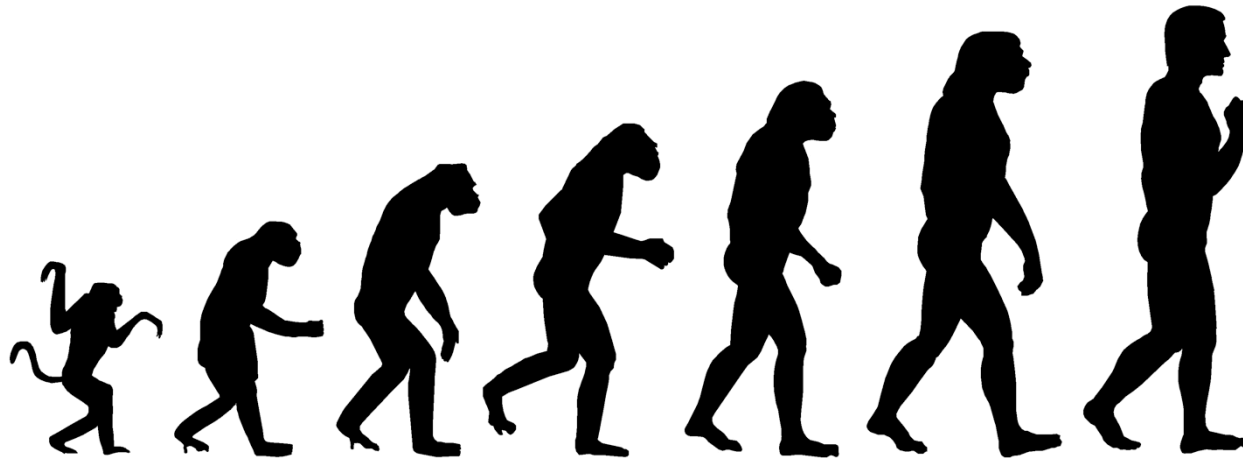


Evolution

Matt Keeling



MA 999: Topics in Mathematical Modelling

Tuesday 11-12

Thursday 2-4

Evolution

Lecture 1 Tuesday 6th 11-12

Introduction. Evidence for evolution. Fitness. Competition.

Lecture 2 Thursday 8th 2-3

Games & Genes.

Lecture 3 Thursday 8th 3-4

Computer-based practicals – example programs and questions.

Lecture 4 Tuesday 13th 11-12

Sex and Speciation. Sexual selection. Males as parasites. Why sexual reproduction? How do new species arise.

Lecture 5 Thursday 15th 2-3

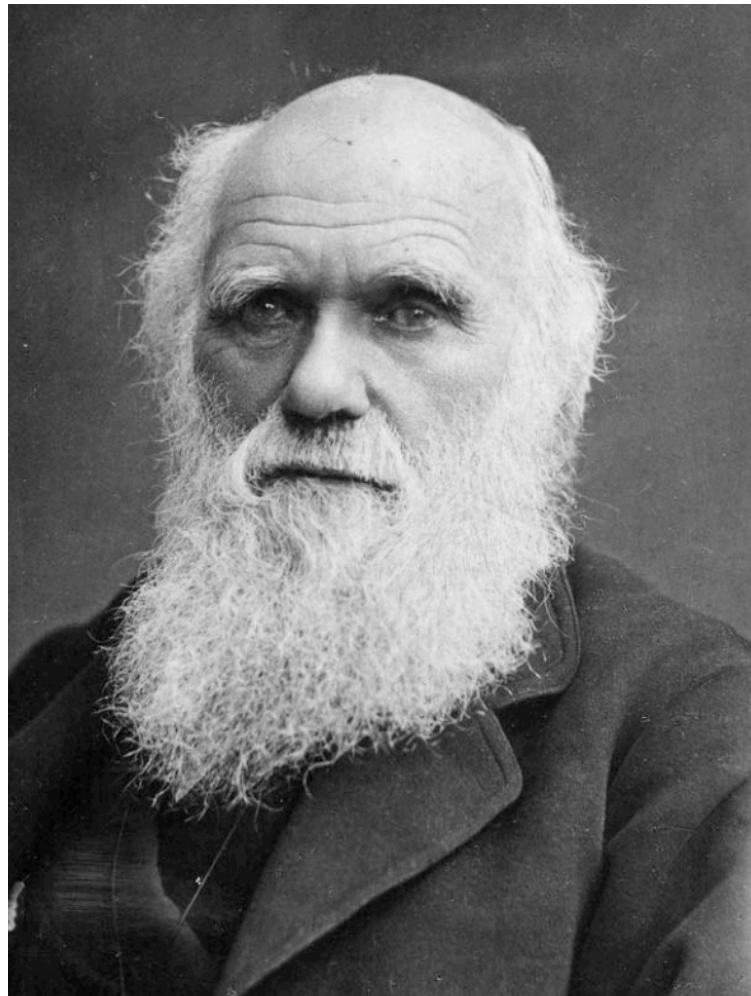
Disease evolution. Why aren't we all wiped out by killer infections?

