

EVOLUTION Harvard Case Solution & Analysis

Big Question: How do organisms evolve?
 Main Question: What are the mechanisms of evolution?
 How do organisms evolve?

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Brief History

What did people think about life on Earth 200 years ago?

Science Does Not Happen In A Vacuum

Darwin didn't freestyle Evolution from nothing. Thinking about life was pretty standard scientific fare for the 19th century. Had life always existed as it does now? Was it always changing? How old was the Earth (Bible: ~7,000 years old).

1687 Newton's laws of motion and universal gravitation.
1687 Hooke's cell theory.
1735 Buffon's geological time scale.
1781 Lamarck's theory of evolution.
1809-1882 Darwin's theory of evolution.
1859 Darwin's 'On the Origin of Species'.

What's the deal with that? Does God get tired of some organisms? Isn't God perfect?

Deformation: The process happening on Earth now are similar to those that happened in the past.

Principle of Uniformity: VERY OLD Earth.

Lamarck: a. Inheritance of Acquired Characteristics
 b. The Great Chain of Being
 c. Why the first bit might just eat this pop!

Populations would like to grow forever.

Charles Lyell: Uniformitarianism.

Thomas Malthus: Populations would like to grow forever.

What?

This Was The Thought Stew That Darwin Worked In!

Darwin: Brief Biography (1809 - 1892)

A remarkably unspectacular young life.
 Comfortable family wealth.
 Notoriously undecided about a job: Med school, Parsonage, Naturalist, Whatever.

Family connections got him a gig as the captain's companion on the HMS Beagle.

Circumnavigation of the globe!
 5 years (22-27)!
 Became the ship's naturalist.

Read, Collected, Wrote & Thought!

The Galapagos Islands
 An important stop for Darwin.
 Weird, unique animals.

The "A-ha!" Moment:
 "The natural history of these islands is eminently curious, and well-deserves attention. Most of the organic productions are aboriginal creations, found nowhere else; there is even a difference between the inhabitants of the different islands, yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean, between 300 and 400 miles in width... Hence, both in space and time, we seem to be looking somewhere near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth." - Darwin (journal entry).

Giant Tortoises!

All 8 species.
 Different shell shapes due to different ocean plants on different islands.

Marine Iguanas!

The only swimming lizard in the world!
 Algae eaters.

Finches!

There are 13 species of Galapagos Finch.
 Different beak structure driven by different feeding behavior.
 All share a common migrant finch ancestor.
 The only example of natural selection in the "Ultimate Specimen".

And Then...

Darwin came home...
 ...published his journal...
 ...married his cousin...
 ...had four children...
 ...buried one of them...
 ...did a lot of other work...

Until...

He wrote a quick paper.
 Both papers were published simultaneously.
 He didn't like the way Darwin presented his theory.
 ...and didn't publish his theory FOR 20 YEARS!

Natural Selection

How it Works:

- Overproduction of Offspring (Malthus)**

 Most babies won't grow up!
- Variation among individuals (observation)**

 No two are quite the same!
- Competition for Limited Resources (inference)**

 It's the "struggle for Existence".
- Successful competitors survive, reproduce, & pass on their traits (observation)**

 FITNESS!!!
- Repeat 1-4 every generation over millions of years (Lvell)...**

 ...& life will adapt to the environment.

Some Examples:

Artificial Selection
 Darwin provided a lot of examples of "artificial selection". Just like natural selection, but "fitness" is determined by human needs/wants. Big changes can happen very fast.

About those finches...
 The selective pressure of the Galapagos Environment has driven the evolution of the finches. Beaks are very important for birds.
 Any birds that can't eat pass on their beak traits to their offspring.
 Repeat for millions of years.

Pesticide Resistance
 Life will always adapt if it can.
 Spreading of genes kills all of the pests who aren't resistant. The survivors reproduce.
 ...resistance increases (leading to more spraying, more resistance...) similar mechanisms drive the evolution of antibiotic resistance in bacteria & natural resistance in viruses.

Modern Science
 Organisms do have a remarkable amount of "natural selection" in common. The evolution of the finches has been an example of natural selection on the characteristics of a population.
 The effect of head shape on the length of the neck of the giraffe's leg.

