Animal Traditions in Evolution

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Life is more than DNA

Denis Noble (21/10/2010)

What more? And does it not boil down to DNA – eventually?

What is evolution if not a change in the genetic constitution of populations?


ENYMA
THERE IS GRANDEUR IN THIS VIEW OF LIFE, WITH ITS SEVERAL POWERS
HAVING BEEN ORIGINALLY BREATHED INTO A FEW FORMS OR INTO ONE; AND WHILE...
ANAT 7/06

Inputs to development and heredity: The five (potential) mothers

- genetic (DNA) resources
- the non-DNA part of the egg (nuclear and cytoplasmic)
- early nourishment (womb & milk)
- home and care
- Socially constructed and transmitted symbols

Epigenetic Cellular Inheritance Systems

The systems that underlie the transmission of functional and structural non-DNA sequence variations between cells.

- Self-sustaining loops
- Structural inheritance
- **Chromatin marking**
- RNA-mediated inheritance

- **Organismal epigenetic inheritance/reconstruction**
- **Behavioural inheritance/reconstruction**
- **Cultural symbol-based inheritance/reconstruction**

What are animal cultures/traditions?

An animal **culture/tradition** can be defined as a system of **socially transmitted** patterns of behavior, preferences, and products of activities that characterize a group of social animals.

Cultural evolution is the change, through time, in the nature and frequency of socially transmitted preferences, patterns, or products of behavior in a population.

How is behavior transmitted?

Routes of transmission of normal and abnormal (pathological) traits through parental (mostly maternal) state and behavior:

Food/drink habits

Gut bacteria and associated traits

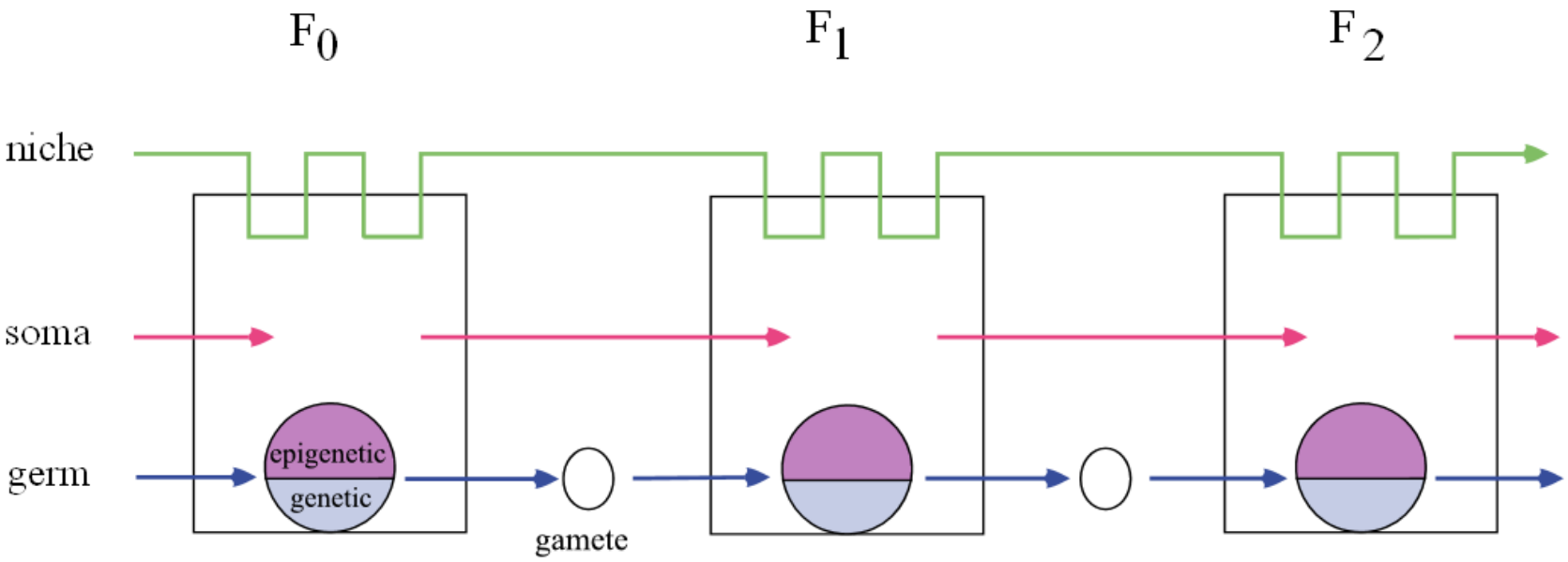
Hormonal inputs with associated traits (e.g. sexual maturation timing, aggression etc)

Shyness or exploratory behavior, stress response

Metabolic disorders

Teratoloigcal disorders.

