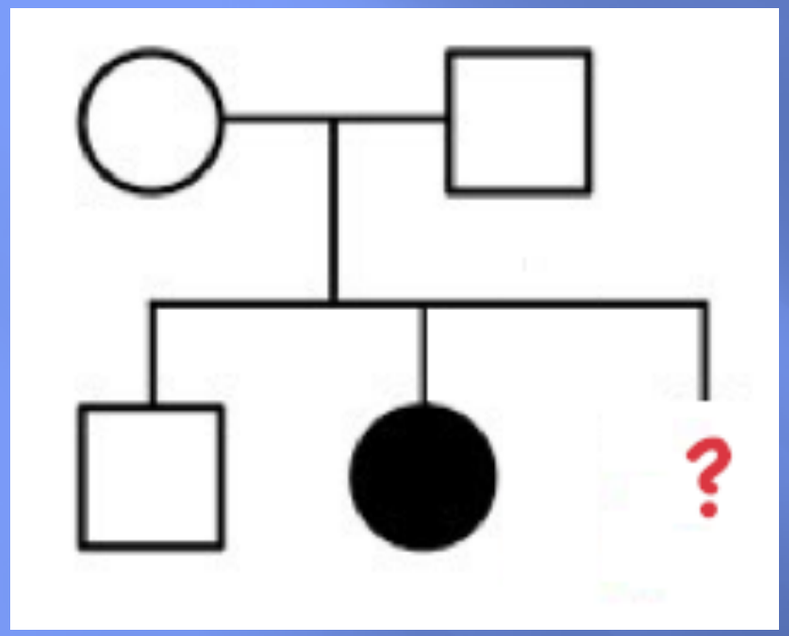
Prader-Willi Syndrome



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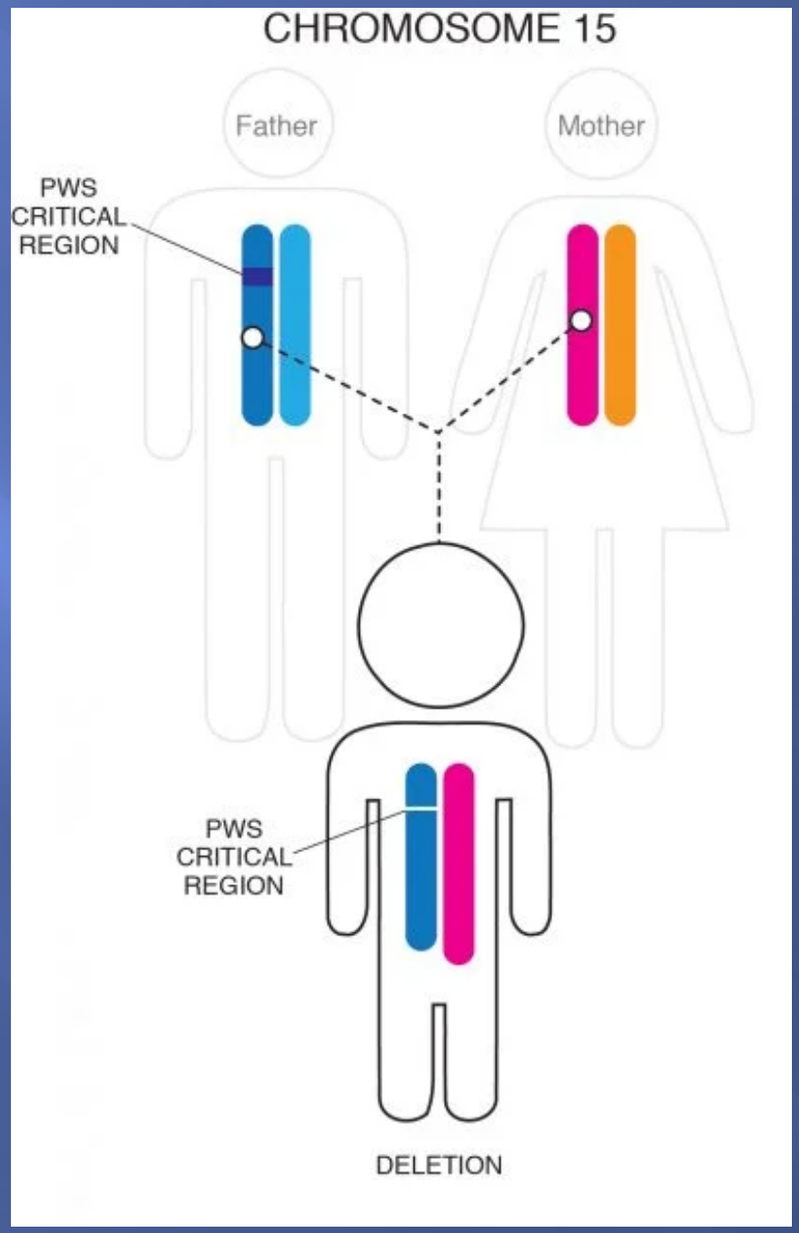

affected

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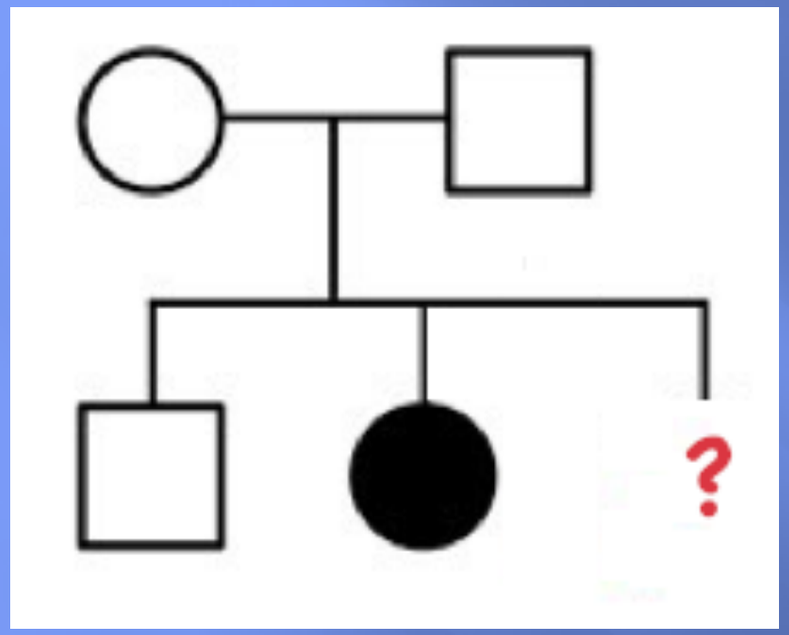
Prader-Willi Syndrome



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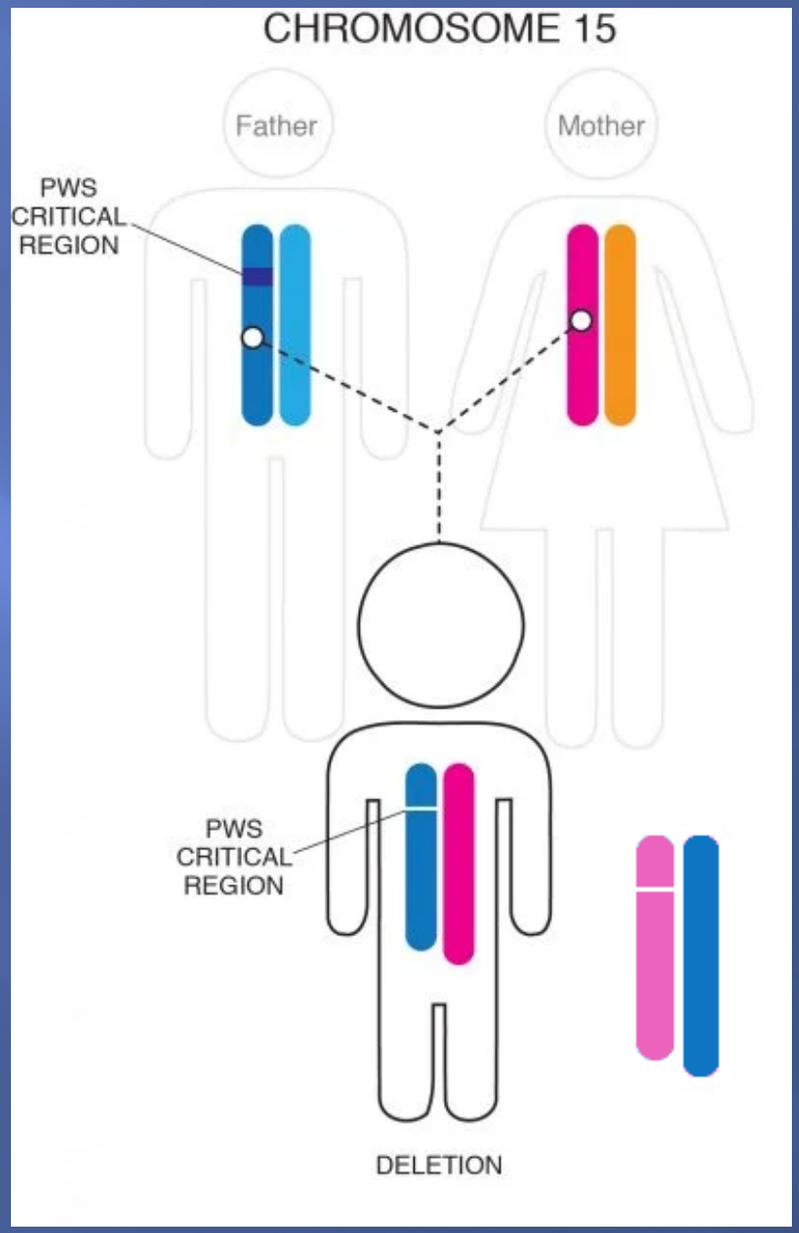
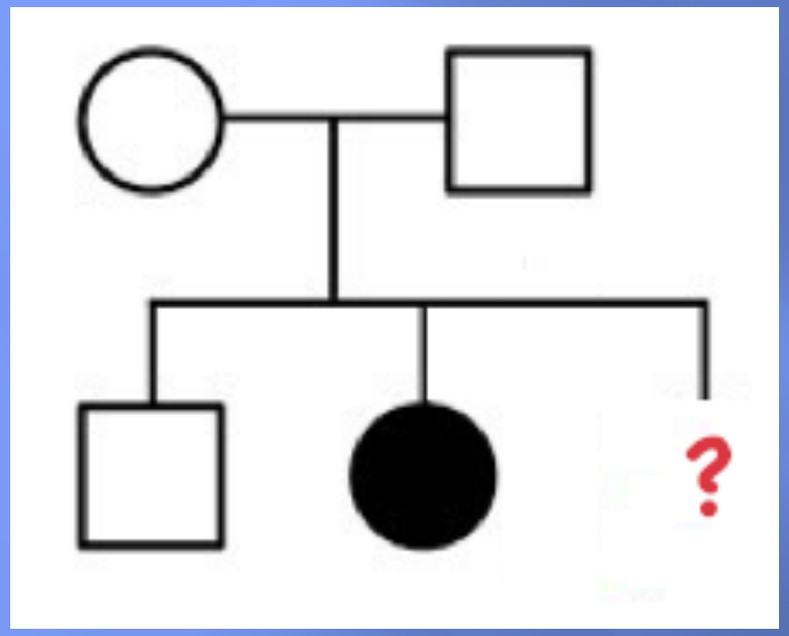


