The Origin of Species

INTRODUCTION

BRIEF BIOGRAPHY OF CHARLES DARWIN

Charles Darwin was an English naturalist and writer best known for developing and popularizing his theory of evolution. He remains one of the most renowned scientists of all time, and his landmark book *The Origin of Species* (first published in 1859) remains influential. Darwin grew up in a wealthy English family and read widely, although he disappointed his father by failing to follow in his footsteps and become a doctor. While Darwin had long been interested in nature, the turning point in his life came when he joined the crew of the H.M.S. *Beagle* on a voyage that included a stop at the Galapagos Islands. His observations on that voyage—most notably of the different types of finches on the islands—helped spur his theories about natural selection and evolution that he would develop over the course of his career, most notably in *The Origin of Species*, but also in his later books like *The Descent of Man* (1871) and *The Expression of the Emotions in Man and Animals* (1872). By the time Darwin died in 1882, he was already regarded as a revolutionary scientist, and he continues to be studied, debated, and celebrated into the present.

HISTORICAL CONTEXT

Darwin lived and wrote primarily during the Victorian era (when Queen Victoria was on the throne in Britain). Though this era is often associated with repressive social conditions, it was also a time of radical change, particularly in the sciences. Though the Enlightenment (which came before the Victorian era) saw the beginnings of new widespread interest in science and philosophy, by Darwin's time the scientific method had become more formalized and a wider popular readership helped spread ideas more rapidly. Though Darwin benefited from his ability to travel around the world and collect specimens, this ease of travel was related to British colonialism, which involved conquering and repressing people in other countries in order to exploit their resources. After Darwin's death, a variety of different philosophies would claim influence from him, ranging from humanism and Marxism to eugenics and fascism, some of which are arguably based on misunderstanding Darwin's original work. Evolutionary scientists have since expanded on Darwin's ideas, but he remains a foundational figure in the field.

RELATED LITERARY WORKS

Darwin's theories were inspired by the writings of other scientists and thinkers with who preceded him, including the geologist Sir Charles Lyell (*Principles of Geology*), the economist and political theorist Thomas Malthus (*An Essay on the Principle of Population*), and the philosopher Jean-Jacques Rousseau (*The Social Contract*). One of Darwin's biggest inspirations was Jean-Baptiste Lamarck (*Philosophie zoologique*), who developed an earlier theory of evolution that was ultimately replaced by Darwin's. After the publication of Darwin's books and his death, many of his ideas—and particularly their implications for religion—were influential for writers in the Modernist movement. This period, which went from the late 19th century to the early 20th century, included authors such as Joseph Conrad, James Joyce, D.H. Lawrence, and Virginia Woolf and is often closely associated with a philosophy called humanism (which emphasized human agency and reason while minimizing the significance of divine forces).

KEY FACTS

- **Full Title:** The Origin of Species
- **When Written:** 1837–1859
- **Where Written:** England
- **When Published:** 1859
- **Literary Period:** Victorian
- **Genre:** Science
- **Setting:** Global
- **Antagonist:** There is no traditional antagonist, but Darwin presents his peers' unscientific views as a sort of antagonist.
- **Point of View:** First Person

EXTRA CREDIT

Hungry for Knowledge. Darwin not only observed rare animals from around the world: he also ate them. Some of his favorites include armadillo (which he compared to duck) and puma (which he compared to veal). This habit got him in trouble when he realized midway through one Christmas dinner that he was eating a very rare bird—he immediately stopped and tried to salvage what remained of the specimen.

PLOT SUMMARY

Charles Darwin, a British naturalist who took a life-changing trip to the **Galapagos Islands** on a ship called the *H.M.S. Beagle*, announces that at the urging of colleagues like Sir Charles Lyell and Dr. Joseph Dalton Hooker, he will finally publish some of the theories that he has been working on for a while. At the center of Darwin's new ideas is the theory of natural selection—the idea that all species are in competition with each

other to exist and that the specimens with the best chances of surviving are "naturally selected."

Darwin goes on to describe natural selection in more detail. He explains how all individuals within a species have slight variations, and that over millions of years, these variations could be passed down hereditarily. This can then cause the variations to become more pronounced, even giving birth to new species. Whether an organism uses or doesn't use a body part seems to affect what traits get passed down and survive in a population. Some traits might not have an obvious link to survival; for example, the colorful feathers on some male birds play a vital role in helping them to attract mates, even though the feathers aren't necessary for the bird to acquire food or avoid predators. (This process is called sexual selection.) To make natural selection easier to understand, Darwin draws frequent comparisons to domestic breeding, showing how what experienced humans do with domestic plants and animals isn't all that different from what happens in nature when organisms are left on their own to compete in their environment.

Darwin devotes chapters and sections of his book to expand on some of the most interesting or difficult parts of his theory. For example, rudimentary parts of an organism (that is, body parts that aren't useful), such as the wings on an ostrich, might seem difficult to explain if natural selection leads to adaptations that improve an organism's chances to survive and pass on its genes. Nevertheless, Darwin shows that because of the principle of economy of growth, natural selection could lead once-useful parts to become rudimentary—since "giving" to one part of an organism usually involves "taking" from another part, rudimentary features allow an organism to adapt in other ways. Similarly, it might seem strange that the offspring of some hybrid crosses between organisms turn out to be infertile. Darwin concedes that the laws behind sterility are complex but argues that, while hybrid sterility is not a result of natural selection, it also does not necessarily contradict the theory.

Darwin often stops in the book to address the concerns of his critics. Darwin insists that species change over time and are therefore not immutable (which means unchanging): some interpret this as a challenge to traditional religious teachings. By Darwin's own admission, one of the most serious objections to his theories is the **eye**, which seems like such a complex, highly functioning organ that it could only have been created all once (usually by a Creator, such as God, according to these critics). Darwin, however, provides evidence to show why even the worthiest objections to his theories can nevertheless be answered. In the case of the eye, for example, he shows how many past and present organisms actually have eyes that fall on a spectrum—less complex than the human eye but more complex than a simple optical nerve. Looking at all these examples, it is possible to imagine how even the most complicated eye could have been naturally selected, through a series of small but significant improvements, over a very long period of time. He still allows that issues like the imperfections of the geological record make his job difficult, but he nevertheless promises to go into even greater detail on some of his theories in future books and treatises.

Darwin argues that species don't arise in multiple places; they more likely originate once and then migrate around the world, developing new adaptations over time. Occasionally, in geographically isolated locations, they form endemic species. Ultimately, Darwin takes this line of thinking to its logical extreme, suggesting that if you go back far enough, all life descends from just a few progenitors or perhaps even just one.

Darwin ends the book with a concise summary of all the issues he covered in the previous chapters. He reiterates that he believes his ideas are not inconsistent with the idea of a Creator and that he believes that evolution simply means that all creatures are on their way towards becoming more beautiful and wonderful.

CHARACTERS

Charles Darwin – Charles Darwin was a British scientist from the 19th century who is best known for helping to develop and popularize the theory of evolution. Though he wrote several books, he is today best remembered for *The Origin of Species*, which he worked on for many years before publishing in 1859; he continued to revise it for rest of his life. *The Origin of Species* is written in the first person, and while it is a scientific text, it also has a conversational tone at times, with Darwin directly addressing both the reader and other contemporary scientific writers. The "character" of Darwin in the book is humble and always willing to consider the objections of his opponents, as well as possible flaws and shortcomings of his own conclusions. In the book, Darwin also sometimes hesitates to take his ideas to their fullest conclusion, most notably when he avoids directly suggesting that human beings themselves would have evolved from an ape-like progenitor. Darwin's book persona is fairly traditionally religious and frequently mentions a Creator, while outside of the book, Darwin was more reluctant to share religious views; historians debate what he really believed. Ultimately, the version of himself that Darwin presents in *The Origin of Species* is one that he hoped would appear reliable and reasonable, both to the most accomplished scientists of his day as well as to a wider audience of curious general interest readers. The enduring popularity and significance of *The Origin of Species* are due partly to how successfully Darwin turned himself into a character for a mass audience.

Charles Lyell – Charles Lyell was a well-known Scottish geologist who was a friend and colleague of Darwin's; his work helped inspire some of Darwin's most enduring ideas. In the book, Lyell is frequently cited as an authority, perhaps in the

hopes that some of Lyell's prestige would help to bolster the standing of Darwin's own new ideas. Though today Darwin is better known than Lyell, Lyell's ideas about geology were revolutionary in their own way. More than perhaps any other scientist, Lyell is credited with helping to popularize the idea that geological changes to the earth happen very slowly over very long periods of time. In a way, Darwin's theory of natural selection is simply an extension of Lyell's theories to organisms, since Darwin too believed that changes in nature happened slowly over long periods of time.

Thomas Malthus – Thomas Malthus was a British writer and philosopher who was a predecessor of Charles Darwin and an influence on his work. Malthus is best known for his idea that populations will grow faster than food supplies, and so eventually the populations will reach a "catastrophe," causing some of the population to die off. Though Malthus is mentioned only briefly in *The Origin of Species*, his ideas were clearly influential on Darwin, specifically on Darwin's ideas about survival of the fittest. This idea suggested that species were in competition for limited resources. Today, many of Malthus's ideas about overpopulation are discredited, but they remain historically important and are still debated.

St. George Jackson Mivart – St. George Jackson Mivart was an English scientist who originally held ideas similar to Darwin's but who went on to became one of Darwin's most vocal critics. Out of all the critics that Darwin replies to in *The Origin of Species*, Mivart is one of the ones who gets the most words devoted to him. Darwin seems to believe that there are merit to Mivart's ideas but nevertheless, Darwin ultimately uses the objections of critics like Mivart as a way to bolster his own arguments.

Joseph Dalton Hooker – Joseph Dalton Hooker was a British botanist and explorer who was one of Darwin's good friends. He's credited in the book with encouraging Darwin to publish *The Origin of Species*. Hooker was one of Darwin's earliest and most public supporters, and his work studying plants from around the world helped Darwin form some of his theories.

TERMS

Adaptation – **Darwin** uses the term adaptation to mean a trait that helps improve an organism's "fitness" and its ability to survive in nature and overcome competition. Most adaptations arise through natural selection.

Dimorphism – Dimorphism is when a species has two different forms with very different characteristics. Sexual dimorphism is a very most common version (for example, when the male of a species looks different from the female). Trimorphism is less common than dimorphism and involves three different forms.

Endemic – An endemic species is a species that only lives in a limited area. Islands, like the Galapagos, are some of the most common places to find endemic species.

Hermaphrodite – A hermaphrodite is an organism with both male and female reproductive organs. Many plants are hermaphrodites, and **Darwin** studied them to better understand reproduction.

Hybrid – A hybrid is the offspring of two different species. **Darwin** extensively looked at whether hybrids were fertile or sterile, and what that would mean for natural selection.

Immutability – Immutability is the quality of being unable to change. It is the opposite of "mutability," which refers something that can be easily changed.

THEMES

In LitCharts literature guides, each theme gets its own color-coded icon. These icons make it easy to track where the themes occur most prominently throughout the work. If you don't have a color printer, you can still use the icons to track themes in black and white.

NATURAL SELECTION AND THE POWER OF NATURE

At the heart of Charles Darwin's landmark book *The Origin of Species* is a concept called natural selection. He referred to the "origin" of species in his title because when the book was first published in the mid-1800s, there was a controversy over how species arose. Many believed that each species was created separately and that once created, species were immutable (meaning they didn't change). While this was not necessarily a religious belief on its own, it tended to go hand in hand with the belief that a Creator was the one who oversaw the individual creation of each species. While Darwin argued that his views were perfectly consistent with the idea of a Creator, ultimately he was making a radical statement about the power of nature, suggesting that all life on the planet descended from only a few progenitor species, or perhaps even just one.

According to the theory of natural selection, all organisms are in a struggle for survival over limited resources. Because of this, the organisms best adapted to their environment have an advantage and are more likely to survive and pass these advantages on to offspring (since many adaptations are hereditary). As an organism became better adapted than its competition, it might diverge and become a new variety or even a new species. On a long enough time scale, this process could account for the full diversity of life on earth, without requiring a Creator to individually create each new species. Such a process could even explain the origin of humans (although Darwin only implied this possibility in *The Origin of Species*, and it took his later books plus commentary from other scientists to fully explain and develop the idea). Darwin's book revolutionized

humanity's understanding of the history of nature by providing a process—natural selection—that could comprehensively explain how modern life originated.

REASON, ARGUMENT, AND THE SCIENTIFIC METHOD

Throughout *The Origin of Species*, Darwin makes it clear that his book is not simply a collection of facts, but structured in the form of an argument. Whole sections and even chapters of the book are dedicated specifically to answering the objections of critics, which Darwin attempts to do methodically and with hard evidence. While scientific writing is often associated with dry, impartial language, Darwin was writing for a relatively wide audience, and he knew his ideas would be controversial, particularly among people who held certain religious beliefs.

Darwin made his arguments in an orderly fashion: first he identified real or potential objections, then he acknowledged the potential value of these objections, then he offered evidence that he believed was enough to overcome or at least minimize the objections. This orderly pattern resembles the scientific method, which also involves identifying questions and then trying to answer them with impartial evidence. In this way, Darwin tried to practice what he preached, and his methods seem to suggest a belief that the best way to persuade people was with rationality and reason. In both its structure and its content, then, *The Origin of Species* argued for the value of reason as a way to better understand both humanity and the natural world.

TIME AND PROGRESS

One of Darwin's central ideas in *The Origin of Species* was that over time, organisms would become better adapted to their environment. As less well-adapted organisms die out and become extinct, the organisms that remain are better suited to compete for resources, often containing organs and body parts of remarkable complexity, like the skull or wings or **eyes**. While not all critics agreed, Darwin believed that even these very complex structures could arise in a species through a series of gradual, incremental improvements. For example, species with complex eyes today likely descended from species that originally had much simpler eyes, and it is possible to imagine intermediate species with eyes that improved on the original structure but still lacked the organization of the modern version. In some cases, an organ or feature might lose its original function, like the wings on an ostrich; yet this, too, is a type of progress because it allows the organism to grow and adapt in other ways (due to a principle called economy of growth). Also, adaptation is not necessarily a linear process, since changes in the environment, climate, and other species can all affect the conditions for survival. Nevertheless, Darwin argued in the book's final chapter that due to natural selection, "all corporeal and natural endowments will tend to progress towards perfection." Darwin's personal opinions have been the subject of much speculation, but in *The Origin of Species*, at least, he makes the case that his scientific theories reveal a world that is in a constant state of progress and improvement.

COLLABORATION AND SCIENCE

Although today Charles Darwin is one of the most famous names in science, in *The Origin of Species*, Darwin presents a more limited view of his own influence, suggesting that many of his ideas were merely adapted from the work of other eminent scientists of his era. While it could be argued that this was a rhetorical strategy—a way for Darwin to minimize how potentially radical his ideas were—it is also clear that Darwin read widely to supplement the research he was doing on his own in the **Galapagos** and elsewhere. He drew inspiration from the research of other naturalists and in some cases, he even directly incorporated their ideas into his own, particularly on issues where he himself wasn't necessarily an expert. For example, Charles Lyell's discoveries about geology were critical to Darwin's understanding of how time worked with natural selection, and Lyell is among the scientists cited most extensively in *The Origin of Species*. In later editions of the book, Darwin also addressed his critics, occasionally dismissing their views but much more often answering their questions and even sometimes acknowledging the shortcomings of his approach. Ultimately, Darwin believed that just as species could be improved through natural selection, ideas could be refined through collaboration, and his book is a testament to the communal nature of scientific research.

SYMBOLS

Symbols appear in **teal text** throughout the Summary and Analysis sections of this LitChart.

THE GALAPAGOS ISLANDS

Darwin's trip to the Galapagos Islands as the naturalist on board the *H.M.S. Beagle* was one of the biggest inspirations behind *The Origin of Species*, and the islands represent how one small part of nature can act as a microcosm for the whole of nature. Darwin studied the birds on the islands, most notably their endemic species of finches. He was surprised by the variety of life present on the islands and also by how the birds on the islands differed from birds on the nearby mainland. Ultimately, he found that each variety and species of bird seemed to have adaptations that made it particularly well-suited to its specific environment. These

findings were crucial to Darwin's development of the theory of natural selection. In the book, they provide an especially clear example of a place where several species and varieties all seemed to have descended from a common ancestor. The relatively remote location of the Galapagos Islands is also significant because it shows how Darwin hoped to create theories that would hold true across the entire world. The Galapagos Islands represent the success of the scientific method, showing how Darwin used his own meticulous observations of one small area to develop a theory of natural selection that would change the entire science community's understanding of nature.

EYES

Darwin's critics often bring up the topic of eyes, since they seem to be an organ of such complexity that only a Creator could have made them. For Darwin, however, eyes represent exactly the opposite: they show how even a process as slow and gradual as natural selection could lead to results as shockingly organized and elaborate as the eye. He admits that eyes are a formidable challenge to his theory, but crucially, he believes they are a challenge that can be explained. In *The Origin of Species*, Darwin demonstrates that not all eyes are as complex as the human eye—many organisms have eyes that exist on a spectrum between rudimentary optical nerves and fully developed eyes. The diversity of eyes in living creatures and the fossil record helps make the case that complex eyes did not have to arise all at once but in fact could have easily been the result of gradual, successive adaptations over a long period of time. Additionally, eyes present another, opposite problem for Darwin: why do some organisms that live underground or in caves have nonfunctioning eyes if natural selection favors improvement? Here, Darwin explores the idea that features of an organism that don't get frequent use will eventually be selected against in natural selection. This is because of the principle of economy of growth—losing eyes that no longer serve a purpose helps an organism adapt in other ways. Ultimately, eyes serve a variety of functions in *The Origin of Species* and perhaps are especially significant because they can also symbolize observation—and observation was the basis of many of Darwin's most noteworthy discoveries.

QUOTES

Note: all page numbers for the quotes below refer to the Signet edition of *The Origin of Species* published in 2003.

Introduction Quotes

❝ When on board H.M.S. *Beagle*, as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent.

Related Characters: Charles Darwin (speaker)

Related Themes:

Related Symbols:

Page Number: 3

Explanation and Analysis

This quote begins the introduction of the book. In it, Charles Darwin describes his formative experience acting as a naturalist on board a ship called the H.M.S. *Beagle*. In particular, Darwin was influenced by the time he spent in the Galapagos Islands, where he observed the plant and animal life closely, especially the birds. The experience was beneficial to Darwin for many reasons, including because islands tend to have endemic species that are different from what's on the mainland, and also because the Galapagos are in the Southern Hemisphere, meaning they were a different environment from Darwin's native Europe. Darwin already had a background as a naturalist before his voyage on the *Beagle*, but many historians credit the trip with causing him to have an epiphany that helped him to develop the theory of natural selection, particularly when he saw the variety of life there on each island. The fact that Darwin references this trip at the very start of his book further cements the idea that the voyage was important to him. More broadly, Darwin's reference to the Galapagos emphasizes how new scientific insights are driven by personal observation and by going out into the world to explore, rather than simply staying back and theorizing.

❝ This abstract, which I now publish, must necessarily be imperfect. I cannot here give references and authorities for my several statements; and I must trust to the reader reposing some confidence in my accuracy. No doubt errors may have crept in, though I hope I have always been cautious in trusting to good authorities alone.