Epigenetic inheritance: broad and narrow conceptions

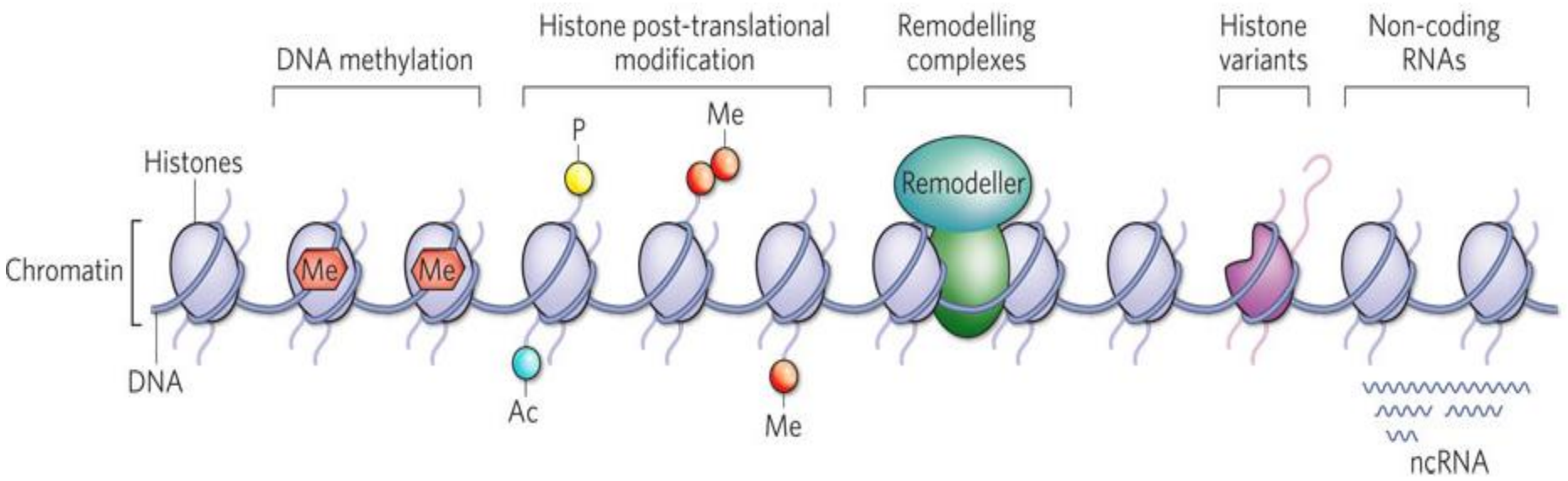


Beaver

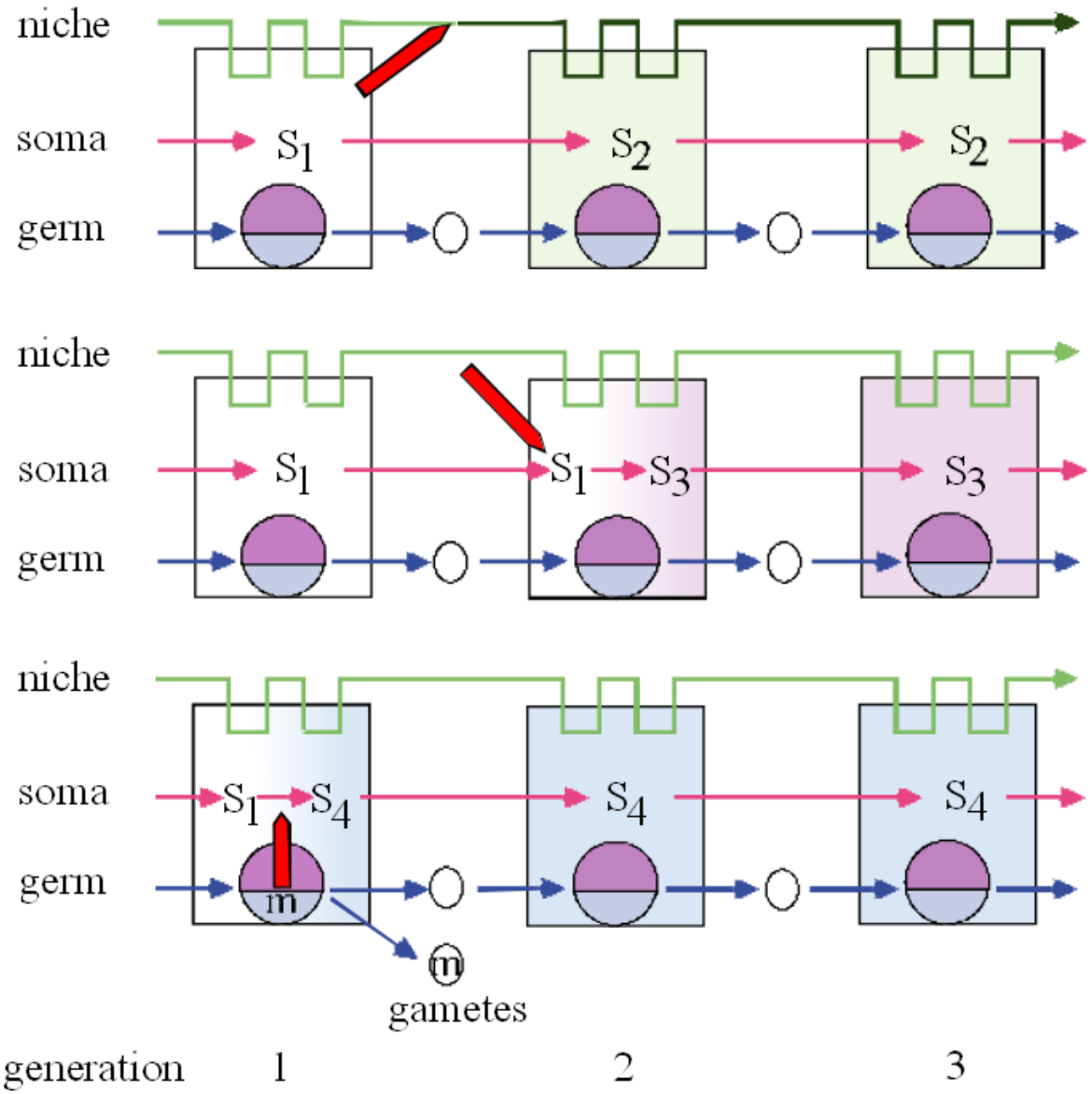
Figure 1: Mechanisms involved in chromatin modification