Lecture 6 Thursday 15th 3-4

Computer-based practicals – example programs and questions.

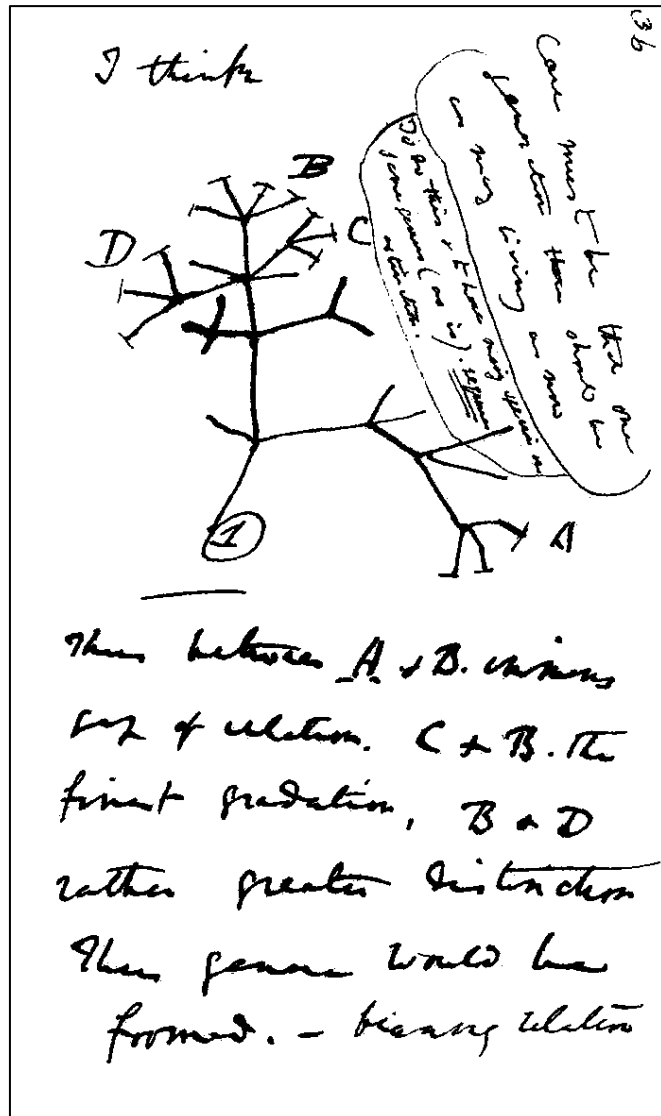
Charles Robert Darwin (1809 – 1882)

“On the Origin of Species” 1859



Charles Robert Darwin (1809 – 1882)

