UNIT 5 - TEACHING INVESTIGATION 5

HOW AND WHY DO THEORIES EVOLVE?

Process Overview

Note: This can be treated as a one-day or two-day activity

1. **Part 1 (Day 1)**
   Explore, Read, and Analyze Texts– Have students establish the purpose of the Investigation, use the texts in the Investigation Library, and apply disciplinary concepts to develop an answer to the driving question. This could be part of one class or assigned as homework.

2. **Part 2 (Day 2)**
   Communicating Conclusions – Give students **no more than 50 minutes** to complete a five- to six-paragraph essay (about 2 pages) responding to the Investigation question. Do not assign this as homework. Please make sure this is an in-class activity. Allow students to use the work from their prewriting task to help them during their in-class writing time, and make sure students type their responses into word processing software, not into the Investigation 5 input form. They can copy/paste their responses into the Investigation 5 input form when they are done writing. Please remind students to check, and, if necessary fix the formatting of their essays to ensure paragraph breaks and any other formatting is in place.

Note: You are, of course, free to use this Investigation any way you want. That is, you might add or subtract texts from the Library, extend the time students work on the question, or adjust the ways they communicate their conclusions. However, sticking to the suggested process helps prepare students for the Investigations you'll submit to BHP Score, and also mimics some standardized testing environments.

Purpose

Historical Purpose of the Investigation: Historian Edward J. Larson has argued that "[i]n science, a theory never stands still. It either evolves with use and new findings or withers away through disuse or in the face of better scientific explanations"[1]. No theory emerges fully formed, like Athena from Zeus's head, and remains unaltered over time. New contexts, discoveries, perspectives, tools, ideas, or people – to name but a few possible catalysts—prompt change or further development. In short, everything has a history, even theories. Part of the value of the study of history is understanding the degree to which things *have* changed and what *caused* things to change. The historical problem in this Investigation focuses on how a well-articulated and quite important theory – Darwin's theory of evolution by natural selection – has changed over time and the various reasons for those changes.

Pedagogical Purpose of the Investigation: Too often, students carefully study the origin or the originator of an idea, such as Copernicus's heliocentric theory of the Solar System or Darwin's theory of evolution, but rarely study as carefully the changes in the theory over time. For example, few world history courses take the Copernican theory

1. Edward J. Larson, Evolution: The Remarkable History of a Scientific Theory, A Modern Library Chronicles Book (New York: Modern Library, 2004), 212.

beyond Galileo by extending it to the twentieth century, Hubble, or the Big Bang. Very few look beyond Darwin's publication of his theory of natural selection, except possibly to raise questions about the controversy surrounding it. Few history courses consider ways that new evidence and ideas have strengthened, altered, or challenged Darwin's view of evolution by natural selection.

It is not surprising that students often freeze an idea in its original version or think that only a dramatic event, a brilliant thinker, or new idea could possibly alter a well-established theory. This Investigation seeks to help students understand that ideas and theories grow over time by asking them to consider the scientific history of Darwin's theory *after* Darwin wrote the *Origin of Species*. It is like Investigation 2 and Investigation 4, since this Investigation also encourages students to look beyond the ideas of an originator of a theory (Ptolemy in UNIT 2 and Wegener in UNIT 4) to consider how others have supported, extended, or challenged an idea or theory.

Instructional Process

By now, students should know the drill for Investigations, and this one is no different from the others. They'll need to think about the Investigation problem, including offering their initial thoughts and conjectures on it. Then they'll read and analyze the texts in the Investigation Library, using the texts as well as other Big History concepts to help them reach a conclusion. Finally, they'll communicate their conclusions by writing an evidence-based response to the Investigation's driving question. That, of course, is the general inquiry process. In what follows, we provide details for teaching this Investigation.

Part 1 – Explore, Read, and Analyze Texts

Exploring the Driving Question and Capturing Students' Initial Conjectures

A good place to begin any Investigation is to make sure students understand the driving question and have thought about their initial ideas or conjectures. There are several ways you could do this. Many teachers have students read the Investigation problem on the first pages of the student materials, and then informally write and discuss their initial ideas about the driving question or inquiry problem. In this Investigation, you might ask students questions such as:

> Have you ever wondered how ideas change over time? What makes them get stronger? Or weaker? Survive? Or die? Why might people develop different versions of the same idea? Do ideas grow and develop like living organisms? Is there a "natural selection" of ideas that causes them to evolve and change? Can you think of an idea or theory that has changed in your life? Or in your study of the past? How did it change? Why did it change? What caused it to change? Did anything hinder its change?

To hook them into thinking about Darwin's theory, you could ask more specifically about when and why people might change Darwin's theory of evolution through natural selection by asking:

> How might Darwin's theories have changed in the 150 years or more since he published *Origin of Species*? Were there any problems with the theory? What new ideas, tools, or evidence might lead scientists to strengthen, weaken, or change Darwin's ideas?

When connecting students to this big question about how and why ideas, theories, and collective learning might change over time, you could remind them that in an earlier Investigation (Unit 2), they focused on Copernicus and Galileo to develop an explanation of why people change their minds. Students should already have developed some ideas about when and why people change their minds, ideas that they might use–with a reminder from you–as they speculate on these questions. If you taught Investigation 4, you might also connect students to the ways the scientific community developed confidence in Wegener's ideas about moving continents.

In framing the problem and talking about students' initial ideas, it will be very important to make sure they understand Darwin's theory of evolution as he articulated it. Since the Investigation looks at ways new ideas and evidence supported, extended, or challenged his theory, it is critical that students understand the theory as presented in Unit 5. Students should know that Darwin's theory is one of the most significant breakthroughs in the history of science. It transformed the way people saw the natural world, and provided a new point of view to guide scientific inquiry, research, and interpretation.

Your students should already be familiar with some of the key points of Darwin's theory including:

- Species are a collection of individuals that are similar and that can breed with one another. There are variations among individuals in a species.
- Variations in living organisms enable some organisms to reproduce more successfully in specific environments. These organisms produce more offspring than other variants, and thus later populations inherit these variations.
- Species adapt and change through natural selection.
- Evolution is slow, gradual, and endless.
- Darwin supported his theory by using a small number of fossils, his observations of nature, and his understanding of breeding patterns.
- Many scientists already understood that life evolved, but had not reached consensus on the mechanisms for evolution. Natural selection appeared as the logical mechanism for evolution that scientists were seeking, and thus many readily accepted his theory and applied it in their own work

Activating this background knowledge will be helpful, as students will investigate some of the problems with Darwin's theory and the changes in support and modification or extension of its fundamental principles since its publication.