Brain function and chromatin plasticity

Catherine Dulac Nature 465:728–735, 2010
doi:10.1038/nature09231

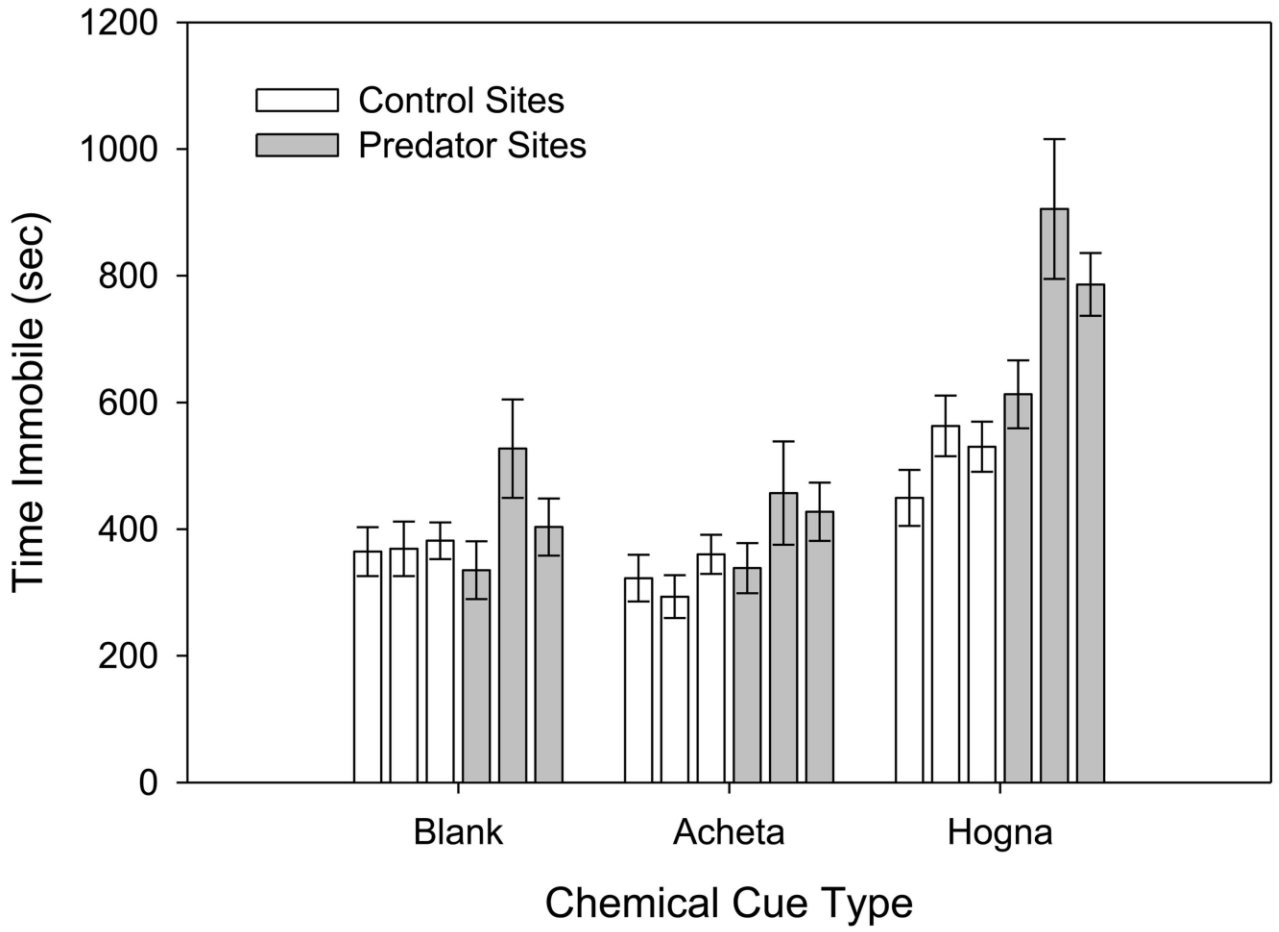


Induction and soma-to-soma inheritance of phenotypic variation

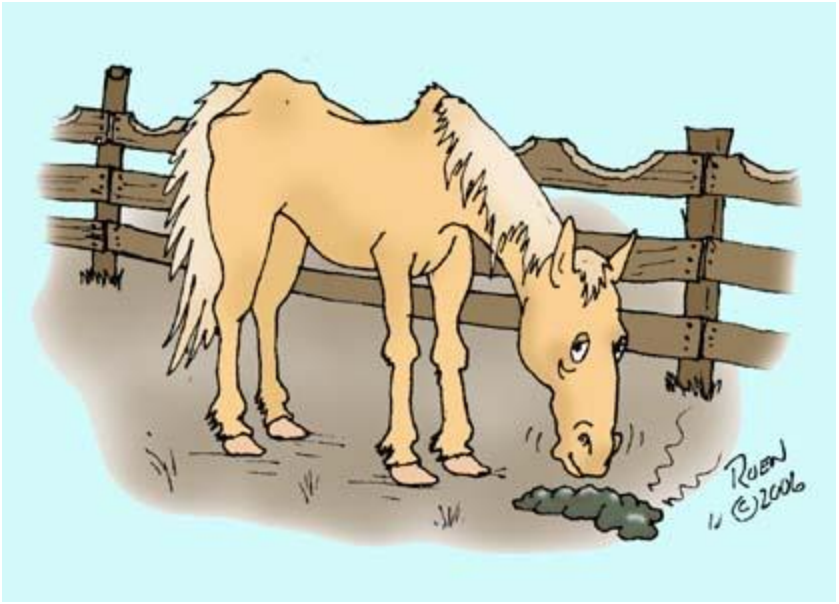


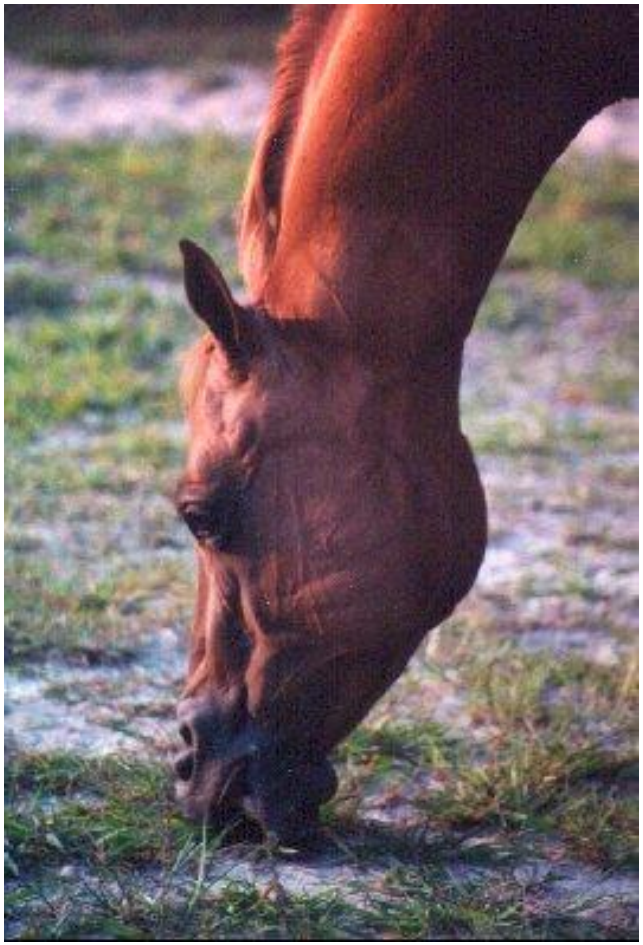
Mothers Forewarn Offspring about Predators: A Transgenerational Maternal Effect on Behavior

Mean time spent immobile by predator-naive offspring of fall field crickets from control and predator field sites. When exposed to chemical cues of *Hogna*, offspring from females collected at predator sites exhibited significantly greater immobility than did offspring from control sites. Offspring did not differ between predator and control sites in response to blank filter paper or the chemical cues of the domestic cricket *Acheta domesticus*.



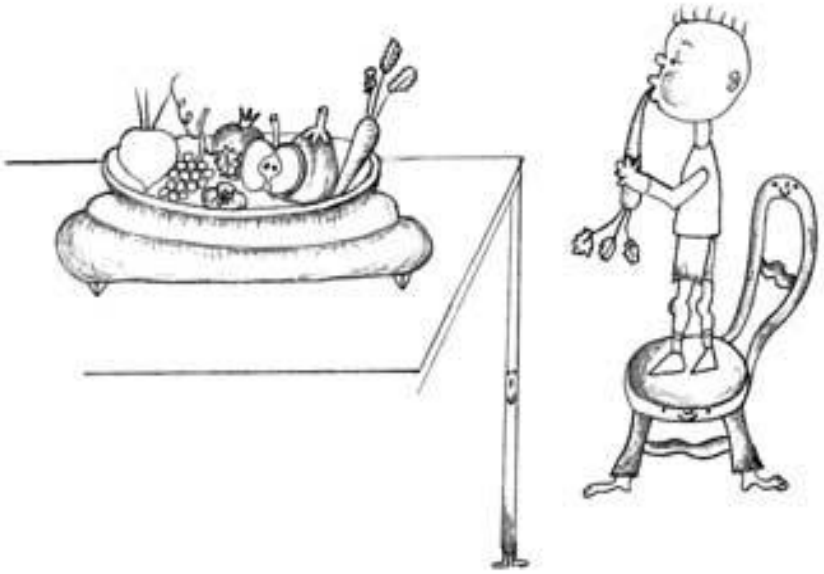
Coprophagy



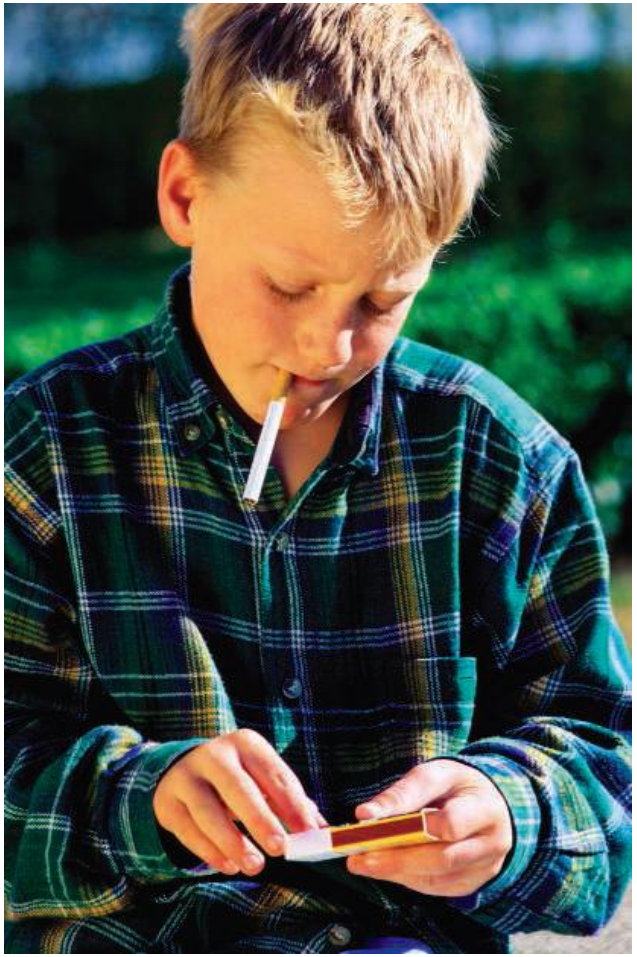


Food preferences in European rabbits

Food preferences in humans



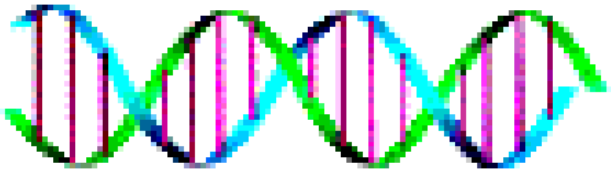
There were 166 fathers who started smoking before age 11, and Pembrey found that these fathers' sons were on average heavier than sons of fathers who took up this habit later in life or who never smoked. Daughters were unaffected.



Hormonally mediated inheritance of acquired characteristics in Mongolian gerbils

Maternal behaviour in the rat

Environmental programming of gene activity



Glucocorticoid receptor gene

PUP (Day 1-6)

LOW LG

HIGH LG

ADULT (Day 90)

