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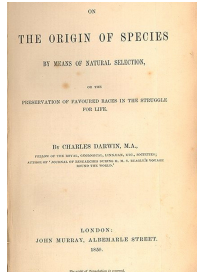
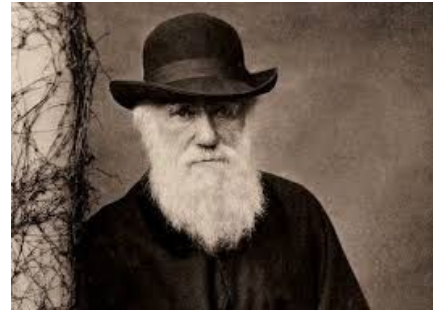
# Evolution by Natural Selection

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Introduction to Evolution and Scientific Inquiry  
Dr. Spielman; [spielman@rowan.edu](mailto:spielman@rowan.edu)

# The Origin of Species (1859)



- "...amongst organic beings in a state of nature there is some individual variability."
- "How have all those exquisite adaptations of one part of the organisation to another part, and to the conditions of life, and of one distinct organic being to another being, been perfected? We see these beautiful co-adaptations most plainly in the woodpecker and missletoe; and only a little less plainly in the humblest parasite which clings to the hairs of a quadruped or feathers of a bird; in the structure of the beetle which dives through the water;..."



# The struggle for existence

"A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product."

# Why aren't there billions of elephants?

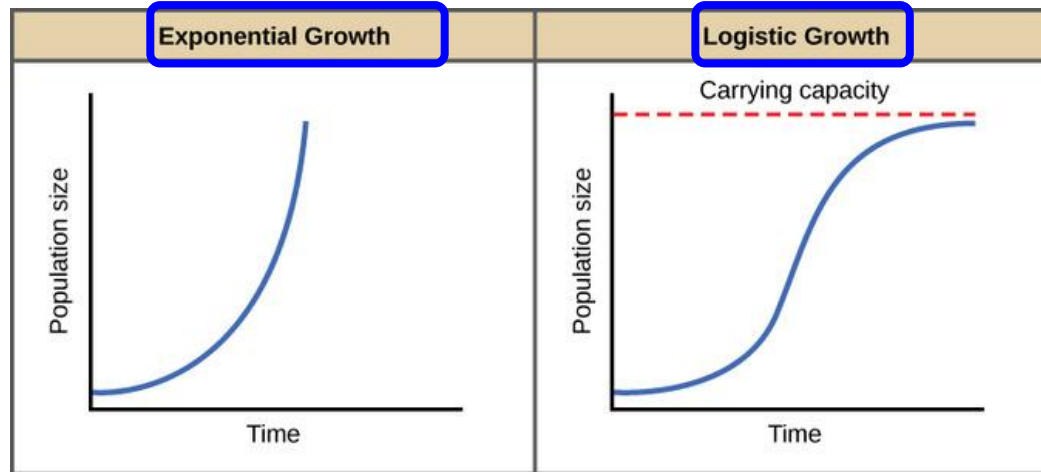


"The elephant is reckoned to be the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase: it will be under the mark to assume that it breeds when thirty years old, and goes on breeding till ninety years old, bringing forth three pairs of young in this interval; if this be so, at the end of the fifth century there would be alive fifteen million elephants, descended from the first pair."

# The struggle for existence occurs due to carrying capacity

- **Carrying capacity** = the number of individuals the environment can support

Exponential (geometric):  
Population will keep growing forever, faster and faster



Logistic:  
Population grows exponentially (geometrically) until it reaches carrying capacity, then tapers off

See page 27 of textbook, figure 3.2

# Evolution by natural selection\*

"A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as **more individuals are produced than can possibly survive**, there must in every case be a **struggle for existence**, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life."

**Plain english: Individuals with traits that give them an advantage in survival or reproduction are more likely to survive than other individuals. Over time the population will tend to have this trait more and more.**