Analyzing documents and making claims

Once your students understand the problem and have surfaced their initial conjectures or theories, have them turn to the Investigation Library. Even though this might be the fourth or fifth time they have engaged in this work, it will be important to remind them about the process as it applies specifically to this task:

1. Reading and analyzing documents: Explain to the students that they are reading each text to see how (or if) it supports, extends, or challenges Darwin's theory. Encourage them to pay attention to who created the text, when it was created, and, how the text supports, extends, challenges their thinking about this problem or other texts in the Library. Feel free to provide necessary support, scaffolds, or handouts to help students read and analyze the texts effectively. We have provided an example of a helpful tool in the student materials.

2. Connecting texts to each other and the Investigation problem: Remind students to consider ways the texts relate to each other and to the driving question or investigation problem. Ask them to consider questions such as: Do dates matter? Do some texts support others? Extend others? Challenge others? How does text contribute to a claim about change in Darwin's theory? It might be useful to have students group the texts either by time or by similarity.

3. Applying disciplinary concepts to make initial claims: Encourage students to use the texts to make some tentative claims about if of how the theory of evolution has changed since 1859. Also ask them to think about other disciplinary concepts they might use to inform their thinking? For example, you might ask them if using concepts such as claim testing, or collective learning, or different disciplinary ways of knowing would help them reason toward a stronger conclusion about if, how, or why Darwin's theory evolved over time.

4. Establishing a major claim or thesis and structuring their argument through prewriting activities: Have students develop a major claim that captures the conclusion they've reached through their investigation.
   You might try using a sentence starter such as "Darwin's theory of evolution has had X major changes since he published it (1) xxxxx (2) xxxx (3)xxxx. It changed because _____________ Therefore, I think that theories evolve because …

It might be useful to have students identify the claims and evidence that support their thesis or major claim. The following sentence starters might help some students frame their argument:

- My thesis statement or major claim is ________________.
- My first minor claim to support, extend, or explain the thesis statement is ________________. The evidence I can use to support this claim is ________________.
- My second minor claim to support, extend, or explain the thesis statement is ________________. The evidence I can use to support this claim is ________________.
- My third minor claim to support, extend, or explain the thesis statement is ________________. The evidence I can use to support this claim is ________________.
- In conclusion ____.

Part 2 – Communicating Conclusions

Give students **no more than 50 minutes** to complete a five- to six-paragraph essay (about 2 pages) responding to the Investigation question. Do not assign this as homework. Please make sure this is an in-class activity. Please allow students to use the work from their prewriting task to help them during their in-class writing time, and make sure students type their responses into word processing software, not into the Investigation 5 input form. They can copy/paste their responses into the Investigation 5 input form when they are done writing. Please remind students to check, and, if necessary fix the formatting of their essays to ensure paragraph breaks and any other formatting is in place.

Note: You are of course free to use this Investigation any way you want. You might want to add or subtract texts from the Library, extend the time students work on the question, or adjust the ways they communicate their conclusions. However, sticking to the suggested process helps prepare students for the Investigations you'll submit to BHP Score, and also mimics some standardized testing environments.

Rationale for documents in the Investigation Library:

Text 1: Christian, David, Cynthia Stokes Brown, and Craig Benjamin. 2014. "Evidence for and Problems with Darwin's Theory." These few paragraphs from Christian, Brown, and Benjamin's college texts will help remind students of the evidence upon which Darwin based his ideas, and some of the problems with his theory. The rest of the texts are essentially in conversation with this one.

Text 2: Lyell, Charles. *Principles of Geology*. 1830. This reworking of the "In their own words" essay from Unit 4 articulates Lyell's thinking about how slow change is in geology and life, a position that Darwin adopts. In Text 8 in the Investigation Library, Gould rejects gradualism to explain all evolutionary change.

Text 3. Jordan, David Starr. "Darwinism Fifty Years After," *Scientific American Supplement*, February 21, 1909: 134-135. Published on the fiftieth anniversary of *Origin of Species*, Jordan, president of Stanford University, points to a few areas in which Darwin, in 1859, had "scanty knowledge," while pointing out that because of the compound microscope and Mendel's ideas, scientists in 1909 were helping to put Darwin on firmer footing.

Text 4: 1933 Nobel Prize in Medicine to Thomas H. Morgan for his discoveries concerning the role played by the chromosome in heredity: Text explains why Morgan won the Nobel Prize in 1933, arguing that because of Morgan's use of fruit flies, he was able to further Mendel's studies showing empirically the role chromosomes play in heredity and thus evolution.

Text 5: Dobzhansky, Theodosius. 1950. "Genetics." *Scientific American*, 183:55-58. This essay, written by a one of the leaders in connecting genetics to evolution, summarizes the new understanding of the genetic mechanism, particularly genetic mutation, on the eve of Watson, Crick, and Franklin's description of DNA.

Text 6: BHP Chart on Age of the Earth, 2017: The BHP project team created a chart showing major changes in how the age of the Earth was ascertained, from the seventeenth century to the present. Since the Earth is the stage upon which evolution occurs, understanding geochronological claims and the tools people used to make their claims is important to understanding how evolution developed.

Text 7: Crick's Letter to His Son, 1953: In what might be the most interesting explanation of DNA, if not the clearest, we have included the letter Crick wrote to his 13-year-old son weeks before Crick and Watson published their letter in Nature.

Text 8: Gould, Stephen Jay. "The Episodic Nature of Evolutionary Change," from The *Pandas Thumb* (New York: Norton, 1980): pp179-186: In this essay, Gould argues that Darwin was warned against tying his theory only to gradual change. Gould argues for a more pluralistic stance, holding that evolution is both gradual, as Darwin claimed, and sudden and episodic. Essentially arguing Darwin deferred to Lyell as the authority and ignored the fossil evidence, making this a prime piece for students claim test.

Text 9: Zuk, Marlene. "Drug Resistance Explained," ***New York Times*****, Well Blog, March 27, 2008:** This essay describes an evolution that is occurring in the present moment, using evolution by natural selection to explain today's worrisome drug-resistant bacteria. Since *all* Darwin's evidence was *ex post facto* – that is he never saw anything evolve — his makes a strong case for the natural selection and for sudden, episodic evolution.

UNIT 5 - INVESTIGATION 5

HOW AND WHY DO THEORIES EVOLVE?

Introduction

By now, you know the drill for Investigations, and this one is no different from the others. As you know, you must first become familiar with the problem and develop your initial thinking about it. Then, you'll read and analyze the texts in the Investigation Library. Next, you'll apply other BHP concepts and facts to help you frame a response to the Investigation question. Finally, you'll use the texts, concepts, and facts to write your response. So let's get to work on this Investigation problem: How and why do theories evolve?

