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Key Points:

(1) What exactly were the components of Darwin’s theory of Evolution, and what was missing?
(2) What exactly did Mendel contribute?
(3) What is the difference between Lamarck vs. Darwin’s ideas, and how do Lamarck’s ideas contribute today?

Charles Darwin (1809-1882)

- His father was a doctor (Richard Darwin) and his grandfather was Erasmus Darwin, also a doctor and a prominent scholar who was already thinking about evolution
- Initially he studied Medicine at the University of Edinburgh
- He neglected his studies and could not stand the sight of surgery or the sight of blood (had nausea, fainted)
- Sent by his father at Christ’s College, Cambridge University to become an Anglican priest
- He still neglected his studies, but he did pursue a passionate interest in Natural History
- He became close to botany professor Rev. John Henslow and met other leading naturalists who saw scientific work as religious natural theology (and viewed adaptation [i.e. evolution] as God acting through laws of nature)

Today’s OUTLINE:

(1) Development of Darwin’s Thought
(2) Lamarck vs. Darwin
(3) The Contribution of Darwin
(4) The Contribution of Mendel
(5) Conflict between “Mendelism” and “Darwinism”
(6) Next Time: The “Evolutionary Synthesis” of Mendel and Darwin

Charles Darwin (1809-1882)

- Origin of Species is one of the most influential texts of this century

Reverend John Stevens Henslow (1796-1861)

- “I fully believe a better man never walked this earth.”
  Charles Darwin to J.D. Hooker, 1861
- Darwin’s Botany professor at Christ’s College (Divinity School), Cambridge University
- Henslow encouraged students to make observations of their own, rather than being spoon-fed
- After Darwin completed his final examination in 1831, Henslow persuaded him to begin studying geology, and made arrangements for him to take Adam Sedgwick’s geology course and a trip to map geological strata in North Wales
- Shortly thereafter, in 1831, Henslow encouraged Darwin to join the Voyage of the Beagle as the ship’s naturalist

More on Henslow:

- Darwin’s Mentor: John Stevens Henslow 1796-1861
- By Walters & Slow
**Voyage of the Beagle**

**HMS Beagle**, a ship sent by British Navy to chart coastline of South America.

**During the 5-year Voyage**

- Darwin was supposed to be primarily a geologist; he had some expertise in geology, beetle collecting and dissecting marine invertebrates.
- He made observations on geological formations as the ship was mapping the coastline.
- At Punta Alta in Patagonia, he made a major find of fossil bones of huge extinct mammals in cliffs beside modern seashells, indicating recent extinction with no signs of change in climate or catastrophe (“extinctions happen”).

**The Galapagos Islands**

Archipelago of volcanic islands distributed around the equator in the Pacific Ocean, 972 km (525 nmi) west of continental Ecuador.

**The Galapagos Islands**

Why were these islands so important in shaping Darwin’s thinking?

- As an archipelago, there were many islands with different populations of a “species” on each island.
- The populations were related, but were slightly different on each island... (not clear boundaries).
- This led Darwin to conclude that the populations descended from a common ancestor... and he ultimately concluded that they had evolved and were evolving...
- → led Darwin to question the stability of the concept of a “species”.

**Darwin’s Mockingbirds**
"My attention was first thoroughly aroused by comparing together the various specimens ... of the mocking-thrush"
C. Darwin, *The Voyage of the Beagle* [1839]

- On Sept 17 1835, Darwin disembarked from the Beagle in the Galápagos near Sappho Cove on Chatham Island (now known as Isla San Cristóbal), and was struck by the bold, terrestrial mockingbird.
- The bird is known today as *Mimus melanotis*, the San Cristóbal Mockingbird. Over the next 6 weeks that Darwin spent in the Galápagos, he observed mockingbirds on three other islands.
- Darwin noticed the mockingbirds differed between islands. Nicolas Lawson, acting Governor of Galápagos, told Darwin that the tortoises also differed from island to island.
- Towards the end of the voyage, Darwin speculated that the distribution of the mockingbirds and the tortoises might "undermine the stability of Species." Species might not be fixed entities, but are changing over time...