GR GENE

GR GENE

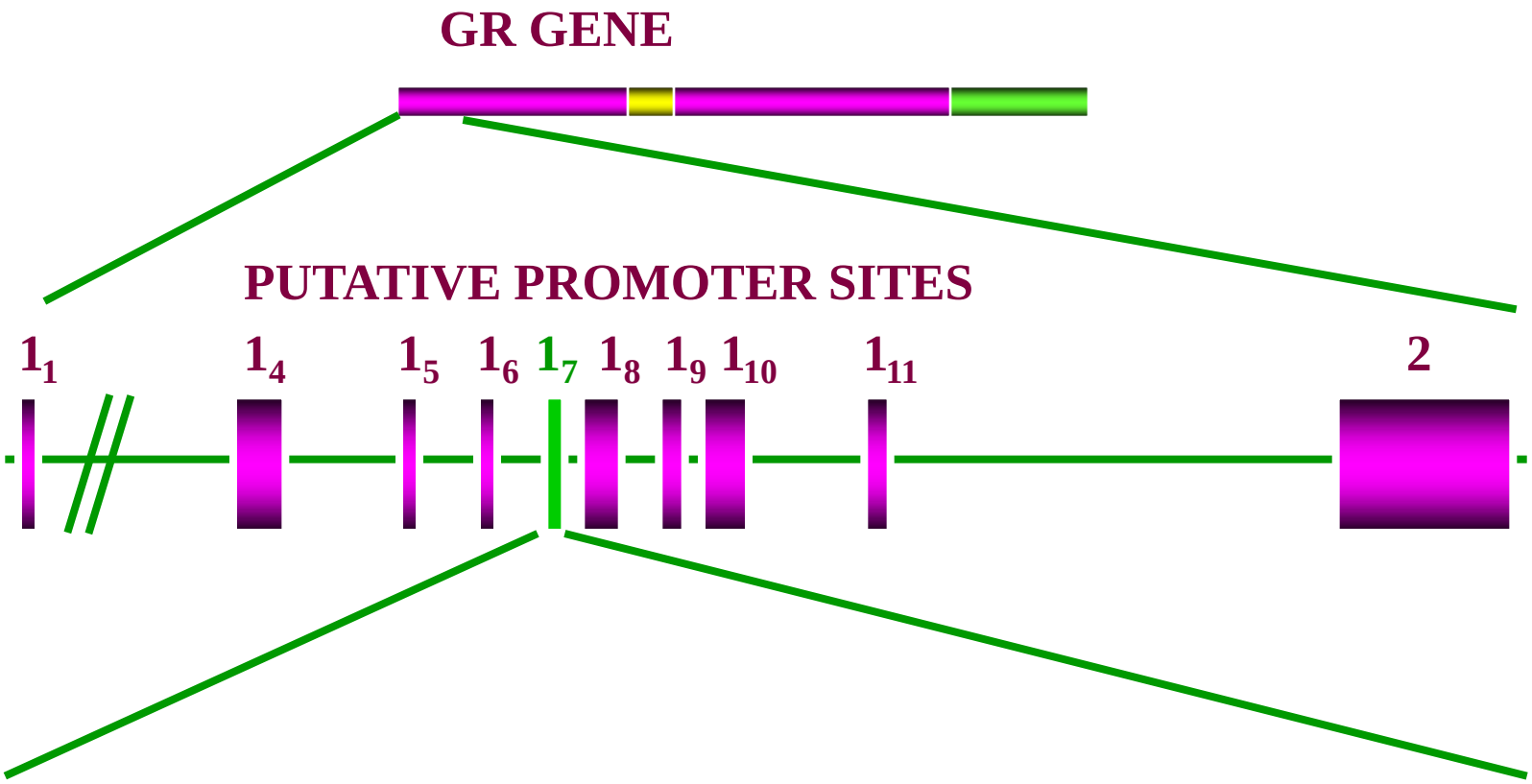
GR RECEPTORS

GR RECEPTORS

STRESS RESPONSE

STRESS RESPONSE

Putative promoter sites of genomic GR



1681 ccc

1741 ctctgctagt gtgacacact t[1]**cg**[2]**cg**caact c[3]**cg**cagttgg [4]**cg**gg[5]**cg**[6]**cg**ga ccacccctg[7]**c**

1801 **g**gctctgc[8]**cg** gctggctgtc accct[9]**cg**ggg gctctggctg c[10]**cg**accca[11]**cg** ggg[12]**cg**ggct

1861 c[13]**cg**ag[14]**cg**gtt ccaagcct[15]**cg** gagtggg[16]**cg** gggg[17]**cg**ggag ggagcctggg agaa

NGFI-A

(*McCormick J.A., Mol Endo. 2000*)

Epigenetic Transmission of the Impact of Early Stress Across Generations

BIOL PSYCHIATRY 2010;68:408–415

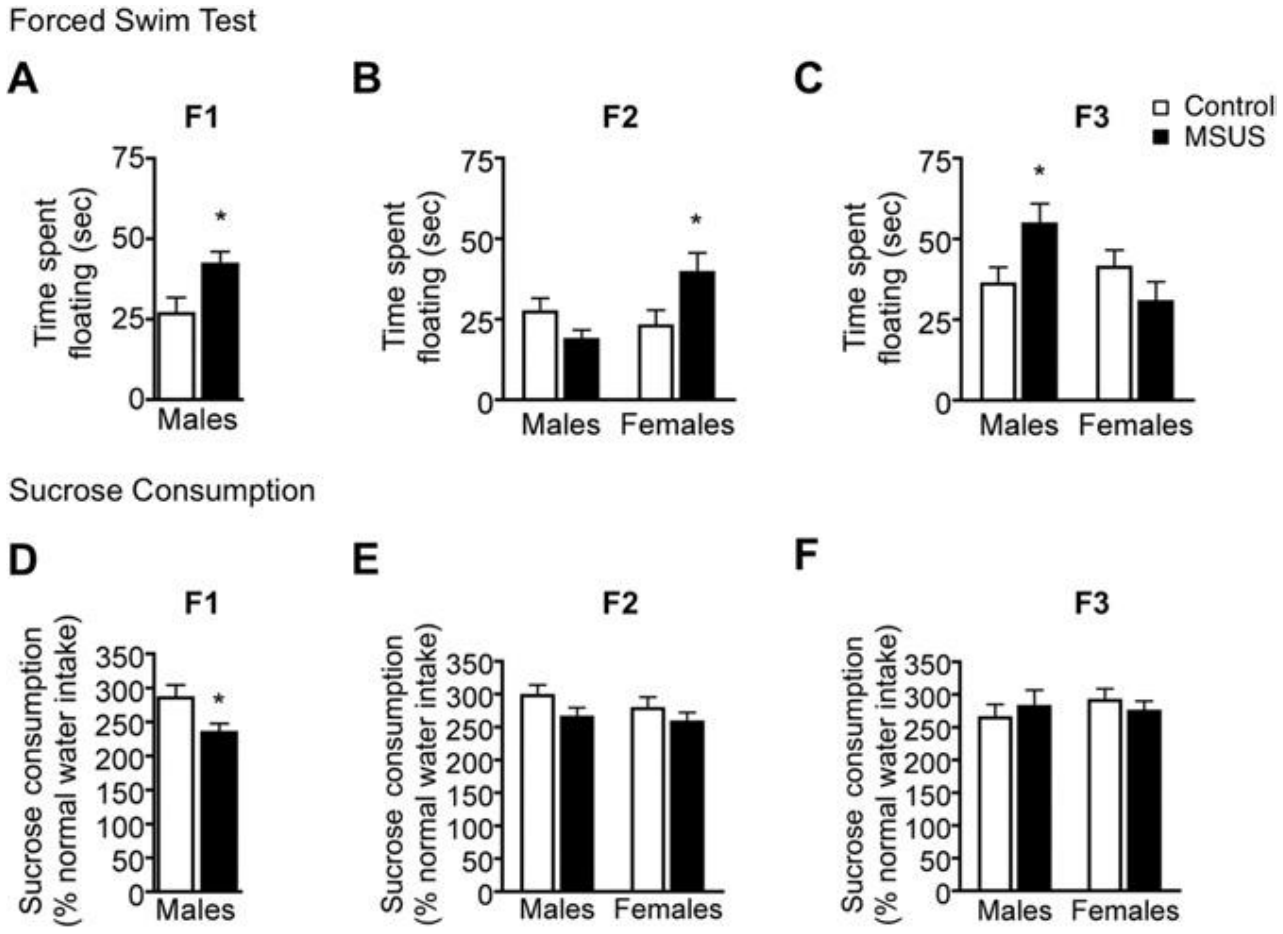
Tamara B. Franklin, Holger Russig, Isabelle C. Weiss, Johannes Gräff, Natacha Linder, Aubin Michalon,Sandor Vizi, and Isabelle M. Mansuy