Purpose

Historian Edward J. Larson has argued that "[i]n science, a theory never stands still. It either evolves with use and new findings or withers away through disuse or in the face of better scientific explanations".[1] No theory emerges fully formed and remains unaltered over time. New contexts, discoveries, perspectives, tools, ideas, or people – to name but a few possible catalysts—prompt change and further development. In short, everything has a history—even theories. Think about Galileo's theory of heliocentricity. Did Hubble challenge, support, or extend that theory? Very few of us look beyond Darwin's publication of his theory of natural selection, except possibly to raise questions about the controversy surrounding it. Few history courses consider ways that new evidence and ideas have strengthened, altered, or challenged Darwin's view of evolution by natural selection.

Part 1 – Explore, Read, and Analyze Texts

Exploring the Driving Question, "How and Why do Theories Evolve?" and Your Initial Conjectures:

"In science," historian Edward Larson argued, "a theory never stands still. It either evolves with use and new findings or withers away through disuse or in the face of better scientific explanations." And that is what we want you to investigate: How does a theory "evolve?" How do new findings, better scientific explanations, use—or even disuse—change a theory?

In Big History, you've been studying many important theories and discoveries that have altered our collective understanding. For example, you've studied Copernicus, Galileo, Mendeleev, Hubble, Wegener, Crick, Watson, and Franklin. People whose ideas changed the way humans see the Universe, Solar System, Earth, elements, and even life itself. It's very important to learn about new ways of thinking, as we did in this unit in our study of Charles Darwin and his theory of evolution by natural selection.

However, too often we stop our study with the originator of a theory, or with an inventor or discoverer. That is, too often we ignore how theories or inventions evolve, how they change over time.

In this Investigation, we want you to develop an argument to explain how and why theories continue to evolve.

1. Edward J. Larson, Evolution: The Remarkable History of a Scientific Theory, A Modern Library Chronicles Book (New York: Modern Library, 2004), 212.

Specifically, we want you to investigate why and how Darwin's theory of evolution by natural selection evolved in the years since he published the *Origin of Species* in 1859.

Your conjectures: As always, start capturing your thinking on paper. Think of an idea or theory that has changed either in your own history or that of our society. How did it change? Why did it change? Did others cause it to change? Did it get stronger from people using it? Or weaker? What caused the change?

Now, take a few minutes to think about **Darwin's theory of evolution by natural selection**. As you learned in Unit 5, the key points in his theory are:

- Species are a collection of individuals that are similar and can breed with one another.
- There are variations among individuals in a species.
- Variations enabled some organisms to reproduce more successfully in some environments.
- Darwin called the process by which organisms better adapted to their environment survive and reproduce, "natural selection." Natural selection is the mechanism that causes species to adapt and change.
- Evolution is slow, gradual, and endless.
- Darwin supported his theory by using a small number of fossils, his observations of nature, and his understanding of breeding patterns.

Take a few minutes to jot down your thinking about how and why this theory of evolution might change as well as why any theory or idea might change.

- What do you think would cause this theory to evolve? What would change it? Strengthen it? Weaken it? Support it? Extend it? Challenge it?
- Do you see any problems or weaknesses with his theory? Which claim testers did Darwin use to support his claims? What new ideas, tools, or evidence might lead scientists to strengthen, weaken, or change Darwin's ideas?

Analyzing Documents and Making Claims

1. Read and analyze texts in the Investigation Library: As you read and analyze the texts in the Investigation Library, please remember your job is to decide how (or if) it supports, extends, or challenges Darwin's theory of evolution. When reading each text, please pay attention to who wrote the text, when it was written, and how it supports its claims. Feel free to use handouts your teacher provides or the reading guide below.
2. Connect texts to each other and the Investigation problem: As you read and analyze each individual text, think about how the texts connect to each other and to the driving question or Investigation problem. For example, are there some texts that support or extend each other? Are there texts that disagree with each other? How do the texts relate to Darwin's theory of evolution?
3. Apply disciplinary concepts to make your claims: Using the texts, try to make a few claims about whether or not people made changes to Darwin's theory. Try to think of BHP ideas that might help you support your claims.
4. Establish a major claim or thesis and structure your argument: Try to create a major claim or thesis and then some minor claims to make your argument about how people helped Darwin's theory evolve. Your teacher will likely have some good ideas to help you make claims and link your claims to evidence and BHP concepts.

Part 2 – Communicating Conclusions

Your teacher will give you instructions for how to communicate your conclusions. Remember to:

- clearly state your major claim or thesis, and all your minor claims
- use the texts in the Investigation Library and other BHP concepts to support your claims
- Write clearly and effectively

UNIT 5 - INVESTIGATION 5

RESEARCHING THE INVESTIGATION LIBRARY WORKSHEET

Directions: Fill out this worksheet for each text in the Investigation Library.

<table>
<tr><td rowspan="2">Author and title of text</td><td rowspan="2">Type of document (for example, article, letter, chart, map)</td><td colspan="2">Date</td></tr>
<tr><td>Primary</td><td>Secondary</td></tr>
<tr><td>What do you know about this author/source?</td><td colspan="3">Do you trust this author/source? Why? Why not?</td></tr>
<tr><td>What was the original purpose of this document?</td><td colspan="3">What's the main idea of this document?</td></tr>
<tr><td colspan="4">How does this document help you answer the Investigation question?</td></tr>
<tr><td colspan="4">What other document or concept supports or challenges the information in this document?</td></tr>
</table>

5

INVESTIGATION LIBRARY

TEXT 1

EVIDENCE FOR AND PROBLEMS WITH DARWIN'S THEORY

Christian, David, Cynthia Stokes Brown, and Craig Benjamin. 2014. "Evidence for and Problems with Darwin's Theory," excerpts from Big History: Between Nothing and Everything. pg. 60- 61

> "Darwin's theory of natural selection rested on three kinds of evidence: (1) fossils, which showed that species have changed; (2) geographic distribution, like the data he collected on the Galapagos Islands, which showed that species are descended from local ancestors, not products of deliberate engineering by a creator; and on (3) homologies, or unexpected similarities between species.
>
> In addition to religious objections, real gaps in the knowledge of his day hindered Darwin as he defended his theory. His problems were that (l) he believed natural selection moved too slowly ever to be observed in one lifetime, (2) he did not understand how characteristics are inherited, (3) he could not prove that species were related, and (4) he did not know how old Earth is. In the first edition of The Origin of Species Darwin estimated the age of the Earth at some 300 million years, while his learned contemporaries were calculating much less than that.
>
> Darwin did not know how heredity, or inheritance, worked; no one in his day understood the specific way in which traits are passed from parents to their offspring. Darwin adopted a theory called pangenesis. This theory implied that parental traits are combined, rather than being transmitted as separate units, which would dilute the potentially successful mutations of one individual and undermine the whole theory of natural selection. Gregor Mendel (1822–84), an Austrian Augustinian monk, demonstrated in his studies of peas, published only two years after The Origin of Species, that for many traits the offspring show either the characteristics of mother or father, not a blend of the two. Mendel's work, however, received little attention for many years, when it eventually became clear that it was the basis for a whole new theory of heredity.

