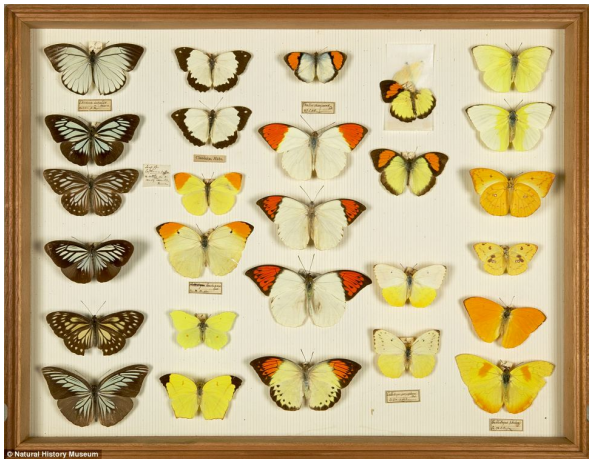
Evolution and Genetic Algorithms

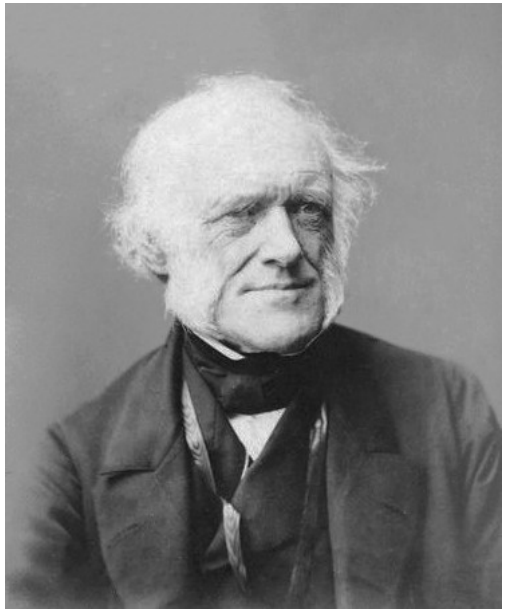


Alfred Russel Wallace (1862)

Population multiplies geometrically and food arithmetically

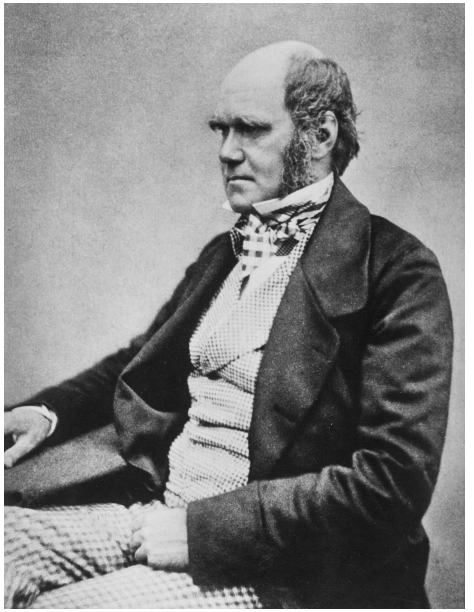
Rev. Thomas Robert Malthus (1798)

These causes or their equivalents are continually acting in the case of animals also; and as animals usually breed much more quickly than does mankind, the destruction every year from these causes must be enormous in order to keep down the numbers of each species [...] It occurred to me to ask the question, why do some die and some live? And the answer was clearly, on the whole the best fitted live.



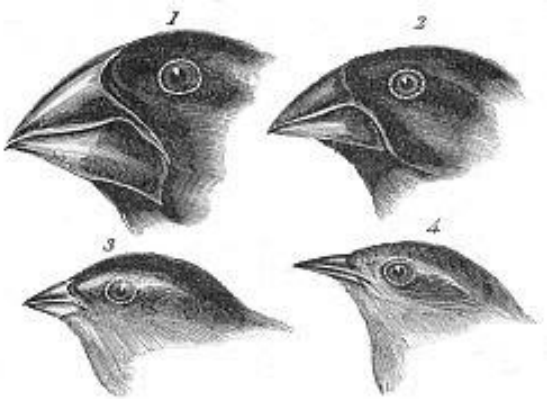
Sir Charles Lyell (1865)

HMS Beagle by Conrad Martens



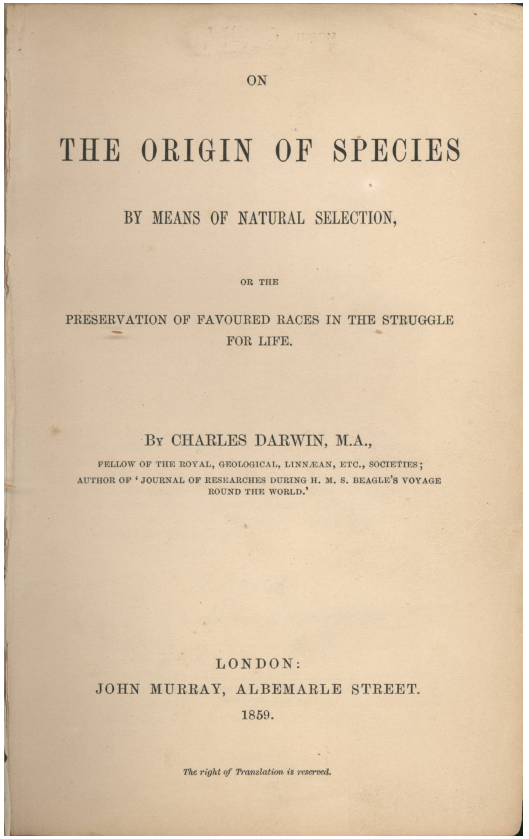
Charles Robert Darwin (1854)

In October 1838, that is, fifteen months after I had begun my systematic enquiry, I happened to read for amusement Malthus on Population, and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species. Here, then, I had at last got a theory by which to work..."