affected

unaffected

https://www.fpwr.org/what-is-prader-willi-syndrome

Prader-Willi Syndrome



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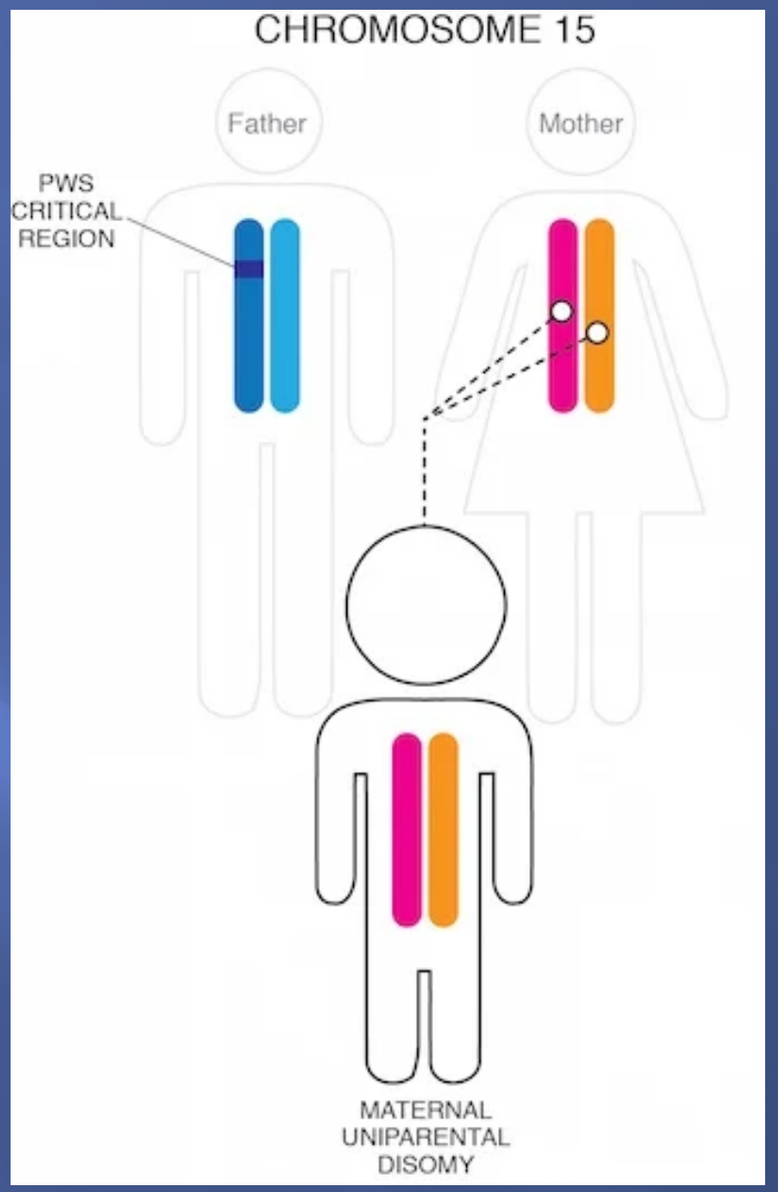

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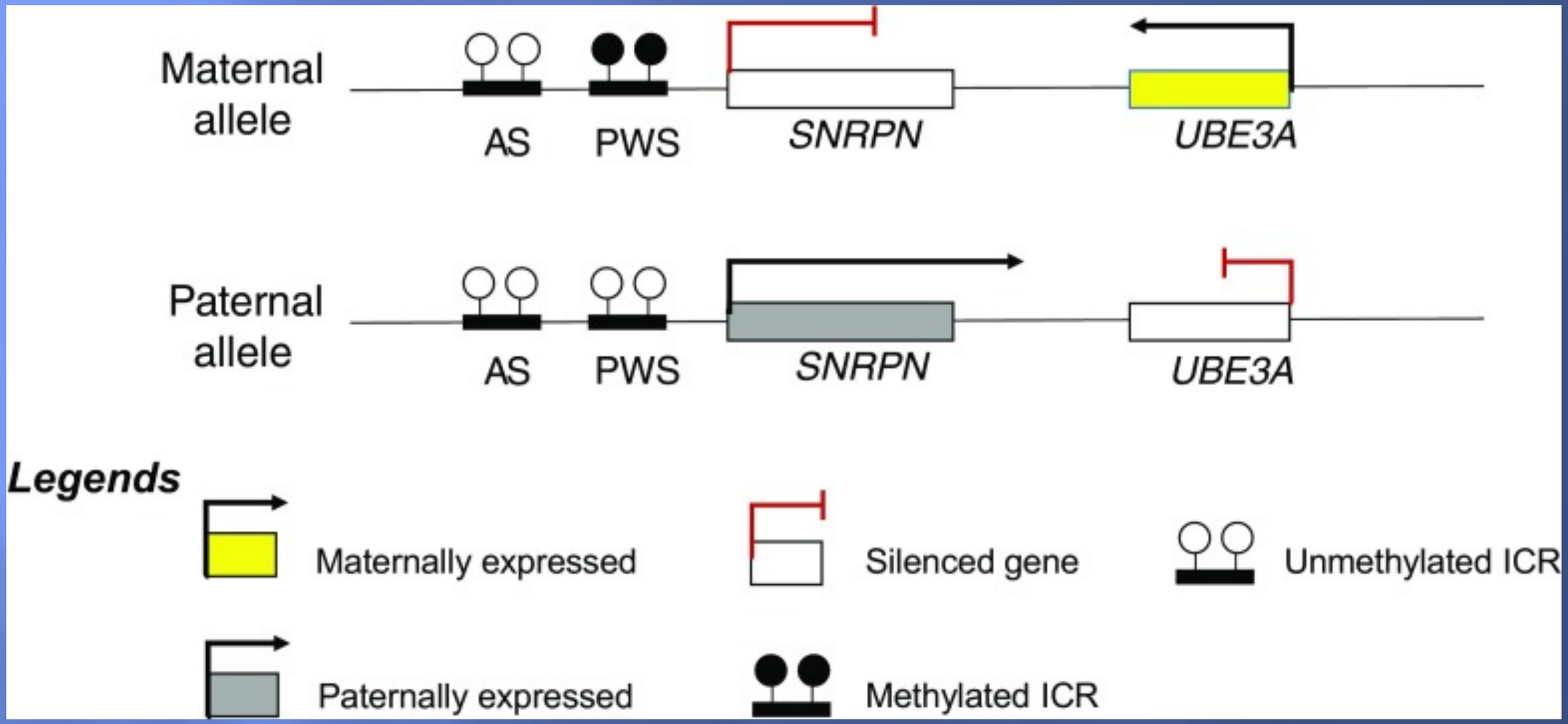
Prader-Willi Syndrome



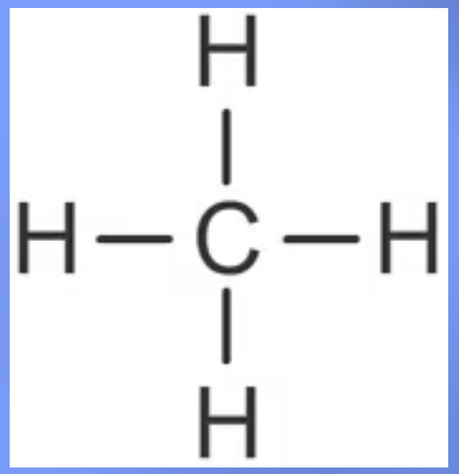
Important developmental gene is only expressed from PATERNAL chromosome 15

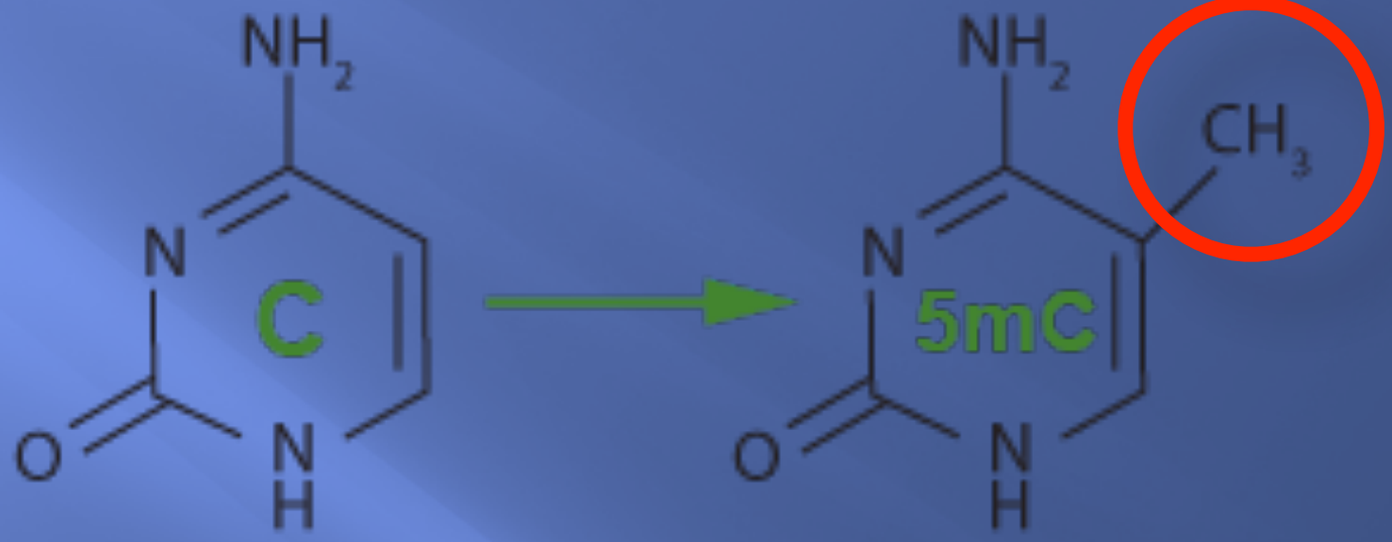
Through years and multiple cell divisions

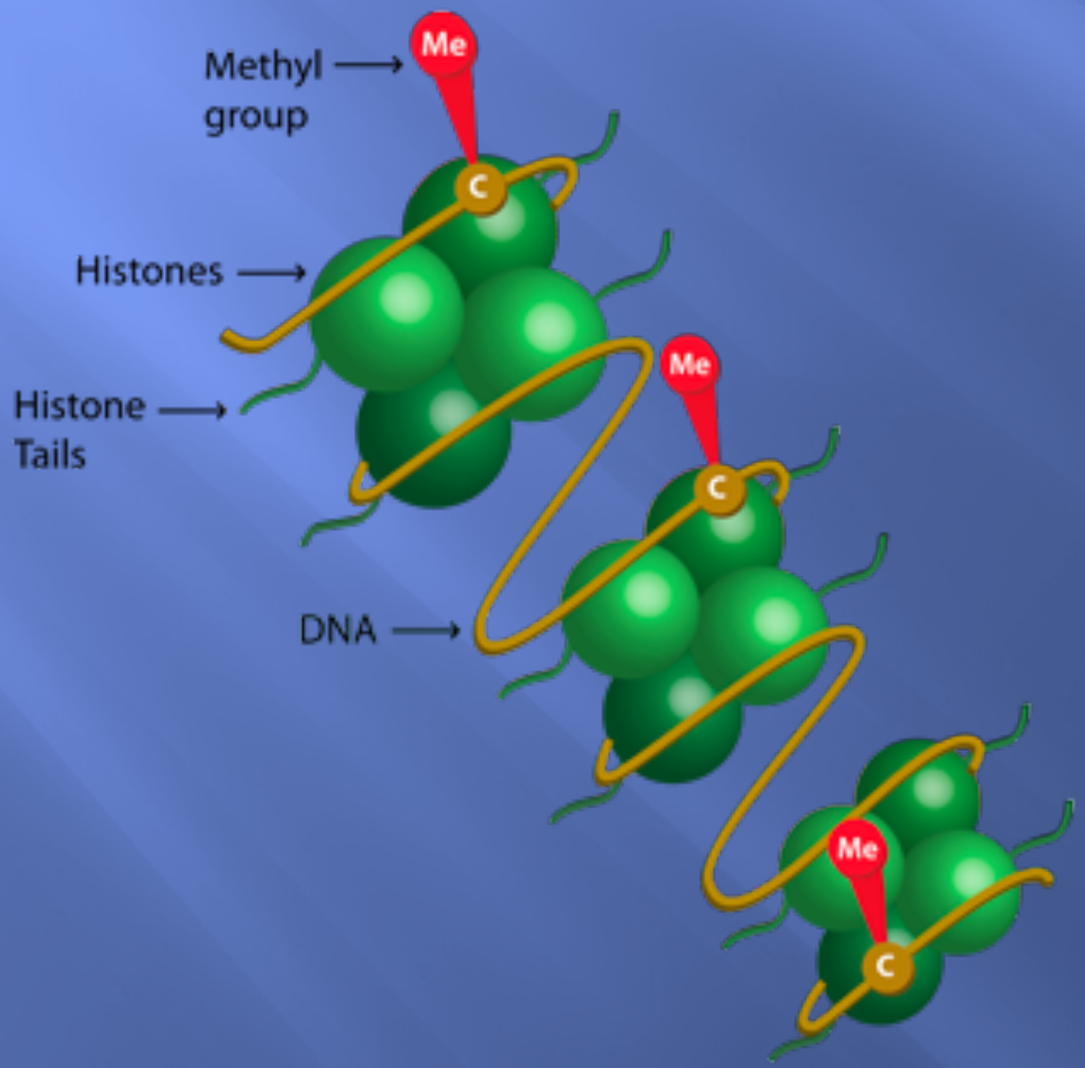
Elhamamsy, Amr Rafat. "Role of DNA methylation in imprinting disorders: an updated review." *Journal of Assisted Reproduction and Genetics* 34 (2017): 549-562.

