The Beak of the Finch

INTRODUCTION

BRIEF BIOGRAPHY OF JONATHAN WEINER

Jonathan Weiner was born into a Jewish family in New York City in the 1950s. After graduating from Harvard University in 1976, he went on to teach writing at Princeton University, Arizona State University, and Rockefeller University before being named the Maxwell M. Geffen Professor of Medical and Scientific Journalism at the Columbia University Graduate School of Journalism. Weiner received the 1995 Pulitzer Prize for General Non-Fiction for *The Beak of the Finch*, which is his best-known book. He is also the author of *Time, Love, Memory*, a book about the American physicist Seymour Benzer, and *Long for This World: The Strange Science of Immortality*, a scientific take on the search for the Fountain of Youth. Weiner lives in New York City with his wife Deborah Heiligman, a children's writer who has also published books on the life and times of Charles Darwin and his wife, Emma.

HISTORICAL CONTEXT

The Beak of the Finch was researched and written in the early 1990s, and it focuses primarily on the research conducted by Peter and Rosemary Grant in the Galápagos Islands throughout the late 1970s and early 1980s. The early 1990s were a period of time during which science was advancing rapidly, with new forms of DNA sequencing technology available all the time. Thus, the scientists working in the early 1990s were able to build upon the data that scientists like the Grants had compiled in earlier years and learn new things from it. Rather than just observing finches and measuring their beaks, for instance, researchers could extract DNA samples from the finches' blood to learn new things about their ancestries and their evolutionary patterns. The 1990s were also a fraught time as the AIDS epidemic was spreading all over the world. Seeing new and deadly viruses in action spurred many researchers to consider how unseen things like diseases were evolving, spreading, and adapting.

RELATED LITERARY WORKS

The Beak of the Finch is a unique book in that it takes inspiration from both modern research in the field of evolutionary biology, as well as the foundational texts upon which the field was built. The most seminal text in the field is, arguably, Charles Darwin's *On the Origin of Species*, which was published in November of 1859. Darwin himself built on the research of scientists like the geologist Charles Lyell (*Principles of Geology*, 1833) and the botanist Carolus Linnaeus (*Systema Naturae*, 1735). Darwin's work inspired the writings of scientists like David Lack (*Darwin's Finches*, 1947) and Peter and Rosemary Grant (*40 Years of Evolution: Darwin's Finches on Daphne Major Island*, 2014). Biographers have long studied Darwin's diaries in order to better understand the man whose controversial views forever changed the course of human understanding. Adrian Desmond's *Darwin: the Life of a Tormented Evolutionist* was published in 1994, around the same time as *The Beak of the Finch*, and it sought to contextualize the era in which Darwin lived, worked, and wrote, as well the pressures he faced as he faced by coming forward with controversial theories that flew in the face of Creationism.

KEY FACTS

- **Full Title:** *The Beak of the Finch: A Story of Evolution in Our Time*
- **When Written:** Early 1990s
- **When Published:** 1994
- **Literary Period:** Contemporary
- **Genre:** Nonfiction, Science Writing
- **Setting:** Princeton University, The Galápagos Islands
- **Climax:** The El Niño of 1982 arrives in the Galápagos islands, bringing torrential rain and, with it, the stark and undeniable reversal of a selection event that had initially pressurized the island's finches to develop larger beaks in the preceding dry season.
- **Antagonist:** There is no traditional antagonist in *The Beak of the Finch*, though humanity's influence on the Earth's species' evolutionary patterns could be seen as an antagonistic force.
- **Point of View:** Third Person

EXTRA CREDIT

Surviving and Thriving. In the 1980s, the Grants discovered a new kind of finch on the island of Daphne Major—a hybrid finch that they nicknamed the "Big Bird." While many selection events can produce new hybrids, these hybridized animals often die out. But the "Big Bird" lineage—the Grants are still hesitant to call the lineage an entirely new species—is thriving on Daphne Major, and there are roughly 30 of them still on the island.

