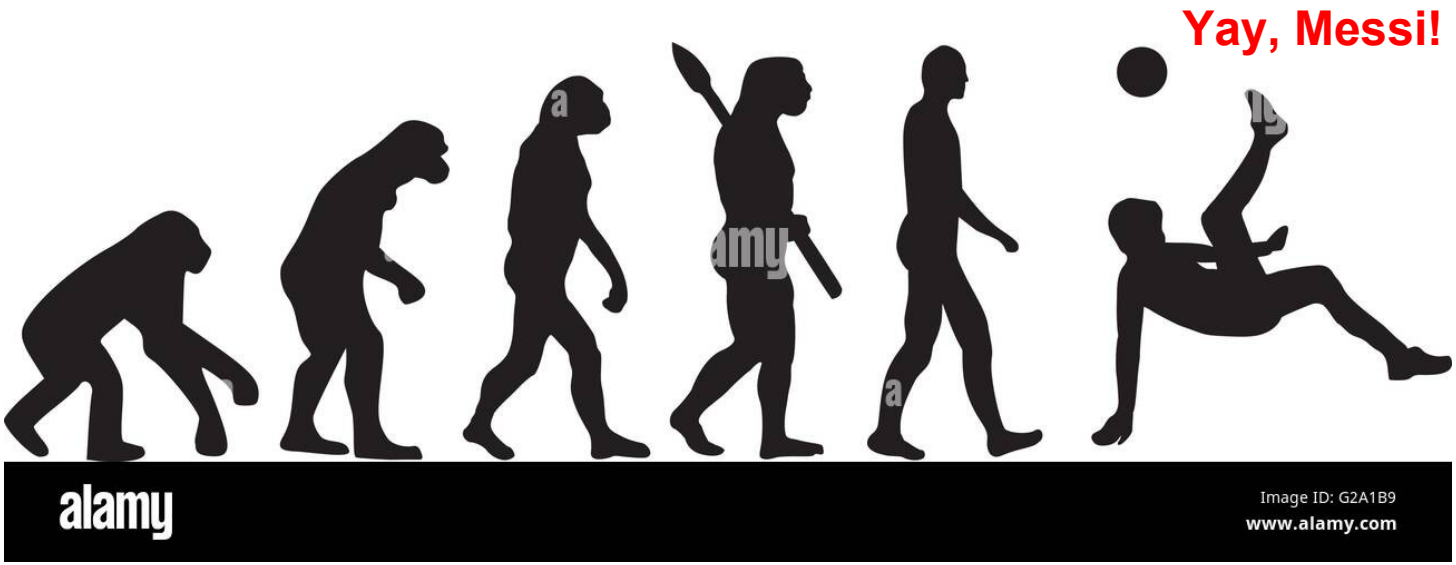
# Lecture 12: Evolution




Part 1: Evolution of biomolecules

Part 2: Darwin
Evolution of populations
Molecular mechanism of evolution
How does our knowledge of evolution help us?

**You have learned about DNA, RNA, proteins, lipids and other biomolecules**

**How did they come into existence?**

**How they self-assemble into higher order structures?**

**How did they eventually become “alive”?**

# Evolution of the first life: a series of steps

Formation of Earth

↓

Inorganic substances

↓

Primordial soup (simple organic compounds)

↓

Polymerization (complex organic substances)