Related Characters: Charles Darwin (speaker)

Related Themes:

Page Number: 4

Explanation and Analysis

This quote, from the middle of the introduction, is where Darwin describes the process of publishing *The Origin of Species*. It is the first of many times in the book where he notes the shortcomings of his methods and apologizes for any potential errors. This might seem surprising, given that today *The Origin of Species* is regarded as one of the most influential books of all time, but there are a couple potential reasons why Darwin does this. Sometimes, he is simply being honest. Darwin would in fact expand on many of his ideas from *The Origin of Species* in his later books, and future scientists would only continue to refine and shape Darwin's ideas as new data and research methods became available. While Darwin's work was revolutionary and important, he also avoided overstating his case.

But another possible explanation for Darwin's modesty is that it was a rhetorical strategy. Darwin makes reference several times to the fact that his book is an argument and his hope that he can persuade people in the audience who may be slow to accept his ideas. He was aware that many of his ideas were controversial, not just because they challenged the views of his fellow scientists but because they also seemed to challenge many people's religious beliefs. Rather than emphasizing the controversial elements of his book, then, Darwin seems to deliberately downplay them, suggesting that his goal for the book is to make it approachable to a wide reading audience.

Chapter 1 Quotes

❝ When we compare the individuals of the same variety or sub-variety of our older cultivated plants and animals, one of the first points which strikes us is, that they generally differ more from each other than do the individuals of any one species or variety in a state of nature.

Related Characters: Charles Darwin

Related Themes:

Page Number: 9

Explanation and Analysis

This quote comes from the beginning of the first chapter. When Darwin writes "our older cultivated plants and animals," he's referring to domesticated plants and animals, like wheat and corn or dogs and cattle. He suggests that domesticated plants and animals tend to show more variety than wild plants and animals (for example, that dogs show more variety than wolves). Ultimately, he is setting the stage to introduce the concept of natural selection—the theory at the center of the book that explains how species originate.

Before getting to natural selection, however, Darwin describes the human-driven processes that happen under domestication. While domestication does not fully mirror what happens in nature, it provides a useful reference point, in part because there is a long-recorded history of humans observing domestic species, and this means it is easier to observe and track the results of reproduction. Darwin often makes his arguments by starting with well-known facts before using them to make more surprising arguments, and for this reason, it is natural that he starts the book with the well-studied topic of domestication.

Chapter 2 Quotes

❝ Finally, varieties cannot be distinguished from species—except, first, by the discovery of intermediate linking forms; and, secondly, by a certain indefinite amount of difference between them; for two forms, if differing very little, are generally ranked as varieties, notwithstanding that they cannot be closely connected; but the amount of difference considered necessary to give to any two forms the rank of species cannot be defined.

Related Characters: Charles Darwin

Related Themes:

Page Number: 58

Explanation and Analysis

This passage, from the middle of Chapter II, demonstrates one of Darwin's attempts to determine the distinction between *variety* and *species*. This is a topic that he returns to several times throughout the book. It might seem like a minor issue (and in fact Darwin himself notes that the border between *variety* and *species* can at times be arbitrary), but it is important for Darwin to consider the matter because he is writing about how new species originate.

Ultimately, Darwin resists giving a straightforward answer about where the boundary between *variety* and *species* lies and in fact even goes on to suggest that it may not be possible to clearly define the difference. This does not mean that he believes classification is unimportant (he devotes a chapter to it later), but it does mean classification's ability to explain things is limited .By making this distinction, Darwin emphasizes that his intention is to avoid being swayed by existing classification systems and that he intends to use

observation and data to make his arguments.

Chapter 3 Quotes

❝ A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase.

Related Characters: Charles Darwin, Thomas Malthus

Related Themes:    

Page Number: 62

Explanation and Analysis

This quote describes one of the most important concepts in Chapter III and in the whole book—the idea that species are constantly in a competition to survive. This idea forms the basis for the concepts of survival of the fittest and natural selection. In this sentence in particular, Darwin shows the influence that the economist and political theorist Thomas Malthus had on his writing. (Elsewhere in the book, Darwin credits Malthus by name.)

Though Malthus wrote on a wide variety of topics, he is most famous for his idea that populations grow at a faster rate than the food supply, and that the inevitable result is some sort of "catastrophe" that will result in part of the population dying off. Here, Darwin is clearly referencing Malthus's ideas about how quickly populations grow. This passage is one of many that highlights how Darwin relied on the work of thinkers before him and how even his most revolutionary ideas often had precursors.

❝ Many cases are on record showing how complex and unexpected are the checks and relations between organic beings, which have to struggle together in the same country.

Related Characters: Charles Darwin, Thomas Malthus

Related Themes:    

Page Number: 69

Explanation and Analysis

This sentence, from later in Chapter III, shows how Darwin took the basic premise of Malthus's theories and expanded them into something that was new and original. What Darwin describes in this sentence is not necessarily natural selection—instead, it is the conditions that make natural selection possible. An important condition for natural selection is that species must be in competition with each other. Darwin describes this competition as "checks"—this could mean predators that limit populations of prey by feeding, or it could mean similar species that compete for the same limited resources. This competition can even occur within a species, where individuals with favorable adaptations have a better chance of surviving and reproducing than other individuals of the same species. Darwin emphasizes that these checks can be "complex and unexpected," suggesting that perhaps humans can't even understand what they are—an important distinction from domestic breeding, which is driven by humans. Again, Darwin shows how his ideas rely on past thinkers while also expanding into new territory.

Chapter 4 Quotes

❝ As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature, if I may be allowed to personify the natural preservation or survival of the fittest, cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 79

Explanation and Analysis

After hinting at the concept of natural selection in previous chapters, Darwin finally begins explaining the concept in more detail in Chapter IV, including in the passage here. On the one hand, Darwin's argument is logical: if humans can do so much through the breeding of domestic animals, then surely even more amazing things could happen in nature. Natural selection, then, is just nature's equivalent of the role human selection plays in domestic breeding.

Darwin's decision to personify "Nature" could be read as a conscious choice to find a middle ground between the religious and secular. While Darwin's own religious beliefs have been the subject of debate and speculation, what is clear is that in *The Origin of Species* he strives to avoid any statements that would require divine intervention to drive evolution. Darwin leaves it up to his audience to determine whether "Nature" refers to a deity or whether it is just a

convenient way to personify the workings of the natural world, showing once again how Darwin strives to appeal to a wide audience.

"This leads me to say a few words on what I have called sexual selection. This form of selection depends, not on a struggle for existence in relation to other organic beings or to external conditions, but on a struggle between the individuals of one sex, generally the males, for the possession of the other sex. The result is not death to the unsuccessful competitor, but few or no offspring.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 84

Explanation and Analysis

This passage is from the section where Darwin describes sexual selection, an important component of natural selection. Sexual selection is a massive topic, and Darwin himself would later devote a whole book to it, but here, Darwin gives a more abridged overview. The important insight behind sexual selection is that not all competition between organisms is a literal fight for survival—sometimes what traits get passed on to future generations is determined by how organisms reproduce.

Darwin gives the famous example of male birds with colorful feather patterns. These feather patterns often seem to exclusively serve the purpose of attracting females to reproduce with. Darwin suggests that these feather patterns could be affected through natural selection (specifically as sexual selection) because of their importance to reproduction. His insights show his ability to think methodically, taking the basic premises of natural selection and expanding them out to their logical conclusion in order to explain a phenomenon he noticed in nature.

Chapter 5 Quotes

"In one sense the conditions of life may be said, not only to cause variability, either directly or indirectly, but likewise to include natural selection, for the conditions determine whether this or that variety shall survive.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 130

Explanation and Analysis

After establishing what natural selection is, Darwin moves on to describing its workings in more detail, and this sentence from Chapter V looks at the important issue of variability. Darwin makes the important distinction that natural selection does not *cause* variability; it simply preserves it in some situations where it is beneficial. This raises a new question, though: if natural selection doesn't cause variability, then what does?

Darwin's answer, as he begins laying out in this passage, is that the conditions of life seem to naturally cause variability. In his time, scientists did not have a comprehensive knowledge of genetic mutations, but Darwin nevertheless understood that offspring inherited traits from parents, and sometimes the crossing led to minor variations that were not present in either parent. Ultimately, for Darwin's purposes, the origin of variations is not the most important thing—it's how these variations can be preserved through natural selection (or lost through the reproductive process or extinction).

Chapter 6 Quotes

"Long before the reader has arrived at this part of my work, a crowd of difficulties will have occurred to him. Some of them are so serious that to this day I can hardly reflect on them without being in some degree staggered; but, to the best of my judgment, the greater number are only apparent, and those that are real are not, I think, fatal to the theory.

Related Characters: Charles Darwin

Related Themes:  

Page Number: 160

Explanation and Analysis

This quote from the beginning of Chapter VI announces Darwin's intention to respond to the objections of his critics. He does this not only for the entirety of Chapter VI but for the chapters immediately following it as well. This preoccupation with critics suggests that Darwin was being fairly literal when he referred to his book as an "argument," and that he felt that answering objections was an important part of making this argument. Additionally, the sheer number of critics that Darwin mentions suggests that his ideas faced resistance, especially (although not exclusively)

when he first published them.

This passage follows the same basic pattern that Darwin uses in the majority of his responses to critics. First, he acknowledges the seriousness of the critic's objection and the ways in which it could seem to be correct. After spending time on the merits of the critic's position, however, Darwin ultimately transitions into reasserting why his own ideas can withstand the critic's objections. This is a classic debating technique, and Darwin uses it to help give the impression that he is reasonable, open-minded, and—most importantly of all—correct in his assertions.

❝ To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree.

Related Characters: Charles Darwin

Related Themes:

Related Symbols:

Page Number: 172

Explanation and Analysis

This passage contains Darwin's response to an objection to his theories that he considered among the most serious. Some of Darwin's critics believed that an organ like the human eye was too organized and complex to have arisen through a gradual, step-by-step process like natural selection. These critics felt that such a complex organ must have been created all at once (an argument that often had a religious tone to it). Darwin himself seemed to believe eyes were a serious issue and mentions them throughout the book in various contexts. Ultimately, however, he did not find his critics' opinions convincing enough to sway his own, and he believed that eyes developed just the same as any other feature under natural selection. To bolster his argument, Darwin looked at the eyes of many currently existing species. While he acknowledged that it might seem like an unbridgeable gap between the simple optical nerve of some organisms and the fully formed human eye, in fact, there existed a whole spectrum of intermediate examples that provided evidence of how the eye could have become more complex through gradual, successive improvements.

Chapter 7 Quotes

❝ All Mr. Mivart's objections will be, or have been, considered in the present volume. The one new point which appears to have struck many readers is, "That natural selection is incompetent to account for the incipient stages of useful structures." This subject is intimately connected with that of the gradation of the characters, often accompanied by a change of function, for instance, the conversion of a swim-bladder into lungs, points which were discussed in the last chapter under two headings. Nevertheless, I will here consider in some detail several of the cases advanced by Mr. Mivart, selecting those which are the most illustrative, as want of space prevents me from considering all.

Related Characters: Charles Darwin (speaker), St. George Jackson Mivart

Related Themes:

Page Number: 211

Explanation and Analysis

Throughout the book, Darwin responds to many of his critics by name, and in this passage, he answers St. George Mivart. Darwin gives particular attention to Mivart in part because Mivart had collected and compiled the objections of other critics to Darwin, making him one of Darwin's most formidable opponents. Nevertheless, despite their differing views, Darwin is always respectful toward Mivart, suggesting a preference for reasonable language and discourse instead of sharper personal attacks.

The fact that Darwin names so many critics (as well as allies) suggests that interpersonal relationships played an important role in science, particularly when it came to gaining acceptance for new ideas. In some ways Darwin has an advantage—he is free to cherry-pick arguments from opponents that he already has enough evidence to disprove—but Darwin's engagement with his critics seems to also reflect a belief that science is a conversation and that new discoveries affect the whole scientific community.

Chapter 8 Quotes

It will be universally admitted that instincts are as important as corporeal structures for the welfare of each species, under its present conditions of life. Under changed conditions of life, it is at least possible that slight modifications of instinct might be profitable to a species; and if it can be shown that instincts do vary ever so little, then I can see no difficulty in natural selection preserving and continually accumulating variations of instinct to any extent that was profitable.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 245

Explanation and Analysis

In this passage at the beginning of chapter VIII, Darwin notes that natural selection not only acts on physical features of organisms but even on less tangible things like instinct. At first, this might seem surprising, since an instinct seems on the surface like it would be a very different thing from a body part. Darwin is aware of this potential strangeness and acknowledges it before moving on to argue that, in fact, natural selection's impact on instinct is simply a logical outcome of the arguments he developed earlier in the book.

Just as Darwin drew connections between domestication and natural selection, here he draws a parallel between how natural selection works on physical parts of an organism and how it works on instinct. He argues that instinct has just as much impact on the welfare of an organism as physical traits, and in some cases even more so. Ultimately, he takes a surprising premise and makes it sound reasonable, once again displaying his skill at communicating and arguing.

As natural selection acts only by the accumulation of slight modifications of structure or instinct, each profitable to the individual under its conditions of life, it may reasonably be asked, how a long and graduated succession of modified architectural instincts, all tending towards the present perfect plan of construction, could have profited the progenitors of the hive-bee? I think the answer is not difficult: cells constructed like those of the bee or the wasp gain in strength, and save much in labour and space, and in the materials of which they are constructed.

Related Characters: Charles Darwin

Related Themes:   

Related Symbols: 

Page Number: 268

Explanation and Analysis

This passage describes another one of the challenges to Darwin's theories that he considered significant enough to address in his book. Basically, Darwin's critics believed that the intricate honeycombs made by bees represented an instinct too complex to have arisen gradually through natural selection. At its core, this argument is very similar to the argument that some of Darwin's critics made about the complexity of the human eye. The main difference is that the eye is a body part, while making honeycombs is an instinct.

Perhaps unsurprisingly, then, Darwin responds to critics who bring up honeycombs similarly to how he responded to critics who brought up eyes. He looks at species that currently exist and finds that, in fact, not all bees make the complex honeycombs in the most well-known hexagonal structure. He notes that different species show different levels of complexity in their nests, and from that it's possible to imagine what the intermediate steps might have looked like in the natural selection of complex honeycombs. Again, Darwin shows a preference for reason as a tool for arguing, taking his opponents' objections seriously while ultimately insisting that his own theories remain correct.

Chapter 9 Quotes

The view commonly entertained by naturalists is that species, when intercrossed, have been specially endowed with sterility, in order to prevent their confusion. This view certainly seems at first highly probable, for species living together could hardly have been kept distinct had they been capable of freely crossing. The subject is in many ways important for us, more especially as the sterility of species when first crossed, and that of their hybrid offspring, cannot have been acquired, as I shall show, by the preservation of successive profitable degrees of sterility. It is an incidental result of differences in the reproductive systems of the parent-species.

Related Characters: Charles Darwin

Related Themes:    

Page Number: 279

Explanation and Analysis

This quote from the beginning of Chapter IX introduces the concept that hybrids that arise from the crossing of different species are frequently sterile and unable to give birth to their own viable offspring. Unlike the previous chapter, where Darwin makes the surprising yet logical argument that natural selection can work on instinct, in this chapter, Darwin actually argues that sterility in hybrids is not related to natural selection and is only "incidental." While Darwin believed that natural selection was a remarkably comprehensive theory, applying throughout history and around the world to many aspects of an organism's life, he was also careful to draw distinctions and avoid extending his theory too far.

It might seem strange that Darwin would devote a whole chapter to something that is not directly affected by natural selection, but in fact, the issue of sterility in hybrids does relate to natural selection in some ways and helps illuminate some key points. In particular, Darwin pushes back against the idea that this sterility is valuable because it prevents "confusion." The argument about preventing confusion perhaps carries religious undertones and could suggest an interventionist Creator who designed species to be a certain way. While Darwin does not want to antagonize religious critics, he disagrees because he believes that nature is always changing and not already in a perfect state, which is why the argument about preventing "confusion" doesn't fit with his theories.

❝ First crosses between forms known to be varieties, or sufficiently alike to be considered as varieties, and their mongrel offspring, are very generally, but not, as is so often stated, invariably fertile. Nor is this almost universal and perfect fertility surprising, when it is remembered how liable we are to argue in a circle with respect to varieties in a state of nature; and when we remember that the greater number of varieties have been produced under domestication by the selection of mere external differences, and that they have not been long exposed to uniform conditions of life. It should also be especially kept in mind, that long-continued domestication tends to eliminate sterility, and is therefore little likely to induce this same quality.

Related Characters: Charles Darwin

Related Themes:

Page Number: 312

Explanation and Analysis

In this quote from near the end of the chapter, Darwin once again returns to the theme of the distinction between varieties and species. Here, he notes that one of the key features of varieties is that, despite their differences, their offspring are usually fertile, which is not the case with species. Nevertheless, what's interesting about this passage is how many times Darwin hedges his language or notes exceptions. The concept of sterility in hybrids is complex, and even after exploring it for a whole chapter, Darwin notes that some questions are unanswered and that therefore it is difficult to make sweeping generalizations. The chapter as a whole provides an example of how science adapts to deal with unknowns and how it is often still possible to draw conclusions and make inferences even from limited available data. Darwin returns to this issue throughout the book, perhaps most notably in the upcoming chapters, which mention the imperfections of the geological record.

Chapter 10 Quotes

❝ Independently of our not finding fossil remains of such infinitely numerous connecting links, it may be objected that time cannot have sufficed for so great an amount of organic change, all changes having been effected slowly. It is hardly possible for me to recall to the reader who is not a practical geologist, the facts leading the mind feebly to comprehend the lapse of time. He who can read Sir Charles Lyell's grand work on the Principles of Geology, which the future historian will recognise as having produced a revolution in natural science, and yet does not admit how vast have been the past periods of time, may at once close this volume.

Related Characters: Charles Darwin, Charles Lyell

Related Themes:

Page Number: 316

Explanation and Analysis

This passage describes the work of the geologist Sir Charles Lyell (who was both one of the most prominent scientists of his time and a friend of Darwin's). In particular, it describes how Lyell influenced Darwin's thinking by introducing him to the idea that geological changes happen gradually over periods of time that are so long that they are difficult to even imagine. By praising the work of the well-known Lyell, Darwin perhaps hopes to attract some of that prestige by association, since Darwin writes that his own work grew out of reading Lyell's.

But Darwin is not just using Lyell to prop up his own

arguments about natural selection. The common ground between geology and evolution is that they are both different perspectives for looking at the history of nature. Darwin enriched and expanded his ideas about evolution by reading widely and by engaging with experts from outside his own discipline.

> It has been asserted over and over again, by writers who believe in the immutability of species, that geology yields no linking forms. This assertion, as we shall see in the next chapter, is certainly erroneous.

Related Characters: Charles Darwin

Related Themes:    

Page Number: 333

Explanation and Analysis

This quote is one of the first places in the book where Darwin discusses the immutability of species, an idea that many of his opponents believed in. Darwin rejects the theory outright, using comparatively stronger language than he does when addressing other criticisms. This dismissal makes sense: the immutability of species is a concept that would invalidate the entire theory of natural selection. "Immutable" means unchanging, and the entire premise of Darwin's book is that species can and have changed over time.

There is, however, one point where Darwin agrees with the "immutability of species" proponents: the existing fossil record is relatively sparse when it comes to intermediate forms (i.e., specimens that would document the transition of one species into another). The difference is that Darwin does not believe that this is enough of a basis to invalidate his theories, and in fact, he believes it is possible to deduce quite a lot even from an imperfect geological record.

