

Darwin, Evolution, and Natural Selection

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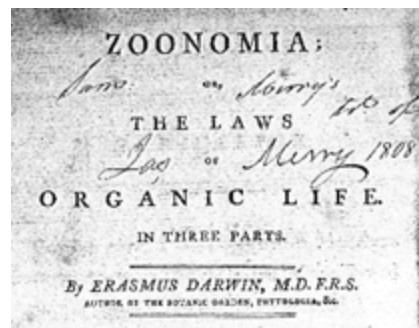
Overview of Darwin and Evolution

- What is evolution and what led Darwin to **The Origin of Species**?
- *What is the law of natural selection?*
- What can we say about the origin of *life*?
- *How does evolution work?*
 - Mendel and inheritance
 - DNA and the Human Genome (future topic)
- *Modern interpretations and implications*
- *Challenges*

Aristotle

- “Concept” of the chicken is in the egg
- Acorn is “informed” by the plan of the oak tree

Which Darwin?



Published
1794

Organic life beneath the shoreless waves
Was born and nurs'd in ocean's pearly caves;
First forms minute, unseen by spheric glass,
Move on the mud, or pierce the watery mass;

These, as successive generations bloom,
New powers acquire and larger limbs assume;
Whence countless groups of vegetation spring,
And breathing realms of fin and feet and wing.

Erasmus Darwin, *The Temple of Nature*. 1802

Charles Darwin (1809-1882):

Born to upper middle class
- father and grandfather were doctors
- mother was from the Wedgwood family



- interested in chemistry
- an avid collector
 - Shells
 - Bugs
 - Birds
 - Minerals
 - Maritime fossils



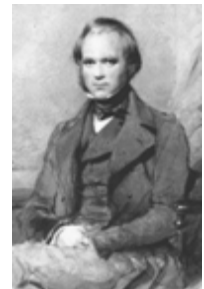
* Each species contained many different variants, few if any were identical.

Darwin's academic training

- Not an exemplary student
- Two year medical school: Edinburgh
- Liked geology and biology, but not operations on humans without anesthetics
- Dropped out, went to Cambridge to study theology for Church of England

Through his professors, Darwin was invited to serve as Naturalist aboard the **H.M.S. Beagle** for a five year expedition to map South America and Islands in the Indo-Pacific.

He made observations on everything geological and biological, was astonished by the vast array of species and adaptations, and came back a transformed person.



Charles Darwin at 31

Voyage of H.M.S. Beagle, 1831-1836



Biogeography partitioning

- 13 species of mice on the Atlantic side of Andes were completely different from 5 species on the Pacific side.



Changing land masses

Found petrified trees on bare slope 7,000 feet above sea level
 Found fossil shells at an elevation of 12,000 feet.

Galapagos Islands

Contained an astonishing assortment of species

-some unique to only one island.
 e.g. Each island had a discernable form of tortoise



“Why should the species which are supposed to have been created in the Galapagos Archipelago and nowhere else, bear so plainly the stamp of affinity to those created in South America?”

Darwin observed 13 varieties of finches in the Galapagos islands

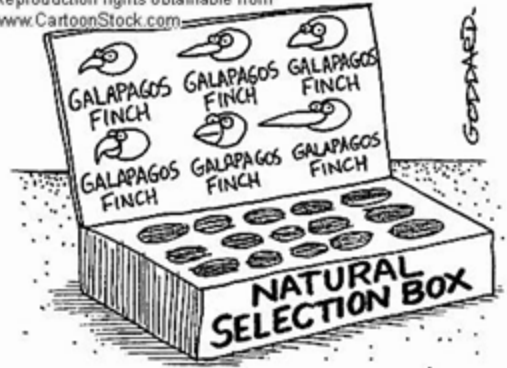


Variation in finch beaks



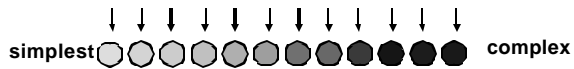
- A retrospective revelation by Darwin after his return from the Galapagos, when an ornithologist told him that his bags of different bird specimens were mostly finches.
- Thicker beaked species cracked nuts and seeds
- Narrower beak species ate insects
- Found on different islands

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Prevailing Pre-Darwin explanation of the diversity of life

Linnaeus and many other naturalists held this view .
"special creation"



Diversity of life established through separate creations

Upon returning from this voyage Darwin continued to think about all that he had seen.