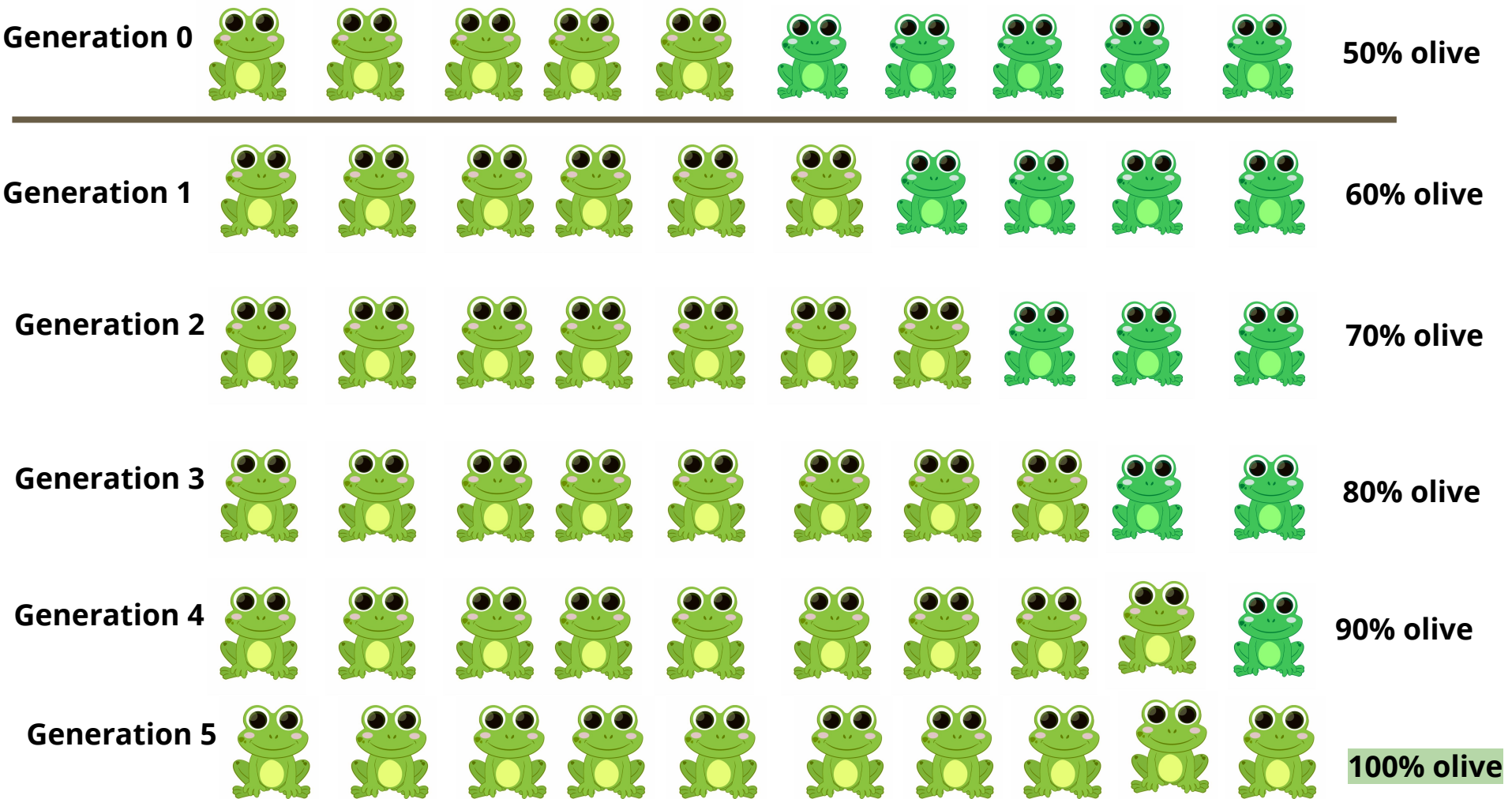
\*Natural selection is NOT the only way evolution happens!

# Natural selection in action!

In a **population** of frogs, some are olive green and some are bright green.

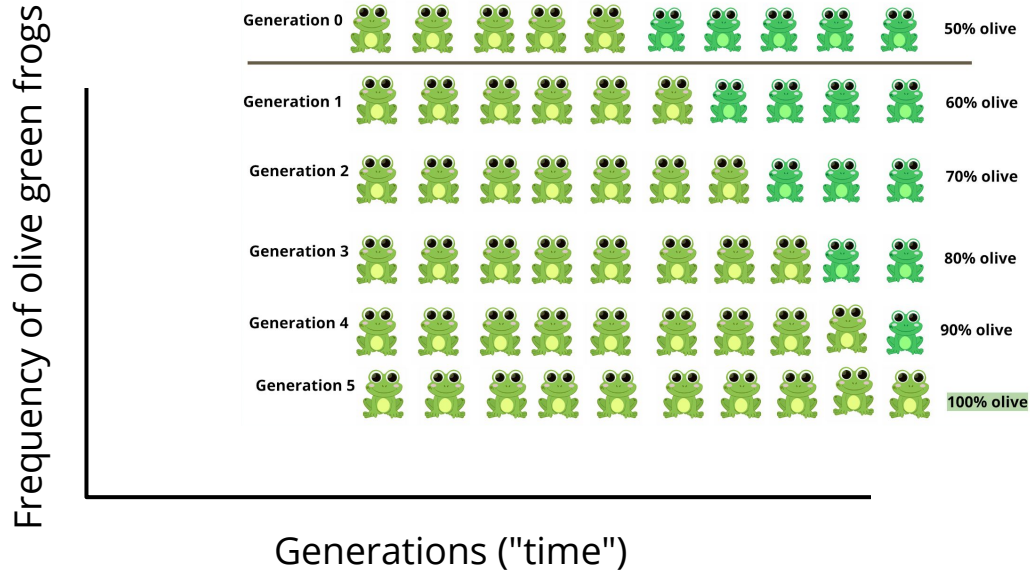


The olive green frog tends to be better at hiding from predators, through camouflage. This is a survival advantage, meaning olive frogs *have a higher fitness*.