1. Geospiza magnirostris
2. Geospiza fortis
3. Geospiza parvula
4. Certhidea olivacea

Finches from Galapagos Archipelago



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

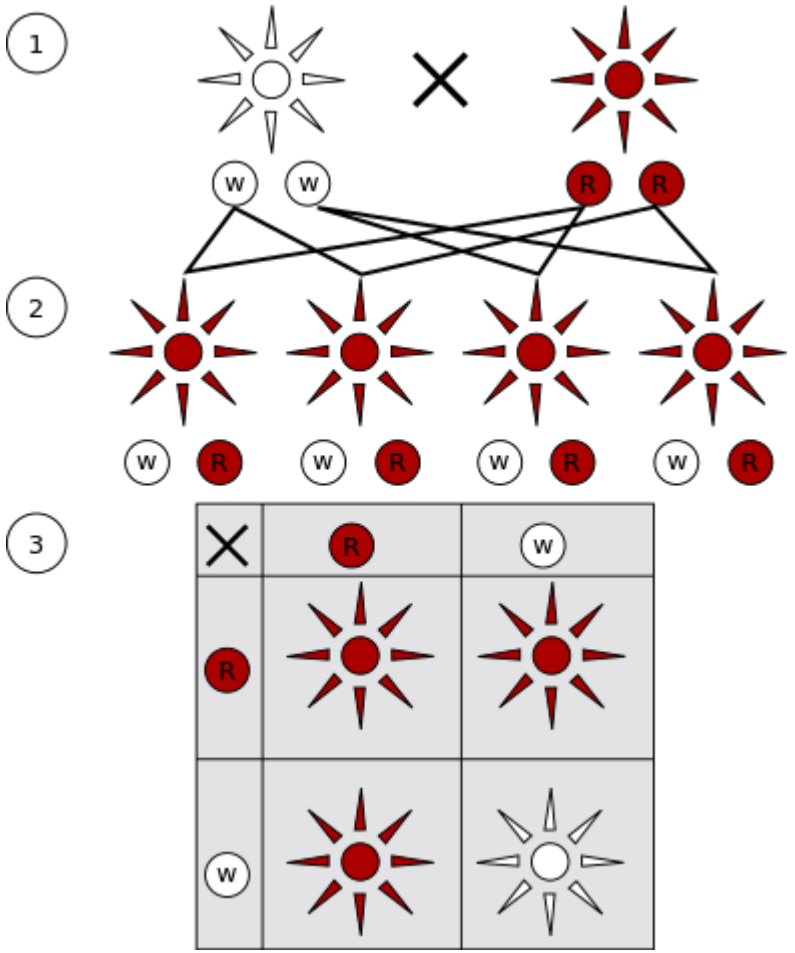
By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

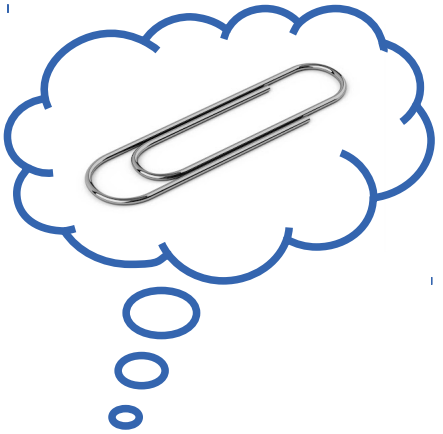
If during the long course of ages and under varying conditions of life, organic beings vary at all in the several parts of their organisation, and I think this cannot be disputed; if there be, owing to the high geometrical powers of increase of each species, at some age, season, or year, a severe struggle for life, and this certainly cannot be disputed; then, considering the infinite complexity of the relations of all organic beings to each other and to their conditions of existence, causing an infinite diversity in structure, constitution, and habits, to be advantageous to them, I think it would be a most extraordinary fact if no variation ever had occurred useful to each being's own welfare, in the same way as so many variations have occurred useful to man. But if variations useful to any organic being do occur, assuredly individuals thus characterised will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance they will tend to produce offspring similarly characterised. This principle of preservation, I have called, for the sake of brevity, Natural Selection.



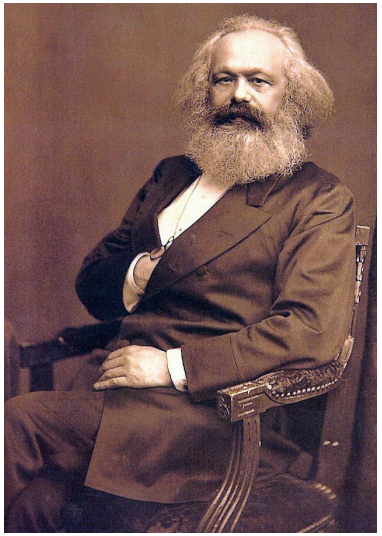
Gregor Johann Mendel (1860)

Sir Ronald Aylmer Fisher (1913)

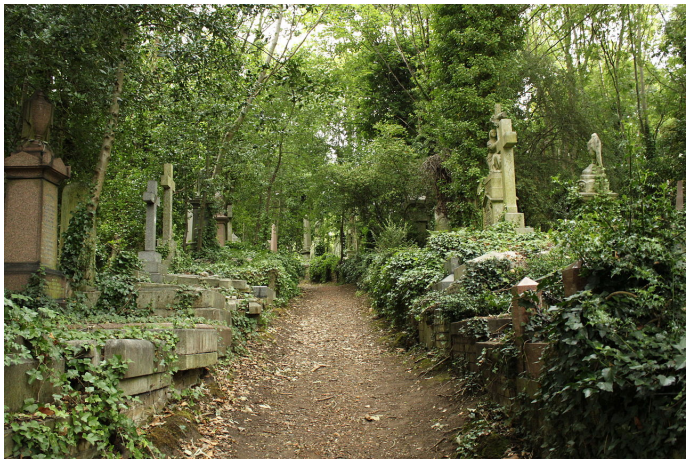
Darwin's work is most important and suits my purpose in that it provides a basis in natural science for the historical class struggle



