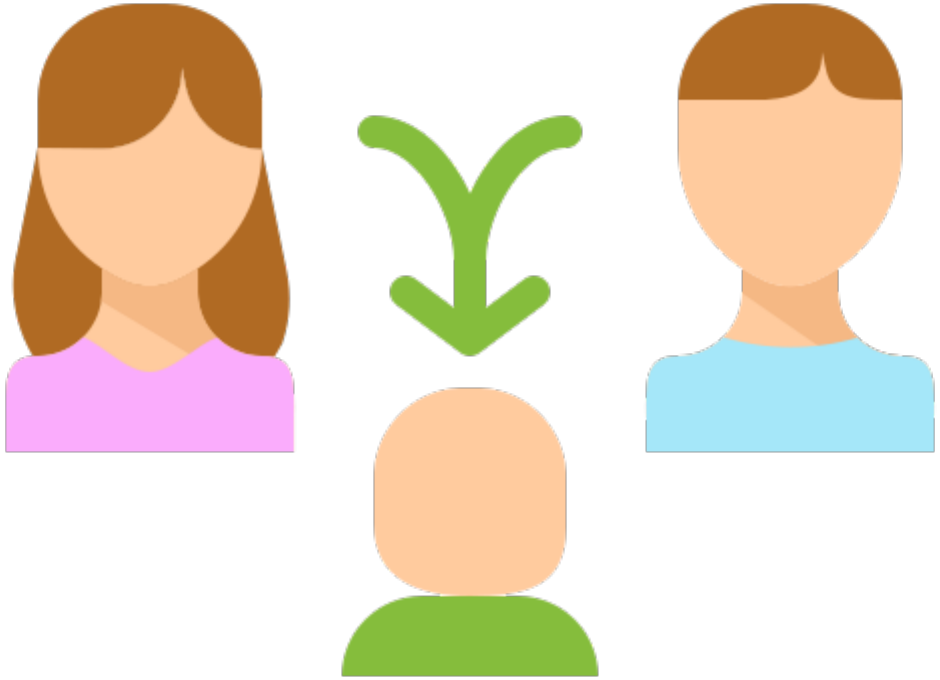
Genes are the only hereditary material

VS

Inclusive Inheritance

The definition of inheritance



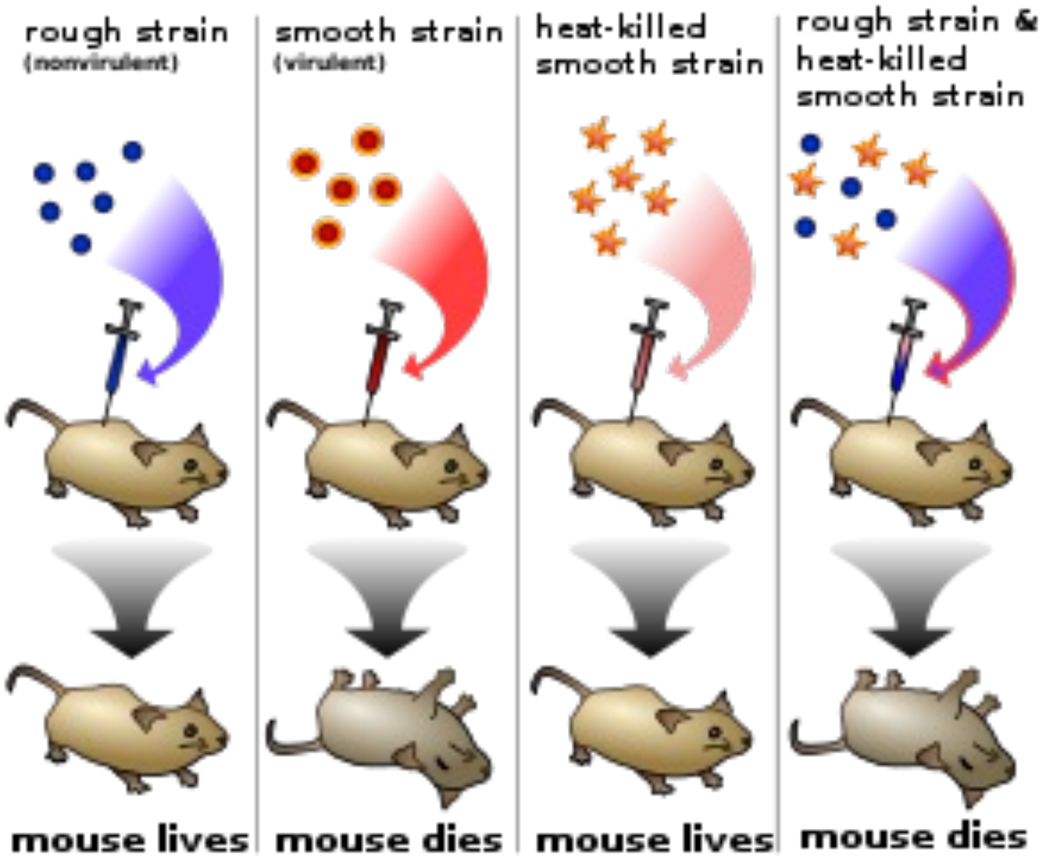
Genes

Inclusive inheritance

The discovery of gene & DNA

- **1928** 肺炎双球菌转化实验
- **1944** Avery的体外转化实验
- **1952** T2噬菌体增殖实验
- **1952 5月** “照片51号”的拍摄
- **1953** 沃森克里克揭示DNA结构
- **1958** DNA半保留复制的证实

1928



Griffith利用III-S型(光滑)和II-R型(粗糙)感染小鼠

The III-S strain covers itself with a polysaccharide capsule that protects it from the host's immune system. This means that the host will die. The II-R strain does not have that protective shield around it and is killed by the host's immune system.

conclude

the type II-R had been "transformed" into the lethal III-S strain by a "transforming principle" that was somehow part of the dead III-S strain bacteria.

1944 Avery–MacLeod–McCarty experiment

TABLE IV

Titration of Transforming Activity of Preparation 44

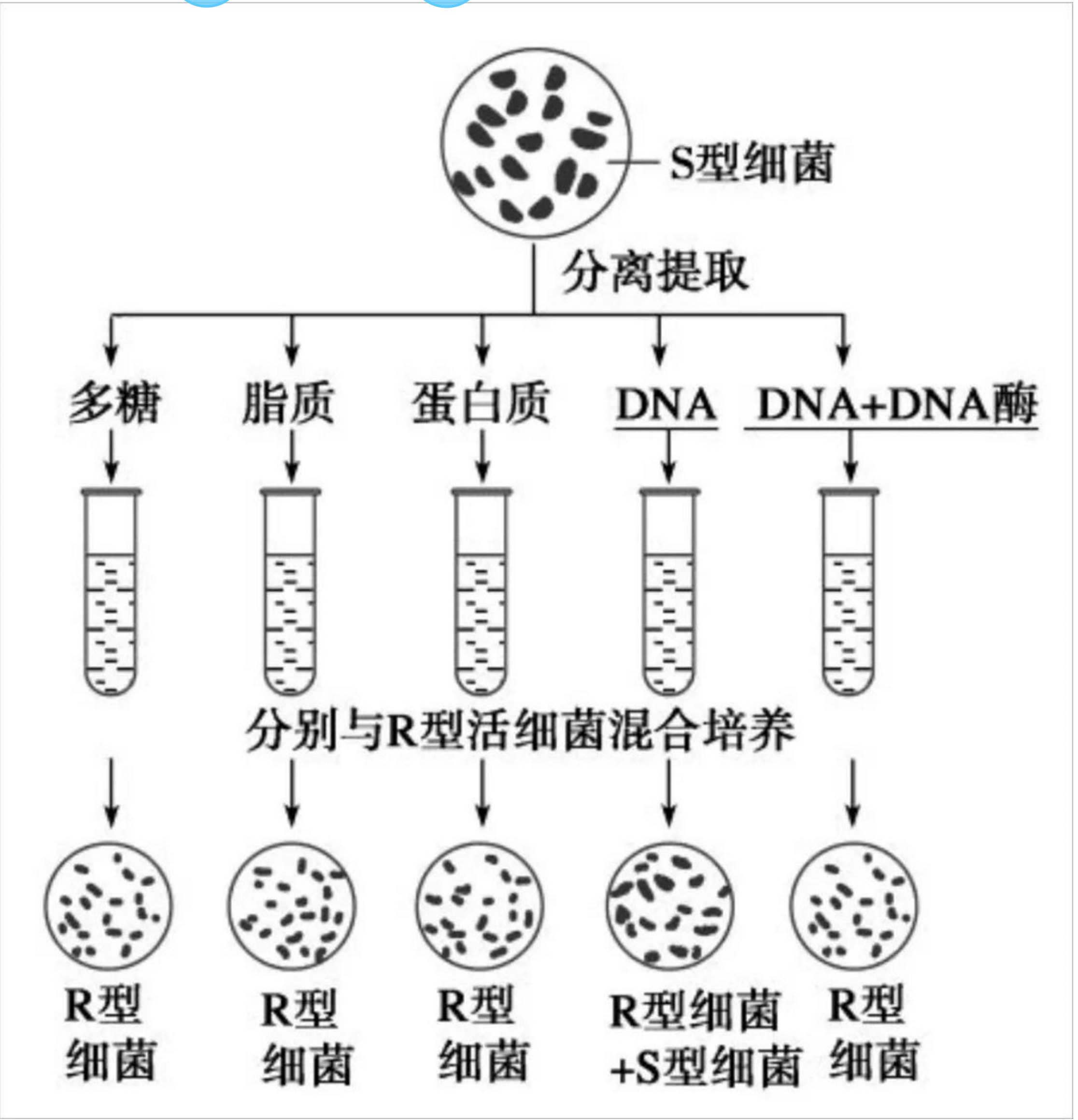
Transforming principle Preparation 44*		Quadruplicate tests							
		1		2		3		4	
Dilution	Amount added	Diffuse growth	Colony form	Diffuse growth	Colony form	Diffuse growth	Colony form	Diffuse growth	Colony form
	μg.								
10^{-2}	1.0	+	SIII	+	SIII	+	SIII	+	SIII
$10^{-2.5}$	0.3	+	SIII	+	SIII	+	SIII	+	SIII
10^{-3}	0.1	+	SIII	+	SIII	+	SIII	+	SIII
$10^{-3.5}$	0.03	+	SIII	+	SIII	+	SIII	+	SIII
10^{-4}	0.01	+	SIII	+	SIII	+	SIII	+	SIII
$10^{-4.5}$	0.003	−	R only	+	SIII	−	R only	+	SIII
10^{-5}	0.001	−	R "	−	R only	−	R "	−	R only
Control	None	−	R "	−	R "	−	R "	−	R "

* Solution from which dilutions were made contained 0.5 mg. per cc. of purified material. 0.2 cc. of each dilution added to quadruplicate tubes containing 2.0 cc. of standard serum broth. 0.05 cc. of a 10^{-4} dilution of a blood broth culture of R36A is added to each tube.

- From Type III pneumococci a biologically active fraction has been isolated in highly purified form which in exceedingly minute amounts is capable under appropriate cultural conditions of inducing the transformation of unencapsulated R variants of Pneumococcus Type II into fully encapsulated cells of the same specific type as that of the heat-killed microorganisms from which the inducing material was recovered.

- of a highly polymerized, viscous form of desoxyribonucleic acid.

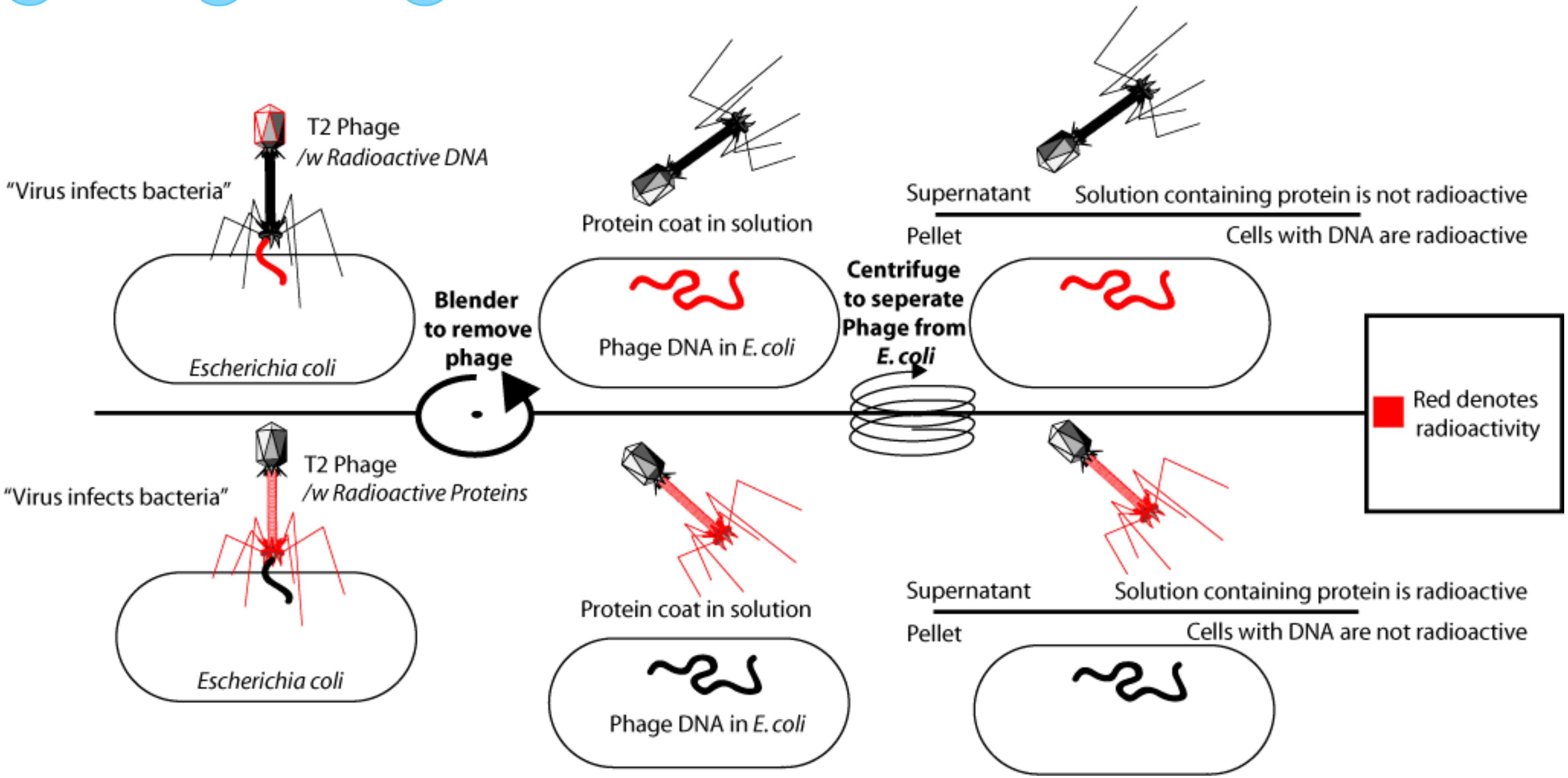
1944 Avery–MacLeod–McCarty experiment



conclusion

The evidence presented supports the belief that a nucleic acid of the desoxy-ribose type is the fundamental unit of the transforming principle of Pneumococcus Type III.

