Darwin
Connecting all of biology

Outline
- Darwin
- Darwin's great idea: evolution by natural selection
- Evidence for natural selection, old and new
- Examples of Natural Selection

What do you know about Charles Darwin?

Darwin Chronology
- Born 1809
- Voyage of the Beagle, 1831-1836
- Wrote essay on Evolution by Natural Selection, 1844, but did not publish
- Published books on worms, barnacles, the expression of emotion in man and animals
- Gathered further evidence about "descent with modification"
- Received Wallace's manuscript, 1858, and arranged co-presentation of ideas
- Published Origin of Species, 1859
- Died 1882

Darwin's great adventure
- Voyage of the HMS Beagle

What did he see?
- Galapagos (Darwin's) finches
What was the scientific framework when Darwin came up with his ideas about evolution by natural selection?

Studies paving the way for Darwin’s theory of evolution by natural selection

Evidence of the age of the earth

- Hutton (1726-1797)
  - Geological features change gradually

- Lyell (1797-1875)
  - Uniformitarianism: forces that build and erode geological forms have been consistent through time.
  - You can see these processes at work (and it’s hard to find evidence of past catastrophes)

Pre-Darwinian thought

Darwin did NOT discover evolution! Species changing over time is an old concept:
- Greek philosophers (>2500 years ago)
  - Scaly fishlike animal → terrestrial species

Western cultures in 1800s, however, largely believed species do not change and earth is static, except perhaps for catastrophes (the flood described in the bible), and young (9000 years?)
- But research of several investigators during the 1700 and 1800’s began to suggest the earth and species are dynamic…….

* And he didn’t even use the word “evolution” — he called it “descent with modification”

Let’s do the math!

- Hutton and Lyell:
  - Depth of sediments - 10000s of feet.
  - Rate of accumulation of new sediments - fractions of an inch per year.
  - 30,000 ft x 500 y/foot = 15 million years
  - Also - after forming, sediments are uplifted, sometimes miles in the air - how long does that take?
  - Darwin found marine fossils at high elevations in the Andes.
  - The summit of Mount Everest is made of marine limestone!
Evidence for continual change in living things

- Cuvier (1769-1832)
  - History of life in earth's strata
    - The deeper the layers, the more the fossils differ from those present now

More studies paving the way for Darwin's theory of evolution by natural selection

- Lamarck (1744-1829) suggested a mechanism for evolution
  - Use and disuse
  - Inheritance of acquired characteristics

- Malthus (1766-1834) pointed out that organisms have high reproductive potential but limited success:
  - Populations tend to increase faster than the supply of food available for their needs.

So if Darwin didn't propose Evolution, what did he do?

- He explained HOW and WHY evolution happens. By NATURAL SELECTION

Darwin's observations and ideas (1)

- Observations:
  1) All species can increase in numbers exponentially
  2) Populations usually remain stable from year to year
  3) Resources are limited

- Idea: Inevitably, only some can survive and reproduce. Most individuals fail to reproduce.

Darwin's observations and ideas (2)

More Observations:
- Individuals in a populations vary
- Much of this variation is heritable

Darwin's Ideas:
- Individuals with the inherited traits that best fit the environment have more offspring
- Populations change gradually over time accumulating the most successful traits

In a nutshell

- Individuals compete for survival and reproduction.
- Some survive and reproduce better.
- The next generation resembles the successful parents, those "selected" by nature to survive and breed.
- Over time, species are modified by this process, and given enough time and "natural selection," species can change quite dramatically.
Artificial Selection
- Darwin understood Artificial selection in domesticated animals and plants
  - Quick enough for humans to see (and cause)
  - Darwin thought if we could do this, natural selection over millions of years could have profound results

20,000 years ago, these were all wolves

Alfred Wallace (1823-1913)
- Explored Indonesian archipelago in early 1850’s
- Independently developed theory of natural selection

Darwin and Wallace
- Darwin wanted to be sure of his ideas so he collected much more data before he published
- Alfred Wallace in 1858 published his, almost identical, ideas about natural selection
- Publication = property rights
- Science is not complete unless it has been communicated
- Why does Darwin still get almost all of the credit?

Darwin’s implications
- Age of Earth and organisms
- Humans are ‘evolved animals’

Acceptance was not immediate...
- “Men stumble over the truth from time to time, but most manage to pick themselves up and run off as if nothing happened.” - Winston Churchill
But acceptance was quick

Nothing shocks me. I'm a scientist. –Indiana Jones

- Within a decade, most scientists understood and accepted "descent by modification" from a common ancestor as the origin of the diversity of species present on earth
- Theodosius Dobzhansky (1900-1975): "Nothing in biology makes sense except in the light of evolution"
- Did scientists believe in evolution because people like Dobzhansky said they should?
- Of course not! Let's look at the evidence.