Chapter 11 Quotes

> We can clearly understand why a species when once lost should never reappear, even if the very same conditions of life, organic and inorganic, should recur.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 347

Explanation and Analysis

This quote, which comes from the beginning of Chapter XI, begins Darwin's discussion of how extinction plays a role in natural selection. While Darwin has hinted at the importance of extinction before when discussing the competition for survival, he clearly felt that the issue was significant and complicated enough to dedicate a whole chapter to it.

This sentence establishes an essential premise about extinction: that species that disappear don't come back, even if the conditions that originally created them come back. Perhaps this seems obvious—the definition of extinction is when a species disappears for good—but it is an important basic fact to establish before proceeding. Darwin is trying to establish that the history of life can be mapped into a continuous tree-like diagram. If species could come back from extinction, there would not be a continuous tree—there would be all sorts of gaps and new branches appearing. As he's done earlier in the book, Darwin starts this chapter with the most basic point before introducing new complications later.

> On the theory of natural selection, the extinction of old forms and the production of new and improved forms are intimately connected together.

Related Characters: Charles Darwin

Related Themes:   

Page Number: 349

Explanation and Analysis

This quote comes a few paragraphs after the previous quote and helps extend the idea introduced at the beginning of the chapter. Darwin has previously described natural selection as a process by which the best-adapted organisms live to pass on their characteristics, but in fact, that's not the whole story. Another key element of the theory is that organisms that are less well adapted will die out and, in many cases, become extinct. Perhaps Darwin emphasized adaptation and described it before extinction because he felt that this view was more optimistic and would therefore be more appealing, or perhaps he simply felt that adaptations were a more foundational part of the theory that needed to be presented first.

In any case, the link between extinction and the origin of

new species helps to drive home Darwin's larger point about the interconnectedness of all organisms in nature. It isn't possible to understand the survival (or extinction) of one species without also understanding its relationship to the other species it interacts with.

Chapter 12 Quotes

❝ Undoubtedly there are many cases of extreme difficulty in understanding how the same species could possibly have migrated from some one point to the several distant and isolated points, where now found. Nevertheless the simplicity of the view that each species was first produced within a single region captivates the mind. He who rejects it, rejects the vera causa of ordinary generation with subsequent migration, and calls in the agency of a miracle.

Related Characters: Charles Darwin

Related Themes:

Page Number: 380

Explanation and Analysis

This quote explains the importance of migration to Darwin's theory of natural selection. Elsewhere, Darwin establishes that the same species does not independently arise in multiple locations (and this is related to why a species never comes back after going extinct). Still, by denying this, Darwin is forced to explain the fact that some species are preserved in the fossil record in very different parts of the world and that, furthermore, different species in different parts of the world often show surprising similarities. If these species did not independently arise in multiple locations, then the only explanation (and the one that Darwin gives) is that after arising in one location, the species must have migrated broadly. Darwin believes that, especially over long time frames, organisms have a tremendous ability to migrate, but he also believes that when barriers to migration do exist, they can play an important role in the development of new species.

Darwin's use of the word "miracle" in the above passage continues a trend of cautiously criticizing opponents who invoke religion in their arguments. While Darwin frequently argues that his ideas don't contradict religion, he is also careful to clarify that direct divine intervention (like a miracle) is not the basis behind any of his theories.

Chapter 13 Quotes

❝ As lakes and river-systems are separated from each other by barriers of land, it might have been thought that fresh-water productions would not have ranged widely within the same country, and as the sea is apparently a still more formidable barrier, that they would never have extended to distant countries. But the case is exactly the reverse. Not only have many fresh-water species, belonging to different classes, an enormous range, but allied species prevail in a remarkable manner throughout the world.

Related Characters: Charles Darwin

Related Themes:

Page Number: 407

Explanation and Analysis

This passage from the beginning of Chapter XIII expands on the topic of migration from the previous chapter and discusses one of the most formidable objections to Darwin's theory: freshwater environments. As Darwin noted, some freshwater habitats that are far away from each other and totally disconnected nevertheless have similar wildlife. Conversely, sometimes streams that are right near each other will have different plant or animal life inside them.

Though Darwin admits this may seem like a problem, he provides several possible explanations. In some cases, separate freshwater habitats actually were connected at some point, and it was only relatively recent changes in the environment that caused them to diverge. In other cases, there are mechanisms by which organisms can migrate between isolated freshwater sources (such as on the leg of a bird or during a flood). Such events might seem unlikely, but over a long enough time scale, they could be effective. As always, Darwin tries to be methodical, explaining strange or complicated observations by referring back to processes he has already established and extending them to see how they could apply to new circumstances.

Chapter 14 Quotes

All the foregoing rules and aids and difficulties in classification may be explained, if I do not greatly deceive myself, on the view that the natural system is founded on descent with modification—that the characters which naturalists consider as showing true affinity between any two or more species, are those which have been inherited from a common parent, all true classification being genealogical—that community of descent is the hidden bond which naturalists have been unconsciously seeking, and not some unknown plan of creation, or the enunciation of general propositions, and the mere putting together and separating objects more or less alike.

Related Characters: Charles Darwin

Related Themes:

Page Number: 437

Explanation and Analysis

In this passage, Darwin explains his belief that classifying organisms should be based on their genealogy. While other classification systems focus on factors like physical similarity or geography, Darwin believes that genealogy is the best way to organize classification. The advantage of genealogy is that, at least in theory, it provides an orderly framework that can account for the full spectrum of organisms. If Darwin's theories are accurate, then every organism has a genealogy that can be traced, with progenitor species that diverge into new species over long periods of time.

In practice, it is not always possible to accurately trace descent, particularly due to issues such as the imperfections of the geological record (which Darwin mentions in an earlier chapter). Nevertheless, having an ideal, orderly goal is much better than "the mere putting together and separating objects more or less alike," which is what Darwin accuses critics of doing. Darwin advocates for genealogy as the basis for classification because it is based on reason and offers more rigor than alternative methods.

Chapter 15 Quotes

As this whole volume is one long argument, it may be convenient to the reader to have the leading facts and inferences briefly recapitulated.

Related Characters: Charles Darwin

Related Themes:

Page Number: 478

Explanation and Analysis

In this sentence from the beginning of the final chapter, Darwin announces his intention to spend the last chapter summarizing what came before. The fact that Darwin ends almost every chapter with a summary, then spends the entire last chapter on more summary, shows just how deeply Darwin strove to make his ideas understandable to a wide audience. While Darwin's many recaps might resemble the structure of a modern textbook, one of the key differences is that Darwin is not simply presenting information but making an "argument." (Darwin means "argument" more in the academic sense than the confrontational sense, though of course some of his views did provoke strong negative reactions among critics.) Throughout *The Origin of Species*, Darwin attempts to take on the role not just of a naturalist but also of a communicator, appealing to reason and attempting to present ideas in a logical order that can be easily understood, even by people who aren't scientists.

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

Related Characters: Charles Darwin

Related Themes:

Page Number: 507

Explanation and Analysis

This quote is the last sentence of the book. Given Darwin's resistance to incorporating explicit religious beliefs into his explanations of natural selection, it might seem surprising that he would choose to end his book with a reference to the Creator. Beyond this, he talks about how life was "breathed" by the Creator, recalling the Book of Genesis when God breathed life into Adam, the first human being. Given Darwin's apparent goal of appealing to both religious and secular readers elsewhere in the book, it seems likely that this final line is intended to lend itself to multiple interpretations. For religious readers, the final line is a reassurance that, while Darwin tries to avoid relying on

divine intervention in his theories, his ideas are not at their core incompatible with religious belief. For secular readers, however, the reference to the Creator might be interpreted not as God but as a personification for nature, similar to the way Darwin uses personification to describe nature's actions in Chapter IV.

The final image that Darwin leaves his audience with is one of order and beauty, suggesting that his revolutionary ideas don't have to be frightening and that, despite its methodical nature, science can also provoke wonder.

SUMMARY AND ANALYSIS

The color-coded icons under each analysis entry make it easy to track where the themes occur most prominently throughout the work. Each icon corresponds to one of the themes explained in the Themes section of this LitChart.

INTRODUCTION

Charles Darwin was the naturalist on board a ship called the H.M.S. *Beagle* which traveled to South America before returning home to Britain in 1837. Darwin encountered some unusual creatures in South America, and after considering the subject for a while and writing about it, he finally published a draft of his thoughts in 1859 (as *The Origin of Species*). Darwin stressed that his work wasn't finished and that he intended to continue writing, but he had been urged to publish what he currently had by some friends in the scientific community.

Though Darwin mentions his trip on the H.M.S. Beagle *only briefly in this section, many historians consider it the turning point in his life when he first began to develop his revolutionary ideas about evolution. Darwin's claim that* The Origin of Species *is incomplete is modest. Partly, this is a rhetorical strategy to make his argument more appealing to hesitant readers, but it is also true that Darwin had many more things to say about evolution, and that he greatly expanded on his ideas in the books published after* The Origin of Species.

Two of Darwin's most important supporters were Sir Charles Lyell and Dr. Hooker. Darwin wrote that he also received assistance from other naturalists who were too numerous to name.

Like many scientists of his time, Darwin blended personal and professional relationships, and some of his friends and supporters were also people whose work was very influential on his own.

Darwin laid out how he arrived at the idea that species (of organisms) arise by descending from other species. Domesticated animals provided one way to look at how species modify and adapt over time, so Darwin decided to dedicate part of his book to this issue.

Here, Darwin begins to lay out ideas that he will explore in greater detail in later chapters of the book. Domestic animals are a recurring theme because they provide quantifiable proof about how certain traits can be inherited.

Darwin also decided to spend part of his book on exploring the ideas of Thomas Malthus. Darwin's interpretation of Malthus was that all species are in competition to exist, and the specimens with the best chance of surviving are "naturally selected." For this reason, Darwin devoted a chapter of his book to natural selection, then several following chapters to defending the idea, which he admitted seemed to present difficulties at first.

Thomas Malthus was most famous for his philosophies about the danger of overpopulation. He believed that populations grew faster than food supplies, and at a certain point, this would lead to a catastrophe like war or famine to reduce the population size. Darwin adapted these ideas when working out his own theory of natural selection, particularly the idea that organisms are in competition for limited resources.

Darwin wrote that although humans remained ignorant on many scientific matters, including issues related to the origin of species, investigating these issues would be essential for the general welfare in both the present and the future. Despite granting that some problems may remain a mystery for a long time, Darwin asserted that natural selection must be the most important (though not the only) way through which species are modified.

Darwin makes the case for why his theories are important. While he acknowledges the limits of his ideas, as well as the general limits of human knowledge, he nevertheless argues that humanity benefits from better understanding nature. This philosophy is behind much of what Darwin writes in the chapters that follow.

CHAPTER 1

Causes of Variability. Darwin noted that, as a general rule, different varieties of domesticated plants and animals appear to be more distinct from each other than different varieties in the wild. Even the oldest domesticated plants and animals, like wheat, can be cultivated to yield new varieties.

In Darwin's time, breeding and heredity in domestic animals was better understood than in wild animals. Darwin starts with what most people understood best in order to draw inferences and move on to less-studied topics.

Darwin suggested that there were two factors that led to variations: the nature of an organism and the nature of its environment. He introduced the concept of "indefinite variability" to refer to the slight variations between individuals of the same species. Over millions of years, these slight differences have the potential to become extreme. Differences related to the reproductive system were particularly important.

Darwin begins laying the foundation for his theory of natural selection. One of the principles of natural selection is that organisms evolve through gradual, successive changes. Here, Darwin describes how these changes arise in the first place, explaining what the concept of variability means in biology.

Some naturalists believed that all variations were connected to sexual reproduction, but Darwin noted that gardening, and particularly techniques like grafting, introduce variations that are rare in nature but common under domestication.

Grafting is the act of connecting separate parts of plants so that they grow together. When two different plants are combined, this is a type of asexual reproduction. Darwin uses this example because many people are familiar with it, and because it shows how humans can play an active role in reproduction under domestication

Effects of Habit and of the Use or Disuse of Parts; Correlated Variation; Inheritance. Darwin wrote that when organisms change their habits, it can produce an inherited effect. This means, for example, that the wings of a domesticated duck weigh less than a wild duck's, because the domesticated duck doesn't have to fly as much.

Darwin again uses an example that his audience was likely to be familiar with. While it might not be common knowledge that a domesticated duck's wings weigh less than a wild duck's, it makes intuitive sense.

Darwin noted that sometimes traits were inherited together: for example, white cats with blue **eyes** were typically deaf, but mostly only if they were male. He suggested that, while many parts of the inheritance process were mysterious, ultimately it followed certain laws. He also clarified that he was only interested in variations between organisms that could be inherited, but that even with this limitation, the possibilities were endless.

Darwin sets the parameters of his argument by noting the limits of his approach. By limiting the size and focus of his book, Darwin increased its accessibility. Understanding the basics of how inheritance of traits works is essential for understanding how Darwin's theories work.

Darwin didn't have an explanation for why a child organism might inherit a trait from a grandparent that wasn't present in either parent. He also didn't know why some traits seemed to only be transmitted from males to males in domestic breeds.

Darwin published the first edition of The Origin of Species *before Gregor Mendel's famous experiments about heredity in pea plants were widely known. While some aspects of inheritance were known in Darwin's time, much of genetics remained a mystery.*

Other naturalists in Darwin's time noted that when domesticated animals were let out in the wild, their offspring gradually reverted to something more similar to the wild animals. Some took this as evidence that domestication could never add traits that would help an animal in the wild, but Darwin doubted this statement, although he admitted it was hard to prove either way. He believed that with an unlimited amount of time, it was possible to breed an animal for just about anything.

Sometimes Darwin explains his theory of natural selection by looking at the theories of other naturalists to show how his theory differs. In this case, other naturalists had a more limited view of what could be achieved under domestication. Darwin presents his theory as more expansive, arguing that the possibilities under domestication were almost unlimited. This is important, because he will eventually apply his ideas about domestication to what happens in nature.

Character of Domestic Varieties; difficulty of distinguishing between Varieties and Species; origin of Domestic Varieties from one or more Species. Darwin wrote that domestic plants and animals often had a "somewhat monstrous character" compared to their wild counterparts, meaning that one specific part of them differed in an extreme way.

Though Darwin is making a comparison between what happens in nature and what happens under domestication, he acknowledges that because of human involvement, domestication can lead to some unusual outcomes that would not occur naturally.

Darwin wrote about the difficulties of assessing differences between similar types of domestic plants and animals. For example, Darwin didn't know whether the different breeds of dogs had all been produced through domestication of a single species or whether, in addition to the effects of domestication, dog breeds were also determined through the mixing of multiple distinct species. Darwin believed the latter view.

Today, it is known that all breeds of dogs are part of the same species. Darwin, however, was working with more limited information and did not have access to anything close to the genetic tools that modern scientists have.

Some naturalists assumed that humans specifically picked animals and plants for domestication that were predisposed to develop variations and adapt to different environments. While Darwin believed variability was an important factor in determining a species' suitability for domestication, he believed that many plants and animals that hadn't yet been domesticated also possessed incredible potential for variation.

Darwin's theory of natural selection only makes sense if there is a high degree of variability among animals in nature. He takes this idea to the logical next step: that if there is a lot of variability in nature, then there is a lot of opportunity for humans to make use of this variability under domestic breeding.

Darwin conceded that the origin of most domestic animals would probably remain obscure. He repeated his belief that modern dogs involved the mixing of several *Canidae* (a biological family that includes modern dogs and other dog-like creatures). Darwin looked at other species like cattle, sheep, horses, fowl, rabbits, and goats, weighing how likely it seemed to him that they descended from a single species or from a mixing of species.

The difficulty for Darwin is that domestication of most animals took places thousands and thousands of years ago. With only a limited ability to see what animals looked like in the past (through the fossil record), he makes many of his inferences based on what can be observed from currently existing species.

Darwin considered ideas about the descent of species held by other naturalists, many of which Darwin found ridiculous. One naturalist, for example, believed that at one point, there used to be eleven different species of wild sheep in Great Britain alone—Darwin found this very improbable. Even with dogs, which Darwin himself believed came from multiple species, Darwin felt that some peers held views that were too extreme, like the idea that animals that looked like a pug or greyhound ever existed in nature.

Other naturalists had other explanations for the diversity of species that existed in the world. While some of their observations may have made sense on an intuitive level, ultimately these naturalists did not bring the same breadth and depth of analysis to their observations as Darwin. Today, we know that Darwin's views, despite occasional mistakes (like believing dogs descended from multiple species), are nevertheless closer to being correct.

Breeds of the Domestic Pigeon, their Differences and Origin. Darwin believed there was value in looking at specific examples in detail, so he decided to focus on domestic pigeons, obtaining samples of skins from as many varieties of pigeons around the world as he could. He found the variations among them extreme and surprising, particularly when seeing the pigeons from outside of England.

Birds were one of Darwin's specialties, and he refers to them often. Here, he notes that seeing pigeons from outside of England helped him to expand his views. This demonstrates his goal to develop theories that would apply around the world and not just to European species.

The pigeons often had fundamental differences in their anatomies, including different skeletons. The differences were so wide that if an ornithologist observing the domesticated pigeons had been told they were wild, he might have categorized them as different species or even in a different genus. Nevertheless, Darwin believed that most naturalists held the correct opinion: that all domesticated pigeons were descended from one original species: the rock-pigeon.

Darwin often admits whenever any of his ideas seem strange on the surface. He tries to anticipate his audience's reactions and tailor his arguments accordingly. Here, Darwin appeals to authority by noting that, while it may seem strange on the surface that all pigeons descended from one species, nevertheless, this is what leading naturalists believe.

Darwin himself experimented with crossing some pigeons to see what would happen, and in particular, which traits were inherited. His findings seemed to confirm the idea that all pigeon varieties were descended from wild rock-pigeon, since the mixtures generally produced results similar to a rock-pigeon. Additionally, these hybrid pigeons all remained fertile, and modern wild rock-pigeons have proven capable of being domesticated. Given that pigeons have been domesticated since at least the time of ancient Egypt, there was plenty of time for domestic pigeon variations to arise.

Darwin's example with pigeons is similar to the example with dogs. He includes both examples to emphasize that this is a common pattern in nature and that it isn't necessarily rare for so much diversity to arise in descendants of a single progenitor species. The fact that pigeons have been domesticated for such a long time (and that historical records survive) makes them a particularly useful example for Darwin.

Darwin acknowledged that his overview of domesticated pigeons was too short to fully cover the topic and that some people may still have trouble believing that all domesticated pigeons originated from one species. He also admitted that breeders—not only of pigeons, but of everything from cattle to rabbits to pears to apples—were often most likely to believe that different varieties arose from different species, because these experts are skilled at seeing differences. Darwin asked how naturalists, who know less than breeders about specific characteristics, can be confident that domestic plants and animals often descended from a single species.

As he does throughout the book, Darwin acknowledges the limits of contemporary scientific knowledge. He also acknowledges the limits of how much detail he can go into in a book intended for a relatively wide audience (which The Origin of Species *was). Darwin's argument that naturalists understand some things better than expert breeders is an argument for the value of the scientific method, since even the most experienced breeders often work in a way that's unscientific.*

Principles of Selection anciently followed, and their Effects. Darwin decided to answer the question posed at the end of the last section by going through the steps of how domestic species of plants and animals were produced. The important factor in domestication is that it results in adaptations that are useful to humans, not necessarily to the animal or plant itself. It was commonly known that these useful varieties of plants and animals didn't arise all at once but that the adaptations were refined over successive generations.

