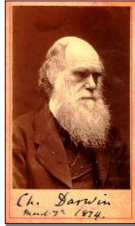


## Essence of Darwin's ideas

- **Variation** exists in natural populations
- Many **more offspring** are born each season than can possibly survive to maturity
- As a result, there is a **struggle for existence**
  - **competition**
- **Characteristics beneficial** in the struggle for existence will tend to become more common in the population, changing the average characteristics of the population
  - **adaptations**
- Over long periods of time, and given a steady input of new variation into a population, these processes lead to the **emergence of new species**



## LaMarckian vs. Darwinian view

- LaMarck
  - in reaching higher vegetation giraffes stretch their necks & transmits the **acquired** longer neck to offspring
- Darwin
  - giraffes born with longer necks survive better & leave more offspring who **inherit** their long necks



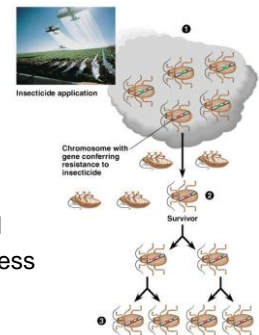
## Convergent Evolution

- filling similar ecological roles in *similar environments*, so similar adaptations were selected
- ...but are *not* closely related



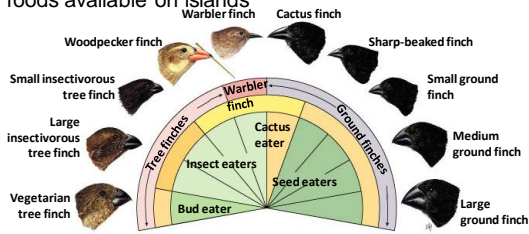
## Natural selection in action

- Insecticide & drug resistance
  - insecticide didn't kill all individuals
  - resistant survivors reproduce
  - resistance is inherited
  - insecticide becomes less & less effective

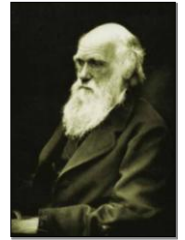


## Darwin's finches

- Differences in beaks
  - associated with eating different foods
  - survival & reproduction of beneficial adaptations to foods available on islands



## Evolution by Natural Selection



2006-2007



**DOCTRINE**

*the Creation of the Animals 1550*

## But the Fossil record



**OBSERVATION**



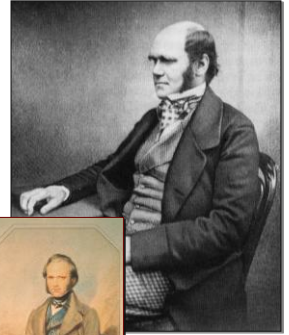
## LaMarck



- Organisms adapted to their environments by acquiring traits
  - ◆ change in their life time
    - **Disuse**  
organisms lost parts because they did not use them — like the missing eyes & digestive system of the tapeworm
    - **Perfection with Use & Need**  
the constant use of an organ leads that organ to increase in size — like the muscles of a blacksmith or the large ears of a night-flying bat
  - ◆ transmit acquired characteristics to next generation

## Charles Darwin

- 1809-1882
- British naturalist
- Proposed the idea of evolution by natural selection
- Collected clear evidence to support his ideas



## Voyage of the HMS Beagle

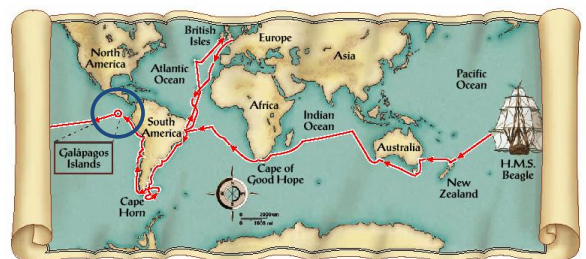
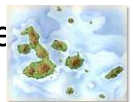
- Invited to travel around the world
  - 1831-1836 (22 years old!)
  - makes many observations of nature
    - main mission of the *Beagle* was to chart South American coastline

Robert Fitzroy



## Voyage of the HMS Beagle

- Stopped in Galapagos Islands
  - 500 miles off coast of Ecuador





## Darwin found... birds

Collected many different birds on the Galapagos Islands.