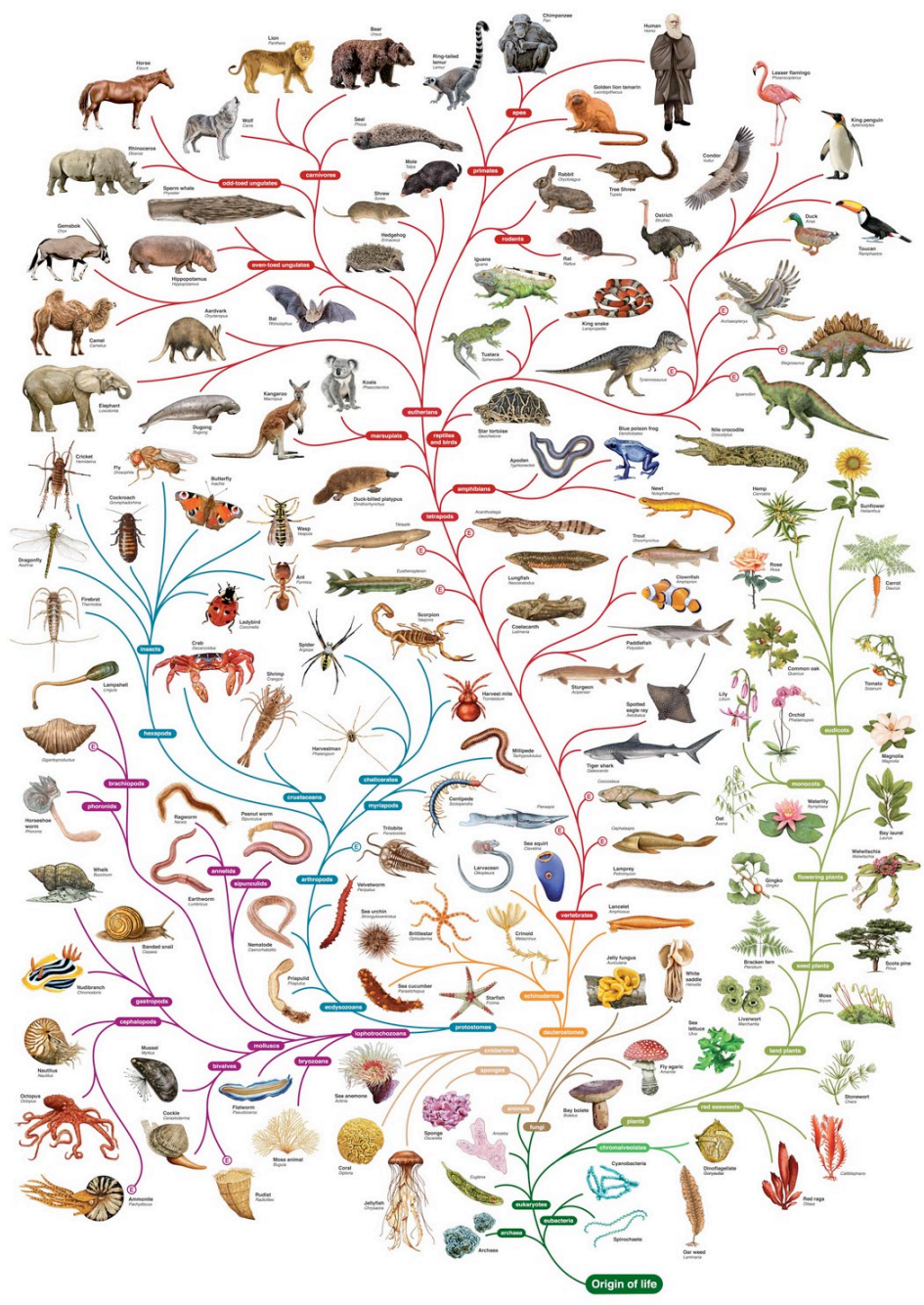
“On the Origin of Species” 1859



I think

Case must be that one generation then should be as many living as now. To do this & to have many species in same genus (as is) requires extinction.

Thus between A & B immense gap of relation. C & B the finest gradation, B & D rather greater distinction. Thus genera would be formed. — bearing relation to ancient types with several extinct forms...



We still use such a “Tree of Life” today.

However, one has to be very careful about its shape and the implications of being “at the top”.

Its very easy to see this as saying that humans and apes are *better* than monkeys, and all mammals are *better* than reptiles.