BHP created this text from Christian, David, Cynthia Stokes Brown, and Craig Benjamin. 2014. *Big History: Between Nothing and Everything*. pp 60- 62.

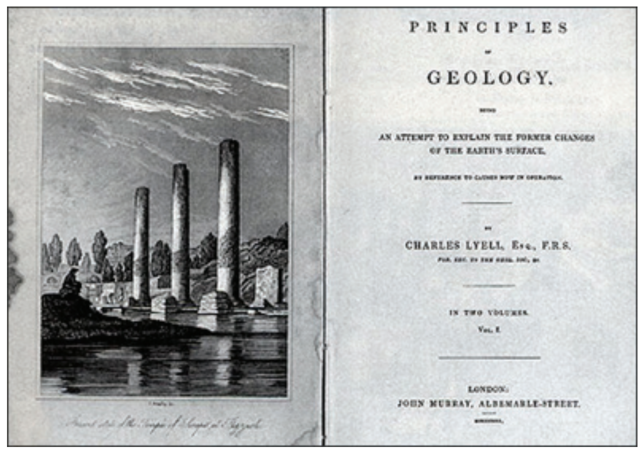
Who are the authors? You should be familiar with the authors of *Big History: Between Nothing and Everything*, David Christian, Cynthia Stokes Brown, and Craig Benjamin. Not only are they leaders in the big history field but they also created some of the content for the Big History Project curriculum. As you might know, David Christian created a course covering almost 14 billion years in 1989 in Sydney, Australia and named it "big history." After learning of Christian's work, Cynthia Stokes Brown began to offer such a course at the Dominican University of California. Craig Benjamin was a student of David Christian's in Australia, where he assisted Christian in teaching big history. Dr. Benjamin is now a professor at Grand Valley State University in Michigan, U.S.A.

TEXT 2

CHARLES LYELL, PRINCIPLES OF GEOLOGY

Lyell, Charles. 1830. Principles of geology, being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation (London: John Murray Publisher, 1830).

Who is the author? Charles Lyell (1797 — 1875) was a British lawyer and the foremost geologist of his day. He is the author of Principles of Geology: An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation. The book argues that slow-moving forces still in operation today, such as erosion, have been shaping the Earth for about 300 million years – the approximate age of the Earth according to Lyell. Lyell's Principles of Geology was one of the few books that Darwin carried on his famous voyage on the HMS Beagle.


PRINCIPLES

GEOLOGY.

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES OF THE EARTH'S SURFACE,

CHARLES LYELL, Esq., F.R.S.

IN TWO VOLUMES.

LONDON:
JOHN MURRAY, ALBEMARLE-STREET.

"Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature. It inquires into the causes of these changes. And it describes the influence which they have exerted in modifying the surface and external structure of our planet.

The form of a coast, the layout of the interior of a country, the existence and extent of lakes, valleys, and mountains, can often be traced to earthquakes and volcanoes in regions which are now tranquil. These ancient upheavals are the reason why some lands are fertile, and others are sterile. They determine the elevation of land above the sea, the climate, and various peculiarities.

Much of the Earth's surface was formed by slow operations such as the gradual depositing of sediment in a lake or in the ocean.

To select another example, we find in certain areas underground deposits of coal, consisting of vegetable matter which drifted into what were formerly seas and lakes. These seas and lakes have since been filled up. The lands the forests once grew upon have disappeared or changed their form, the rivers and currents which floated the vegetable masses can no longer be traced. And the plants belonged to species which have passed away from the surface of our planet ages ago."

Charles Lyell, Principles of Geology, 1830, excerpts taken from Chapter I.

TEXT 3

DARWINISM FIFTY YEARS AFTER: THE BIOLOGICAL LESSON OF EVOLUTION

By David Starr Jordan
President of Leland Stanford, Jr. University.

It is a century since the birth of Darwin and half a century since the publication of the "Origin of Species," the great book of the nineteenth century, and one which changed the entire face of biology and of philosophy.

Darwin showed that competition is at work everywhere and favors the individual who can best make headway as young or as adult in the conditions that actually are. The struggle for existence is ever present. The essential factors in "organic evolution" are (1) variation, which Darwin took as a fact without explanation; (2) heredity, which he also took as a fact, with an attempt at explanation, as nearly adequate as the scanty knowledge of histology [the microscopic study of cells of plants and animals] in his day would permit; and (3) selection.

Now, after these fifty years what is our conception of organic evolution?

Since Darwin's time, the compound microscope has opened the secrets of histology [the microscopic study of cells of plants and animals]. We have given meaning to the "physical basis of heredity." We have learned the process by which two germ cells from two different individuals divide and mingle to form a new individual. With the microscope, we have traced the life history of thousands of species, from germ cell to adult life.

The discovery of Gregor Mendel's ideas has proved a valuable basis for investigation in the methods of heredity. But no change in the theory of Darwinism is made necessary by it. The position of Darwin is very safe standing ground.

The chief and essential contention of Darwin, that species are formed by natural tangible processes, is now absolutely beyond question from those competent to form an opinion. That the animals and plants today, man included, are descended from the animals and plants of earlier periods by natural lines of descent with natural modifications, due to innate and external causes, is one of the certainties of science.

BHP created this text from Jordan, David Starr. 1909. "Darwinism Fifty Years After." Scientific American Supplement, February 21, 2009: 134–35.