Thought he found very different kinds...



"This wonderful relationship in the same continent between the dead and the living will...throw more light on the appearance of organic beings on our earth, and their disappearance from it, than any other class of facts."

## But Darwin found... a lot of finches

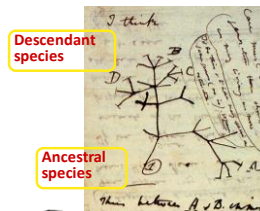
Darwin was amazed to find out:  
All 14 species of birds were finches...

But there is only one species of finch on the mainland!

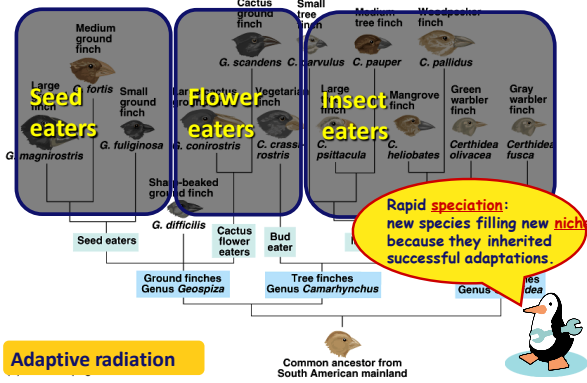


How did one species of finches become so many different species now?

## Tree Thinking

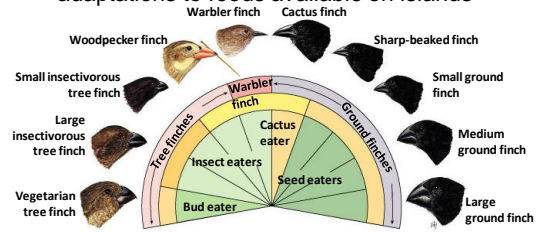


Correlation of species to food source



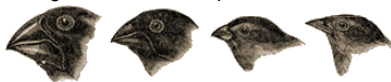
Darwin's finches

- Differences in beaks
  - associated with eating different foods
  - survival & reproduction of beneficial adaptations to foods available on islands

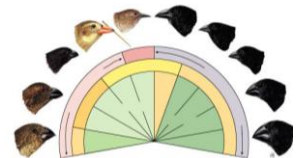
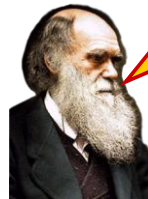


Darwin's finches

- Darwin's conclusions
  - small populations of original South American finches landed on islands
    - variation in beaks enabled individuals to gather food successfully in the different environments
  - over many generations, the populations of finches changed anatomically & behaviorally
    - accumulation of advantageous traits in population
    - emergence of different species



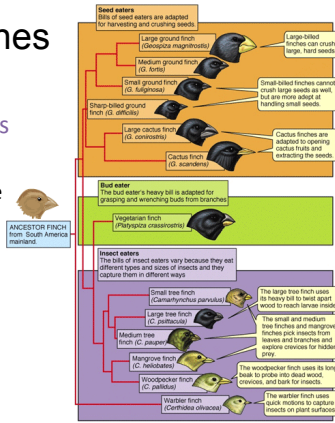
Seeing this gradation & diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species has been taken & modified for different ends.



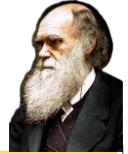
## Darwin's finches

- Differences in beaks allowed some finches to...