PLOT SUMMARY

Author Jonathan Weiner's *The Beak of the Finch* explores the work of Princeton scientists Peter and Rosemary Grant, a married couple originally from England who have devoted their lives to studying Darwin's finches. The finches—originally discovered by their namesake, Charles Darwin, the English naturalist who pioneered groundbreaking theories about natural selection and evolution—live on the island archipelago of the Galápagos, off the coast of Ecuador in the Pacific Ocean. As Weiner spends time with the Grants in their lab at Princeton and in the field on the Galápagos islands of Daphne Major and Genovesa, he provides a history of evolutionary theory as well insight into what modern Darwinists—many of them former or current students of the Grants—are discovering about how our world is changing.

In the first part of the book, Weiner explores how naturalists and scientists have learned from the finches of the Galápagos by closely observing how the isolated birds have grown and evolved over the years. Intense weather events, changes in food sources, and complex mating process are all different forms of selective pressures that have the power to change how a species looks. For instance, in a period of drought on Daphne Major in the late 1970s, bigger birds with bigger **beaks** that could wrestle open the tough, dry seed pods that were the only source of food on the island did best and survived—so they passed on their bigger beaks to their offspring, and there were many more big-beaked finches on the island. But a few years later, when a particularly powerful El Niño brought a torrential flood to the island, the big-beaked birds struggled to adapt to their new primary food source: tiny seeds that fell to the ground from the many new plants that were thriving in the wet environment. Soon, the big-beaked birds began to die off, and birds with smaller beaks began to thrive. This process shows that evolution is constantly taking place—and that it can be observed, in species like the finches, from month to month and year to year.

In the second part of the book, Weiner delves into the specifics of how variations within species come to be. There are "invisible coasts," he argues, between different species—and one species of finch can recognize that another species is not its own. These different species won't mate with one another ordinarily—but again, drastic shifts in population, often driven by weather events or other climate-changing phenomena, can mean that species will interbreed or "hybridize." Species can, in this way, fuse together—but then, as that new hybridized species begins to specialize, it drifts apart from the others once again. This constant war between fission and fusion often results in new species with new specific skills or evolutionary "niches."

In the third part of the book, Weiner examines how modern-day science—and humanity's changing relationship to nature—can influence natural selection and evolution. By offering intimate looks into the research projects of some of the Grants' associates and former students, Weiner shows that animals of all kinds can be manipulated and changed in laboratory settings—and perhaps even in the wild, too—through human intervention. This is a massive and dangerous responsibility, Weiner suggests. He offers examples of how certain moths have evolved to camouflage themselves within grimy urban environments to illustrate that humanity needs to understand the delicate balance of the natural world (and do its best to preserve that balance).

Weiner also examines the "resistance movement" taking place within nature as humanity expands its reach. He touches on how antibiotic-resistant bacteria represent evolution in action—as do elephants who have stopped developing tusks in order to avoid ivory poachers, as well as insects who have evolved immunity to pesticides in order to survive humanity's attempts to eradicate them. Weiner concludes his book by examining human evolution and suggesting that humanity might also be in the process of evolving further—and that our animal counterparts, such as chimpanzees and even birds, are evolving new social learning mechanisms that allow them to share information with one another. The ability to share, retain, and pass down knowledge and experience, Weiner suggests, is the most helpful key to a species' ongoing evolution.

CHARACTERS

MAJOR CHARACTERS

Jonathan Weiner – Jonathan Weiner is the author and narrator of *The Beak of the Finch*. A renowned writer whose work primarily focuses on nonfiction and science writing, Weiner talked and traveled with the scientists Peter and Rosemary Grant throughout the early 1990s as they entered their third decade of research on the evolutionary patterns of Darwin's finches on the Galápagos archipelago islands of Daphne Major and Genovesa. Through the Grants' story, Weiner uses *The Beak of the Finch* to explore the history of evolutionary biology, the remarkable patterns of natural selection, sexual selection, stabilizing selection, and evolution the Grants and their students have witnessed over the years, and the potential for the future of the field. Weiner's work highlights both the fragility and the hardiness of all varieties of life on earth. He clearly admires the meticulous, painstaking work that the Grants and their students, mentees, and colleagues have conducted over the years—and yet Weiner is careful to highlight how dangerous any unprecedented human forays into the natural habitats of still-evolving species can truly be. By focusing on the past, present, and future of evolutionary biology, Weiner suggests that there is still much work to be done in the field. He ultimately suggests that new DNA sequencing technology combined with scientists' ever-deepening understandings of how living organisms from bacteria to humans pass on adaptive traits and useful knowledge in order to survive and thrive might yet reveal how humanity is still evolving, even in contemporary times.