Methylation

methane





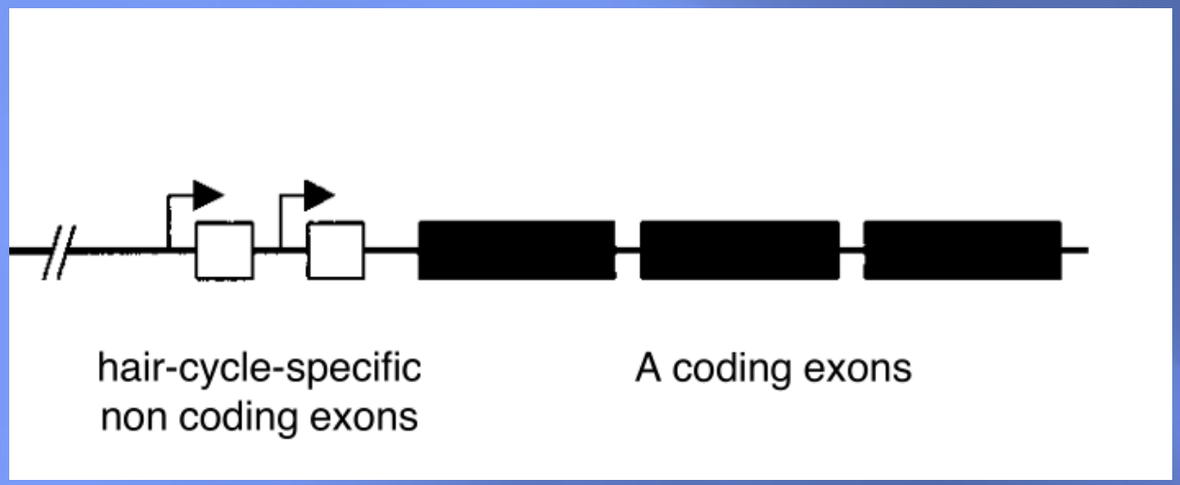


Methylated -> gene OFF

unMethylated -> gene ON

Inherited variable expression

drives yellow expression ONLY
in hair for short duration



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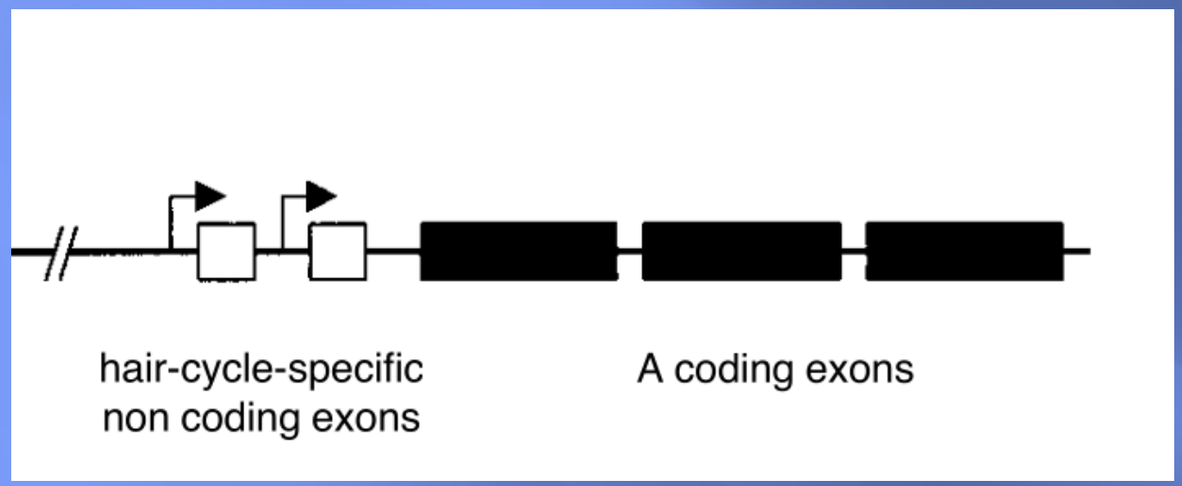

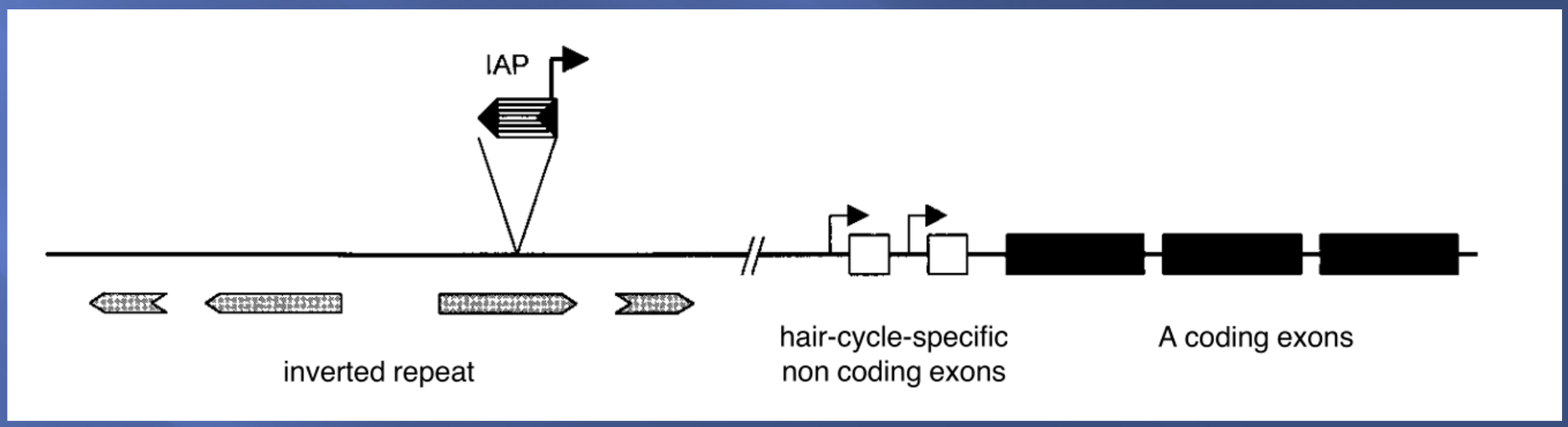

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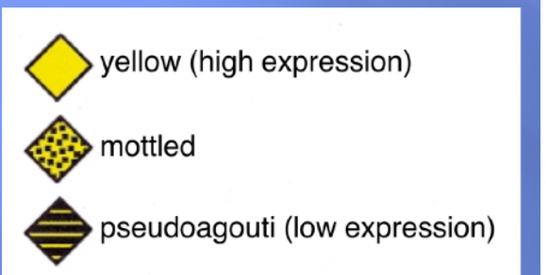