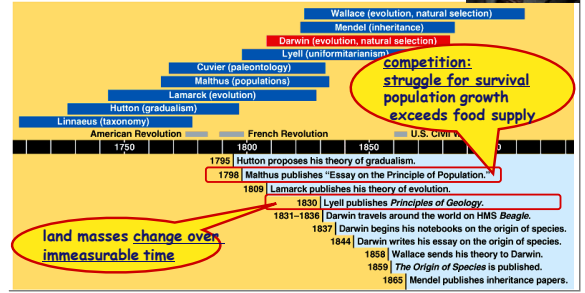
- successfully compete
- successfully feed
- successfully reproduce
- pass successful traits onto their offspring



## In historical context



- Other people's ideas paved the path for Darwin's thinking



## A Reluctant Revolutionary

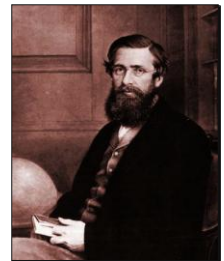
- Returned to England in 1836
  - wrote papers describing his collections & observations
  - long treatise on barnacles
  - draft of his theory of species formation in 1844
    - instructed his wife to publish this essay upon his death
    - reluctant to publish but didn't want ideas to die with him



## And then came the letter....

Then, in 1858, Darwin received a letter that changed everything...

**Alfred Russel Wallace**  
 a young naturalist working in the East Indies, had written a short paper with a new idea. He asked Darwin to evaluate his ideas and pass it along for publication.



Voyage: 1831-1836

# The time was ripe for the idea!

November 24, 1859, Darwin published

## "On the Origin of Species by Means of Natural Selection"

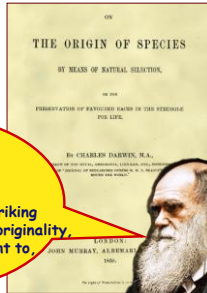
**1858 ON THE TENDENCY OF VARIETIES TO DEPART INDEFINITELY FROM THE ORIGINAL TYPE**  
 by Alfred Russel Wallace written at Ternate, February, 1858  
**Instability of Varieties supposed to prove the permanent distinctness of Species**

COPY of the strongest arguments which have been adduced to prove the original and permanent distinctness of species in their various provinces as a result of dissimilarity are here to their variety, and others have a tendency, if left to themselves, to revert to the original form of the parent species; but this tendency is counteracted in the respective provinces of all regions, and the result is a permanent and distinctness of species.

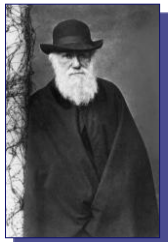
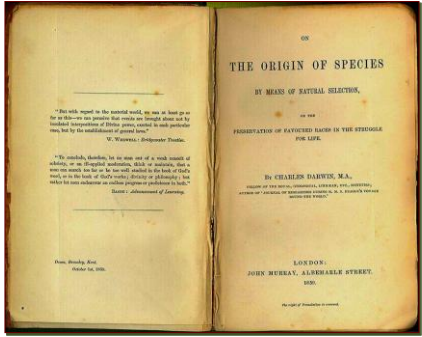
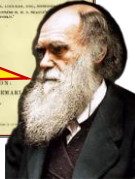
In the absence of society of force and other agencies, the tendency of varieties to depart indefinitely from their original form is not counteracted, and the result is a permanent and distinctness of species. This is the case with the various forms of the same species which are found in the same province, and the result is a permanent and distinctness of species.

It will be observed that the result of the present paper is to show that the various forms of the same species which are found in the same province, and the result is a permanent and distinctness of species.

**The Struggle for Existence.**



**To Lyell—  
 Your words  
 have come true  
 with a vengeance...  
 I never saw a more striking  
 coincidence...so all my originality,  
 whatever it may amount to,  
 will be smashed.**

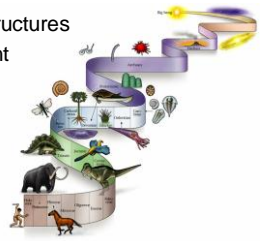


### Evidence of Evolution by Natural Selection



### Evidence supporting evolution

- Fossil record
  - transition species
- Anatomical record
  - homologous & vestigial structures
  - embryology & development
- Molecular record
  - protein & DNA sequence
- Artificial selection
  - human-caused evolution