The survival of the fittest

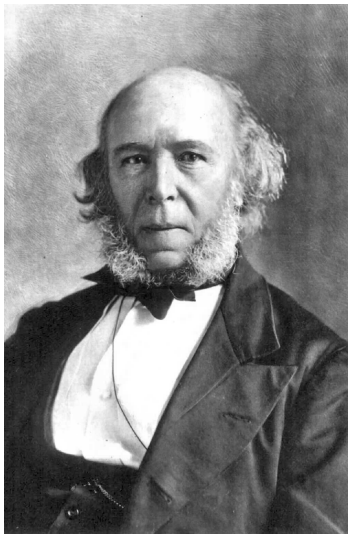


Karl Marx (1875)



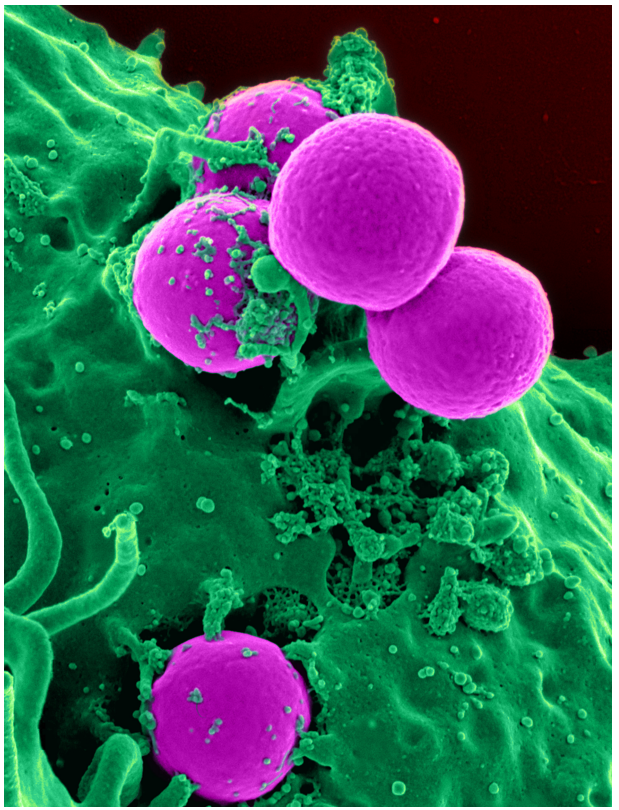
Highgate Cemetery East

Tombs of Marx & Spencer

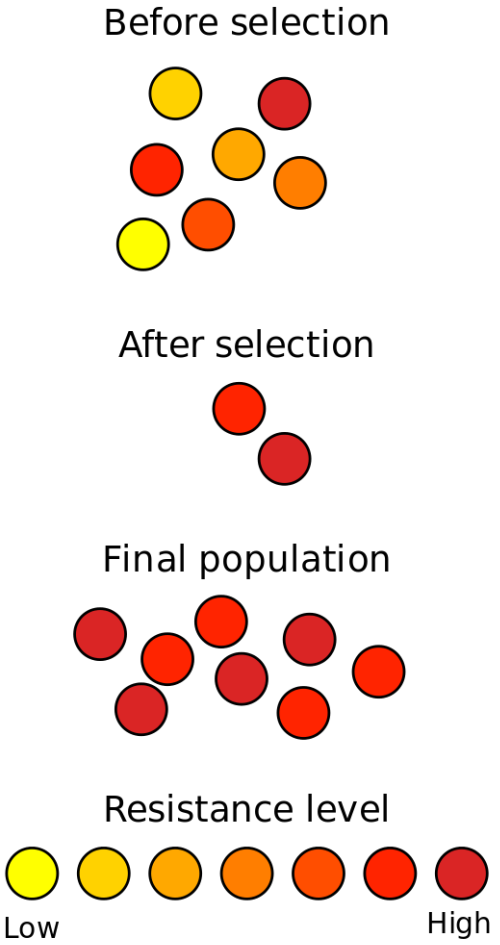


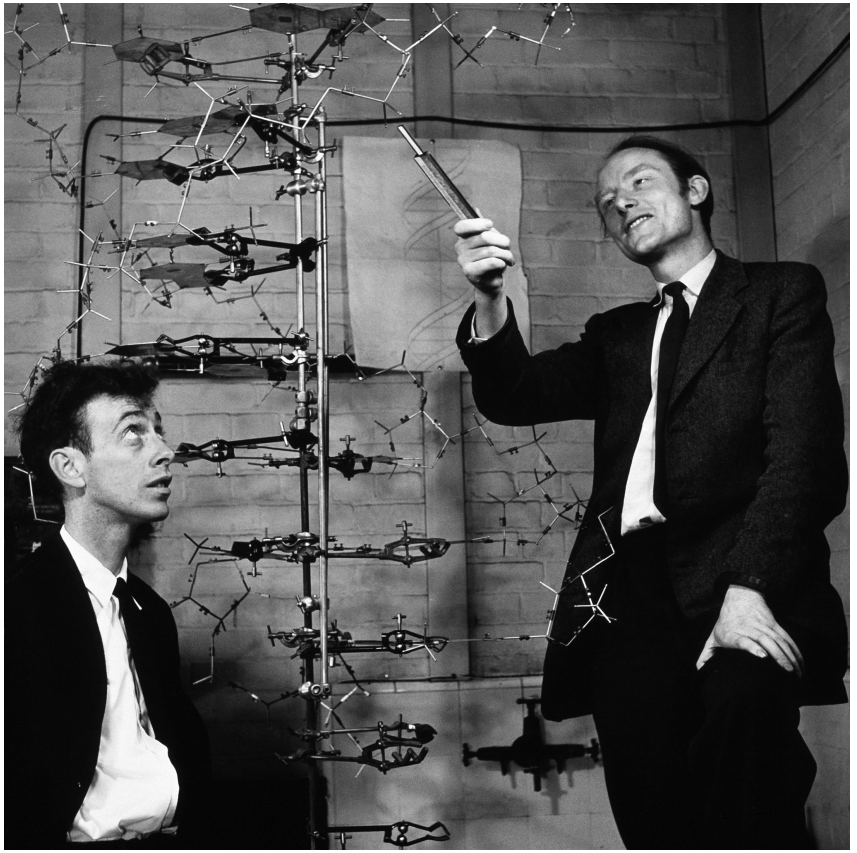
Herbert Spencer (1893)