Who was David Starr Jordan (1851-1931) was a naturalist, an educator, and a very important ichthyologist. Ichthyology is the scientific study of fish. During his career, Jordan named more than 2,500 species of fish. He taught biology at Butler University, Indiana University, and Stanford University. In 1891, he became the first president of Leland Stanford Junior University, now Stanford University. He was an early contributor to the theory of Darwinian evolution and was one of the major promoters of the eugenics movement in the United. An interesting, though unrelated, fact is Dr. Jordan enjoyed the company of his pet monkeys at his home. The David Starr Jordan Prize is awarded every 3 years for "innovative contributions to the study of evolution, ecology, population or organismal biology." More information about Dr. Jordan can be found at https://goo.gl/ENw0AU

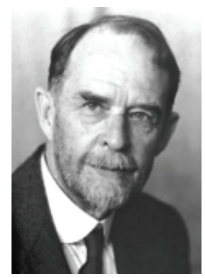
David Starr Jordan, c. 1908. Library of Congress,

TEXT 4

THE 1933 NOBEL PRIZE IN PHYSIOLOGY OR MEDICINE AWARDED TO THOMAS H. MORGAN

The Nobel Prize in Physiology or Medicine 1933 was awarded to Thomas H. Morgan "for his discoveries concerning the role played by the chromosome in heredity".

What are the Nobel Prizes? The Nobel Prizes are awards given to those who have had done their best to benefit mankind in the fields of physics, chemistry, medicine, literature, and peace. Created by Alfred Nobel, an inventor and businessman, the first awards were given in 1901. The winners get a diploma, a medal, and a cash award that has ranged between $350,000 and $1.5 million. All Nobel Prizes are awarded in Stockholm, Sweden, except for the Nobel Peace Prize, which is awarded in Oslo, Norway



Who was Thomas Hunt Morgan? By conducting statistical studies of the way genetic traits are passed on in fruit flies, Thomas Hunt Morgan broke new ground in genetics during the first decade of the 20th century. Morgan used fruit flies to study inheritance to that show that genes are stored in chromosomes inside cell nuclei… He was one of the first to move Mendel's genetics from the plant world to the animal world by studying fruit flies? Why fruit flies? First, the fruit fly can create a new and large of children in two weeks and 30 generations in just one year. So, Morgan would not have to wait for a year or more to see a change in heredity. Second, the fruit fly has only four chromosomes and so it was easier to show how a gene located on one of those chromosomes could pass on a trait from one generation to another. In this way, Morgan and his students were easily able to see the results of mating individual flies having specific characteristics. For his discoveries about the role of the chromosome in heredity he won the 1933 Nobel Prize.

Excerpts from speech awarding Thomas Hunt Morgan the Nobel Prize in 1933

"Modern hereditary researches are of a recent date…. Their founder is the Augustine monk Gregor Mendel…who published (1866) his experiments on hybridization among plants…. Mendel's observations are of revolutionizing importance. As a matter of fact they completely upset the older theories of heredity, although this was not at all appreciated by his contemporaries. Mendel's discoveries met with the same fate as many other great discoveries that have been made before their time. Their significance was not understood. They fell into oblivion. Darwin apparently knew nothing about his great contemporary…. [O]therwise he could have made use of Mendel's works for his own researches… [T]he rediscovery of Mendel's work was made only about 1900. When, at last, Mendel's discoveries came to light, their significance was soon perceived.

In 1910, the American zoologist Thomas Hunt Morgan began his researches in heredity. These soon led him to the great discoveries regarding the functions of the chromosomes as the bearers of heredity that have now been rewarded with the Nobel Prize for Medicine in 1933. The results of the Morgan school are daring, even fantastic[.] [T]hey are of a greatness that puts most other biological discoveries into the shade. Human hereditary researches have already made great use of Morgan's investigations. Without them modern human genetics and also human eugenics would be impractical."

BHP created this text from the speech made on the Nobel Ceremony honoring Dr. Morgan, December 10, 1933 (entire speech at https://goo.gl/yFz6qk)

TEXT 5

GENETICS

The organized study of the mechanism of heredity and evolution began only with the 20th century and the rediscovery of the lost work of Gregor Mendel.

Man's deepest urge…is to understand himself and his place in the Universe, to fathom his own nature as a living organism.


Dobzhansky

In this quest for self-understanding no investigation of the past 50 years has been more enlightening…than the study of heredity. The discovery of the basic laws of heredity is one of the major conquests of 20th-century science. Genetics has become a cornerstone of modern biology.

Genetics is peculiarly a science of our century. To be sure, its founder, the Austrian monk Gregor Mendel, reported his historic conclusions from his experiments with peas in 1865. But, nobody then paid attention to them. It was in the year 1900 that Hugo de Vries rediscovered Mendel's findings and thereby initiated the growth of a new science. By then biology was prepared to appreciate the significance of Mendel's work, and from 1900 on the study of heredity developed very rapid.

Very early in the study of genetics biologists began to pay particular attention to the aberrations now known as mutations.

A gene, by definition, is a living particle that reproduces itself, and nearly always it does so exactly. But occasionally it forms an imperfect copy of itself. If this altered gene is able to reproduce itself in its new form. The result is a mutation…a permanent change in some trait of the organism.

The mutation process, in short, supplies the building blocks of evolution. With this discovery, the biologists of the 20th century started to unravel the mechanisms of that evolutionary process which Charles Darwin and their successors of the 19th century had suggested but only dimly understood.[G]enetics will surely play a major role in the still infant technology of biological engineering. Already it has borne a huge harvest of "practical" results through improvements in breeds of food plants and animals. And genetics steadily becomes more and more important as a tool for improvements in the prevention, diagnosis and treatment of many diseases.

There remains the ultimate hope that genetics will point the way to improving the human species. Some of the early attempts to apply eugenics in the human realm were based more on enthusiasm than on understanding. But as our understanding of the genetics of human populations grows, the possibilities for useful application of our knowledge doubtless will multiply.

Who was Theo Dobzhansky? He was a major leader in investigating the relationship between genetics and the study of evolution. Born in Russia, he came to the California Institute of Technology in 1929 and in 1940 became a professor of zoology at Columbia University. In 1937, he published a very important book, Genetics and the Origin of Species. In this book, he made a strong case for uniting genetics with evolutionary biology.

BHP created this text from Dobzhansky, Theodosius. 1950. "Genetics." Scientific American 183: 55-58.

TEXT 6

BHP CHART ON THE AGE OF THE EARTH 2017

This chart shows major changes in the ways people have measured the age of the Earth.

