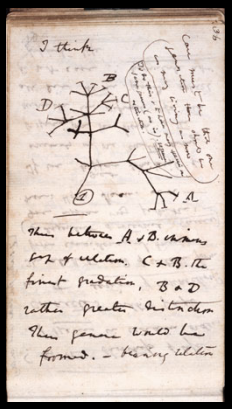
The history of evolutionary theory & natural selection



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Where do initial ideas about natural history come from?

- Every culture has their origin/creation stories
- Mythological/religious cosmologies
- e.g., Vedic Sanskrit texts describe a heliocentric system – further developed by Indian astronomers Yajnavalkya (9-8 century BC), Aryabhata (476-550 CE) and Bhaskara (1114– 1185 CE)

2

Impediments to the development of the theory of evolution

- Concept of fixity of species
- Concept of the great chain of being
- A short geological time scale

3

Early Western ideas about natural history

- Fixity of species
  - Every species was created in the past exactly as it appears today.
  - No new species can be created or go extinct.
  - Species diversity (variation) is just 'noise' in the system around an 'ideal type'.
  - Part of religious doctrine from the Western Middle Ages – naturalists were trying to seek God's purpose, rather than natural mechanisms.

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Early Western ideas about natural history

- "The great chain of being" (*Scala naturae*)
  - Aristotle, 4th c BC
  - The idea that all organisms exist in a hierarchical ladder with humans on the top rung

Didacus Valades, *Rhetorica Christiana* (1579)

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Biblical literalism

- Archbishop James Ussher, 1581-1656
- Natural theologian
- Counted up descendants of Adam & Eve in the Bible & determined the world began on Oct 23, 4004 BC

  – young Earth (6,000 years old)

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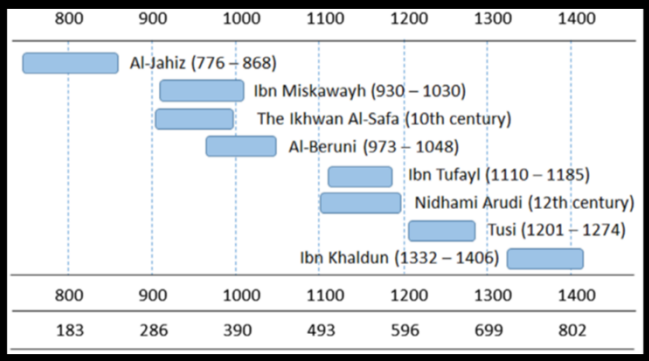
Muslim scholars (8th-14th c)



Malik et al. (2017)

- Many ideas foreshadowing key points of modern evolutionary theory!
  - kingdoms of life; common descent (esp. w/ monkeys); struggle for existence; change over time

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European Renaissance (14-16 c)

- social change – with the advent of capitalism, society is not as rigidly stratified or hierarchical as it once was
  - possible to move up/down the social ladder
- Colonization of "new" lands and "discoveries" of "new" species
- world view no longer of a fixed, unchanging world

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European Renaissance (14-16 c)

- ASTRONOMY: The Copernican revolution showed the Earth is not the center of the universe. The heavens are not immutable, but rather change.
- PALEONTOLOGY: Scientists began to see how structures in fossilized organisms changed through time.
- GEOLOGY: It was determined that the Earth was much older than 6 000 years, thus allowing time for evolution to occur.

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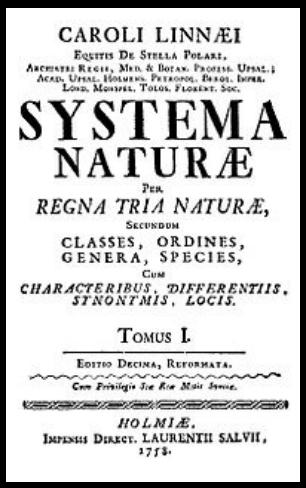
Classification of the living world

- Carl Linnaeus (1707-1778): *Systema Naturae* (Systems of Nature)
- Classification of plants & animals using binomial nomenclature
- Genus & species names - e.g., *Homo sapiens* for human beings
- Placed humans within the animal kingdom, but still believed in fixity of species.


CAROLI LINNÆI
EQUITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.;
ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

SYSTEMA NATURÆ

PER
REGNA TRIA NATURÆ,
SECUNDUM
CLASSES, ORDINES,
GENERA, SPECIES,
CUM
CHARACTERIBUS, DIFFERENTIIS,
SYNONYMIS, LOCIS.

TOMUS I.

EDITIO DECIMA, REFORMATA.

HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1758.