Peppered moth

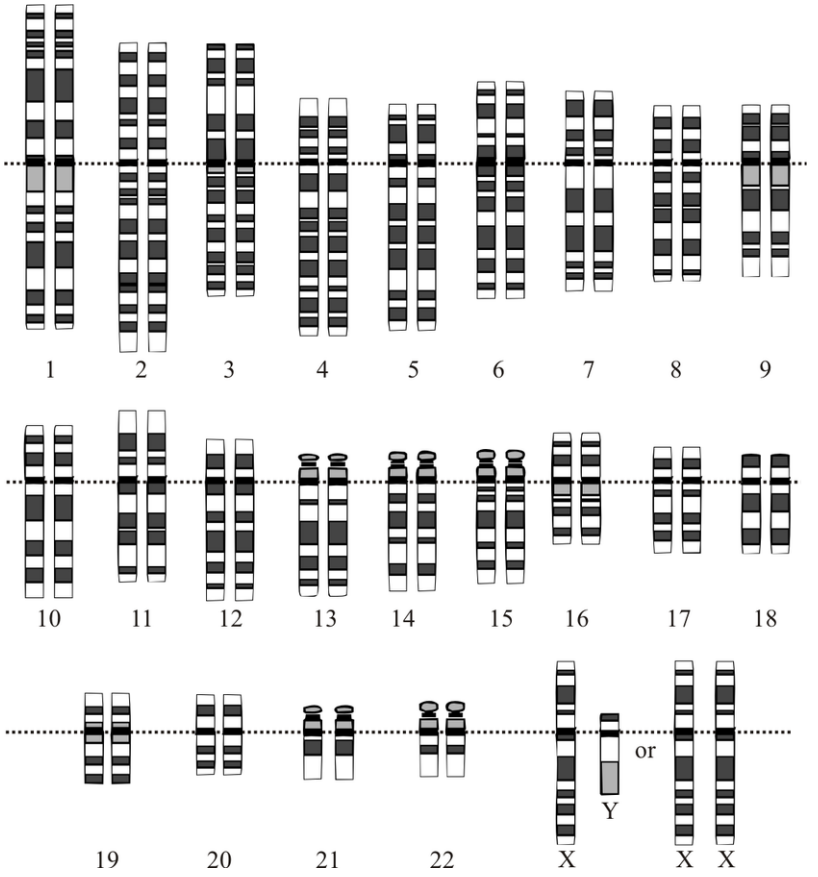


Methicillin-resistant
Staphylococcus aureus (MRSA)

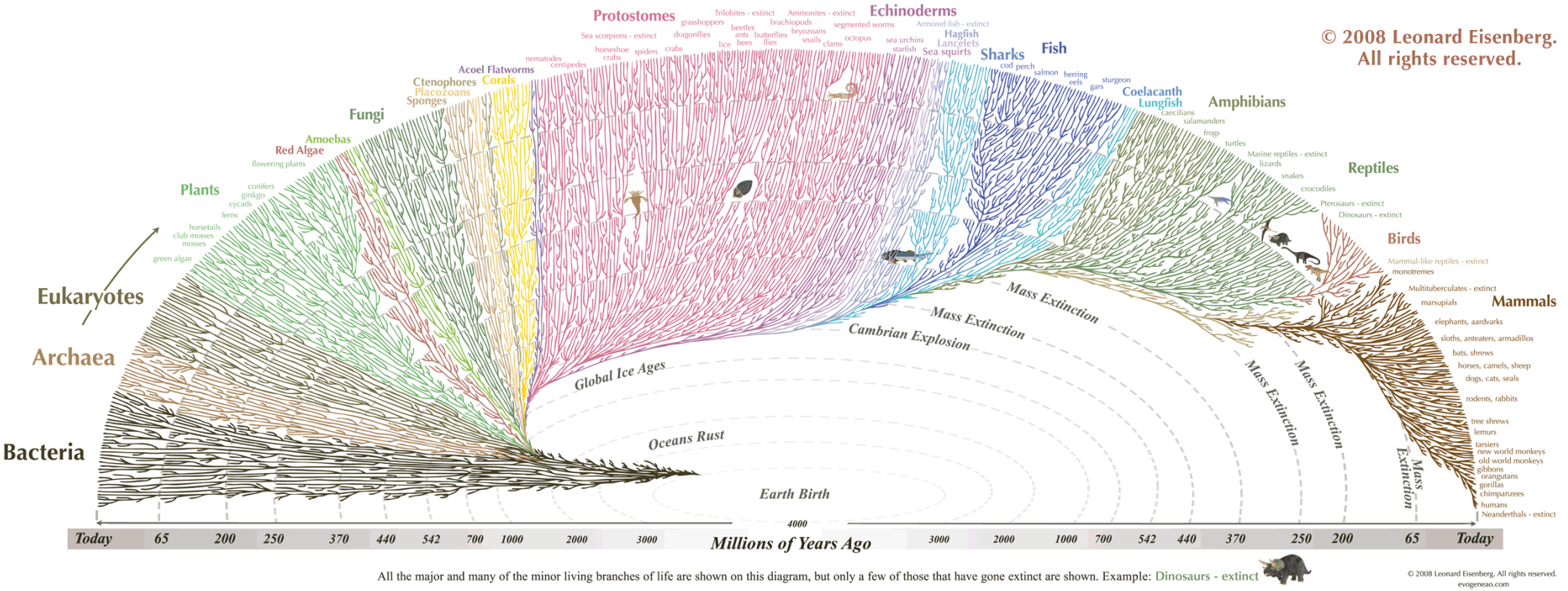




James Watson and Francis Crick (1953)