Again, Darwin limits the focus to domestication, but later he will expand the focus and apply the same principles to natural selection without human interference. He notes that a key difference between domestication and nature is who benefits from adaptations—in domestication all new adaptations are deliberately chosen for the benefit of humans.

The most expensive domestic animals with good pedigrees were generally created by never crossing different breeds, unless the sub-breeds were extremely similar. Propagating traits useful for humans wasn't easy and often required careful attention to details—details so small that Darwin himself couldn't see them. The same applied for plants, although in plants variations sometimes arose more quickly.

Darwin admits that experienced breeders are more attentive to specific details of breeding than he would be. Nevertheless, Darwin doesn't believe that you need to see details on this level in order to understand the broader principles behind breeding.

Some argued that the methodical breeding of plants and animals had only been a practice for about 75 years before the publication of *The Origin of Species*. But Darwin argued that despite the importance of modern innovations, the basic principles of breeding are ancient, and that ancient writings make reference to it, including classical Roman writers and the book of Genesis. Even people from central Africa, who went for a long time without contact with Europeans, had their own version of breeding.

Darwin's arguments depend on the idea that domestication has been happening for a long time, since he believes that adaptations happen gradually instead of all at once. Fortunately for him, there are many surviving ancient texts that testify to how long domestication has been occurring.

Unconscious Selection. Darwin noted that while skilled modern breeders employ selection methods that are precise and intentional, for observing nature it is helpful to look at unconscious mechanisms for selection. Even inexperienced breeders and "savages" tend to unconsciously encourage the selection of animals that are better at leaving more offspring.

Throughout The Origin of Species, *Darwin occasionally uses words like "savages" that reflect racist attitudes prevalent at the time. Though Darwin was curious about people, plants, and animals from around the world, his observations sometimes seem to be distorted by prejudices and preconceived ideas.*

All of these unconscious changes accumulated to result in descendants that often seemed to bear little resemblance to their wild parents. Darwin believed that this explained why "uncivilised" regions like Australia and the Cape of Good Hope didn't have any plants worth cultivating elsewhere—since their traits hadn't been refined by civilizations with ancient origins.

Darwin's ideas about civilization are biased by his British background. This causes him to make sweeping generalizations about plants in entire regions that he deems "uncivilized."

Darwin reiterated that humans were the main force in driving domestication. He admitted that, for example, the first person to breed a pigeon with a slightly unusual tail probably couldn't have predicted what a modern fantail pigeon would look like. Experts would be skilled at noticing differences, and so the changes in the pigeon's tail would have been gradual over time.

Darwin emphasizes the slowness of new adaptations, even under domestication. The fact that change in domestication happens slowly—and sometimes even unconsciously—is important, since this is similar to how Darwin believes natural selection operates in nature.

Circumstances favourable to Man's Power of Selection. Darwin wrote that he would weigh both the pros and cons of the proposition that humans have the power to drive selection in animals. To Darwin, it seemed that creating specific changes in a plant or animal involved both a lot of expertise and a large stock of the plant or animal in question to work with.

Here, Darwin begins to add some nuance to his previous claims. After establishing that humans have tremendous power to make changes through domestication, he now analyzes how different circumstances can increase or decrease this power to create new adaptations.

Darwin found that some animals were better suited for breeding than others. Pigeons were easy to breed quickly in great numbers, but cats were much harder to pair up for breeding—leading to less variation among varieties of domestic cats.

Naturally, an animal's potential for breeding is connected to its reproductive habits. But this doesn't mean that animals that are difficult to breed can't be domesticated: cats are an example of this.

Some naturalists believed that domestic animals were reaching a limit in their adaptability for humans. While Darwin acknowledged that there were certainly limits to the possible adaptations of an animal, he didn't believe that humans had reached that limit yet.

In general, many of Darwin's opponents believed that the world was always destined to turn out the way it did. Darwin, on the other hand, frequently argues that other possibilities exist and that things could have turned out quite differently.

Darwin concluded the chapter by repeating and summarizing all his ideas about how different kinds of domestic plants and animals arose. He reasserted that selection was unquestionably the main force driving variations, regardless of whether that selection happened in a fast, methodical way or in a slow, unconscious way.

Darwin wanted to make sure that his arguments were understood, so he followed an organized structure and made frequent use of summaries. Just about every chapter in the book starts with an overview and ends with a summary.

CHAPTER 2

Darwin wrote about the structure of his book, and how before continuing the ideas of the first chapter, the second chapter would look at whether organic beings out in nature (as opposed to in domestication) were subject to a similar variation. Darwin acknowledged that there were reasons to doubt that variations would survive in wild populations, and promised to explore the issue in more detail in a later chapter.

Darwin structures his arguments methodically, both giving previews of topics he'll cover as well as summarizing them afterwards. He now begins the transition from talking about domestic animals to talking about wild populations of animals, which are really the main focus of his theories.

Individual Differences. Darwin described how offspring from the same parents showed slight differences. Many naturalists considered these details as only affecting unimportant parts of organisms, and while Darwin acknowledged that this was often the case, he believed that his own experience and the work of other naturalists suggested that in fact, variations often affected important parts of animals, like interior organs and nerves. Even skeptics acknowledged that there was often wide variation between male and female offspring, with the different sexes having different forms.

Again, Darwin's observations were held back by a general lack of knowledge about genetics during the time period when he was writing. Nevertheless, in spite of this limitation, Darwin analyzed the reproductive process in a methodical way and was able to draw important insights about how variations among offspring were affected by seemingly random chance and by sex.

Doubtful Species. Darwin wrote about the criteria for determining whether different forms of a particular animal or plant were a new species or just variation within a species. In many cases, this distinction was simply decided by a majority of naturalists, although many accepted classifications had dissenters, and some classification cases presented complicated difficulties. Botanists in Britain, France, and the U.S., for example, often disagreed on how many types of flora their countries contained, with counts differing by the dozens.

Though Darwin does not believe that the boundary between species and variation is totally arbitrary, he nevertheless questions current methods of classification at times. Ultimately, he argues that natural selection does not necessarily follow the orderly classification systems imposed by humans, and that is why classification systems sometimes contain flaws.

When Darwin compared his experience with American birds versus the birds on the **Galapagos** Islands (which he saw during his time traveling with the *Beagle*), he found that the distinction between varieties and species often seemed arbitrary. Darwin gave an overview of many other organisms where the boundary between species and variety was contested by naturalists.

Visiting the Galapagos Islands was a formative experience for Darwin. As he describes, he was able to see the diversity of life firsthand. Because of their isolated geography, islands often contain unusual species that would not be found on mainlands, and which helped Darwin develop his theories.

Darwin explained how young naturalists tended to prefer categorizing things as new species in order to emphasize and account for the differing traits. He believed, however, that naturalists with a wider range of experience, particularly with global specimens, seemed to be more inclined to recommend fewer species (which have several varieties within them).

Darwin believes that people with more experience are more likely to see similarities between different organisms and, as a result, to recognize broad patterns and categorize them more accurately.

While some naturalists might not see minor differences within a species as especially significant, Darwin argued that these little differences were extremely important to his theories, since he believed in adaptations that came from an accumulation of little changes over time. Not all little variations eventually lead to a new species: some become extinct or remain as simply varieties for a long time. Ultimately, Darwin found that terms like "species" and "variety" are somewhat arbitrary, and while they can be useful in indicating the degree of difference (with "species" signifying bigger differences), in essence the terms mean the same thing.

Darwin emphasizes that for his theories, even seemingly small details are nevertheless extremely important. He acknowledges that many small differences don't matter, and that some of them lead to negative changes that cause extinction. Still, natural selection is based on the idea that small variations can add up over time to create major adaptations, and so even minor variations are important to notice and classify correctly.

Wide-ranging, much-diffused, and common Species vary most. Darwin began this new section by writing that, although the topics deserve greater detail, he would attempt to briefly explore issues related to the "struggle for existence" and "divergence of character." He found that with plants in a given country, the species that flourish the most are often also the ones that are the most widely distributed. This widely spread species often yields offspring that have slight modifications that help them survive in specific environments. This is why wide-ranging species have the most variety.

Darwin makes the relatively common-sense argument that a species that ranges widely must be able to survive in a wide variety of environments. He goes on to suggest that over this wide range, there might be varieties of the species with adaptions that help specimens survive in their more specific local environments.

Species of the Larger Genera in each Country vary more Frequently than the Species of the Smaller Genera. Similar to the last section, genera with many species in them have more variety in them. Darwin admitted that this wasn't the most surprising finding, but argued that it wasn't a given and that it required a close look at the data to see this fact. Darwin found this out by comparing plants and tables of genera and species from his own collections.

It makes sense that genera with more species in them would have more variety in them, but Darwin sometimes takes time to establish the obvious point, because sometimes what seems obvious or intuitive is not actually accurate and the reality is more complicated (even though that isn't the case here).

Many of the Species included within the Larger Genera resemble Varieties in being very closely, but unequally, related to each other, and in having restricted ranges. Darwin noted that, as any naturalist would admit, the different species within a genus are not equally distinct. Amid all the variety, there are clusters and sub-groups of species that are actually quite similar to each other. One of the key points of difference between these similar species is that they often have limited geographic ranges.

Most of what Darwin says here was common knowledge among naturalists, but Darwin explains it under the presumption that many in his audience are not trained naturalists. He emphasizes the idea that classification is not a one-size-fits-all system and that even the most organized system can struggle to account for the full variety of nature.

Summary. Darwin concluded that it wasn't possible to distinguish varieties from species, at least not without going through a complicated classification system.

Darwin reiterates that, while human classification systems are helpful for the study of nature, these classification systems don't necessarily reflect what actually happens in nature.

CHAPTER 3

Darwin wrote about his intention to examine how the struggle for existence affected natural selection. He believed that because of each species' struggle to survive, even light variations in a species help the offspring to survive. This process of preserving small, helpful variations is natural selection.

This is the part of Darwin's theories that is most influenced by Thomas Malthus (the famous economist and political theorist whom Darwin mentions in the introduction). Malthus believed that populations grow faster than food supplies, and that as a result, a population would start to die off once it exceeded the available food reserves.

The Term, Struggle for Existence, used in a large sense. Darwin clarified that when he used the term "struggle for existence," he meant it not just in the literal sense but also in the metaphorical sense. He clarified that he didn't just mean dogs literally fighting over food, but also cases like desert plants that "struggle" to get enough moisture.

As with most chapters, Darwin spends the early part of this chapter defining terms and setting the parameters of what he'll cover over the course of the rest of the chapter. Here he clarifies that not all "struggles" are physical combat and that in some ways, he uses the word as a metaphor.

Geometrical Ratio of Increase. Darwin noted that every organism encounters some form of destruction in its lifespan. Otherwise, its population would increase geometrically and quickly outgrow available resources, similar to what Thomas Malthus wrote about. Darwin had evidence from humans and domestic animals of just how quickly populations could increase under favorable conditions. But while many plants and animals have the potential to grow this rapidly, it is rarely the case. Factors like food scarcity and climate all contribute to "destruction" that prevents rapid, endless increases.

The concept of populations growing at a geometrical rate is one that Darwin borrows directly from Thomas Malthus. But while Malthus was primarily thinking about human populations, Darwin's innovation is to expand the idea beyond human populations and to consider how similar principles might be applied to organisms in nature.

Nature of the Checks to Increase. Darwin admitted that the "checks" which stopped a population from increasing at a rapid rate were not always clear or easy to determine. The food supply is one obvious, extreme limit, but more often the size of a species is limited by predators. Climate also restricts population growth, with extreme cold and droughts being particularly effective at checking growth.

Darwin explored the different factors that could stop a population from growing. These factors are important because the adaptations that arise through natural selection help a species to better overcome these factors.

When a species experiences very favorable conditions and grows rapidly in a small area, it often faces other checks, such as an epidemic, that help keep the population size under control. In other cases, a species population must be large in order to survive its predators—for example, corn must produce a lot of seeds to account for how many seeds get eaten by birds.

Darwin provides examples of how some populations grow quickly under the right conditions. Nevertheless, if a population keeps growing geometrically, eventually it will hit barriers to growth. While Malthus wrote about limited food supplies, here Darwin considers other important limits: disease and predators.

Complex Relations of all Animals and Plants to each other in the Struggle for Existence. Darwin noted how the populations of plants and animals are often checked through their relationships with each other. For example, in some areas, cattle stop Scotch fir trees from growing because they eat the saplings, but once the cattle are enclosed, the Scotch firs spring up. These relationships between species can take many forms and be affected by other factors like geography, climate, and seasons.

Species don't exist in a vacuum, and so in this passage, Darwin explores how the success or failure of one species in an area can affect the population of another species. Two species do not have to be directly competing for resources to be related. For example, in this passage the Scotch fir are not competing with the cattle for food, but their populations are nevertheless closely intertwined.

Struggle for Life most severe between Individuals and Varieties of the same Species. Darwin asserted that the more similar species are, the more directly they will be in competition with each other. Even very different species can have similarities, however, and the claws of a tiger are not so different from the claws of a parasite riding on the tiger.

Despite the example of cattle and Scotch fir in the previous section, however, Darwin argues that the fiercest competition is among creatures that are most similar. This makes sense, because individuals of the same species have the same needs and are therefore often in competition for them.

Darwin suggested that his audience should try to imagine what could happen to give one species an advantage over another. He argued that every living thing is struggling to try to increase its population at a rapid rate, but that in the pursuit of this, it will also experience occasional destruction. While this could seem dark, Darwin took it as a consolation that ultimately "the vigorous, the healthy, and the happy survive and multiply."

By this point in the book, Darwin has not yet fully laid out his theory of natural section, but he continues to build it part by part. In this chapter, he aimed to convince audiences beyond any doubt that organisms in nature are in a constant competition to survive, and that those best adapted to their environment are the ones that, in most cases, will survive.

CHAPTER 4

Darwin asked rhetorically how the struggle for existence could lead to variation. He suggested that because humans had so much evidence of how it was possible to intentionally breed animals for human use, it should be no surprise that similarly helpful variations might arise in a wild population over many generations. Similarly, unhelpful variations would quickly die out. This is what Darwin called natural selection or survival of the fittest.

Now that Darwin has laid the important groundwork for his theories, he transitions into what natural selection actually is. Crucially, natural selection is different from what happens during breeding under domestication, but Darwin nevertheless continues to use domestication to help illuminate what happens in the wild.

Some writers misunderstood the concept of natural selection. They suggested that natural selection creates variations, but in fact, it just preserves variations, which is an important distinction. Darwin admitted that he found it difficult to avoid personifying the word "Nature" and treating it like an entity, but in fact, he believed that nature was simply an aggregation of laws and events.

Here, and elsewhere, Darwin is careful to avoid creationist language that might suggest that an active divine presence is guiding evolution. Darwin was writing for both a secular and a religious audience, and he carefully chose his words to make his ideas palatable to a wide spectrum within both groups.

Darwin argued that if humans could produce such amazing results by breeding domesticated plants and animals, natural selection would produce even more stunning variations, since unlike humans, nature does not have to work with external, visible characteristics. Similarly, humans are limited in the way they create variations in plants and livestock, often staying within the same regions and climates and breeding them for specific purposes, but the struggle to exist in nature is more open-ended.

Many of Darwin's arguments hinge on the idea that nature is full of possibilities. He believed that domestic breeding was limited by humans, but that in a state of nature, much more surprising variations could arise in species.

The key feature of natural selection is that helpful modifications to organisms must not only arise, but also have a way of being preserved and passed on to offspring. Even matters that seem insignificant to humans may prove significant in the natural selection process, such as how leaf-eating insects are green, giving them camouflage.

Darwin further explores the theme of how human perception is limited, and so as a result, human breeders are limited in what they can accomplish with domesticated plants and animals.

Though natural selection works to the advantage of individual species, it can have advantages that go beyond an individual organism: for example, natural selection can affect a whole community of social animals. What natural selection can't do, however, is preserve a modification in one species that gives an advantage to a second species—at least not unless there is also some benefit for the first species.

Darwin continues the theme that adaptations don't occur in a vacuum. While he shows how adaptations can have effects beyond a single organism, he makes the important distinction that because different species are competing to exist, one species will never develop an adaptation that is solely of benefit to another species.

Natural selection is not a perfectly orderly process, and sometimes organisms that would have had advantages are destroyed through some accidental means. In such cases, natural selection might seem powerless, but these exceptions don't negate the fact that natural selection is very powerful under other circumstances.

Darwin considers the role that probability plays in natural selection and gives an example of how an organism that is theoretically better adapted could nevertheless fail to pass on its useful adaptations to offspring due to a freak accident.

Sexual Selection. Darwin wrote how, as part of natural selection, the sexes of the species may be modified in relation to each other. Darwin called this sexual selection, by which he meant the struggle of "one sex, generally the males, for the possession of the other sex." Some species of males, particularly carnivores, will literally fight each other for females. Others, like birds, have more peaceful competitions, but they nevertheless compete by performing strange ceremonies to show off.

Here, Darwin expands the idea of what competition among individuals means. He has already clarified that competition can be metaphorical and not necessarily physical. In this passage, Darwin emphasizes, through the concept of sexual selection, that much of natural selection revolves around reproduction.

Darwin concluded that if males and females of a species have the same habits but differ in form or external appearance, the main cause of the difference is usually sexual selection. Sexual selection can involve giving organisms ways to attack, ways to defend, or even simply ways to charm.

Though the struggle for food is important, ultimately organisms are struggling to pass on their traits to offspring. Sexual selection shows the important role of reproduction in the process of survival of the fittest.

Illustrations of the Action of Natural Selection, or the Survival of the Fittest. Darwin suggested illustrating his points with some imaginary examples. He imagined wolves, where some of the wolves have to be slim enough to chase after deer but still muscular enough to overpower their prey, while other wolves have to be stockier but don't need to be as fast to hunt sheep. Over time, wolves with one of these advantages would tend to out-survive others and through chance would pass some of their traits on to offspring.

Because real populations can be difficult to track and study over time, sometimes Darwin uses hypothetical examples in order to demonstrate certain principles. Wolves make an obvious choice for an example, since they resemble domestic dogs, whose breeding has been well-studied. Here, Darwin shows how a population can diverge.

In the case of wolves or other animals, the different regions where the different varieties live are often what keep them from intermixing with others of their species (which might result in the varieties not being passed on).

Geography and environment continue to play a significant role in natural selection.

Darwin put forward another example of plants that put out nectar, which attracts insects. While these visits from insects don't benefit the individual plant, they help spread pollen, crossing different individual flowers of the same species. Because the plants with the most nectar would be visited the most frequently and therefore spread their pollen most widely, these plants tended to survive in populations.

Darwin's hypothetical example with plants is more or less based on real life, but he has simplified the process in order to make the principles simpler to understand. He uses this case to show how relationships between different species can play a role in natural selection.

From the insects' perspective, some individuals may also have variations that help them get more nectar. For example, some bees might have a proboscis shaped to give it a slight advantage in getting nectar, even if the change is too small for humans to perceive.