Charles Darwin – Charles Darwin was an English naturalist who lived from 1809-1882. He was a geologist and biologist who is renowned in the modern world for his contributions to the science of evolution. He pioneered the theory that the branching pattern of the evolution of species resulted from the process of natural selection, during which adaptive or useful traits are "selected for" and passed down, while traits that become a liability to any given species are "selected against," and not passed down. Darwin's idea that in the struggle for existence, only the fittest survive—and that their survival drives the evolution of subsequent generations—was considered controversial and even heretical, as many prominent thinkers of his era subscribed to Creationism. Darwin himself wrestled with questions of faith throughout his life as he studied variations, adaptations, and events of sexual selection in plants, animals, and even humans. By the 1970s, due to the landmark 1859 publication of Darwin's *On the Origin of Species*, evolution became an accepted theory amongst the majority of the scientific community. Throughout *The Beak of the Finch*, author Jonathan Weiner contrasts what Darwin was able to see and understand within his lifetime against the pioneering research that has been conducted throughout the 20th century—specifically Peter and Rosemary Grant's research. The Grants took Darwin's theory that evolution could be observed on a long enough scale one step further. Through their study of the finches that Darwin himself observed during his journey to the Galápagos in the early 1830s, the Grants proved that natural selection and the changes it created could be observed within the span of years or even months. Darwin's work has left a profound legacy on the modern world, having forever changed the field of evolutionary biology and our more general human understanding of how species evolve.

Peter and Rosemary Grant – Peter and Rosemary Grant are a married pair of evolutionary biologists and professors emeritus at Princeton University. The two are best known for their work studying Darwin's finches on the island of Daphne Major in the Galápagos archipelago off the coast of Ecuador. The Grants began traveling to the Galápagos in 1973, and at the time *The Beak of the Finch* was published, they were still regularly spending the majority of each year there. In the early 1990s, Jonathan Weiner spent time traveling with the Grants, interviewing them in their laboratory at Princeton and accompanying them to the Galápagos to study how they worked. Throughout *The Beak of the Finch*, author Jonathan Weiner portrays Peter and Rosemary as meticulous yet lighthearted researchers who have come to know each one of the finches on Daphne Major on sight alone. The Grants have mentored many notable biologists, scientists, and researchers, including Peter Boag, Dolph Schluter, Jamie Smith, and Trevor Price. The Grants' research has expanded upon Darwin's own—while Darwin believed that evolution was a slow process that could only be observed from a distance, the Grants' yearly work with the finches has illustrated that natural selection can be observed in the wild from month to month and year to year. Dedicated, good-humored, and often eerily in sync with one another, the Grants appear in Weiner's book to be perpetually mesmerized by nature's surprisingly powerful forces. As of the late 2000s, they continue to give talks and interviews about their ongoing research. Both of the Grants are Fellows of the Royal Society, recipients of the Linnean Society of London's Darwin-Wallace Medal, and recipients of the Kyoto Prize, among many other awards and honors.

Peter Boag – Peter Boag is a contemporary of Peter and Rosemary Grant's who conducted research on Darwin's finches on the island of Daphne Major in 1976 and 1977. During this time, the island was experiencing a major drought, which prevented Boag from conducting the experiments he'd originally planned to. But through the drought—and the selective pressures it placed on the finches—Boag and his team witnessed natural selection in action. Most notably, smaller birds died out while larger ones, who could more easily extract rare seeds from tough pods, survived. By the early 1990s, Boag had pivoted to studying the DNA of Darwin's finches, becoming one of the first people on Earth to sequence the finches' DNA.

Dolph Schluter – Dolph Schluter is Peter and Rosemary Grant's former mentee and one of the foremost researchers on Darwinian divergence in the modern era. While working with the Grants, Schluter studied the **beaks of the finches** on the Galápagos island of Pinta. His research helped him develop a model that explained the adaptive "peaks" and "valleys" that species cycle through as natural selection pressures them to evolve. Schluter went onto an independent study of stickleback fishes in British Columbia, pioneering new research on the process of adaptive radiation.