Date	Name	Method Used to Calculate the Age of the Earth	Age of the Earth
1650	James Ussher	Analyzed Biblical references and generations referenced in Bible.	Earth created on October 22, 4004, BCE. Earth is around 6,020 years old.
1788	James Hutton	Observed and measured erosion and sedimentation in present day, and used present to hypothesize about Earth's history. Hutton claimed his studies could "find no vestige of a beginning –no prospect of an end."	Earth is much older than 6,000 years, since there is no evidence of a beginning or end.
1830	Charles Lyell	Like Hutton, observed current process to explain Earth's past. Agreed with Hutton that Earth's history was over an "inconceivably vast" period of time.	Estimated about 80 million years for the Cenozoic Era alone or about 300 million years old.
1862	Lord Kelvin	Kelvin assumed that the Earth initially was totally molten and calculated a date based on cooling through conduction and radiation. He used laws of physics and thermodynamics and heat measurements to develop a mathematical approach.	Earth was anywhere between 20 million and 40 million years old.
1899	John Jolly	To determine the age of the oceans, Jolly calculated the rate at which they would have accumulated sodium.	Oceans, and hence the Earth, is between 80 million and 100 million years old.
1927	Ernest Rutherford & Arthur Holmes	New discoveries of radioactivity by Rutherford and Curie showed that radioactive decay is constant. By measuring the decay in minerals, particularly uranium and lead, scientists began to estimate the age of rocks.	Earth is between 1.6 and 3 billion years old.
1953	Clair Patterson	Assumed meteorites are left over from the formation of the Solar System; used a new tool, mass spectrometer, to measure isotopes in meteorites. Oldest rock is about 4.5 billion years old.	Earth is 4.550 billion years old (give or take 70 million years).

BHP created this text from Matterson, James. "Historical Development of Dating Methods," in Jack Rink and Jaren Thompson (eds.), Encyclopedia of Scientific Dating Methods, 2015: 319-329.

TEXT 7

CRICK'S LETTER TO HIS SON

What is this letter? "On March 19th of 1953, weeks before it was announced to the public [in a letter to the magazine *Nature*], scientist Francis Crick excitedly wrote a letter to his son [Michael] and told him of one of the most important scientific developments of modern times: his co-discovery of the 'beautiful' structure of DNA, the molecule responsible for carrying the genetic instructions of living organisms; or, as Crick explained it to 12-year-old Michael, 'the basic copying mechanism by which life comes from life.' Although DNA was isolated back in the 1860s by Friedrich Miescher, its now-famous double-helix structure wasn't correctly modelled until the early 1950s by Crick and his colleague, James Watson, thanks in no small part to work already done by Maurice Wilkins, Rosalind Franklin, and Raymond Gosling. In 1962, Crick, Watson, and Wilkins were awarded the Nobel Prize for their efforts." (Source: *The Letters of Note* https://goo.gl/IL3msV)

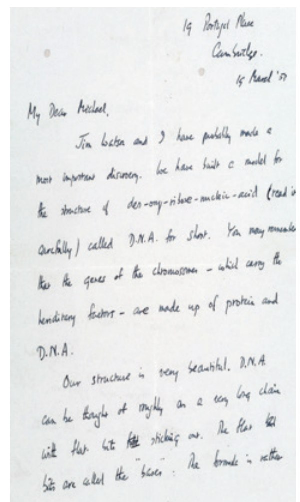
By the way, Michael Crick sold the letter at auction on April 10, 2013 for $5.3 million . He gave half of the money from the sale to the Salk Institute in San Diego, California, where his dad, Francis Crick, was a professor. Michael was 13 at the time he got this letter and learned before everyone else about the structure of DNA. To learn more about the Salk Institute, go to https://goo.gl/UV2bmh.

19 Portugal Place
Cambridge
19 March '53

My Dear Michael

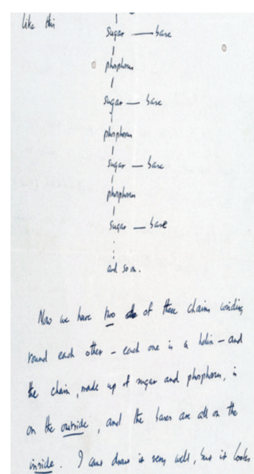
Jim Watson and I have probably made a most important discovery. We have built a model for the structure of de-oxi-ribose-nucleic-acid (read it carefully) called D.N.A. for short. You may remember that the genes of the chromosomes - which carry the hereditary factors - are made up of protein and D.N.A.

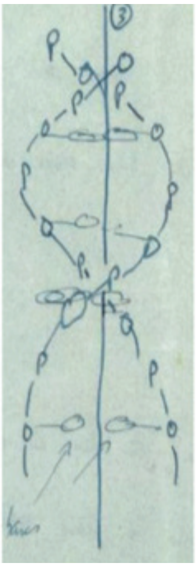
Our structure is very beautiful. D.N.A. can be thought of roughly as a very long chain with flat bits sticking out. The flat bits are called the "bases". The formula is rather like this.



|
sugar —— base
|
Phosphorus
|
sugar —— base
|
Phosphorus
|
sugar —— base
|
Phosphorus
:
and so on.

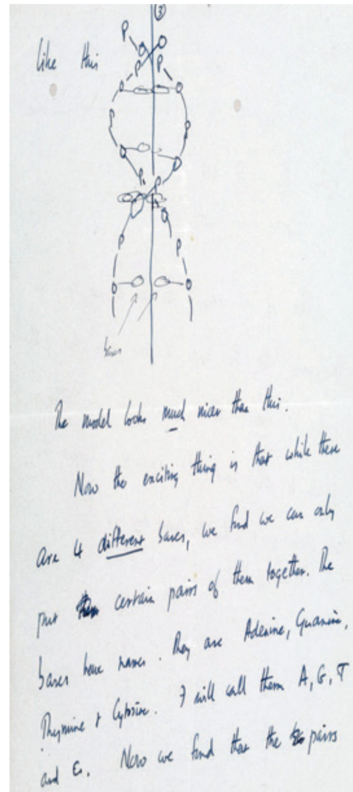
Now we have two of these chains winding round each other - each one is a helix - and the chain, made up sugar and phosphorus, is on the outside, and the bases are all on the inside. I can't draw it very well, but it looks like this.





The model looks much nicer than this.

Now the exciting thing is that while there are 4 <u>different</u> bases, we find we can only put certain pairs of them together. The bases have names. They are Adenine, Guanine, Thymine & Cytosine. I will call them A, G, T and C. Now we find that the pairs we can make - which have one base from one chain joined to one base from another - are only A with T and G with C.


like this

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we can make - which have one base from one chain joined to one base from another - are only A with T and G with C.