### Galapagos Islands

**Darwin’s Mockingbirds**
(he did not focus that much on the finches; they were studied more later by Peter and Rosemary Grant)

- Mockingbirds on different islands differed slightly in size, shape and coloration
- And all shared some traits (homologous traits)
- He concluded that these birds must have shared a common ancestor—and were not independently created

**Tortoises and other animals**

- Mockingbirds on different islands differed slightly in size, shape and coloration
- And all shared some traits (homologous traits)
- He concluded that these birds must have shared a common ancestor—and were not independently created

**Significance of the HMS Beagle Voyage**

- Amassed collections to study later
- Exposed Darwin to geological formations, fossils embedded in strata—animals that no longer exist today and are clearly extinct—this was known, but Darwin got to see this himself
- Exposure to animal diversity, related populations within species living in different habitats:
  1. "Species" are not immutable fixed entities
  2. Organisms are related by common ancestry (tree-like branching)
  3. They are changing and branching in response to the environment ("Adaptation")

**Return to England**

- Returned and discussed his geological and biological finding with other scholars, influenced by Malthus, etc.
- Married the wealthy Emma Wedgewood—financed his work
- Did not have to work, and could study the samples he collected, perform experiments, make observations, think, and write books for the rest of his life

*Emma Wedgewood*
**Historical Context:**

- By mid-1800s scientific context was in place for development of theory of Evolution

**Developments in Geology:**
- Discovery that earth is more than 6,000 years old
- Fossil Record showed change in species over time

- [http://www.ucmp.berkeley.edu/history/evotmline.html](http://www.ucmp.berkeley.edu/history/evotmline.html)

**Influences on Darwin**

**Geology:** Darwin had Lyell’s *Principles of Geology* on board the HMS Beagle (given to him by ship captain FitzRoy) [https://www.amazon.com/Principles-Geology-1-Charles-Lyell/dp/0226497941#reader_0226497941](https://www.amazon.com/Principles-Geology-1-Charles-Lyell/dp/0226497941#reader_0226497941)

- Lamarck’s (1744-1829): Concept of Adaptation, Inheritance of acquired characteristics

- Malthus (1766-1834): Competition within species and the struggle for survival

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**Jean-Baptiste Lamarck**

- French Naturalist (1744-1829)
- “Professor of Worms and Insects” in Paris
- The first scientific theory of evolution (inheritance of acquired characteristics)

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**Influences on Darwin**

- Lamarck’s (1744-1829) theory of Evolution
- Inheritance of acquired characteristics

- Proposed the most influential mechanism of evolution before Darwin:

- **Introduced the idea of Adaptation**, though he was mostly incorrect on the predominant mechanism (though sometimes correct; will discuss Epigenetic Inheritance)

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**Influences on Darwin**


  The idea of competition:

  - Malthus’ calculations showed that rate of population growth was greater than rate of increase in food supply
  - Thus, not all individuals could possibly survive
  - Based on this fact of competition, Darwin concluded that individuals that are better adapted would be the ones that survive and leave more offspring (and win the competition)
From Malthus, Darwin came up with the idea of competition and the "struggle for survival" as a component of Natural Selection.

With these influences on this thought and data from the Galapagos Islands...

Darwin developed the theory of Evolution via Natural Selection...

The scientific community was primed for a theory of Evolution.

Darwin was one of many scholars at his time that were thinking about Evolution.

Many scholars accepted the idea of Evolution at the time... what puzzled them was the mechanism.

In fact, Alfred Wallace (1823-1913) came up with the idea of natural selection independently.

Darwin rushed to publish Origins in 1859 when he learned of Wallace’s work.

Alfred Russel Wallace (1823-1913)

“On the Tendency of Varieties to Depart Indefinitely from the Original Type”

Based on his work in the Malay Archipelago.

He also studied populations on different islands and came to the same conclusion as Darwin.

Alfred Russel Wallace (1823-1913)

Father of Biogeography… focused on adaptation to the environment.

In 1858 Wallace sent Darwin a copy of his manuscript.

Darwin was shocked that Wallace came up with the idea of natural selection independently.

They decided on a joint presentation at the Linnean Society in 1858, but it received little attention.

After which Darwin rushed to publish his book in 1859.

Charles Darwin (1809-1882)

On the Origin of Species (1859)

- Living species are related by common ancestry
- Change through time occurs at the population not the organism level
- The main cause of adaptive evolution is natural selection
**Darwin’s Main Points:**

1. **Organisms Evolve** (Darwin not first)
2. **Common Descent**: species arise from common ancestors, in a tree-like branching process (Wallace also)
3. **Gradualism**: changes are gradual (we now know that this is not always true)
4. **Population Speciation**: change in proportions of individuals having a trait in a population (Darwin’s original idea) (Wallace also)
5. **Natural Selection**: is the mechanism (Wallace also)

So… Darwin did **NOT** originate the idea of Evolution…

... BUT he provided a plausible Mechanism (along with Wallace)

... and much evidence

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**Lamarck vs Darwin**

Before Darwin had developed his ideas on the mechanism of evolution, Lamarck had proposed an alternate mechanism that was popular at the time

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**Lamarck’s View on Pattern of Evolution**

- Continuum between physical and biological world (followed Aristotle)
- Scala Naturae (“Ladder of Life” or “Great Chain of Being”)
- “Transmutation of Species” – one species turns into another
- Linear progression from primitive to advanced

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**What is wrong with a ladder?**

- Evolution is not linear but branching
- Living organisms are not ancestors of one another
- The ladder implies progress
Darwin envisaged Evolution as a Tree

“The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth……

….The green and budding twigs may represent existing species; and those produced during former years may represent the long succession of extinct species…..