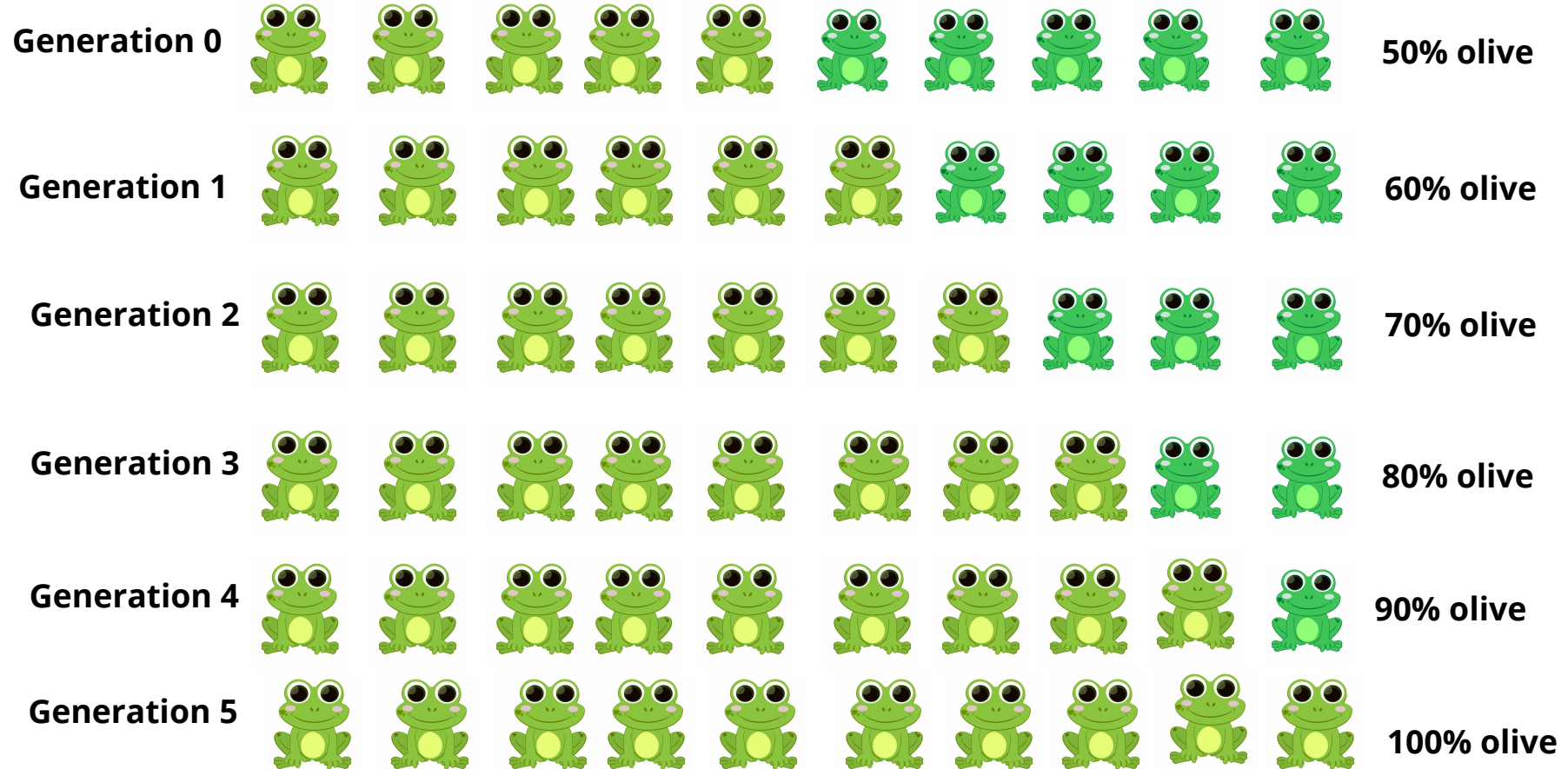
# With your table, graph this data



# Conditions that allow for natural selection to occur

1. There is **variation** in natural populations
2. The variation is **heritable**
3. More offspring are produced than will survive each generation, because there is a **struggle for existence**
4. If the heritable variation affects fitness, some individuals are more likely to survive than others. Their traits will be more common in the next generation.

# Which generation(s) *cannot* experience natural selection?



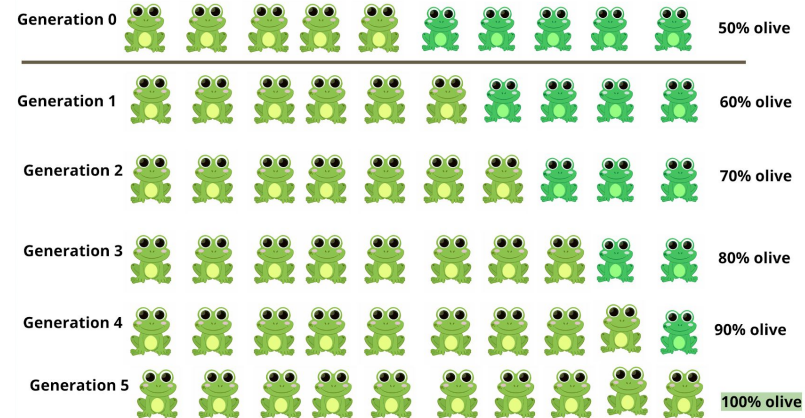
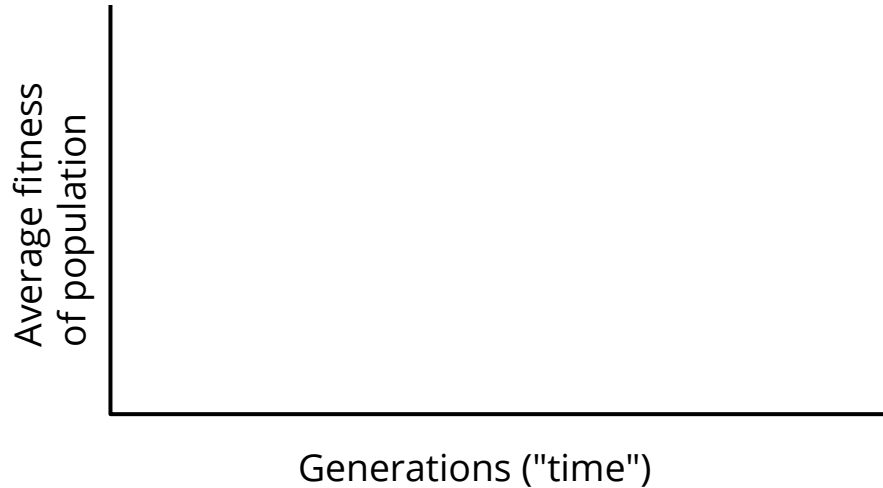
# Natural selection increases the fitness of the population