↓

**Self-replicating systems (RNA)**

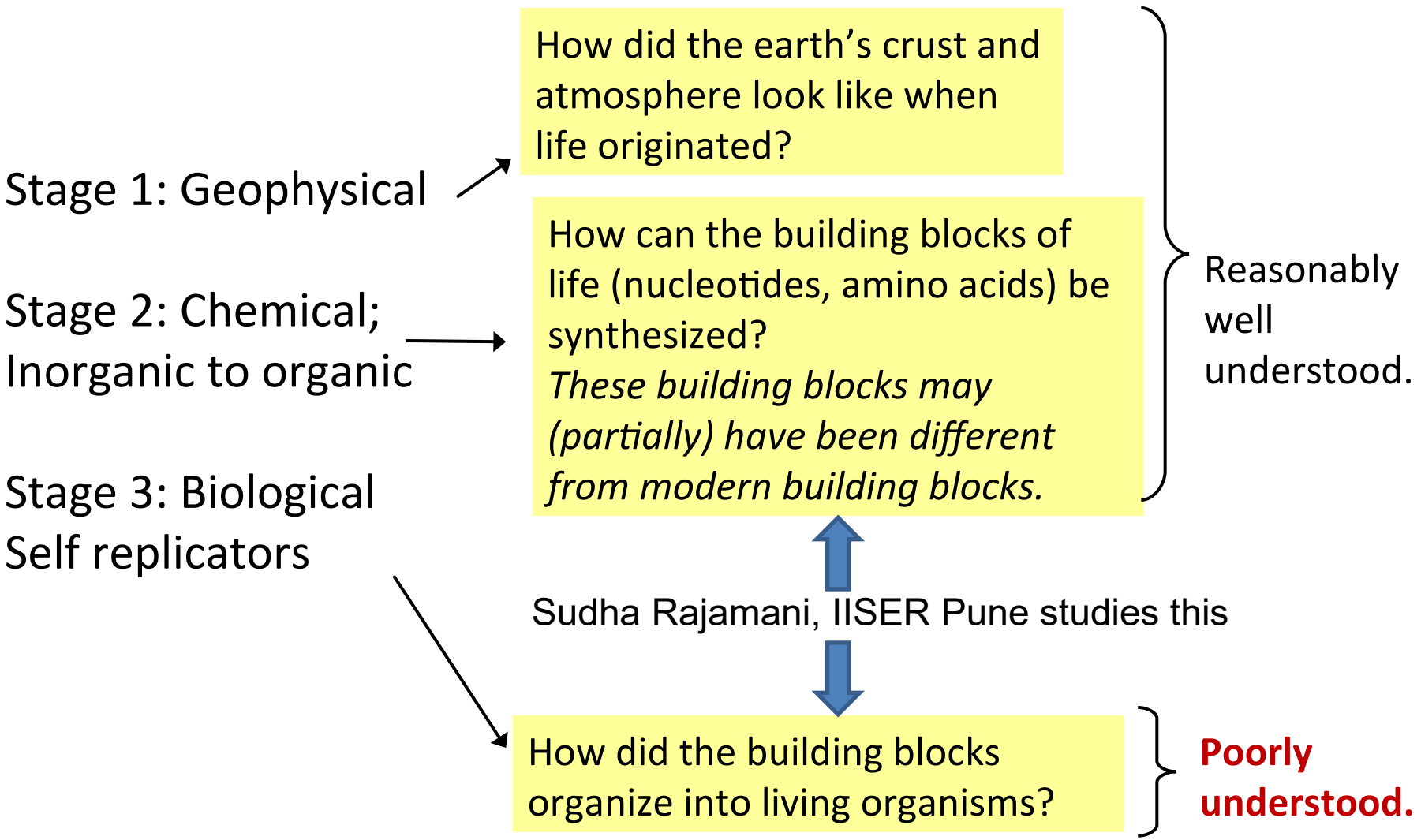
↓

**Proto-cells (using properties of lipids)**

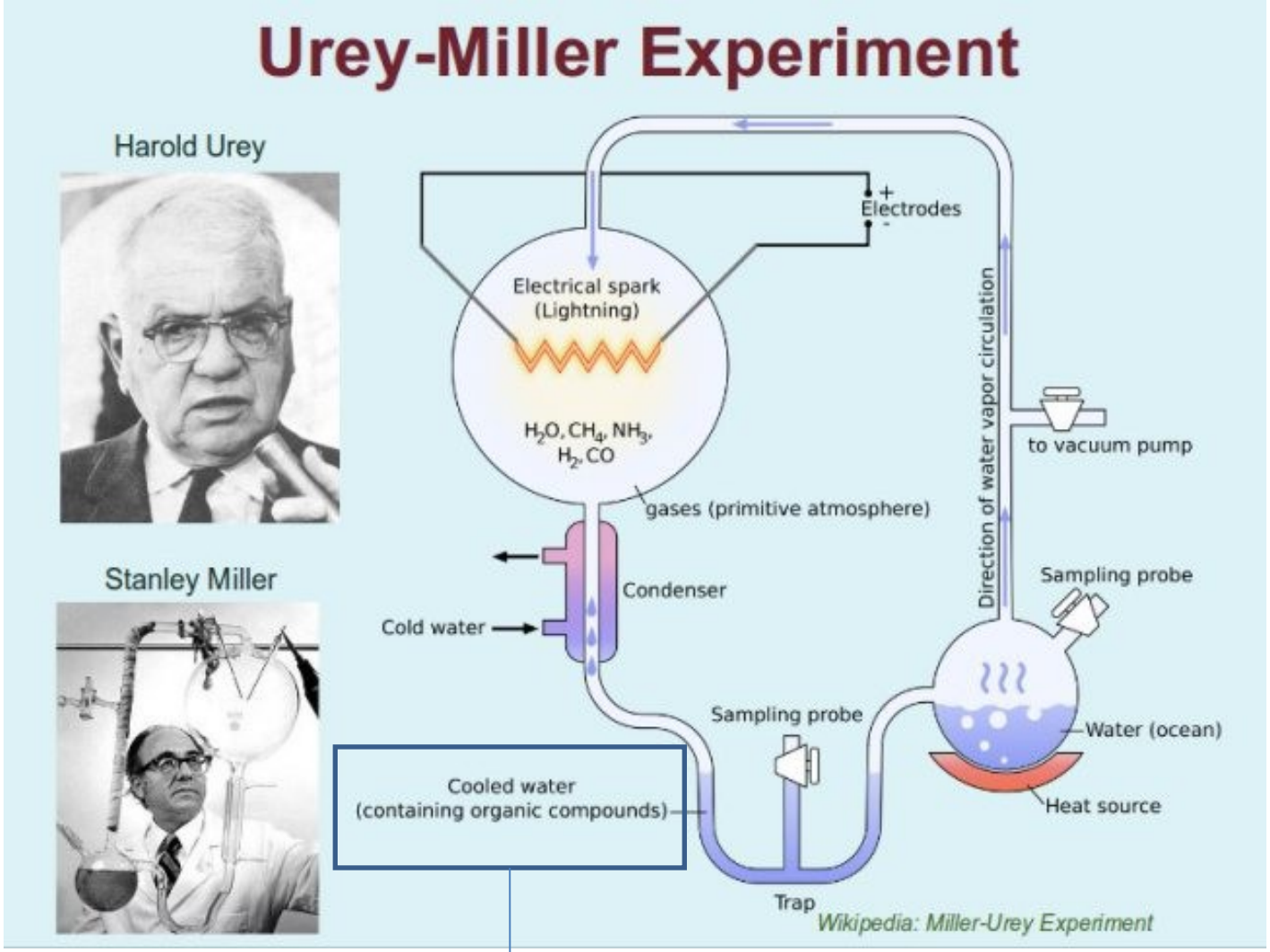
↓

**Complex cells (DNA, RNA, proteins, etc)**

# Stages of prebiotic evolution



# Simulation of the pre-biotic environment: formation of simple bio-molecules occurs



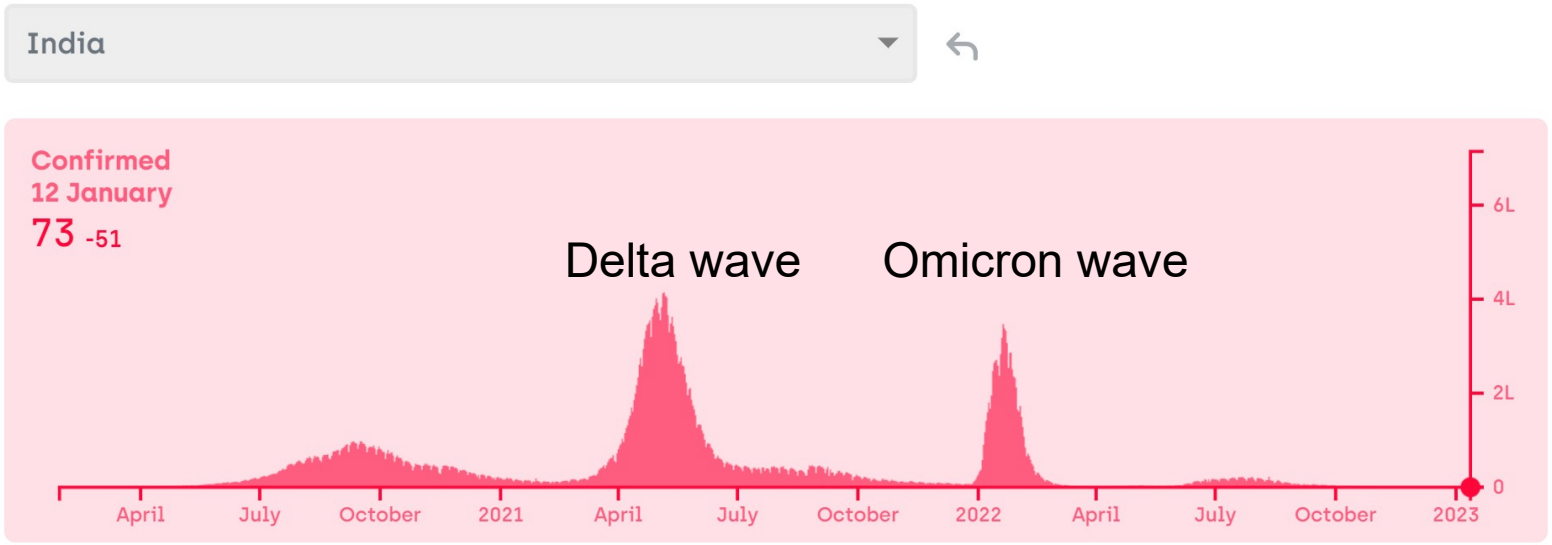

**Two percent of the carbon had formed amino acids that are used to make proteins in living cells, with glycine as the most abundant. Sugars were also formed.**

**Evolution**

**Darwin**

**Why and how?**

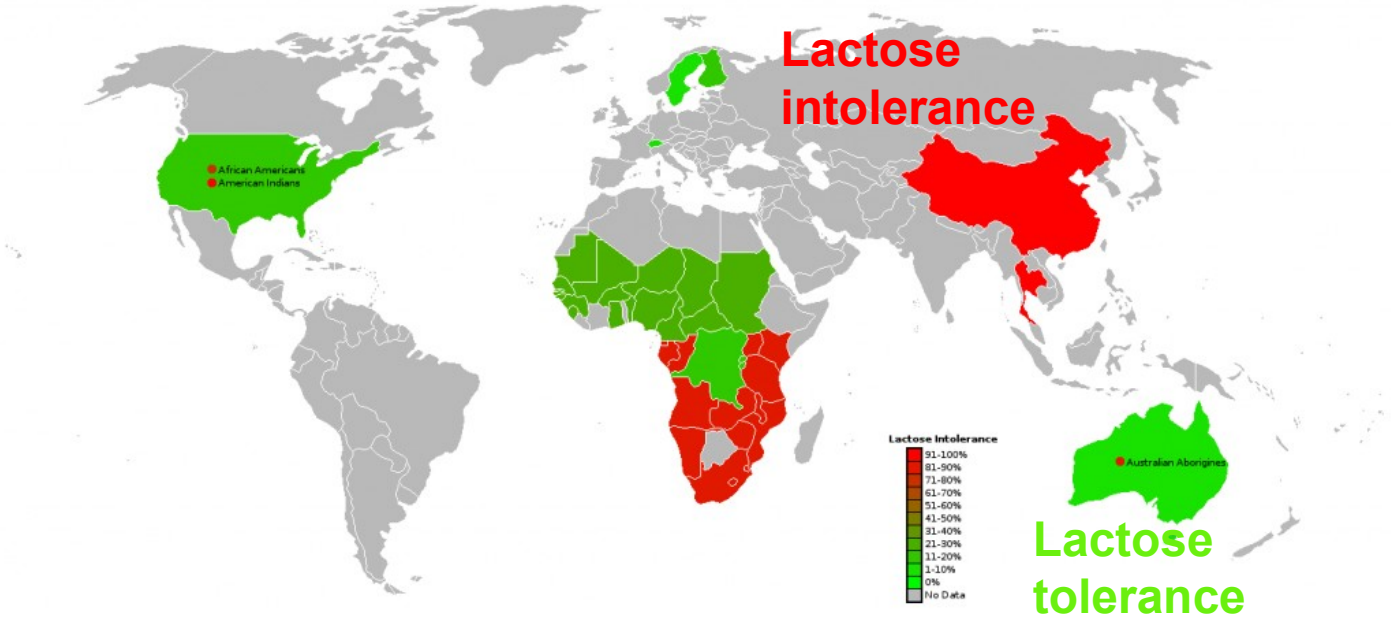
# Data from covid19bharat.org




What is happening to the SARS CoV-2 virus to cause these waves of infection in two years?

# Got milk?

**The ability to digest milk as an adult is a trait acquired over thousands of years**




Lactase persistence (LP), the dominant Mendelian trait conferring the ability to digest the milk sugar lactose in adults, has risen to high frequency in central and northern Europeans in the last 20,000 years. This trait is likely to have conferred a selective advantage in individuals who consume appreciable amounts of unfermented milk.

# Why study evolution at all?

- Essential for the progress of biology
- Evolutionary concepts are a major part of modern biology experiments
- Study of virus evolution (influenza/HIV/H1N1/SARS CoV2), cancer progression, bacterial drug resistance, etc  can save thousands of lives
- **Nothing in Biology makes sense except in the light of evolution-Theodor Dobzhansky**

# Evolution

- **Before Darwin, there was creationism (God made man)**
- The book that forever changed Biology
  - ***On the Origin of Species - 1859***
- Darwin presented evidence that the today's organisms are descendants of ancestral species
- Darwin proposed a mechanism for the evolutionary process: **natural selection**

# What is a species?

Organisms that can interbreed and produce viable offspring constitute a species
This definition has several exceptions + does not apply to organisms that divide to multiply

Eastern meadowlark Western meadowlark

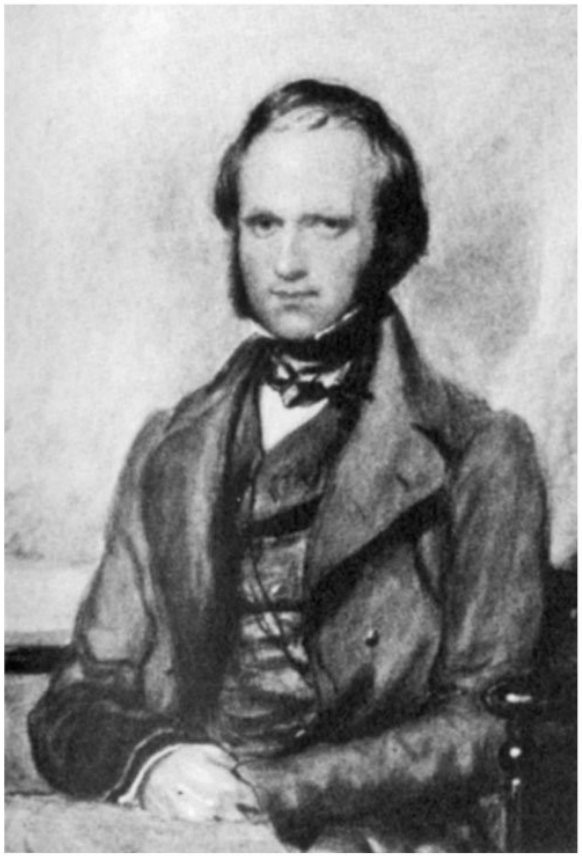
Similar in appearance but… songs + other behaviour are quite distinct… different species

Diverse appearance but same species

Figure 24.2 (Campbell's Biology)

