The following slides are for teaching only

It is not allowed to use any of the slides for other purposes than learning

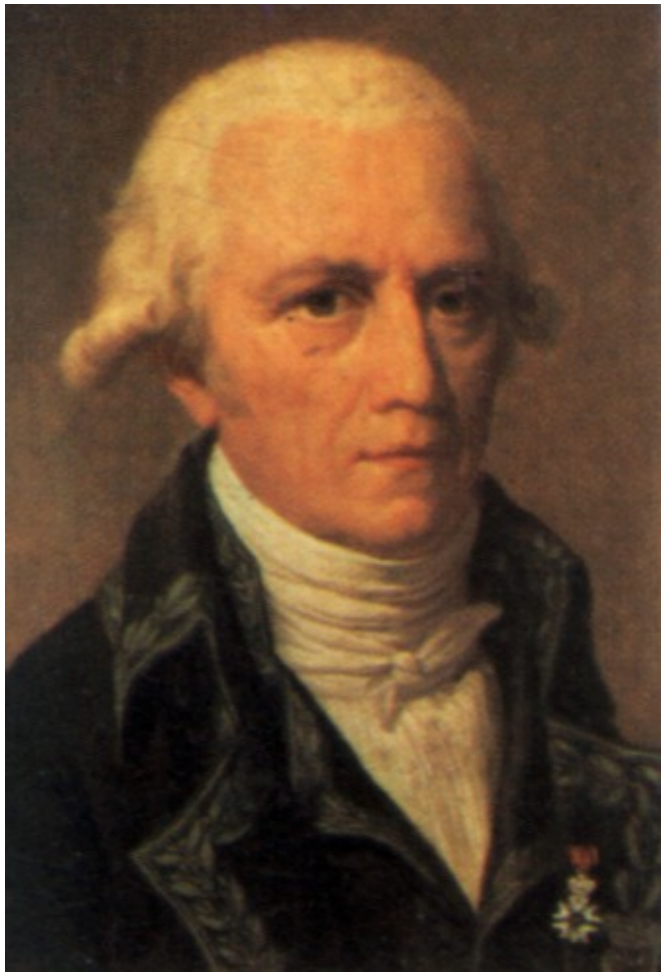
Genes, Brains and Behaviour: lecture 7

Are genes important for our own behaviour?

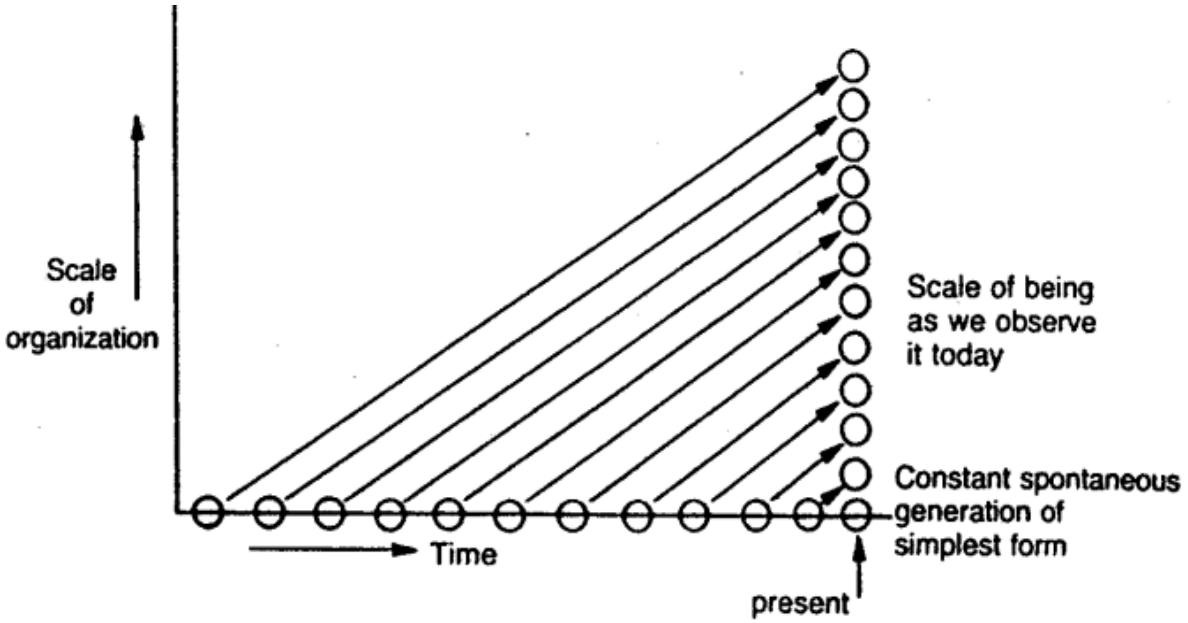
An evolutionary excursion

- What does the Darwinian concept of „Survival of the fittest“ mean?
- The gene mutation as the selection unit
- What is inclusive fitness?
- What are the behavioural consequences of inclusive fitness of gene mutations?