1952 Hershey–Chase experiment



1952 Hershey–Chase experiment

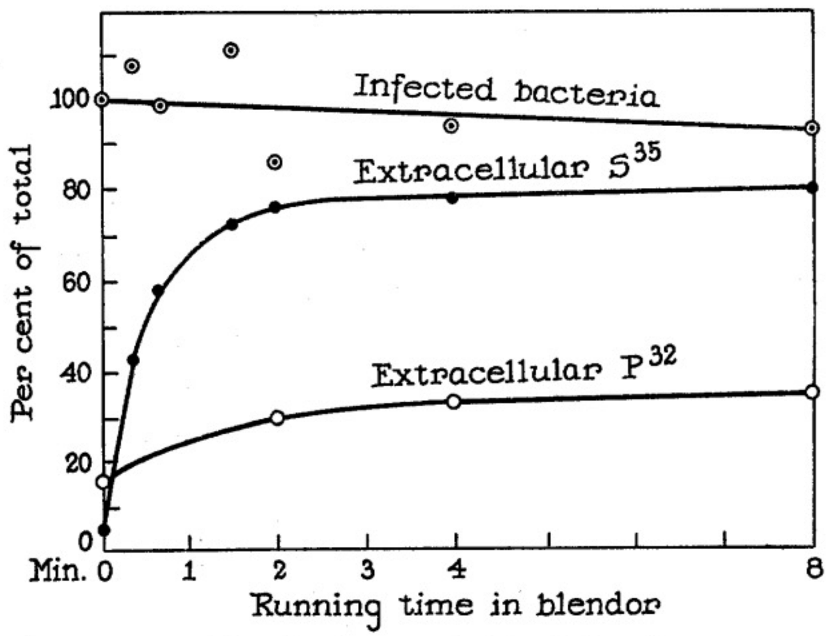
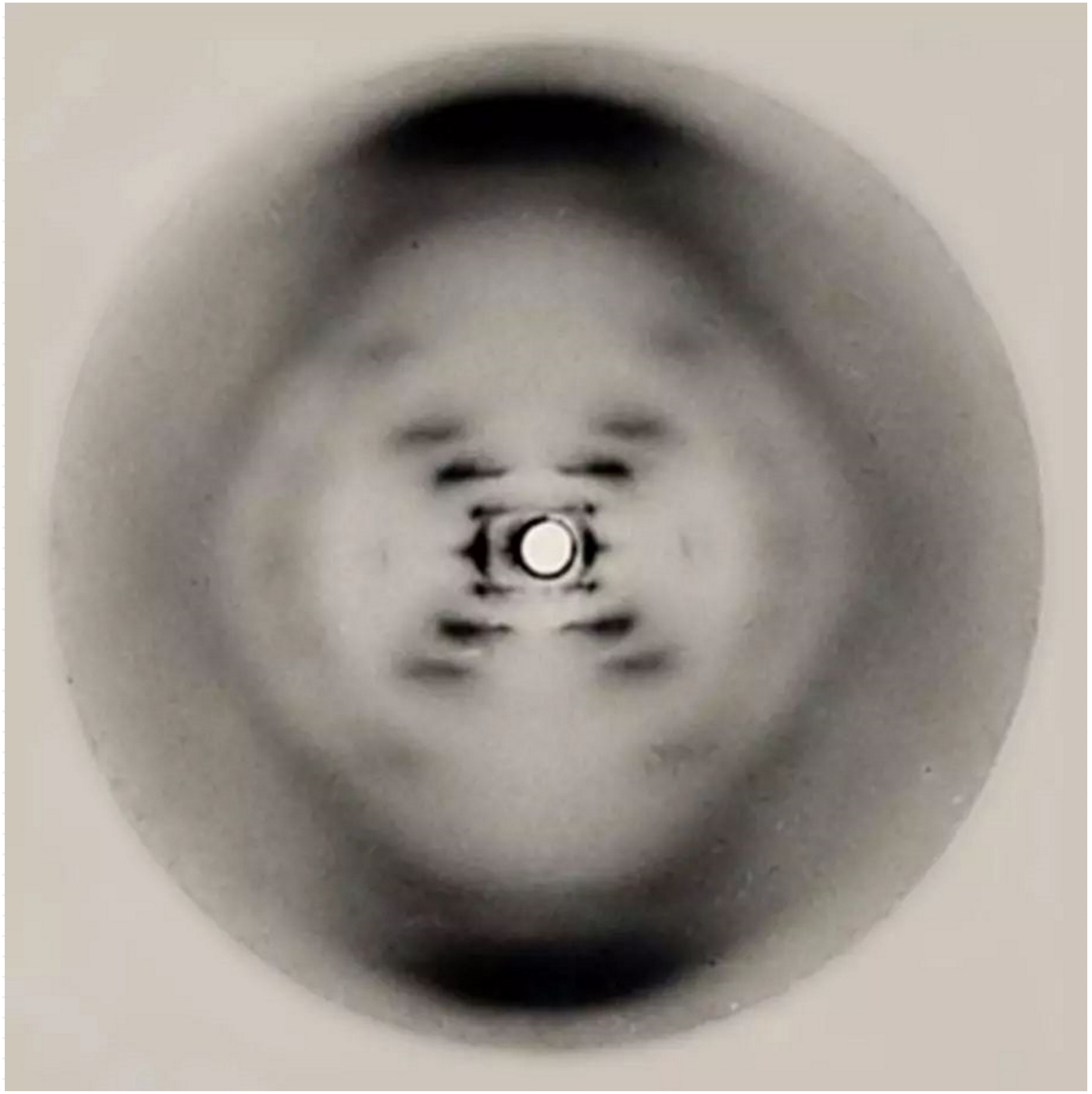


Fig. 1. Removal of S^{35} and P^{32} from bacteria infected with radioactive phage, and survival of the infected bacteria, during agitation in a Waring blendor.

The facts stated show that most of the phage sulfur remains at the cell surface and most of the phage DNA enters the cell on infection. All types of evidence show that the passage of phage DNA into the cell occurs in non-nutrient medium under conditions in which other known steps in viral growth do not occur

By contrast, the components of the bacterium essential to this inter action are remarkably stable. The nature of the interaction is otherwise un known.

1952.5 photo 51



1953 Molecular structure of nucleic acids

No. 4356 April 25, 1953 NATU

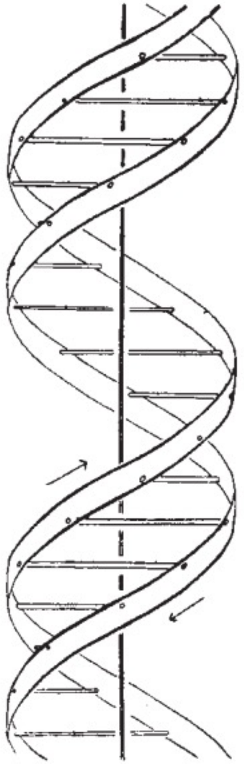
equipment, and to Dr. G. E. R. Deacon and the captain and officers of R.R.S. *Discovery II* for their part in making the observations.

[1] Young, F. B., Gerrard, H., and Jevons, W., *Phil. Mag.*, **40**, 149 (1920).
[2] Longuet-Higgins, M. S., *Mon. Not. Roy. Astro. Soc., Geophys. Supp.*, **5**, 285 (1949).
[3] Von Arx, W. S., Woods Hole Papers in Phys. Oceanog. Meteor., **11** (3) (1950).
[4] Ekman, V. W., *Arkiv. Mat. Astron. Fysik.* (*Stockholm*), **2** (11) (1905).

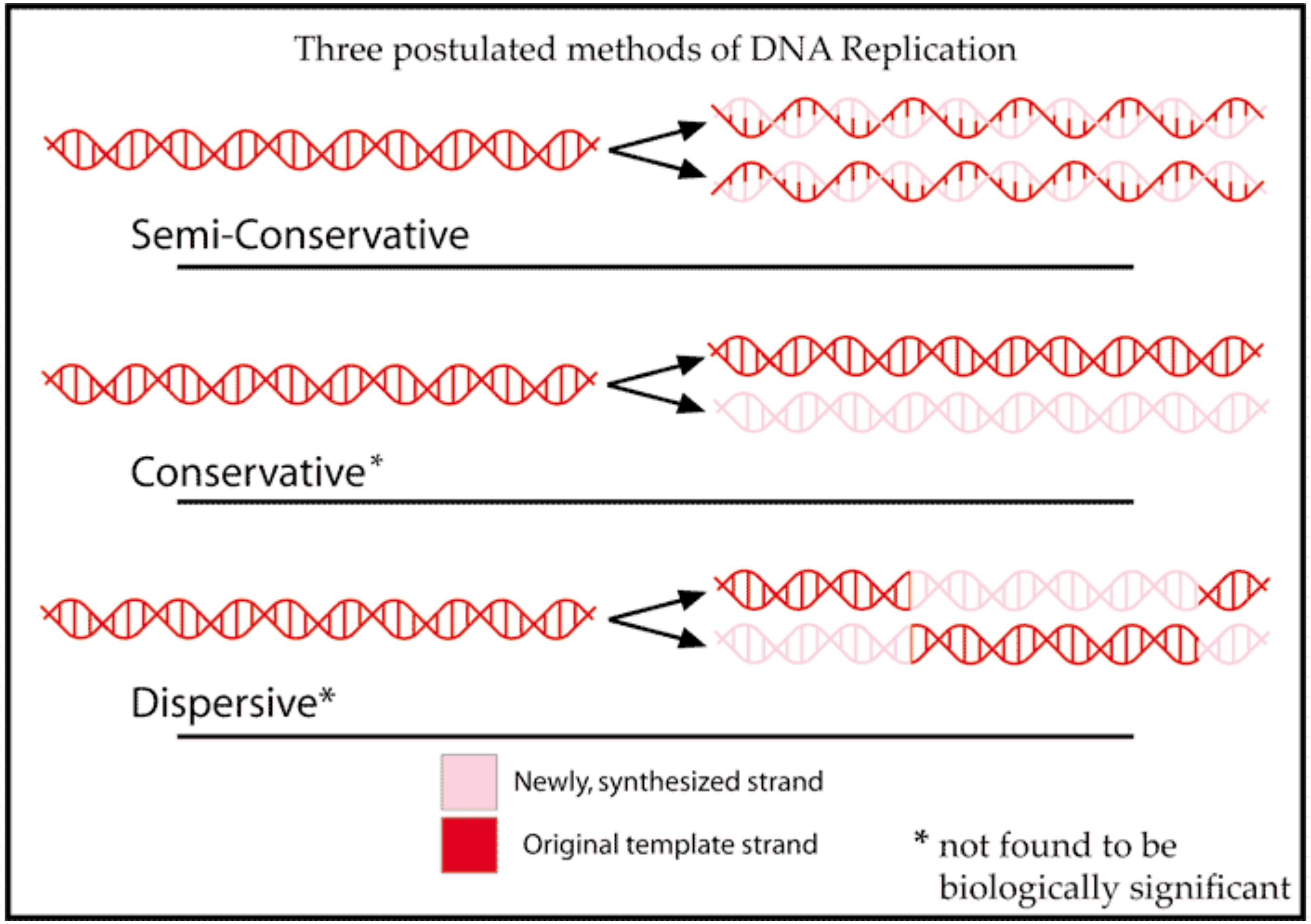
MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid

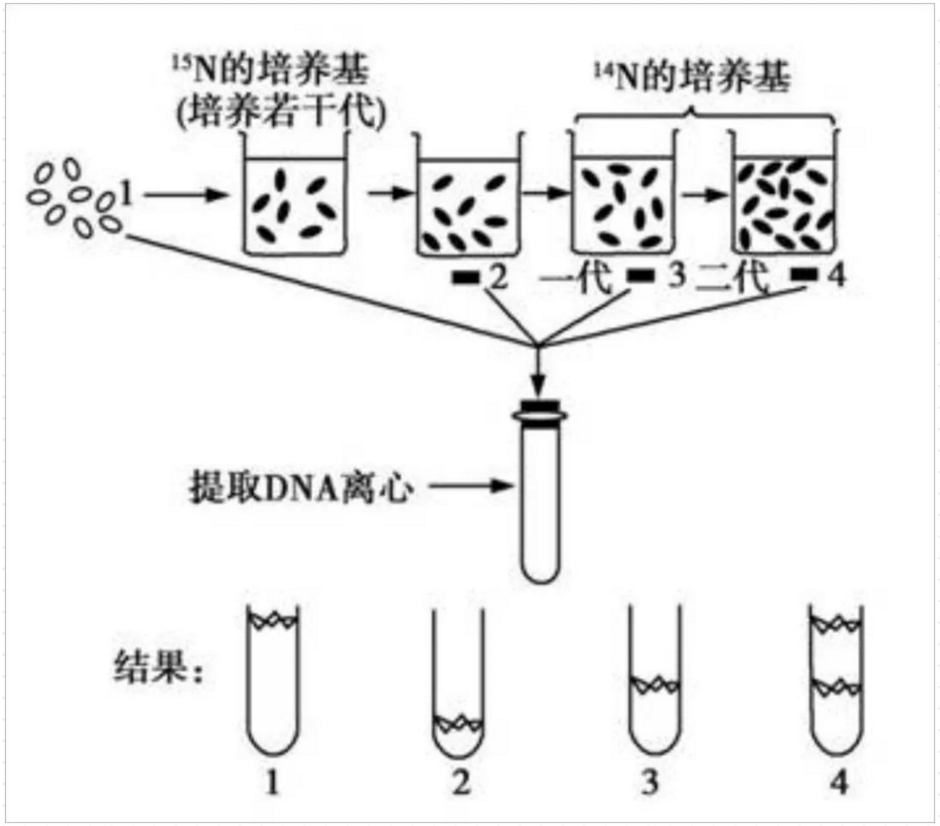
1. This structure has two helical chains each coiled round the same axis.
2. And each chain consists of phosphate diester groups joining β-D-deoxy-ribofuranose residues with 3’5’ linkage.
3. The two chains are related by a dyad perpendicular to fiber axis.