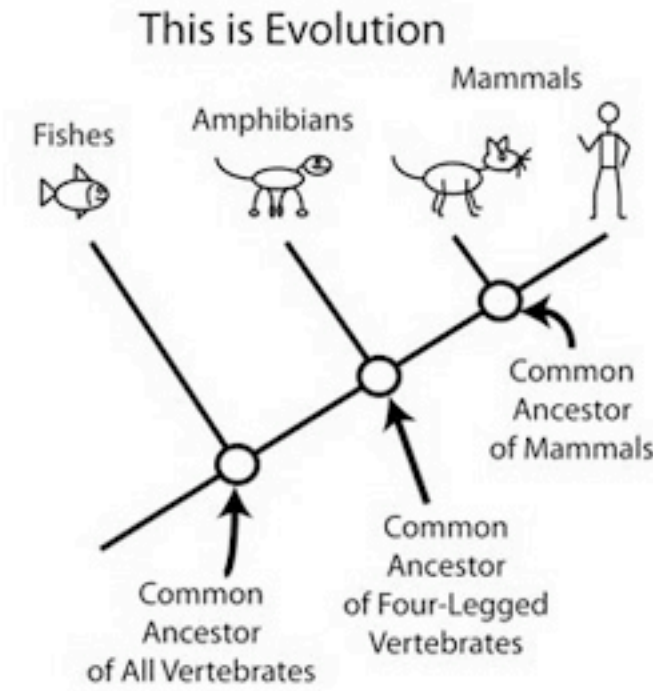
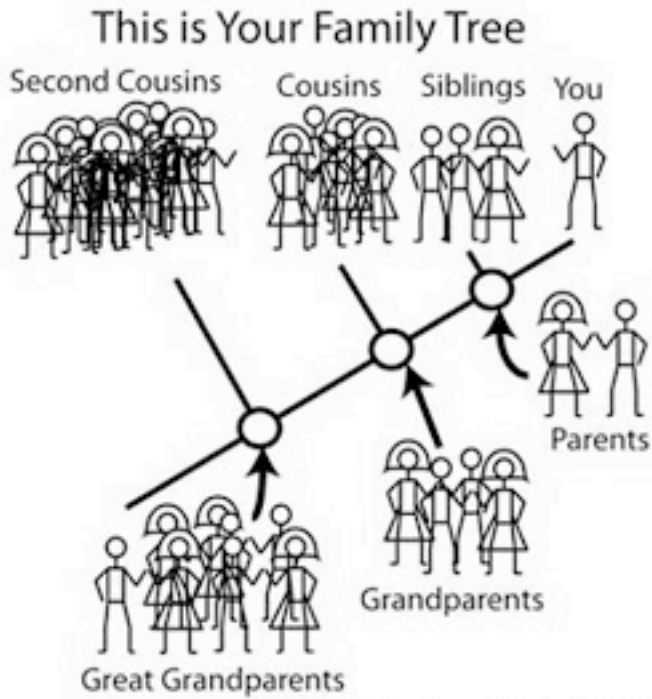
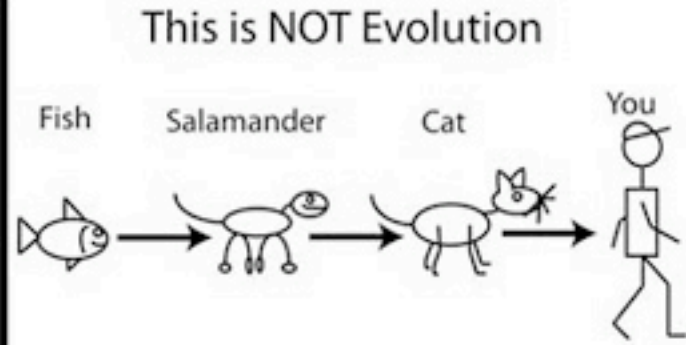
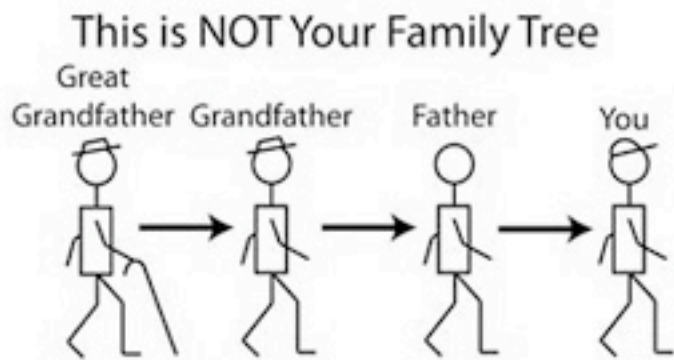
This is **not** true – the only real meaning of *better* is a measure of evolutionary fitness; and as we’ll see later this is a complex concept.