Jean Baptiste de Lamarck (1744-1829



Lamarcks Transformationstheorie - und die kontinuierliche Urzeugung

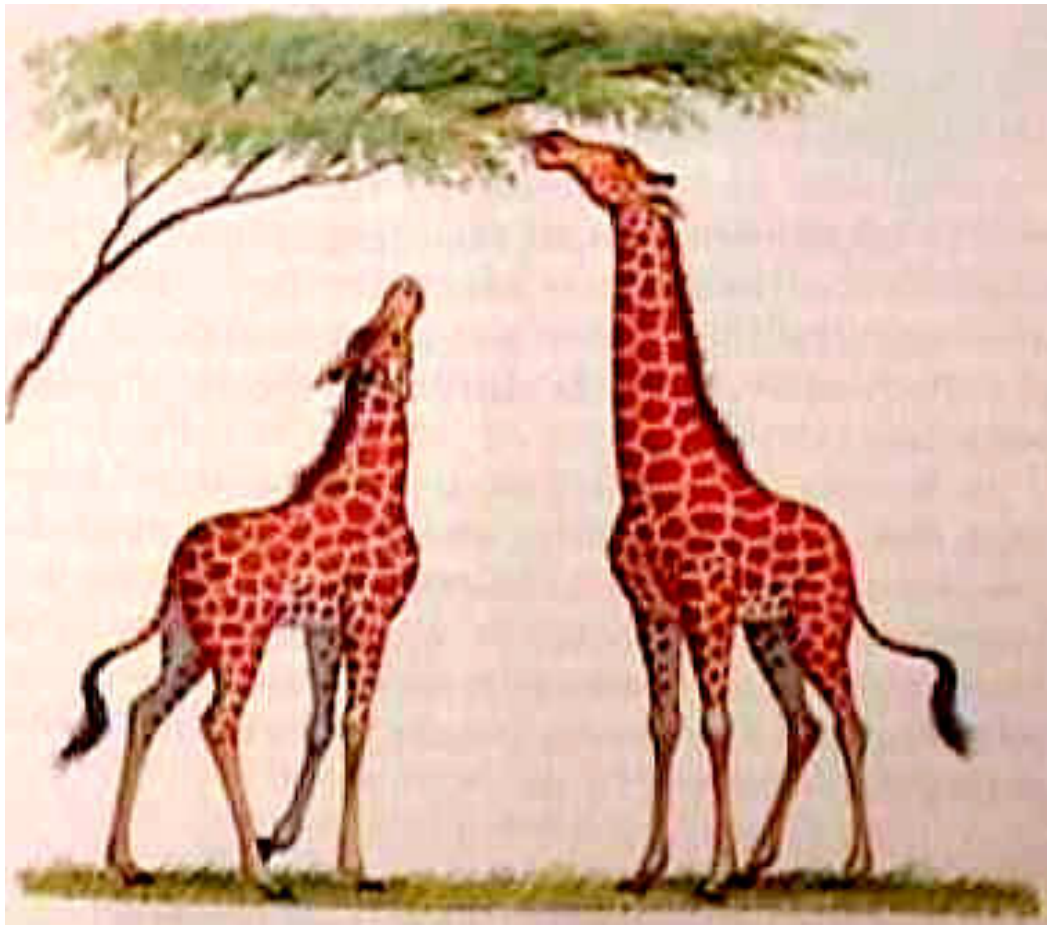


Lamarck's Theory of Organic Progression.