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Ideas about adaptation

- Count George-Louis Leclerc de Buffon: *Natural History* in 1749
- Emphasized importance of a changing universe & changing nature of species
- Outlined ideas using comparative anatomy, geology, biogeography…
- STILL DID NOT believe that one species could evolve into another.
- BUT, did understand that species can change by adapting to their environment.

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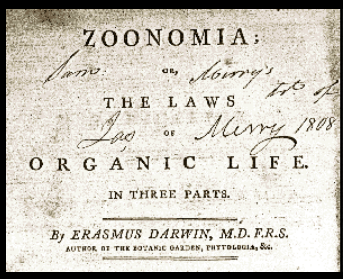
Precursors to the theory of evolution: Erasmus Darwin (1731-1802)

- Charles Darwin's grandfather
- Early supporter of evolution & idea of change in a species through time
- Believed that life originated in the seas & that all species are descended from a common ancestor
- Ideas were not widely accepted because he did not provide a MECHANISM by which evolution occurs



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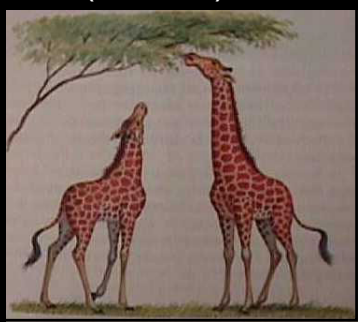
Inheritance of acquired characteristics

- Jean-Baptiste Lamarck (1744-1829)
- The first to try to explain HOW evolution works - tried to get at the mechanism behind evolution
- The key factor was the environment (correct)
- Species changed due to environmental influences
- Coined term "biology"



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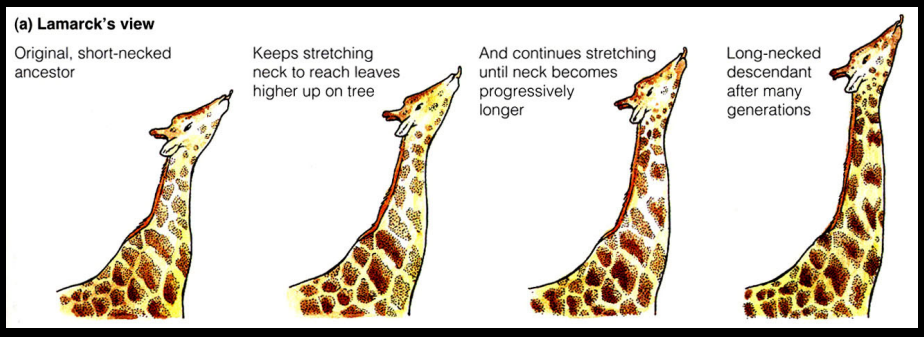
Lamarck's theory of the inheritance of acquired characteristics



Activity changes to accommodate a new environment. Certain body parts may be used more than others. As a result, the structure is modified. As the change provides a benefit to the organism, the new trait is passed down to its descendants – "Lamarckian evolution"

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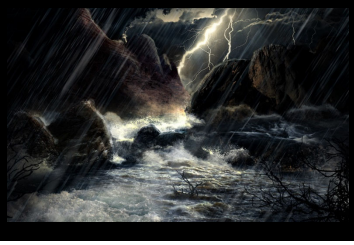
Catastrophism

- Georges Cuvier proposed the idea of EXTINCTION to explain the disappearance of animals represented only by fossils
- Worldwide catastrophic events responsible for the Earth's geological features
- Once extinction occurs, new & more advanced forms colonized the region. These new forms are the result of more recent creation events.



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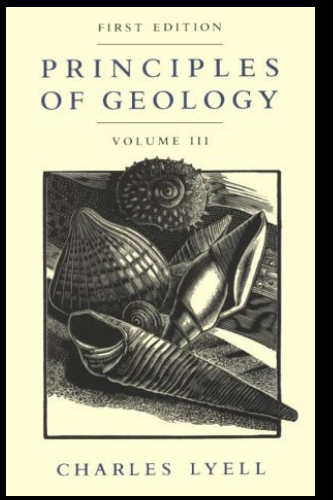
Uniformitarianism: "The present is key to the past"

- The Earth looks the way it does today as the result of LONG-TERM processes that operated in the past and continue to operate today (unlike catastrophism)
- James Hutton, Charles Lyell
- Implied the Earth is MUCH OLDER – many millions of years old, not a few thousand
- Darwin read it on the *HMS Beagle*



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Struggle for existence

- Thomas Malthus (1766-1834) *Essay on the Principle of Population*
- Populations have a limitless potential for reproduction unless they are kept in check by limited food supplies.
- In nature, population growth is controlled by resource availability - this leads to a struggle for existence
- both Darwin and Wallace read it