Common Ancestry of Life: A fundamental conclusion of Natural Selection

If we accept that life evolves, logic suggests that all of life should share a common ancestor. This is supported by all evidence we have found. I suggest it is the most amazing thing ever determined about life on Earth.

"Tree Thinking"
 The pattern of evolution of life on Earth.

The ultimate tree (DNA-approx)

2 facts, both explained by common ancestry:

Similarity in skeleton's of 5 great Ape species
 Gorilla, Human, Orangutan, Gink, Chimpanzee.

Similarity between fossils and modern organisms
 Fossil: 100,000 to 200,000 years old.

Reaction to the Theory

Public reaction was mixed.
 Certain religious perspectives can't reconcile evolution with their modes of thinking. These are not mainstream religious beliefs.

Knuffke's Law:
 Almost entirely, issues with evolution are due to misunderstandings about the Theory.

For whatever reason, it's a particular problem in the US.

Nothing in Biology makes sense except in the light of evolution!
 -Theodosius Dobzhansky

Scientifically, Evolution is the unifying principle of all other fields of Biological study.
 Natural selection (and other modes of evolution) are as close to biological "laws" as anything going.

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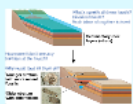
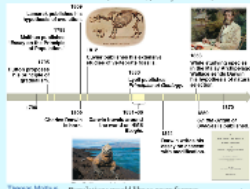
Big question: How does evolution work?
Main question: How did it happen?
What evidence do we have for evolution?
How do we know it's real?

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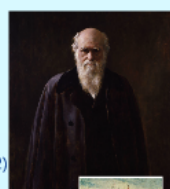
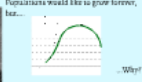


This Was The Thought Stew That Darwin Worked In!

Geologists: What's the deal with that? Does God give some organisms (and God) perfect?

Evolutionary evidence: The process happening on Earth now are similar to those that happened in the past.

"The struggle of existence," VERY OLD! Earth is a Life Deathland. Inheritance of acquired characteristics! A "use and disuse" (Only the fittest live & breed, see oak this guy).



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The natural history of these islands is extremely curious, and well deserves attention. Most of the organic productions are aboriginal creations, found nowhere else; there is even a difference between the inhabitants of the different islands, yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean, between 300 and 400 miles in width. Hence, both in space and time, we seem to be brought somewhere near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth. —Darwin (diary entry).

Giant Tortoises!



Marine Iguanas!



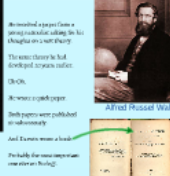
Finches!



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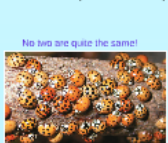


How it Works:

1. **Overproduction of Offspring (Malthus)**



2. **Variation among individuals (observation)**



3. **Competition for Limited Resources (inference)**



4. **Successful competitors survive, reproduce, & pass on their traits (observation)**



5. **Repeat 1-4 every generation over millions of years (Lyell)...**



...& life will **adapt** to the environment.

Natural Selection

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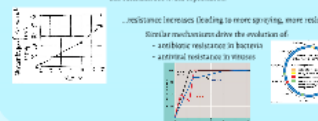


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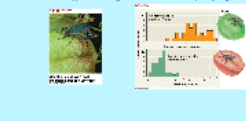
Pesticide Resistance

Life will always adapt if it can. Spraying of pesticides kills all of the pests who aren't resistant. The resistant survivors reproduce. Resistance increases (leading to more spraying, more resistance...) Similar mechanisms drive the evolution of antibiotic resistance in bacteria and artificial resistance in viruses.



Modern Science

Genes flow. Includes a mention of some form of natural selection in action. The effect of heat type on the length of the beak of the Galapagos finch.