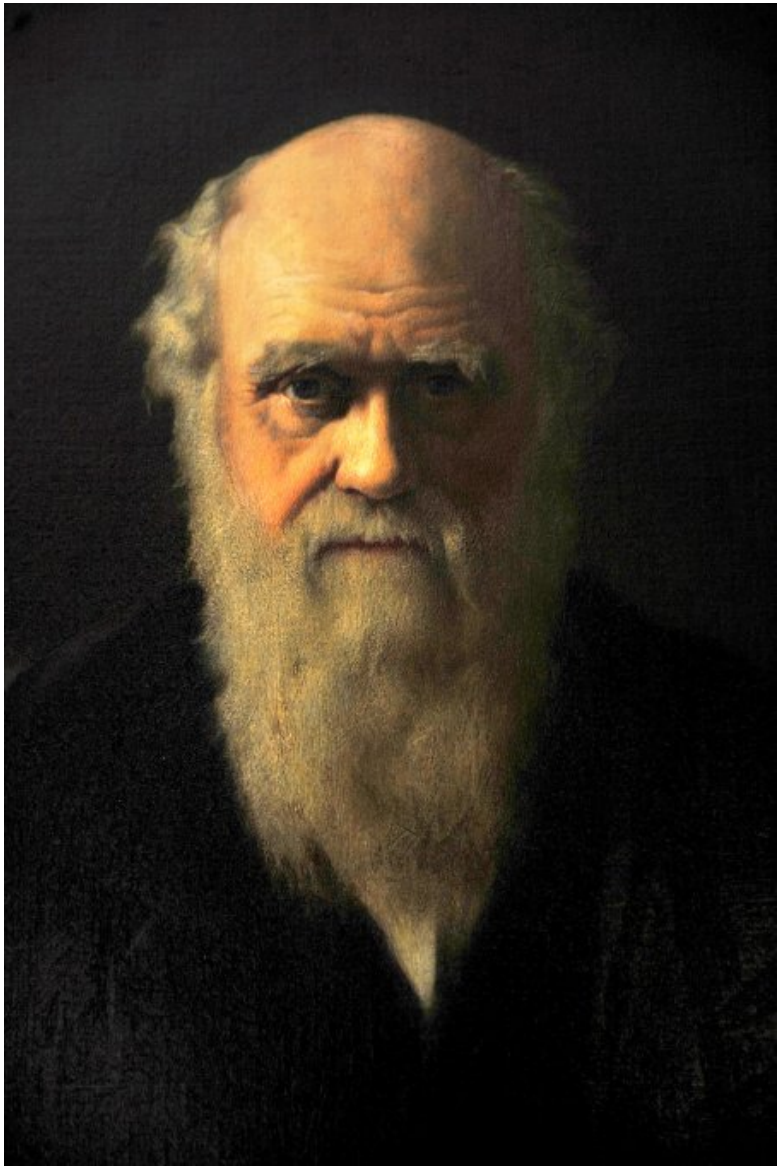
Each point on the scale of being we observe today has been derived by progression from a separate act of spontaneous generation. The lower down the scale the organism is today, the more recently its first ancestor was produced. Thus evolution is not a system of common descent but consists of separate lines progressing in parallel along the same hierarchy.

Abb. 2 Schema zu Lamarcks Transformationstheorie aus Bowler [1984] 80. Vgl. das entsprechende Schema in Lefèvre [1984] 37.

Evolution by usage or survival of the fittest?



Charles Robert Darwin (1809-1882)



What Darwin did not know

- Darwin did not know anything about chromosomes and genes.
- He did not know the germ line concept.
- He did not know the mechanistic origin of variabiliy in a given animal population (i. e. he did not know anything about mutations).

What is a population?

- A population is a group of animals of one species where individuals of different sexes potentially can have viable offspring.
- One species can be split in several populations (geografically or by habitat).
- Evolution takes place inside populations. Different populations of the same species can genetically become distinct, eventually leading to the formation of new species.
- All alleles of all genes in a population are often called the population‘s **gene pool.**

The Hardy-Weinberg Law

describes the allele frequencies in a population

a = frequency of allele 1

b = frequency of allele 2

If only two alleles are present in a **population**, i. e.

$a + b = 1$

in diploid organisms then the frequency of genotypes can be calculated as

$(a+b)^2 = a^2+2ab+b^2$ (Hardy-Weinberg Law)

→ for rare alleles most alleles are hidden in heterozygous individuals , e.g. b = 0,001; $b^2 = 0{,}000001$; $2ab = 0{,}001998$

Hardy Weinberg for multiple alleles

3 alleles: $(a+b+c)^2 = a^2+b^2+c^2+2ab+2ac+2bc$

4 alleles: $(a+b+c+d)^2 = a^2+b^2+c^2+d^2+2ab+2ac+2ad+2bc+2bd+2cd$

in general, if there are n alleles there are
n x n combinations and n x n – n heterozygous individuals.

If there are hundreds of common alleles in a population there is hardly any homozygous individuum.