wrong



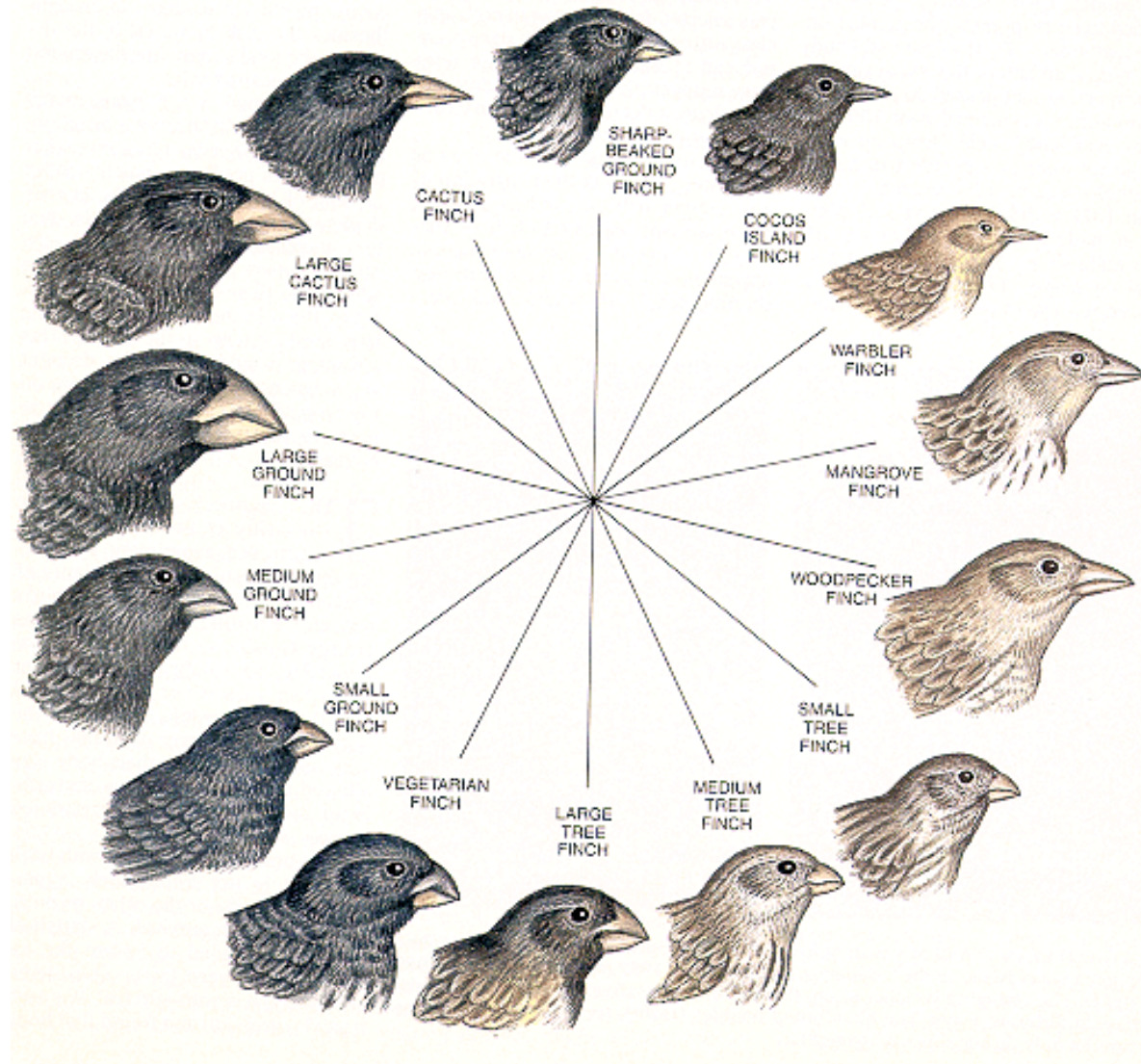
right



Cartoon by Matthew Bossan of Macomb, IL, with kind permission of Florida Citizens for Science, Sept. 2010

Evidence for Evolution: observation

Darwin's Ground Finches



Evidence for Evolution: observation



Darwin's Ground Finches

Peppered Moth

Due to pollution leading to darker environments, the wild-type (white) Peppered Moth is being replaced by mutant (black) variety.