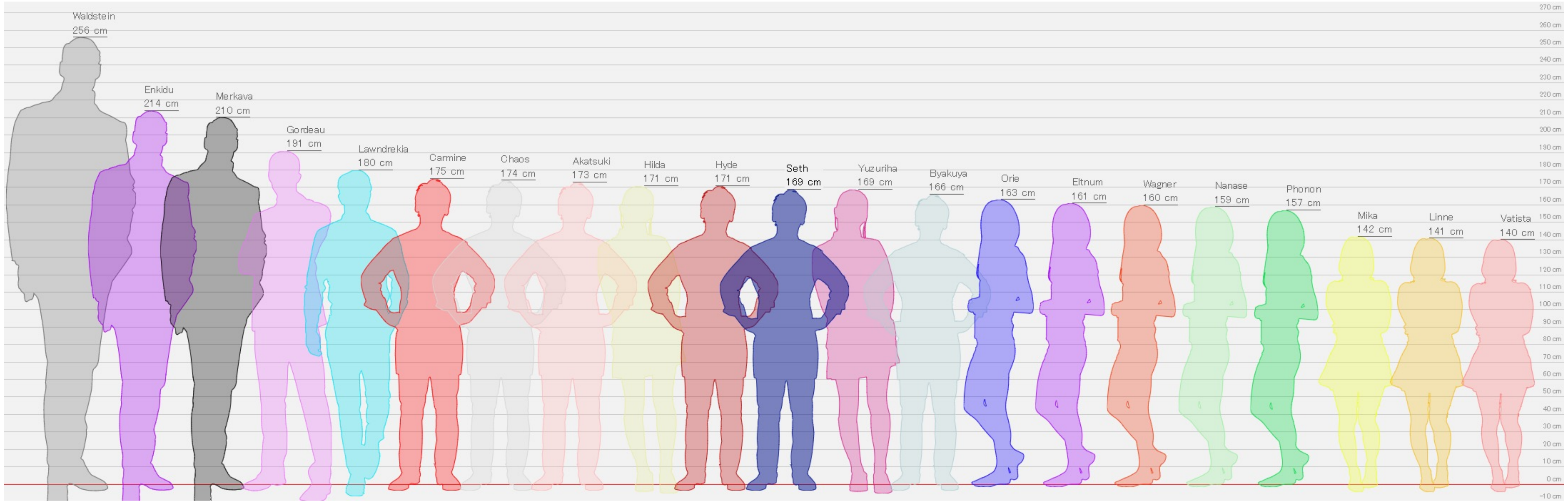
1958 Meselson–Stahl experiment



Meselson and Stahl found that DNA employs semi-conservative replication.



Height could not be explained by common genetic variants



There is increasing awareness that non-genetic information can also be inherited across generations

inclusive inheritance

汇报人：黄子健、林富强

2022年10月9日

CONTENT

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CHAPTER ONE

Parental Effects

CONTENT

Parental Effects

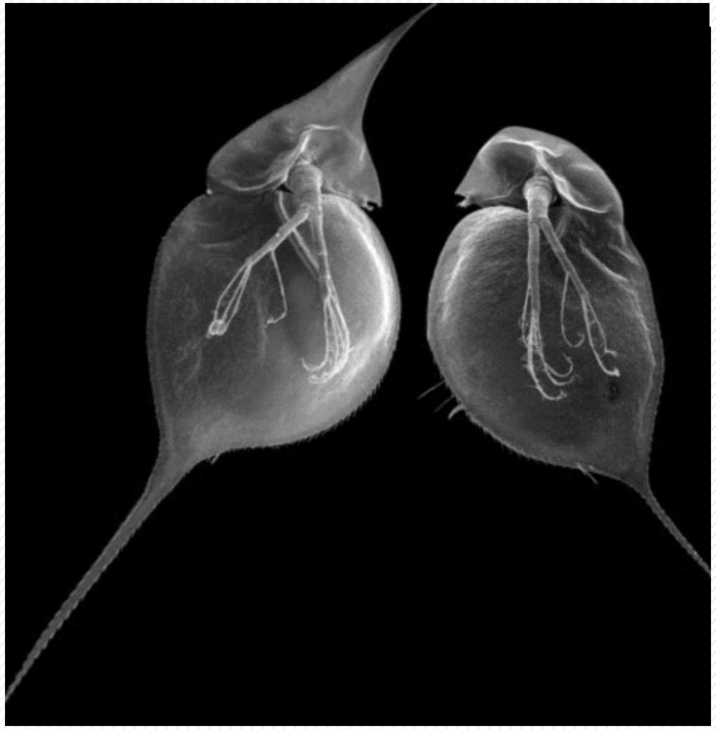
Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

1.1

Inheritance by the contents of a fertilized egg



Inheritance of water flea’s Helmet

Parental effects are any effect parents may have on the phenotype of their offspring over and above direct genetic transmission.

In EES’s opinion, parental effects is a part of inclusive inheritance。

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CONTENT

Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

1.2

Effects of Maternal Behavior leading to Inheritance

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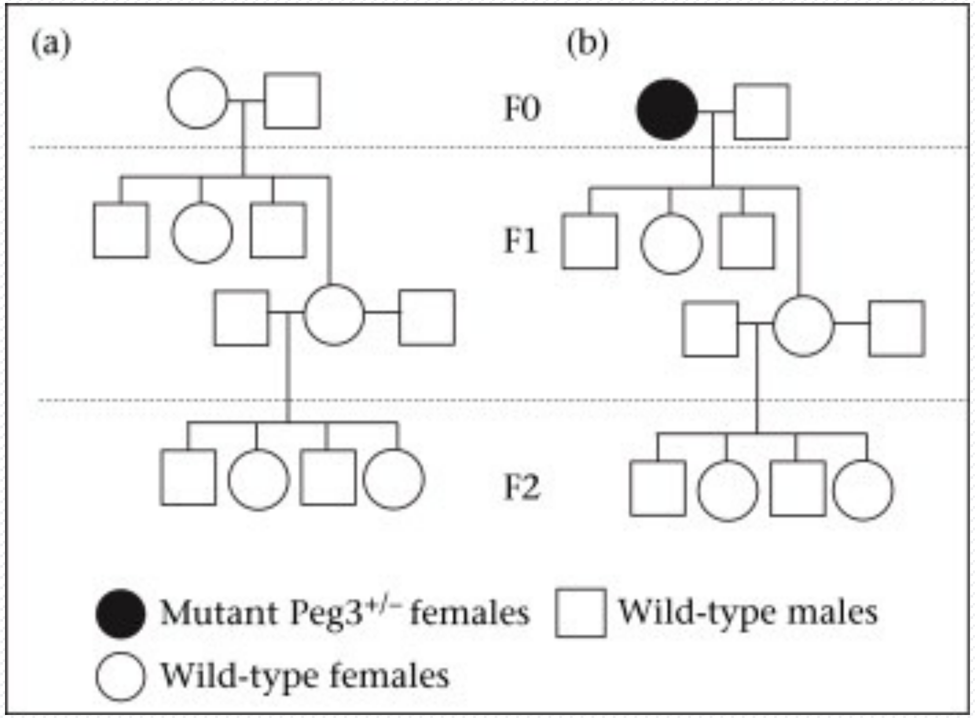
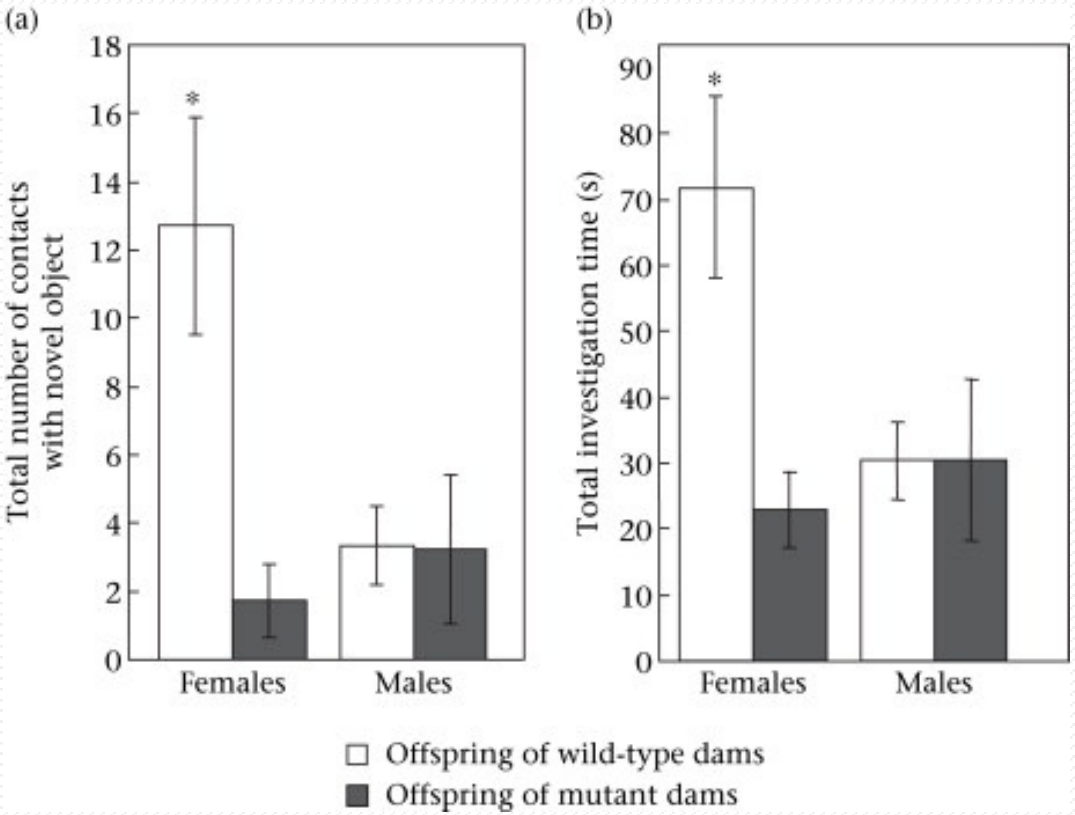


Breeding design



F1 Generation investigation of a novel object

(Curley, Champagne, Bateson and Keverne, 2008)

CONTENT

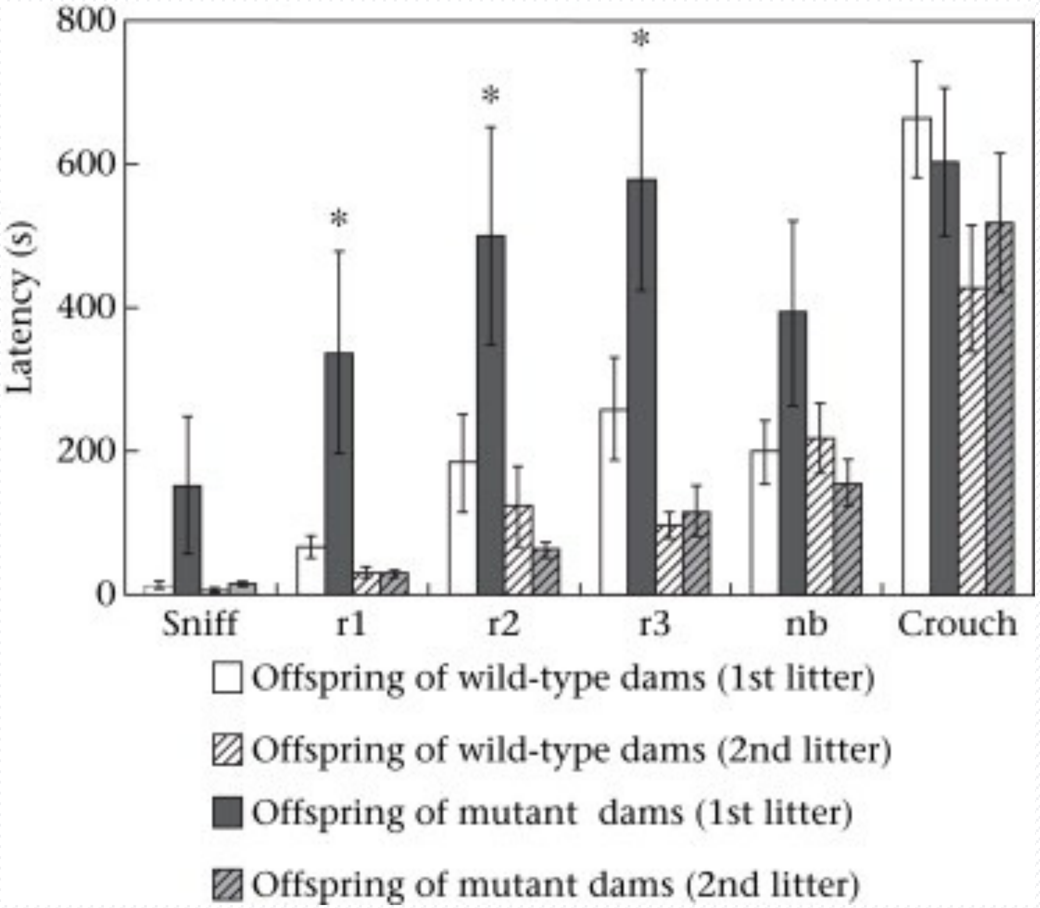
Parental Effects

Cultural Inheritance

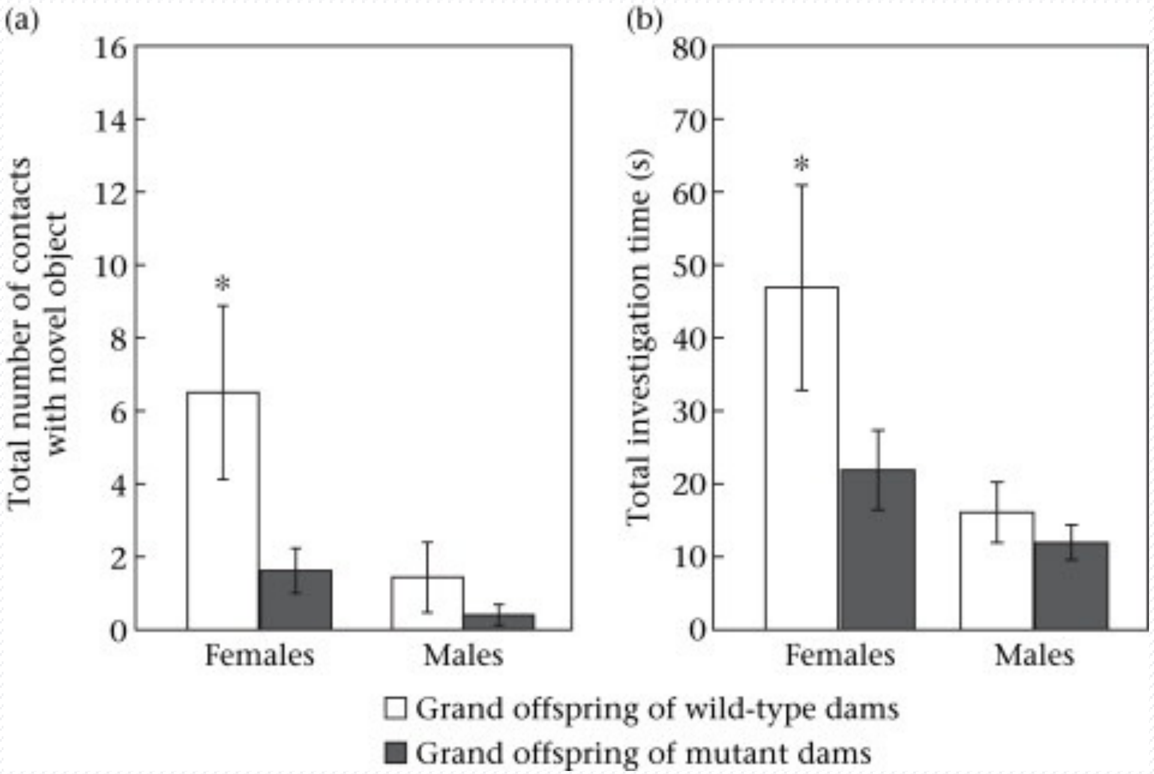
Ecological inheritance

Epigenetic inheritance

1.4



Maternal behavior of F1 females in a retrieval test



F2 Generation investigation of a novel object

(Curley, Champagne, Bateson and Keverne, 2008)