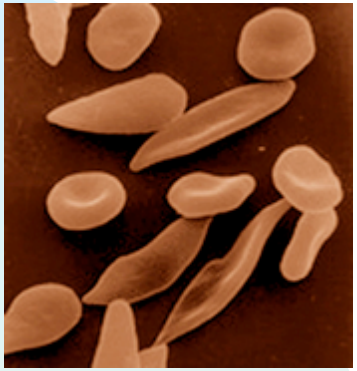
The Hardy-Weinberg Law

$(a+b)^2 = a^2+2ab+b^2$

Negative selection for **bb** would decrease allele frequency of **b** from generation to generation, that of a would increase

but what when ab has an advantage over aa?

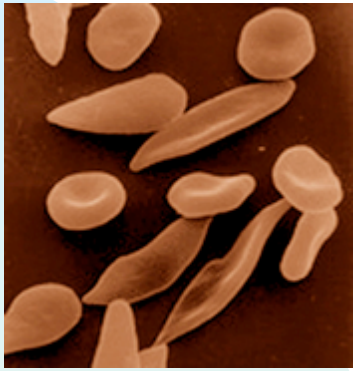
→ then an equilibrium would be reached



Sickle cell anemia

(recessive autosomal inheritance)

Sickle-cell disease, or sickle-cell anemia (SCD or SCA) or drepanocytosis, is a genetic blood disorder characterized by red blood cells that assume an abnormal, rigid, sickle shape. Sickling decreases the cells' flexibility and results in a risk of various complications. The sickling occurs because of a mutation in the haemoglobin gene. Life expectancy is shortened, with studies reporting an average life expectancy of 42 in males and 48 in females



Sickle cell anemia

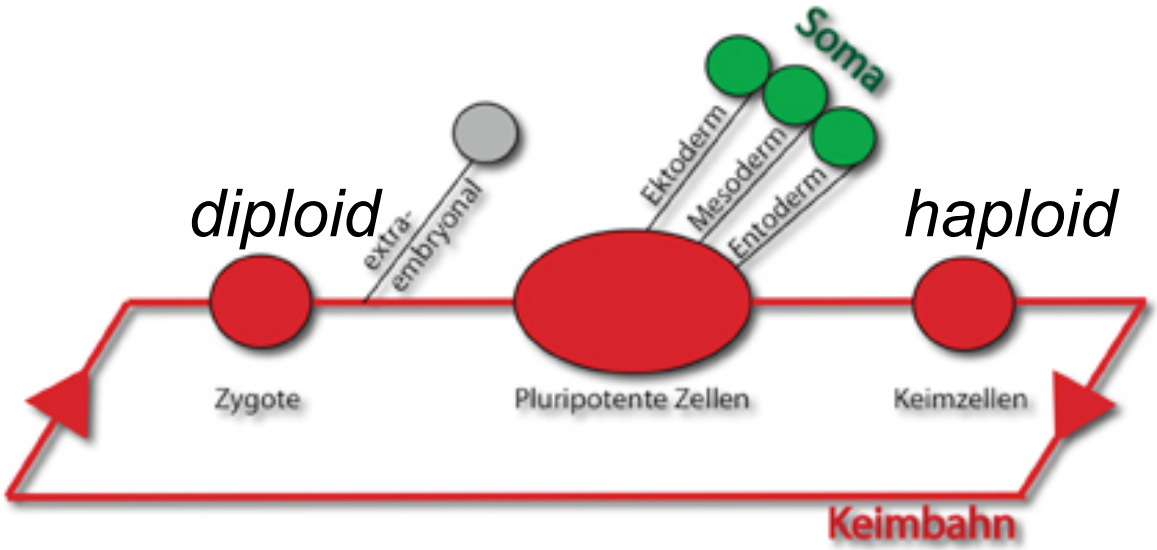
One-third of all indigenous inhabitants of Sub-Saharan Africa carry the mutation, because in areas where malaria is common, there is a survival value in carrying one single sickle-cell mutation (sickle cell trait)

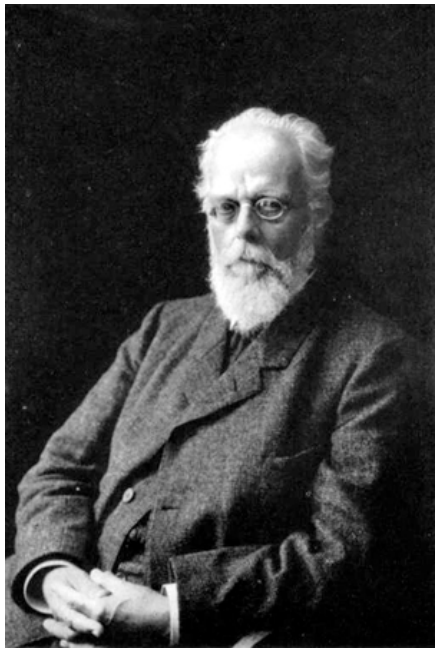
- bb is negatively selected
- ab is positively selected

What does *survival of the fittest* mean?