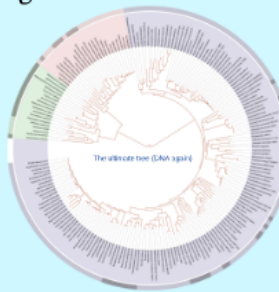
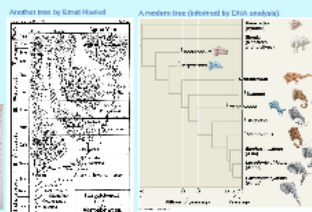
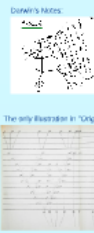


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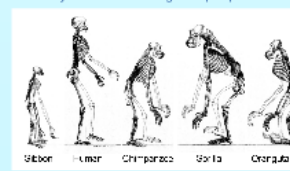
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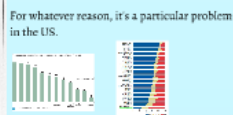
Similarity between fossils and modern organisms



Reaction to the Theory



Public reaction was mixed. Certain religious perspectives can't reconcile evolution with their modes of thinking. These are not mainstream religious beliefs.

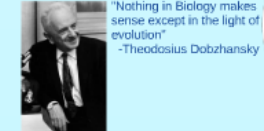


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-Theodosius Dobzhansky



...and didn't publish his theory FOR 10 YEARS!

Compared to what actually goes on, this seems quaint!



Big Question

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Thomas Malthus (1766-1820): Populations would like to grow forever. *Why?*

Jean Baptiste Lamarck (1744-1825): 1. Life Feeds! 2. Inheritance of Acquired Characteristics! 3. Use and Disuse! (Only the first bit is right, just ask this graph!)

Charles Lyell (1797-1871): "Principles of Geology": VERY OLD Earth

Georges Cuvier (1769-1844): **Extinction:** What's the deal with that? Does God get tired of some organisms? Isn't God perfect?

Uniformitarianism: The process happening on Earth now are similar to those that happened in the past.

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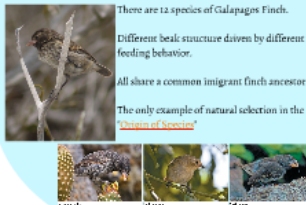
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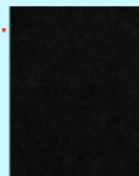


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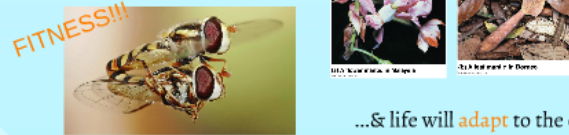
He received a paper from a young naturalist asking for his thoughts on a new theory.
The new theory he had developed against earlier UK fits.
He wrote a draft paper.
But papers were published infrequently.
And Darwin wrote a book.
Probably the most important one ever on biology.
Introducing whole new ideas.



...and didn't publish his theory FOR 20 YEARS!

How it Works:

1. **Overproduction** of Offspring (Malthus) *(Most Babies won't grow up!)*
2. **Variation** among individuals (observation) *(No two are quite the same!)*
3. **Competition** for Limited Resources (inferred) *(It's the "Survival of the Fittest")*
4. **Successful competitors** survive, reproduce, & pass on their traits (observation) **FITNESS!!!**
5. Repeat 1-4 every generation millions of years (Lyell)...



Common Ancestry

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"Tree Thinking"

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Darwin's Notes:

Another tree by Ernst Haeckel:

A modern tree (informed by DNA analysis):

The only illustration in "Origin" (1st ed.):