Crucially, the plants do not adapt specifically for the insects—the plants adapt for their own benefit, and the fact that some insects also benefit is simply a side effect, at least from the plants' perspective.

Darwin ended the section by admitting that some might object to his ideas, but that his work was like that of the renowned geologist Charles Lyell, whose ideas inspired Darwin and fundamentally changed the way that people in the field of geology thought.

In addition to being Darwin's friend, Lyell was well-respected in his field, and Darwin appeals to Lyell's authority in order to hopefully generate more respect for his own work.

On the Intercrossing of Individuals. According to Darwin, with some exceptions (like parthenogenesis), animals and plants have different sexes, and an individual of each sex is required to produce offspring. Even in the case of hermaphrodites, Darwin noted that reproduction in animals usually involved two individuals that pair (although there remain some exceptions that do not pair). Among plants, the majority are hermaphrodites.

Parthenogenesis is when an organism reproduces without being fertilized (and is a type of asexual reproduction). Some hermaphrodite plants can reproduce by combining their own male and female parts, but Darwin notes that it is still more common for a plant to be fertilized by a different plant. He explores the reasons for this in the following sections.

Darwin found that with plants and animals, interbreeding helped produce more vigorous and fertile offspring, except for very close interbreeding, which had the opposite effect. With plants, certain varieties have pollen that are more potent than other varieties, but the pollen of a plant's native species takes precedence over pollen from other species.

It was common knowledge in Darwin's time that inbreeding of plants and animals can lead to unusual and potentially harmful characteristics in the offspring. By contrast, wider interbreeding can add diversity and lead to healthier offspring.

Some animal species, like earthworms, are hermaphrodites that pair to reproduce. However, Darwin wasn't aware of any terrestrial animals that could fertilize themselves. Many aquatic animals self-fertilize, although this may be because the currents of the water create the opportunity for crossings.

Darwin was fascinated by worms and would write about them in greater depth in one of his later books. In this passage, he notes how reproduction in animals is usually (although not always) quite different than reproduction in plants.

Circumstances favourable for the production of new forms through Natural Selection. Darwin noted that variability in a population was always favorable, since it offers increased probability for helpful variations to arise and eventually be preserved. It might seem that free crossing between animals would get rid of the effects of natural selection, since it might cause traits to move toward the average instead of toward new varieties. In fact, however, there are many factors like geographic isolation or even different niches within the same environment that keep varieties of animals distinct from each other.

Darwin explains why free interbreeding results in greater variety rather than simply smoothing all of a population toward the average. As is often the case, the crucial factors are geography and environment. A diversity of environments means that beneficial adaptations for a species won't be uniform and that a variation that is beneficial in one environment could be detrimental in another.

Isolation is an important condition for allowing new varieties to arise through natural selection. The passage of time itself is not enough to create natural selection; it is only important because natural selection can be a slow process, and more time gives more opportunity for variations to arise and be preserved.

Darwin's ideas about long time scales are influenced by his readings of Charles Lyell's books about geology and the long time periods involved in that field. Like the movements of the earth, changes in species also happen gradually.

Extinction caused by Natural Selection. As better adapted organisms grow in number, less well-adapted organisms become rarer, and this leads to the possibility of extinction. New varieties and species tend to put the most pressure on their closest relatives, often driving them to extinction.

Though natural selection is about organisms becoming better adapted to their environments, one of the unavoidable consequences of this process is that less-well-adapted organisms will tend to die off, often eventually becoming extinct.

Divergence of Character. Darwin believed that varieties were "incipient species" and that they were often in the process of becoming different species. In small areas with a lot of competition for resources, there is often a lot of diversity, coming from different genera and orders. This advantage of diversity is why foreign plants sometimes thrive compared to indigenous plants when they are introduced in a new country.

This section is why Darwin made the point earlier that the distinction between varieties and species is somewhat arbitrary. Under his theory, varieties can eventually become species, and this explains why it is sometimes difficult to draw the line between them.

The Probable Effects of the Action of Natural Selection through Divergence of Character and Extinction, on the Descendants of a Common Ancestor. The descendants of a species will be most adapted to survive if they become more diverse. In this way, the descendants of a species can be plotted as a sort of "tree" with lines branching out, some of which end (in extinction) and others of which continue branching off.

The tree image that Darwin describes helps to illustrate both how life becomes more diverse over time but also how not all of that diversity survives into the present (because of many extinctions). It provides a visual representation of an idea Darwin explores in greater detail later: how diverse modern species and varieties are often descended from only a couple of progenitors.

Darwin admitted that in the real world, natural selection probably doesn't proceed as methodically as in his tree diagram. Nevertheless, the diagram shows important ideas, like how extinction plays a role in natural selection. It also shows how, over generations, one species tends to become many different descendant species, and sometimes branches become so separated that they become different genera or even families.

Like many scientific diagrams, Darwin's tree of life is a simplification of messier ideas. Nevertheless, it provides a clear demonstration of how seemingly unrelated species may nevertheless share important connections, particularly if you look back far enough in evolutionary history.

Though it might seem that this means the future will have more diversity and the past had less diversity, because of the role extinction plays, it's possible that diversity in both periods would be similar to the present.

Darwin explains how extinction and diversity maintain a careful balance and how the future outcomes of natural selection are not inevitable based on the past.

On the Degree to which Organisation tends to advance. Because natural selection preserves positive traits, organisms tend to become better adapted to their conditions. This means natural selection tends to lead toward organization, such as the development of specialized, interlocking systems of organs within a creature.

One of the challenges from critics that Darwin addresses later in this book is how complex organs like the eye could have arisen through natural selection. Here, Darwin lays the groundwork for arguments that he'll explore in greater detail later.

As Darwin wrote, however, this seems to present a problem: if natural selection leads to organization, why do simple organisms still exist? He argued that this wasn't actually a problem: if there is no advantage for an earthworm to have a more complex system of organs, then it will not be naturally selected. All life would have originally started out as simple unicellular organisms before new variations arose.

Though natural selection leads toward helpful adaptations in species, Darwin stresses that this does not necessarily mean greater complexity. He notes that for many organisms, more complexity would have no benefit and in fact might even be detrimental.

Convergence of Character. One of Darwin's critics believed that he overestimated the importance of divergence between species. This critic believed that Darwin didn't put enough emphasis on convergence, and that creatures of different species might actually come to resemble each other over time and go from two genera to one genus. Darwin believed this view was unlikely—that if species did converge like this, they would be vulnerable to extinction.

While it is easy to dismiss Darwin's critics today, it is important to remember that his theories were competing against many others, some of which were advanced by eminent naturalists. The idea that species could converge might seem just as feasible as the idea of divergence to some observers, but Darwin correctly points out that such a convergence would provide little advantage under natural selection.

Summary of Chapter. Darwin repeated some of the main ideas from the chapter: how helpful variations arise in nature and are preserved; how sexual selection plays a role; how extinction acts as part of natural selection; how widely diffused species show more variation; and how the process of new species descending from ancestors can be diagrammed as a tree.

With this chapter, Darwin has finished his broad overview of natural selection. Though there is more detail to explain in future chapters, he pauses here to review what he covered previously, since this information is the foundation of all that comes after it in the book.

CHAPTER 5

Darwin began laying out his plan to explain in more detail how variation arose in species. He acknowledged that it was difficult to tell precisely what role factors like climate or food supply play in any given situation. Ultimately, he believed that the conditions of life not only cause variations but also natural selection.

While Darwin has explained the mechanics of how natural selection preserves helpful variations, he has not fully explained how variations arise in the first place, and this chapter explores the topic in greater detail.

Effects of the increased Use and Disuse of Parts, as controlled by Natural Selection. Many of Darwin's peers and predecessors wondered about why many creatures have "deficient" parts, such as beetles with wings that can't fly. Darwin believed such features could be explained through natural selection, which involved gradual selection based on lack of use. This is why some subterranean animals lack proper **eyes**, whether in the Old World or the New.

The fact that some beetles have wings but can't fly seems at first like a problem for Darwin's theories, because he argued that only useful variations get passed down, and useless wings seems counterproductive. Darwin goes into greater detail on the issue later—here, he simply notes that use or disuse of a part seems to affect what happens to it through natural selection.

Acclimitisation. Plants inherit habits like flowering periods and sleep schedules through heredity. While nature usually limits the range of organisms, sometimes, plants can become acclimated to new regions and thrive, even better than in their original home. How much a plant or animal species can get acclimated is based on its habits. Habits include use and disuse of various parts, and they play a role in modifications through natural selection.

Climate and geography often play an important role in natural selection. Darwin wrote when Britain was still a global empire, and one of the side-effects of British colonialism is that it was possible to witness what happened when European plants and animals were introduced to the rest of the world.

Correlated Variation. When some parts of an organism are modified, the change can have a related effect on other parts. For example, changes in embryos or larvae can affect a mature adult animal. Another example is how the shape of the pelvis bones in a bird seem to be correlated to the shape of its kidneys.

Darwin understands that changes in an organism don't happen in a vacuum, and so changes to one aspect often, by necessity, have corresponding changes in other aspects.

Compensation and Economy of Growth. Darwin examined the idea of some of his predecessors that when nature gives to one area of an organism, it takes away from another. It is difficult, for example, to fatten a cow and have it create a lot of milk at the same time. Darwin expanded on the idea, suggesting that natural selection is always trying to organize things more efficiently. This means getting rid of characteristics or habits that become unnecessary.

Economy of growth is an important concept because it helps solve Darwin's earlier problem of why some organisms had features that seemed to be useless. It turns out that useless features give an organism more opportunity to develop new adaptations that better suit its present conditions.

Multiple, Rudimentary, and Lowly-organised Structures are Variable. For both varieties and species, "rudimentary parts" (like the vertebrae on a snake) are likely to be variable, since individually, they are not especially useful.

Darwin explains the nature of how variation works by looking at one extreme: when the parts of an organism are seemingly of little individual importance.

A Part developed in any Species in an extraordinary degree or manner, in comparison with the same part in allied Species, tends to be highly variable. Darwin noted that the most developed parts and organs in a species tend to be the most important and therefore the most subject to variation. He looked at the example of the wing of the bat, which is abnormal among mammals, and concluded that it was not a good example of this principle because it must have existed for a long time in its current state. It is only more recent highly developed parts that show an increase in variability.

Darwin switches to look at the other extreme: when a part of an organism seems to be highly important. Bats are an interesting example that he returns to throughout the book because although they are mammals, they can fly—something that most other mammals can't do. For this reason, the wings of a bat make an interesting topic to study, since they resemble features in other mammals while also being something that's quite unique.

Specific Characters more Variable than Generic Characters. Darwin believed that species-level characteristics are more variable than genus-level ones. He used the example of a large genus of plants with some blue flowers and some red flowers and how variation here would be more expected than in a genus where all plants within it were blue.

Darwin's observation here is common sense: it probably seems obvious that a genus (which is a bigger classification group than a species) is more likely to contain variation. Nevertheless, this basic observation is important to establish, because he builds on it to draw conclusions that are not necessarily common sense.

Secondary Sexual Characters Variable. Following the opinion of most other naturalists, Darwin believed that secondary sexual characteristics are highly variable. For example, in birds where males have elaborate feather patterns to attract females, there is a lot of variation in the males' feathers.

Darwin's observation here also isn't surprising. The spectacular feathers of some male birds show a lot of variation, even for untrained observers. Again, Darwin establishes an obvious principle in order to build a foundation for something less obvious.

Distinct Species present analogous Variations, so that a Variety of one Species often assumes a Character Proper to an allied Species, or reverts to some of the Characters of an early Progenitor. Darwin noted that domestic pigeons, even in countries far apart, sometimes develop variations more typically found in pigeons from other parts of the world. This seems to be the result of them having a common parent species. Even characteristics that have been lost for many generations can suddenly reappear in offspring.

Darwin has discussed the evolution of pigeons in a prior chapter, but he brings it up again specifically to illuminate some principles about variation. In this way, he shows how the previous chapters about common progenitors and diverging species relate to the current chapter about variations.

Darwin also looked at the example of horses. He found that throughout the horse genus, there was a tendency for offspring in different species to develop some form of stripes. He believed this was evidence that each species of horse was not "independently created," but that in fact all modern creatures in the horse genus once had an ancestor that was striped like a zebra (although it may have had a different form).

As with Darwin's observations about dogs, his observations about horses reveal his ability to apply scientific logic and draw inferences from the data available to him at the time. As Darwin notes elsewhere, he differs from many of his peers by believing that modern species came from relatively few progenitor species.

Summary. Darwin admitted that he and other naturalists were still ignorant about many of the laws surrounding variations. Nevertheless, he believed there was enough evidence to draw some conclusions based on the patterns visible in samples from the species and genera that existed in his day.

Darwin frequently admits the limits of his knowledge, but he almost always follows these caveats with a renewed insistence on why his proposals are logical.

CHAPTER 6

Darwin acknowledged that his readers might have objections at this point in the book and stated that he wanted to address them. He identified four main objections: 1. If species all descend through gradual variation, where is the record of all the transitional forms? 2. How could an animal currently living (like the bat) have been formed from another animal with such different habits? 3. Can habits and instincts really be inherited through natural selection? 4. How come when species are crossed the offspring are sterile, but when varieties are crossed, the offspring are still fertile?

Darwin spends a large portion of the book responding to the objections of his critics, sometimes even addressing them by name. While Darwin's narrator persona remains amiable, the sheer amount of space that Darwin spends responding to critics suggests that his ideas faced a lot of criticism but that Darwin nevertheless believed that his arguments were enough to overcome this criticism.

On the Absence or Rarity of Transitional Varieties. Darwin addressed the first objection by noting that the geological record is imperfect—perhaps even more so than some of his colleagues believed. More challenging to Darwin was the question of why intermediate forms seem to be so rare among currently existing species.

Darwin tries to base his arguments on solid evidence, which is why the imperfect nature of the geological record makes things difficult for him—the conditions that cause a specimen to be preserved as a fossil are specific and sometimes haphazard. But while Darwin often admits to the limits of the available data, he still argues that nevertheless his theories make more sense based on the available data than his opponents' theories do.

Darwin observed in his travels that species were generally limited to inhabiting a continuous area. He found that in general, whenever two similar varieties of a species range over large, continuous areas, there is a third variety that exists in a small intermediate zone between them. The small population size means that the varieties in this zone are much rarer and more prone to extinction. This explains why species are relatively well-defined instead of being a chaotic mix of intermediate forms.

Once again, geography and environment turn out to play an essential role in the development of species. Because of the aforementioned gaps in the geological record, Darwin is forced to make observations based on available data, including observations about modern species distributions, and he uses this information to make logical inferences that are sometimes surprising but always supported by evidence.

On the Origin and Transition of Organic Beings with peculiar Habits and Structure. Darwin noted that some of his opponents questioned how it was possible that a terrestrial carnivore could have descended from an aquatic one. Darwin admitted it was a difficult problem and that he had only collected a few specimens that seemed to show transitional species of this sort. Bats presented a similar problem.

Explaining how aquatic species became terrestrial species has long been one of the greatest challenges for theories of evolution, and can be difficult to understand intuitively. Darwin does not dismiss the issue—in fact, he admits that it is an objection worth serious consideration.

Nevertheless, however, Darwin believed that modern creatures like flying squirrels provided an example of what a transitional species between bats and other mammals might look like. He also noted that many crustaceans and mollusks can breathe underwater but are adapted to live on land.

As with all the objections Darwin considers, however, there is a simple answer. In fact, there are many currently existing species that live a hybrid life between land and sea or land and air. This shows Darwin's skill at crafting arguments—he anticipates or addresses objections specifically so that he can reveal how his own theories are better.

Organs of extreme Perfection and Complication. Darwin confessed that it seemed at first absurd to him that something as complex as the **eye** could have arisen through natural selection. Nevertheless, he believed that by following reason, it was possible to imagine the gradual development of the eye over time, with early imperfect versions being subtly improved upon over generations.

Darwin's critics focused on the development of the eye, because it is a complex, highly organized organ with a lot of sub-parts. To them, it seemed impossible that such a complex organ could have arisen part-by-part—it must have been created all at once (and many of them believed it was God who did this creation). While Darwin is careful not to antagonize religious readers, he strongly believes that no part of an organism is created all at once—natural selection is always an accumulation of small, gradual changes.

Because the imperfections of the geological record make it impossible to look back at a species' descent in a straight line, Darwin believed that explaining the **eye** involved looking at different species and genera within a larger group. He found that some species have a very simple organ that could nevertheless be called an eye, with just an optic nerve, some pigment-cells, and some translucent skin around it. Other species have slightly more complex eyes, incorporating pupils but still lacking complex features like lenses.

When Darwin can't draw on the geological record for evidence, he often looks to the wide variety of life that exists in the present. While the species of the present aren't the same as the species that existed in the past, they can still offer hints about how things used to be, and some current species have descended in more or less the same form for thousands and thousands of years.

Ultimately, Darwin observed a wide range of **eyes** and believed these were evidence that the human eye could have been perfected through gradual adaptations over millions of years.

The long time period is important for Darwin's theory—such small changes need long periods of time in order to be effective. Reading about the geological work of Charles Lyell is part of what encouraged Darwin to think about such long periods of time.

Modes of Transition. Darwin believed that if there existed an organ so complex that it couldn't have been formed through a process of slight, successive variations, it would break his whole theory; he also believed there was no solid evidence that any such organ existed. While human organs may seem complex, in many cases they have analogous forms in less complex animals that hint at what transitional organs may have looked like.

Darwin had ambitious goals for his book and aimed to develop a theory that would cover how virtually all species came to be in their present forms. He offers opponents a chance to prove him wrong, but ultimately, he shows that natural selection is such a powerful, flexible process that it would be difficult, if not impossible, to prove that any organ was truly too complex for natural selection.

Special Difficulties of the Theory of Natural Selection. Darwin addressed some of the most serious criticisms of his theory of natural selection. Neuter insects were a strange case that Darwin promised to explore in the next chapter. The electric organs of some fish also seemed odd, but Darwin argued that the real difficulty here was that so little was known about these organs to begin with, making it difficult to infer how they might have developed gradually. Luminous organs in insects presented a similar issue.

Even for a theory as comprehensive as natural selection, however, there are some odd examples from nature that, on the surface, seem difficult to account for. As always, Darwin adopts a reasonable tone and never dismisses objections before considering whatever possible value the objections might have.

Darwin noted that with electric organs and luminosity, a similar function was performed by organs that might have developed in very different ways. The wings of a bird, a bat, and a butterfly are similar in some ways but also very differently constructed, suggesting a different development process. Darwin summed up this situation by quoting another naturalist who suggested that Nature presented a lot of variety but not much actual novelty. He reiterated his belief in natural selection and how it acted only in small steps, never taking big, sudden leaps.

Ultimately, Darwin argues that while electricity or luminosity seem like extraordinary developments on the surface, a closer inspection reveals that these traits are just like any other trait that arises through natural selection. When Darwin says that nature has variety but not novelty, he means that things in nature that look very different often serve purposes that, in the end, are quite similar.

Organs of little apparent Importance, as affected by Natural Selection. Darwin found difficulty explaining how natural selection was involved with parts and characteristics of creatures that seemed to have little importance. He cautioned, however, that it was not always easy to tell the difference between an unimportant part and one that only appears that way. It's also possible that today's unimportant organs once played a very important role in a progenitor species.