Given enough time, what can gradual evolution do?

- Hypothetical example: Selection on a population of mice increases average weight by 0.1% per generation.
- Human equivalent: Average Parent: 150 lb. Average child 150 lb, 2.4 oz
- What happens if that rate of change happens for 10,000 generations?

Mouse example, cont.

- 1 oz x $1.001^{10,000} = 21,917$ oz = 1370 lb
- Average mouse now weighs over half a ton!
- Note that 10,000 years is a tiny fraction of the age of the earth (4.5 billion years) or of the oldest known fossils (~4 billion years).

Examples of the power of artificial selection were some of Darwin's most persuasive points

- In fact, Darwin coined the phrase "natural selection" by analogy with the "selection" that humans already practiced in breeding domestic animals and plants.

OK, so it's logically possible that evolution could give rise to new species

- And artificial selection can produce what look like new species.
- It's still a big step to say that humans are cousins of mushrooms.
- How do we know that N.S. really did produce the species here today?
- How do we know N.S. operated in the past?
- What is the evidence that all living things are descended from a common ancestor?

Homologous Structures
Analagous Structures

Why wouldn't you call these homologous?

Homologous structures

How do we know these structures are similar by descent?

Transitional Forms are also evidence for common ancestors

- Even for groups that are very different today, the fossil record should show transitional forms - "missing links"

Transitional Forms

Transitional Forms

What is Homologous Between a Plant and a Mammal?

- What is homologous between a mushroom and a flea? Between a worm and a human?
- What is homologous between a bacterium and a human?
There are over 2,000,000,000 ways to match codons with amino acids, but all living things use this code*

Modern Evidence Confirms the Great Age of the Earth

- Radioactive Dating of Rocks:
  - Uranium (but no lead) is incorporated into certain minerals
  - Over time, Uranium 238 spontaneously decays to lead at a predictable rate (half-life of 4.5 billion years)
  - Ratio of Uranium to Lead reflects time since mineral formed
  - Oldest rocks on Earth formed about 4.5 billion years ago
  - Oldest fossils are in rocks about 4 billion years old

Two examples of Evolution by Natural Selection

- 1. Evolution of insecticide resistance in insects

Drug Resistance to Tuberculosis (TB)

- TB is caused by the bacterium *Mycobacterium tuberculosis*
- There is evidence of TB in Egyptian Mummies (2400 BC)
Drug Resistance to Tuberculosis (TB)

- Bacteria live in and harm organs, especially lungs.
- Infectious, spreads in droplets.
- Especially hits those with weakened immune systems.

TB dominated deaths from disease in 19th century London

Drug Resistance to TB

- Streptomycin, 1st effective anti-TB drug (1944)
- Within months, streptomycin-resistant strains developed
- Resistant strains have arisen with all new TB drugs
- Resistance can be overcome by drug combination therapy, for now...

TB Deaths are no longer declining

- TB still kills 1-2 million a year - more than any other microbe except HIV (2-3 million).

How does resistance come about?

- Single-celled bacteria grow and multiply by cell division
- Host (sick human) may contain hundreds of millions of bacteria
- Mistakes occur in DNA replication (gene mutations), leading to heritable variation

Drugs select for resistant bacteria

- Exposure to a single effective anti-TB drug kills almost all the bacilli
- If bacterial population is large, mutant bacteria are likely to be present
- A few drug-resistant mutants will multiply freely (no competition)
Evolution by Natural Selection in TB

- **Variation** - mutants, produced by mistakes in copying genes, exist
- **Differential survival and reproduction** - only drug-resistant mutants survive in the presence of the drug
- **Evolution** - genetic structure of the population changes over time

**Note (avoid common misconceptions)**

- The drug does not cause resistant mutants to appear.
- The drug does not cause mutations.
- The drug-resistant mutants are already there. The drug creates conditions where the mutants can thrive (no competition).
- Individual bacteria don’t evolve. Individuals live or die, reproduce or fail to reproduce.
- POPULATIONS of bacteria evolve - the genetic composition of the population changes as the individuals live or die.

What does the future hold?

**Review Darwin’s Ideas**

- Individuals in all populations vary
- Some of the variation is heritable
- Because of limited resources, all living things compete with others of their kind
- Variant forms that compete better will leave more offspring
- Over time, the population will accumulate more of the successful variants
- This process explains why each living species is so “perfect” (well adapted) for its situation.
- Over long time scales, accumulated evolutionary changes have formed all the species on earth.

**Review the evidence**

- All living things do vary; populations are stable
- Artificial selection works
- Radiometric dating indicates the earth is 4.5 billion years old
- Homologies are common
- Transitional forms are common
- All living things share the same genetic code