Olive fitness = 1.0



Olive fitness = 0.9



# “Survival of the fittest”

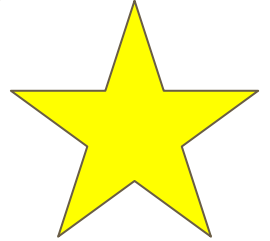
- Fitness is how well an organism **survives** and **reproduces**
  - There is no specific formula for fitness!!! People use fitness “proxies” in experiments
- "I should premise that I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) **not only the life of the individual, but success in leaving progeny.**"

# What do we mean by "evolution" in biology?

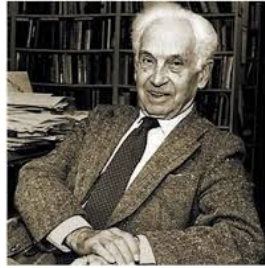
Biological evolution is *heritable* change in *populations* over *time* (generations)



- Heritable: evolving trait requires a genetic\* basis
- Populations: individuals do not evolve
- Time: evolution occurs over multiple *generations*, not within a generation

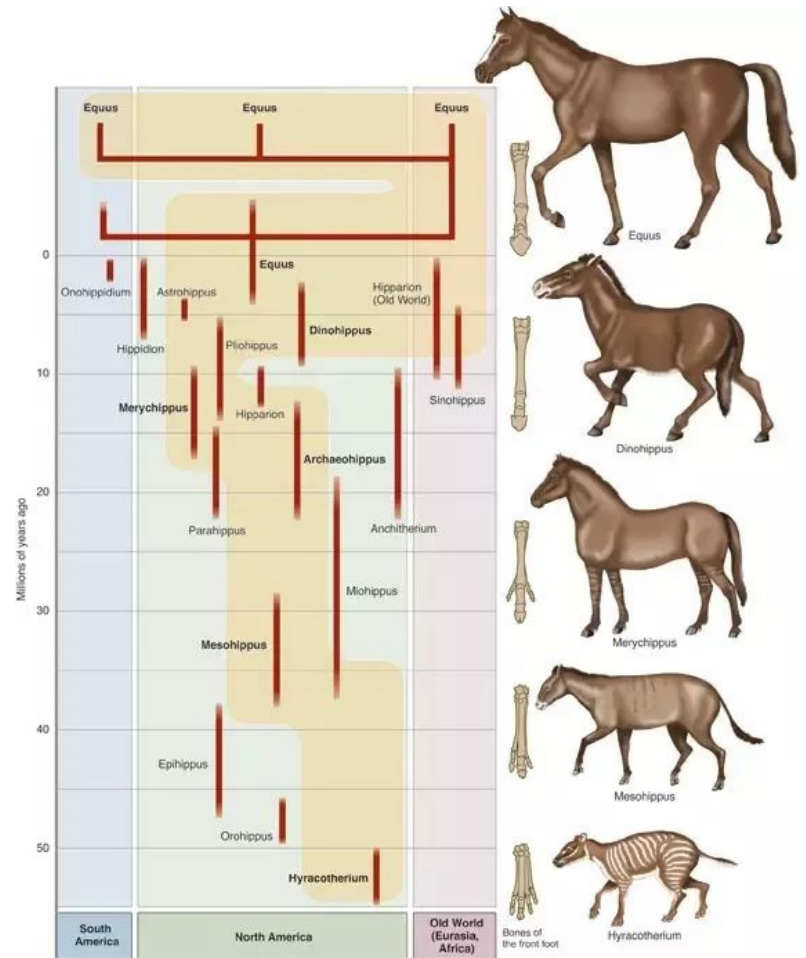


# The "Five Model" view of evolution



1. **Evolution "per se":** the very idea that evolution occurs
2. **Natural selection:** Darwin's primary mechanism for how evolution occurs. Competition and variation mean that some individuals are more likely to survive than others.
3. **Multiplication of species:** Eventually, with enough changes over time, populations will eventually become entirely new species\*
4. **Common descent:** Species are related through ancestry. All species are, to one degree or another, related to each other.
5. **Gradualism:** Evolution is (generally) a very slow process

# Multiplication of species, as seen in fossil record

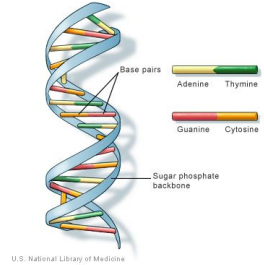


Red bars show when  
the fossil was observed

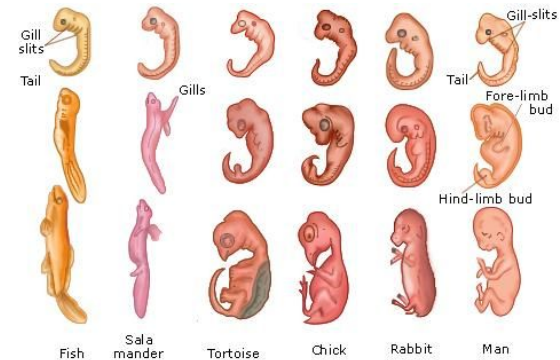
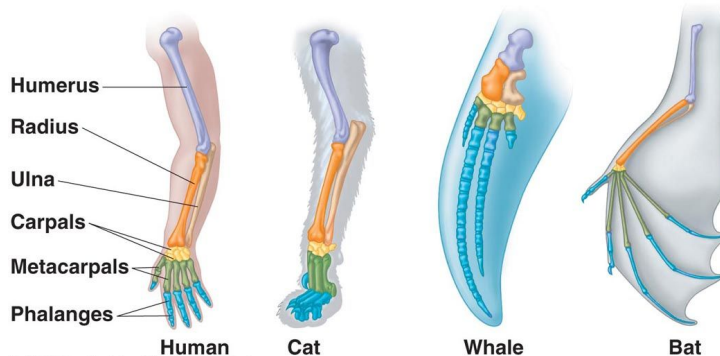