Darwin has touched on the issue of seemingly useless body parts earlier in the book and explained it through the theory of economy of growth. His answer here shows his cautious approach to making sweeping statements. His reluctance to declare part of an organism useless demonstrates that he is methodical and always careful to avoid making statements that he doesn't necessarily have the evidence to prove.

Utilitarian Doctrine, how far true: Beauty, how acquired. Some naturalists protested against Darwin by arguing that some beautiful things in nature seem to have been created for the pleasure of man or a Creator. Darwin argued, however, that beauty is subjective and is not necessarily innate or unchangeable. While he admitted that beauty certainly played a role in sexual selection, he believed that other types of beauty may have simply arisen as a result of other forces like symmetry of growth.

The arguments of Darwin's opponents about beauty here are maybe not the most serious from a scientific standpoint, but Darwin often uses grand language about the beauty of nature, and the idea that evolution only enhances the wonder of nature is central to his argument. In particular, Darwin often talks about beauty and natural selection to refute the idea that his theories are anti-religious.

Natural selection doesn't modify one species exclusively for the good of another species. It can lead to features that hurt other species (like the venomous fangs of a snake), but it can't lead to structures that solely hurt the organism itself with no benefit. While it might seem like the sting of the bee violates this principle (since the bee dies after stinging), Darwin argued that such an adaptation is good for the species as a whole, and that it is still possible to imagine such a mechanism arising from earlier versions that did not cause the insect's death.

Darwin is not arguing that species don't develop traits that benefit over other species. For example, some species of plants are better adapted to accept certain bees. What Darwin is arguing is that these adaptations cannot only *benefit the other species. In the case of the plant adapted for bees, it benefits from having its pollen spread more widely by the bees.*

Summary: the Law of Unity of Type and of the Conditions of Existence embraced by the Theory of Natural Selection. Darwin summarized that while the objections to his theories are worth serious consideration, he believed they all had explanations. He repeated his conviction that the best explanation for the similarities among present organisms ("Unity of Type") is to look back for a common ancestor. He believed that an even more important principle than Unity of Type was Conditions of Existence, by which he referred to the external conditions of an organism's life that led to the inheritance of variations and adaptations.

Despite dedicating a full chapter to the objections of his critics, he isn't finished with the topic and will consider it for a couple more chapters. Ultimately, Darwin is not only addressing the objections of critics, but also using the criticisms as a way to organize the structure of his book, presenting the criticisms in an order that will allow him to naturally build his argument up.

CHAPTER 7

Darwin announced his intention to use this chapter to respond to some miscellaneous critics of natural selection. Darwin believed that perhaps the most serious objections came from Heinrich Georg Bronn, a distinguished German paleontologist. Bronn thought it unlikely that a variety would live side-by-side with its parent species. He also believed that different species must differ not just in a single characteristic but in multiple ways. Finally, Bronn (and others) suggested that many creatures have characteristics that seem to be useless and therefore could not have been influenced by natural selection.

In order to properly respond to his critics' objections, Darwin often explained these objections in great detail. While this might at first seem counterproductive to his argument, in fact, Darwin's argument benefits from the strategy because he takes the time to prove that his theories are comprehensive enough to counter even the most serious of objections.

While Darwin acknowledged the validity of Bronn's concerns, he cautioned against making sweeping generalizations about what was and wasn't a useful characteristic. The ears of mice, for example, were listed by Bronn as an example of a trivial adaptation, but Darwin noted that these ears were full of nerves and that their size likely did play an important role. Darwin also acknowledged that he had adapted his own views on the issue since the previous edition of the book.

Darwin's scientific way of thinking sometimes led him to unexpected conclusions. For example, on the surface, the large ears of a mouse might not seem to be particularly useful. Nevertheless, careful observation showed that in fact, the ears might play an important role because of the nerves inside them.

A prominent zoologist named St. George Mivart was a critic whom Darwin respected and wanted to answer. Mivart had a couple objections, notably that a giraffe didn't make sense under natural selection because the additional bulk added by its neck (requiring an increased supply of food) surely outweighed any potential advantages. Darwin argued that the increase in food was great enough to justify the neck and that perhaps the tall neck also helped the giraffe observe and fend off predators.

The fact that Darwin spends so much time responding to St. George Mivart suggests that he took Mivart's objections seriously (and perhaps also that readers in Darwin's initial intended audience would have taken Mivart seriously). Giraffes come up elsewhere in the book and are an interesting example because of their unusual anatomy. Here, Darwin argues that despite a giraffe's unusually long neck, its relationship to food and predators is much the same as any other animal's.

Mivart's second objection was that if a giraffe is so well adapted, why haven't all four-legged mammals developed a long neck like giraffes and, to a lesser extent, camels have? Darwin believed that this objection could be dealt with by considering the different geographies of different creatures' environments. Another solution is considering how a feature like a long neck requires other body adaptations to be an advantage, meaning it would not be naturally selected for in all animals.

The strength of Darwin's ideas is that they are flexible, and natural selection often acts differently depending on the specific situation. Mivart's argument makes sense based on logic, but Darwin's reply makes more sense based on observation and the scientific method.

Darwin continued looking at some of Mivart's other objections, including the idea that the jaw of a Greenland whale is so large and complex that it couldn't have arisen through slight successive adaptations under natural selection. Darwin held firm in his disagreement, however, using the example of the shoveler-duck's beak to show how a structure like a whale's jawbone could have similarly arisen through natural selection. Mivart had other objections of a similar nature, and Darwin responded in turn to each of these with examples.

The issue of the Greenland whale's jaw is similar to that of the human eye, and Darwin's answer for both of these objections is the same. Again, Darwin's wide familiarity with species living around the world (particularly birds) helped him find examples of different species that could have existed in the past.

Ultimately, Darwin's disagreement with Mivart was that Mivart believed drastic adaptations like a bat's wings happened suddenly, rather than through successive variations as Darwin proposed. While Darwin acknowledged that in some ways Mivart's view sounded reasonable, he ultimately believed it required making too many assumptions, and that there was not enough evidence in the geological record or in studies of embryos to suggest that it was valid.

Though the disagreements between Darwin and Mivart may seem minor at times, Darwin knew that the success of his theory rested on its accuracy, even on small details. He used critics like Mivart as an opportunity to refine and expand on his own ideas.

CHAPTER 8

Darwin found some creatures' instincts so amazing that he predicted some readers would object to his theories based on instinct alone. Darwin believed that there was a way for habitual actions to be inherited, and moreover that some traits like the hive behavior of ants and bees was so coordinated that it had to be more than just habit. As with other characteristics, instinct only arises through natural selection due to the gradual accumulation of small but useful variations. Ultimately, Darwin believed that under natural selection, instinct was similar to physical characteristics and followed similar laws.

Instincts might not seem like something that can be affected by natural selection, since they are not as concrete as an organ or other body part. Nevertheless, over the course of this chapter, Darwin makes the argument that for the purposes of natural selection, instincts act like just about any other feature that gets modified through natural selection.

Inherited Changes of Habit or Instinct in Domesticated Animals. Darwin believed that there was already good evidence of how instinct could be inherited, based on data from domestic breeding. Cats, for example, vary as to whether they prefer to chase mice or rats or birds, and this habit was known to be passed down through generations. He makes the distinction, however, that simply teaching a domestic animal how to do a certain action does not mean it will be passed down to offspring as instinct. Tumbler-pigeons, for example, were never taught how to tumble.

As he did in previous chapters, Darwin shows that his seemingly strange ideas are in fact based on concepts that are already familiar to people. Again, he uses the example of domestic animals. Then, and now, people were familiar with how domestic animals like cats could seem to inherit unique instincts from their parents that were present from birth, but the cats wouldn't inherit any habits or preferences they gained through training.

Some natural instincts are lost in domestication: for example, some fowls lose their instinct to sit on their eggs as they would in the wild. This provides further evidence that instincts are inherited and that in these cases, humans affected this process by breeding domestic animals for specific qualities.

The fact that instincts change under domestication is a convincing argument that instincts are determined hereditarily (and so there is opportunity for natural selection to act on them).

Special Instincts. Darwin identified three specific instincts that he felt were central to his argument: the instinct of the cuckoo to lay eggs in other birds' nests, the instinct of some ants to essentially make others their slaves, and the instinct of bees to make complex cells as hives.

This is another case of Darwin approaching abstract ideas by breaking them down into real or hypothetical examples from nature in the present day.

Instincts of the Cuckoo. The habits of cuckoos vary around the world, with some laying their eggs over the course of days and others laying them all at once—this complicates the question of what is motivated by instinct. In some varieties, a blind cuckoo that hatched just three days ago has been observed to kick its foster siblings out of the nest. Darwin believed that this behavior helped the young cuckoo get enough food and that there was every reason to believe that such an instinct could have arisen through gradual, successive variations, just like any other inherited trait.

Cuckoos are birds that are famous for being parasites and laying their eggs in the nests of other birds. Once in the nests, the newly hatched cuckoos will actually push a bird's real offspring out of the nest, in order to get more food themselves. Birds as young as three days old know how to do this, so it is clearly instinct. This was widely known in Darwin's time, but Darwin's contribution is to suggest that the way this instinct first arose was gradually through natural selection.

Slave-making instinct. Naturalists observed that some ants were totally dependent on making other ants into their "slaves." They can't make nests or feed larvae, and they need to be physically carried by slaves in order to migrate. Not all ant species are slave-makers, but even ants that aren't will sometimes carry off the pupae of other species. It is possible that some species like this essentially found it was more efficient to steal workers than to create them through reproduction and that this is how they gradually became slave-making.

Slave-making ants were fascinating to Darwin and other naturalists because they seemed to break the normal rules about relationships between species. To some it seemed impossible that such a strange relationship could have arisen gradually, but here Darwin suggests intermediate steps based on actions that modern ants have been observed doing.

Cell-making instinct of the Hive-Bee. Honeycomb has a beautiful, even mathematical structure. Darwin investigated how such a thing could arise in nature through natural selection. Following the examples of his peers, he looked at the habits of different species of bees and conducted his own experiments, showing how bees reacted to different obstacles placed in their way when building honeycombs. Ultimately, Darwin reached the conclusion that bees likely began by making combs from spheres at equal distances from each other, before gradually improving on the process until the combs reached their famous hexagonal shape.

When viewed in isolation, a honeycomb seems so complex that it had to have been carefully designed. Darwin's critics argued it wasn't possible to build something so intricate gradually. Darwin, however, has already answered this question in various forms (notably for the human eye), and here he employs the familiar strategy of looking for possible intermediate behaviors being practiced by other species that currently exist (and which could give a hint about the behavior of progenitor species).

Objections to the Theory of Natural Selection as applied to Instincts: Neuter and Sterile Insects. As he promised in the previous chapter, Darwin returned to the issue of neuter and sterile insects. Though it was a broad issue, Darwin narrowed the focus to sterile worker ants. The idea that a worker is so different from its parents and sterile seems at first to go against natural selection.

Darwin spends a lot of time on sterile animals since the entire concept of sterility might seem opposed to his theories (which suggest that organisms want to survive and pass their traits on). While the issue can get complex, Darwin always has an answer for the objections of his critics.

Darwin answered the objection first by noting that many characteristics of creatures are associated with specific ages or sexes. Birds, for example, get specific plumage around mating season, so it's possible that the mechanism behind sterile insects is similar. Darwin also noted that selection applies not just to the individual but to the whole species.

The problem with Darwin's critics, in Darwin's view, is that they often focus on the issues too narrowly. Zooming out often reveals that seemingly insurmountable problems can often be explained by analogy to a similar, better-understood issue.

Still, the difficulty with ants is that sometimes neuters differ not only from their parents but even from each other (for example, some are workers while others are soldiers). While Darwin acknowledged this is a serious challenge to natural selection, he believed there was an explanation. Within the worker ants are "castes" of wildly different sizes and shapes. This variation and the presence of ants with "intermediate" forms seems to show a way in which natural selection could have acted on these neuter ants through gradual changes. The different castes seem to be a useful adaptation for the ants.

Ant hives present a particular challenge to Darwin's theories. Darwin doesn't believe that hives disprove natural selection, but he does allow that ants are a difficult case to explain. Ultimately, Darwin's theories look not at the survival of individuals but at the survival of a whole species, and from this angle, it makes sense that there might be neuter ants within a hive that fulfill a specific role that doesn't require reproduction.

Summary. Darwin repeated how evidence from domestication helped bolster his case about instincts and natural selection. He also summarized how natural selection explains the seeming issues with cuckoos, slave-making insects, and neuter insects.

Darwin covered a wide variety of topics in the chapter, so he uses the summary to emphasize the connections between the topics.

CHAPTER 9

Many naturalists believed that the crossed offspring of different species were sterile in order to stop the chaos that might ensue. Darwin, however, argued that this sterility was just an accident. One of the key differences between species and varieties seems to be how fertile the offspring of crosses between species are vs. how fertile the offspring of crosses between varieties are.

As in the previous chapter, sterility represents an interesting challenge to natural selection, because it is unclear what benefit it provides to a species. Darwin's belief that sterility doesn't provide any benefit may seem unusual at first, but he expands on the idea throughout the chapter and shows how it isn't inconsistent with his other ideas.

Degrees of sterility. Building off the work of other naturalists, particularly those working with plants, Darwin noted that sterility is not a black-and-white condition, and that different crossings of parents can lead to different degrees of sterility in offspring. He observed that close interbreeding was often the culprit. Animals had been studied less than plants, but Darwin noted that breeders found that hybrid offspring became more sterile after being bred with siblings over successive generations—although none of these rules were necessarily universal.

Darwin sets the tone for a discussion of sterility by defining what sterility is. Here, he makes the important observation that sterility is not an all-or-nothing condition and that in fact, there can be different degrees of sterility or fertility in offspring. As in many other cases, Darwin draws his observations from domestic breeders, who don't perfectly mirror nature but who have a lot of firsthand experience and data.

Laws governing the Sterility of first Crosses and of Hybrids. Darwin noted that hybrids between two species that are difficult to cross (since the crossing rarely produces offspring) are usually very sterile. Still, there were exceptions, and some specific crossings of plants yielded extremely fertile offspring.Even among hybrid offspring created under similar conditions, fertility can vary widely.

One theme that Darwin returns to throughout this chapter is that while sterility often has general rules, these rules also frequently have exceptions. He gives consideration to exceptions, because he wants to ensure that his theories are broadly applicable, even in unusual circumstances.

It is difficult to figure out which factors govern fertility of offspring. Logically, it would seem that similar species would produce more fertile offspring, but in fact, in some genera of plants, very similar species produce infertile offspring, while in other genera of plants, all species within it can be crossbred freely—even when the genera are in the same family. Rules vary by species: some species cross well with others, and some species are better at creating hybrid offspring that look like them (as opposed to looking like the other species in the hybrid crossing).

Once again, Darwin was limited by the fact that he was writing before many of the great scientific breakthroughs about genetics. Without this knowledge, the fertility or lack of fertility of offspring was difficult to explain, particularly with universal rules. Darwin is careful not to force anything into fitting into a pattern simply for the sake of logic. He steps back and tries to observe the diversity of things as they are, applying the scientific method.

Ultimately, Darwin believed that these complex systems of laws did not support the idea that hybrids were infertile simply to limit confusion in nature. He believed that such a complex system suggested that sterility was either incidental or that it depended on differences in reproductive systems that were difficult for naturalists like him to observe.

Because of the complexity of sterility, it is hard both for Darwin and for his opponents to make generalizations. Ultimately, Darwin is cautious, trying to avoid any claims that can't be backed up by evidence. For him, there is not enough evidence to back up the claim that sterile hybrids provide some benefit by limiting confusion.

Origin and Causes of the Sterility of first Crosses and of Hybrids. Darwin used to believe that sterility in hybrids arose gradually through natural selection and that preventing species from blending was an advantage. After studying the issue more, particularly in plants, he reached the conclusion that it must be due to some other cause and that similar rules probably held true in animals as well.

When it comes to reproduction, plants can be easier to study than animals, because it is easier and quicker to cross them. Because the same principles are broadly applicable, however, naturalists like Darwin often take insights from plant reproduction and then apply them back to animals.

Darwin believed that the real cause behind sterility in hybrids involved changes to the reproductive system. Hybrids generally arise from unnatural conditions, and these unnatural crossings are reflected by disturbances in the reproductive system. Darwin likened this reproductive disturbance to the behavior of elephants, which don't breed in confinement, even in their native countries.

Through the book, reproduction and the reproductive system play a central part in Darwin's theories. Particularly in Darwin's time, reproductive systems could be difficult to observe, but it was often possible to draw conclusions about a reproductive system based on other factors, like the condition of the offspring.

Reciprocal Dimorphism *and Trimorphism.* Some plants look the same on the outside but have different reproductive organs, such as the length of the pistil and stamen. There can be two or even three such varieties ("dimorphic" and "trimorphic"), and some crossings between these different forms produce fertile offspring and others don't. These dimorphic and trimorphic plants help demonstrate that infertility of offspring is solely related to reproductive features and that external features of a plant or animal don't necessarily help predict whether its offspring with a similar-looking variety will be sterile.

Again, Darwin uses reproduction in plants in order to draw conclusions that apply more broadly to other organisms that reproduce sexually too. Plants were particularly interesting to Darwin because reproductive organs like the pistil and stamen were clearly visible, making them easier to observe (and particularly making it easier to see variations).

Fertility of Varieties when Crossed, and of their Mongrel Offspring, not universal. While Darwin argued that there was some truth to the popular idea that varieties produced fertile offspring when crossed but species didn't, he also argued that the rule was not universal. Some varieties of dogs generally don't produce fertile offspring with others. Gourds and maize provide even stronger evidence of the difficulty of creating fertile offspring from crossing varieties in some cases, proving that the rule isn't universal.

Darwin keeps returning to the idea that classification systems often do not account for all possibilities. While there are broad general differences between species and varieties, the exceptions to the rule make it difficult to draw a clear boundary. Ultimately, Darwin is not advocating throwing out classification systems. He is simply suggesting that naturalists must take a flexible approach and be mindful of exceptions.

Mongrels compared, independently of their fertility. Darwin decided to compare the offspring of crossed species and crossed varieties on traits other than simply fertility. He drew a distinction between "mongrels" and "hybrids," arguing that in the first generation of breeding, mongrels were more variable, but in species that have been domesticated for a while, the opposite might be true. Ultimately, he concluded that if you left fertility out of the equation, the offspring of varieties and the offspring of species were, in general, more or less the same.

As Darwin shows, reproduction can get messy, and there are a lot of different ways to categorize the offspring of any given crossing. On the one hand, he believes that this complexity is important and worth considering. On the other hand, however, he believes that the theory of natural selection is broadly applicable and that in the end, nothing about sterility in hybrids offers a serious challenge to natural selection.

Summary of Chapter. Darwin reiterated that the sterility of first-generation crossed offspring was not due to natural selection. He admitted that he didn't know exactly why this sterility arose, but believed that this didn't fundamentally change his ideas about how species and varieties lived in nature.

After getting into the small details of sterility in hybrids, Darwin returns to broad-level generalizations, emphasizing once again that this sterility does not provide a benefit that is naturally selected.

CHAPTER 10

Darwin recounted some of his arguments from Chapter VI (where he answered his detractors), explaining again why it seemed likely that intermediate varieties died out quickly. The geological record seems to confirm this. Darwin noted that his mistake was often to look for intermediate forms that were directly between two current species when, in fact, it was better to look at how current species were related to an unknown ancestor species (for example, how contemporary fantail and pouter pigeons may have both descended from an ancient type of rock-pigeon).