It is not the individium which survives from generation to generation!

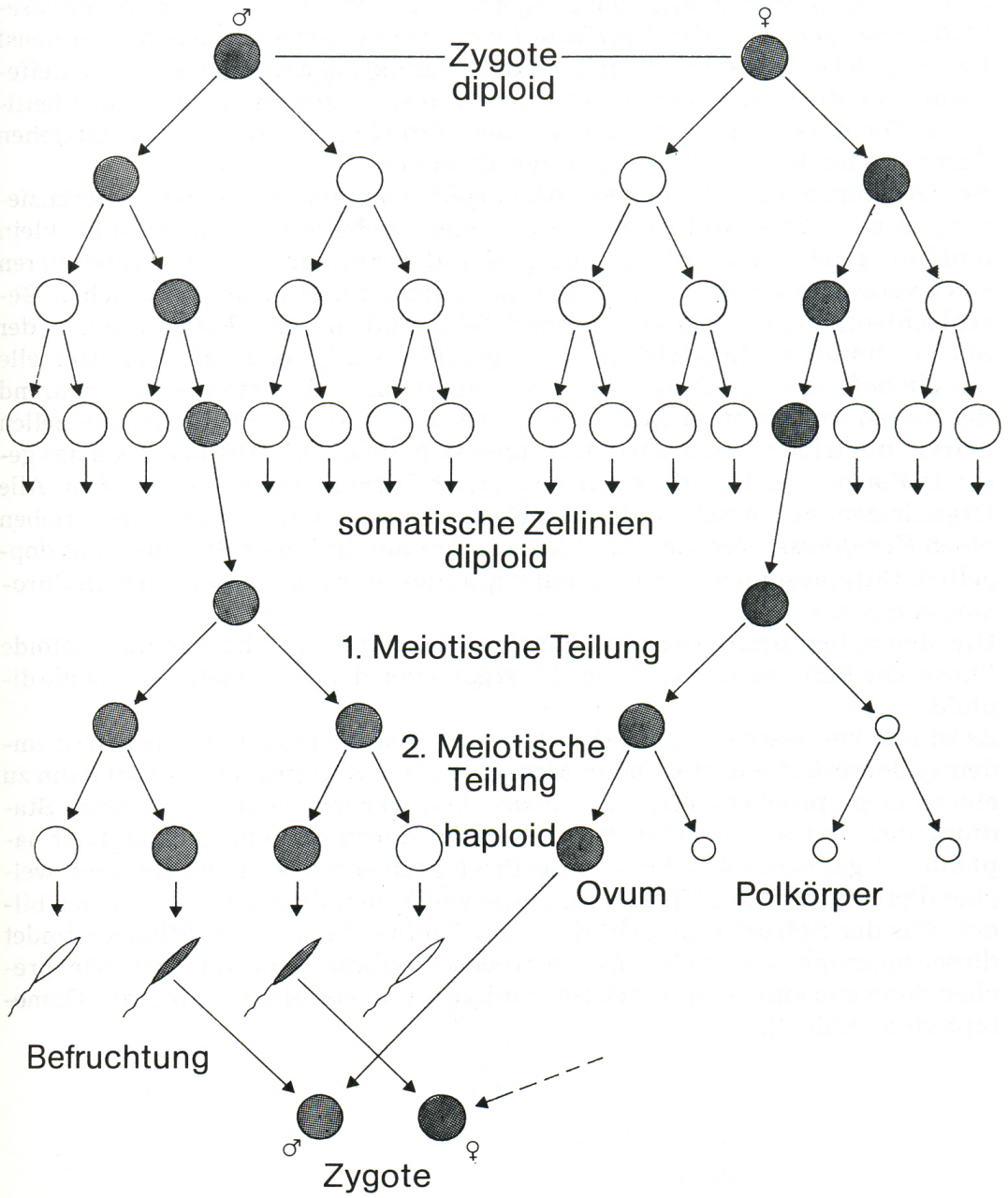
The concept of the germline





Friedrich Leopold August Weismann
17.1.1834 – 5.11.1914

Continuity of the germline



The selfish gene

The Selfish Gene is a book on evolution by Richard Dawkins, published in 1976.

Dawkins coined the term "selfish gene" as a way of expressing the gene-centred view of evolution, which holds that evolution is best viewed as acting on genes and that selection at the level of organisms or populations almost never overrides selection based on genes.