He became skeptical of special creation and felt there must be a better explanation.



The ideas of **Lyell, Lamarck, and Malthus** would positively influence his thinking.

It would take 20 years of reviewing and gathering data before he published "On the Origin of Species."

Charles Lyell: the Dimension of Time

Lyell had championed for geological processes:

If landscapes underwent change slowly, why wouldn't the same gradual process apply to organisms?

Uniformitarianism = a philosophy of science based on conviction that the same processes at work in the past are still at work today

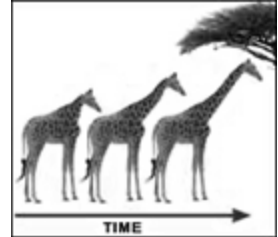
The present was the key to the past!

Jean-Baptiste Lamarck – 1801

Lamarck's principles of inheritance

- Organisms adapt to conditions
- That adaptation is passed to their off-spring

Inheritance of acquired characteristics



Who was Thomas Malthus?

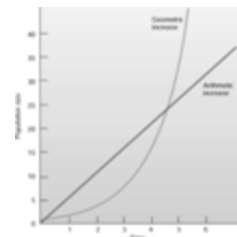
"An Essay on the Principle of Population"

-Thomas Malthus 1798



1. populations tend to increase faster than food supply

- Arithmetic Growth - Growth at a constant rate per unit time
- Geometric Growth – Growth at a constant rate of increase per unit time.



“An Essay on the Principle of Population”

- Thomas Malthus (1798)

2) when population growth outstrips the food production, miseries such as famine, disease and war will intervene

From this struggle there would be winners and losers

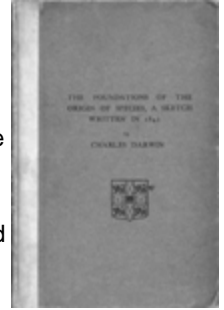
Darwin's thought: Could this be applied to natural systems?

Different species and individual members of the same species struggle for scarce resources among themselves.

Q: What determines the outcome?

Origin of Species

- Finally published in 1859
- Prompted to publish by communication from Alfred Wallace, who reached similar conclusions with less evidence
- Darwin's notebooks from 1830's make clear that his ideas were developed first and more thoroughly documented



Darwin's proposed 4 principles

1. Traits of parents are passed to offspring
2. There are variations in the traits of individual members of a species
3. The population of the species is capable of growing geometrically
4. Resources for any species are finite and will limit its growth

Q: So what are the consequences?

Natural Selection

- Those individuals with traits that favor the competition for limited resources will be more likely to survive and reproduce.
- These traits will therefore exist to a greater degree in subsequent generations.
- Applies to inheritable traits, not learned behaviors

Consequences of Natural Selection

- Species can adapt to their environment.
- Differences can become sufficiently pronounced as to become a different species.
- Species that cannot adapt sufficiently quickly to changes in their environment become extinct.

“It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.”

Charles Darwin

Evolution: the Buffalo Theory



Allegedly explained by Cliff to Norm on *Cheers*:

You see, Norm, it's like this: A herd of buffalo can only move as fast as the slowest buffalo. When a herd is hunted, the slowest and weakest ones, at the back of the herd, get killed first. This Natural Selection is good for the herd as a whole because the average speed and health is improved by eliminating the weakest members.

In much the same way, the human brain only operates at the rate of its slowest cells. And we know that excessive consumption of alcohol kills brain cells. But naturally it kills the weakest cells first. In this way the regular consumption of beer eliminates the weaker brain cells, making the brain a faster and more efficient machine.

And that's why, Norm, you're always feel smarter after a few beers.