# Evidence for common ancestry is everywhere

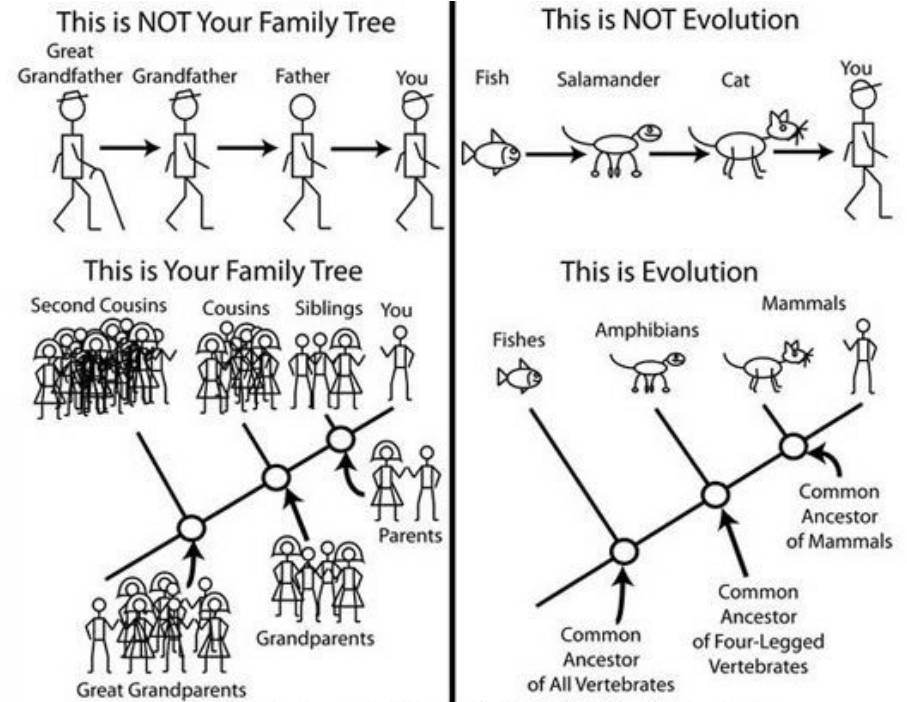
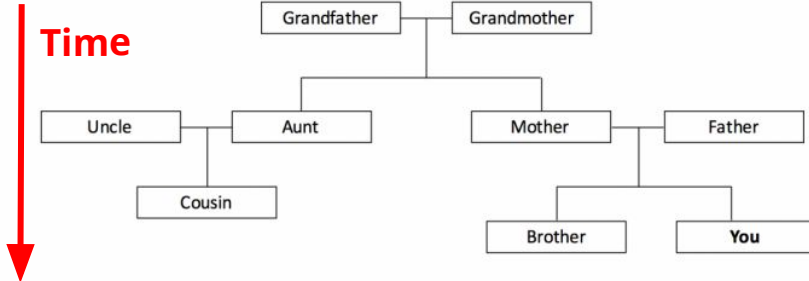
- **All** organisms on earth, use the same genetic code: DNA
- In fact, there are some genes that **all organisms have!**



- Shared anatomy and development provides evidence for **descent with modification**



# Common descent is represented by an *evolutionary tree* ("*phylogeny*")



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

# Some common misconceptions about evolution

1. Humans represent the "goal" of evolution
  - a. Humans are no longer evolving
2. Evolution represents steady progress towards "improving" species
3. Some species/populations are "more evolved"
4. Evolution studies the origin of life on Earth
5. ....?

[https://evolution.berkeley.edu/evolibrary/misconceptions\\_faq.php](https://evolution.berkeley.edu/evolibrary/misconceptions_faq.php)

# The fossil record shows evolution "in action"

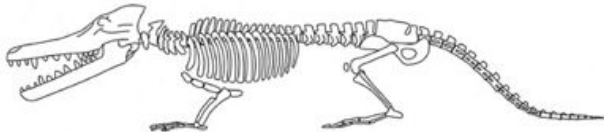
52 million year old  
mammal fossil



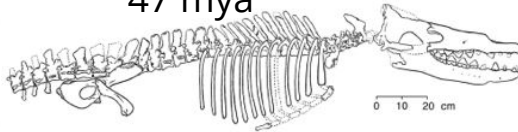
??????



50 mya



47 mya

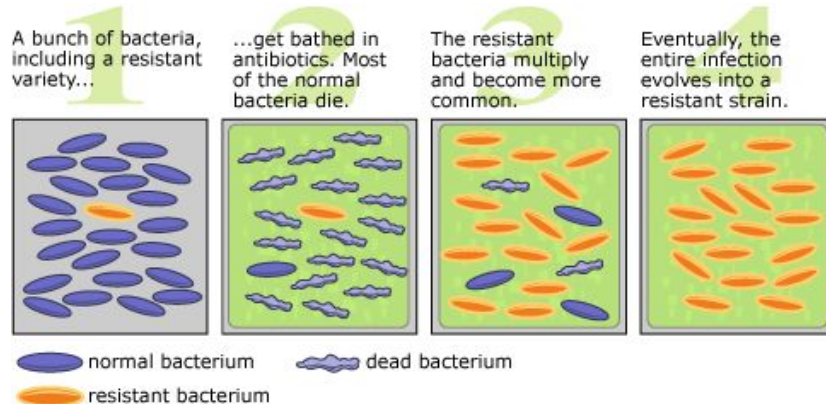


35-40 mya



# Evolution is happening before our eyes in pathogens like viruses and bacteria

- Why do we get a flu vaccination every year?
- Antibiotic resistance evolves and spreads rapidly