Please note that here the term „gene“ is used in the sense of „allele“!

The selfish gene (allele)

(Richard Dawkins)

In describing genes (alleles) as being "selfish", the author does not intend (as he states unequivocally in the work) to imply that they are driven by any motives or will -merely that their effects can be accurately described *as if they were. The contention is that the genes (alleles) that get passed on are the ones whose consequences serve their own implicit interests (to continue being replicated), not necessarily those of the organism, much less any larger level.*

What does *survival of the fittest* mean?

It is the allele frequency which counts. Positive selection means that the frequency of an allele increases from generation to generation.

When is an allele positively selected?

Only when it increases the offspring of its carrier directly?

What does *inclusive fitness* mean?

An allele is positively selected when it secures its increase in frequency from generation to generation.

This has to take into account that it is with a certain probability present not only in the children of the carrier, but also in other relatives!

The **coefficient of relatedness (*r)*** between two individuals is defined as the percentage of genes (alleles) that those two individuals share by common descent.

What does *inclusive fitness* mean?

Relateness to direct offspring in diploid organisms
in the absence of incest

mother/father

↓

children $r=0,5^1 = 0,5$

↓

grandchildren $r=0,5^2 = 0,25$

↓

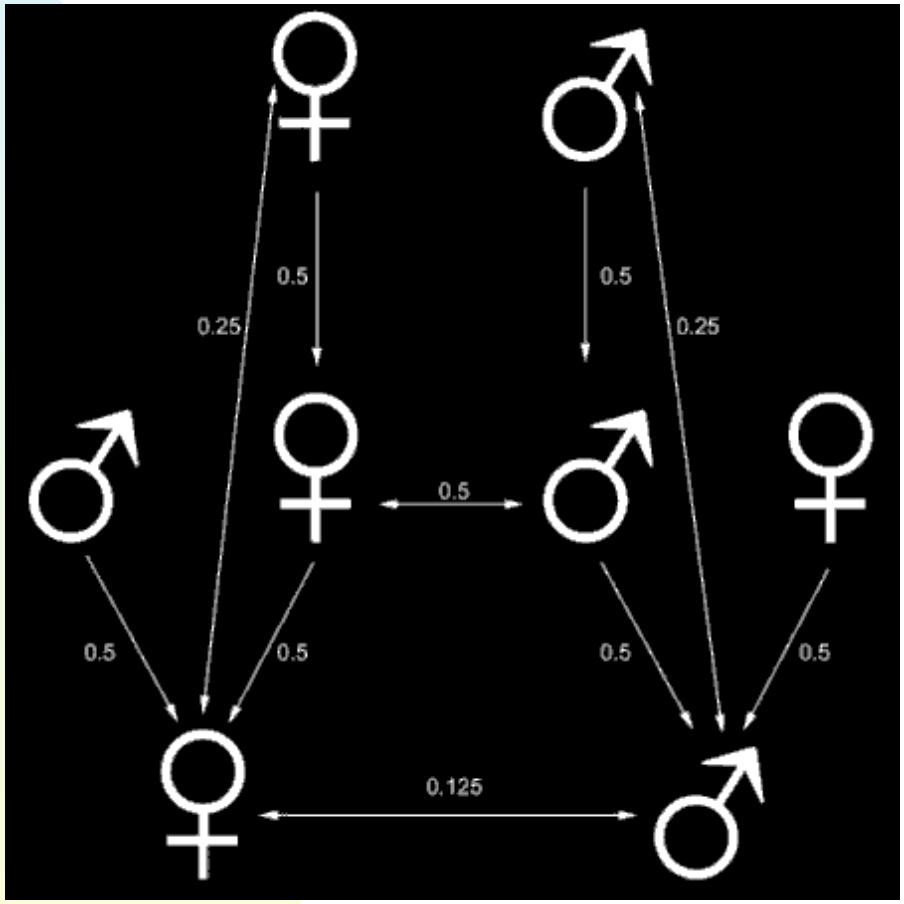
↓

↓

n^{th} generation $r=0,5^n$

What does *inclusive fitness* mean?

We are not only related to our direct offspring!



$r^{siblings} = 0{,}5$

$r^{cousins} = 0{,}125$

What does *inclusive fitness* mean?

How is then fitness to be defined?

- You can increase the frequency of your genes (alleles) by helping your direct offspring, but also by helping your relatives!