Closing Sentence – Origin of Species

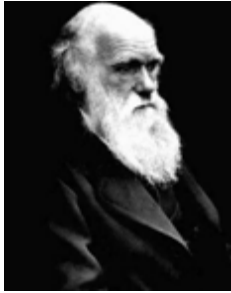
“There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms, or into one, and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms most beautiful and most wonderful have been,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

Opposition was immediate



- “Is it on your grandfather's or your grandmother's side that you claim descent from a monkey” –

Bishop Wilberforce, 1860
Oxford debate with T. Huxley



"The Descent of Man" in 1873



Scopes Trial – Tennessee 1926



- Lawyers:
- William Jennings Bryant
- Clarence Darrow

Inherit the Wind

At Bryant's urging, 1923 Florida legislature passed a resolution condemning evolution as improper and subversive

Evolution still questioned? - 2005

Dover, PA school Board requirement for "intelligent design" as a mandatory alternative to evolution was ruled unconstitutional

Intelligent Design judged not a science



Old views die hard

- **Florida schools to teach evolution as 'scientific theory'**
 - Miami Herald -Feb.20, 2007
 - vote of study commission = 4-3
- **State Legislators Seek Bills to Allow Questioning of Evolution Theory in Schools (Florida)**
 - Fox News, May 1,2008

Evolution is a theory and a fact

“It is a theory in that the specific mechanisms for how evolution occurs remain under intense research

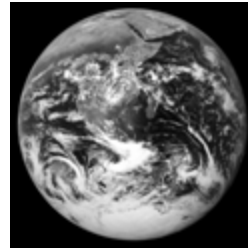
That evolution occurred is a fact.

In science, a fact can only mean confirmed to such a degree that it would be perverse to withhold provisional assent.”

- Stephen Jay Gould, 1981

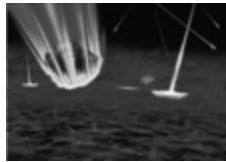
BEGINNINGS

Early life and the evolution of an oxygenated atmosphere...



HADEAN EON (4600 to 3900 Mya)

- Age of Earth (4.6 B years) estimated by dating moon rock and meteorites.
- (universe 10 B years older)
- Period of coalescence, formation of the solar system
- Earth and moon bombarded by asteroids/meteorites



EARLY ATMOSPHERE:

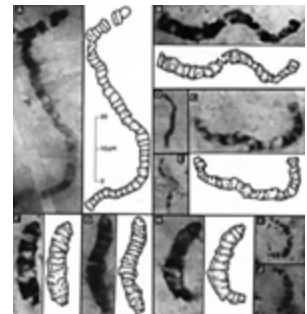
1. Ammonia, methane, hydrogen sulfide (early Hadean)
2. Carbon dioxide, nitrogen, and water vapor (late Hadean)



First signs of life

Stromatolites and microfossils build by bacteria and algae

~3,500 MYA
Australia
South Africa



Stromatolites still exist



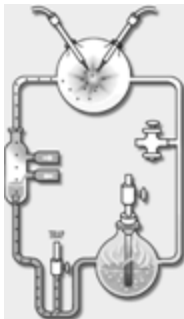
Shark Bay,
Australia

Microbial mats that form laminated mounding structures by trapping sediment or depositing calcium carbonate

“As the earth and ocean were probably peopled long before the existence of animals; and many families of those animals before other families of them, *shall we conjecture that one and the same kind of living filaments is and has been the cause of all organic life?*”

Erasmus Darwin, 1794

Miller-Urey Experiment - 1953



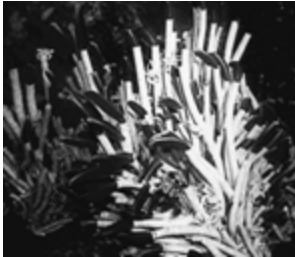
Life in an Extreme Environment

A “black smoker” venting hydrogen sulfide at 380 °C and 7,000 feet depth in central Pacific