Trevor Price – Trevor Price was a student of Peter Grant's who was stationed on Daphne Major beginning in 1979. During his tenure on the island, Price observed the "comedy of sexual selection" that influenced how the finches mated, passed on their traits, and evolved. Price began to believe that selection on the island had begun to favor smaller birds with smaller beaks, and that an external force like a weather event might be able to tip the scales and begin the selection event in earnest. But Price's watch ended before the heavy rains of 1981 reached the archipelago.

Lisle Gibbs – Lisle Gibbs was a graduate student of Peter Grant's who took up the watch on Daphne Major after Trevor Price left. Price had been waiting for rain to come to the island, because he believed that a significant weather event could begin a major selection event on the island. Price's theory was confirmed when Gibbs and his assistant arrived just in time for the strongest El Niño recorded in the 20th century. The storm reversed the tides of natural selection on the island and began pressuring finches to evolve to become smaller, with narrower **beaks** that would allow them to hunt in the soil for the now-plentiful seeds that new plant growth brought to the island.

Captain FitzRoy – Captain FitzRoy was the captain of the HMS *Beagle* during Charles Darwin's famous voyage to the Galápagos, during which Darwin gathered the specimens that would come to influence his views on natural selection and evolution. Darwin was brought onto the expedition at just 22 as FitzRoy's hired companion—a person who would offer company, conversation, and friendship during the voyage.

David Lack – David Lack was a British ornithologist who traveled to the Galápagos in the 1930s to study Darwin's finches. He eventually concluded that the many species of finch on the island were constantly specializing to get out of one another's niches, reduce competition, and ensure their offspring's survival. His 1947 monograph, *Darwin's Finches*, proved that there was enough difference between the **beaks** of individual finches to confer competitive advantages that would power natural selection—and, eventually, evolution.

Charles Lyell – Charles Lyell was a Scottish geologist whose *Principles of Geology*, published in 1833, presented a theory that the Earth was still changing and evolving. Lyell's views were deemed heretical at the time—but they greatly influenced Charles Darwin, who took Lyell's position a step farther and posited that not only the Earth, but the species that called it home, were in a state of constant flux.

John Endler – John Endler is a naturalist who became well-known in the 1970s for his research with guppies found in the rivers and streams of northeast South America. Through a series of experiments both in the wild and in controlled laboratory settings, Endler was able to deduce that guppies who were threatened by predators would evolve to have drab, dull spots, while those who lived in safer environments evolved to have brighter, shinier spots meant to attract mates. Endler, Jonathan Weiner writes, is to guppies as the Grants are to finches.

MINOR CHARACTERS

Jamie Smith – Jamie Smith is a Canadian biologist and former field assistant of the Grants' who became well-known for his research on the selective behaviors of sparrows living on the island of Mandarte off the coast of British Columbia.

Martin Taylor – Martin Taylor is a researcher in the Grants' laboratory at Princeton. Taylor was, at the time of the writing of *The Beak of the Finch*, studying the DNA of pesticide-resistant moths in the United States of America's cotton belt.

TERMS

Adaptive Radiation – Adaptive radiation is the process by which a group of organisms diversify and specialize into narrow ecological niches in order to prevent competition with similar species, and thus more carefully ensure their own survival. For instance, there are many species of finches on the islands of the Galápagos—but these finches each have their specialties. Cactus finches have special beaks for eating cacti; ground finches have special beaks for opening seed pods; tree finches have special beaks for peeling off tree bark. Because each species has its own niche, or specialty, they're able to survive without competing with each other for food, mates, or other resources.

Creationism – Creationism is the belief that God created the world exactly as it is today. Creationist beliefs run counter to Darwinist beliefs, the latter of which are founded in observable scientific fact rather than in spirituality or religion.

Darwin (Unit of Measurement) – The darwin is a unit of measurement created by the evolutionist J.B.S. Haldane in 1949 to describe the rate of evolution. The darwin is defined as a rate of change of one percent per million years.

Darwinism –Inspired by the work of naturalist **Charles Darwin**, darwinism is the belief that the process of natural selection leads to the evolution of species.

El Niño – *El Niño*, which means "the child" in Spanish, is a weather event defined by patches of unusually warm water in the Pacific Ocean. Those patches spread and create strange winds and weather events all over the world. El Niño, like a child throwing a tantrum, is named for its unpredictable climatological effects on different places around the globe.