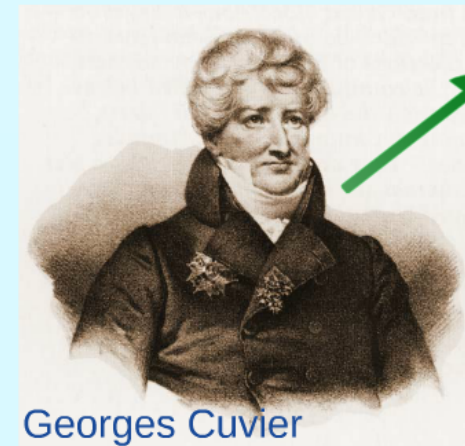
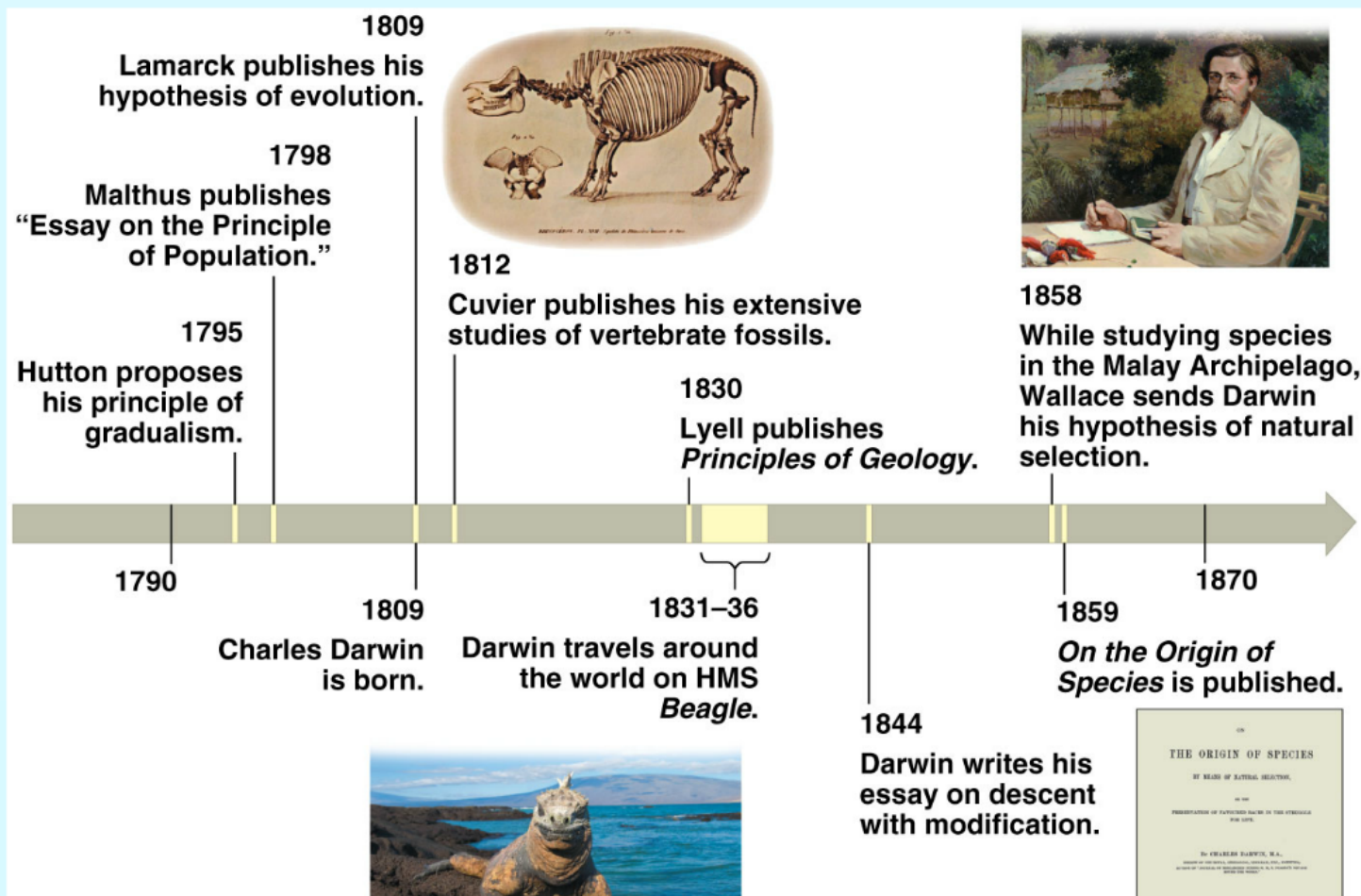
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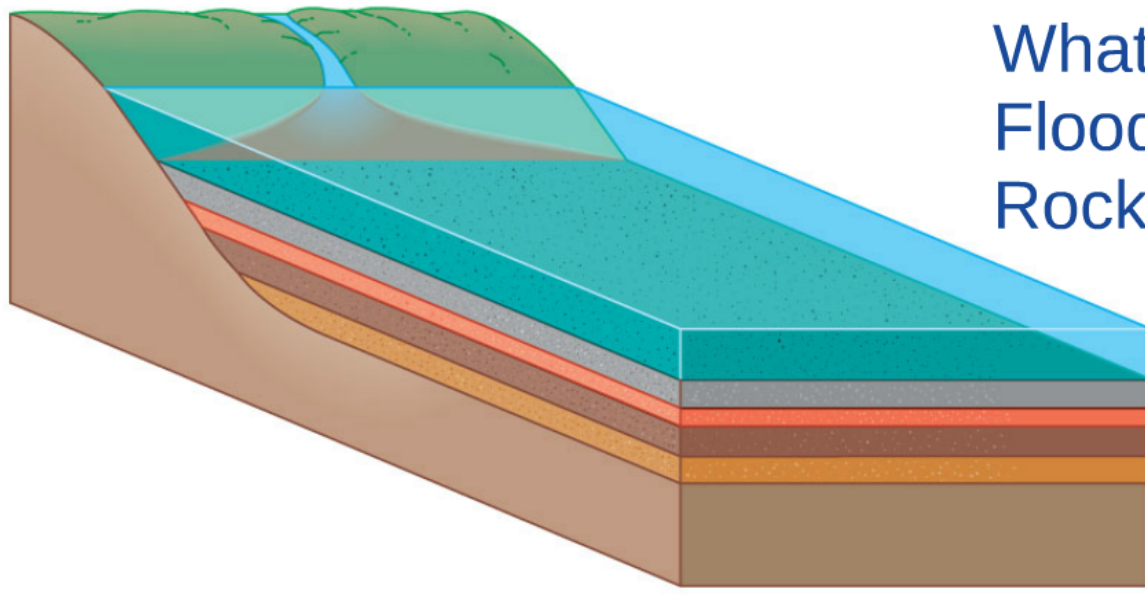
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Uniformitarianism: The process happening o similar to those that happ