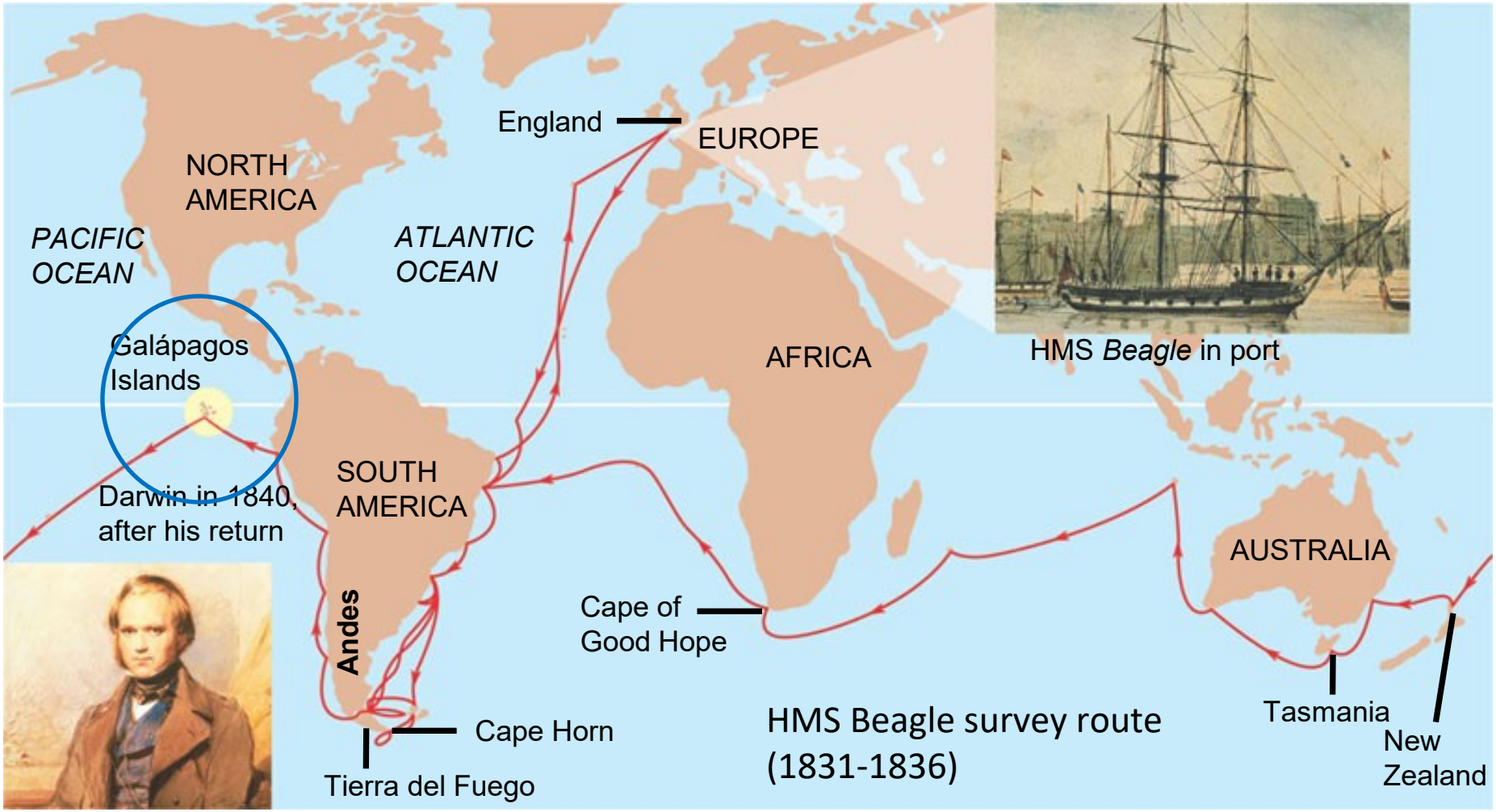
Appearance can be misleading

# Charles Darwin (1809-1882)



- Grandson of Erasmus Darwin
- Naturalist from a young age
- Left medical school and studied marine invertebrates
- In 1831 got an invitation to join the 5 year survey expedition to South America on *HMS Beagle*
- His job title was *"Naturalist"*

# Voyage of the Beagle




Darwin collected birds, insects, spiders, plants and fossils. Because of his travels these specimens came from all over the world, especially from islands (isolated populations).

# Darwin saw many different animals and birds on Galapagos Islands

Many endemic species are still there

- Vertebrates
- Invertebrates
- Mammals
- Plants

The Great Frigate Bird

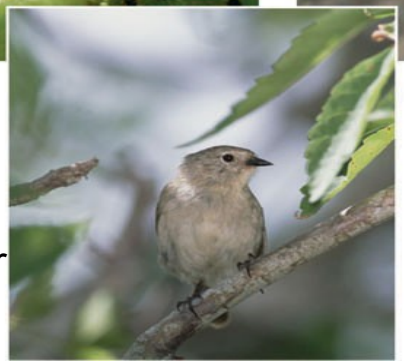
The land iguana

The Giant tortoise

# Some birds showed variability in their phenotypes on different islands around the world

**Cactus eater.** The cactus ground finch (*Geospiza scandens*) has a long, sharp beak.

**Seed eater.** The large ground finch (*Geospiza magnirostris*) has a large beak.



**Insect eater.** The green warbler finch (*Certhidea olivacea*) has a narrow, pointed beak.

**Did this have anything to do with their environment and food habits?**

# Darwin's observations and inferences (1)

Asian ladybird beetles

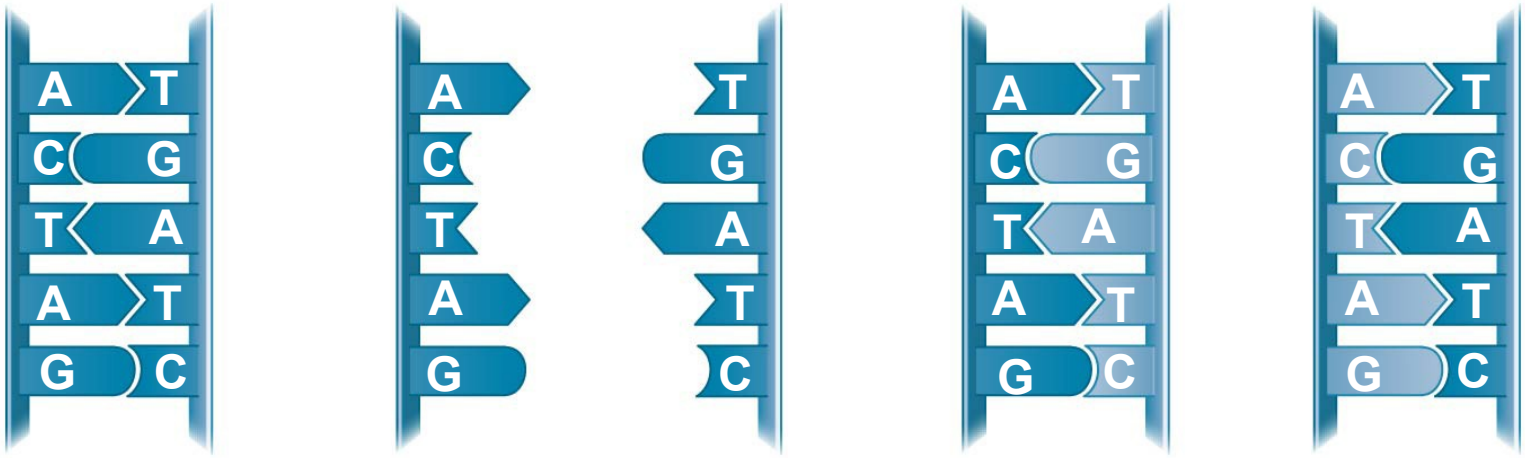
Figure 22.10
Campbell's Biology

Observation #1: members of a population often vary in their inherited traits

Inference: Individuals whose inherited traits give them a higher probability of reproducing in a given environment tend to leave more offspring than other individuals

# Where does variability come from?

A) Replication
B) Transcription
C) Translation




(a) Parental molecule

(b) Separation of parental strands into templates

(c) Formation of new strands complementary to template strands

Replication model envisaged by Watson and Crick and experimentally verified by Meselson and Stahl

# Where does variability come from? Mistakes made during DNA replication


**(a) Parental molecule** **(b) Separation of parental strands into templates** **(c) Formation of new strands complementary to template strands**

The enzyme that replicates DNA makes mistakes!

It is estimated that replicative eukaryotic DNA polymerases make errors approximately once every $10^4$ – $10^5$ nucleotides polymerized.

Thus, each time a diploid mammalian cell replicates, **at least 100,000 and up to 1,000,000** polymerase errors occur.

Many of these are repaired by the cell, but errors do remain and they are the basis of variability

# How does variability result in different phenotypes?

Previous lectures to remember:

Lecture 3: Mendel and the pea plants (variability which was shown to be based on DNA)

Lecture 4: DNA as the genetic material (information carrier for making proteins)

Lecture 5: Flow of information: DNA is transcribed into RNA which is used as an information carrier for making proteins

Lecture 5: Flow of information: Proteins are made using information from codons on the RNA and mutations can be silent, nonsense and mis-sense; such mutations can affect protein structure and function (tutorial)

# Darwin's observations and inferences (2)


Campbell's Biology

Figure 22.11

Observation #2: many species produce more offspring than their environment can support. Consequently, a large number of offspring fail to survive

Inference: Unequal ability of individuals to survive and reproduce leads to accumulation of traits in the population over generations

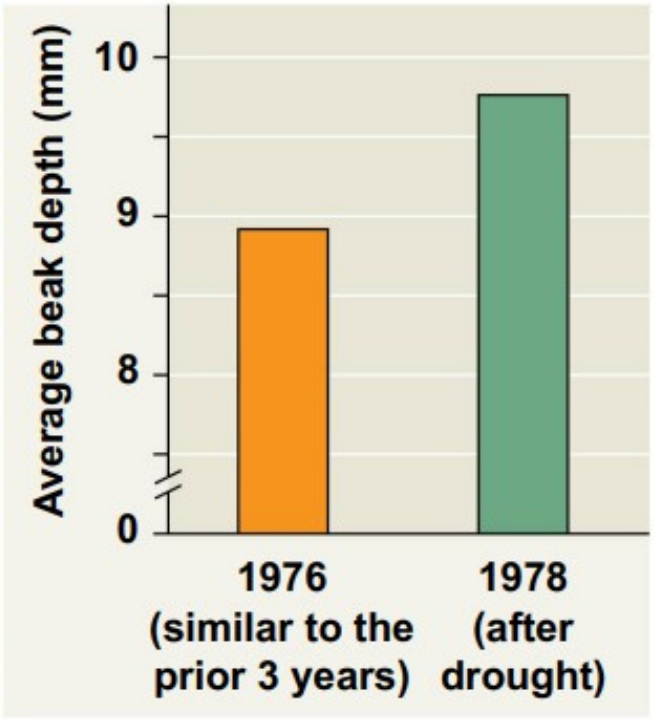
This was based on Thomas Malthus' economic theory that populations increase exponentially while food sources increase in a linear fashion.

**Mismatch of supply and demand**

# Lack of resources results in selection in a population

## Drought and the evolution of medium ground finch population


Daphne major island
(Galapagos islands)