## Fossil record

- Layers of sedimentary rock contain fossils
  - new layers cover older ones, creating a record over time
  - fossils within layers show that a succession of organisms have populated Earth throughout a long period of time

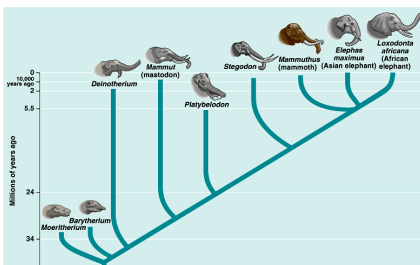


## Fossil Record



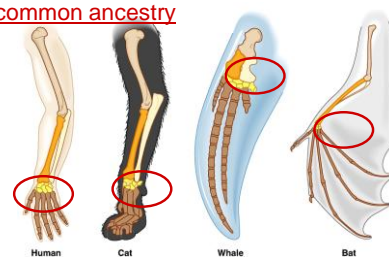
## Fossil record

- A record showing us that today's organisms descended from ancestral species



## Anatomical record

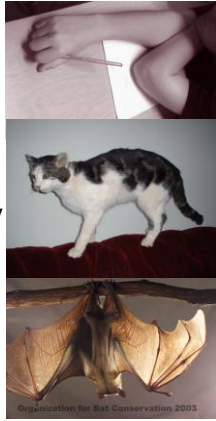
- Homologous structures
  - similarities in characteristics resulting from common ancestry





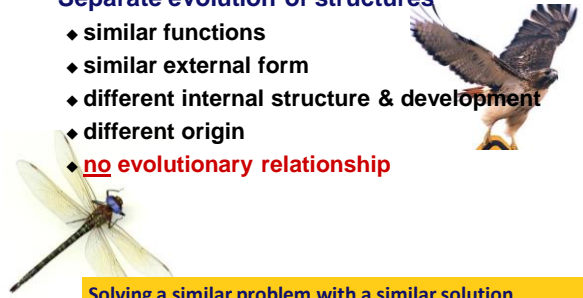
## Homologous structures

- Similar structure
- Similar development
- Different functions
- Evidence of close evolutionary relationship
  - recent common ancestor



## Analogous structures

- **Separate evolution of structures**
  - ◆ similar functions
  - ◆ similar external form
  - ◆ different internal structure & development
  - ◆ different origin
  - ◆ **no evolutionary relationship**



Solving a similar problem with a similar solution

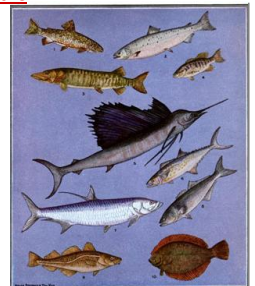
## Convergent evolution

- Flight evolved in 3 separate animal groups
  - evolved similar “solution” to similar “problems”
  - analogous structures



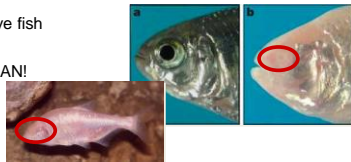
## Convergent evolution

- Fish: aquatic **vertebrates**
- Dolphins: aquatic **mammals**
  - ◆ similar adaptations to life in the sea
  - ◆ not closely related



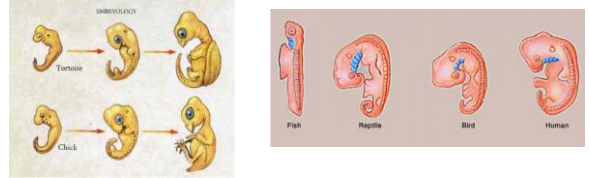
## Vestigial organs

- Modern animals may have structures that serve little or no function
  - remnants of structures that were functional in ancestral species
  - deleterious mutations accumulate in genes for non-critical structures *without* reducing fitness
    - snakes & whales — remains of pelvis & leg bones of walking ancestors
    - eyes on blind cave fish
    - human tail bone
    - NOT LAMARCKIAN!