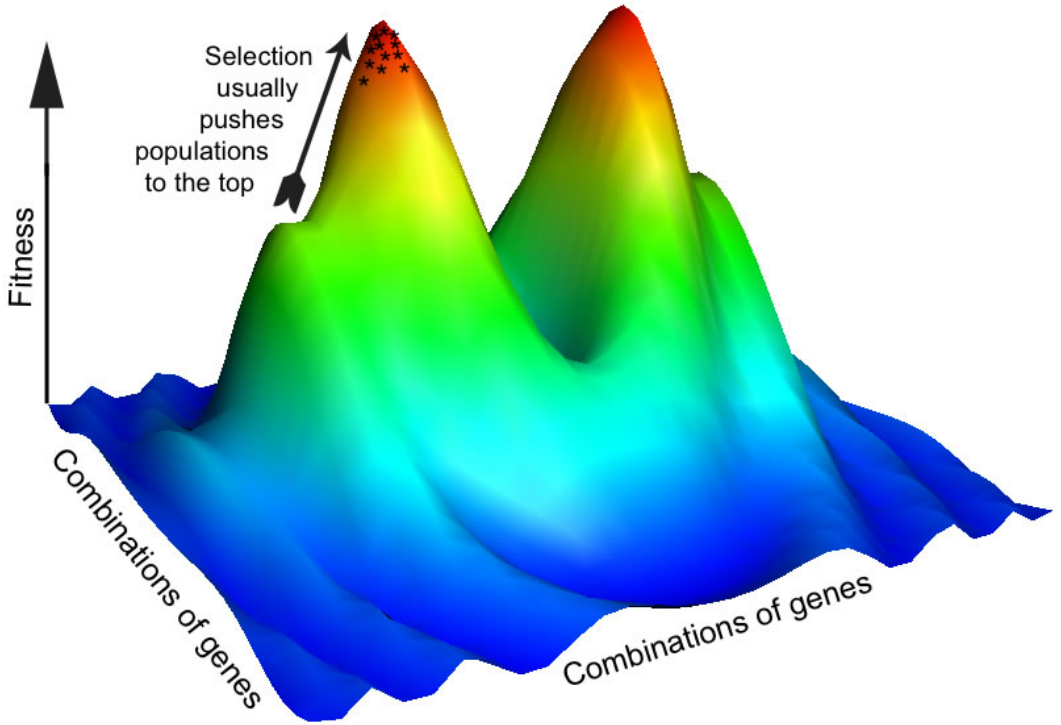
Human diploid karyotype



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

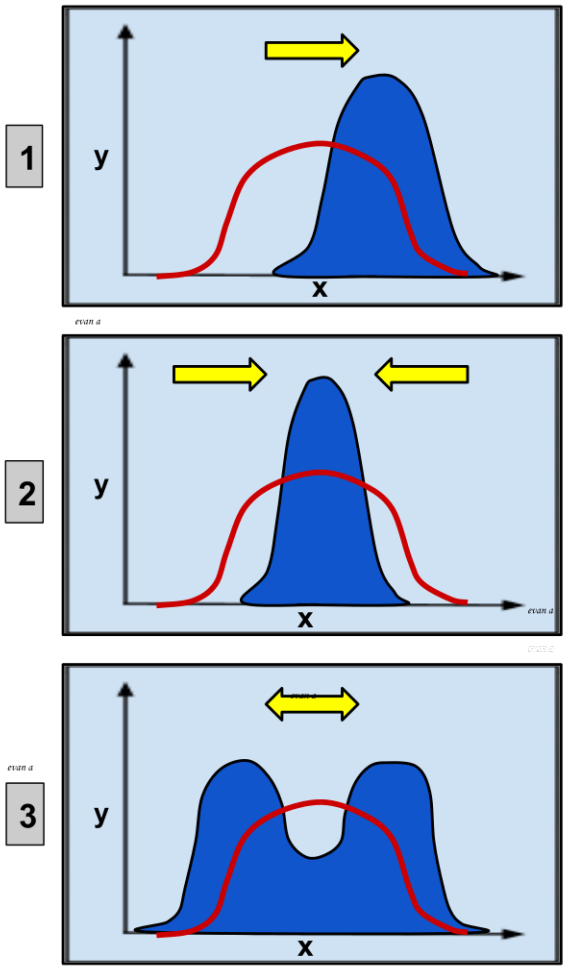
Tree of life

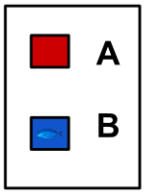
Fitness landscape



Fitness = reproductive success

Genotype → Phenotype

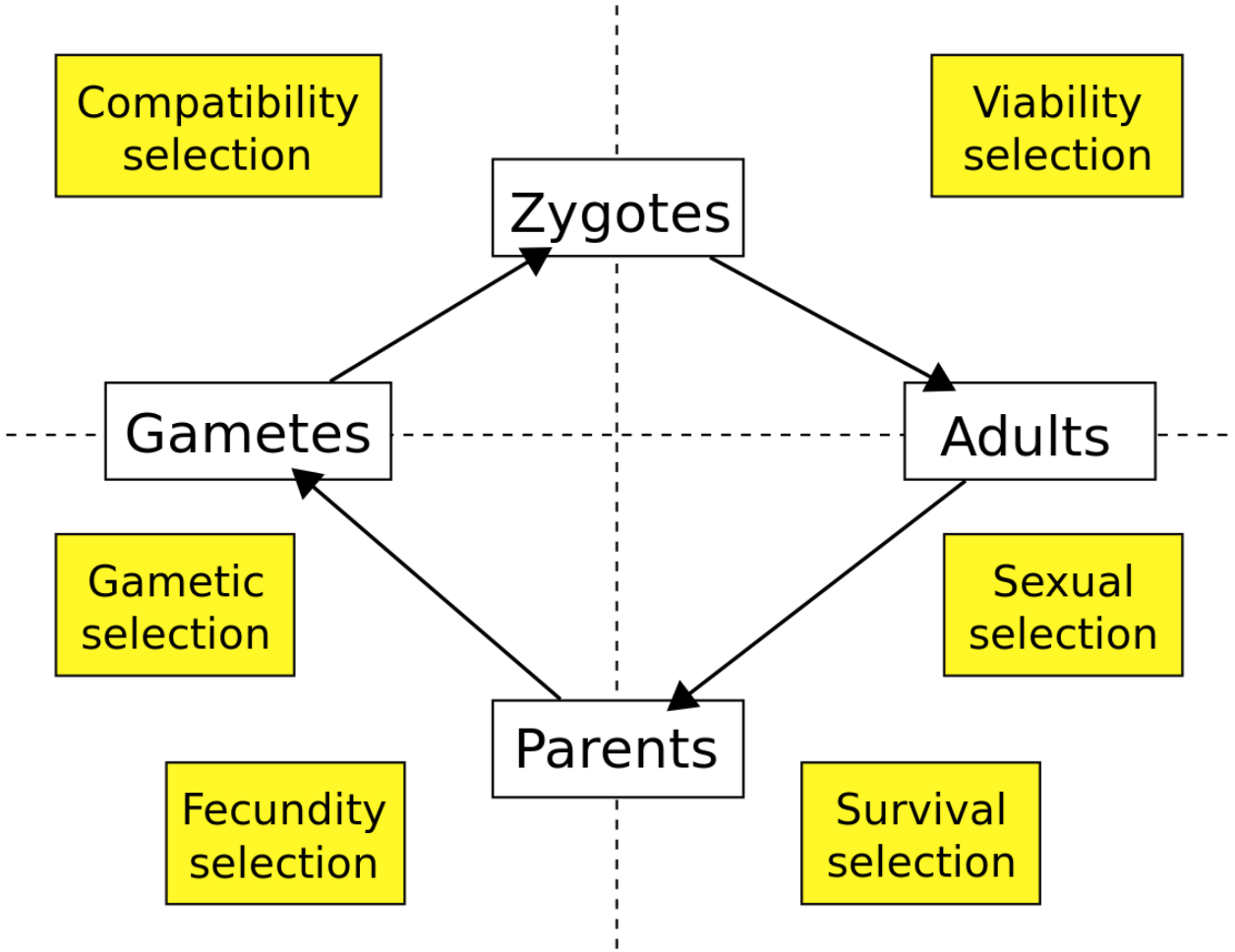




Directional selection

Stabilising selection

Disruptive selection

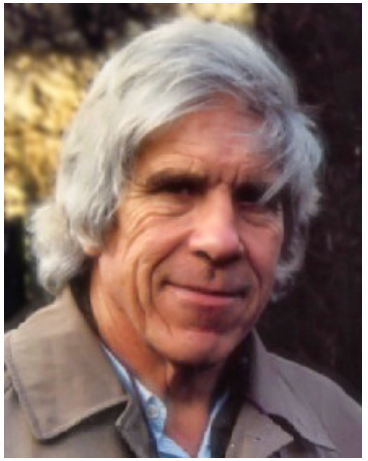


Sexual selection

Fisher: “Sexy son” hypothesis (1930)

Kin Selection

inclusive fitness = own contribution to fitness + contribution of all relatives