Before a long drought in 1977: ~1200 birds

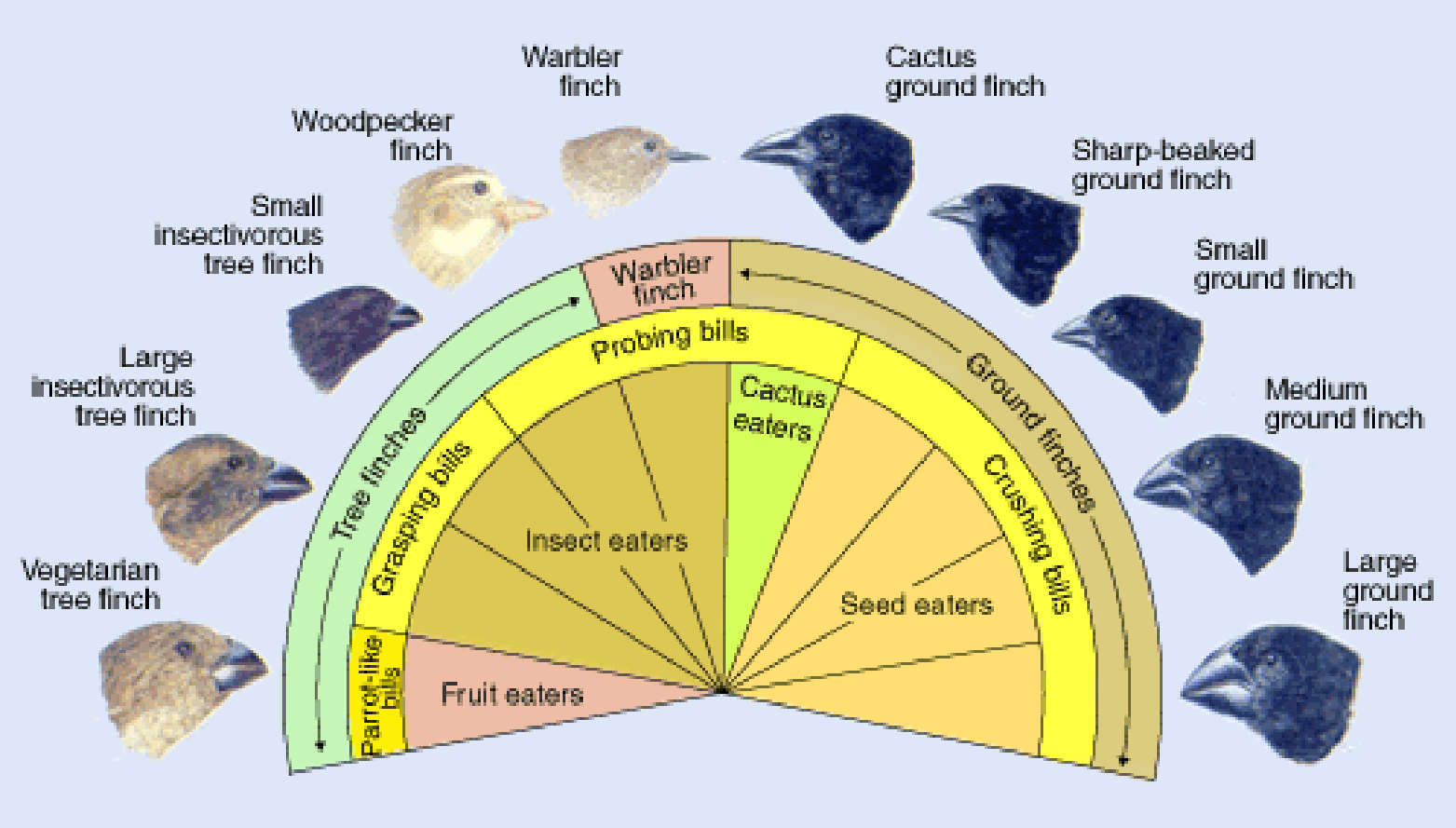
After the drought: ~180 birds survived

Small soft seeds in short supply during drought

Large hard seeds were plentiful

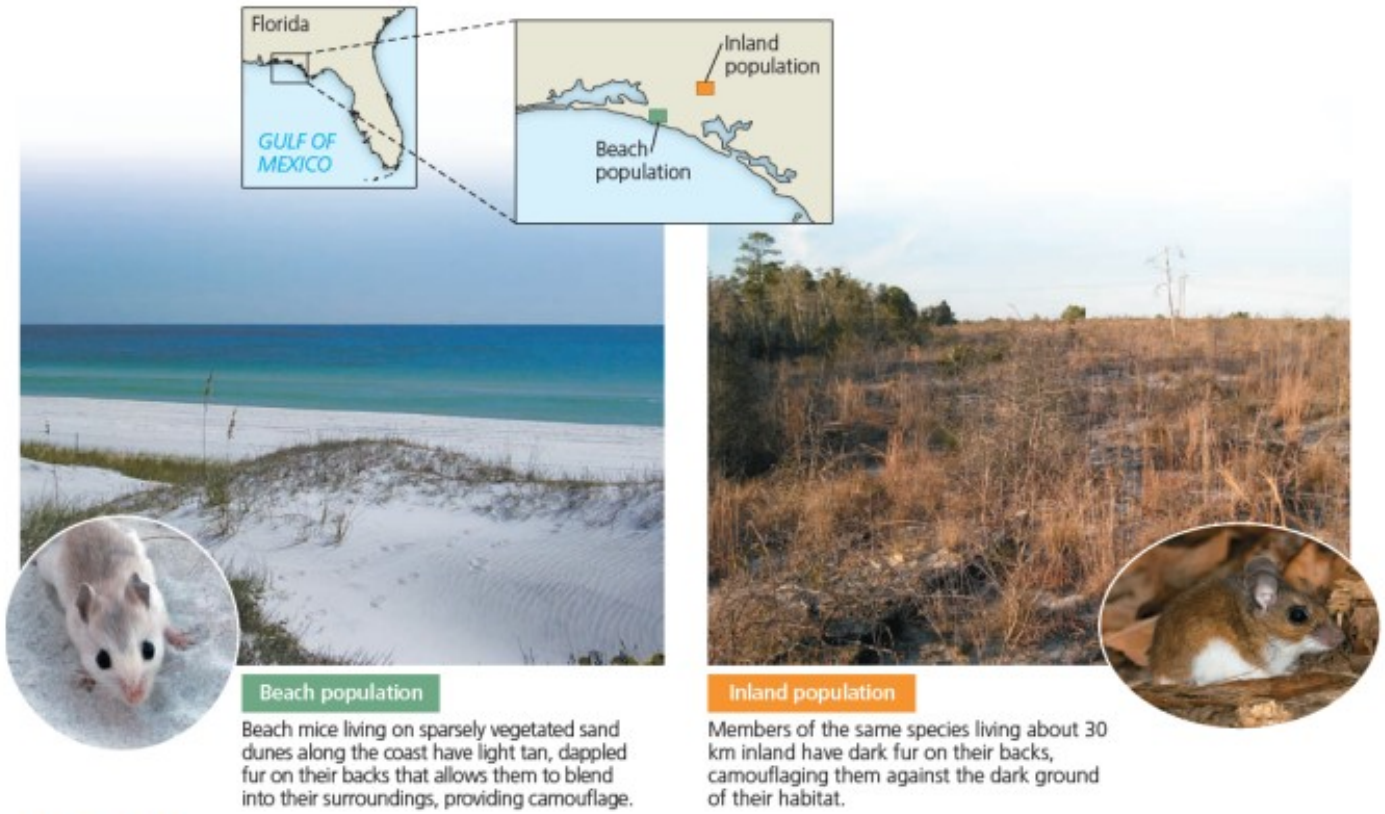
Beak depth changed in a population in 2 years!

# Finches have evolved beak shapes to eat specific types of foods




This diagram presents 10 species of finches on the Galapagos Islands, each exploit different resources on various islands. All of them evolved from one ancestral species, which colonized the islands only a few million years ago. This process, whereby species evolve rapidly to exploit empty ecospace, is known as *adaptive radiation*.

# Different phenotypes have different "fitness" or ability to survive

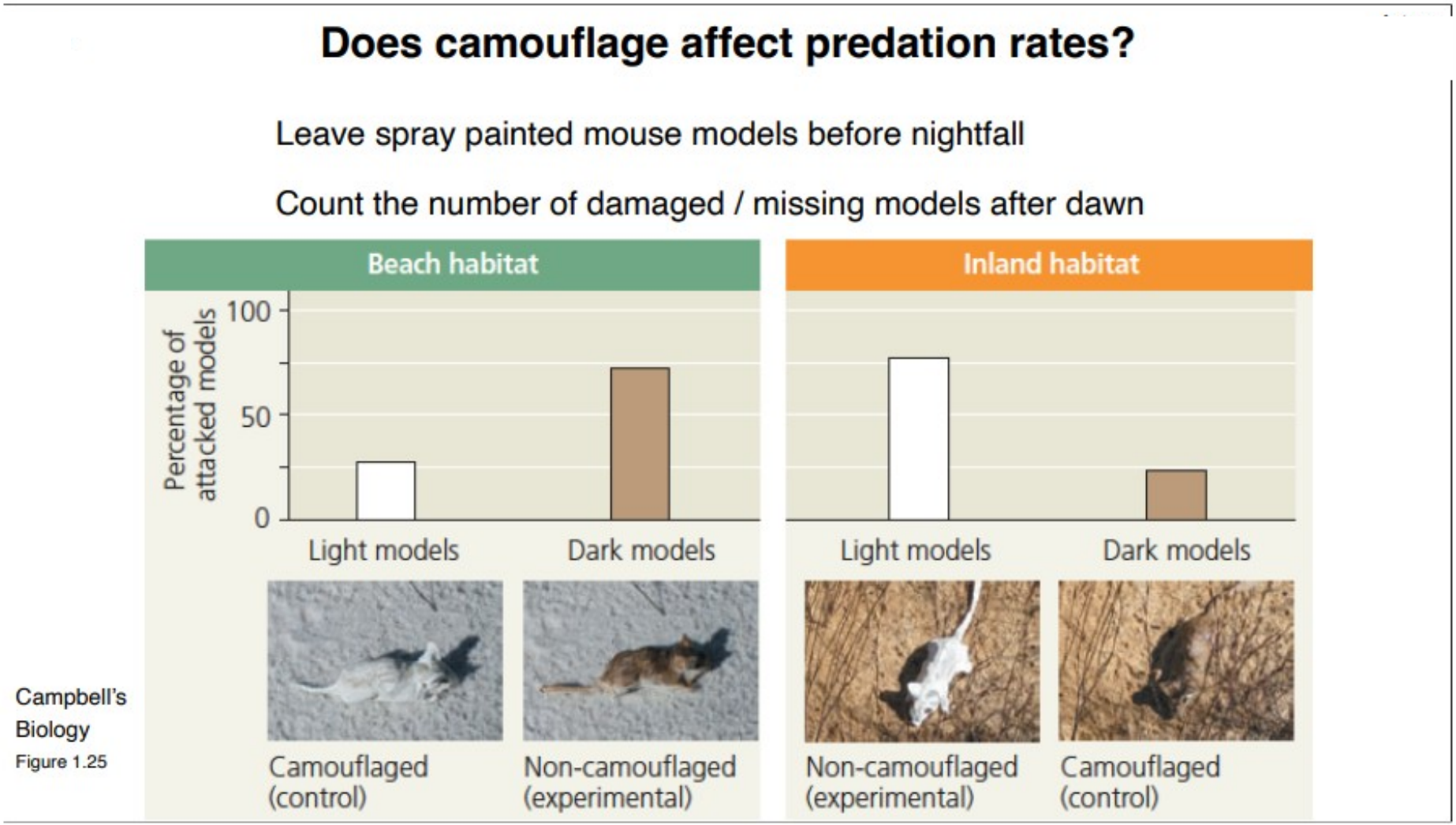



▲ **Figure 1.24** Different coloration in beach and inland populations of *Peromyscus polionotus*.