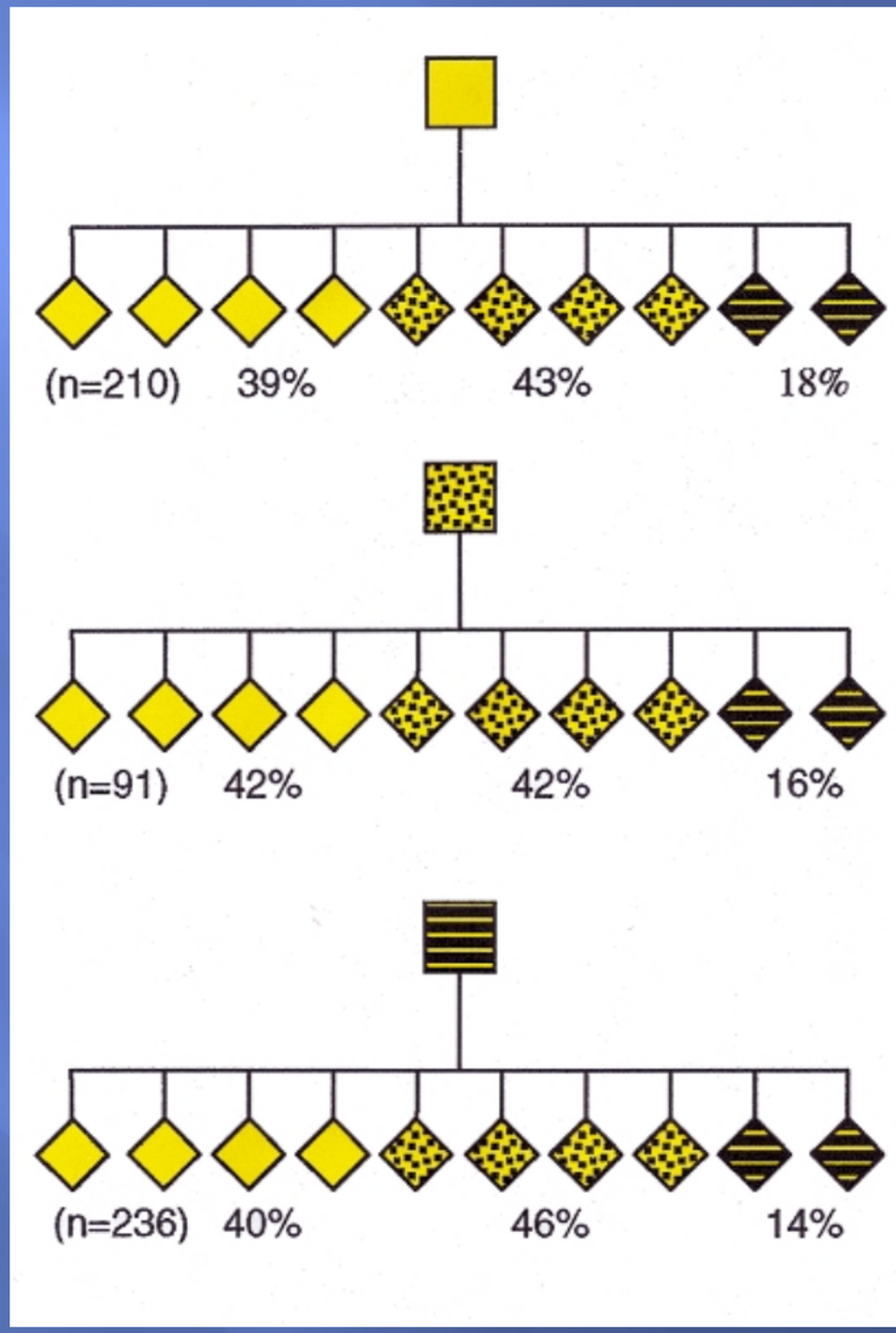

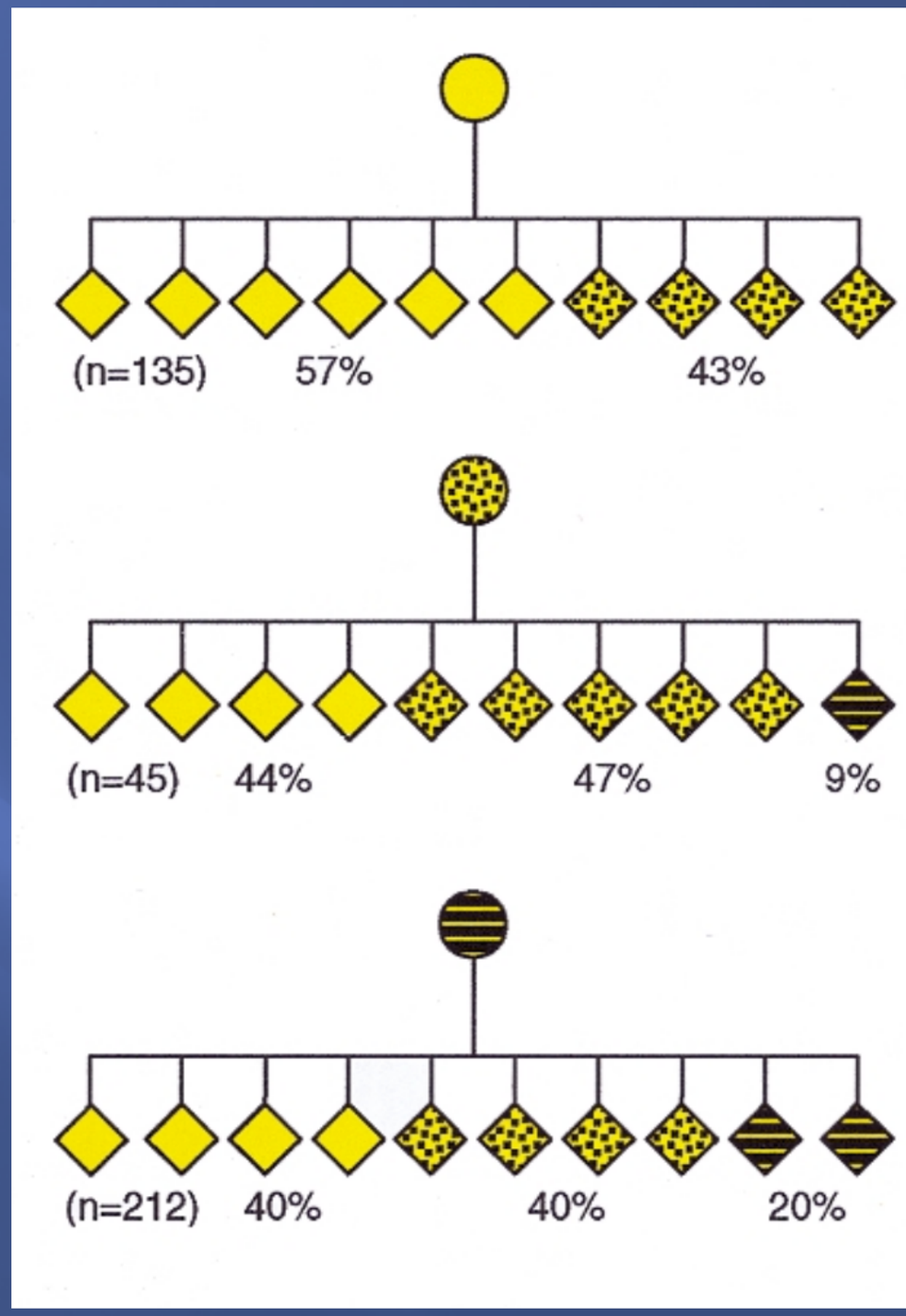

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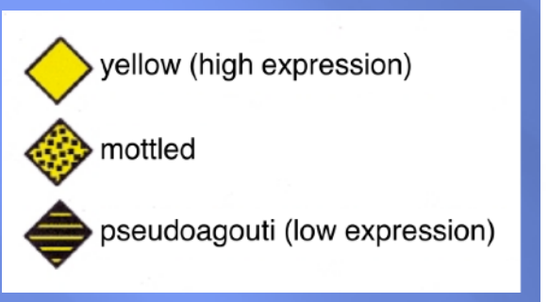
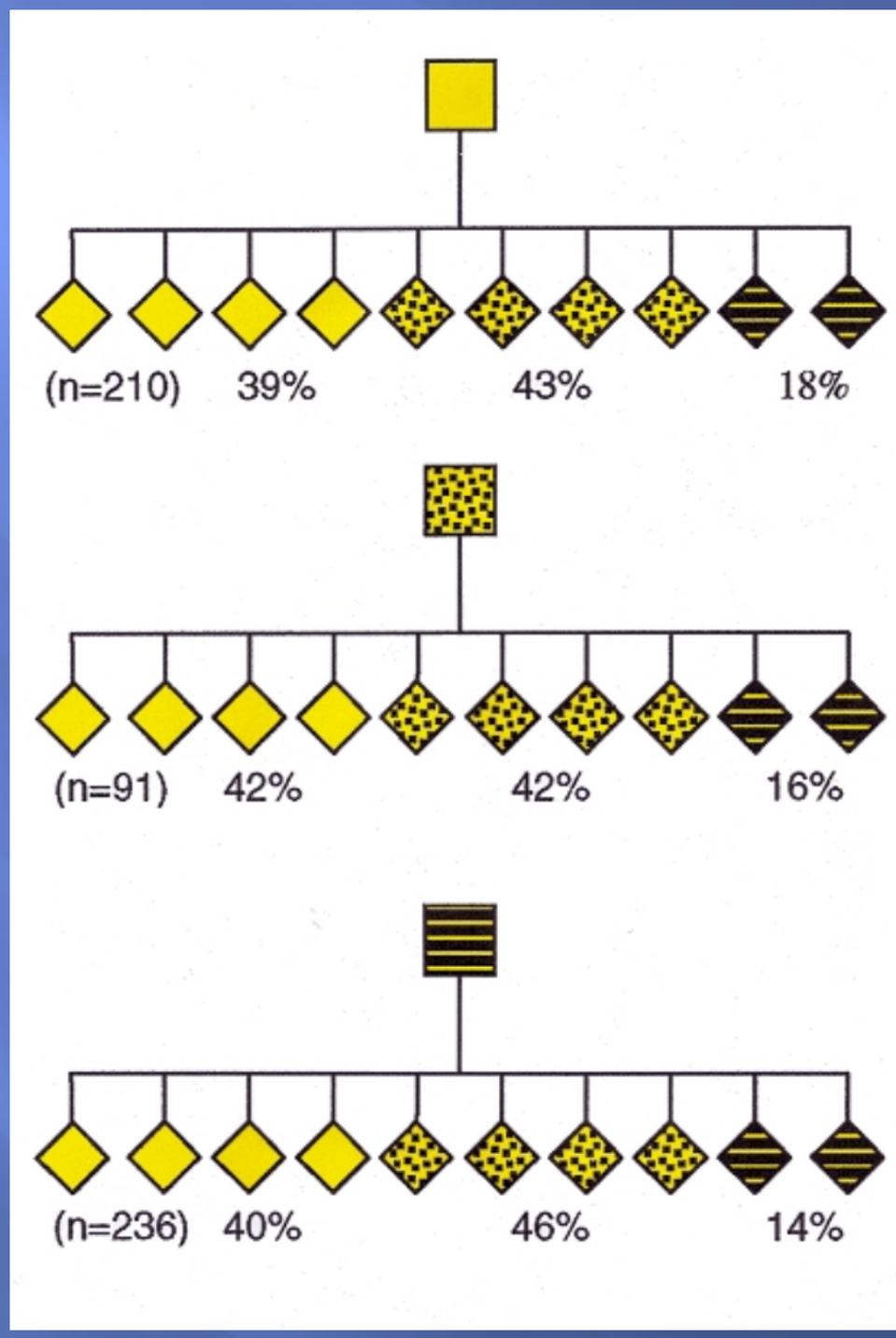
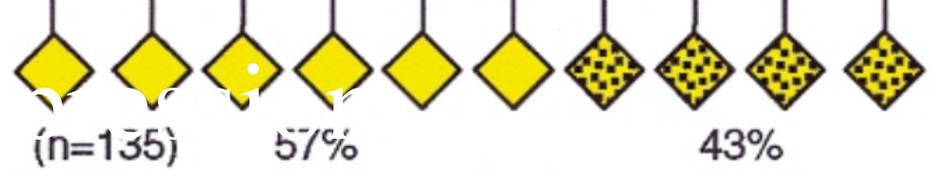
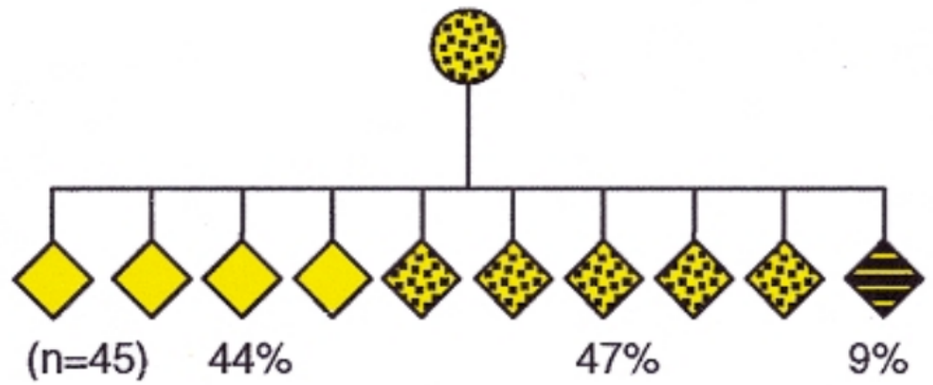
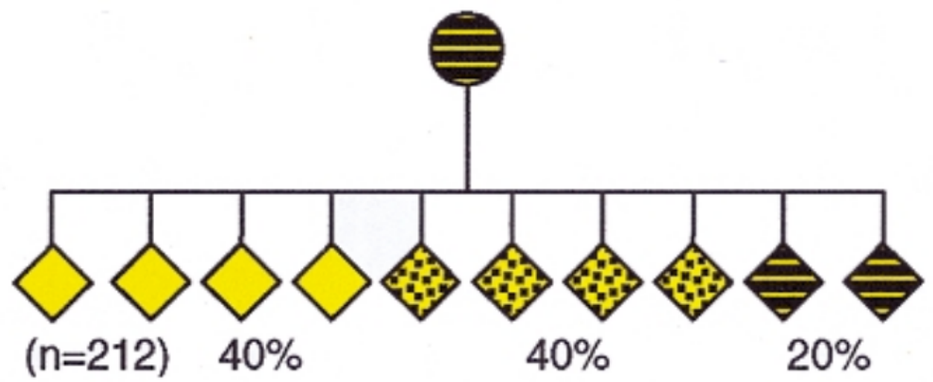
Inherited variable e