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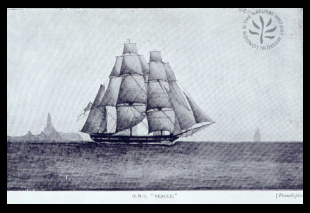
Charles Darwin (1809-1882)

- Studied medicine at Edinburgh University, dropped out after two years! Most of his professors were supporters of Lamarck. Learned taxidermy from John Edmonstone.
- Studied theology at Christ's College in Cambridge. Immersed himself in botany & geology.
- After graduation (in 1831) he took an offer to sail for 5 years on the HMS Beagle as part of a scientific expedition as a "gentleman's companion" to Captain R. Fitzroy



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The HMS Beagle (1831-1836)

- Lyell's *Principles of Geology*
- Evidence that Earth had deep time scale - fossils similar to living species
- Ocean-living fossils on top of mountains
- Animals from different regions slightly different from each other

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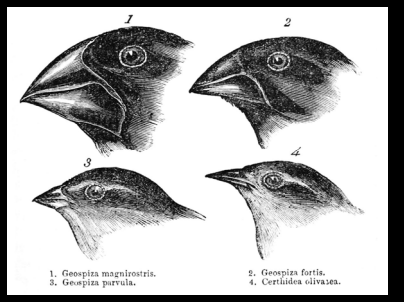
Darwin's Galápagos finches

- Island plants & animals similar to mainland, but not identical
- 12 different types of finches - different sized & shaped beaks
- 1 type on mainland = founding population
- Variation in Galápagos' finches due to different island habitats & diets
- How do we get from 1 species to 12?



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The origins of *natural selection*

- Based on concept of 'selective breeding' - select those animals that possess certain traits so they will be emphasized in offspring
- All domestic dogs (*Canis lupus familiaris*) share a common ancestor (wolf) - variation in dog breeds seen today is the result of artificial selection imposed by humans

- When 'natural' species develop, nature does the selecting - hence NATURAL SELECTION

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The origins of *natural selection*

- In 1838 Darwin read Malthus and realized that:
  - Populations increase at a faster rate than do resources.
  - As a result, there is a constant struggle for existence.
- He put the following ideas together:
  - more offspring are born than survive to adulthood
  - there is competition for resources
  - there is variation within species

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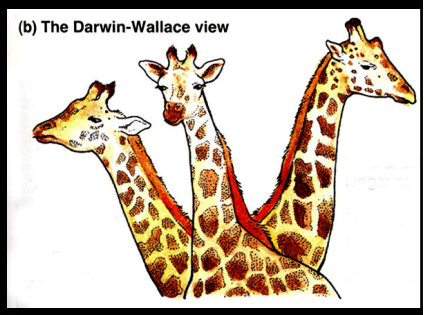
Darwin's theory of natural selection

- Original group exhibits variation in neck length
- Natural selection favors longer necks (e.g., to reach food)
- More long-necked giraffes survive to reproduce than short-necked giraffes
- After many generations, the group still varies in neck-length, BUT there is a general increase in average neck length



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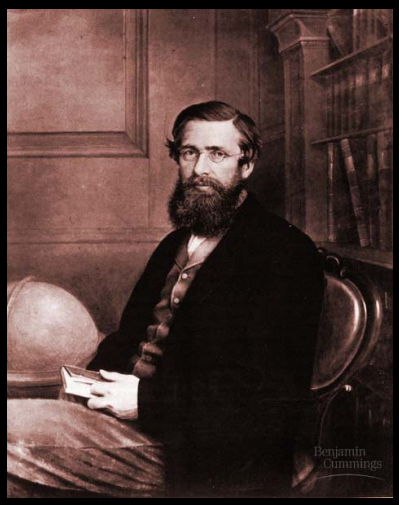
Alfred Russell Wallace (1823 - 1913)

- From 1846 spent time in the Amazon & Malaysia collecting birds & insects
- 1855: published a paper suggesting species descended from other species
- Darwin still resisted publication.
- 1858: Wallace sent Darwin another paper describing evolution as a process driven by competition & natural selection
- Prompted Darwin to publish



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The theory of evolution by means of natural selection

- All organisms are capable of producing offspring at a faster rate than food supplies can sustain.
- Because of limited resources, there is competition between individuals for access to these resources.
- Organisms vary & this variation is heritable.
- Individuals who possess favorable phenotypic traits (speed, disease resistance, etc.) have an advantage in competition for resources over those that do not. These individuals will survive & reproduce more.
- Which traits are advantageous depends on the particular environment at a given time.