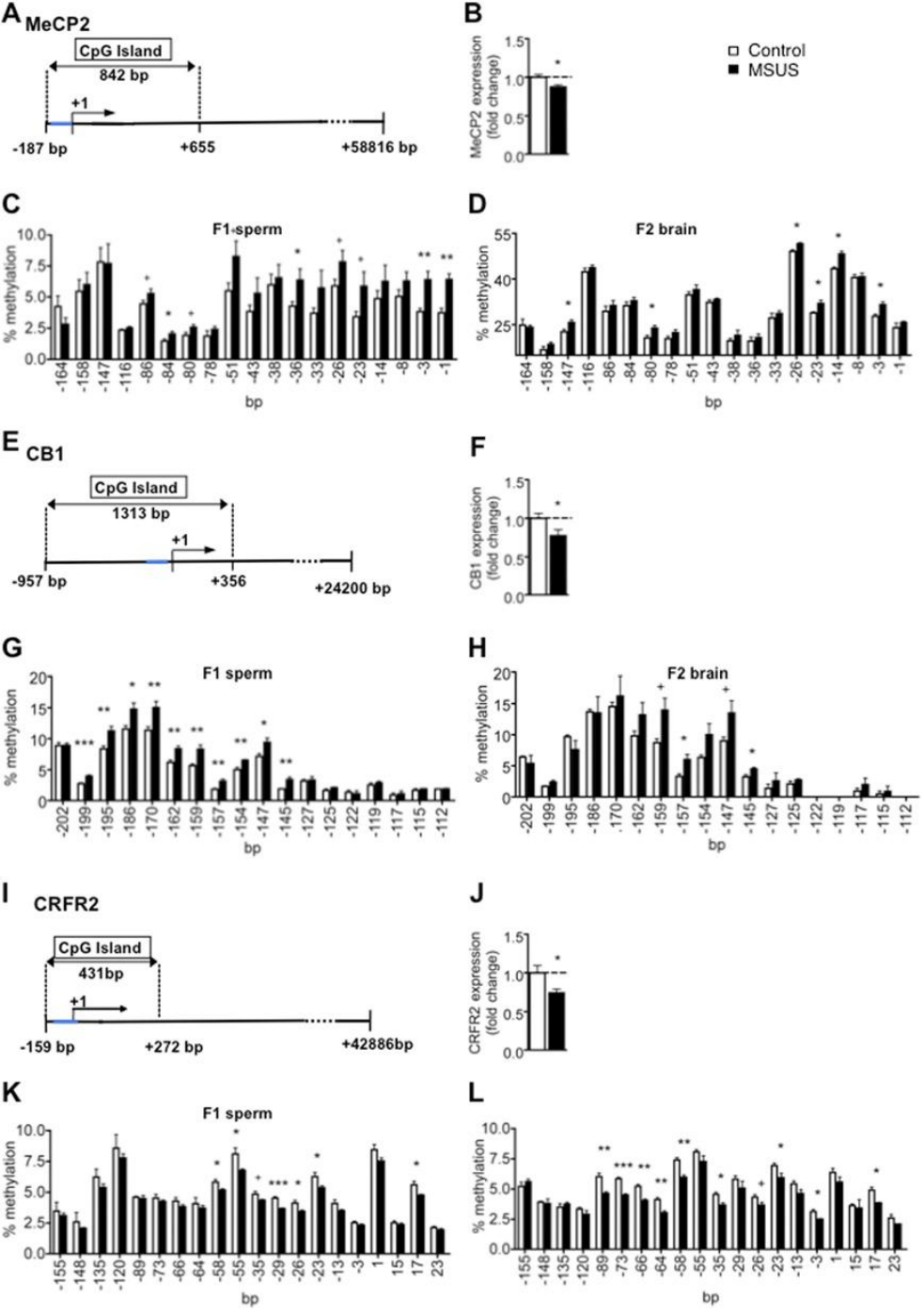
Background: Traumatic experiences in early life are risk factors for the development of behavioral and emotional disorders. Such disorders can persist through adulthood and have often been reported to be transmitted across generations.

Methods: To investigate the transgenerational effect of early stress, mice were exposed to chronic and unpredictable maternal separation from postnatal day 1 to 14.

Results: We show that chronic and unpredictable maternal separation induces depressive-like behaviors and alters the behavioral response to aversive environments in the separated animals when adult. Most of the behavioral alterations are further expressed by the offspring of males subjected to maternal separation, despite the fact that these males are reared normally. Chronic and unpredictable maternal separation also alters the profile of DNA methylation in the promoter of several candidate genes in the germline of the separated
males. Comparable changes in DNA methylation are also present in the brain of the offspring and are associated with altered gene expression.

Conclusions: **These findings highlight the negative impact of early stress on behavioral responses across generations and on the regulation of DNA methylation in the germline.**


Forced Swim Test
A
F1
Time spent floating (sec)
75
50
25
0
*
Males
B
F2
Time spent floating (sec)
75
50
25
0
*
Males
Females
C
F3
Control
MSUS
Time spent floating (sec)
75
50
25
0
*
Males
Females
Sucrose Consumption
D
F1
Sucrose consumption (% normal water intake)
350
300
250
200
150
100
50
0
*
Males
E
F2
Sucrose consumption (% normal water intake)
350
300
250
200
150
100
50
0
Males
Females
F
F3
Sucrose consumption (% normal water intake)
350
300
250
200
150
100
50
0
Males
Females



Methylation of the CpG island surrounding the transcription initiation site of MeCP2 and CB1 genes was increased in F1 MSUS sperm (Figure 5A, 5C, 5E, 5G). In contrast, for the CRFR2 gene, methylation in a stretch of the CpG island located 5= of the transcription initiation site was decreased (Figure 5I and K). Methylation was not changed in target regions of the 5-HT1A or MAOA gene (Supplement 1, Figure S4). These data indicate that DNA methylation is altered in both directions and in a gene-specific manner in the germline of males subjected to early stress. Because they are present in the germline, the changes in DNA methylation could potentially be maintained and transmitted to the following generation. To test this hypothesis, we checked the profile of DNA methylation of the candidate genes in the brain of the female F2 progeny. Strikingly, a similar hypermethylation of the same stretch of CpGs was observed in both the MeCP2 and CB1 genes (Figure 5D and 5H) and a hypomethylation of CRFR2 CpG island (Figure 5L). These changes in methylation were functionally relevant because they were associated with a decrease in the level of mRNA expression of these genes (Figure 5B, 5F, 5J).

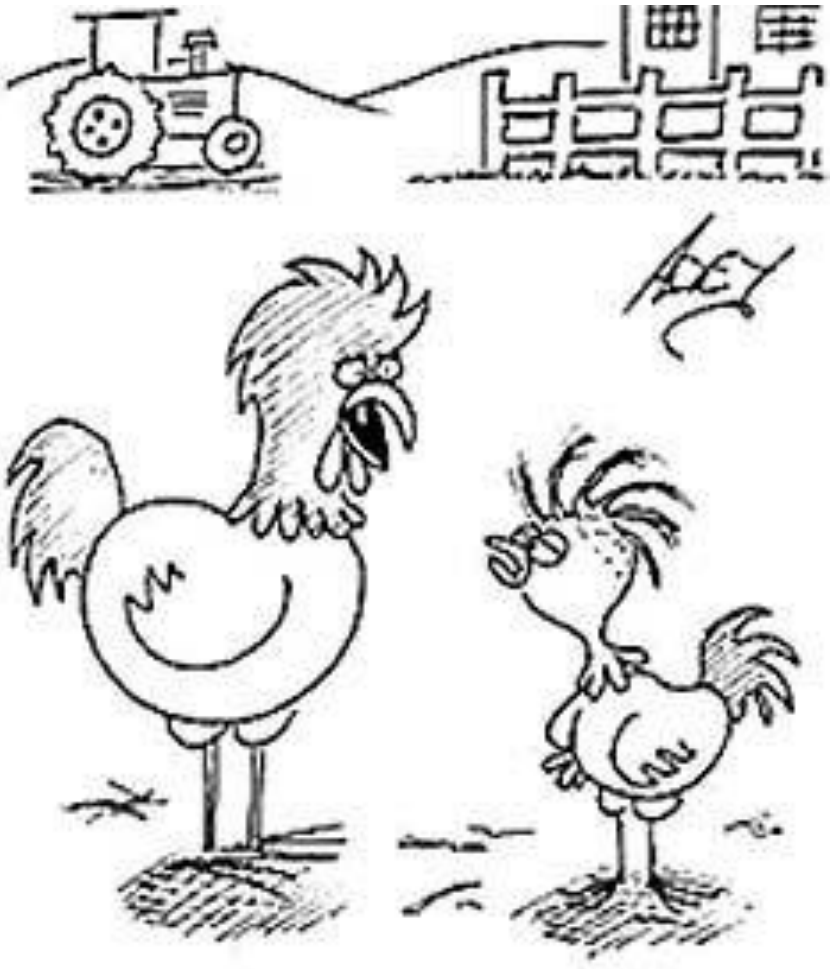
Cannabinoid receptor-1 (CB1), associated with emotionality in rodents;

corticotrophinreleasing factor receptor 2 (CRFR2), a stress hormone receptor;

MeCP2 – control of stress, Rett syndrome.