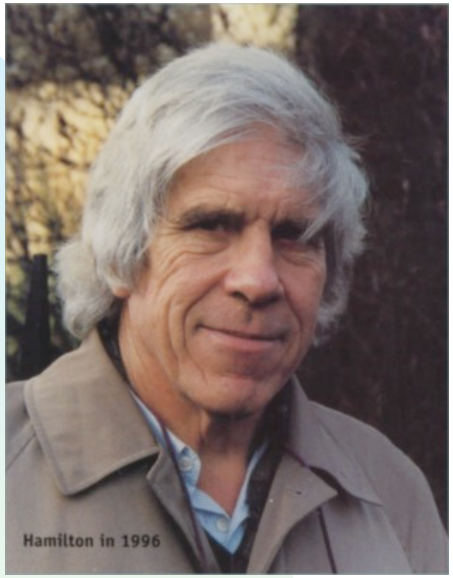
- In evolutionary biology and evolutionary psychology, inclusive fitness is the sum of an organism's classical fitness (how many of its own offspring it produces and supports) and the number of equivalents of its own offspring it can add to the population by supporting others.

The concept of *inclusive fitness* explains the evolution of *altruistic behavior*

- mutations can be selected that „help“ the survival of the same mutation in related individuals
- thus, altruistic behaviour is the natural consequence of the concept of inclusive fitness and of the concept of „selfish genes (alleles)“!

William D. Hamilton

1 August 1936 – 7 March 2000



Hamilton‘s rule:

$C < R \times B$

Where C is the cost in fitness to the actor, R the genetic relatedness between the actor and the recipient and B is the fitness benefit to the recipient. Fitness costs and benefits are measured in fecundity (number of offsprings)

Some important examples demonstrating the effectiveness of the concept of inclusive fitness

In many hymenoptera males are haploid. This results in some unusual relatedness coefficients

Male bees (drones) are haploid and originate by parthenogenesis

Shared gene proportions in haplo-diploid sex-determination system relationships

Sex	Daughter	Son	Mother	Father	Full Sister	Full Brother
Female	1/2	1/2	1/2	1/2	3/4	1/4
Male	1	*N/A*	1	*N/A*	1/2	1/2

Queen (2n)

egg unfertilized ↓

Drone (1n)

Worker bees are more closely related to their sisters than they would be to their own daughters

Shared gene proportions in haplo-diploid sex-determination system relationships

Sex	Daughter	Son	Mother	Father	Full Sister	Full Brother
Female	1/2	1/2	1/2	1/2	3/4	1/4
Male	1	*N/A*	1	*N/A*	1/2	1/2

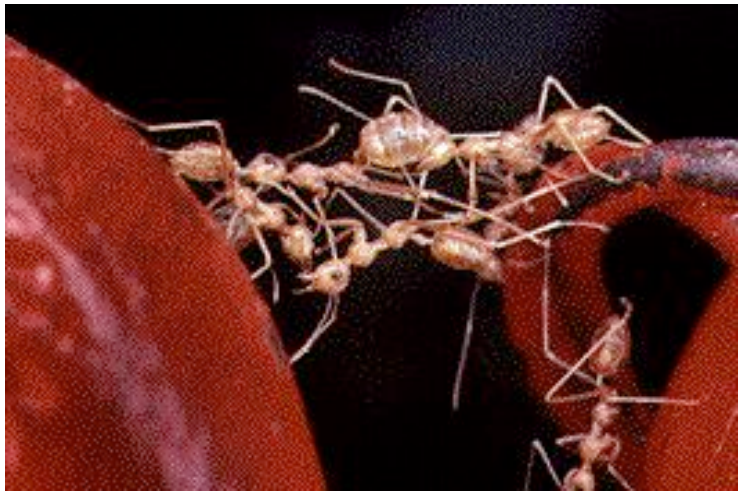
Queen (2n) X Drone (1n)

egg unfertilized ↓ ↓ egg fertilized

Drone (1n) worker bee (2n)

It is more efficient for a worker bee to help the queen than to have own children

These coefficients of relatedness do explain much of the altruistic behaviour of social insects