CONTENT

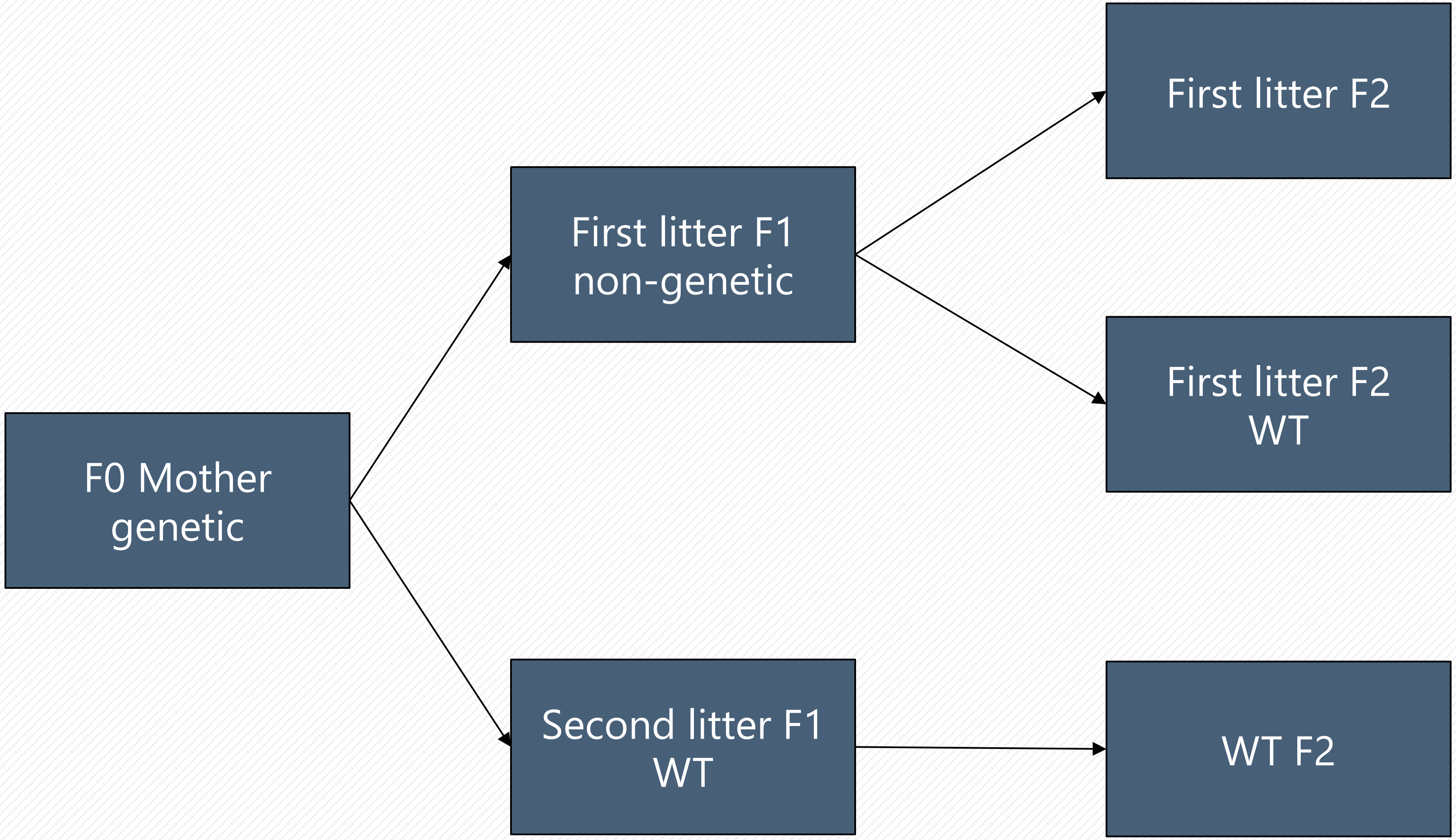
Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

1.5



CHAPTER TWO

Cultural Inheritance

CONTENT

Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

2.2

A NEW DEFINATION OF CULTURE

1. To be cultural a trait must be socially learned.

2. Socially learned information must be transmitted across generations or, more generally, from older to younger individuals.

3. The effect of social learning must be expressed for sufficient time to allow younger individuals to learn it.

4. Individuals must generalize social information by using it in new contexts.

(Danchin and Wagner, 2010)

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Humans' culture and evolution of β-galactosidase

Cultural inheritance of birds and whale's song dialects

CONTENT

Parental Effects

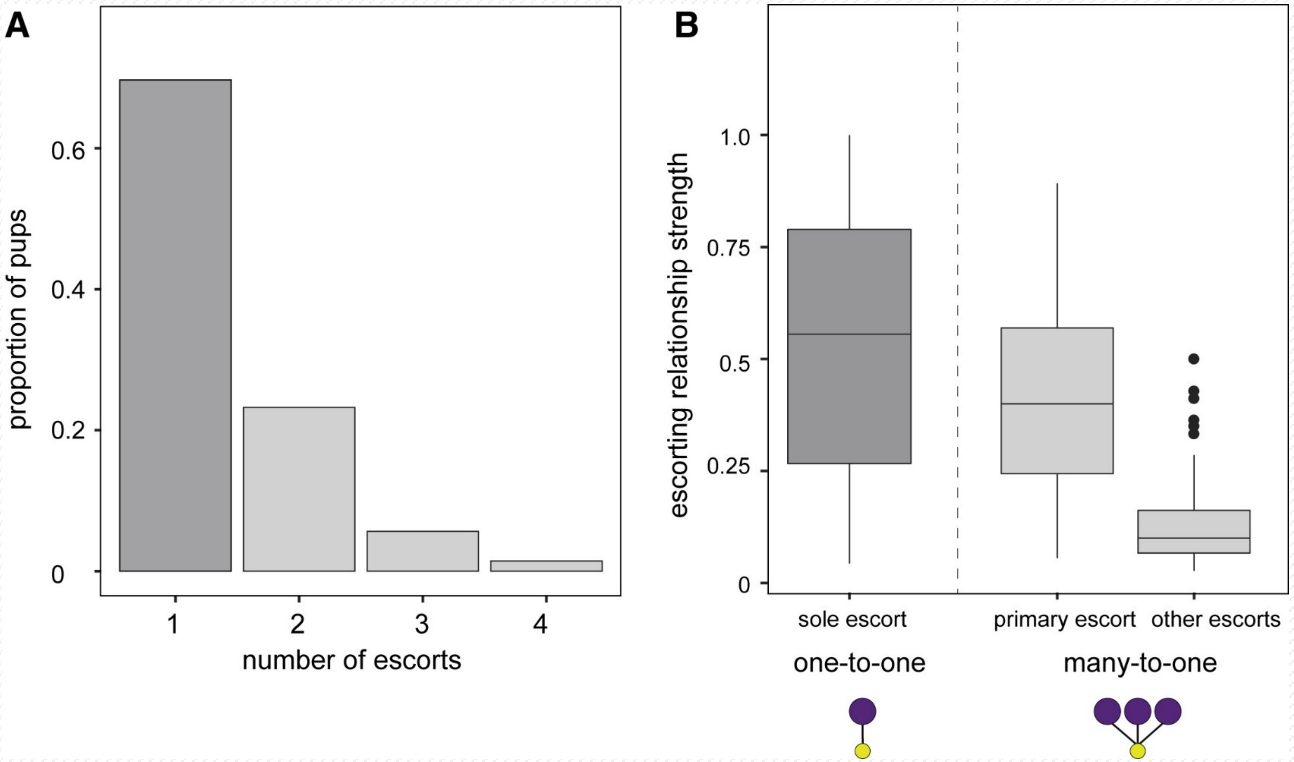
Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

2.3

Escorting in Banded Mongooses



Exclusivity and Strength of Escort-Pup Relationships

(Sheppard et al., 2018)

CONTENT

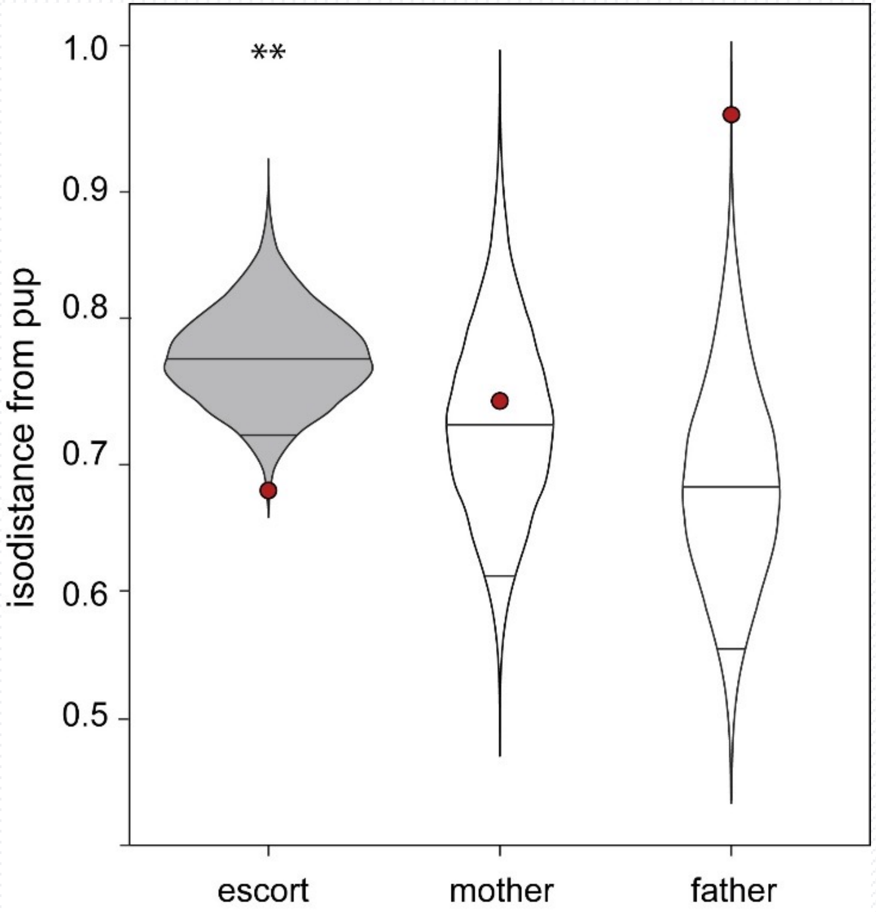
Parental Effects

Cultural Inheritance

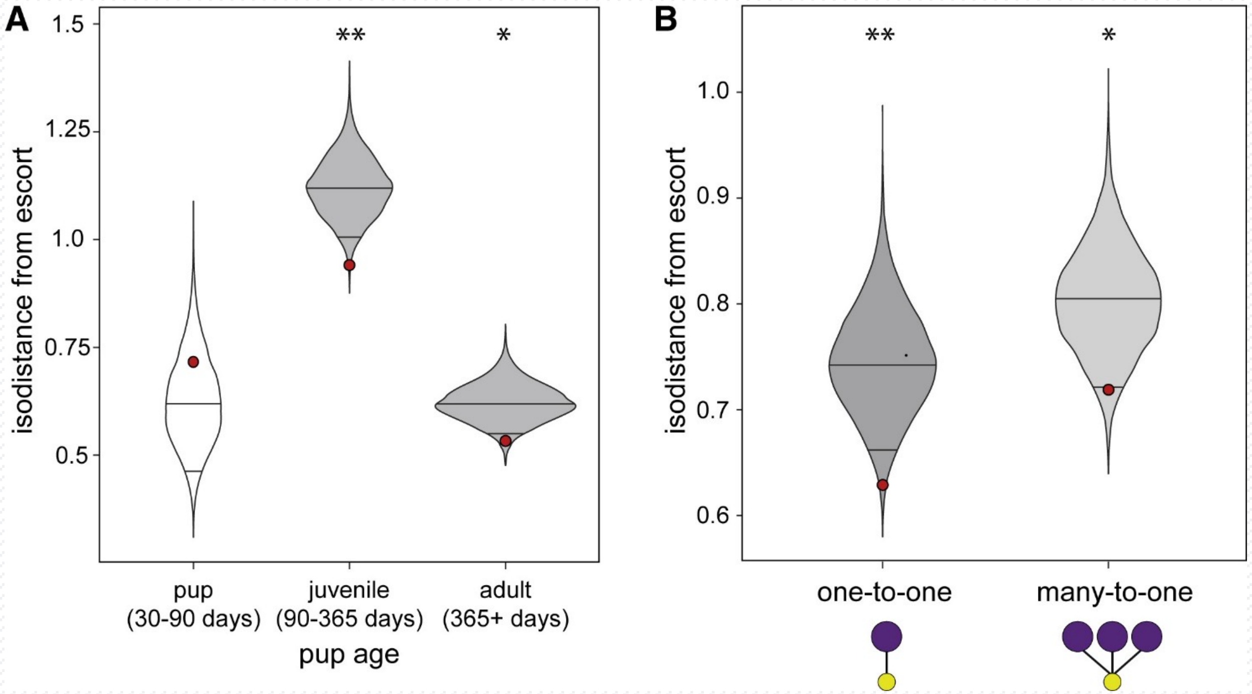
Ecological inheritance

Epigenetic inheritance

2.4



Foraging Niche Is Inherited from Escorts, Not from Genetic Parents



Durability and Fidelity of Cultural Inheritance

(Sheppard et al., 2018)