# Studying evolution at different timescales

- Microevolution
  - Evolution within a species, i.e. evolution of *populations*
  - Changes in allele frequencies across generations
  - We can directly study this
- Macroevolution
  - Evolution between species, i.e. how does an ancestor *diverge* into new species?
  - We infer from genomic and fossil data
- **Uniformitarianism:** The forces that formed and shaped the earth are the *same* forces that are acting today (geologist James Hutton, 1785)

**Macroevolution = microevolution over different periods of time**

# Types of phenotypic variation

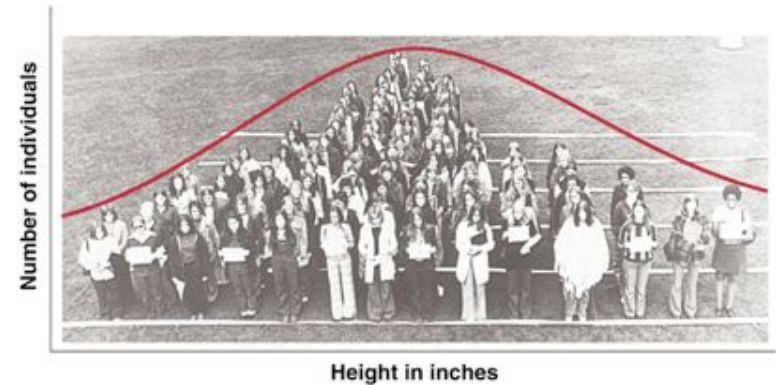
Discrete ("discontinuous")

vs.

continuous



Tobin/Dusheck, Asking About Life, 2/e  
Figure 16.6





# Harlequin ladybirds show variation in spot patterns

Over 200(!) distinct color forms of the species *Harmonia axyridis* have been described





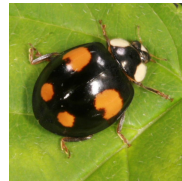
# Is a trait ("phenotype") heritable?



**Heritable spot patterns**



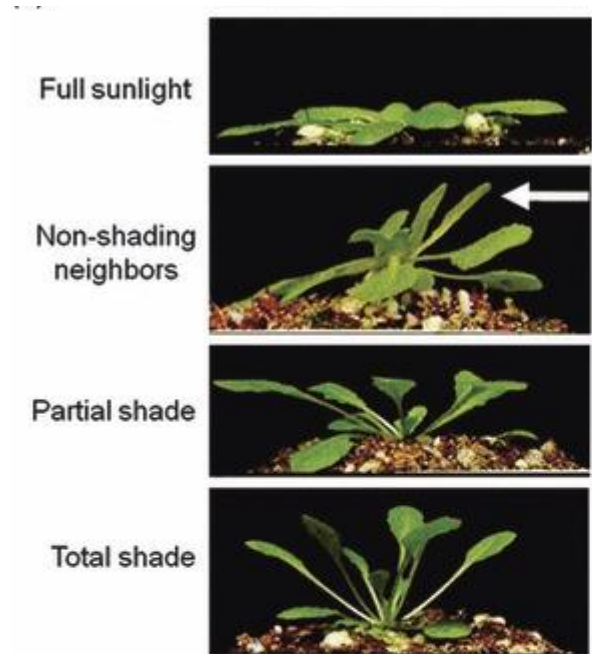
**NOT heritable spot patterns**



**What causes variation in a trait, if not genetics?**

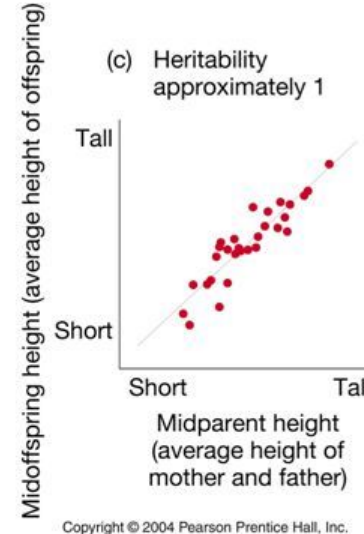
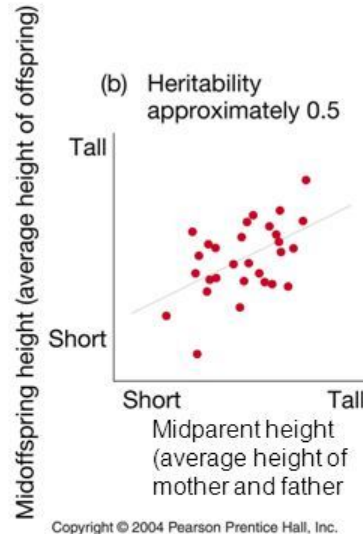
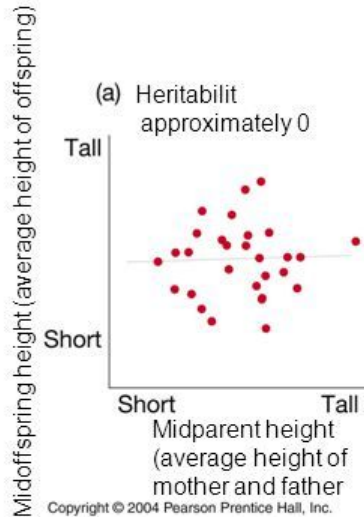
# Variation can also come from the environment