Now on one chain, as far as we can see, one can have the bases in any order, but if their order is fixed, then the order on the other chain is also fixed. For example, suppose the first chain goes, then the second must go

A .... T

T .... A

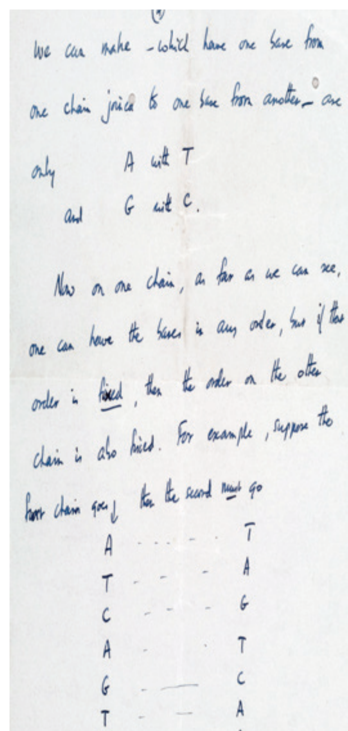
C .... G

A .... T

G C

T .... A

T .... A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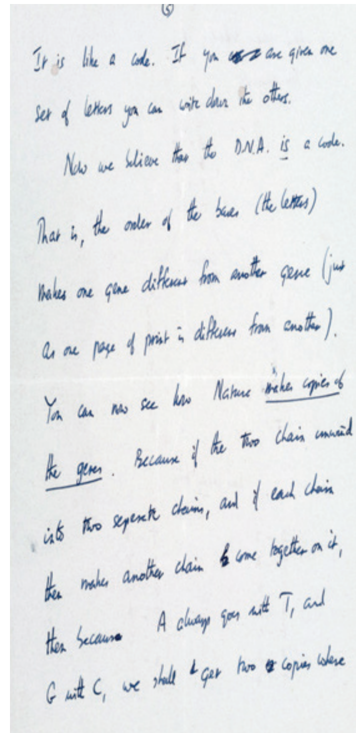
A - - - - T
T - - - - A
C - - - - G
A - - - - T
G - - - - C
T - - - - A

It is like a code. If you are given one set of letters you can write down the orders.

Now we believe that the D.N.A. is a code. That is, the order of the bases (the letters) makes one gene different from another gene (just as one page of print is different from another). You can now see how Nature makes copies of the genes. Because if the two chains unwind into two separate chains, and if each chain then makes another chain come together on it, then because A always goes with T, and G with C, we shall get two copies where we had one before.



(5)

It is like a code. If you are given one set of letters you can write down the others.

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For example

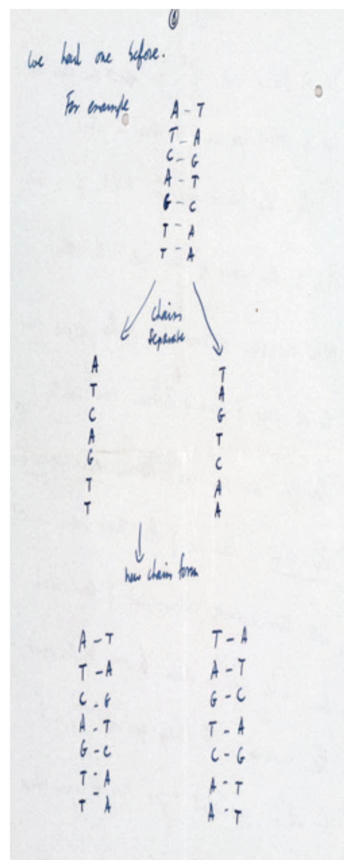
A — T
T — A
C — G
A — T
G — C
T — A
T — A

Chains separate

A T C A G T T   T A G T C A A

new chains form

A — T	T — A
T — A	A — T
C — G	G — C
A — T	T — A
G — C	C — G
T — A	A — T
T — A	A — T



(6)

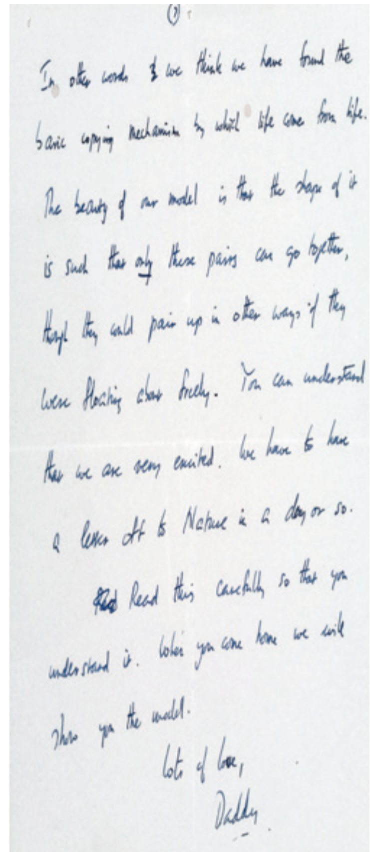
we had one before.

For example

In others words we think we have found the basic copying mechanism by which life comes from life. The beauty of our model is that the shape of it is such that <u>only</u> these pairs can go together, though they could pair up in other ways if they were floating about freely. You can understand that we are very excited. We have to have a letter off to Nature in a day or so.

Read this carefully so that you understand it. When you come home we will show you the model.

Lots of love,
Daddy



(7)

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Lots of love,
Daddy

TEXT 8

THE EPISODIC NATURE OF EVOLUTIONARY CHANGE

On November 23, 1859, the day before his revolutionary book hit the stands, Charles Darwin received an extraordinary letter from his friend Thomas Henry Huxley. It offered warm support in the coming conflict. But it also contained a warning: You have loaded yourself with the unnecessary difficulty in adopting Natura non facit saltum [Nature does not make leaps] so unreservedly.

Darwin was a strict adherent to this ancient motto. As a discipline of Charles Lyell, the apostle of gradualism in geology, Darwin portrayed evolution as a stately and orderly process, working at a speed so slow that no person could hope to observe it in a lifetime.

Huxley felt that Darwin was digging a ditch for his own theory. Natural selection required no postulate about rates; it could operate just as well if evolution proceeded at a rapid pace. The road ahead was rocky enough; why harness the theory of natural selection to an assumption both unnecessary and probably false? The fossil record offered no support for gradual change: whole faunas had been wiped out during disarmingly short intervals. New species almost always appeared suddenly in the fossil record with no immediate links to ancestors in older rocks in the same region.

I do not know why Darwin chose to follow Lyell and the gradualists so strictly. But I am certain of one thing, preference for one view or the other had nothing to do with superior information. On this question, nature spoke and continues to speak in multifarious and muffled voices. The geologic record seemed to provide as much evidence for cataclysmic as for gradual change. Therefore, in defending gradualism as a nearly universal tempo, Darwin had to reject literal appearance and common sense. Darwin's argument still persists. I wish only to point out that it was never 'seen' in the rocks.