….the great Tree of Life….covers the earth with ever-branching and beautiful ramifications”

Charles Darwin, *On the Origin of Species*; pages 131-132

The only figure in *Origin of Species*

Lamarck’s View on Mechanism of Evolution

- Individuals are evolving
- If you got a tan, you’d pass it on

Some balls get tan during their lifetime

We now know that acquired traits could get passed on sometimes when epigenetic modifications are inherited
Darwin’s View on Mechanism of Evolution

- **Natural Selection**
  
  A heritable difference (now known to be due to different mutations)

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Darwin’s View on Mechanism of Evolution

- **Natural Selection**
  
  Selection might favor this mutation

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Darwin’s View on Mechanism of Evolution

- **Natural Selection**
  
  Greater Fitness: individuals with this mutation survive and leave more offspring

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Darwin’s View on Mechanism of Evolution

- **Natural Selection**
  
  The individuals themselves are not changing, but the population is changing in composition (% of alleles)

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**Darwin’s contribution:**

“Population Speciation as a result of Natural Selection”

- More offspring are produced than can survive
- Limited resources and competition for resources (“The Struggle for Survival”)
- There is variation in a population
- Individuals better adapted to environment survive
- Survivors leave more offspring (“Survival of the Fittest”)
- Thus, average character of population is altered

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**Chapters of Origins (1859)**

On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life

1. Variation Under Domestication
2. Variation Under Nature
3. Struggle for Existence
4. Natural Selection
5. Laws of Variation
6. Difficulties on Theory
7. Instinct
8. Hybridism
9. On the Imperfection of the Geological Record
10. On the Geological Succession of Organic Beings
11. Geographical Distribution
12. Geographical Distribution continued
14. Recapitulation and Conclusion

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Other books by Darwin on Evolution

- *The Variation of Plants and Animals under Domestication*
- *The Descent of Man*
- *The Expression of the Emotions of Man and Animals*

But… Darwin’s theory was not complete

- Because Darwin knew nothing about mutation, he had no idea how variation was generated in populations
- Because Darwin knew nothing about genetics or genes, he had no idea how variation was passed on to offspring (Mendel & Hardy-Weinberg)
- Darwin did not know about nonadaptive evolutionary forces, such as Genetic Drift

Sample Exam Question

- Which of the following was NOT part of Darwin’s theory of Evolution?
  1. Natural Selection
  2. Populations as the units of Evolution
  3. Mutations as sources of genetic variation
  4. Survival of those who produce more offspring

Mendel’s work held part of the key to what was missing in Darwin’s Theory

- Mendel published in 1865… was ignored until 1900
- Present a mechanism for how traits got passed on
  “Individuals pass alleles on to their offspring intact”
  (the idea of particulate (genes) inheritance)

Hardy-Weinburg Equilibrium (Lecture 4)

- Wilhem Weinberg
  - January 13, 1908
- G. H. Hardy
  - July 10, 1908 in *Science*

The Mathematical expression of Mendel’s Principles of Inheritance

Hardy-Weinburg Equilibrium (Lecture 4)

- Wilhem Weinberg
  - January 13, 1908
- G. H. Hardy
  - July 10, 1908 in *Science*
- Could mathematically show expectations of Mendelian inheritance and whether expectations are realized in nature
**PROBLEMS!**

**BUT...** Mendel and Darwin’s ideas seemed Incompatible

- Mendel’s principles: dealt with particulate (discrete) traits (e.g. yellow vs. green, wrinkled vs. smooth)
- BUT, Darwin observed continuous traits (e.g. beak size, body length)

Q: So, how would continuous traits get passed on?

**Selection vs Mutations**

- Mutations discovered after 1900

Q: If mutations are arising, why need selection... ... if things are just mutating?