W. D. Hamilton (1996)

$$w_i = b_i + \sum_j r_{ij} b_j$$

$$1 < (1 - C) + RB$$

$$R > C/B$$

Gene-centred view of evolution

r/K selection theory

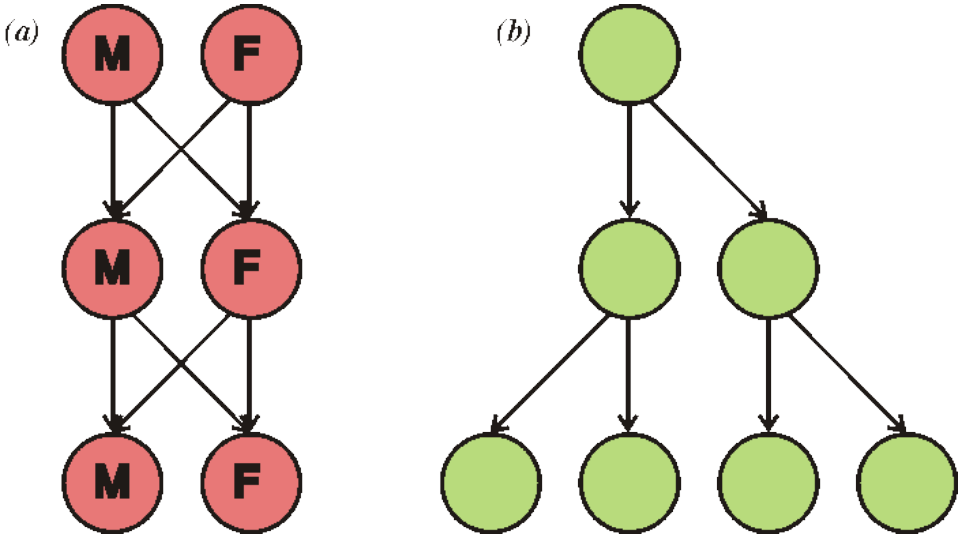
$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

Growth rate

Carrying capacity

r-selected species exploit empty niches, and produce many offspring, each of whom has a relatively low probability of surviving to adulthood. In contrast, K-selected species are strong competitors in crowded niches, and invest more heavily in much fewer offspring, each of whom has a relatively high probability of surviving to adulthood.