Photo from the sub Alvin, 1977



Tube worms at ocean thermal vent

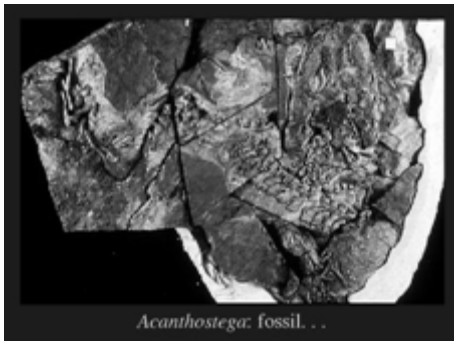


Insidies are lined with bacteria that oxidize H₂S, turning it into usable nutrients for the worms. The bacteria benefit from the relationship because the worms deliver hemoglobin which helps the bacteria to break down the sulfides.

Simplified Time Scale

- If 4.6 billion year age of earth = 1 year
(1 hour = 534,000 years)
- When?
 - First indications of life.....March
 - First marine animals.....October 20
 - Dinosaur extinction.....Dec. 26
 - *Humanoids diverge from chimps.* Dec. 31 noon
 - Plato.....Dec. 31, 11:59:46 pm

Fossil of “Darwin fish”



Acanthostega

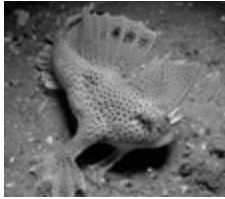


Transitional form
between lobe-finned
fishes & amphibians

Full fossil found
Greenland, 1987

Dated to 360 mya

Hybrid fish exist today



-Handfish
(*Brachionichthys hirsutus*)



-Australian lungfish
(*Neoceratodus forsteri*)

Current examples of evolution??

Foxes to dogs?

- Siberian Scientists Dimitri Belyaev and Lyudmila Trut (1959-1999)
- Bred wild silver fox for tameness
- Within 8 generations, doglike tameness



-Many properties parallel tameness



characteristic	animals per 100,000 with trait		increase in frequency
	domesticated population	non-domesticated population	
degeneration (star)	12,400	110	+1,040
brown mottling	400	90	+320
gray hairs	500	100	+400
floppy ears	200	170	+30
short tail	140	2	+6,900
tail curled in circle	9,400	600	+1,500

What is a Species?



Lab



Poodle

+



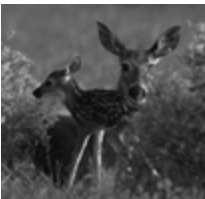
-Labradoodle

How are traits inherited?

- “The laws governing inheritance are for the most part unknown. No one can say why the same particularity in different individuals of the same species, or in different species, is sometimes inherited and sometimes not.”

Charles Darwin, Origin of Species

Heredity: Do you look like your parents?



Mendel: Genes

Watson and Crick: DNA



Why do we rely on sex?

For live to perpetuate itself, every organism has a built-in drive for reproduction

- Asexual reproduction – common in one celled organisms
- Some small animals produce by parthenogenesis – female lays eggs which develop without fertilization by male

Early Observations on Heredity

(by gardeners and animal breeders)

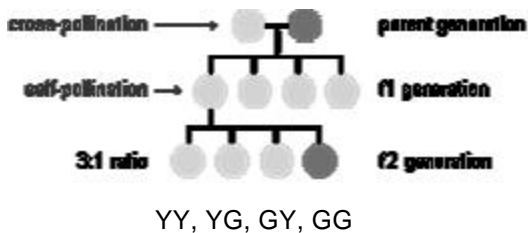
- Both sexes contribute to look of offspring
- Certain traits passed to offspring may come from either the female or the male.
- In some cases, one character seemed to merge with related characters. (blended)
- A trait can disappear in offspring, then reappear in later generations.

How do traits get inherited?

- Mendel - 1862
- Paper rediscovered 1900
- Crossed yellow and green peas

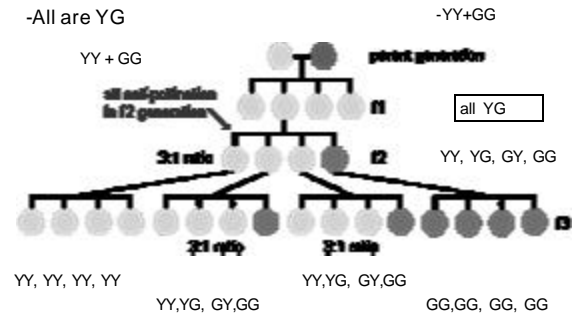


First two generations



-VVWhat will f3 generation look like?