Evidence for Evolution: breeding



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

Evidence for Evolution: breeding



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

Dog breeding



Evidence for Evolution: Lab experiments



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

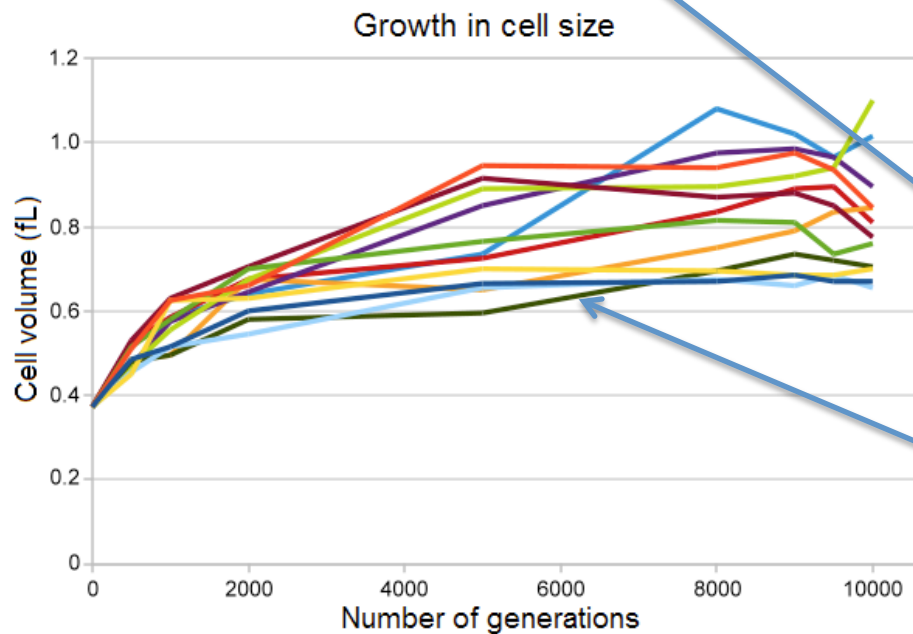
Dog breeding

***E. coli* in the lab (Richard Lenski)**

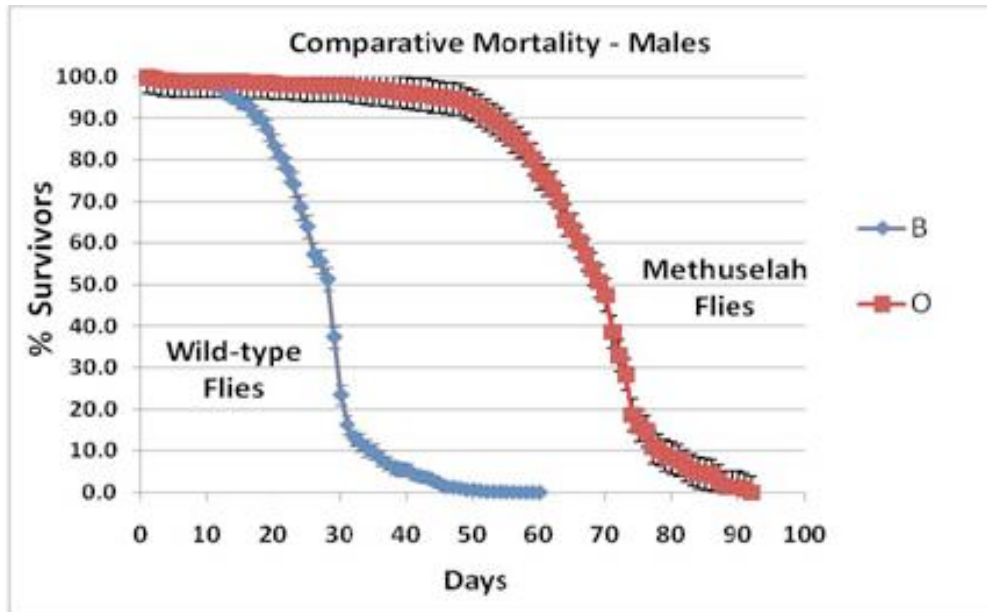
50,000 generation of *E. coli* bacteria in lab populations.

One of the populations evolves to exploit citrate in the growth medium, leading to faster growth.

Increased fitness of all populations; 70% faster growth than the ancestor.