## Comparative embryology

- Similar embryological development in closely related species
  - all vertebrate embryos have similar structures at different stages of development
    - gill pouch in fish, frog, snake, birds, human, etc.

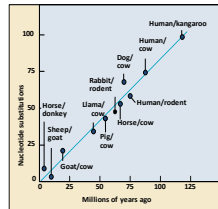


## Molecular record

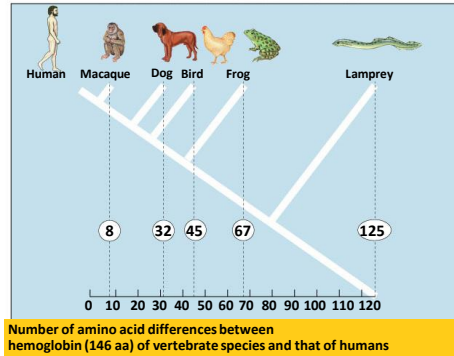
- Comparing DNA & protein structure
  - universal genetic code!
    - DNA & RNA
  - compare common genes
    - cytochrome C (respiration)
    - hemoglobin (gas exchange)

Closely related species have sequences that are more similar than distantly related species

- DNA & proteins are a molecular record of evolutionary relationships



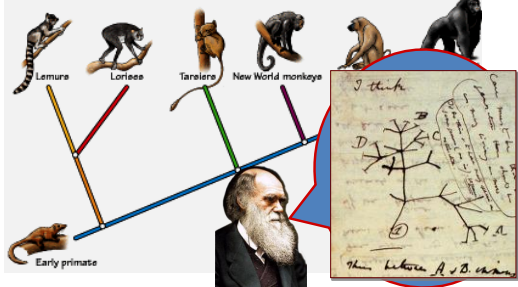
## Comparative hemoglobin structure



Number of amino acid differences between hemoglobin (146 aa) of vertebrate species and that of humans

## Building “family” trees

Closely related species (branches) share same line of descent until their divergence from a common ancestor



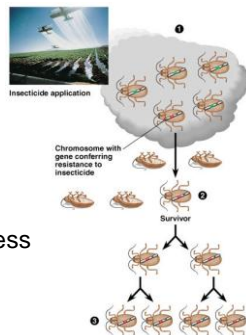
## Artificial selection

- Artificial breeding can use variations in populations to create vastly different “breeds” & “varieties”



## Natural selection in action

- Insecticide & drug resistance
  - insecticide didn’t kill all individuals
  - resistant survivors reproduce
  - resistance is inherited
  - insecticide becomes less & less effective



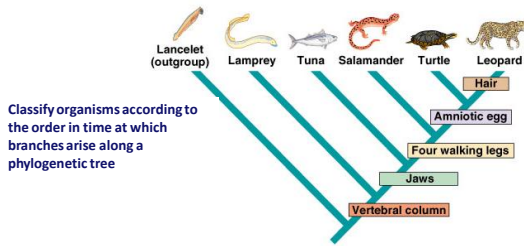
## Phylogeny & Systematics



An unexpected family tree. What are the evolutionary relationships among a human, a mushroom, and a tulip? Molecular systematics has revealed that—despite appearances—animals, including humans, and fungi, such as mushrooms, are more closely related to each other than either are to plants.

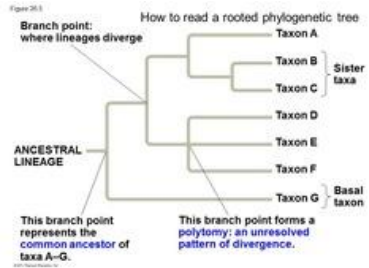
## Illustrating phylogeny

- Cladograms
  - patterns of shared characteristics

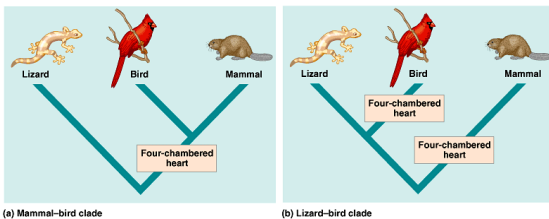


## Illustrating phylogeny

- Page 538 fig. 26.5: How to Read a Phylogenetic Tree



## Parsimony & analogy vs. homology



Phylogenetic trees are hypotheses  
Which is the most parsimonious tree?