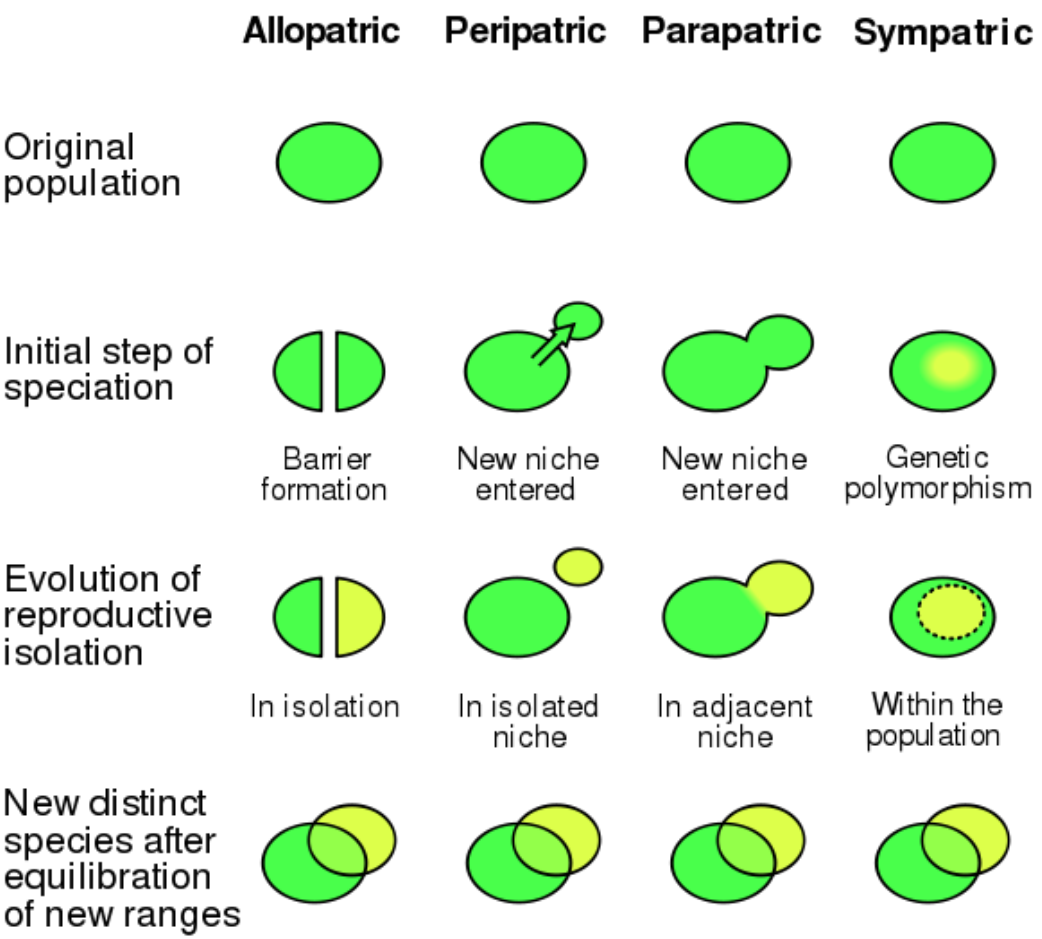
Why sex?



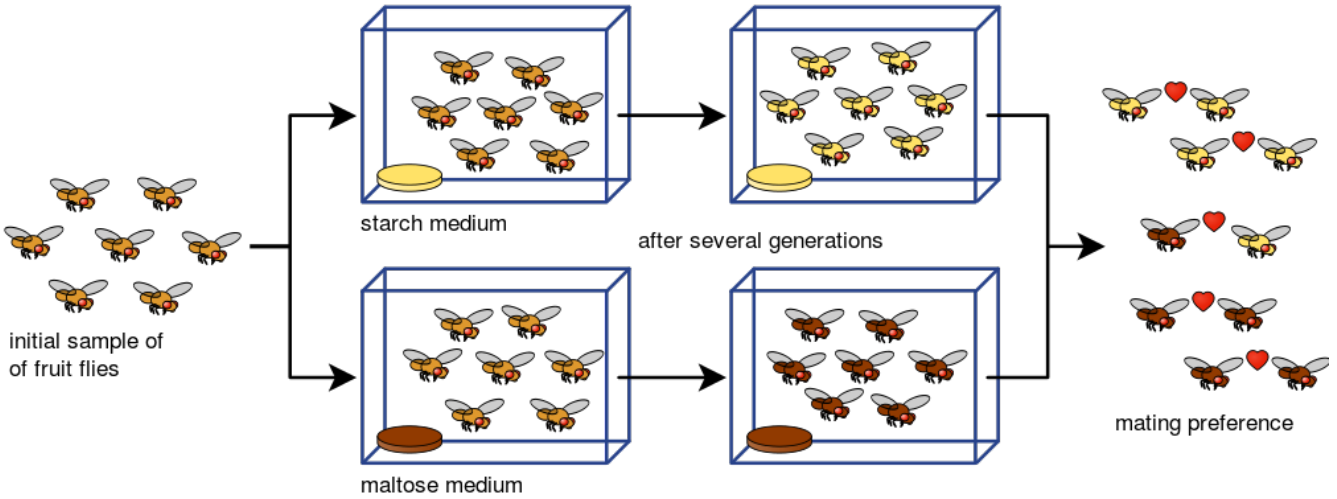
"Two-fold cost of sex"

Red Queen hypothesis: arms race against parasites

Speciation


Allopatric
Peripatric
Parapatric
Sympatric
Original population
Initial step of speciation
Barrier formation
New niche entered
New niche entered
Genetic polymorphism
Evolution of reproductive isolation
In isolation
In isolated niche
In adjacent niche
Within the population
New distinct species after equilibration of new ranges

Speciation


initial sample of
of fruit flies
starch medium
maltose medium
after several generations
mating preference

Genetic algorithms

John Henry Holland (1970s)

Genetic representation of solutions

Fitness function (how good is a solution)

1. Start with population of candidate solutions (individuals)

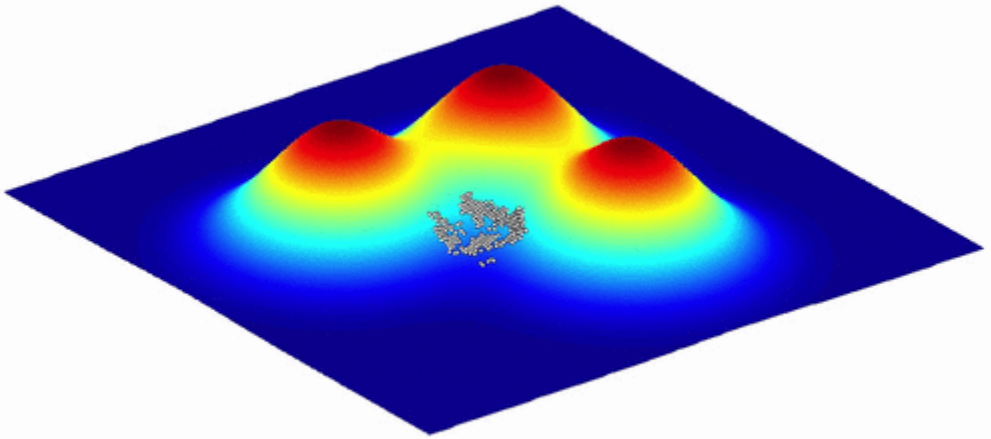
2. Reproduce individuals, applying operators (mutation, crossover...)