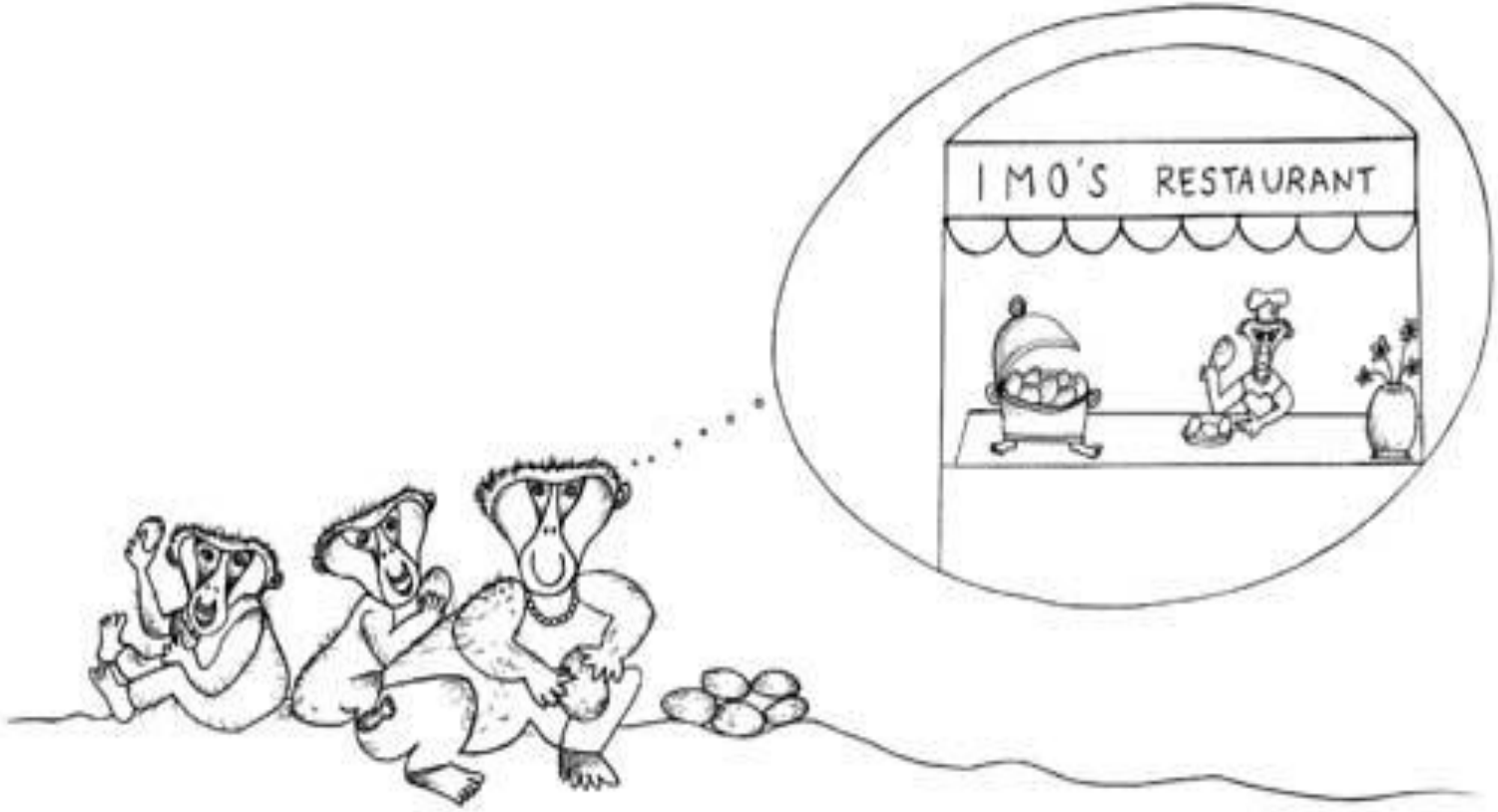
MAOA role in depression, and an enzyme that catalyzes the degradation of serotonin

Social observational learning



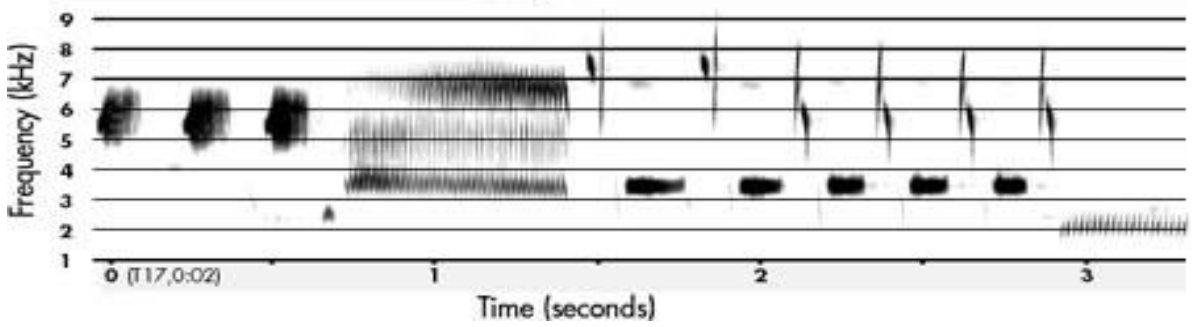
"....Cockle - doodle - doo! Not cockle - doodle - whatever."

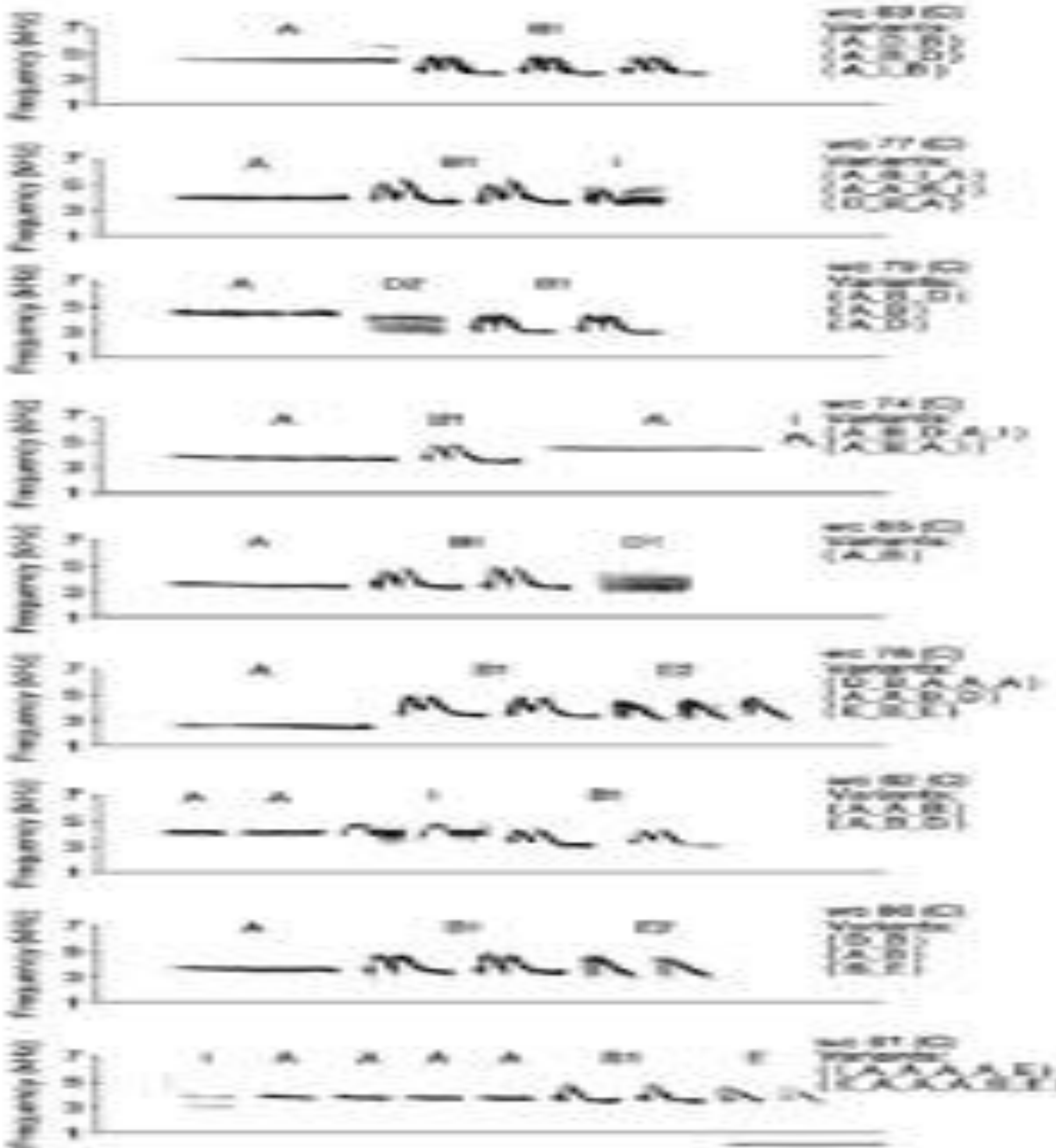
Social learning in rats (Terkel and Aisner)