Hybridization – Hybridization is the crossing of species. It sometimes takes place in nature, such as when horses and donkeys mate to create mules (male offspring) or hinnies (female offspring), though oftentimes these hybrids are born sterile or struggle to find mates when they are old enough to breed. But advantageous hybridization has been observed in lots of species, such as in fruit flies in Hawaii and more recently in finches in the Galápagos.

Natural Selection – Natural selection is a process in which organisms, such as plants, animals, or bacteria, that are best-suited to their respective environments tend to thrive and pass on their favorable traits to their offspring. Useful traits—such as a specialized beak for prying open the hard shell of a pinecone—are "selected for," or passed down. But traits that represent are a liability—such as an inferior beak that isn't shaped well enough for the task of opening up the pinecone—are "selected against," and are not passed down (often because the organism, unable to keep up with its peers, passes awaydies). As generations of a species go by, more and more positive traits show up while fewer of the negative traits do. Thus, over time, a species changes and evolves to become more fit for its environment.

Sexual Selection – Sexual selection is a form of natural selection that arises through a preference by one sex for certain traits present in the other sex. For instance, a female finch might choose to mate with a male finch whose plumage is darker, indicating he's more mature, than a male finch whose plumage is lighter. So the males who are unable to attract mates might develop or, over time, evolve traits that make them more likely to attract a mate and thus continue their lineage.

Stabilizing Selection – Stabilizing section is a form of natural selection in which extreme traits are selected against. For instance, in a cold snap in New England, sparrows that are either too large or too small might be unable to survive the extreme weather for various reasons., Bbut average-sized sparrows, who don't have any "extreme" traits, might survive better than their counterparts at the opposite ends of the spectrum.

THEMES

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NATURAL SELECTION AND EVOLUTION AS ONGOING PROCESSES

Charles Darwin, one of the most well-known contributors to the field of evolutionary science, noted that the finches on the isolated Galápagos Islands off the coast of Ecuador had observable variations in **beak size** and shape. His investigation into why and how these finches had developed specialized traits led to a theory of evolution immortalized in his 1859 book *On the Origin of Species*. But according to *The Beak of the Finch* author Jonathan Weiner, "[Darwin] vastly underestimated the power of natural selection. Its action is neither rare nor slow. It leads to evolution daily and hourly, all around us, and we can watch." Throughout *The Beak of the Finch*, Weiner argues that while many might conceive of evolution as something that is complete, or so slow as to be invisible, this isn't at all true. In fact, the book argues, natural selection and evolution are still happening all over the world, each and every hour of the day, in observable ways.

The book examines what the processes of natural selection and evolution actually are and how they function in order to debunk the idea that evolution is a process that's already complete. Evolution is not necessarily, as many might think, an extremely slow process that can only be observed over the course of thousands or millions of years. In reality, bacteria, plants, and animals produce offspring with slight variations every day. These variations, in turn, are acted upon by natural selection, which is the "the preservation of one favored race [or trait] in the struggle for life." Individuals in a species with an advantageous trait are more likely to survive and produce offspring with that same (or even more pronounced) trait. As favored or advantageous traits are "selected for" and passed down through generations, disadvantageous traits that pose a liability to a species' survival are "selected against"—and, over millennia, species change. Though people might think of the world around them as fixed or permanent, the natural world (and even the human one) are still constantly evolving. Weiner writes: "We think of the plumage of birds [...] as fixed and permanent, or as constant as anything else in the living world." But in reality, many small processes influence how something like the colors of a bird's feathers or the shape of its beak is under constant pressure to change in order to survive. These things "look solid, but they are as fluid as ripples on the stream." "The Darwinian view of evolution," Weiner continues, "shows that the unrolling scroll is always being written, inscribed as it unrolls." Here, Weiner is trying to impress upon his readers the continuous and spontaneous process of evolution. Evolution isn't something that happens once and stops. As an animal or plant's environment changes, whether due to weather, new species entering the ecosystem, or some other factor, the dying-off of unfit specimens and the survival and procreation of fit ones actively changes, from generation to generation, what a species looks like and how it behaves.