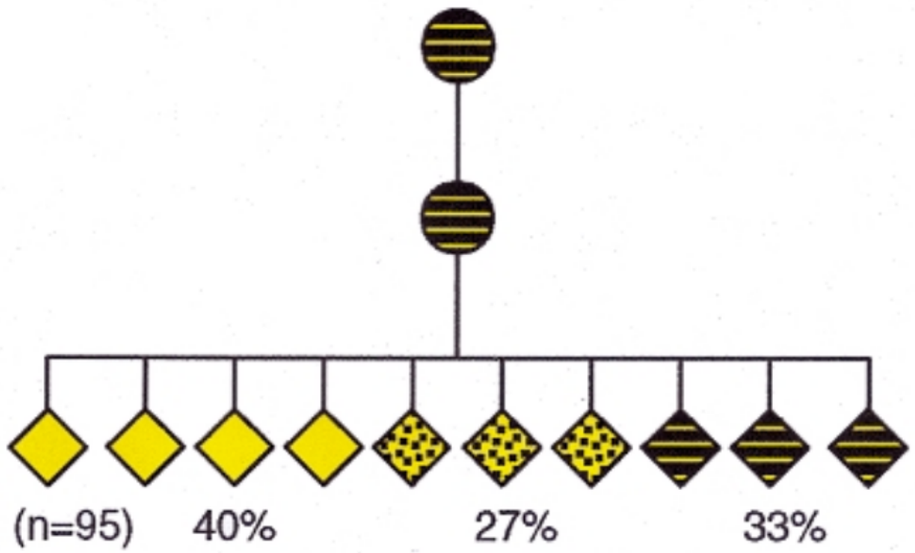












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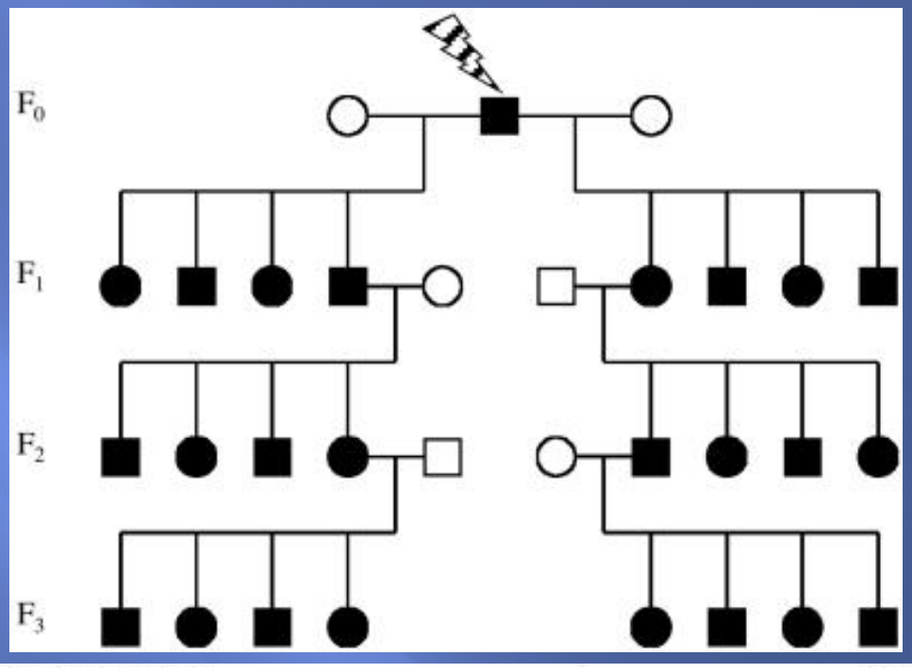
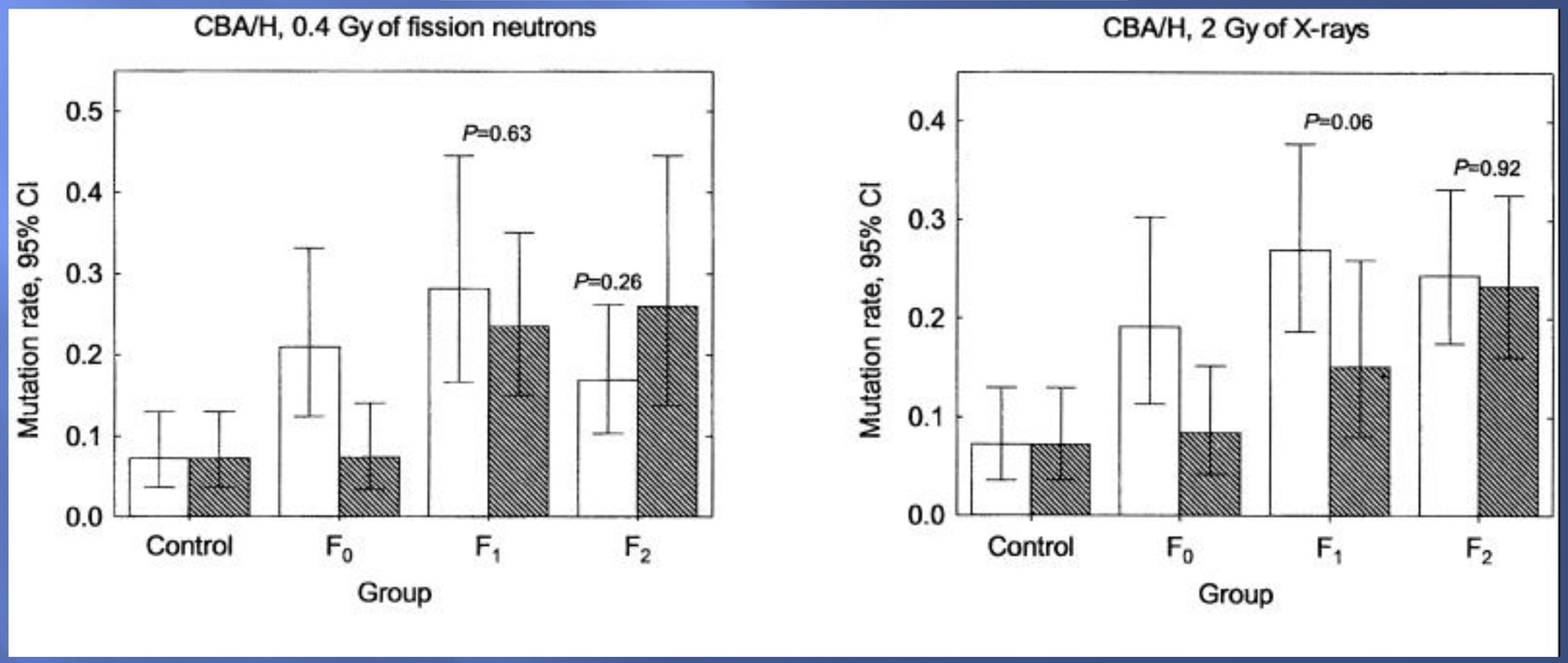
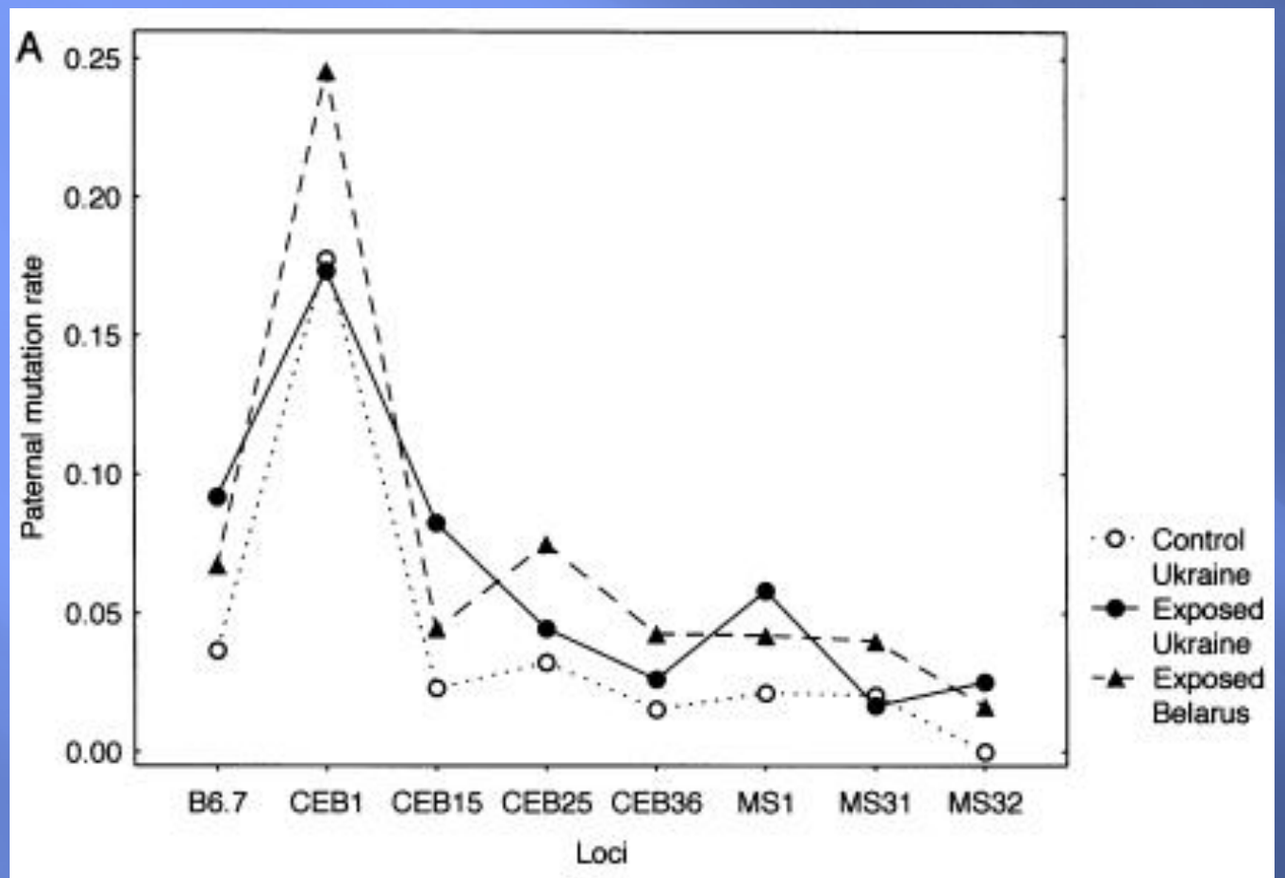
Transgenerational Genetic Instability

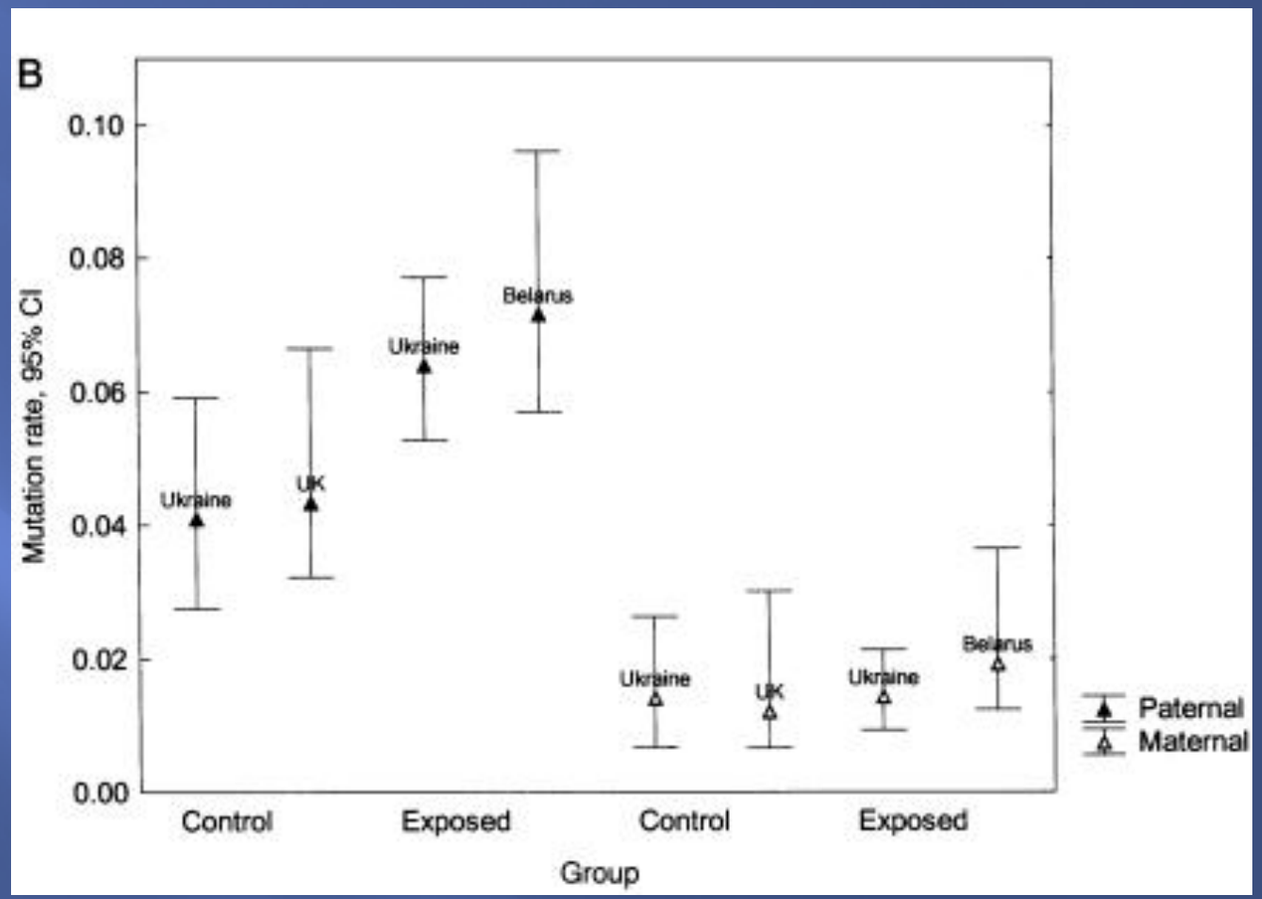




Barber, Ruth, et al. "Elevated mutation rates in the germ line of first-and second-generation offspring of irradiated male mice." *Proceedings of the National Academy of Sciences* 99.10 (2002): 6877-6882.