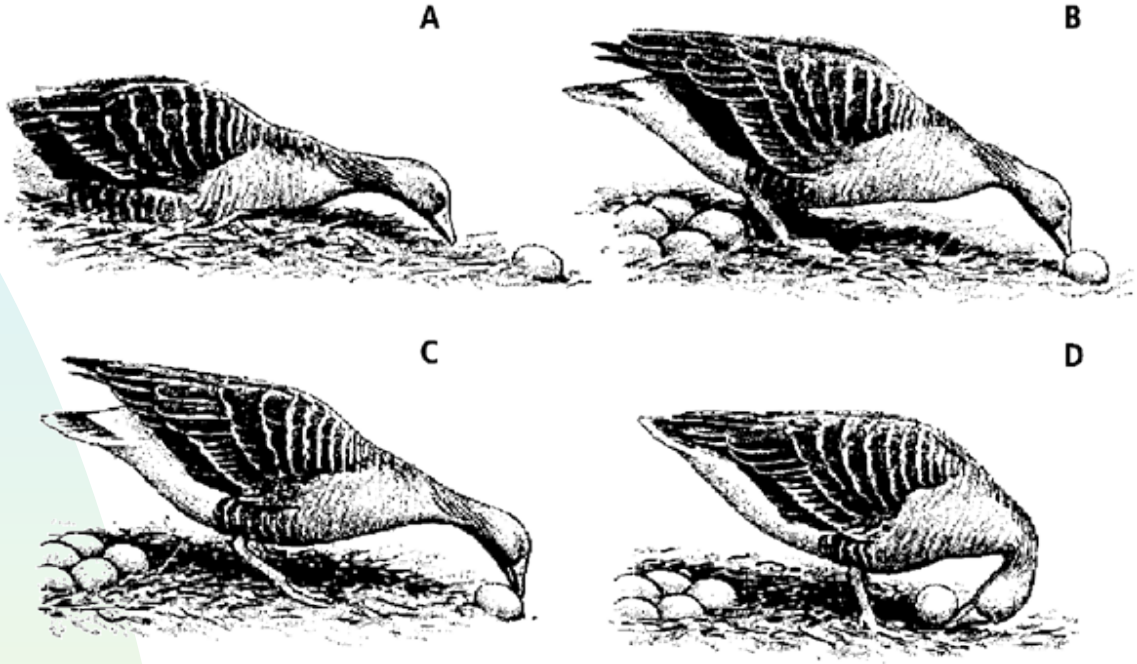


... only in insects?

... only in insects?

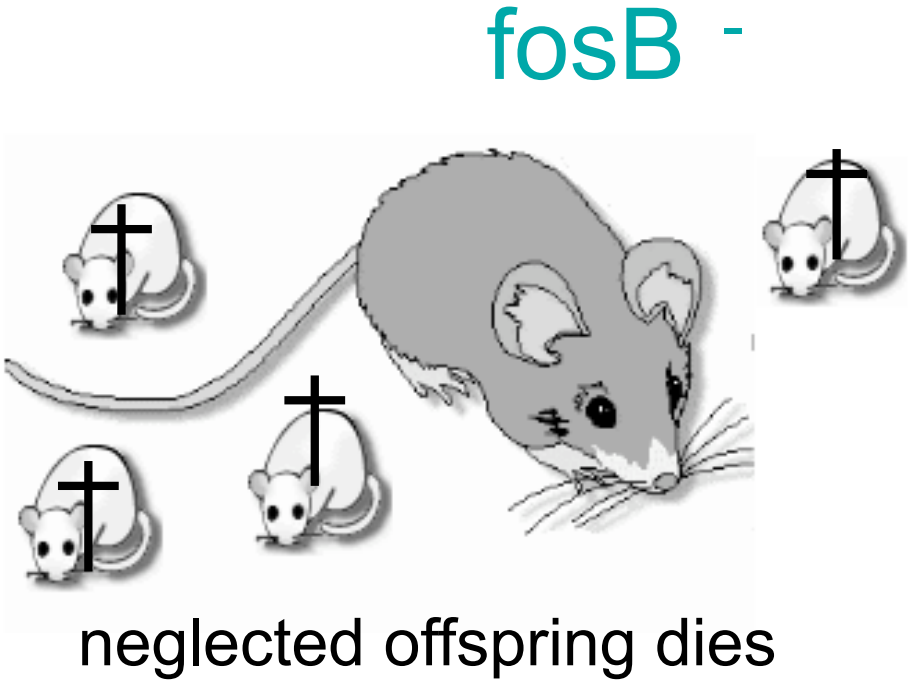
Konrad Lorenz

egg-rolling behaviour is inborn



Some behavioural subroutines are a reliable outcome of development – similar to the „Gestalt“ of a body part

gene mutations influence rearing behaviour in mice



neglected offspring dies

- FosB is a transcription factor and belongs to the „immediate early genes“, which are expressed immediately after visual experiences.
- FosB expression in the so-called preoptic region of the hypothalamus of male and female mice is increased, when they are confronted with newborns.
- FosB is required for visual imprinting.

Imprinting

Imprinting

adoption in the animal kingdom

„Social closeness“ substitutes for the factor of genetic relatedness and is a brain dependent parameter