Evidence for Evolution: Lab experiments



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

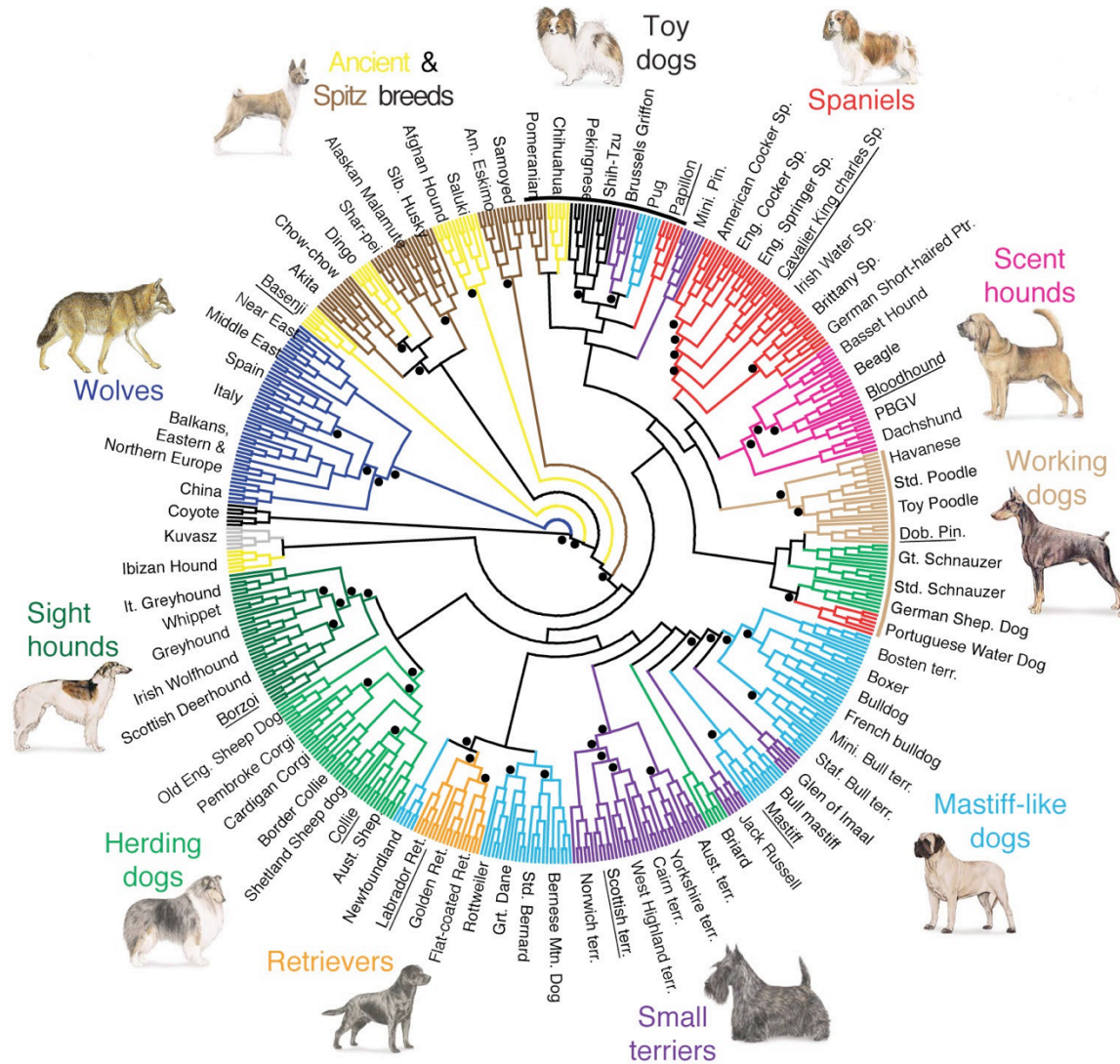
Dog breeding

E.coli in the lab (Richard Lenski)

Fruit flies in the lab (Michael Rose)

Populations of fruit flies are selected for late reproduction, leading to longer lived individuals.

Evidence for Evolution: Phylogenetics



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

Dog breeding

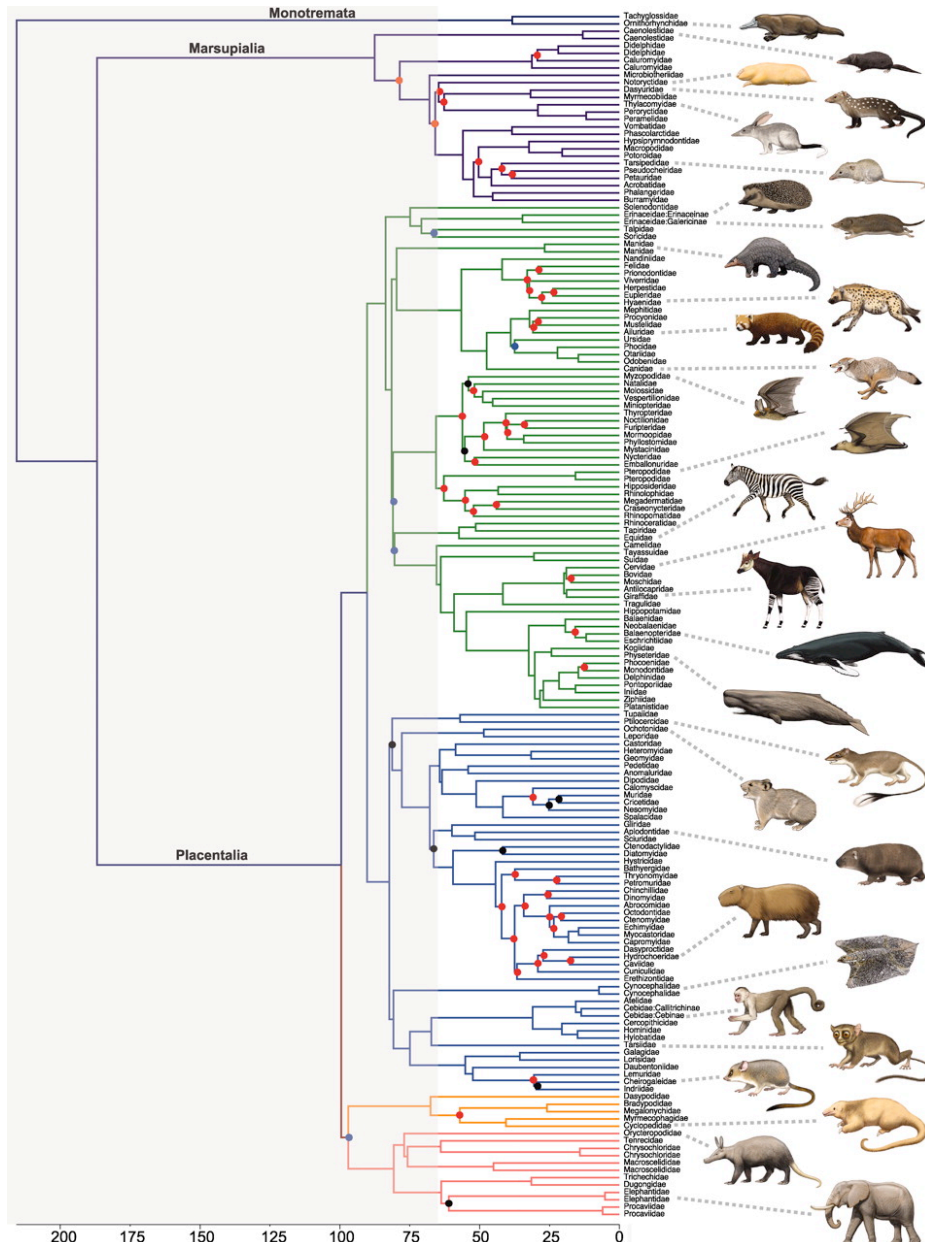
E. coli in the lab (Richard Lenski)