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CONTENT

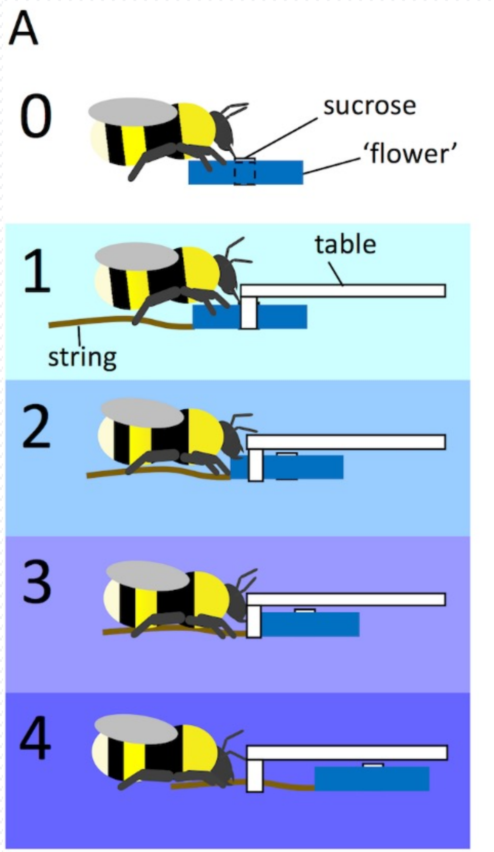
Parental Effects

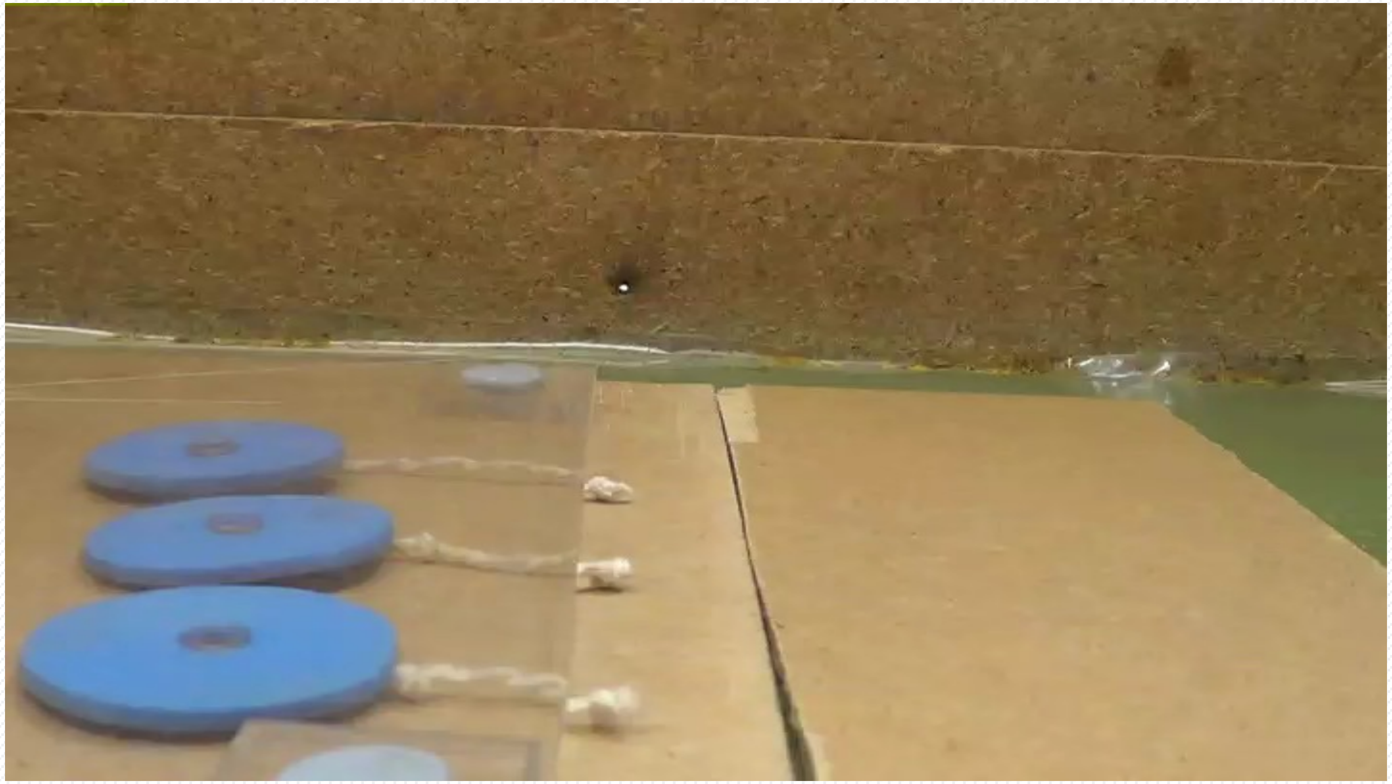
Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

2.5





Training plan and result of demonstrators.

(Alem et al., 2016)

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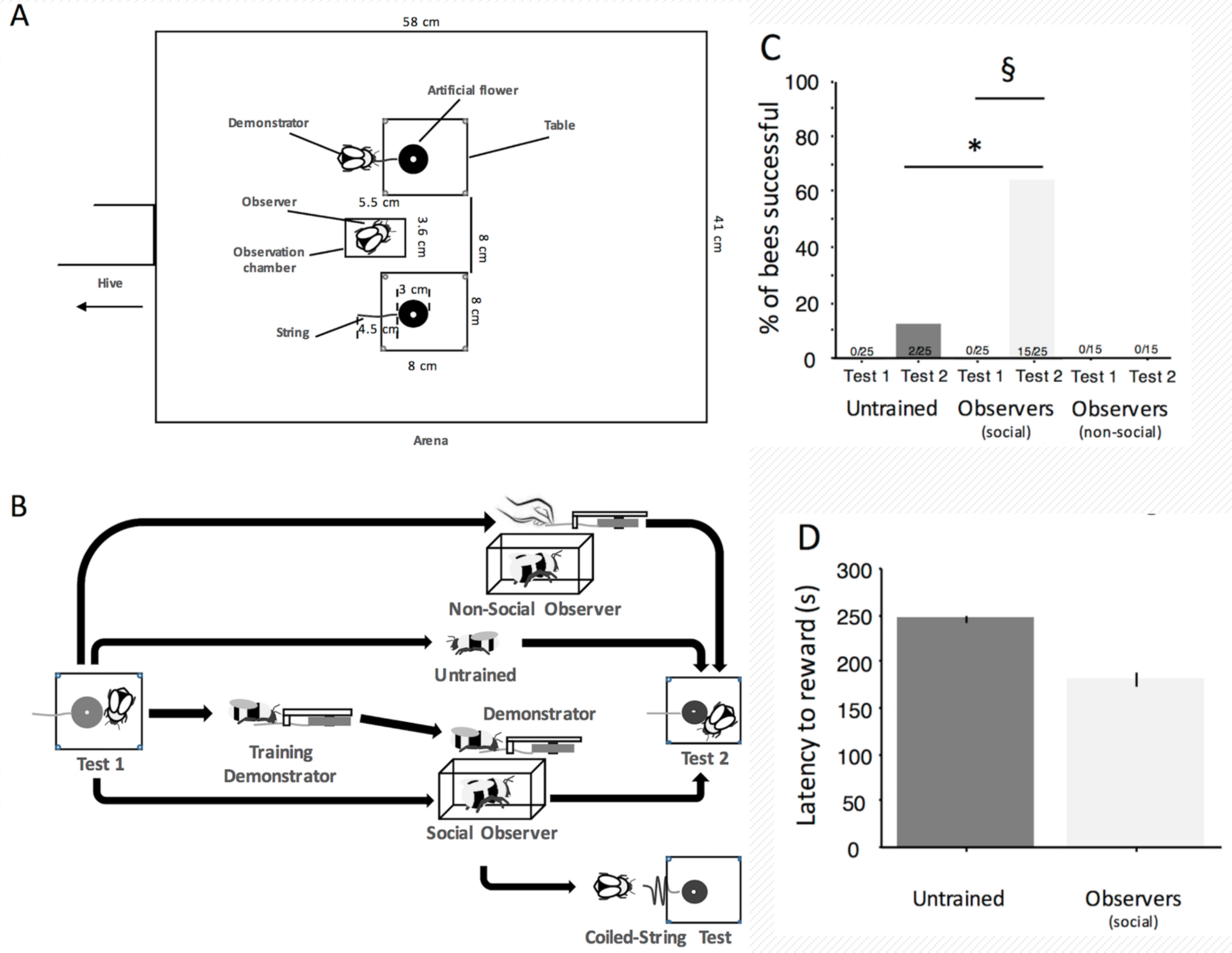


Social transmission of string pulling.

(Alem et al., 2016)