- Total variation = genetic + environmental
  - Genetic variation is *heritable*
  - Environmental variation is *not heritable*
- Most traits are some combination of genetic and environmental



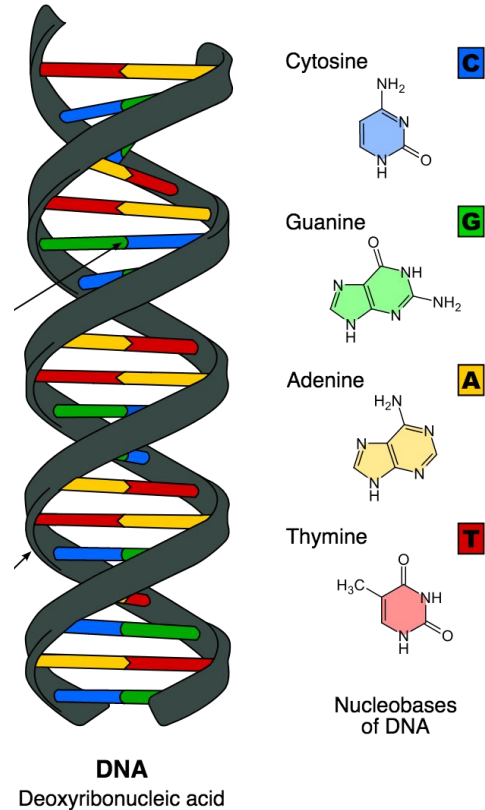
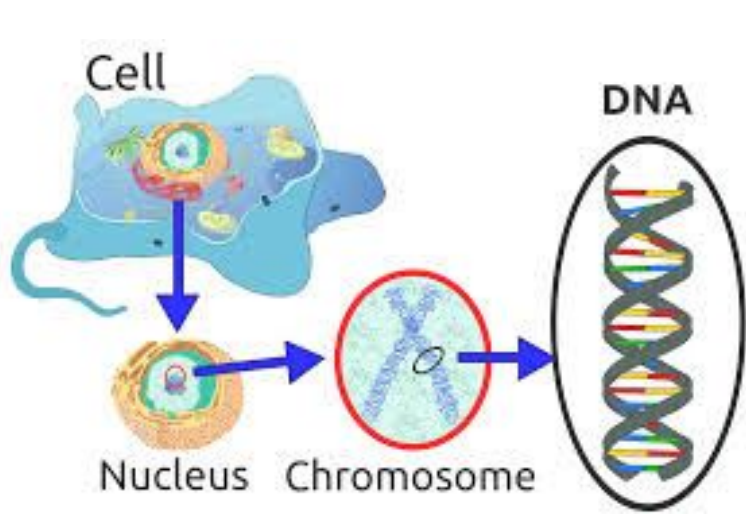
# How can we test if a trait is heritable?

**Midparent-midoffspring regression** shows the relationship between parent and children values for a trait



Slope of 0 = not at all heritable  
Low slope = somewhat heritable  
High slope = highly heritable

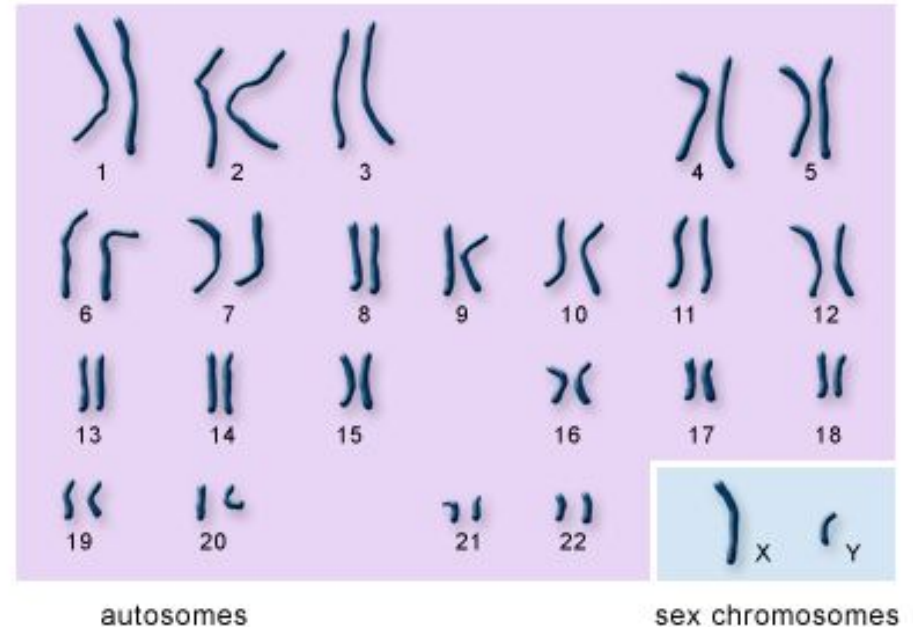
# The genetic basis of variation: A brief overview