I believe that Huxley was right in his warning. The modern theory of evolution does not require gradual change. The operation of Darwinism processes should yield exactly what we see in the fossil record. It is gradualism we must reject, not Darwinism.

The history of most fossil species includes two features inconsistent with gradualism. 1. Stasis: Most species exhibit no directional change. They appear in the fossil record looking much the same was when they disappear. 2. Sudden appearance: In any local area, a species does not arise gradually by steady transformation of its ancestors; it appears at once and fully formed.

I prefer this scheme as the model of punctuated equilibria. Gradualism sometimes works well. (I often fly over the folded Appalachians and marvel at the striking parallel ridges left standing by gradual erosion of the softer rocks surrounding them.) I make a simple plea for pluralism.

Who was Stephen Jay Gould? Stephen Jay Gould (1941-2002) was an evolutionary biologist, paleontologist, and a historian of science who taught at Harvard University for over thirty years. Gould warned against scientists allowing their beliefs or an authority to intrude on their interpretations. This sometimes led to ignoring evidence. Gould argued, for example, that Darwin was so committed to his belief in "gradualism" as described by Charles Lyell that he ignored the evidence in the fossil record. Gould, by the way, did not reject gradual change though in studying the fossil record, he and his colleague Niles Eldridge argued the evidence also supports sudden change.

Note: BHP edited this text from the original essay

TEXT 9

DRUG RESISTANCE EXPLAINED

Who is Marlene Zuk? Dr. Marlene Zuk is an evolutionary biologist. She is professor of biology at the University of Minnesota. Growing up, Dr. Zuk became interested in insects, and decided to study biology. She earned a Ph.D. in biology at the University of Michigan and has become an expert in germs and bug reproduction, among other specialties. Dr. Zuk has written four books and over 100 articles in peer-reviewed journals. You could learn more about Dr. Zuk and her research at https://cbs.umn.edu/zuk-lab/home.

Drug Resistance

People can be forgiven for wondering what difference it makes how we kill microorganisms. After all, soap or bleach kills bacteria, and so does penicillin. So why does it matter exactly how you kill them?

It does matter, and the reason for the consequences of killing bacteria with penicillin or killing them with Ivory soap has to do with evolution. Furthermore, I suspect that part of the confusion in the mind of the public lies in the use of euphemisms like "develop" and "change through time," rather than what we really mean, which is evolve.

Bacteria don't "develop" resistance, as if it were a muscle nurtured by going to a microbial gym. Instead, they had it all along, or more accurately a small proportion of them did. The process of natural selection, the same one that brought us a four-chambered heart and different sizes of beaks on Galapagos finches, does the rest.

Antibiotics mainly kill bacteria by targeting components in the cell wall, a structure that surrounds bacteria but which our own cells lack. Antibiotics are highly selective—unlike soap and water, which get rid of bacteria indiscriminately, through mechanical means.

When you take an antibiotic, a few of the bacterial cells in your body already happen to have genes that enable them to be resistant to it, just by random chance. You have many millions of bacteria, so it's not too surprising that they vary. If you don't take the whole course of antibiotics, say the 5 or 7 or 14 days your doctor recommends - or sometimes even if you do - enough of the resistant bacteria may remain to establish a new infection.

And they multiply incredibly quickly, leaving their equally resistant progeny in much greater numbers. The resistant bacteria will spread the way bacteria do, but now they will outnumber the vulnerable ones in the population. Then, when the same antibiotic is used again, it can't gain a toehold because a far greater proportion of the newly-produced bacteria are unaffected by its use. The bacteria have evolved.

In contrast, although soap and water don't completely annihilate the bacteria either, they aren't selective. The bacteria that remain are similar to the ones that went swirling down the drain, and so their offspring are equally vulnerable to the next scrubbing. So using soap or bleach-based cleansers is good, but inappropriate application of antibiotics will be worse than ineffective because it drives evolution.

As microbiologists Dan Andersson and Bruce Levin bluntly stated in the scientific journal "Current Opinion in Microbiology" almost 10 years ago: "The use of antibiotics by humans can be seen as an evolutionary experiment of enormous magnitude."

We're seeing the results of that experiment now. Economic costs of drug resistance—longer hospital stays, use of more expensive alternative medications and higher death rates—have been estimated at anywhere from $150 million to $30 billion each year, depending on exactly how you crunch the numbers.

What do we do? For starters, we all have to understand the crucial role that evolution plays in our lives. Doctors need Darwin, and the media has to stop using vague terminology that makes it sound as if bacteria were suddenly, inexplicably motivated to deter penicillin through spite.

Scientists are also experimenting with altering essential proteins in hosts that bacteria use to mount infections. Right now they're using mice that have genetic mutations that make the proteins inaccessible to the bacteria. It's not clear exactly how this would be applied to people, but these treatments wouldn't use conventional antibiotics and hence might be less subject to evolving resistance. Early days, but hopeful.

Note: BHP edited this text from the original essay

Analysis of texts in this investigation

Text Name	Lexile Measure[1]	Common Core Stretch Grade Band[2]	Mean Sentence Length	Flesch Ease[3]
Evidence for and Problems with Darwin's Theory	900L	4-5	12.96	51.9
Principles of Geology	1150L	6-8	18.27	58.3
Darwinism Fifty Years After: The Biological Lesson of Evolution	1270L	9-10	20.12	45.5
Excerpts from speech awarding Thomas Hunt Morgan the Nobel Prize in 1933	980L	6-8	13.56	37.2
Genetics	1090L	6-8	16.48	40.5
BHP Chart on Age of the Earth, 2017	1210L	9-10	17.6	38.8
Crick's Letter to His Son, 1953	1020L	6-8	17.07	81.4
The Episodic Nature of Evolutionary Change	980L	6-8	13.26	49.9
Drug Resistance Explained	1200L	9-10	17	40.1

[1] Lexile measure indicates the reading demand of the text in terms of its semantic difficulty and syntactic complexity. The Lexile scale generally ranges from 200L to 1700L. The Common Core emphasizes the role of text complexity in evaluating student readiness for college and careers.

[2] We are using the Common Core "stretch" grade bands. The Common Core Standards advocate a "staircase" of increasing text complexity so that students "stretch" to read a certain proportion of texts from the next higher text complexity band.

[3] In the Flesch Reading Ease test, higher scores indicate that the material is relatively easy to read while lower scores indicate greater difficulty. Scores in the 50–70 range should be easily understood by 13- to 15-year-olds, while those in the 0–30 range are appropriate for university graduates.