CONTENT

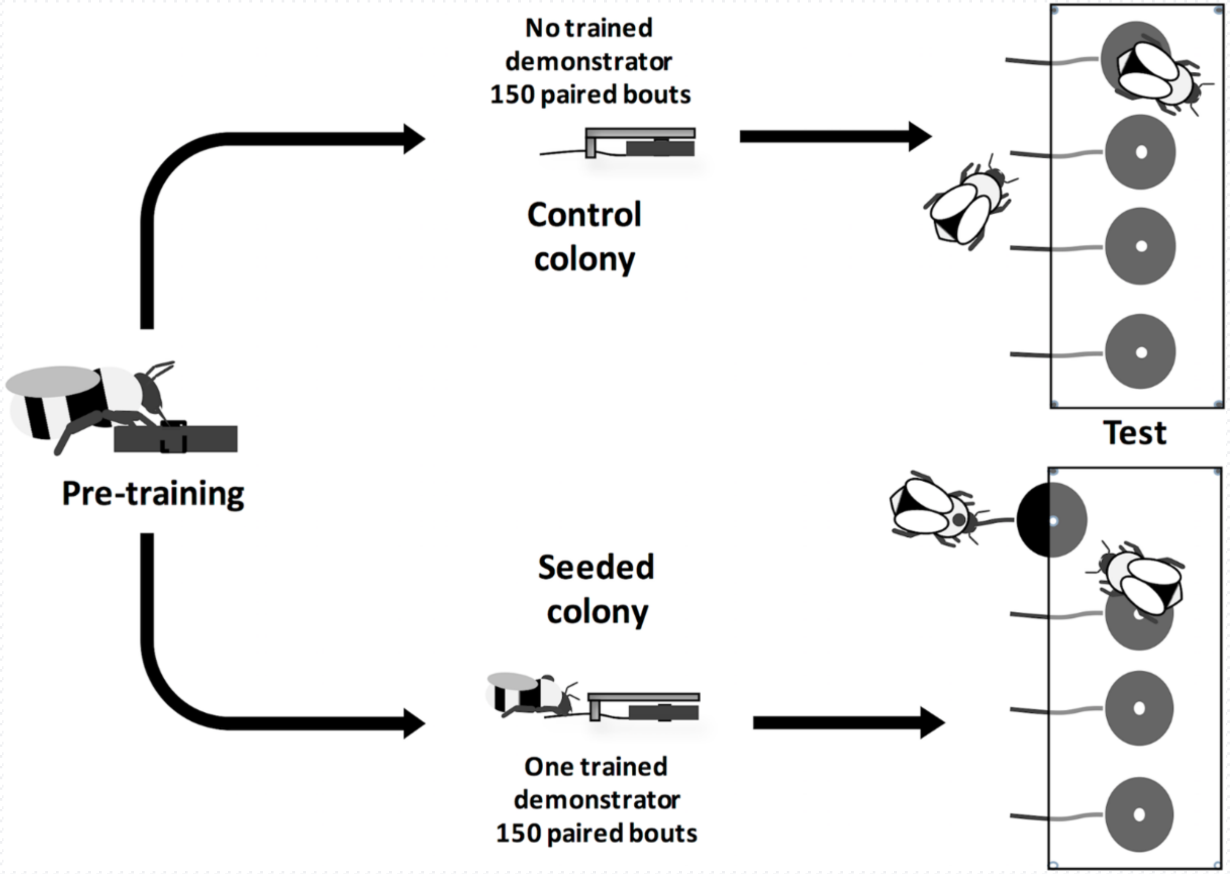
Parental Effects

Cultural Inheritance

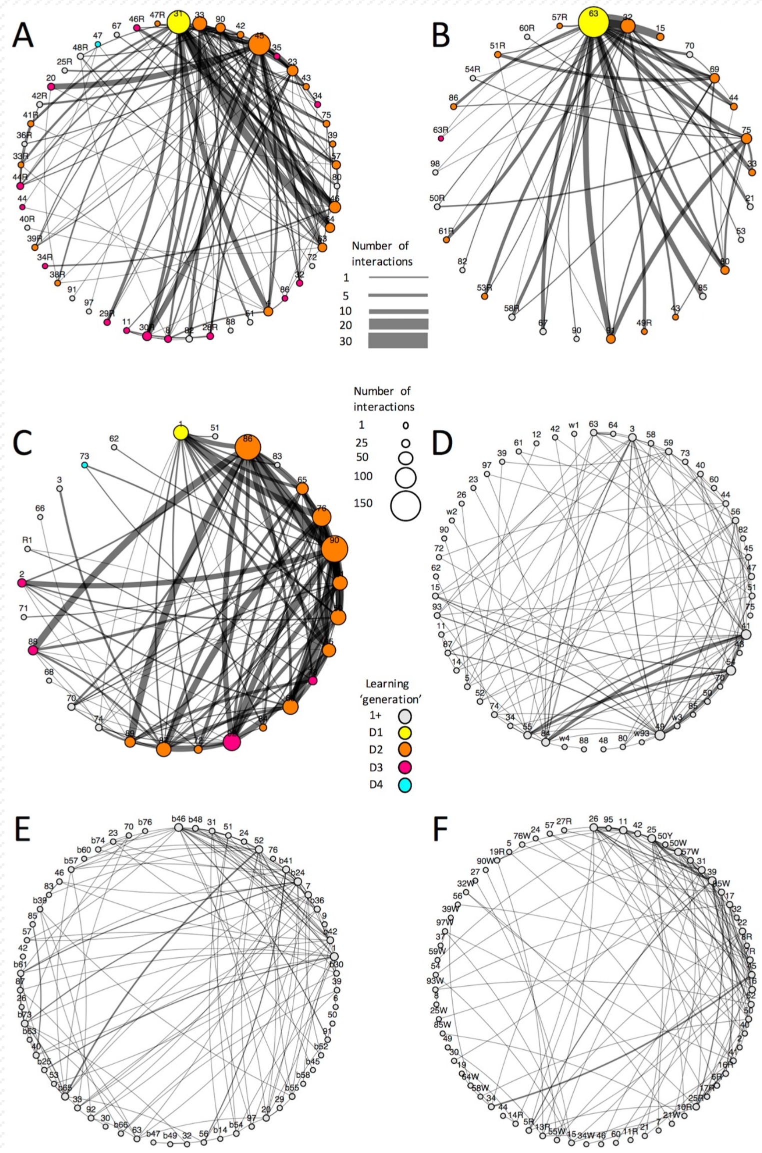
Ecological inheritance

Epigenetic inheritance

2.7



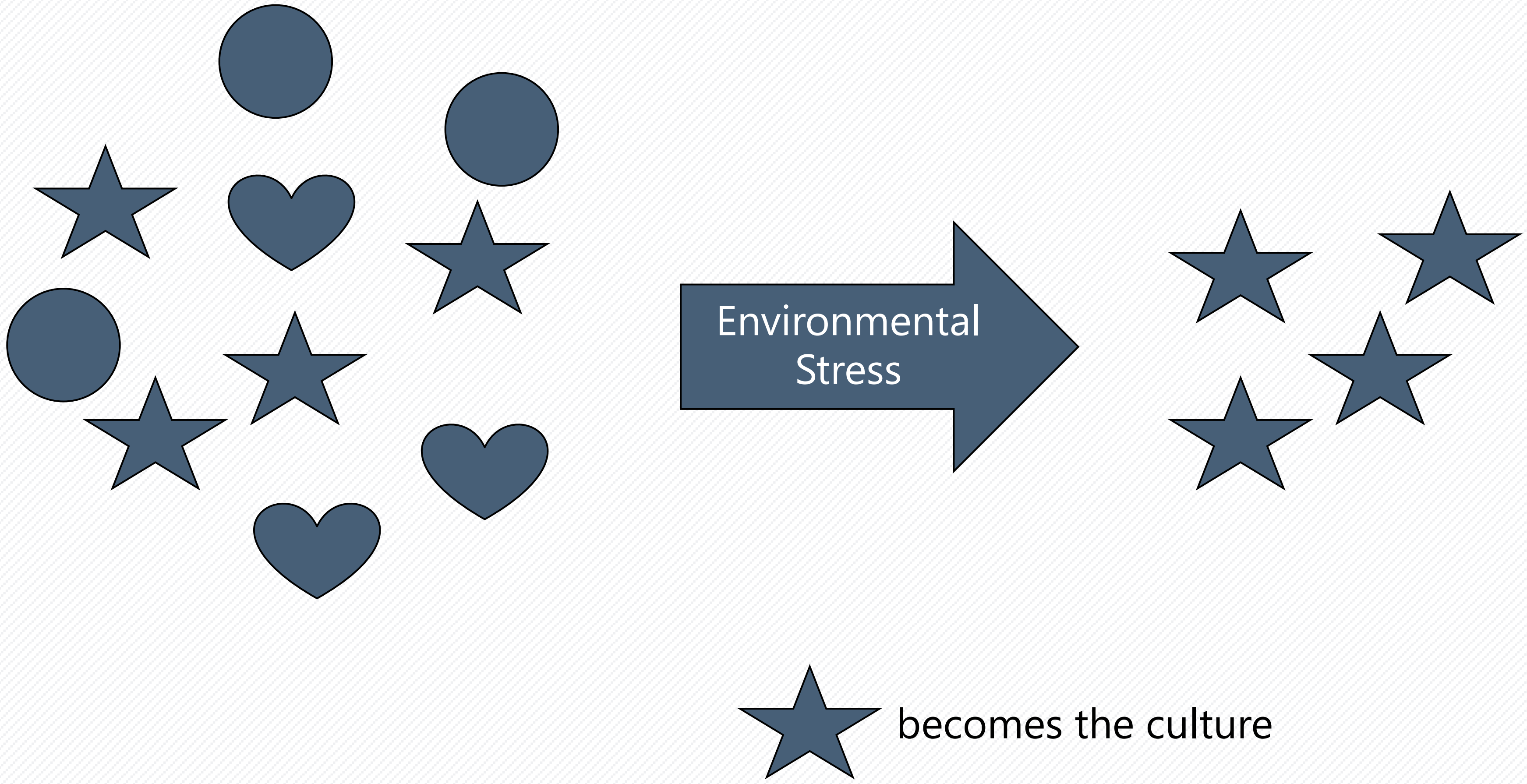
Cultural diffusion paradigm.



Diffusion networks in bumblebee colonies.

(Alem et al., 2016)

CONTENT



CONTENT

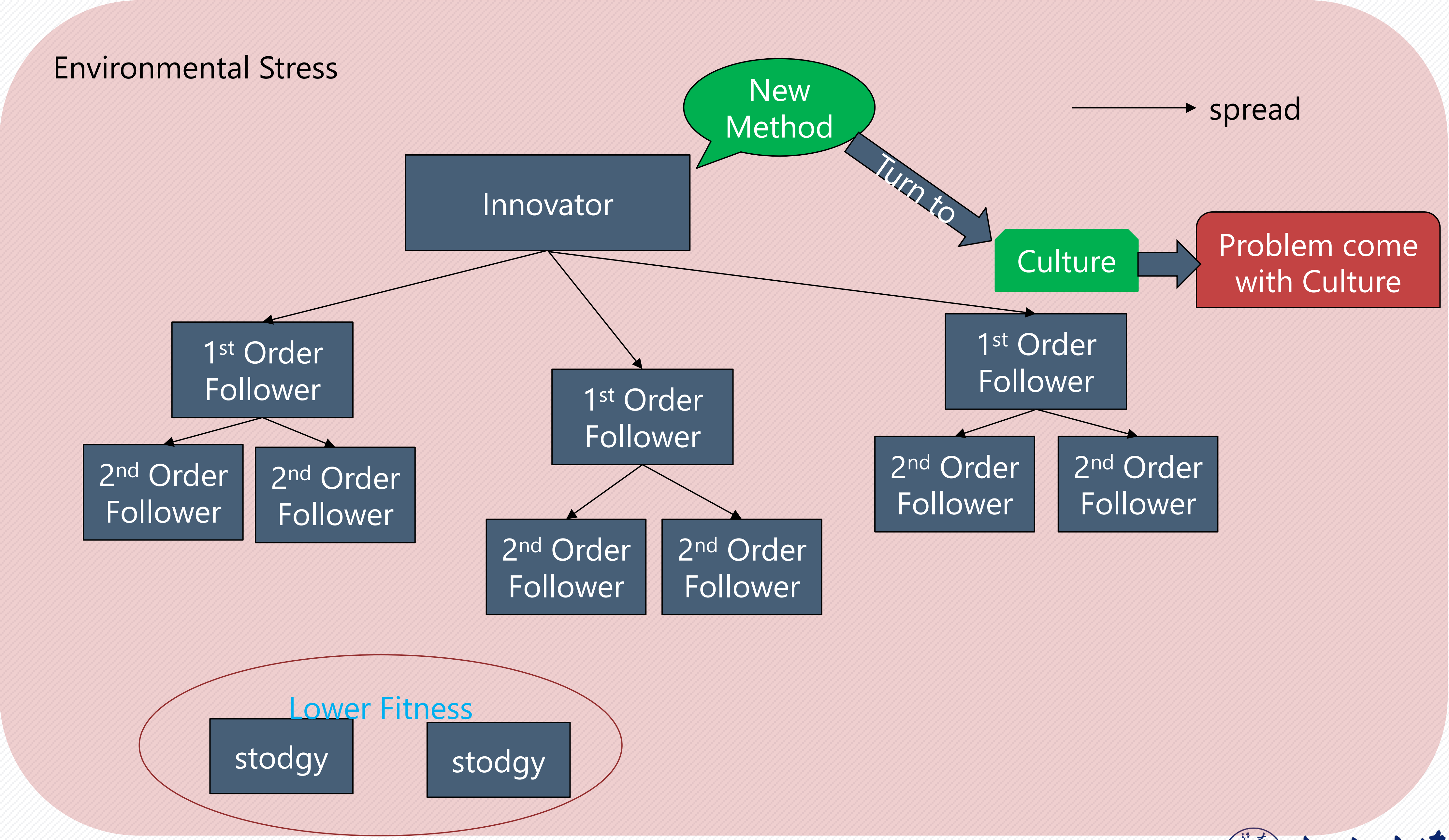
Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

2.9



CONTENT

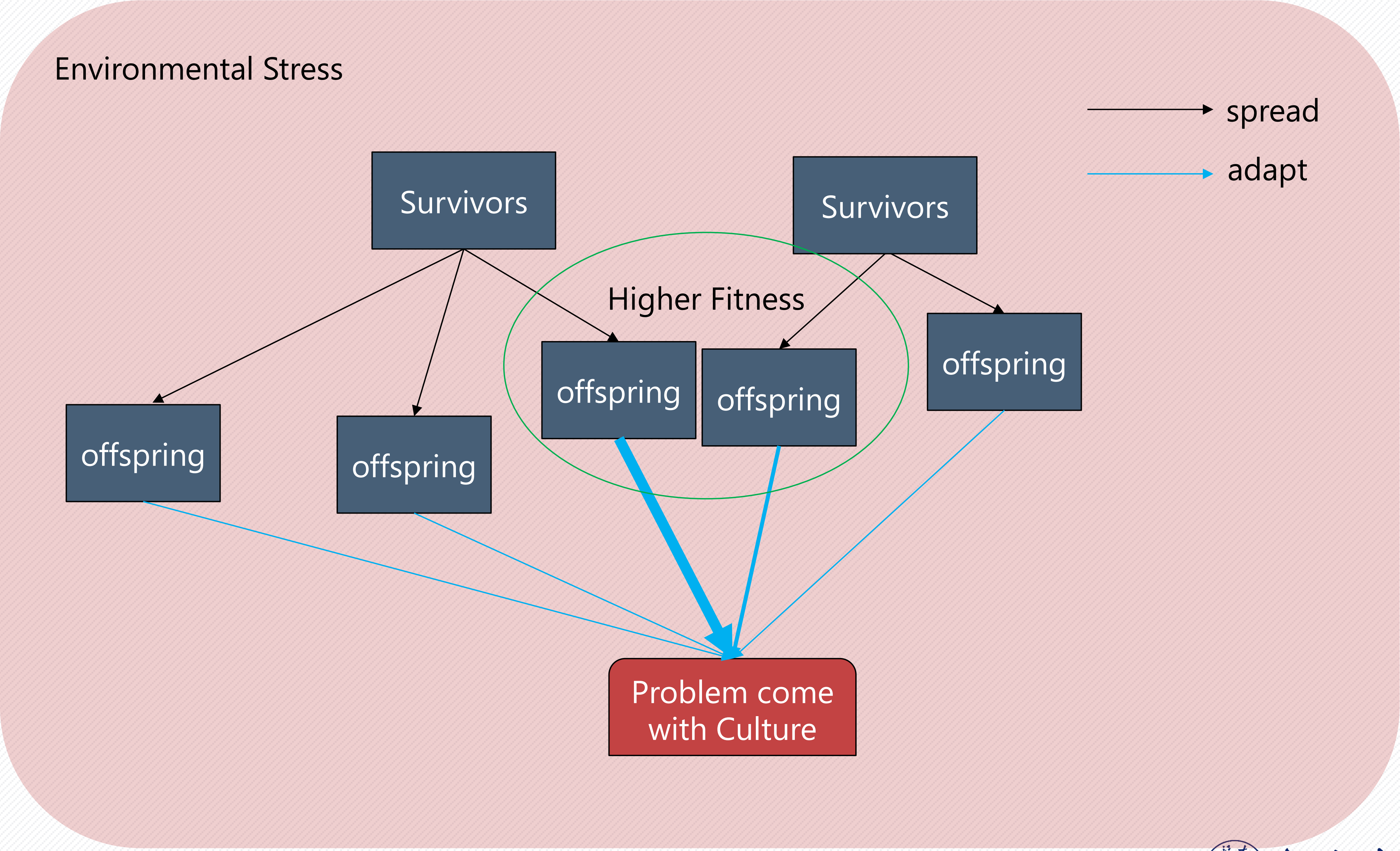
Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

2.10



CHAPTER THREE

Ecological inheritance

CONTENT

Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

3.1

Earthworms change the structure of the soil

Stony corals form coral reefs

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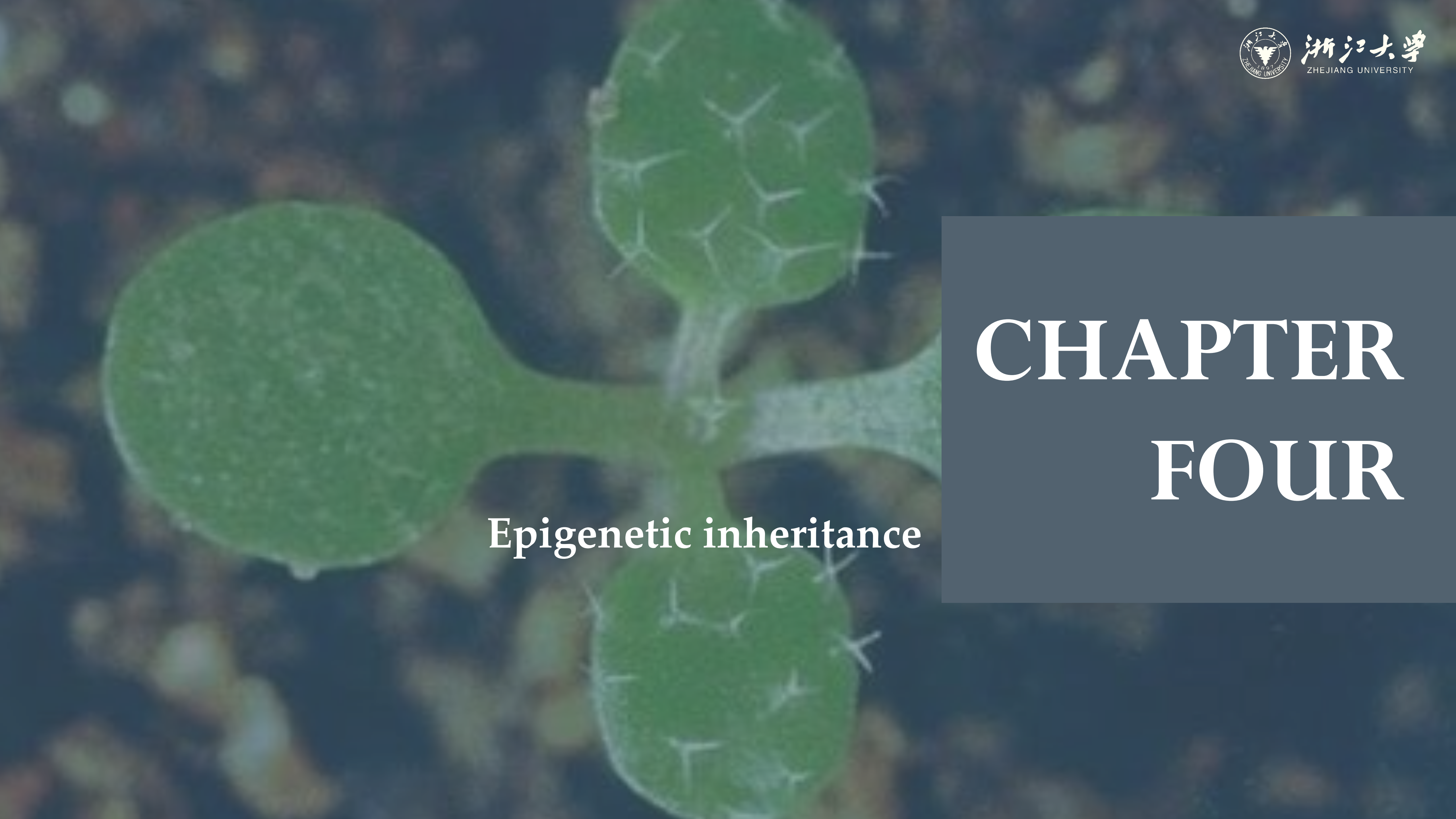