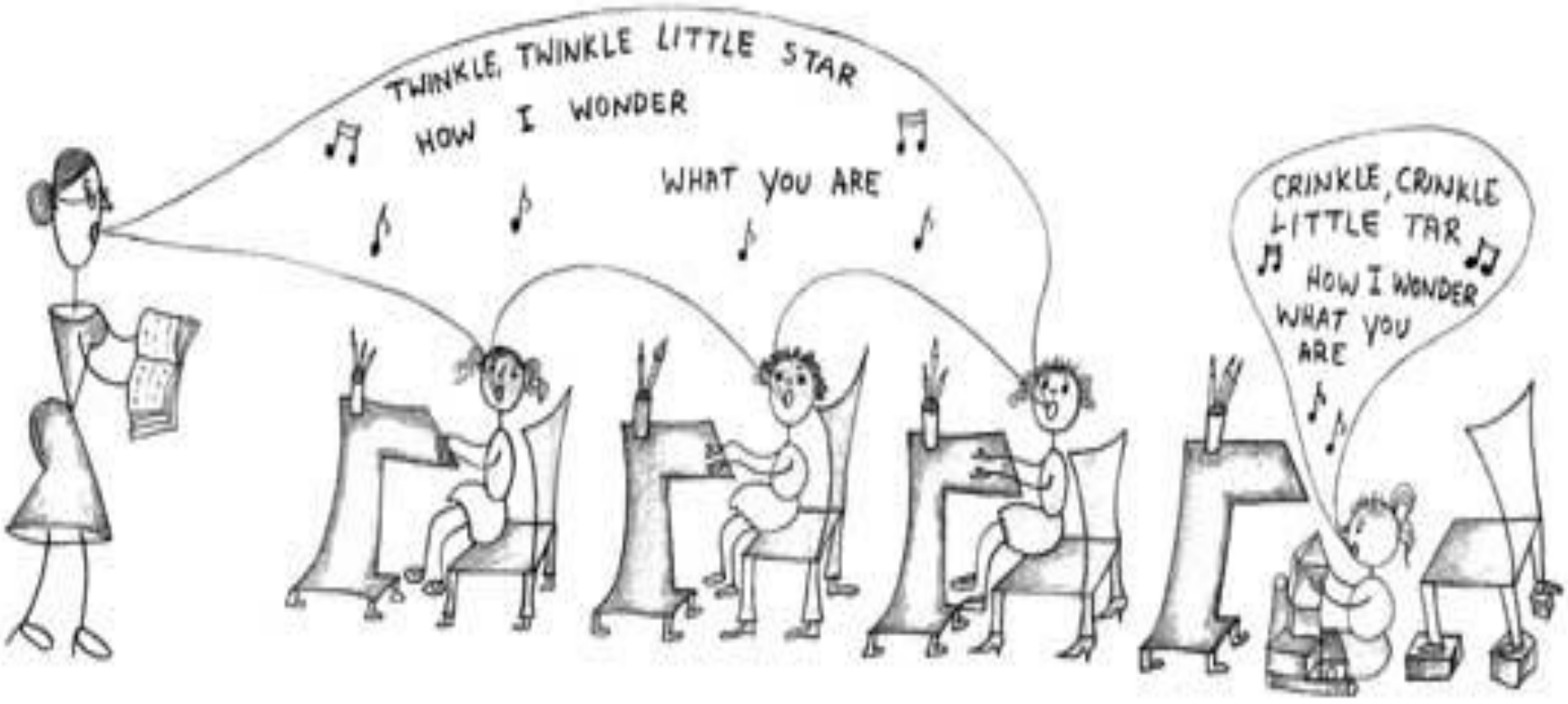

IMO'S RESTAURANT

Social learning through imitation

Figure 13a: SONG SPARROW—PART 1 *Song A*






TWINKLE, TWINKLE LITTLE STAR
HOW I WONDER
WHAT YOU ARE
CRINKLE, CRINKLE LITTLE TAR
HOW I WONDER WHAT YOU ARE

Teaching traditions through imitations in banded mongooses

Chimpanzee cultures

Is cultural evolution a component of bowers' evolution?

Why is considering animal traditions important for understanding evolution?

Better understanding of heredity and developmental processes

Alternative evolutionary explanations of patterns of behavior

Co-evolution of genes and behavior

Implications for conservation practices

Simple experiments can shed light on how traditions are formed.

Experiments like those described above with rabbits can be done with mice, so the effect of maternal diets on the food preferences of her offspring (and of fostered offspring) can be examined.

One can also train mice or rats to reach or handle a food source in different ways and observe whether their offspring follow their practices. The general effect of the parental learning-environment (enriched or normal) on the learning abilities of their offspring and on their exploratory behavior can also be followed.

Questions?????

Social learning and interactions between mates

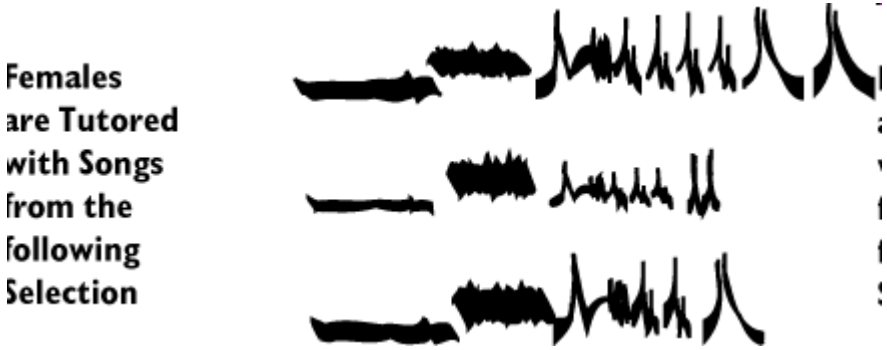
Royal Terns, courtship feeding, Fort DeSoto Park, Tierra Verde, FL

Carotenoids are a class of organic pigments that are produced by plants. These red, yellow, and orange pigments help plants to absorb light energy for photosynthesis and prevent degradation of chlorophyll. But the advantages of carotenoids are not restricted to the plants that synthesize them. Animals that eat plants rich in carotenoids enjoy numerous benefits from these compounds as well.