Campbell's Biology

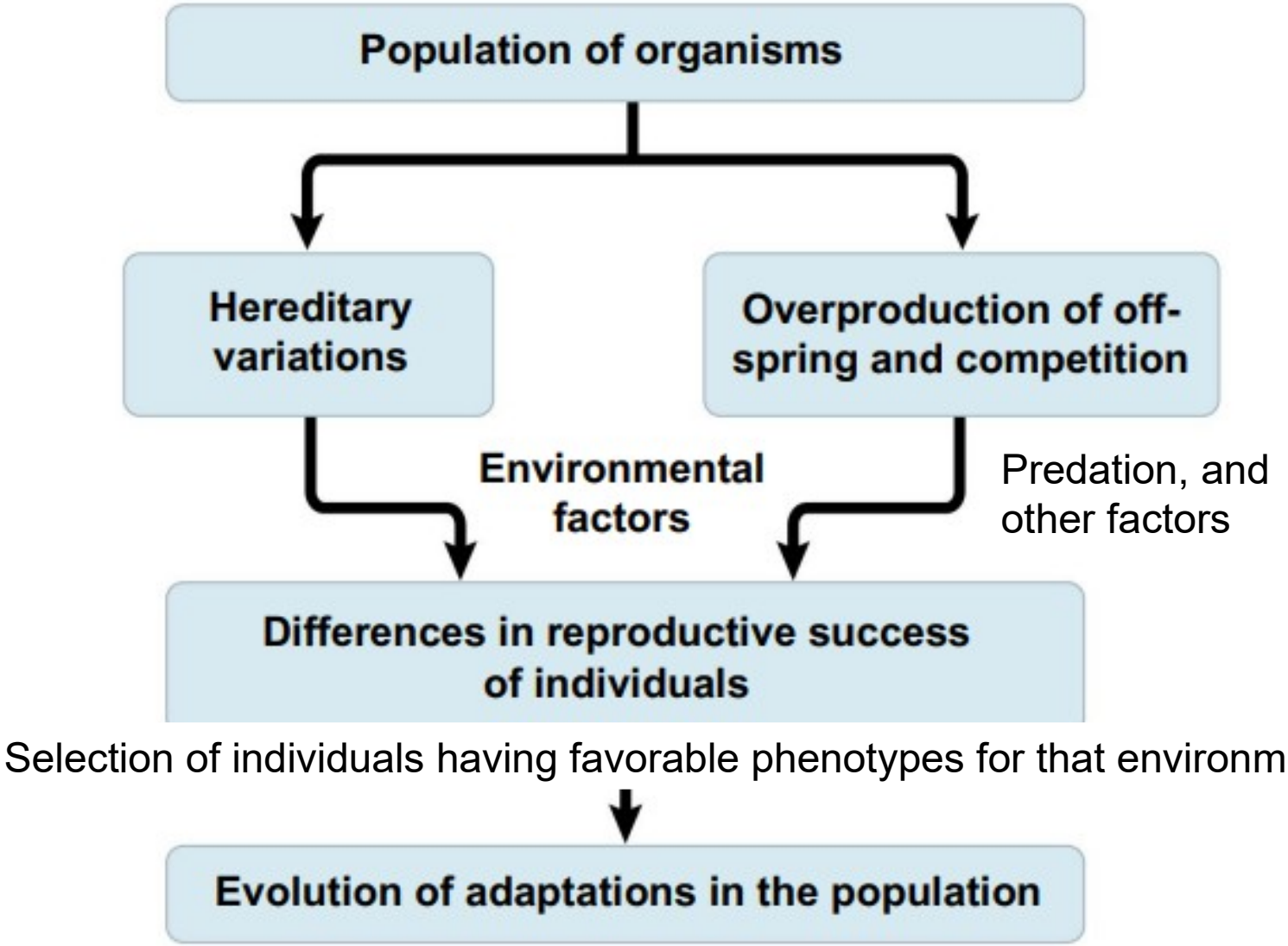
CHAPTER 1 Evolution, the Themes of Biology, and Scientific Inquiry 19

# Different phenotypes have different fitness



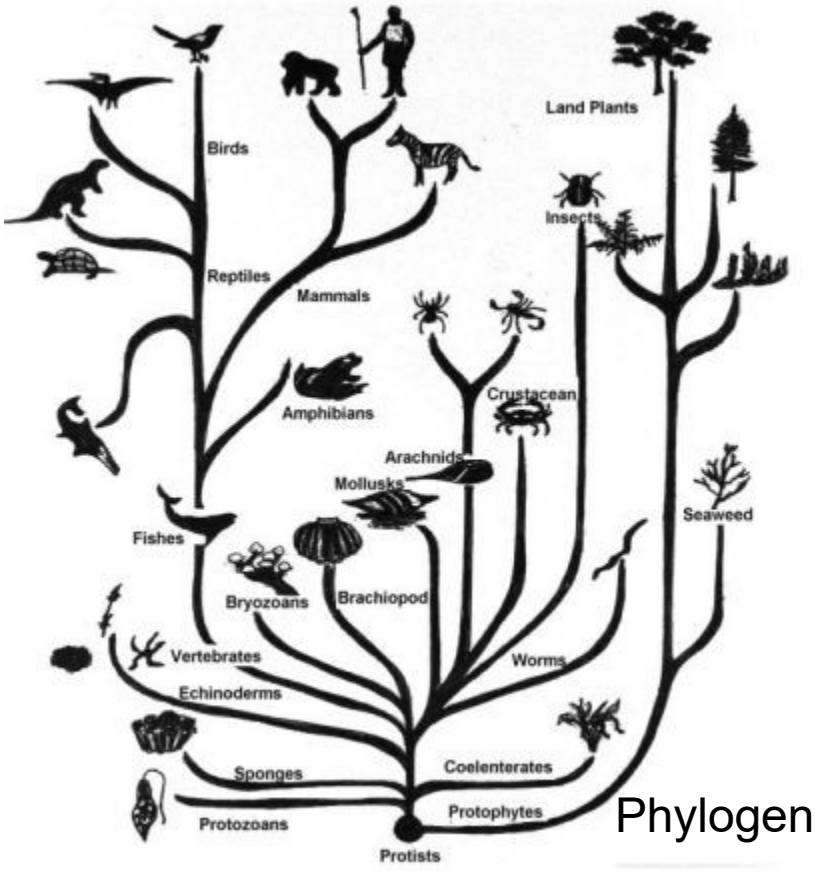

Fitness depends on the environment

# Darwin's observations and inferences

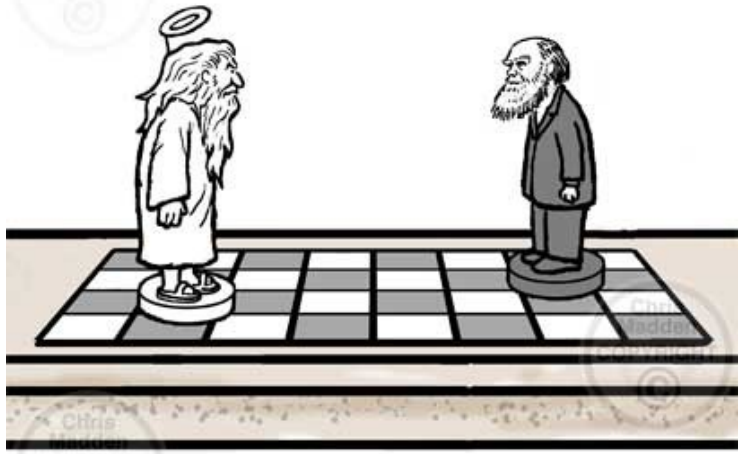


# Darwin proposed the idea of evolution

**Evolution is the change in the inherited characteristics of biological populations over successive generations.**




Phylogenetic tree



Darwin vs. God

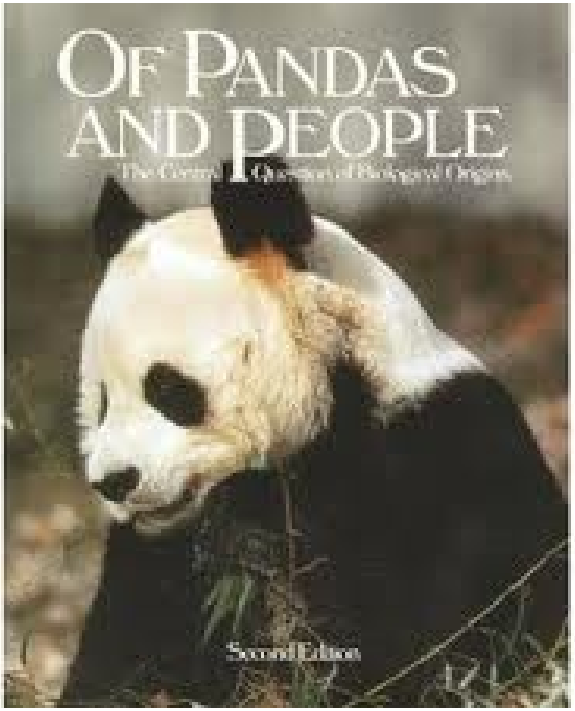
**It gave rise to the revolutionary idea that all life on this planet arose from a common ancestor ("horrifying" idea that humans evolved from apes).**

# Challenges to Teaching Evolution- Controversy

**Statement made in the official curriculum of Dover Area School Board, Pennsylvania in the year 2004!**

"*Students will be made aware of gaps/problems in Darwin's Theory and of other theories of evolution including, but not limited to, intelligent design.* ***Note: Origins of life will not be taught.***"

School board approves reference text: "**Of Pandas and of People**" by Percival Davis




It promotes the theory of intelligent design – Whole book is centered around the idea that various forms of **life began abruptly** through the agency of an intelligent creator with their distinctive features already intact. Fish with fins and scales, birds with feathers, beaks, and wings, etc.

**You can find many such books still being published and many of them are very popular!**



# Department Position on Evolution and "Intelligent Design"

The faculty in the Department of Biological Sciences is committed to the highest standards of scientific integrity and academic function. This commitment carries with it unwavering support for academic freedom and the free exchange of ideas. It also demands the utmost respect for the scientific method, integrity in the conduct of research, and recognition that the validity of any scientific model comes only as a result of rational hypothesis testing, sound experimentation, and findings that can be replicated by others.

The department faculty, then, are unequivocal in their support of evolutionary theory, which has its roots in the seminal work of Charles Darwin and has been supported by findings accumulated over 140 years. The sole dissenter from this position, Prof. Michael Behe, is a well-known proponent of "intelligent design." While we respect Prof. Behe's right to express his views, they are his alone and are in no way endorsed by the department. It is our collective position that intelligent design has no basis in science, has not been tested experimentally, and should not be regarded as scientific.

**Prof. Micheal Behe is a professor of Biochemistry at Lehigh University-proponent of “irreducibly complex”**



Site maintained by Maria Brace
Department of Biological Sciences
Lehigh University

# Challenges to Teaching Evolution- Controversy

## Nobody saw ape turning into man!

hindustantimes

Thursday

india world sports cities opinion ipl 2018 karnataka elections entertainment lifestyle education photos videos board results 2018

HOME › INDIA

**Darwin's theory wrong, nobody saw ape turning into man: Minister Satyapal Singh**

Union minister Satyapal Singh said Darwin's theory needs to change in school and college curriculum.