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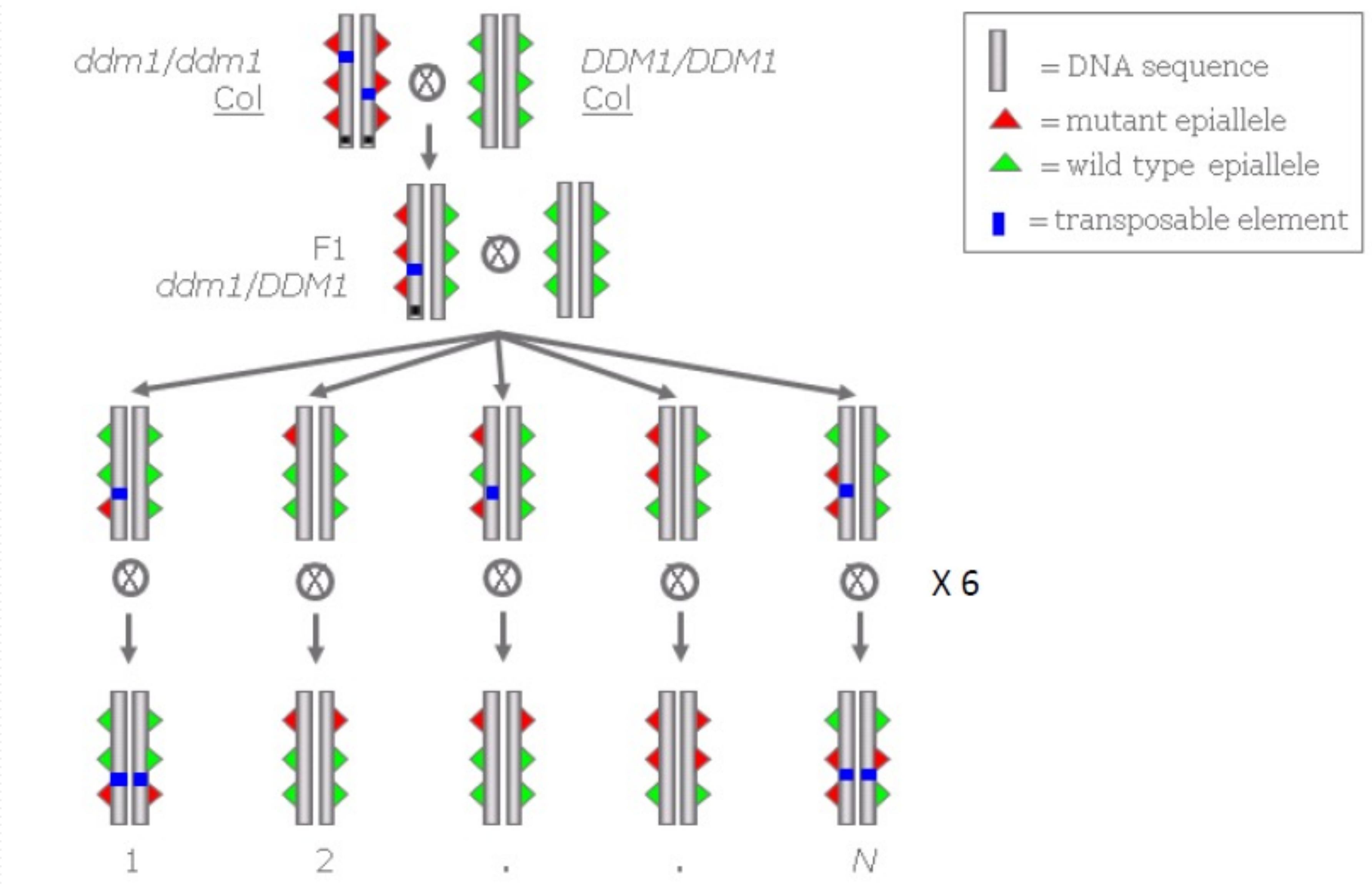
CHAPTER FOUR

Epigenetic inheritance



Transgenerational Inheritance of Hypomethylated DNA in Epigenetic Recombinant Inbred Lines

(Cortijo et al., 2014)

CONTENT

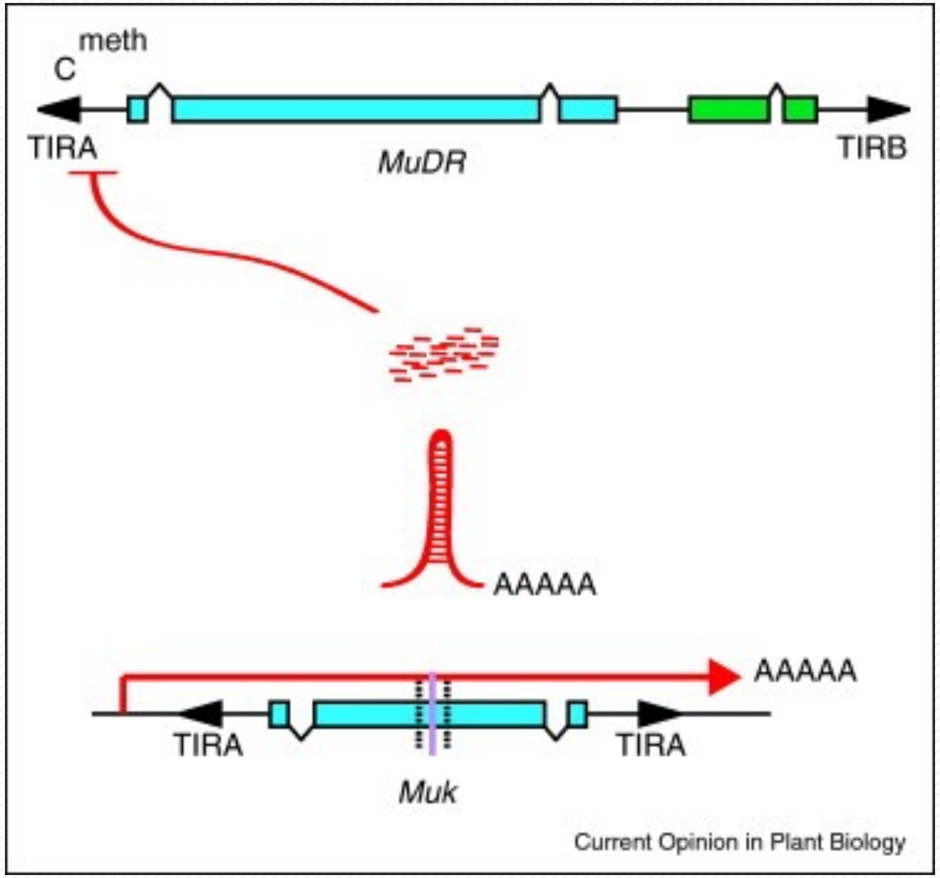
Parental Effects

Cultural Inheritance

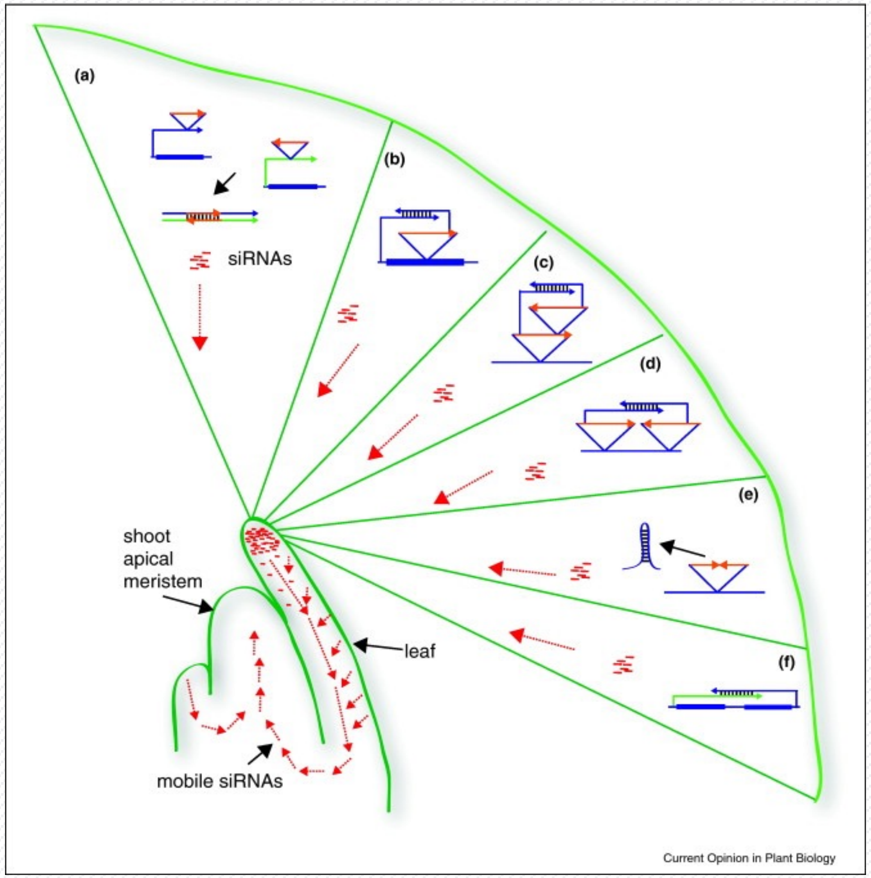
Ecological inheritance

Epigenetic inheritance

4.2

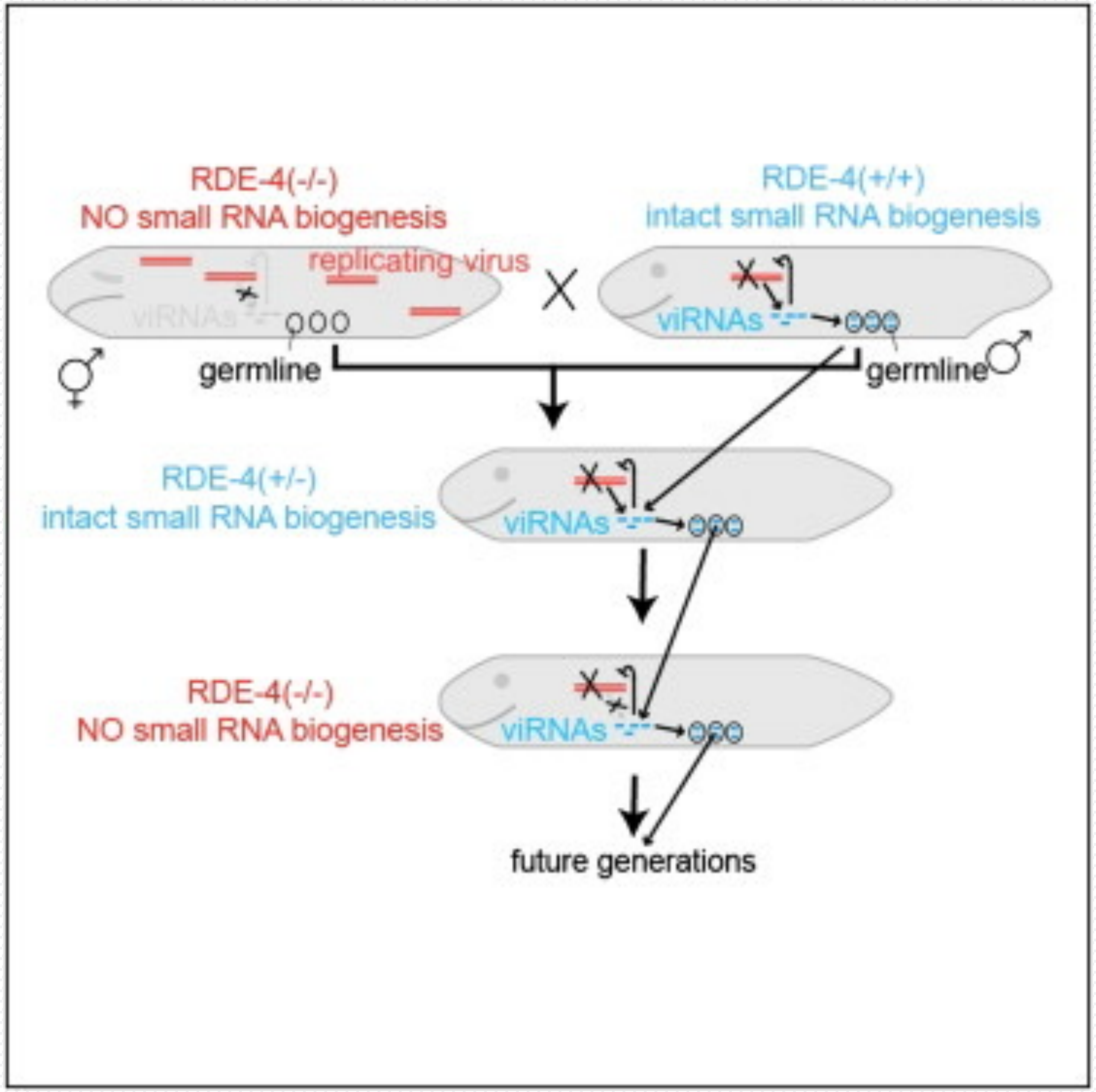


Muk-induced silencing of *MuDR*.