Fruit flies in the lab (Michael Rose)

Modern Phylogenetics

By examining genetic similarity we are able to generate evolutionary trees linking modern species to common ancestors.

Evidence for Evolution: Phylogenetics



Darwin's Ground Finches

Peppered Moth

Pigeon breeding

Dog breeding

E. coli in the lab (Richard Lenski)

Fruit flies in the lab (Michael Rose)

Modern Phylogenetics

By examining genetic similarity we are able to generate evolutionary trees linking modern species to common ancestors.

Modelling Evolution: Fitness

Fitness is the fundamental concept in evolutionary theory.

Despite us all having a general idea of what fitness is, its definition is complex.

Fitness is all about expected reproductive potential

It is a function of both the individual and the environment, and necessarily includes integrals over time.

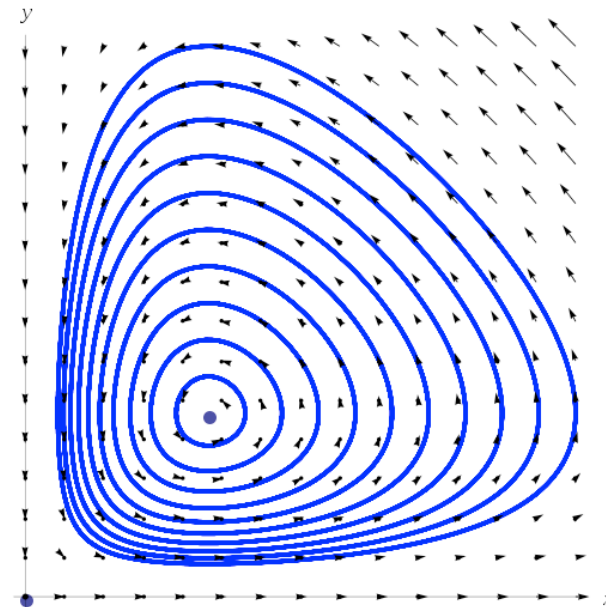
$$\text{Fitness (organism | environment)} = E(\text{number of successful offspring})$$



Modelling Evolution: Competition

The power-house of evolutionary modelling is competition between species / variants / mutations.

Here I'll illustrate the dynamics using the famous / familiar Lotka-Volterra Predator-Prey model.



Modelling Evolution: Competition

There are two basic forms of model:

The first starts with a wild-type population (at equilibrium), adds a small amount of a mutant, and allows the two populations to compete.

This can be examined mathematically.

The second also starts with a wild-type population (at equilibrium) but allows mutation at every step of the process.

This can only really be examined numerically, using PDEs or simulation.

Modelling Evolution: Competition

For two-species competition we generally find that which-ever species can persist in the worst environment wins.