Effects of self pollination in second generation



Mendel's Conclusions

1. inheritance of each trait is determined by a factor that is passed on to descendants unchanged (factors are now called **genes**)
2. an individual inherits one such factor from each parent for each trait
3. one trait may dominate the other
4. a trait that does not appear in an individual can still be passed to the next generation.

Why do we have sex?

- Sexual reproduction passes on two copies of genetic material, one from each parent, so that the species has more ability to adapt to changing environments.

Molecular Basis of Evolution

- DNA Structure
- Watson and Crick
- 1951
- "The greatest, simplest, and most surprising secret in the universe"
- A ladder with 4 types of rungs



Is evolution progress?

- Natural selection suggests that adaptation is useful for **current** environment
- If environment changes, that trait may be less useful, or even destructive
- Loss of genetic diversity may leave an organism less adaptable to change

The Darwin Awards

- What are they?

The Darwin Awards

“.. salute the improvement of the human gene pool by honoring those who remove themselves from it in really stupid ways.”



Unlike Nobel Prizes, this honor is always bestowed posthumously.

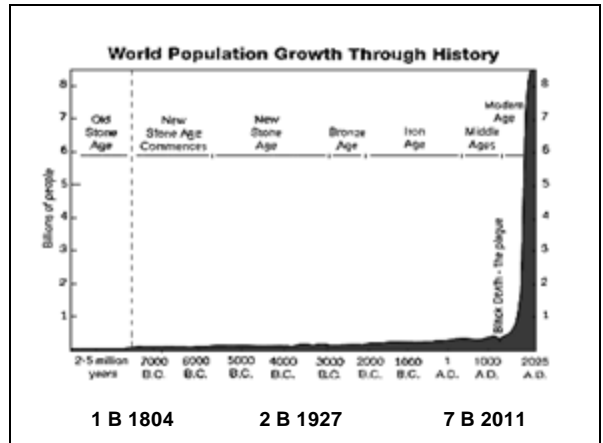
Motto: *“The tree of life is self-pruning”*

Darwin Award winner: A man who decided to dig up and use some abandoned land mines to train elephants to stay out of his fields



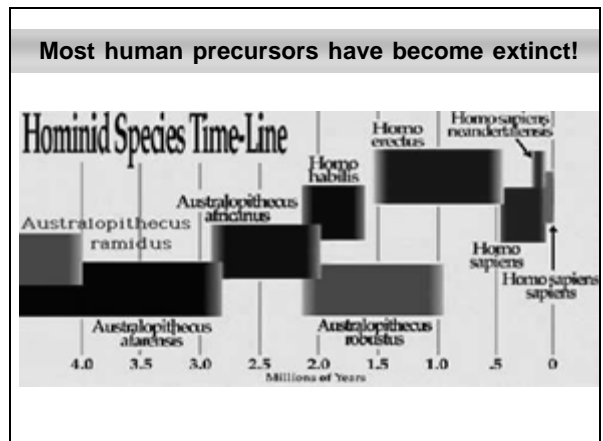
Extinction is a real possibility

- Five major extinctions in last 500 my, each eliminating 20-60 percent of all species
- Most recent = dinosaurs, 65 mya
- Individual species die out continuous, but current rate of lose is many times faster than previous rate
- 99.9% of all species are extinct
- 25% of current species may be extinct in 2050



ABC's of Extinction Dangers to Human Race

- Atomic Warfare
- Biological Weapons
- Climate change
- Disease
- Ecological Disasters
- FUBAR