Hypothetical model for independent somatic events leading to germinal silencing

(Lisch, 2012)



Transgenerational Inheritance of an Acquired Small RNA-Based Antiviral Response in *C. elegans*

(Rechavi, Minevich and Hobert, 2011)

CONTENT

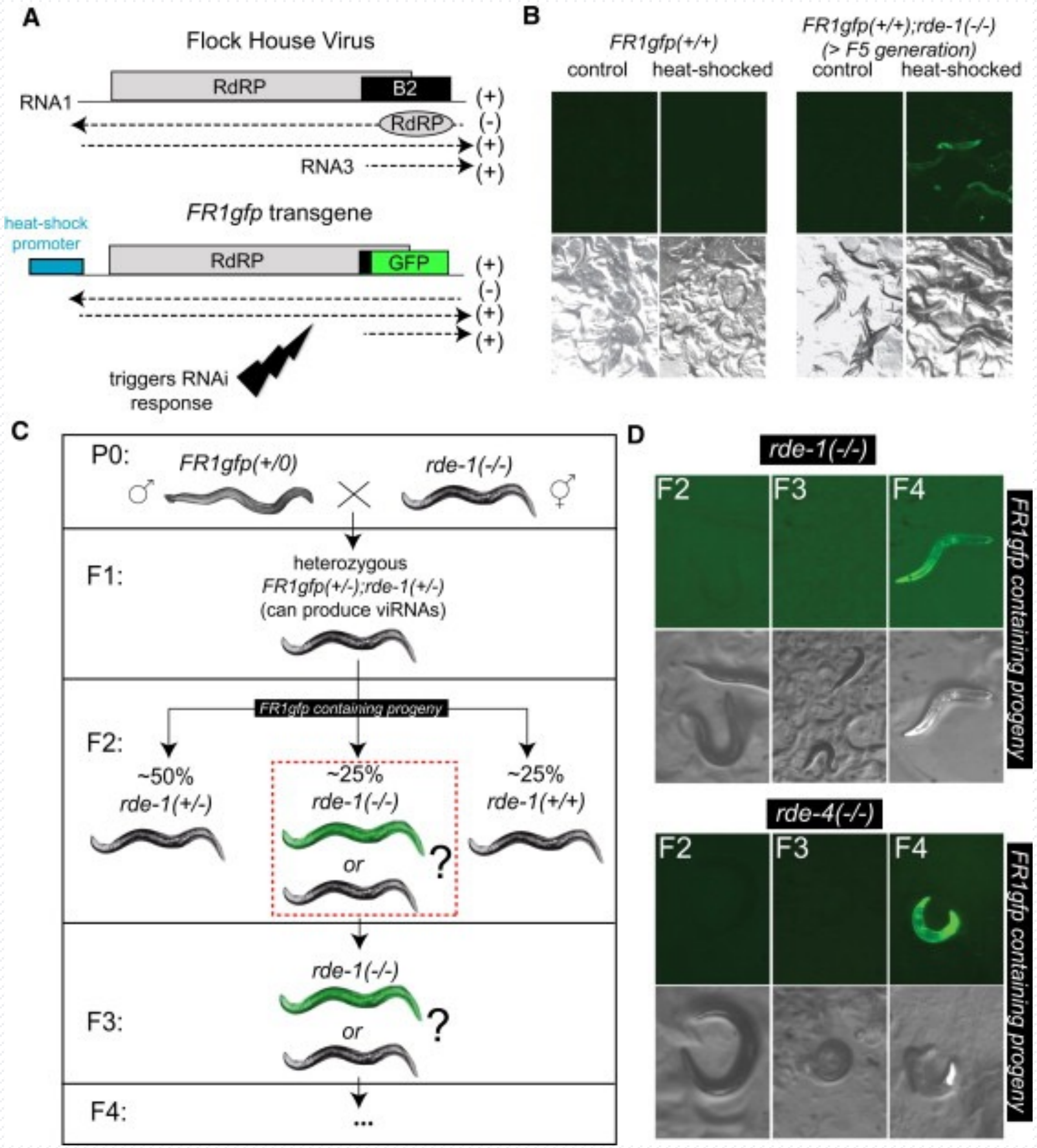
Parental Effects

Cultural Inheritance

Ecological inheritance

Epigenetic inheritance

4.4

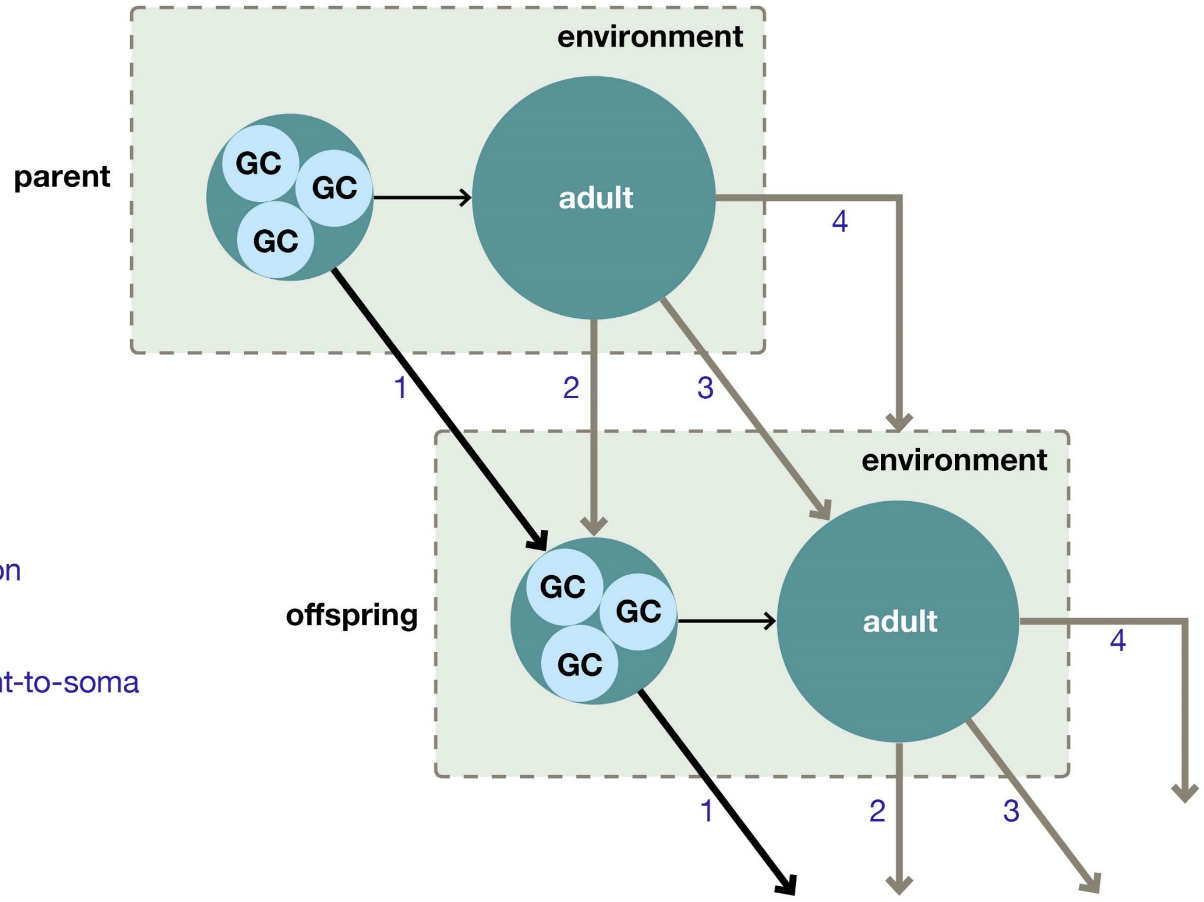


(Rechavi, Minevich and Hobert, 2011)

Genotype	Generation	GFP/Virus(+) Animals after Heat Shock[c]	Total Number of Animals Examined
Wild-type	any	0%	>100
rde-1 (*ne300*)	*rde-1*(−/−) P0[a]	100%	50
	rde-1(+/−) F1 cross-progeny[b]	0%	250 (5 experiments)
	rde-1(−/−) F2	0%	250 (5 experiments)
	rde-1(−/−) F3	0%	250 (5 experiments)
	rde-1(−/−) F4	0.71%	882 (5 experiments)
	rde-1(−/−) F5	10.45%	908 (5 experiments)
rde-4 (*ne299*)	*rde-4*(−/−) P0*	4.9%	102
	rde-4(+/−) F1 cross-progeny[b]	0%	250 (5 experiments)
	rde-4(−/−) F2	0%	250 (5 experiments)
	rde-4(−/−) F3	0%	267 (5 experiments)
	rde-4(−/−) F4	3.4%	441 (5 experiments)
	rde-4(−/−) F5	3.6%	307 (5 experiments)

(Rechavi, Minevich and Hobert, 2011)

Conclusion



Modes of inheritance
1. germ line transmission
2. soma-to-germ line
3. soma-to-soma
4. soma-to-environment-to-soma

GC = germ cell

Adapted from Badyaev & Uller (2009)

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References

Alem, S., Perry, C., Zhu, X., Loukola, O., Ingraham, T., Søvik, E. and Chittka, L., 2016. Associative Mechanisms Allow for Social Learning and Cultural Transmission of String Pulling in an Insect. *PLOS Biology*, 14(10), p.e1002564.

Cortijo, S., Wardenaar, R., Colomé-Tatché, M., Gilly, A., Etcheverry, M., Labadie, K., Caillieux, E., Hospital, F., Aury, J., Wincker, P., Roudier, F., Jansen, R., Colot, V. and Johannes, F., 2014. Mapping the Epigenetic Basis of Complex Traits. *Science*, 343(6175), pp.1145-1148.

Curley, J., Champagne, F., Bateson, P. and Keverne, E., 2008. Transgenerational effects of impaired maternal care on behaviour of offspring and grandoffspring. *Animal Behaviour*, 75(4), pp.1551-1561.

Danchin, É. and Wagner, R., 2010. Inclusive heritability: combining genetic and non-genetic information to study animal behavior and culture. *Oikos*, 119(2), pp.210-218.

Lisch, D., 2012. Regulation of transposable elements in maize. *Current Opinion in Plant Biology*, 15(5), pp.511-516.

Rechavi, O., Minevich, G. and Hobert, O., 2011. Transgenerational Inheritance of an Acquired Small RNA-Based Antiviral Response in C. elegans. *Cell*, 147(6), pp.1248-1256.

Sheppard, C., Marshall, H., Inger, R., Thompson, F., Vitikainen, E., Barker, S., Nichols, H., Wells, D., McDonald, R. and Cant, M., 2018. Decoupling of Genetic and Cultural Inheritance in a Wild Mammal. *Current Biology*, 28(11), pp.1846-1850.e2.

Two alternative interpretations of inheritance

A traditional interpretation

Heredity defined to exclude non-genetic inheritance

The EES interpretation

Heredity defined to include all causal mechanisms by which offspring come to resemble their parents. Phenotypes are not inherited, they are reconstructed in development

Heritability

- Heritability is a statistic used in the fields of breeding and genetics that estimates the degree of variation in a phenotypic trait in a population that is due to genetic variation between individuals in that population. The concept of heritability can be expressed in the form of the following question: "What is the proportion of the variation in a given trait within a population that is not explained by the environment or random chance?

-- From Wikipedia

- A central question in biology is whether observed variation in a particular trait is due to environmental or to biological factors, sometimes popularly expressed as the "nature versus nurture" debate. Heritability is a concept that summarizes how much of the variation in a trait is due to variation in genetic factors. Often, this term is used in reference to the resemblance between parents and their offspring.

-- Citation: Wray, N. & Visscher, P. (2008) Estimating trait heritability. *Nature Education*

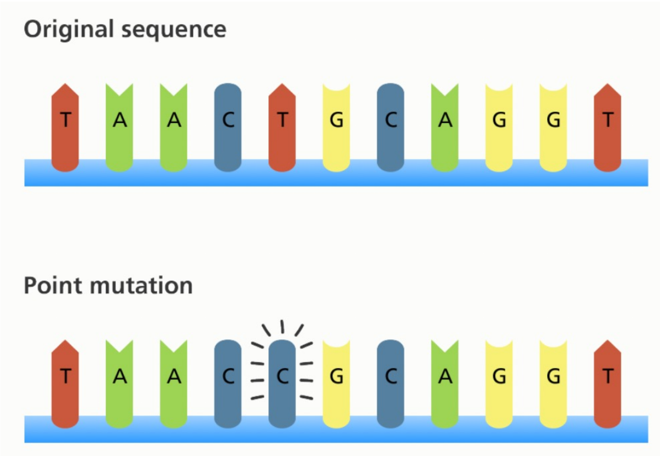
Genetic variation

Genetic variation is the difference in DNA among individuals or the differences between populations.

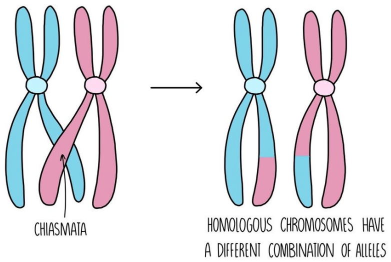
Mutations: original source of variation, new alleles made, make gene pool bigger.

Meiosis: new combinations of alleles because of crossing-over and independent orientation of bivalents

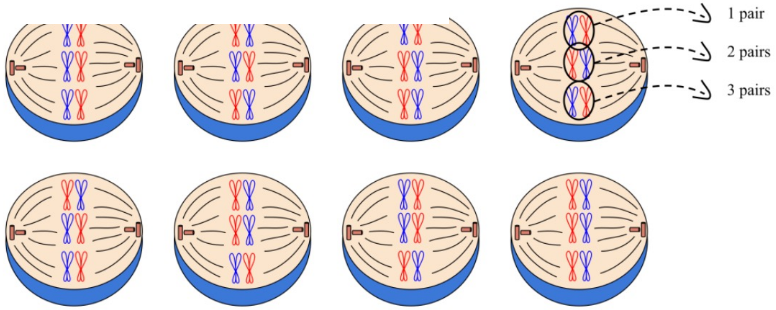
Sexual reproduction: fuse male and female gametes to produce combination of the two in offspring.



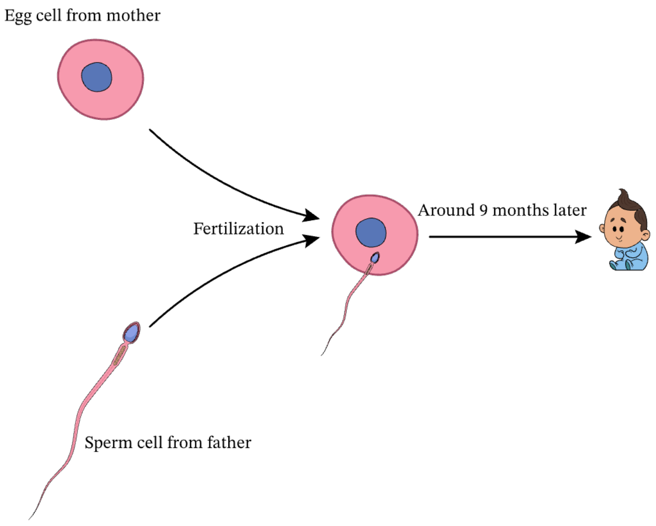
Point mutation



Crossing over



independent orientation of bivalents



Sexual reproduction

Genetic and non-genetic inheritance

1. Does the non-genetic Inherited Information need to be added to the Heritability concept?

epigenetics, parental effects, ecological and cultural inheritance → Genes -> Genes + any inherited information → heritability

2. If non-genetic Inherited information can be added to inheritance, how does it affect traditional genetic inheritance or SET?

Lipombo(芒贝图人): Skull Elongation by the Mangbetu Tribe

- baby sea turtles heading toward the ocean

Dissecting the effects of genetic and non-genetic inheritance is challenging

Étienne Danchin
Directeur de Recherche émérite CNRS
Last update: August 2021

Researcher at:
Évolution & Diversité Biologique (EDB)

Former co-head of the Labex TULIP (Tulip) from early 2011 to the end of 2019

New address:
Laboratoire Évolution & Diversité Biologique (EDB, UMR 5174),
Université de Toulouse; CNRS, IRD.
118 route de Narbonne, Bat 4R1.
31062 Toulouse cedex 9.
FRANCE
Email: etienne.danchin@univ-tlse3.fr

- ❖ We call for an extended modern synthesis that would not reduce inheritance to genes and that would incorporate all forms of inheritance to constitute a comprehensive evolutionary theory.

（我们呼吁一种扩展的现代综论，它不会减少基因对于遗传的重要性，并致力于将所有形式的遗传纳入其中，以构成一个全面的演化理论）

--Étienne Danchin
（Danchin et al., 2011, *Nature Reviews Genetics*）

https://www.edanchin.fr/?lang=en

谢谢观看！

2022年10月9日