What's up with all these fossils?
Flood remnants?
Rock takes a long time to form!



Sedimentary rock layers (strata)

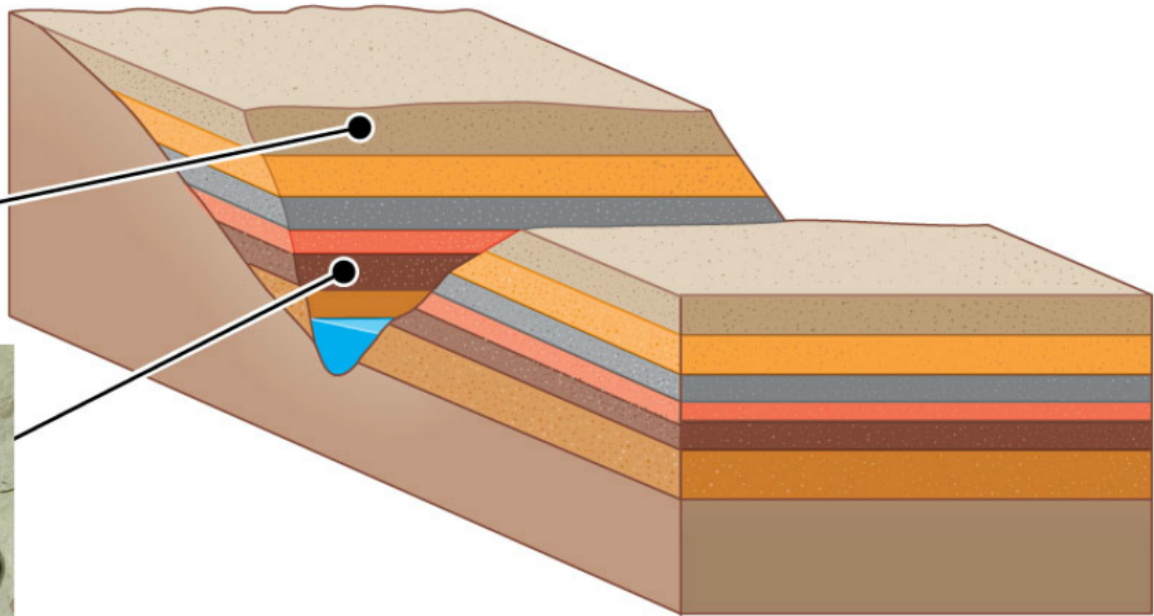
How come I don't see any trilobites at the beach?

Why would God kill them all?

Younger stratum with more recent fossils



Older stratum with older fossils



...with modification.



Thomas Malthus

Populations would like to grow forever, but....



...Why?

win - Brief P