Transgenerational Genetic Instability

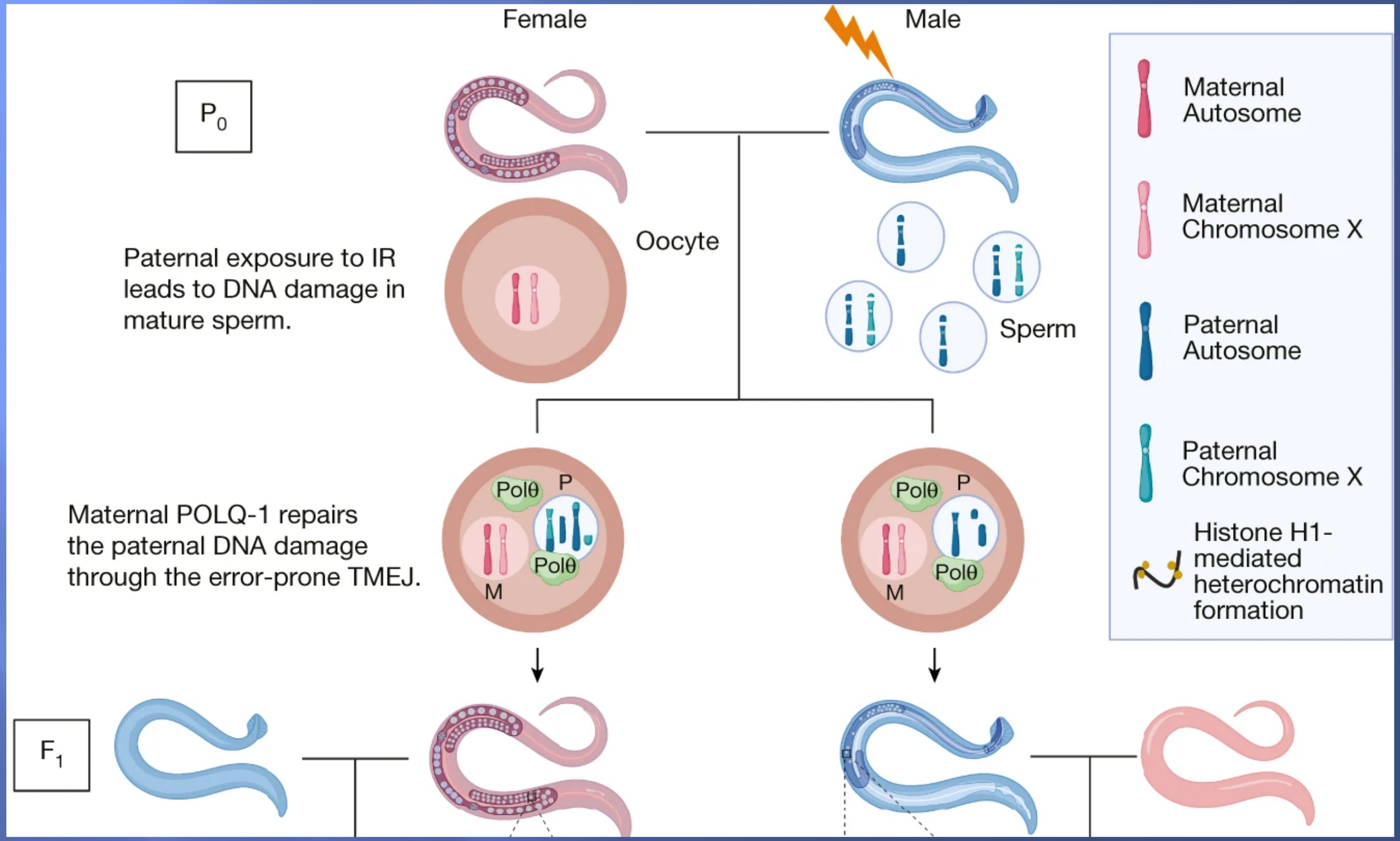




microsatellite instability +1.6 fold in progeny of males exposed to Chernobyl radiation

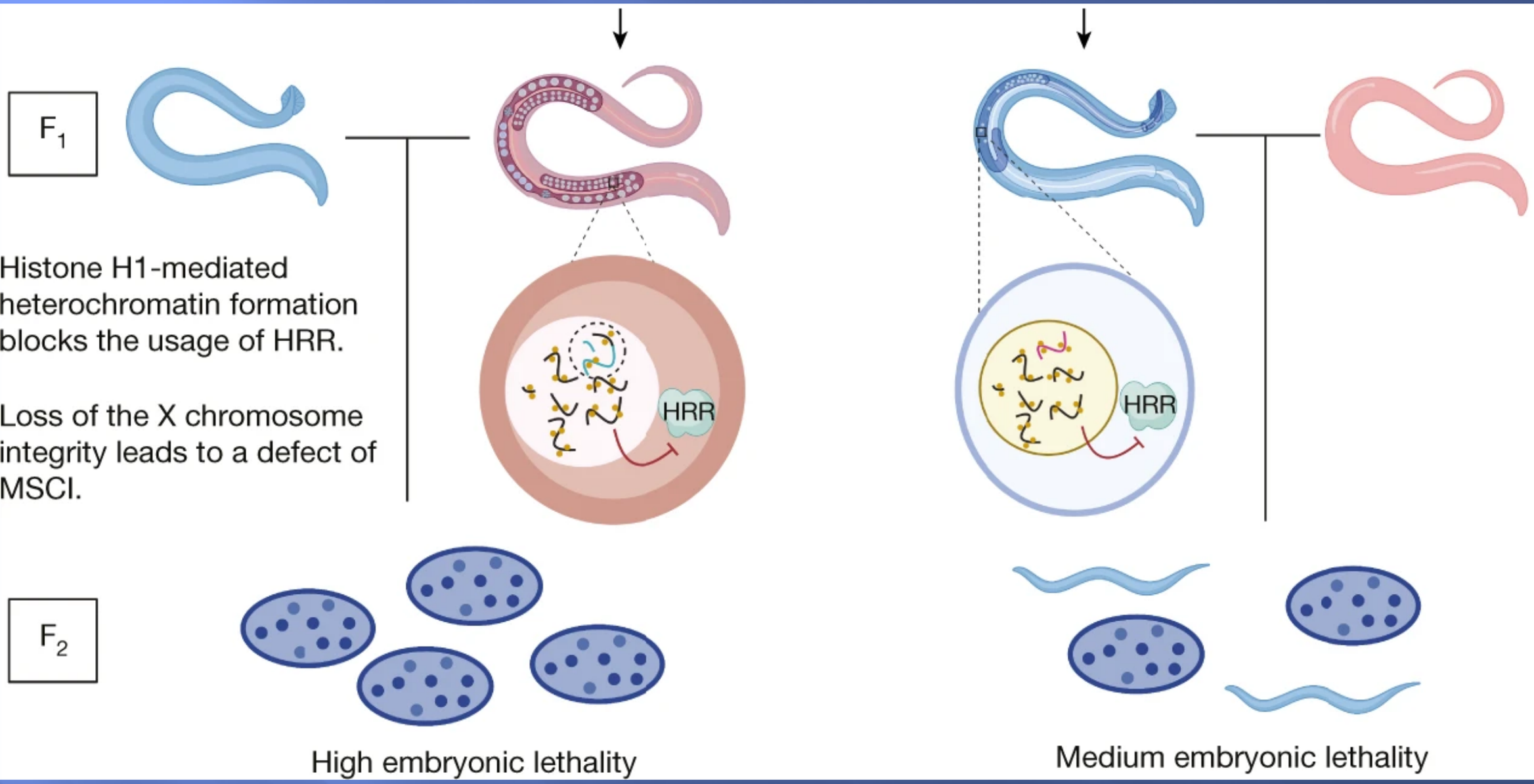
Dubrova, Yuri E., et al. "Elevated minisatellite mutation rate in the post-Chernobyl families from Ukraine." *The American Journal of Human Genetics* 71.4 (2002): 801-809.

Transgenerational Genetic Instability



Wang, Siyao, David H. Meyer, and Björn Schumacher. "Inheritance of paternal DNA damage by histone-mediated repair restriction." *Nature* 613.7943 (2023): 365-374.

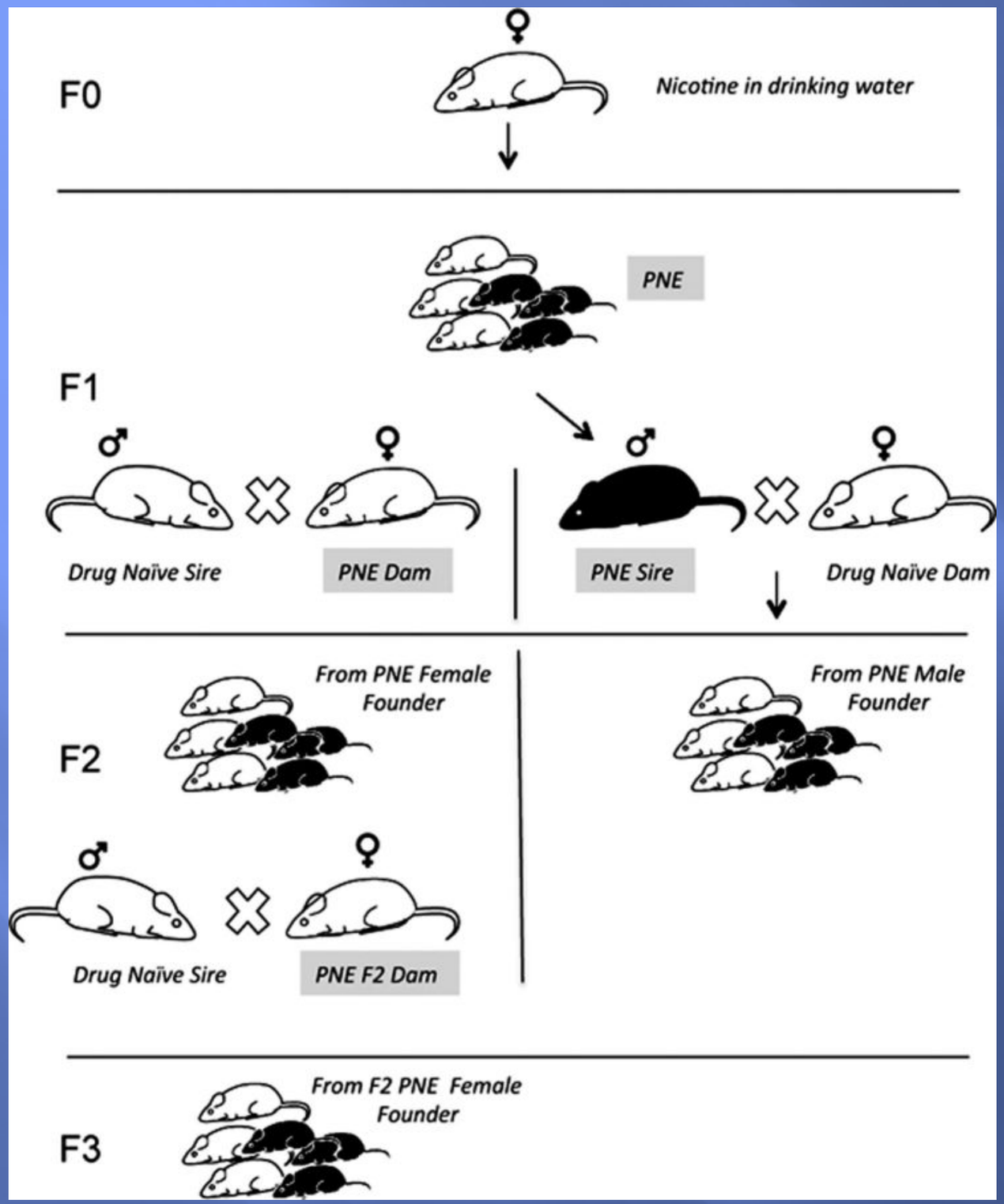
Transgenerational Genetic Instability



lethality is alleviated by decreased repair histones, which allow homologous recombination to repair the breaks in F1

Wang, Siyao, David H. Meyer, and Björn Schumacher. "Inheritance of paternal DNA damage by histone-mediated repair restriction." *Nature* 613.7943 (2023): 365-374.