Darwin's continued emphasis on intermediate varieties shows how serious a challenge their absence in the fossil record potentially posed to his theories. Nevertheless, the situation also provides him with the opportunity to bolster his argument by providing greater nuance. Making the best of the data available to him, Darwin again turns to the abundance of examples present among currently existing species.

Darwin allowed that it was theoretically possible for one current species to have descended from another current species (for example, the horse from the tapir), but this would involve one of the species staying unchanged for a very long period of time, and under natural selection, such a development was improbable.

Probability plays an important role in many of Darwin's theories. As a careful scientist, he is cautious not to overreach with his statements. Instead of stating what definitively happened in the past, he generally prefers to say what is most likely to have happened. This goes hand in hand with the idea that natural selection is a process full of possibilities.

On the Lapse of Time, as inferred from the rate of deposition and extent of Denudation. Some of Darwin's critics argued that the lack of intermediate forms in the fossil record was a sign that not enough time had passed for natural selection to have worked as Darwin argued it did. Darwin acknowledged that his own thinking on the issue of geological time owed a big debt to the geologist Charles Lyell.

Though the relationship between Lyell's work in geology and Darwin's work in evolution might not be immediately obvious, the connecting factor is the long timescales of both processes. Lyell's work proved that the earth was very, very old and that geological changes generally happened very, very slowly. This long time scale also provided enough time for species to adapt and evolve very, very slowly.

Darwin explained how geological processes meant that some parts of the world had better preserved fossil records than others. This presented difficulties when using the fossil record to try to determine just how long it took for a new species to arise through natural selection.

Part of Darwin's rhetorical strategy is to be honest about the shortcomings of the available data. This honesty helps him portray his arguments as even-handed, potentially making them appealing to a diverse audience of readers.

On the Poorness of Palæontological Collections. Darwin wrote that even the world's greatest museums had only a poor, imperfect collection of the geological record. In particular, massive geological shifts, due to factors like plate tectonics, mean that it is difficult to follow the geological record in a linear fashion. Moreover, only some regions had the right conditions to preserve fossils and become rich in them.

One of the hallmarks of Darwin's theories is that he tries to make them comprehensive enough to account for different conditions in different parts of the world. Here, he notes how these different conditions could have led to different geological records, based on various factors that help preserve fossils.

On the Absence of Numerous Intermediate Varieties in any Single Formation. Even within a single geological formation, it is difficult to search methodically for intermediate varieties between species. There are strange cases where one species can be found on both the top and bottom of a formation but not in the middle. Though geological formations arose over a very long period of time, the time period often was not long enough to capture the change of one species into another.

Darwin suggests that the periods of time captured by the fossil record don't match up perfectly with the periods of time over which evolution occurred in species. This means that the fossil record can seldom be used to chart an orderly progression of a new species as it diverges from its progenitor.

To get a perfect "gradation" between two different forms of a plant or animal, there must be a continuous regular geological deposit over a very long period of time. Such cases are very rare, and accumulation is more likely to be intermittent than continuous.

Darwin explains other geological factors that contribute to the difficulty of using the fossil record to try to reconstruct the linear development of new adaptations in a species.

Adding to the difficulties, it usually takes multiple specimens from multiple locations in order to definitively prove the connections between species. Many critics argued that, in fact, the geological record provided no evidence that intermediate forms even existed, suggesting that this means that species are immutable. While Darwin always acknowledged the imperfections of the geological record, he argued that there were cases of links in the geological record, while also acknowledging that it would be helpful to have even more.

Per the scientific method, results of an experiment should be repeatable. This is a challenge for Darwin because the imperfections of the fossil record mean that he often doesn't have enough evidence to confirm some of his specific hypotheses and prove that they are repeatable. Nevertheless, Darwin makes it clear that even with all the geological imperfections, there is more than enough fossil evidence to support the theories about natural selection at the core of his ideas.

On the sudden Appearance of whole Groups of allied Species. Some of Darwin's critics argued that because groups of species tended to suddenly show up in geological formations, this was evidence that species didn't change. Darwin argued that such a view generally rested on too narrow a look at the geological record, and that considering other geological evidence from around the world usually complicated the picture.

As in other places where Darwin responds to his critics, Darwin generally takes a wider view of the situation than his critics do. By attempting to look at the full diversity of life on earth (and in this case the full fossil record), he is often able to reach surprising but well-founded conclusions.

On the sudden Appearance of Groups of allied Species in the lowest known Fossiliferous Strata. For Darwin, the more serious criticism involved some species of animals that began to suddenly appear in the lowest strata of fossil-bearing rocks. For a variety of reasons, geological strata from before the Cambrian era cover much longer periods of time. This long period of time would seem to suggest that there should be unusually rich deposits of fossils, but there aren't, and even the most prominent geologists couldn't fully explain the mystery.

The Cambrian Period, which began over 500 million years ago, was a time when diversity of life exploded and many new species formed. Study of geological eras from so many millions of years ago was a relatively new field in Darwin's time, and the Cambrian Period remains a focal point for many who study evolution.

Darwin concluded that some aspects of the fossil record would have to remain a mystery, at least until new discoveries helped shed further light on the issue. Nevertheless, Darwin noted that prominent geologists like Lyell who once believed in the immutability of species had recently come around to ideas more similar to Darwin's. He ultimately argued that in spite of the gaps in human knowledge, even the limited evidence that is available should be enough to diminish the concerns of his critics.

Though Darwin spends most of the chapter acknowledging flaws in the geological record, his ultimate point is that even with these flaws, there is enough evidence from the past to support his theories about natural selection and how new species formed and diversified slowly over time.

CHAPTER 11

In the geological record on both land and sea, new creatures appeared slowly, one after the other. Once again, Darwin looked to Lyell, who noted that every year, new discoveries helped fill in the blanks between species and reveal the transition to be more gradual than previously realized. One of the lessons from the fossil record was that plants and animals from the same area do not necessarily change abruptly, all at once, or to the same extent. When species or groups of species disappear, they don't come back, even if conditions change back to a favorable state.

Geology is the focus of yet another chapter in Darwin's book. This might seem strange in a book that is ostensibly about biology, but Darwin's theories involve the past and the passage of time—often geology is the best or even the only way to study these matters, particularly when it comes to the prehistoric past. Though Darwin has touched on the significance of extinction before, in this chapter, he expands on those earlier ideas.

On Extinction. Extinction and the introduction of new species are closely related processes. There is no universal law, however, determining how long a species will or won't last before extinction. Though some authors believed that species had a fixed lifespan, Darwin didn't. He did, however, believe that some factors played an important role in determining the lifespan of a species, including the presence of predators and competitors.

In general, Darwin avoids creating new laws to describe nature unless absolutely necessary. He is cautious about making claims he can't support with evidence, which is why he doesn't join with the opinions of other naturalists who believed that there were laws governing how long any given species would last.

On the Forms of Life changing almost simultaneously throughout the World. The geologists of Darwin's day were surprised to discover evidence that many lifeforms changed almost simultaneously, even when separated by vast geographic differences. The findings were particularly striking for marine life.

Darwin attempts to follow the evidence wherever it points. This sometimes means accepting and accounting for strange observations that may at first be difficult to explain.

Natural selection, however, could explain why new forms of life seemed to appear simultaneously around the world. Since new species formed by having advantage over other forms, the new forms would gradually diffuse, ultimately spreading around the world. Thus, while the change did happen over time, when viewed on a large timescale, it would appear to have happened simultaneously.

The timescales involved with evolution are difficult for humans to understand and can often only be understood indirectly by studying evidence from the geological record. This is why many of Darwin's disagreements with critics or even with allies often hinge on chronology.

On the Affinities of Extinct Species to each other, and to Living Forms. Darwin looked at how extinct species could have potentially served as bridges between currently existing species. One particularly surprising case was the possible connection between modern birds and reptiles. Darwin found truth in the common belief that more ancient forms were more likely to have played an intermediate role in connecting modern forms.

Darwin has previously touched on the idea that intermediate forms were more likely to go extinct. Here, he extends the idea to note how this would specifically apply to modern species and how the links between different modern species (such as an intermediate species between birds and reptiles) may have gone extinct a long time ago.

Darwin observed that the animals alive during any one period in earth's history will, on the whole, seem to be intermediate between the animals in the previous era and the animals in the succeeding one, although he allowed that in some genera, there were exceptions to the rule. As a result, fossils from consecutive formations in the same era were more similar to each other than fossils from more remotely separated formations.

The previous section looked at similarities moving horizontally along a hypothetical tree of life diagram. With this passage, Darwin extends the idea to apply similar principles to vertical relationships on the tree of life (i.e., relationships between current species, future species, and ancestor species).

On the State of Development of Ancient compared with Living Forms. Darwin hypothesized that if the ancient inhabitants of the world were pitted against its current inhabitants, the latter would survive because they are better adapted to earth as it currently exists. He admitted that such a conclusion was difficult to prove, but explained how he arrived at it. Despite its flaws and gaps, the fossil record does seem to show that modern lifeforms have become more organized on the whole than their ancient counterparts.

Darwin believes that natural selection results in organisms that are better adapted to their environment, and he believes that the environment of earth has changed over time. Therefore, he puts these two facts together to conclude that modern species are better adapted to the current environment than ancient species would have been.

On the Succession of the same Types within the same Areas, during the later Tertiary periods. Darwin explained why, for example, terrestrial mammals like marsupials seemed to be endemic to areas like Australia. He explained that there was historical evidence of marsupials in other places like Europe, but that over time, the inhabitants of specific regions of the world tended to stay in their regions and pass on their unique characteristics to their descendants in the region.

Though Australia is a continent, it is also geographically isolated, which is why its species are often different from those found in the rest of the world. Notably, however, this isolation isn't total, and there is some evidence of migration between Australia and the rest of the world. This demonstrates how widely animals migrated over time while also showing how local geography shapes natural selection.

Summary of the preceding and present Chapters. Darwin conceded that anyone who rejects the idea of an imperfect geological record might reject his theories, but he argued that available evidence pointed clearly to an imperfect record and that what did survive from this record generally lent additional support to his theories.

The imperfect geological record remains both a hindrance to Darwin's argument (because it limits the amount of evidence he has to work with) and an advantage (because it allows for a wide range of possibilities in the past that have not been preserved).

CHAPTER 12

Darwin suggested that the way organisms are spread across the planet couldn't be fully explained simply by looking at climate or other physical conditions. He believed that the so-called Old World and New World were both vast enough to encompass just about every imaginable climate, but that in spite of this, they had unique organisms living in them. One of the key factors behind these differences was obstacles to migration.

The topic of migration was important for previous chapters, but in this one, Darwin explores it in even greater detail. Darwin's theory rests on the idea that species migrate widely (especially over long periods of time), but that there could also be serious obstacles to migration that limited it.

Single Centres of supposed Creation. The naturalists of Darwin's time often wondered whether species originated at one or many points on the earth's surface. Though Darwin admitted it was astounding to consider how a species could originate in one area, then migrate so widely, he ultimately believed that this was the case.

Darwin's theory rests on the idea that species migrated widely in the past and that that is why there are similarities between creatures in very different parts of the world (as shown in the fossil record and in surviving current species). The alternative (that the same species could have independently arisen in multiple locations) puts less emphasis on migration but involves such an improbable coincidence (Darwin calls it a "miracle") that it would not happen through natural selection, even over millions of years, let alone frequently.

Furthermore, Darwin argued that the differences in land mammals in Europe versus the United States suggested clearly that the same species doesn't originate in two or more points, since these differences seem to be due to the fact that land mammals can't migrate across oceans. If species could originate in more than one place, there would be more uniformity around the world.

While Darwin believes that animals migrated widely in the past, it is also crucial to this theory that there were barriers to migration. It is the contrast between free migration and barriers to migration that led to the current diversity of life on earth.

Means of Dispersal. Darwin summarized the findings of Lyell and other writers. Changes in climate were a major force in causing organisms to migrate. Raising and lowering of the sea level (which sometimes either connected or severed connections between land masses) also influenced migration.

Perhaps the most important barrier to migration is water. In the past, sea levels were different, and this means that migration could occur in some areas where it can't now, and vice versa.

Darwin also described what he called "accidental means" of migration, specifically for plants. Experiments showed that some seeds could survive long periods in saltwater, perhaps even long enough to cross an ocean. Birds, insects, driftwood, or even icebergs could have also carried seeds across landmasses. Nevertheless, the barriers were still significant enough to ensure that plants from vastly distant continents, like North America and Europe, would mostly remain distinct.

Plants can't migrate in quite the same way as animals, but in this section, Darwin shows that in fact there are some unexpected ways that plants could have spread widely. Though each of the dispersal methods Darwin describes here may have been individually unlikely, together, over long periods of time, they help explain similarities between plants in very different parts of the world.

Dispersal during the Glacial Period. Many naturalists in Darwin's time and before marveled at how species on mountain-tops, separated by hundreds of miles, could have so many similarities. Such similarities could be explained by the movements of glaciers, which used to provide a bridge between the climates of different mountaintops before they moved and the climate got warmer.

Even in Darwin's time, geologists understood how glaciers moved, based on the geological features they left behind in the land. Darwin suggests that the movement of these massive bodies of ice would have affected migration, even providing a way for species to easily travel from one mountaintop to another (until the glacier moved).

Alternate Glacial Periods in the North and South. Europe in Darwin's time showed distinct evidence of a glacial period in the distant past. But while the phenomenon was most studied in Europe, it appeared to affect the whole planet. Animal and particularly plant distributions in South America show clear signs of there having been a glacial period at some point in the past.

Darwin explains that because the climate is different in the Northern and Southern Hemispheres, glacial periods and other climate change would have occurred at different times. Though it is not always possible to fully reconstruct the past, the species the survive today often provide indirect evidence of how migration likely occurred in the past.

It seems, however, that the Southern Hemisphere and Northern Hemisphere went through glacial periods at different times. One of the strangest signs of this that the naturalists in Darwin's day observed was how many more species seem to have migrated from the north to the south instead of vice versa, which seems to provide evidence of alternating glacial periods. While not all the mysteries of organism dispersion have been resolved, it is still possible to deduce a lot from the evidence that does exist.

A hallmark of Darwin's thinking (and of the scientific method in general) is that he tries to adapt his theories to fit the evidence instead of vice versa. In this case, he and other naturalists were presented with the surprising finding that species seem to have migrated more from north to south instead of vice versa. Rather than dismissing this finding, Darwin attempts to account for it, relying in part on available geological evidence.

CHAPTER 13

Fresh-water Productions. Though the world's freshwater habitats (lakes and rivers) seem to be well separated from each other, they have a surprising similarity in species. In one case, a freshwater species from New Zealand was found in mainland South America, yet it's also possible for the first populations in adjacent streams to differ.

Darwin notes why freshwater habitats may seem difficult to explain under natural selection. It might seem impossible, for example, that fish could migrate from one landlocked lake to another different one. As Darwin shows, however, conditions in the past—and particularly freshwater habitats—were not static.

Accidental transportation (such as floods and whirlwinds) likely played some role in dispersing freshwater fish, and so too have changes in the flow of rivers, as some diverge over time or run together. Some mollusks have been observed to cling to a duck's feet and are transported between freshwater habitats that way, and this seems to have been the most common way for many freshwater plants and small animals to be dispersed.

Darwin details some of the ways that seemingly isolated freshwater sources could have allowed for migration between them. On the other hand, his theories also help explain how nearby freshwater environments that seem similar can have very different populations due to a past divergence.

On the Inhabitants of Oceanic Islands. Fewer species inhabit oceanic islands than larger continental landmasses, yet they are more likely to contain endemic species that are unique to the area. Some islands are unique for their lack of certain species, like how the **Galapagos** Islands lack reptiles.

Darwin moves on to the topic of oceanic islands. After his extensive studies in the Galapagos Islands, this is a topic that Darwin understands well. Because of their isolation, islands often represent an extreme example of how natural selection develops when there are barriers to migration.

Absence of Batrachians and Terrestrial mammals on Oceanic Islands. One naturalist noted that "Batrachians" (frogs, toads, and newts) were never found on islands. Darwin found this mostly true, with a handful of exceptions, although most of these exceptions are on islands closer to land and not strictly oceanic islands.

Per the scientific method, Darwin considers the available evidence before putting forward a hypothesis. In this case, Darwin considers another naturalist's claims about certain amphibians being absent from islands. Darwin finds that the rule is broadly true while also having exceptions—and he considers both of these factors as he builds toward an explanation.

Terrestrial mammals, too, seemed to be conspicuously absent from oceanic islands (though in some cases they were domesticated by indigenous inhabitants). Again, the handful of possible exceptions to the rule are from islands closer to land. Non-terrestrial mammals, like bats, are also found on many oceanic islands.

Darwin explores how there are broad rules about what sort of life is found on islands, but that these rules also tend to have important exceptions. Both rules and exceptions are important when forming a comprehensive scientific theory, as Darwin is attempting to do.

Some naturalists also noted that the depth of sea between an island and another island or the nearest continent impacts the similarity between species. While Darwin didn't have time to investigate the matter fully, in his experience, he found that shallower seas between islands resulted in more similarity in species. Darwin admitted it was hard to explain the species composition of some of the most remote islands, but he noted that some small species could have been carried between islands on the feet of flying birds, connecting islands to a greater extent than it would first seem.

As he has in the past, Darwin expresses humility and is careful not to extend his argument too far into matters he doesn't understand. Nevertheless, these expressions of humility are often followed by a renewed emphasis on what Darwin can conclude from the available evidence. Here, Darwin's argument about how seemingly remote islands could be connected is a logical extension of his earlier argument about how freshwater environments could be connected.

On the Relations of the Inhabitants of Islands to those of the nearest Mainland. Darwin found it striking how inhabitants of islands near mainlands often resembled the inhabitants of the mainland while also being quite different. He drew in particular on his experience observing birds in the **Galapagos**. He concluded that these endemic populations on islands must be related to populations on the nearest continent (or perhaps just a large island).

The birds on the Galapagos are closely associated with Darwin and often credited with helping him reach his epiphany about natural selection in the first place. Islands and other places with endemic populations provide a particularly good environment in which to study natural selection because of the barriers to migration. Darwin learned a lot by comparing endemic species to other species that were dispersed more widely.

What surprised Darwin in the **Galapagos** and elsewhere was that new species formed on one island did not spread quickly to others. He did find, however, that "lower" organisms (i.e., ones that were generally smaller and less complex) ranged more widely than "higher" ones. Ultimately, he found it unlikely that species were independently created on each island, believing instead that most islands were at some point colonized by a population from a larger landmass, where the isolated population on the island subsequently developed new adaptations.

Elsewhere in the book, Darwin notes the surprising variety of life he found in the Galapagos. He took this as evidence that there was not much migration happening between the islands and that species had adapted to their own specific environment. It would be tempting to draw the conclusion that unique island species originated on their home island, but Darwin noticed enough similarities between island and mainland life to conclude that most island life probably migrated from a larger landmass at one point.

Summary of the last and present Chapters. Darwin summarized the effects that climate and geography had on the development of species. He emphasized the idea that in most cases, similar species descended from a single original source and were not independently created at different locations.

The idea that species developed independently in multiple places around the world makes some intuitive sense and may seem to fit with the fossil record. Nevertheless, Darwin's theories about migration are an even better fit with the evidence and provide a more comprehensive explanation of both the diversity of life as well as similarities in life around the world.