# Humans have 23 *pairs* of chromosomes

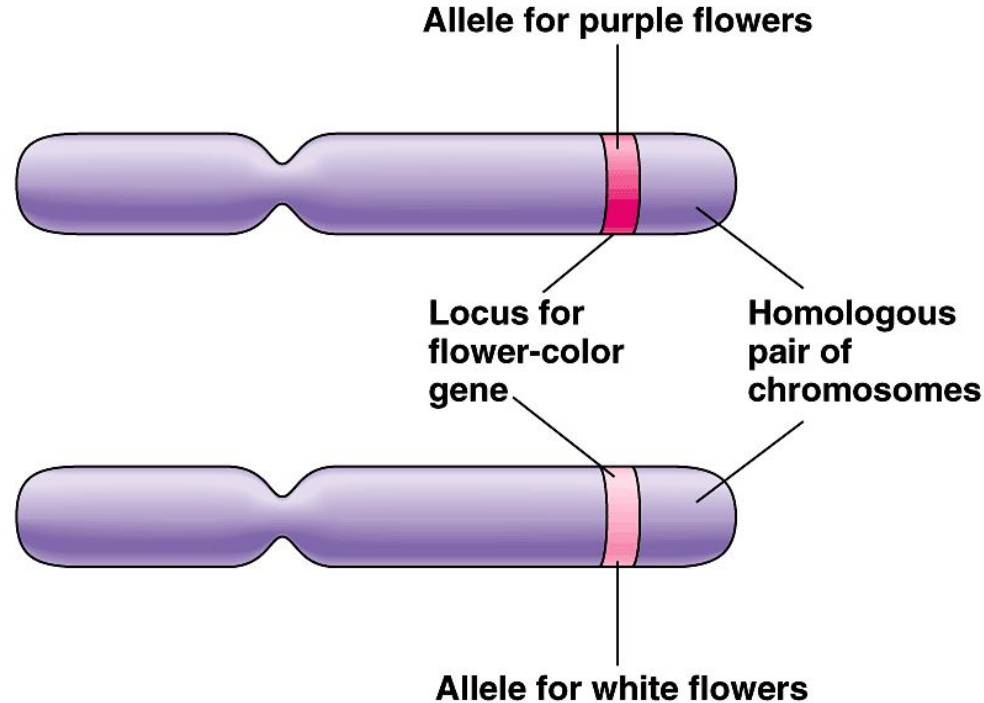
One copy from mom, one copy from dad

Across the chromosomes, there are roughly 20,000 genes



U.S. National Library of Medicine

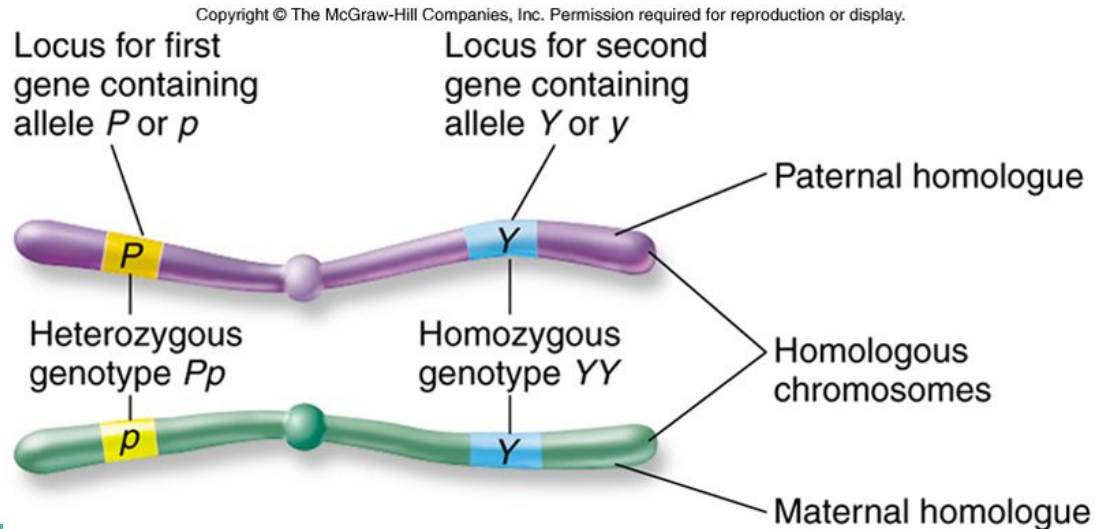
Each homologous chromosome has a version of the each gene. Versions are called alleles.



# Genetic terminology

**Homozygote:** An individual with the *same* version (allele) of the gene on both chromosomes




**Heterozygote:** An individual with a *different* allele on each chromosome



# Genetic terminology

Phenotype = physical appearance

Genotype = underlying genetics

Phenotype		Genotype
Purple		<i>PP</i> (homozygous)
Purple		<i>Pp</i> (heterozygous)
White		<i>pp</i> (homozygous)



# Types of phenotypic variation

*Discrete* variation is usually caused by a single gene

"Big A, little a" combinations.

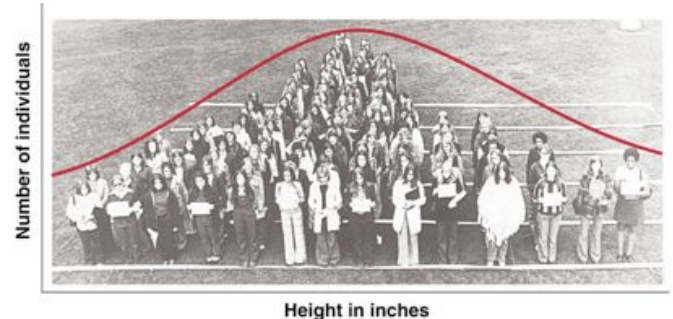
AA: black

Aa: black (with "A" dominant)

aa: white



*Continuous* variation is usually a complex result of *hundreds or thousands* of interacting genes. The exact genotype is often unknown.



# How many alleles does each gene has? Is it always "big A, little a"?

Some genes have **one** allele in a species

Some genes have **dozens or hundreds** of alleles in a species

Brainstorm: Why are there different numbers of alleles across genes? Are more alleles "good", "bad", "neutral"?