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Darwin: *The Origin of Species*

"There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."

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Evidence for evolution in the 19th century

- Artificial selection (domestication)
- Biogeography (geographic distribution)
- Paleontology & archaeology
- Comparative anatomy
- Embryology

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Remaining questions

- Where did variation come from?
- How did inheritance work?

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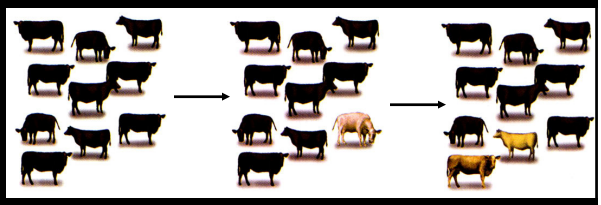
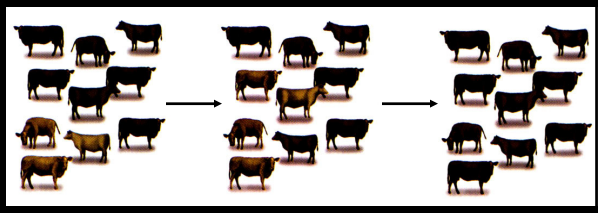
19th century: Blending inheritance

- Each parent contributes equally to offspring
- Contributions are halved at each successive generation
- PROBLEM for natural selection: any advantageous trait is "diluted" in each generation!



Herd of animals Mutants with increased fitness appear



Feature is 'blended out' with each passing generation

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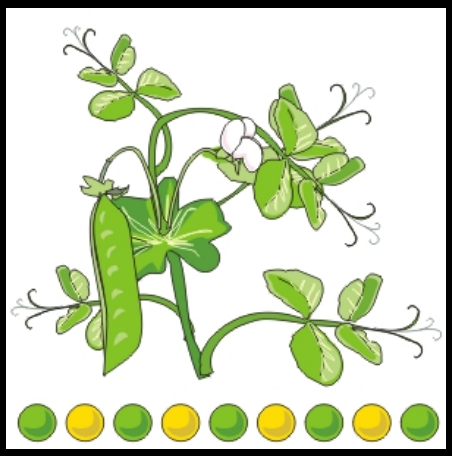
Gregor Mendel (1822-1884)



Pisum sativa

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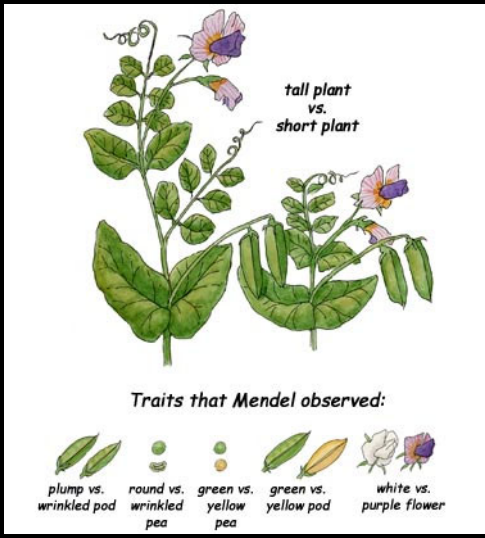
Mendel's pea experiments



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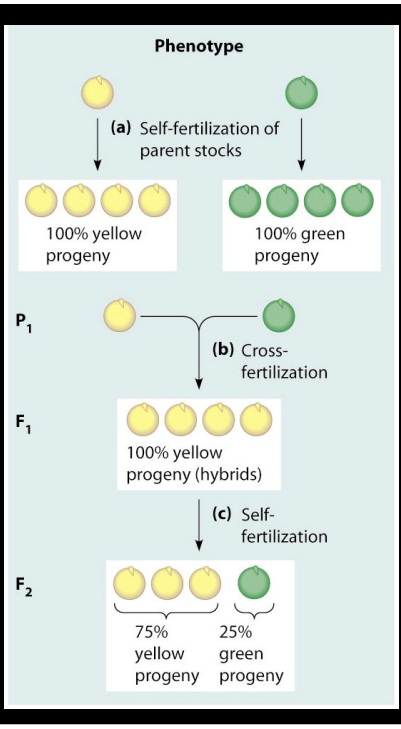

Mendel's Principle of segregation

- Expression of each trait controlled by discrete units (aka genes)
- Units occur in pairs
- Each offspring inherits one unit from each parent
  - a sex cell from a parent contains only 1 unit
  - upon fertilization, sex cells unite and the 2 units make a pair

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Mendel's Principle of segregation

- During the formation of gametes (meiosis), the paired chromosomes separate, or segregate, randomly so that each sex cell receives one or the other with equal likelihood.
- So, offspring may inherit either version of either parent's chromosome 1 & chromosome 2 etc… with 50% chance of each. (Parents inherited their different versions from their parents etc.)