## Phylogeny & Systematics

- Phylogeny
  - evolutionary history of a species
  - based on common ancestries inferred from
    - fossil record
    - morphological & biochemical resemblances
    - molecular evidence
- Systematics
  - connects classification system to phylogeny by categorizing & naming organisms



## Building phylogenies

- Morphological & molecular homologies
  - similarities based on shared ancestries
    - bone structure
    - DNA sequences
  - beware of analogous structures
    - convergent evolution

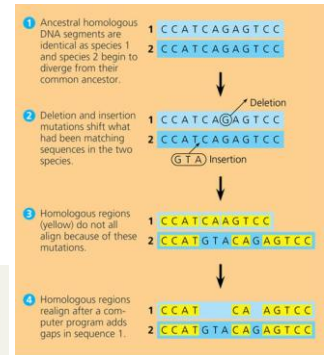


## Evaluating molecular homologies

- Aligning DNA sequences
  - more bases in common = more closely related
  - analyzed by software

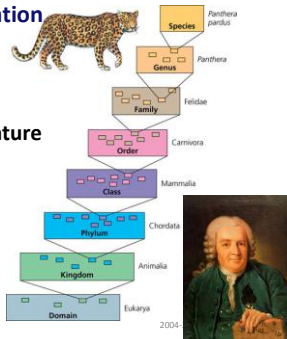
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A C G G A T A G T C C A C T A G G C A C T A
T T A C C G A C A G G T C T T G A C T A G
    
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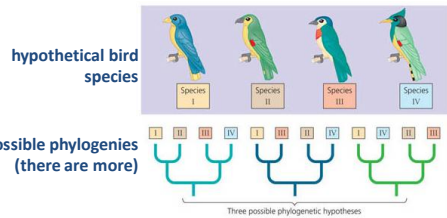
## Systematics

- Connecting classification to phylogeny
  - ◆ hierarchical system
  - ◆ Carolus Linnaeus
  - ◆ Binomial nomenclature
    - genus
    - species



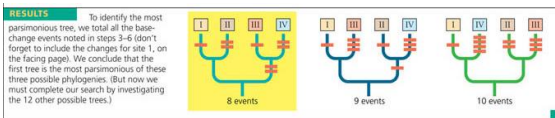
## Molecular Systematics

- Hypothesizing phylogenies using molecular data
  - apply principle of parsimony
    - simplest explanation
    - fewest evolutionary events that explain data



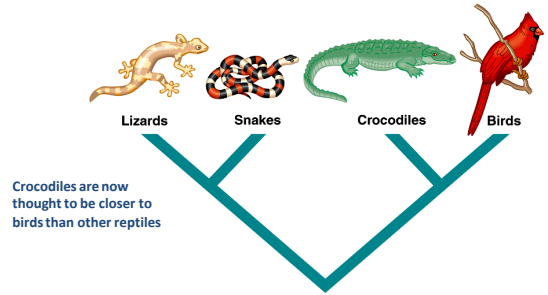
## Parsimony

- Choose the “tree” that explains the data invoking the fewest number of evolutionary events



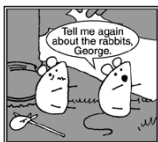
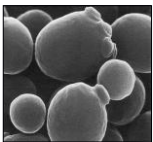
## Modern Systematics

- Shaking up some trees!



## Of Mice and Men...

- Evolving genomes
  - now that we can compare the entire genomes of different organisms, we find...
    - humans & mice have 99% of their genes in common
    - 50% of human genes have a close match with those of yeast!
      - the simplest eukaryote



## Universal Tree of Life

- 3 Domains
  - Bacteria
  - Eukarya
  - Archaea