Can diet influence inheritance?

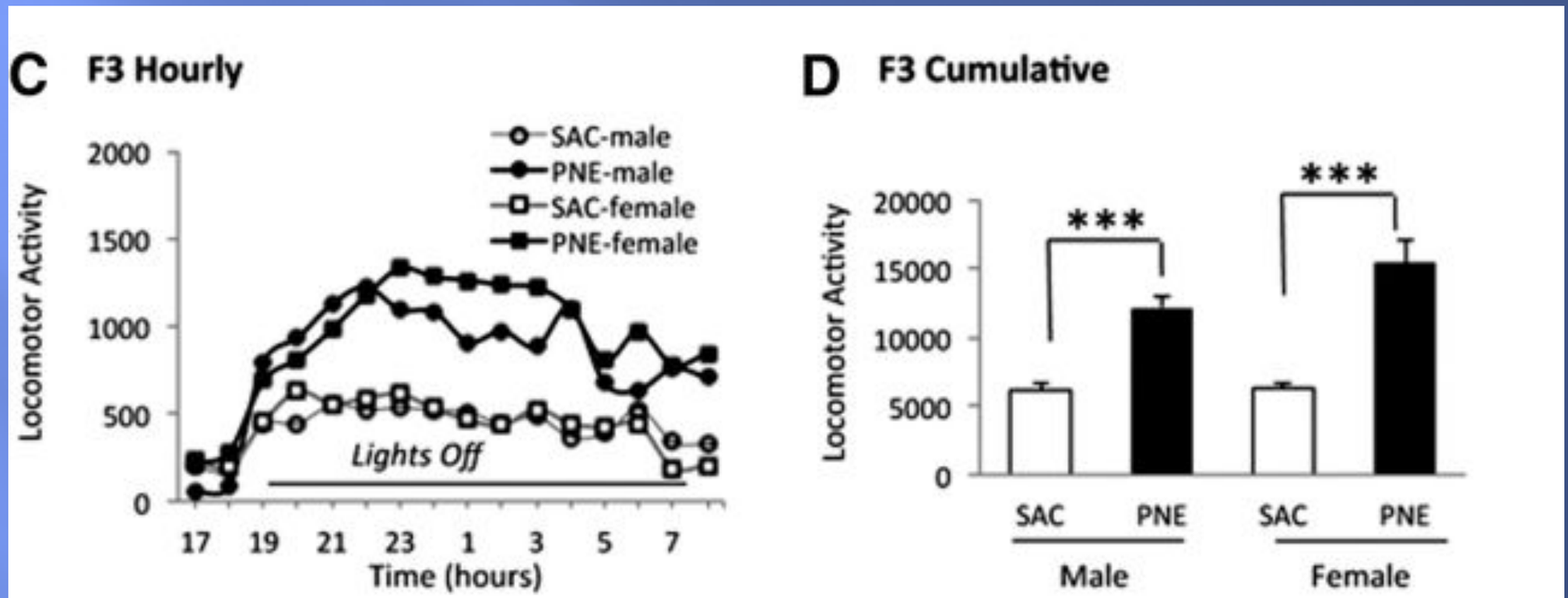


nicotine as a driver of spontaneous locomotor activity

saccharin is used to sweeten the nicotine

Zhu, Jinmin, et al. "Transgenerational transmission of hyperactivity in a mouse model of ADHD." *Journal of Neuroscience* 34.8 (2014): 2768-2773.

Can diet influence inheritance?



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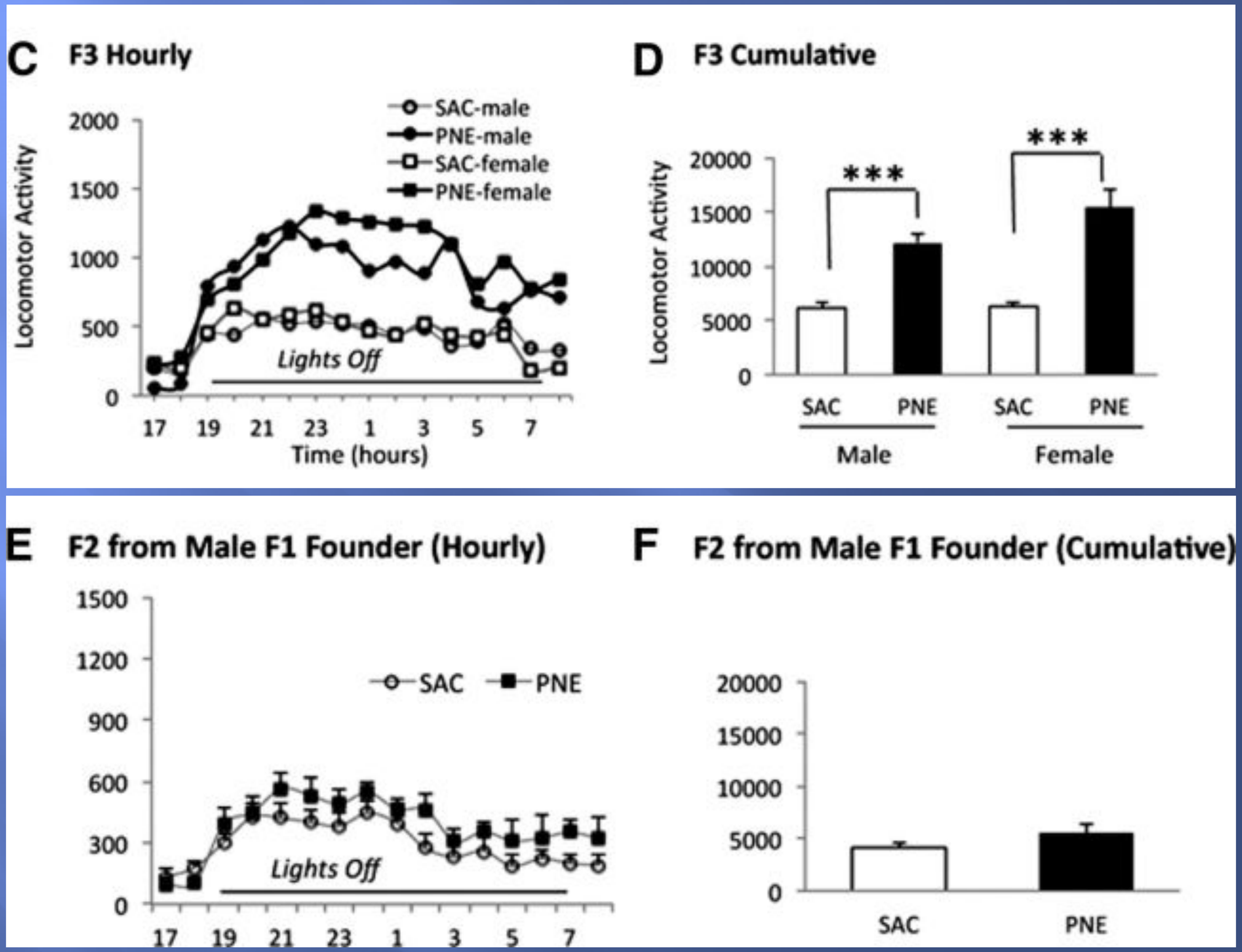

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Other Studied Mouse Diet/Exposures