NEWS Updated: Jan 21, 2018 08:05 IST

Press Trust of India, Aurangabad

Union minister Satyapal Singh said our ancestors have nowhere mentioned that they saw an ape turning into a man.(AP File Photo)

https://www.hindustantimes.com/india-news/darwin-s-theory-scientifically-wrong-nobody-saw-ape-turning-into-man-union-minister-satyapal-singh/story-hZ6R2BihRNfd93sDGWvbuN.html

The Indian EXPRESS

Home › India › Darwin theory row: Union Minister Prakash Javadekar asks Satyapal Singh to refrain from 'such comments'

**Darwin theory row: Union Minister Prakash Javadekar asks Satyapal Singh to refrain from 'such comments'**

Javadekar, the Union Human Resource Development Minister, maintained that science should not be diluted, insisting that the government has no plans to hold a national seminar to prove Darwin's evolution theory wrong.

http://indianexpress.com/article/india/darwin-theory-row-prakash-javadekar-satyapal-singh-monkey-apes-human-evolution-scientifically-wrong-5036269/

If humans evolved from monkeys, why is it that all monkeys have not evolved to be humans?

Statement issued by Sri Satyapal Singh, the then Union Minister of State for Human Resources Development, in January 2018

# Darwin proposed the idea of natural selection

**Darwin's process of natural selection has four components.**

1) Variation. Organisms (within populations) exhibit individual variation in appearance and behaviour. These variations may involve body size, hair color, facial markings, voice properties, or number of offspring. On the other hand, some traits show little to no variation among individuals—for example, number of eyes in vertebrates.

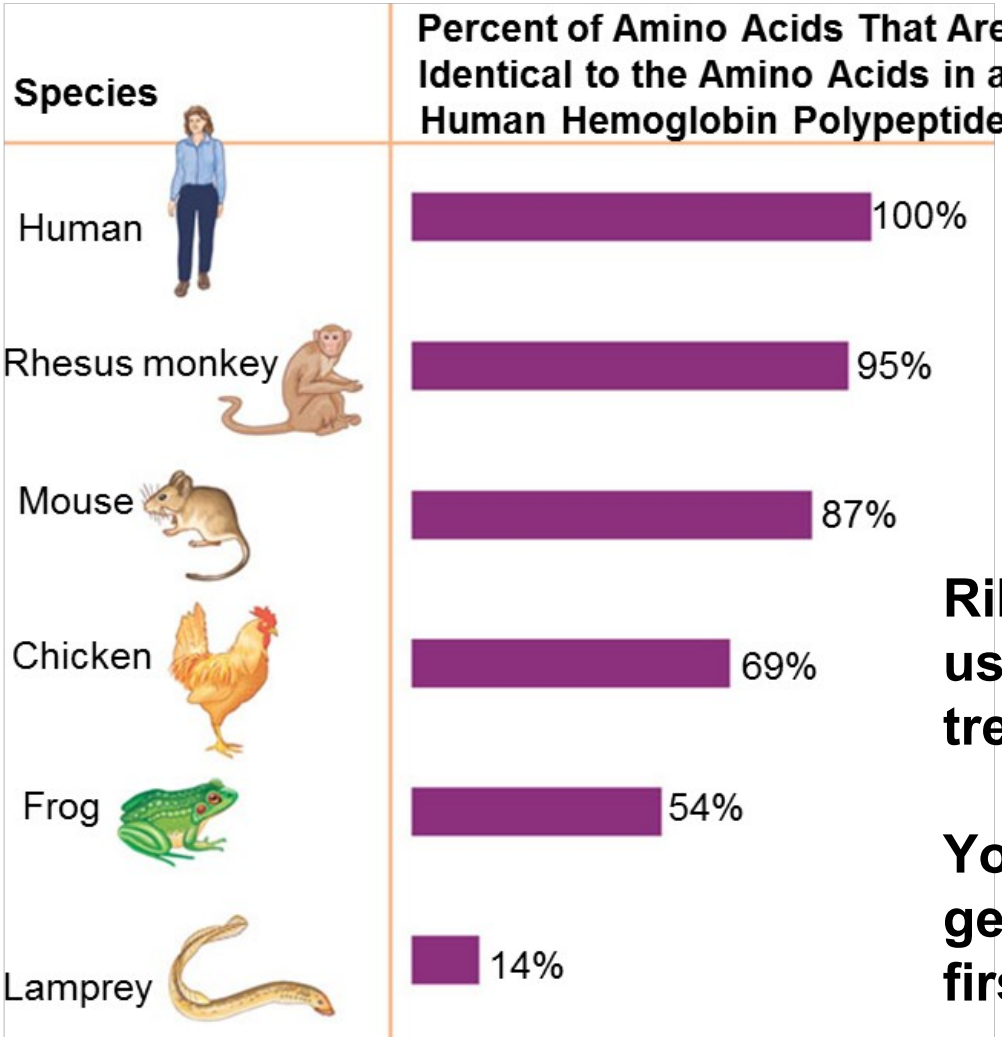
2) Inheritance. Some traits are consistently passed on from parent to offspring, whereas other traits are strongly influenced by environmental conditions. These traits are selected by evolution. (**Darwin** vs. **Lamarck**)

3) High rate of population growth. Most populations have more offspring each year than local resources can support leading to a struggle for resources. Each generation experiences substantial mortality.

4) Differential survival and reproduction. Individuals possessing traits well suited for the struggle for local resources will contribute more offspring to the next generation.

# Today relationships between species ….

… are generally reflected in their molecules, their genes, and their gene products (proteins)

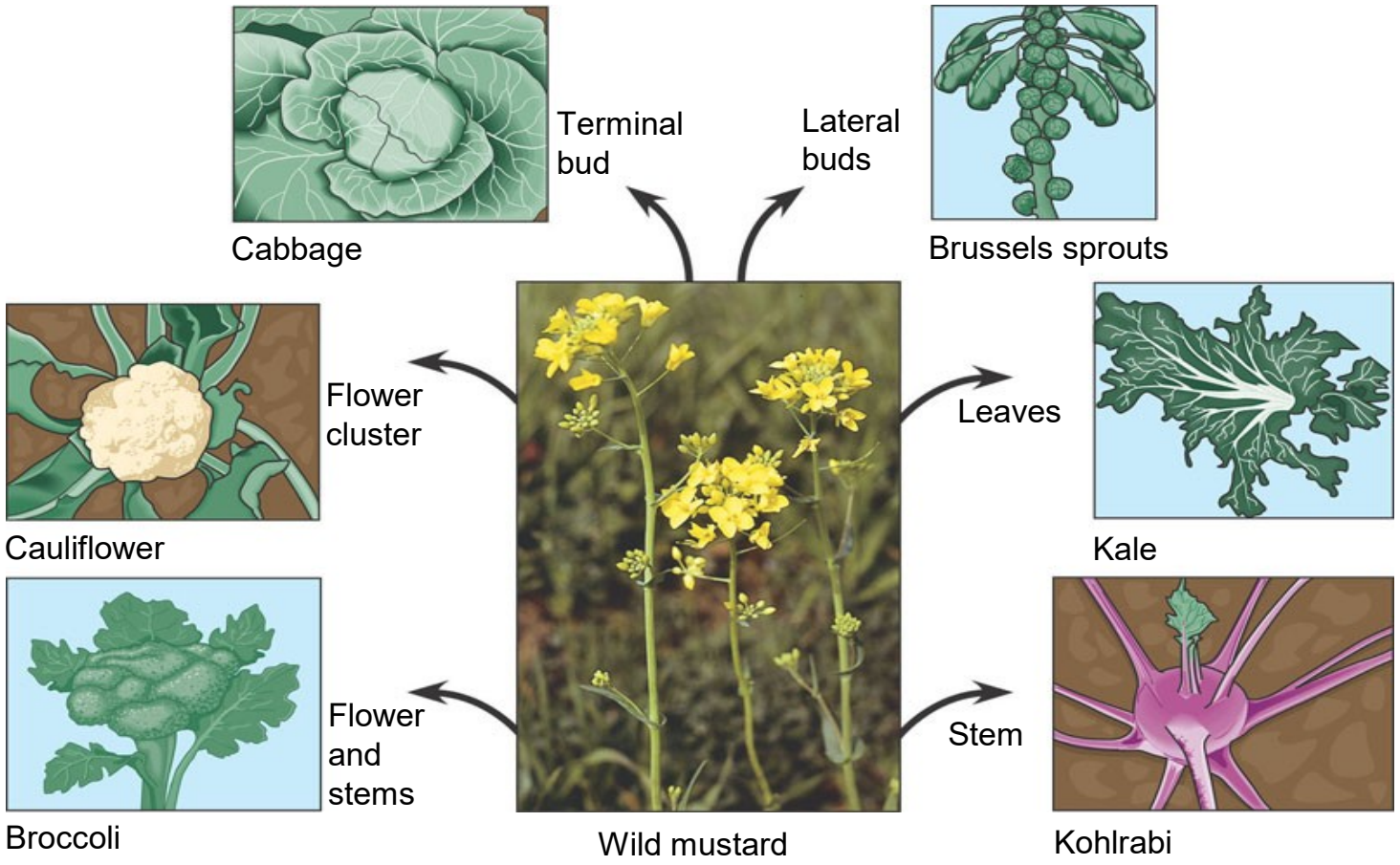



**Ribosomal RNA genes are used to construct phylogenetic trees.**

**You saw the similarities in the genomes of primates in the first lecture.**

# Artificial Selection

- Humans have modified other species over many generations by selecting and breeding individuals that possess desired traits
- **Example:** farmers have cultivated numerous popular crops from the wild mustard, by artificially selecting for certain attributes



# Evolution in the laboratory

Richard E. Lenski started an experiment in 1988

Began with a single bacterium, *Escherichia coli* (*E. coli*)

Generated 12 populations out of this bacterium

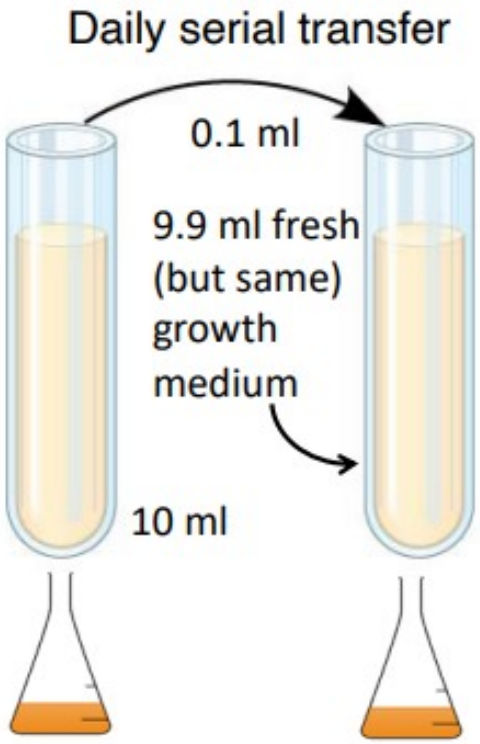
Has been monitoring the evolution of these 12 populations ever since