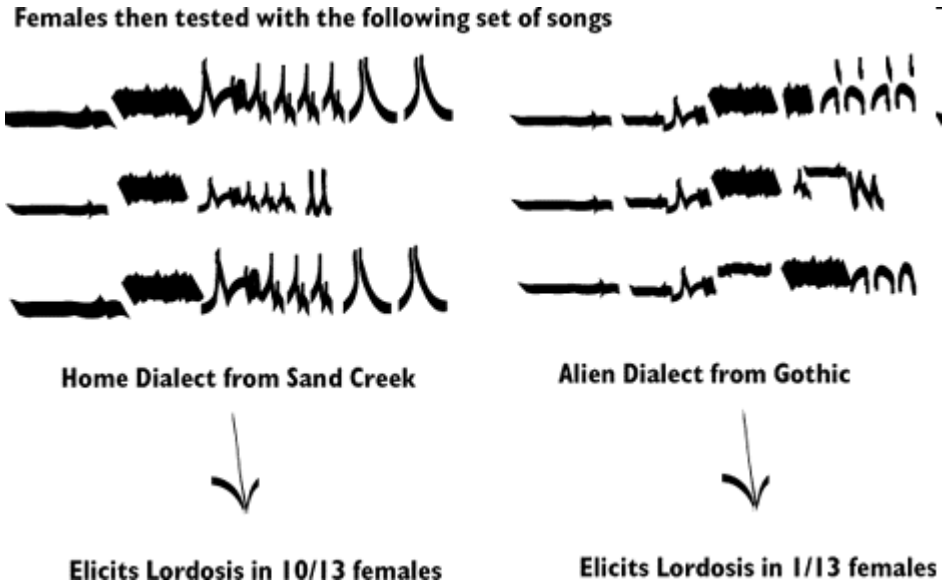
Carotenoids function as antioxidants and boost the immune system. They serve as coloring agents in many organisms. Numerous species of birds (for example, Northern cardinals, scarlet ibises, house finches, flamingos) feast on carotenoid-rich foods. As a result individuals with the best diets are the most colorful and potentially more successful at attracting mates .consumption of carotenoids can improve or 'tune' their color vision, promote the health of offspring as they develop in the egg, and possibly improve male sperm quality

Baker (1981) found that female white-crowned sparrows responded positively to male courtship songs at a higher rate if the song was derived from their home dialect compared to an alien dialect.

The key feature of this study demonstrates that female birds learned the song during the nestling phase. In addition, it is possible to fool females into preferring a truly "non-natal" song, or one from a region other than their true source population. By playing them a song that is from a different source population during the critical song learning period. For example, if tutor songs had been from Gothic the females should have preferred Gothic males at maturity and rejected Sand Creek Songs.



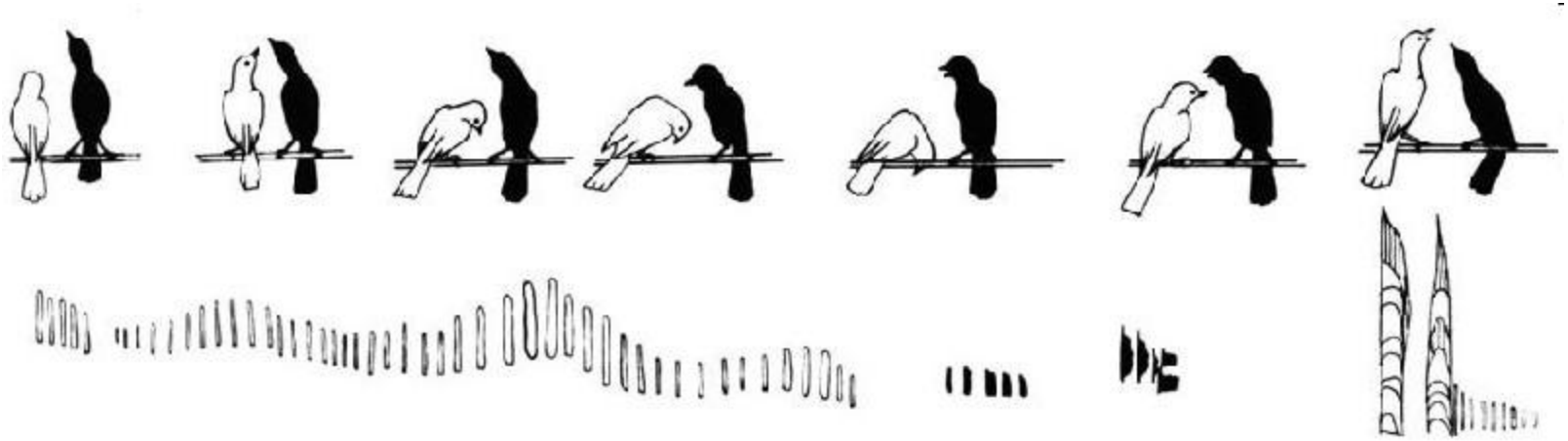
Songs similar to the tutor songs were presented to the females and songs from a different area were presented to the females when they reached maturity

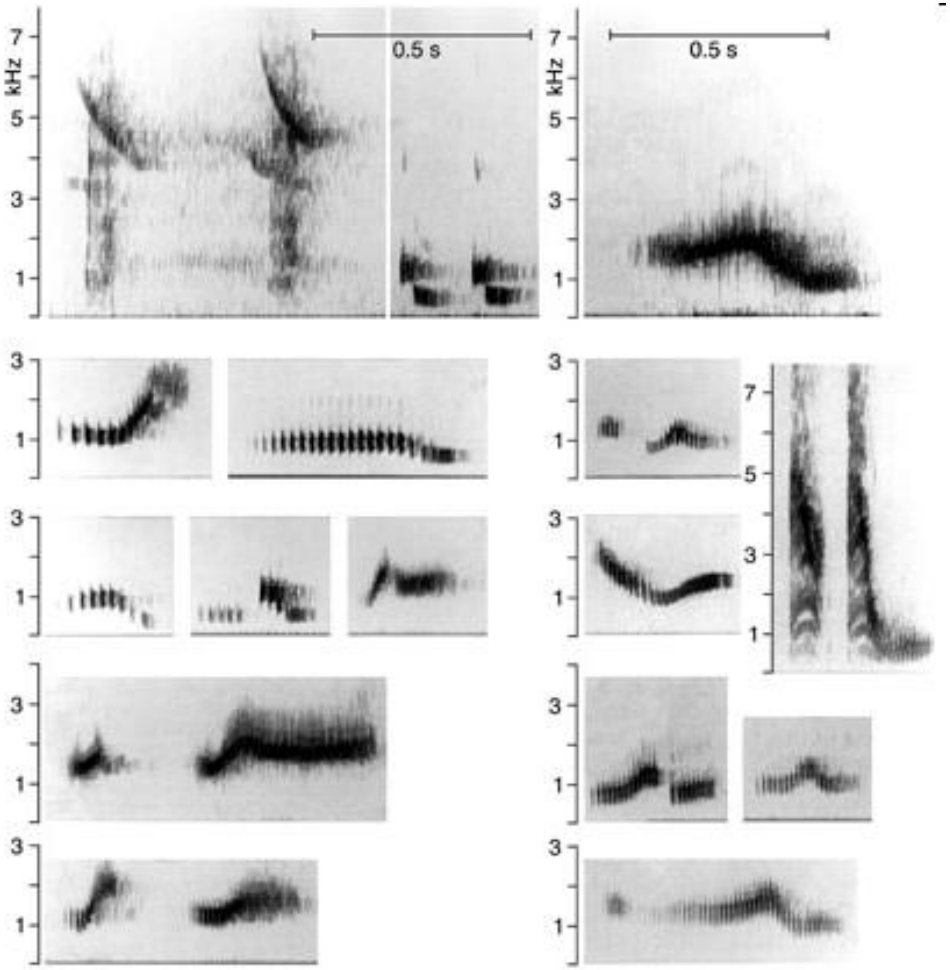


Barnacle Goose: the importance of familiarity

Duetting in Boub-Bou-shrikes

Pair mates of the boubou shrike *Laniarius funebris* bow and stretch their bodies while uttering their sex-specific duet elements (female white, male black; Wickler).





Males and females socially learn sex-specific vocal song elements. Each individual copies the elements of a consexual tutor only. Each pair then combines these elements into a set of pair-specific duets, which remain constant for life.

To achieve this, each individual has to select one element of its own *overt repertoire* according to an element just heard from the partner.

Thus, an individual has to learn both male and female repertoire: it remembers that of the opposite sex as a *silent repertoire.*

Chore sharing in tits

What is the importance of learning in mates' relationship?

Song complexity seems to reflect learning ability

Call similarity is preferred by female budgerigars

What experiments/models can we do?

Are female that are courtship-fed with their natal food more willing?

Are good courtship feeders good fathers?

Does the male improve?

How important is ecological compatibility?

Does the natal song signal common ground? Comparative studies between homogenous and heterogeneous areas may be helpful.

Do naïve mates learn from experienced ones?

Modeling non-transferable shared information (in learnt duetting).