3. Select next generation according to fitness function

4. Repeat until satisfied with solution

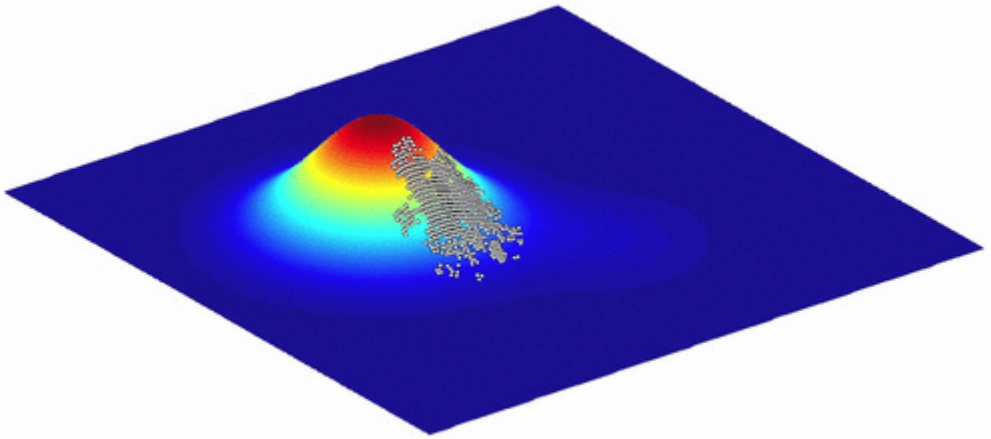
Adaptation in Natural and Artificial Systems (1975)

Static fitness landscape



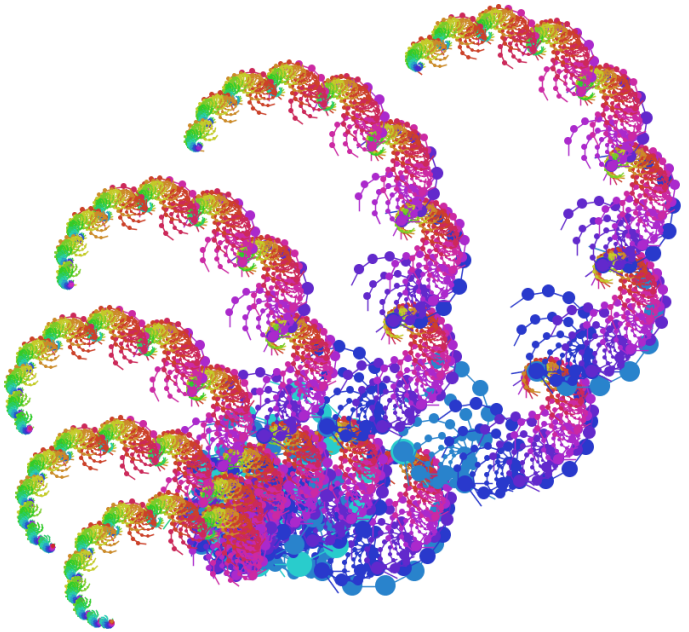
Population size, N = 2,304
Mutation rate, μ = 0.05 per trait

Dynamic fitness landscape



Population size, N = 2,304
Mutation rate, μ = 0.5 per trait

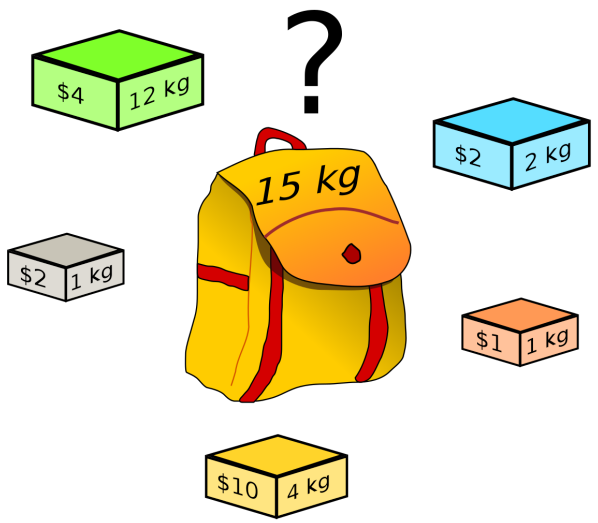
The 2006 NASA ST5
"evolved" spacecraft antenna.



Evolutionary art

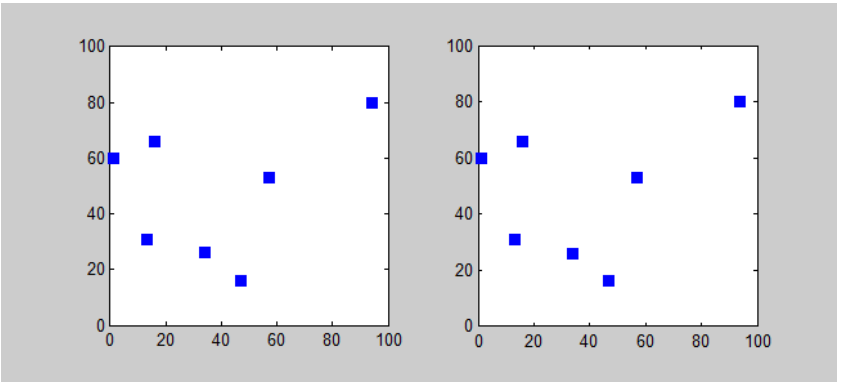
Heike crab

Knapsack problem:



Which boxes should be chosen to maximize the amount of money while still keeping the overall weight under or equal to 15 kg?

Travelling salesman problem:



Which is the shortest path that visits each city exactly once?