In 3,000 days, resulted in 20,000 generations

For human beings, assuming 20 years/generation, it would have taken 4,00,000 years to observe 20,000 generations!

https://alchetron.com/Richard-Lenski

# Evolution in the laboratory




A challenging growth medium was provided

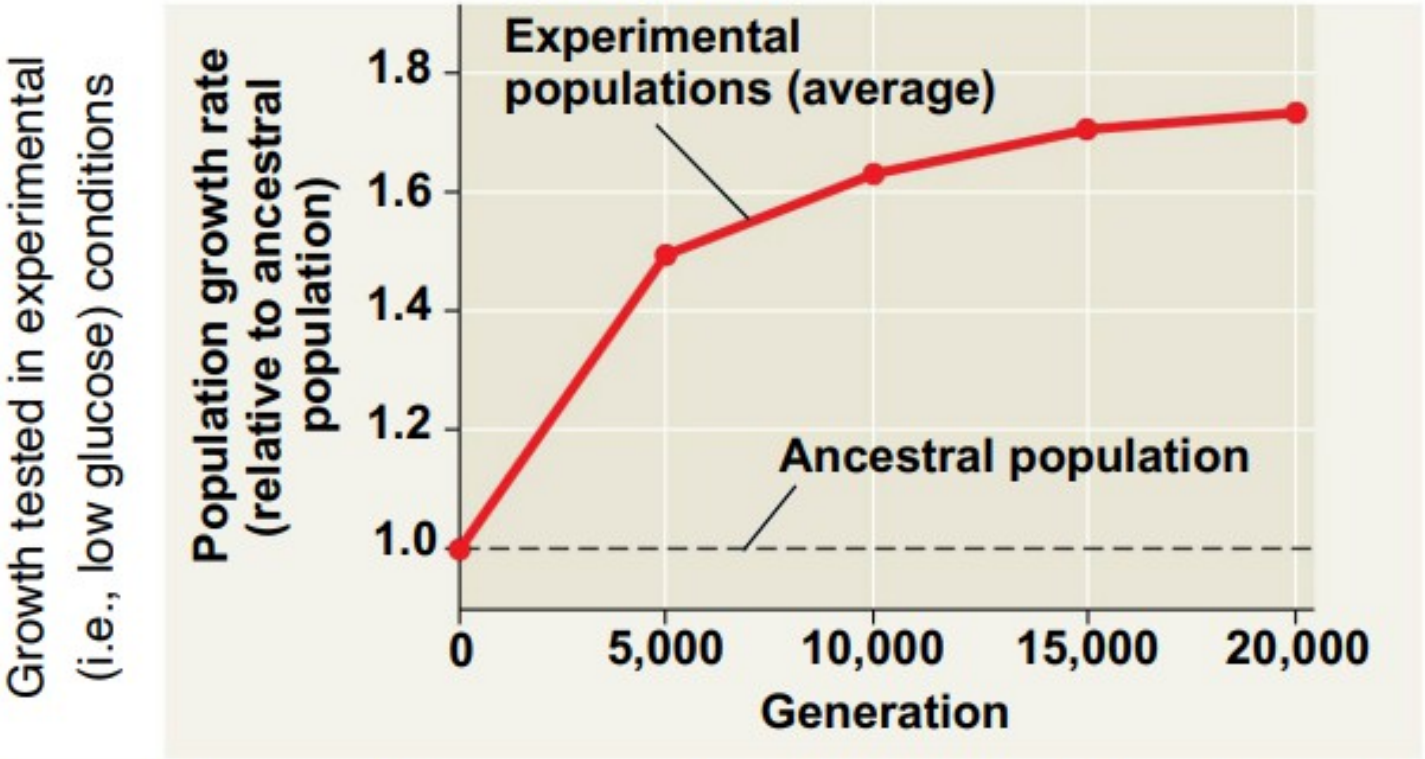
Nutrients (glucose + other resources) required for growth were provided in "low" levels

Bacteria undergo 6-7 binary fissions – limiting resource gets exhausted – wait until they are transferred to fresh medium next day

Saved samples at periodic intervals (once every 100 generations initially; once every 500 generations later)

Campbell's Biology Figure 27.10
https://simple.wikipedia.org/wiki/Erlenmeyer_flask

# Evolution in the laboratory




Fitness of the population measured as the rate at which each population grew

Initially, rate increased rapidly but slowed down later

Campbell's Biology Figure 27.10

**We can evolve desired traits in the lab: antibodies that bind with higher affinity to cancer antigens; enzymes that can degrade plastics, etc., etc.**

# Restating the “funda” behind evolution

Organisms show different traits due to differences in their DNA

Some of these traits may give an advantage in survival, when adverse environmental conditions hit the population

Organisms that survive will pass on those traits to their offspring

The traits will predominate in the population

# Drug resistance is an example of evolution

Probability of a spontaneous mutation in a gene: $1 \times 10^{-7}$ per cell division

Number of *E. coli* cells that arise newly in a person's intestine: $2 \times 10^{10}$ per day

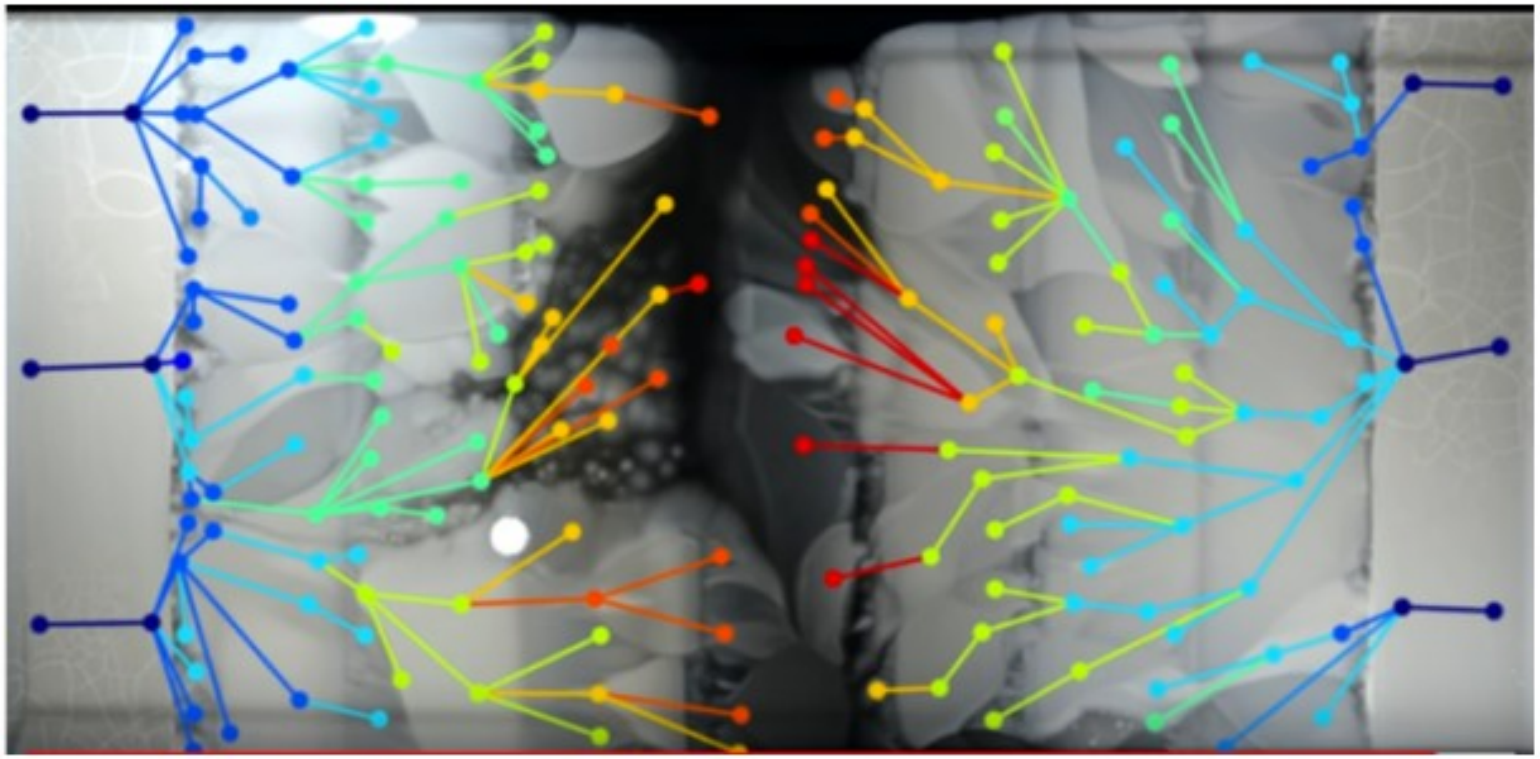
Number of mutations in a gene in the population: $2 \times 10^{3}$ per day

Key point: mutation rates are very low but are sufficient to quickly generate genetic diversity in species with short generation times and large populations

**If we do not take the full dosage of antibiotics, then pathogenic bacteria can survive and replicate. They can evolve to have mutations that confer drug resistance.**

Chest X ray of a patient with XDR tuberculosis

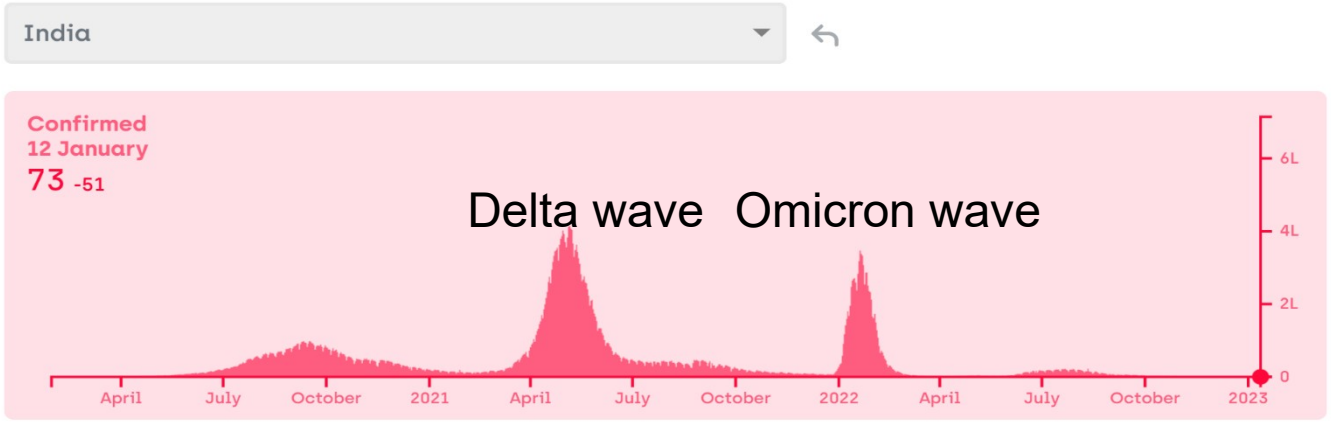
# Simulating the evolution of drug resistance