The challenge

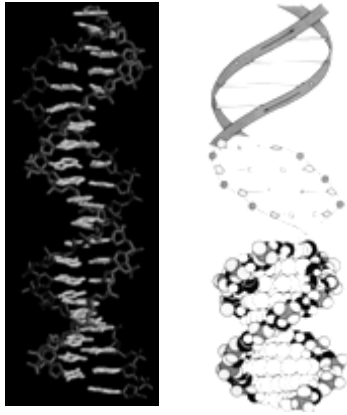
- “The problems of modern civilization rise from the disjunction between our ancient and glacially slow-evolving **genetic** heritage at one level of evolution and our ultrafast **cultural** evolution at the other level.”
- E.O. Wilson, The Creation, 2006

Double Helix

- Molecular Model of DNA
- Models were used by Watson and Crick to solve structure
- 2 complementary strands held together
- Strands can separate to share information



Each letter of one strand matches complementary letter (base) of the other



Human Genome

- Total genetic information in the species
- 100 Trillion cells in human body
- 2 Sets of genome in each nucleus
- One from mother, one from father
- Except for sex cells (one set only)
- None in red blood cells

Genome is a book

- 23 chapters (**chromosomes**)
- Each chapter several thousand stories (**genes**)
- Each story has several paragraphs (**exons**), interrupted by ads (**introns**)
- Each paragraph has words (**codons**)
- Each word written in letters (**bases**)
- Alphabet is only four letters (A, G, C, T or U)
- One billion words in the book
- Linear one-dimensional information

Genetic Code

- All organisms use same words
- Solved by Nirenberg, 1961
- Each code is 3 bases
- DNA is template for messenger RNA
- RNA uses U instead of T, and a different sugar molecule as part of its backbone
- Each code directs the incorporation of a specific amino acid to build a protein

		Second letter					
		U	C	A	G		
First letter	U	UUU } Phe UUC } UUA } UUG } Leu	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA } Stop UAG } Stop	UGU } Cys UGC } UGA } Stop UGG } Trp	U C A G	
	C	CUU } CUC } CUA } Leu CUG }	CCU } CCC } CCA } Pro CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } CGA } Arg CGG }	U C A G	
	A	AUU } AUC } Ile AUA } AUG } Met	ACU } ACC } ACA } Thr ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } AGG } Arg	U C A G	
	G	GUU } GUC } GUA } Val GUG }	GCU } GCC } GCA } Ala GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } GGA } Gly GGG }	U C A G	

Human Genome Project

- 15 year project to sequence every gene
- About 25,000 genes
- Each is a building block for inheritance of a specific trait
- Each has specific location on a chromosome
- Exact number in doubt because a lot of filler (introns)

Implications of knowing Genomes

- Gene Therapy: cure genetic diseases
- Create replacement parts, eg, spinal cords
- Extinction of natural organisms as replaced by "better" ones, designed by humans?

Hold for next time

The Selfish Gene

- Individuals are born and die
- Genes seek to reproduce themselves
- Those genes whose host successfully promote their own propagation will be favorably selected in detriment to their competitors
- “A chicken is just an egg’s way of making more eggs.”
- The selfish gene may be altruistic toward its own kin, if this will increase the probability of the gene being reproduced

Darwin’s Vision

- “But if (and oh, what a big if) we could conceive in some warm little pond, with all sorts of ammonia and phosphorus salts, light, heat, electricity, etc. present, that a protein compound was chemically formed, ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed.”

» Charles Darwin, letter, 1871

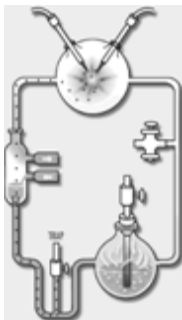
Spontaneous Generation

- Life appears spontaneously
- Worms from mud
- Flies from decaying flesh

Laboratory Creation of Life?

- Miller-Urey experiment, 1953, obtained amino acids from a “pre-biotic soup” (simulated early atmosphere of methane and ammonia) plus electric discharge

Miller-Urey Experiment



Behavior in Light of Evolution

- B. F. Skinner – behaviorism
- Noam Chomsky – language and cognition
- Nico Tinbergen – ethology
- E. O. Wilson - Sociobiology