CHAPTER 14

Classification. Since the beginning of history, humans have classified organisms based on their similarities and differences. Darwin observed that the process wasn't simple—you couldn't simply group all land animals in one category and water animals in another, since even members of the same subgroup often have very different habits.

Darwin has a complicated relationship with classification. On the one hand, he frequently points out the limits of current classification systems, particularly when it comes to distinguishing between a species and a variety. Nevertheless, classification systems also provide a way to order observations, and ultimately Darwin believes in refining classification systems rather than throwing them out.

In ancient times, many naturalists believed that certain parts and characteristics of an organism determined where and how it lived, and so organisms could be classified based on specific parts of their structure. Darwin, however, believed this idea was totally false. The external similarity of a whale to a fish, for example, is not very useful for classification purposes.

Before getting to his modern ideas about classification, Darwin explores how classification worked in the past. By looking at how classification developed, he explores the logic behind these classifications. Understanding this logic (including what it got right and what it got wrong) will be important later when Darwin proposes his own ideas.

Characteristics of organisms are not totally useless for classification, however, and both important and unimportant characteristics played a role in classification during Darwin's time. The seeming importance of a characteristic doesn't relate to its importance for classification, and characteristics in the embryo can be just as important as characteristics in a full-grown adult.

While Darwin criticizes classification systems in the past, he also tries to draw a bridge between those old systems and the present. In this way, he downplays the potentially disruptive nature of his own ideas, suggesting that his beliefs are simply a logical refinement of what eminent thinkers in the past believed.

Darwin described classification in his time as based on "chains of affinities." While, for example, it might be relatively easy to define characteristics common to birds, crustaceans provide a more complicated case. Geography also played a role in classification, though in Darwin's view, it was sometimes applied arbitrarily.

Darwin looks at the many difficulties inherent in constructing an accurate classification system. While he criticizes some aspects of contemporary classification, he acknowledges that creating a comprehensive system to classify the full diversity of life is a very difficult task.

Darwin believed that any logical system of classification should be based on genealogy, but he allowed that in such a system, the amount of difference between different branches of the classification tree might seem to vary wildly. He likened it to the classification of languages: how some ancient languages might have been preserved in more or less the same form, while others changed extensively due to periods of spreading or isolation by the language's speakers. Regardless of the degree of differences, it still made sense to classify and group languages based on how they descended.

Darwin proposes a classification system that is similar to the tree of life diagram that he described elsewhere (particularly in Chapter IV). His focus on genealogy gives evolution and natural selection a central role in the classification process. Darwin also expands on an idea he introduced earlier: how some species descend over time with minimal changes from their ancestors. For example, earlier, Darwin mentions his belief that modern rock-pigeons are similar to an ancient progenitor, while other pigeon varieties show a little more divergence. While change is inevitable under natural selection, the rate and extent of the change is not inevitable.

Darwin argued that all naturalists used descent and genealogy to some extent when classifying species, because some species have males and females with very different external forms or larvae that didn't resemble adults, but naturalists nevertheless classified them together. Since species in nature don't come with written pedigrees, Darwin argued that the best way to determine genealogy was to focus on traits that were least likely to be modified by an organism's condition of life (perhaps the angle of a jaw or the way an insect's wing folds).

Darwin knows that his statements in the previous section about basing classification on genealogy could appear controversial, so in this section, he shows how it resembles something familiar. Males and females of some species look very different—a classification system based solely on appearance or attributes would have to classify the males and females as something separate. The advantage of Darwin's genealogical approach is that it easily factors in differences between males and females (since all individuals in a species, regardless of sex, would have a common genealogy).

Analogical Resemblances. Darwin drew a distinction between what he called "real affinities" and "analogical or adaptive affinities," the latter of which may appear to suggest a relationship between organisms but in fact are just the result of natural selection working in similar ways. Though analogical adaptations may play an important role in an organism's survival, they are mostly useless for classification.

The distinction Darwin makes here is similar to the distinction he made earlier about how fish and whales look alike but should be classified very differently. To use Darwin's language, "real affinities" have a genealogical basis, whereas "analogical or adaptive affinities" don't suggest a genealogical relationship and simply show how natural selection can arrive at similar results through different paths.

On the Nature of the Affinities connecting Organic Beings. Descendants of a dominant species are likely to spread widely because they are well-adapted to do so. This is why, at the higher levels of classification like family, order, and class, the organisms native to Australia are not substantially different from the ones from Europe.

Darwin begins describing the implications of a genealogical classification system. For example, even species from very different parts of the world are likely to be connected at the high levels of classification. This is a result of migration and of divergence.

The enormous differences between species that share a similar lineage can often be explained by extinction, where over time intermediate forms died out, leaving only the most extreme versions. This is all consistent with natural selection, which makes it more or less inevitable that the descendants of any parent species will eventually diverge.

Darwin knows it's strange that two modern species that are supposedly similar from a genealogical perspective might look very different on the outside. His explanation—that, in fact, intermediate species probably existed at some point but have died out—fits well with the ideas about extinction in natural selection that he advanced earlier in the book.

Morphology. Organisms from the same class often have a "unity of type" where they share parts and organs that serve a similar purpose. Naturalists found it odd and hard to explain that, for example, the bones of a bat resemble other mammals, but the wing bones are used for such a different purpose. Similarly, crustaceans with the most complex multi-part mouths tended to have fewer legs and vice versa.

As is often the case, Darwin describes a complex problem and lays out the issues before proposing a solution. In this example, the problem is that genealogically similar animals can have very different features. For example, most mammals don't have wings like a bat, even though bats and many other mammals share similar bone structures.

As Darwin observed, natural selection once again provided an explanation for these strange morphology cases. He noted that the more often a part in an organism is repeated, the more opportunity there is for variability, and so this is why features like vertebrae are particularly responsive to adaptation. Over time, these changes can become great, with a skull, for example, being formed from fused vertebrae.

Darwin notes that the vertebrae of some creatures have bones that seem to correspond with the multiple skull bones of others. He reasons that, due to sheer probability, small distinct parts like vertebrae would be more likely to be affected by natural selection than other body parts, since there is more chance for variability and for gradual improvement.

Development and Embryology. Darwin considered development in embryology to be one of the most important subjects in all of natural history. He also believed that metamorphoses in insects provided a particularly good way to observe how development worked.

Embryology, with its close connection to reproduction, is central to Darwin's arguments about natural selection. It provides a unique way to study characteristics of an organism that may not be reflected in full-grown adult specimens.

Some animals resemble each other as embryos, but their parts differentiate and serve vastly different functions in the adult animal. This is in part because any embryos have to act in similar ways to ensure their own survival. As embryos develop, the organisms tend to become more complex in their organization.

Darwin notes that even organisms that appear very different as adults might have similarities while still in embryonic form. This suggests similarities and supports his idea that organisms that have different characteristics as adults might nevertheless have strong genealogical similarities.

At whatever age a variation appears in an adult parent organism, it will tend to reappear in offspring at the same age. For example, if mature cattle have a variation in their horns, the offspring are most likely to develop the same variation around the same age (although this is not a universal rule and has exceptions). This is part of the reason why embryos can look more similar than adults—because the organism has not developed enough for the adult variations to manifest.

Darwin has explored how natural selection has worked over long time periods, but here he explores how the results of natural selection are reflected over the course of an individual organism's lifespan. He notes that organisms grow and change over the course of their lives, and he makes the natural inference that, in most situations, offspring will tend to develop in ways similar to their parents.

Darwin believed it likely that for many species, embryonic and larval stages of animals helped show what a possible progenitor species may have looked like. For example, crustaceans that look vastly different as adults look surprisingly similar as larvae (called the "nauplius"), suggesting what a possible progenitor species for crustaceans may have been like.

Ultimately, Darwin's genealogical theory of classification reflects his belief that existing forms of life are more closely related to each other than many of his peers realized. He proves the worth of a genealogy-based classification system by showing how it can account for both the similarities and the big differences among crustaceans.

Rudimentary, Atrophied, and Aborted Organs. Darwin observed that many creatures had organs that just seemed to be useless—in fact, almost all higher animals had something of the sort. Snakes, for example, have a useless lung lobe, and birds have a "bastard-wing" digit that doesn't affect flight in any way.

The issue of rudimentary features is one Darwin has explored before, but he brings it up again here because it is also relevant to the issue of classification.

Some organs used to serve two purposes but become useless for one of them. For example, some fish have a swim bladder that doesn't help with buoyancy as it might be expected to, but which does still play a role with respiration.

Though Darwin believes that natural selection follows certain laws, he also believes those laws can lead to surprising conclusions, including body parts that adapt to new purposes different from the purposes they originally served.

Darwin clarified that just because an organ was not well developed did not make it useless or "rudimentary." It might in fact be "nascent," that is, on the way to developing into something more useful. Such a distinction wasn't always easy to make. For example, Darwin considered the wings of an ostrich to be rudimentary, since they provide little practical advantage to the bird. Nevertheless, he considered the wings of a penguin to be nascent, because although they no longer enable flight, they serve an important role as fins.

Darwin's use of the term "nascent" (which refers to something about to be born, either literally or metaphorically) reflects his belief that modern nature is not an endpoint and that natural selection remains an ongoing process. This was controversial for religious reasons (since many took it as doctrine that nature was already in a state of perfection), but it is an unavoidable takeaway from Darwin's theories, since if natural selection happened in the past, there is no reason why it would stop in the present.

Some rudimentary organs, like teeth in whales, appear in the embryo before completely disappearing. In adults, rudimentary organs often retain a sort of embryonic quality. Though Darwin admitted that it might seem shocking that a process like natural selection could result in such rudimentary or atrophied organs, he did not find any contradiction. He found it logical that disuse and successive variations over time would lead to a natural selection process where some formerly useful organs became rudimentary.

The strange development of embryos (such as teeth that appear in embryonic whales, then disappear) presents a challenge to Darwin, but embryos also provide an opportunity—a chance for him to show that genealogical classification has real applications. Though rudimentary organs may seem contrary to natural selection's continual process of adaptation, Darwin has already explained this issue (through the principle of economy of growth and through the idea that some seemingly useless organs are simply "nascent").

There was no reason, however, why organs rendered useless through natural selection could not eventually be adapted for some new purpose. After an organ has totally ceased to have a function, disuse alone is not enough to explain how it would be eliminated under natural selection. On the other hand, the principle of economy of growth, which Darwin explored in an earlier chapter (Chapter V), does provide a possible explanation for how an organ could totally disappear.

Again, Darwin emphasizes how natural selection is an ongoing process and how a feature that seems "useless" now may once have served a purpose, or may one day serve a new one.

Summary. Darwin explained again how his theories of natural selection aligned with the different groups and classifications of organisms. He believed that classification only made sense when based on genealogy and that evidence from many sources, including embryos and larvae, showed that many species that appear different as adults can nevertheless be grouped together based on the fact that they descended from the same common ancestor.

Though Darwin criticizes existing classification systems, he ultimately believes that they get some things correct and that his theory of natural selection helps explain classification better than alternative explanations. His call to focus on genealogical classification is not a call to throw out the old system but simply a call to refine and expand on it.

CHAPTER 15

Darwin summarized his book as "one long argument," and concluded that as a result, it might be helpful to the reader for him to summarize some of the major points.

Very little of what Darwin mentions in the final chapter is new information. Instead, Darwin uses it to summarize his most important arguments and distill his book down to the core points. This reflects his intention to write at least in part for a popular audience rather than exclusively for an audience of scientific specialists (who might not need as much summarizing).

Darwin repeated what he believed to be some of the most reasonable objections to his arguments, in particular the idea that extremely complex organs like the human **eye** give the appearance of having been designed and created all at once. He nevertheless maintained that in fact, it was very possible for natural selection to arrive at complex organs like an eye, and that all of these complex organs can be traced to a series of gradual, incremental improvements.

Darwin spends multiple chapters responding to real and anticipated criticisms of his work, so it is fitting that he takes a moment to summarize some of the most significant. He returns to the issue of the eye, which seems to some to be so complex and organized that it couldn't have arisen under natural selection. For Darwin, however, the eye is just the opposite: a sign of how even the most complex organs can be developed and selected for incrementally.

Darwin also summarized his arguments about the sterility of crosses between species and how the rules governing fertility in these cases were complex and not as universal as some other naturalists of his era claimed.

Reproduction is a central part of Darwin's theories, and the sterility of hybrids is an interesting aspect of reproduction that helps illuminate how natural selection works (and where it can't work due to infertility).

Darwin moved on to the subject of geographical distribution and repeated his belief that many species descended from a few ancestor species that migrated around the world, and in isolated geographic locations, the process of adaptation and natural selection often led to endemic species.

Another big part of Darwin's argument is the role that migration plays (and as a result, the role that barriers to migration play in creating new divergences). These ideas reflect the influence of his important Galapagos Islands voyage on his way of thinking.

On the topic of intermediate forms, Darwin once again covered the imperfections of the geological record, why intermediate forms are more likely to go extinct, and how even with these issues, it is still possible to reconstruct what role intermediate forms played in natural selection. He went on to explain the causes behind the imperfections of the geological record in greater detail, and also why the fossil deposits that do remain show development consistent with natural selection.

Here, Darwin recounts the influence that Charles Lyell and other geologists have played on his thinking. Geology suggests that events on earth happen over a long time frame, but the imperfections of the geological record suggest that the past is not perfectly preserved and that often recreating the past involves making inferences from the limited (but important) evidence that does survive.

Darwin then changed the focus to domestication and what it can and can't demonstrate about natural selection. Darwin reminded readers that humans don't cause variability in domestic animals and plants, they simply create conditions of life that cause certain characteristics to be passed down. Similar principles occur in nature, just without the direction of humans. Struggles for mates and changes in climate are some of the factors that can lead organisms with certain variations to survive.

Studying domestication helped Darwin understand important principles about reproduction because it provides a controlled environment where humans watch the results of each crossing of parents to create new offspring. Though domestication does not perfectly line up with nature, nature is also harder to observe. Additionally, by comparing natural selection to the better-understood topic of domestic breeding, Darwin helps make his ideas more familiar and approachable.

Darwin repeated that species were simply "strongly marked and permanent" types of varieties. In some ways, the distinction was arbitrary, although it could also convey important information about genealogy and fertility. New varieties and species with improved adaptations will eventually supplant less well-adapted species and cause them to become extinct. As always, natural selection works in small, successive steps, never in great leaps, even when the end results do seem to lead to a large divergence.

Though Darwin believes classification is important, he also believes it can be arbitrary, specifically when it comes to distinctions between varieties and species. Darwin believes that through natural selection, varieties often actually become new species, and so for this reason, it is difficult to draw a clear boundary between varieties and species that will hold true in all cases.

Natural selection plays a role in everything from physical attributes to instincts to beauty. New species and varieties are not created independently but arise through "descent with modification," diffusing and diverging out from common ancestors. Migration also played an important role in this process and suggests that the same species has never independently arisen in two separate areas.

In this section, Darwin emphasizes the comprehensive nature of natural selection, how it can affect not only body parts but even instincts, too. Though there is a wide variety of life on earth, Darwin believes that it arose through migration and divergence rather than through separate acts of creation.

All current and past organisms can be categorized in classes, a large classification group. Within these classes, some organisms may seem similar on the surface, while others may seem quite different, but ultimately, they all descend from a common ancestor.

Darwin reiterates how all life shares broad similarities, particularly at the highest levels of classification, but also how genealogy can be used to draw more specific distinctions.

Corresponding parts, like the similarities between human hands, bat wings, and horse legs, provide evidence of how natural selection could have worked in successive variations, showing that great leaps in adaptation wouldn't have been necessary. Sometimes disuse of a part or organ causes it to become useless after many generations of natural selection.

Darwin emphasizes the idea that natural selection happens as a series of gradual, successive steps and how, given enough time, these little steps are enough to account for big changes (for example, the difference between a bat's wing and a horse's leg).

Darwin recalled how after earlier editions of *The Origin of Species*, critics misrepresented his position, saying that he credited natural selection with bringing about all modification of species. While he remained convinced of its significance, he allowed that other factors could also play a smaller role in modifying species, even in the first edition.

Darwin revised The Origin of Species *over the course of his life, in some cases to respond to comments on the previous edition. Most (though not all) versions of the book published today incorporate revisions that Darwin made later in his life, well after the book's initial 1859 publication.*

Darwin wrote that he couldn't see why his book would offend religious people, and he noted that religious critics once attacked other scientific principles that were soon commonly accepted, like gravity.

Darwin is potentially understating the issue here—his arguments in defense of his theories elsewhere in the book suggest he was in fact aware of the reasons why certain religious leaders might disagree with him. Nevertheless, Darwin chooses to present himself as humble and agreeable rather than emphasizing the potentially controversial aspects of his claims.

Darwin speculated that the reason why so many naturalists believed in the immutability of species was that it was hard to imagine the individual steps. He compared his work to Lyell's, noting that Lyell's theories about how dramatic geological features like cliffs and valleys formed were also met with resistance, but that people were more likely to believe them once they understood the intermediate steps.

Though not exclusively a religious idea, the concept of immutability of species was often connected to religious beliefs, particularly the belief that God created nature and it is already in its perfect form. Darwin allows that the imperfections of the geological record might at first seem to support immutability, but he argues that a deeper analysis reveals plenty of evidence of intermediate steps, which would suggest that species are in fact mutable (i.e., able to adapt, evolve, and diverge into new species).

Darwin considered the question of how far he would extend his ideas about natural selection. He acknowledged that his arguments carried more force in certain situations than others before ultimately stating his belief that all animals and plants each came from no more than four or five ancient progenitor species. He considered the idea that all animals and plants ultimately descended from a single origin, and considered the idea possible but not necessarily inevitable.

Though Darwin's The Origin of Species *is famous in popular culture for popularizing the idea that humans descended from ape-like ancestors, in fact, Darwin is very careful not to state that idea too directly in the book (even though he did believe it and wrote about it in more detail in future books). This section is probably the closest Darwin comes to mentioning human evolution —if all species descend from a few progenitors, or even just one, then surely humans are no exception.*

Darwin looked ahead to how his views might spark a revolution in natural history, particularly when it came to classification. While he believed it would involve leaving behind some old ideas about species, it would also lead to greater general interest in natural history as a discipline. He also predicted his work could have an impact on research in other fields, such as psychology.

Despite his seeming humility elsewhere in the book, Darwin is aware of the potentially revolutionary nature of his ideas, and he takes a moment here at the end to present this revolution as something to celebrate and embrace rather than something to fear.

Darwin concluded by arguing that in spite of the fact that many prominent authors believed that species arose independently, Darwin believed that natural selection seemed to better reflect the will of a Creator and to give creations more nobility. He believed that under natural selection, all living things would continue to progress toward perfection. Darwin marveled at the grandeur and complexity of nature and how "endless forms most beautiful and most wonderful have been, and are being evolved."

Darwin's religious views (or possible lack of them) are frequently debated and may have changed over the course of his life. In The Origin of Species, *however, Darwin seems to be less interested in advocating for a specific religious position and more interested in presenting a coherent scientific argument. He knows that a good argument often must not only be logical but also be appealing in other ways, and that is likely why he chooses to end with a sentence that emphasizes the beauty of natural selection and its continuity with religious tradition, rather than emphasizing something more pessimistic.*

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