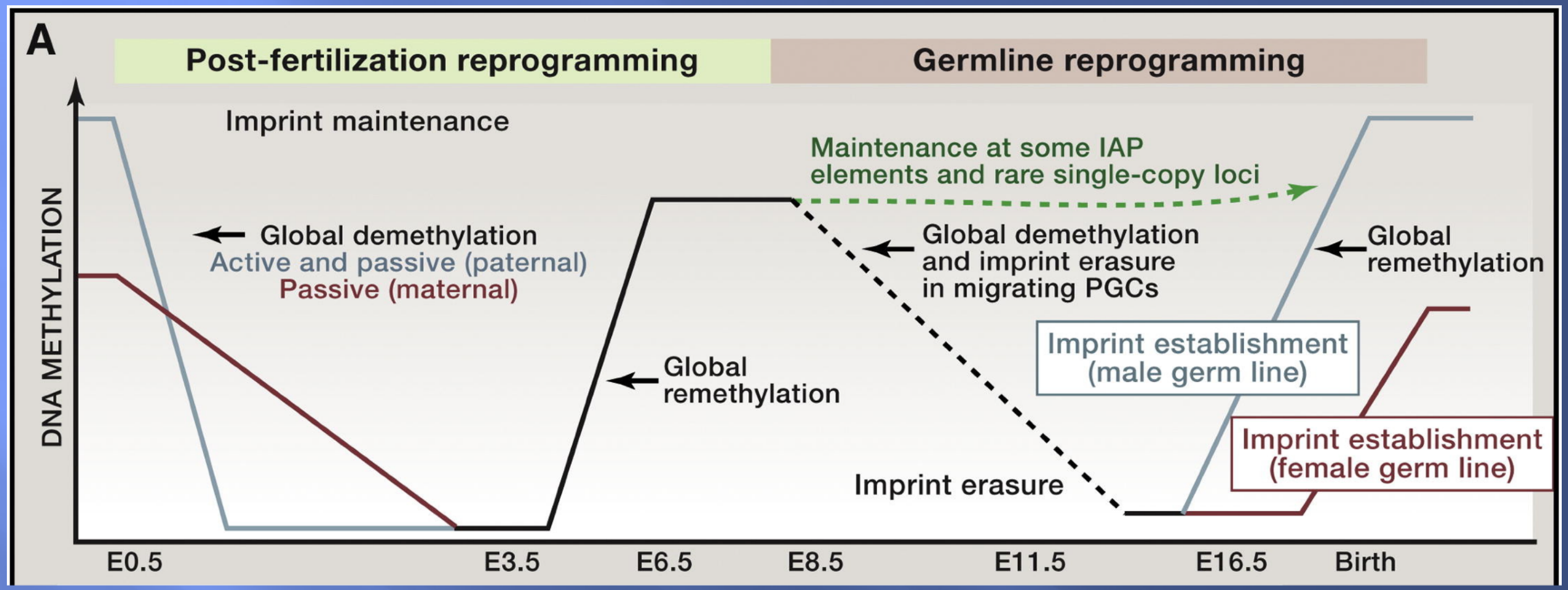
opioids

BPA

alcohol

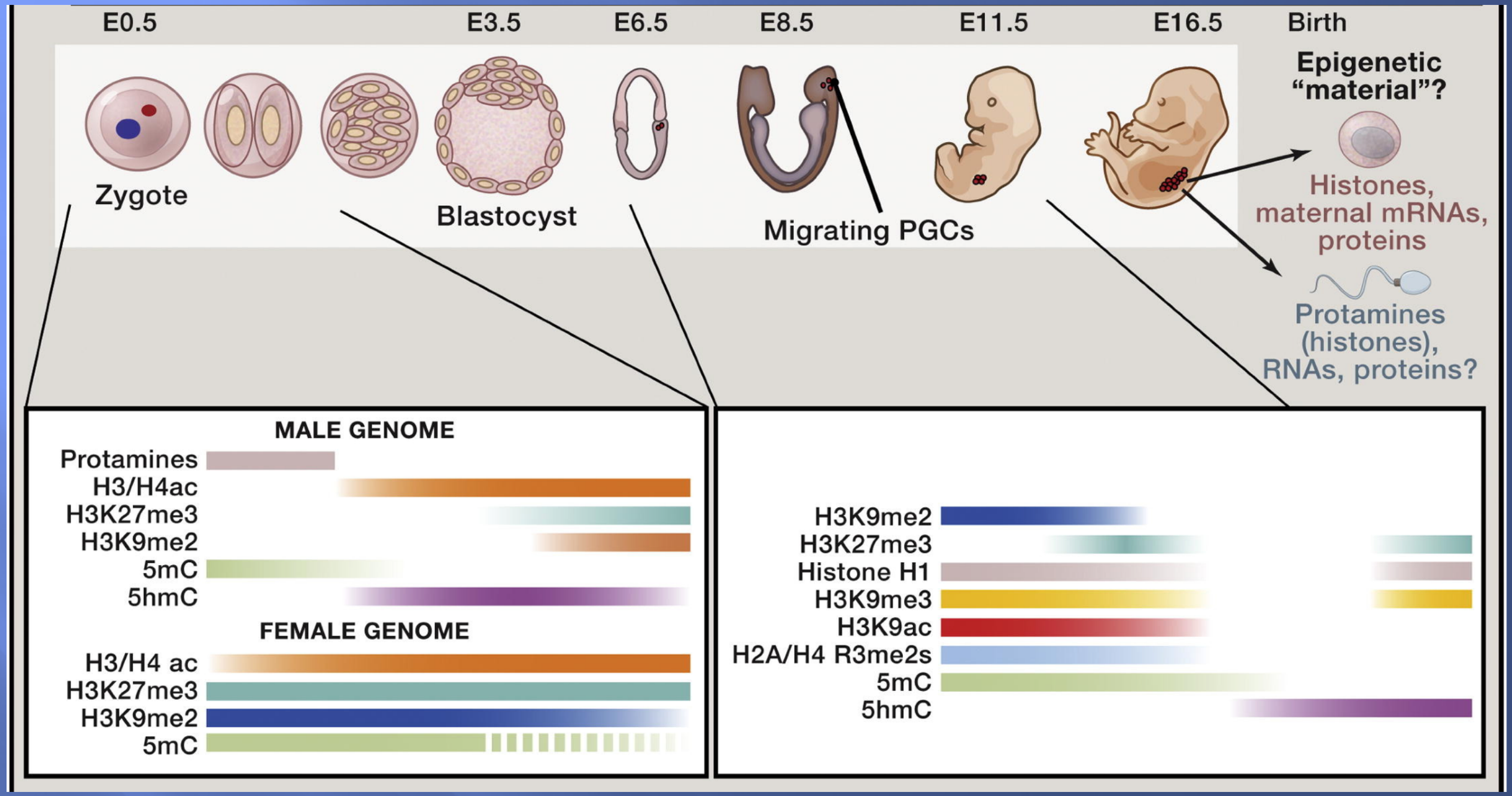
diabetes/obesity (Akita mouse model, genetic disease state)

Methylation States



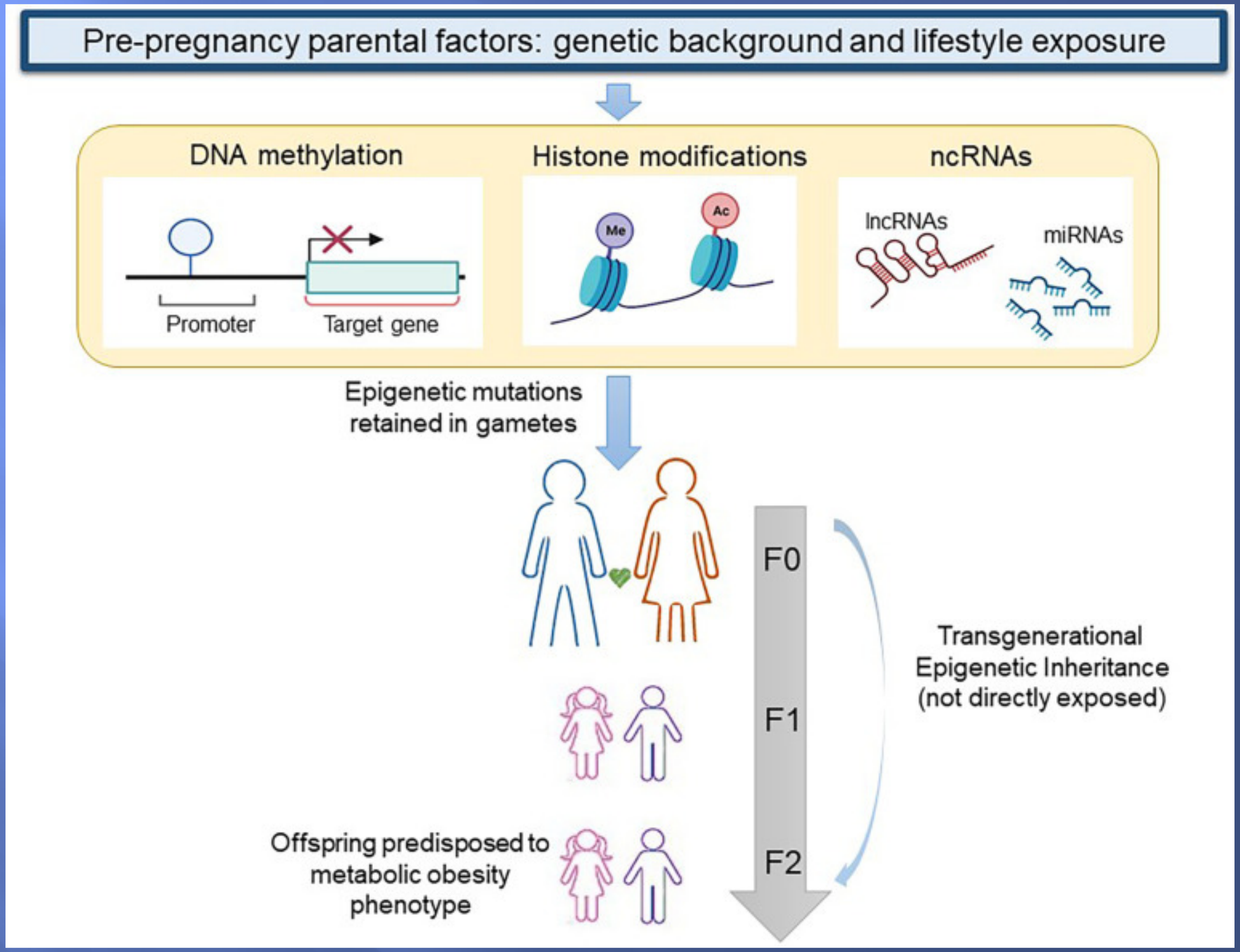
Heard, Edith, and Robert A. Martienssen. "Transgenerational epigenetic inheritance: myths and mechanisms." *Cell* 157.1 (2014): 95-109.

Methylation States



Heard, Edith, and Robert A. Martienssen. "Transgenerational epigenetic inheritance: myths and mechanisms." *Cell* 157.1 (2014): 95-109.

Summary of Transgenerational Inheritance



Panera, Nadia, et al. "Genetics, epigenetics and transgenerational transmission of obesity in children." *Frontiers in endocrinology* 13 (2022): 1006008.

Summary

Inheritance can be cross generational role due to exposure of the parent pre-conception (and the developing embryo as applicable) to environmental exposures

This is due to the phenomenon of specific epigenetic programming being maintained through the general “resets”

How much impact this has in humans is still being clarified

Evolutionary Theory Right Before Darwin

Jean-Baptiste Lamarck (1744 – 1829)

- *Philosophie Zoologique* (1809) Theory of Inheritance of Acquired Characteristics "Lamarckism".
- first cohesive theory of biological evolution
  - alchemical complexifying force drove organisms up a ladder of complexity, and
  - a second environmental force adapted them to local environments through use and disuse of characteristics

Right Before Darwin

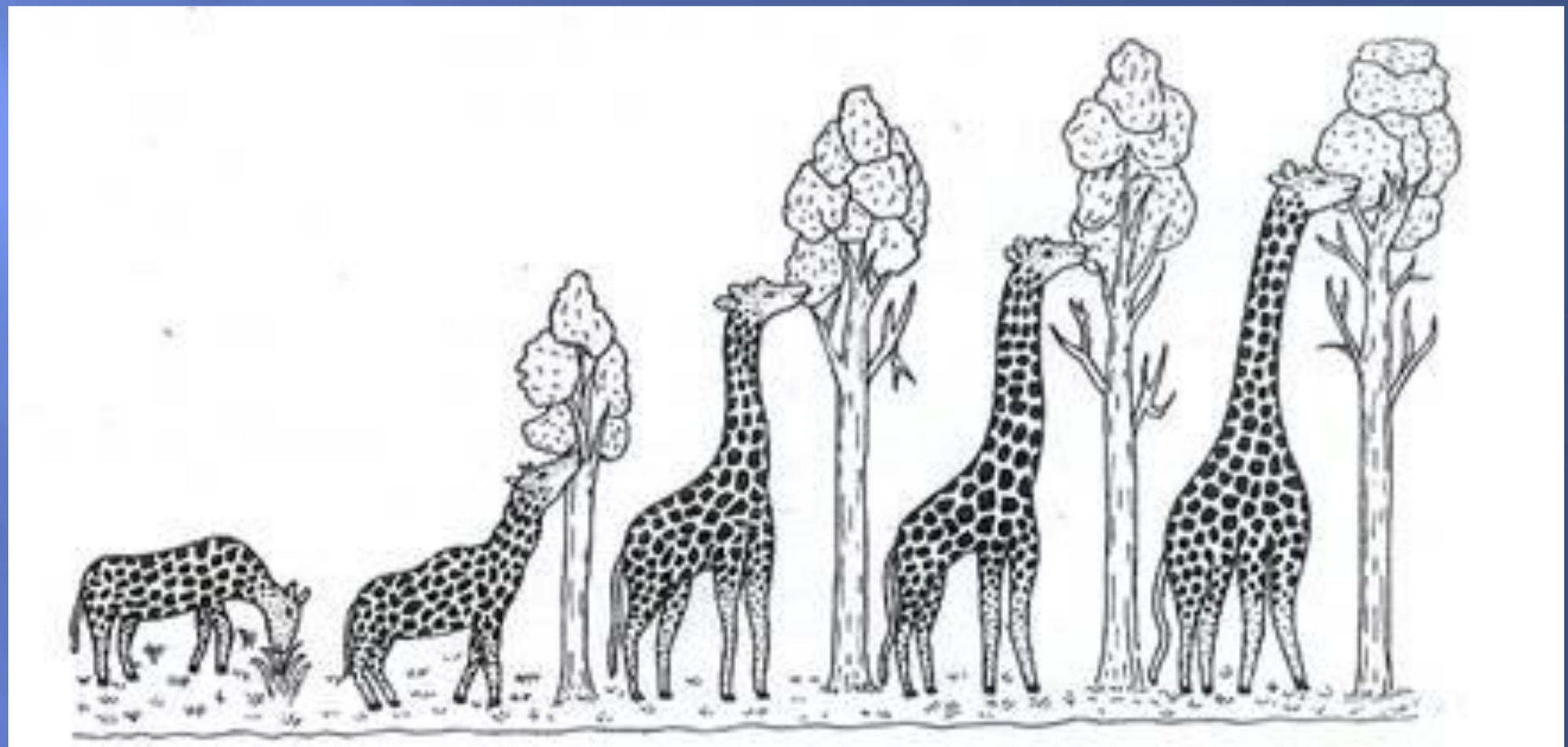


Diagram showing elongation of neck in giraffe according to Lamarck.

Adaptive variation: interaction with environment was driving force for variation

Thank you!