https://science.sciencemag.org/content/353/6304/1147.full

https://youtu.be/plVk4NVIUh8

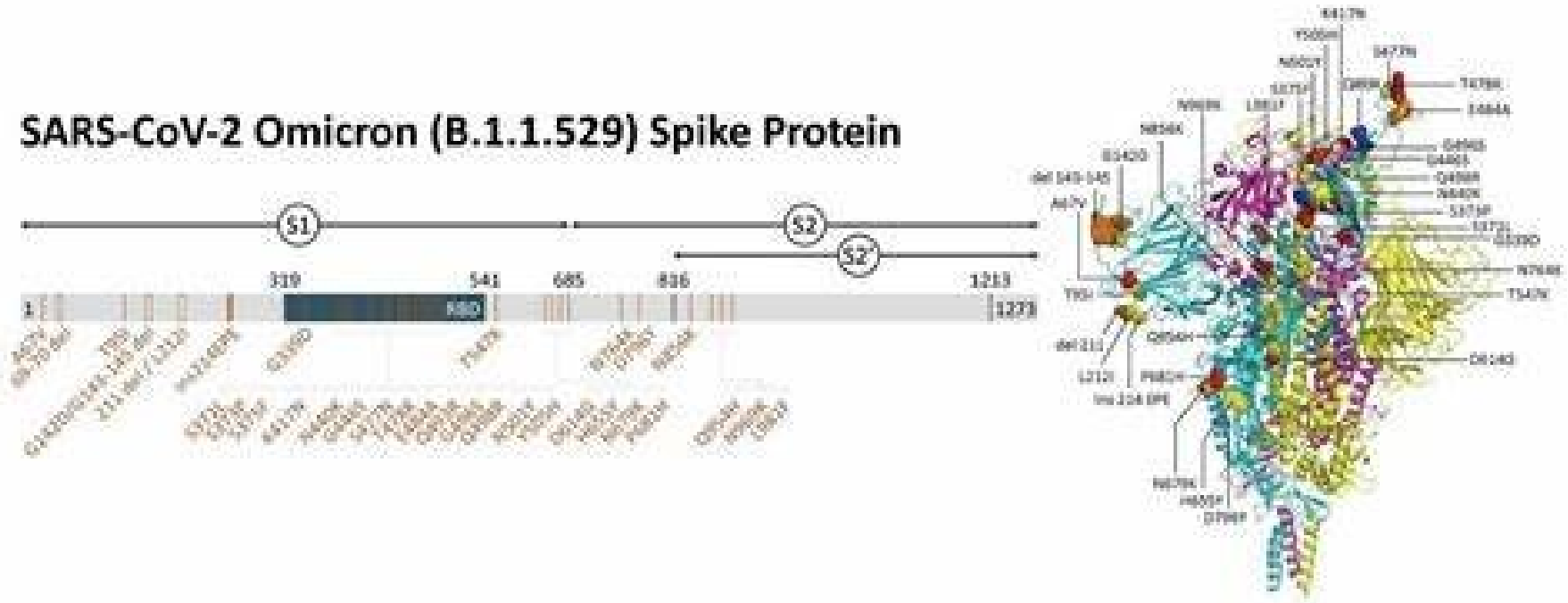
# Data from covid19bharat.org




What is happening to the SARS CoV-2 virus to cause these waves of infection in two years?

The virus is replicating in the human population and acquiring mutations: many neutral / deleterious and some beneficial for viral growth, replication and transmission.

# Evolution of SARS CoV-2

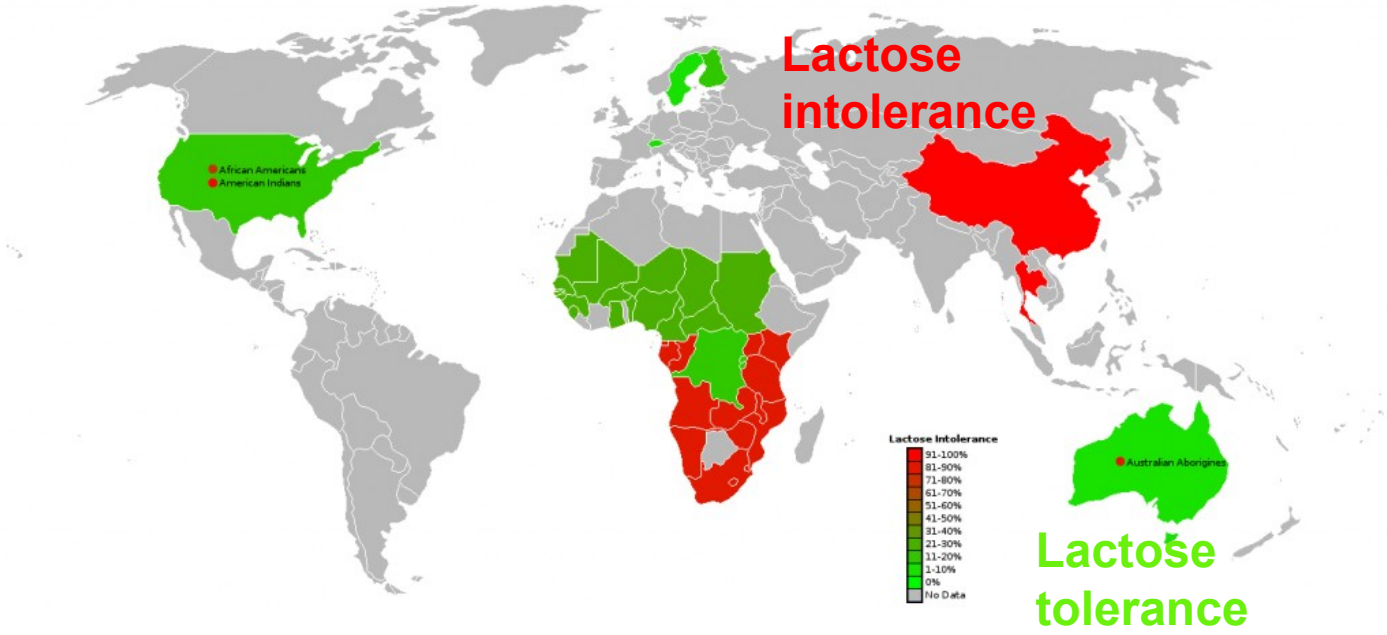



The Omicron wave was caused by a virus that had multiple mutations in the spike protein. These may have caused higher transmission.

The Delta wave was caused by a virus that preferred to infect the lungs, while the Omicron wave was caused by a virus that preferred to infect the upper respiratory tract.

Is SARS CoV-2 evolving to become less lethal? Does not help it to kill the host!

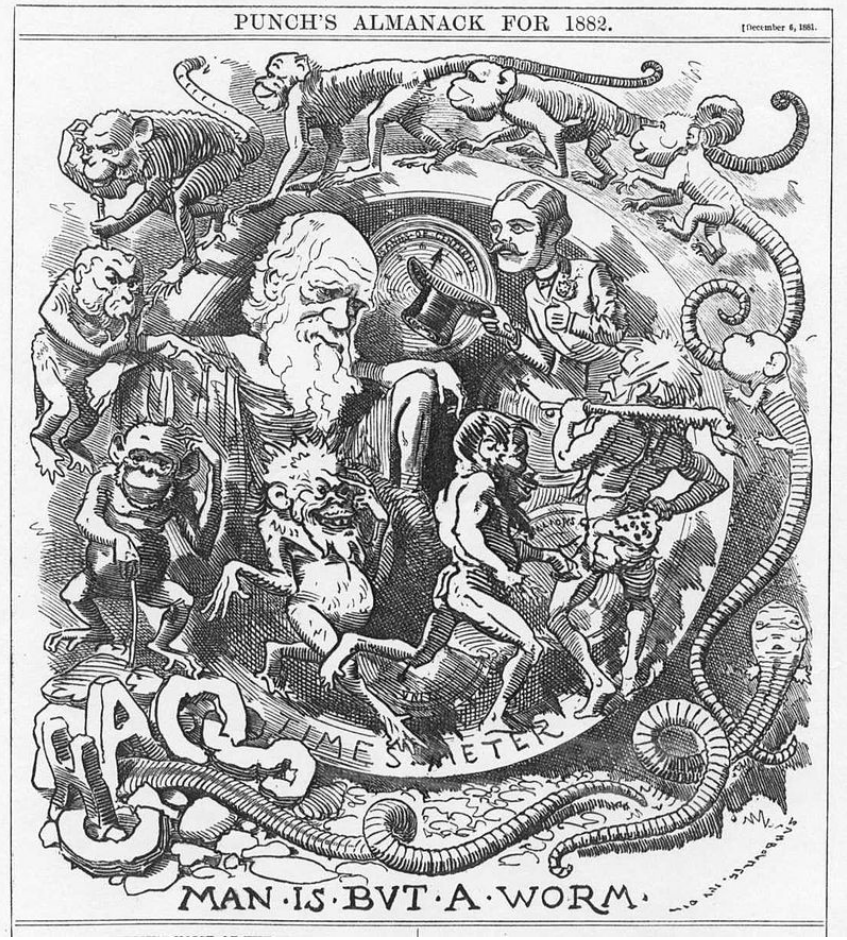
# Got milk?



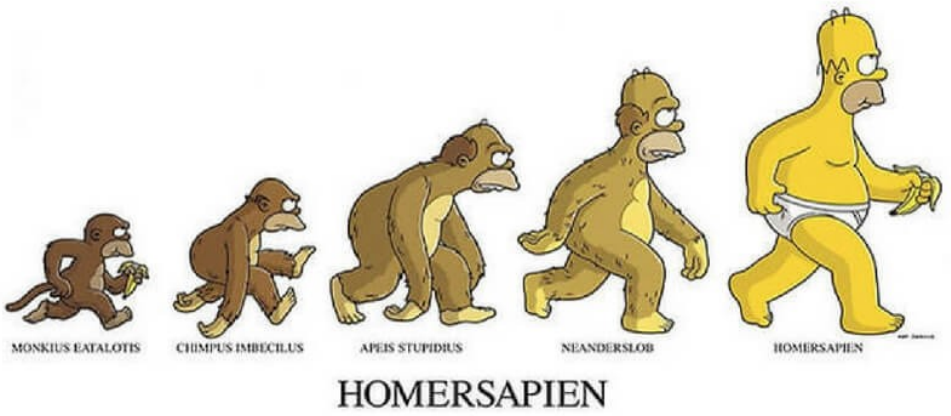

Lactase persistence (LP) has risen to high frequency in central and northern Europeans in the last 20,000 years. This trait is likely to have conferred a selective advantage in individuals who consume appreciable amounts of unfermented milk.

**Lactase mRNA is expressed at high levels in individuals who have lactase persistence. Why did it take 20,000 years? Where might DNA variations be in these people?**

# Darwin's theory was no joke!




Cartoon in the "Punch" magazine shortly after Darwin published his book




Cartoon of Homer Simpson evolving