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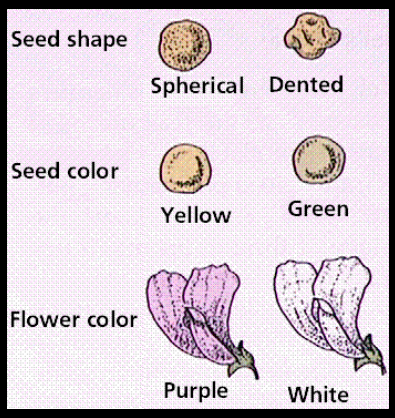
Mendel's Law of independent assortment

- Dihybrid crosses - looked at simultaneous transmission of two traits (e.g., seed color & flower color)
- The genes controlling different traits are inherited independently of one another.
- Results from the chance distribution of chromosomes to daughter cells during meiosis.



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Mendel's "unit" = GENE

- Basic unit of inheritance
- Segment of DNA that controls one or more traits (i.e., codes for a protein)

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Genes & alleles

- Different versions of a gene are called **alleles**
- Example, gene locus Z
  - A allele
  - a allele
- For most genes you will have two alleles, one 'version' from each biological parent
- Example, gene locus Z, three possible genotypes:
  - AA (homozygous A)
  - Aa (heterozygous)
  - aa (homozygous a)

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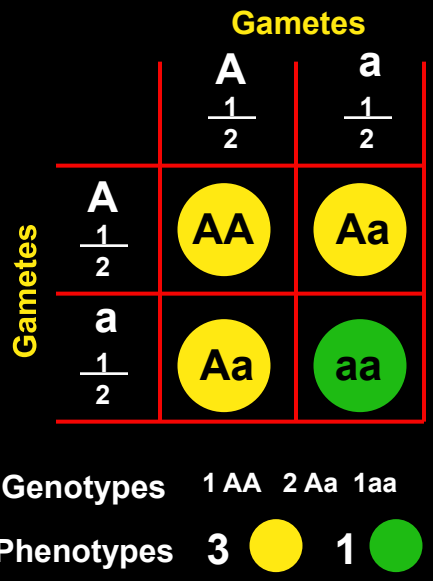
Dominant vs. recessive (alleles)

- Punnett square of F1 gametes and resulting F2 genotypes & phenotypes
- The dominant allele, if present, is always expressed.
- The recessive allele is only expressed in the phenotype if there are two copies - one on each homologous chromosome (otherwise it is masked)



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Mendelian traits

- Controlled by alleles at only one genetic locus.
- Examples include ABO blood type & genetic disorders such as sickle-cell anemia & Tay-Sachs disease
- In contrast to polygenic traits - phenotypic traits that result from the combined action of more than one gene (most complex traits are polygenic!)

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The Modern Synthesis

- Early proponents of Mendelism opposed Darwin's theory of natural selection.
- In the 1930s, various evolutionary biologists worked out the details of how natural selection could work with Mendelian genetics.
- Evolution by natural selection now possessed a well tested theory of heredity.

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Evolution (common usage)

Connotations of progress or hierarchy towards a long-term goal

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Evolution (in biology)

- Evolution in biology is simply *change over time*.
- There is no connotation of progress.
- There is, however, an implication that the past is connected to the present.

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Evolution: modern definition

- Evolution is a change in allele/gene frequencies over time.
- Gene frequency is a measure of the relative frequency of a gene at a particular genetic locus (an allele) in a population (%).
  - A population is a community of individuals within a species where mates are usually found.

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What is *allele frequency*?

- The allele frequency is simply the frequency of an allele at a particular locus in a population.
- Example, Population Y (8 individuals) at Locus Z
  - AA, Aa, aa, aa, AA, Aa, AA, Aa
- Example, Population Y at Locus Z (genotype frequencies)
  - AA 3/8 0.375 (37.5 % of the population is AA)
  - Aa 3/8 0.375 (37.5 % of the population is Aa)
  - aa 2/8 0.250 (25.0 % of the population is aa)
- Example, Population Y at Locus Z (allele frequencies)
  - Frequency of A 9/16 0.5625 (~ 56 %)
  - Frequency of a 7/16 0.4375 (~ 44 %)

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Remember!

- Allele frequencies refer only to populations - not individuals.
- Therefore, only a *population* can *evolve* over time - individuals cannot!

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