**Controversy between Mutationists vs Darwinists**

**Mutationists (+Mendelianism)**

- They thought that evolution required only mutations and passing on of discrete traits

**Darwinists**

- They thought that evolution required only Natural Selection on continuous variation

**Problem**

- Darwin did not understand the unit of inheritance (what is being inherited, genes)
- Mendelism provide that (particulate inheritance), but Darwinian traits did not seem to be inherited in a Mendelian fashion
- **Discrete vs Quantitative Traits**: Darwin was unable to clearly see the pattern of inheritance because he studied quantitative variation

**Discrete vs Quantitative Traits**

- Darwin was unable to clearly see the pattern of inheritance because he studied quantitative variation
- **Discrete trait**: a trait that has distinct values, rather than a range of phenotypes, usually encoded by one or a few genes.
  Examples: number of fingers, color of Mendel’s peas, sickle cell anemia, ABO blood type, number of eggs in a bird clutch, presence/absence of human widow’s peak, presence/absence of dimples, etc.
- **Quantitative (continuous) trait**: a trait that has a continuum of phenotypes and is encoded by multiple genes.
  Examples: body size, height, weight, intelligence (IQ), Running speed, beak shape, hair color, skin color, milk yield of cows, lifespan, etc.
Controversy between Mutationists vs Darwinists

Controversy persisted for ~30 years up till the 1930s, during which little progress was made.

Problem caused by:
- Binary thinking (Black or White thinking): it’s this or that... “if I’m right, you must be wrong”
  - When in fact the two or more factors might interact
- Inability to see overarching mechanism that could explain a wide range of phenomena: “How could your Hardy-Weinberg (Mendel) explain the inheritance of 5.1 cm, 5.5 cm beak length (continuous characters)?”
  - When in fact, another factor might make it possible (think multiple genes, rather than one gene)

Genetic Drift (Lecture 5)
- A concept as important as Natural Selection
- But, not as prominent on people’s minds

- 1872 Gulick: Neutral Theory (Genetic Drift)
- 1921 A.C. Hagedoorn produced data to support Neutral Theory of Genetic Drift

The Modern Synthesis
1930s ~ 1940s

The synthesis of population genetics (role of mutation, genetic drift), paleontology, systematics

Darwin and Mendel Reconciled!!!
(Next Lecture)

Questions:
1. What were the intellectual influences on Darwin’s thought?
2. What role did the discoveries from the Beagle’s voyage play in the development of Darwin’s thought?
3. What were Darwin’s main conclusions?
4. How did Darwin’s thought differ from that of Lamarck?
5. What did Darwin’s theory leave out?
6. What was Mendel’s contribution?
7. What were the sources of confusion between the proponents of Darwin and Mendel’s ideas?

CONCEPTS
- Evolution
- Population
- Natural Selection
- Evolutionary Adaptation
- Fitness
- Mutation
- Genetic Drift
- Recombination
- Hardy-Weinberg Equilibrium
- Development of Darwin’s thought
- Lamarck vs Darwin
- Darwinists vs Mendelists
- Evolutionary Synthesis
Sample Exam Questions

1. Which of the following is TRUE regarding Darwin’s contribution to the theory of Evolution?

(A) Darwin formulated the first comprehensive theory incorporating all mechanisms of evolution
(B) Darwin recognized that evolution occurs at the population level (in terms of changes in frequency of traits within populations)
(C) Darwin proposed that selection acts on mutations and other forms of genetic variation
(D) Darwin agreed with Larmarck’s idea of inheritance of acquired characters, but included the concept of fitness.
(E) Darwin incorporated Mendel’s work on the particulate inheritance of alleles

2. For several decades “Darwinists” and “Mendelists” battled over the mechanisms of evolution. Which of the following did NOT contribute to this particular conflict?

(a) Geneticists/Evolutionary biologists did not understand that continuous and discrete traits follow the same principle of inheritance
(b) Geneticists/Evolutionary biologists did not understand that natural selection acts on mutations in a population
(c) Mendel worked with discrete traits, whereas Darwin worked with continuous traits, leading to differences in perspectives on inheritance
(d) Darwin was unaware of the mechanism or unit of inheritance
(e) Darwin was unaware of the mechanisms of Genetic Drift

3. Darwin’s development of the theory of evolution by natural selection was NOT influenced by which of the following?

(a) The concept of adaptation to the environment, which was proposed by Lamarck
(b) Fossils of extinct organisms
(c) Each island of an archipelago having a population with morphological differences from those on other islands
(d) Malthus’ demography showing exponential growth of populations
(e) Changes in frequency of discrete characters from generation to generation

Answers:
- 1. B
- 2. E (Darwin did not know about Genetic Drift, but that was not a reason for the conflict between the “Darwinists” and “Mendelists”)
- 3. E (Darwin examined continuous characters, Mendel examined discrete characters)