The book illustrates several examples of how natural selection and evolution are still taking place in daily bacteria and animal life all over the earth. Bacteria like *E. coli* develop resistance to antibiotics through evolution. When even just a few bacteria are able to resist a dose of antibiotics, those bacteria then survive to produce offspring with the same resistance. The antibiotics themselves "select for" the traits that will allow bacteria to, over time, gain widespread resistance. Animals like Darwin's finches in the Galápagos Islands are also constantly evolving from generation to generation. Researchers in the Galápagos have traced how weather events have resulted in changes to species within a single generation by pressurizing the process of selection. For instance, a period of drought on the island of Daphne Major produced conditions that made finches with bigger beaks more equipped to survive, as those birds could more easily crack the large, tough seeds that were available to eat in the drought. Birds with smaller beaks died off, while those with larger beaks survived and had offspring, and the overall species of finches shifted toward having larger beaks. The naturalist John Endler showed how quickly evolution can happen in a 1970s experiment with spotted guppies that live in South American rivers. The guppies face a constant evolutionary problem: they must develop camouflage to help them blend in with the rocks at the bottom of the riverbed and hide from predators. But male guppies must also develop bright spots to attract mates. Over a period of five months, Endler bred guppies in test tanks: some tanks with predators, and some without. The guppies with no enemies evolved, in just a few generations, to display gaudier spots in bold colors. In contrast, the guppies with predators in their tanks evolved fewer, smaller spots in more muted colors, because evading predators was a more valuable trait than attracting as many mates as possible.

Evolution is not something that produced the present world and then stopped. Quite the contrary, the research outlined in *The Beak of the Finch* shows that natural selection and evolution are ongoing processes. As Weiner states, each generation is "a canvas that is painted over and over by the hand of natural selection, each time a little differently." And, as *The Beak of the Finch* further captures, the changes to species wrought by natural selection and evolution are often visible on human timeframes, if humans are just patient and careful enough to look.

NATURE AND HUMANITY

"We are hybridizing the planet," author Jonathan Weiner writes of humanity's impact on the natural world in his book *The Beak of the Finch*. In other words, Weiner is implying that modern humans have forever changed the face of the earth in many irrevocable ways. By exploring how human evolution, migration, and industrialization have impacted the natural world, the book suggests that because of humanity's remarkable (yet often destructive) progress, the world's plants and animals have come to a unique and critical point in their evolutionary processes. Ultimately, Weiner argues that humans have a responsibility to recognize and assume responsibility for the impact they've had on the natural world.

The book explores how humanity's long journey toward industrialization has impacted the natural world. Humanity's power to impact the natural world—and the evolution of species—is fact, not hypothesis. Author Jonathan Weiner cites an example from the height of the Industrial Revolution to underscore the realities of humanity's impact on other species. In 1848, an English lepidopterist (the word for a person who studies butterflies and moths) noticed that, in the city of Manchester, a species of moth that had previously been whitish with small black spots was turning black. But moths of the same species in rural parts of the country weren't changing. The "black mutants," it turned out, were turning black in order to blend in with their increasingly grimy, soot-stained urban surroundings. This anecdote illustrates how the activities of the human species have the power to change the evolutionary patterns of insects, plants, and animals. Because, as the book also shows, nature's ecosystems are delicately and profoundly interconnected, changing the behavior or appearance of even an animal as small as a moth has cascading consequences throughout the world's bionetworks.

Climate change brought on by human industry is yet another way that humanity has impacted the natural world. Global warming, for instance, threatens the integrity of the current patterns of the oceans' currents—currents that bring seasons to places like the Galápagos. Shifts in the weather patterns of the Galápagos will certainly impact the evolution of the animals that live on the island, or whether the islands cease to be habitable for those animals at all. Because of climate change, whole species could be eliminated—and because every ecosystem on earth is delicate and interconnected, whole species' evolutionary patterns and relationships with other species could be wiped off the map.

The book suggests that because humans have forever changed the face of the planet—and because humans are the only species on earth with full consciousness of the correlation between action and consequence—humanity has a responsibility to invest itself in the preservation of nature. "Never before was such havoc caused by the expansion of a single species," Weiner writes in *The Beak of the Finch*. "[And] never before was the leading actor aware of the action, concerned about the consequences, conscious of guilt." Here, Weiner suggests that though humans have caused immense "havoc" on and damage to the planet and its many species, humanity is also unique in its ability to understand that it should feel some "guilt" about its actions. That guilt, the passage implies, should be a motivating force that compels humanity to take responsibility for its actions. Weiner goes on to observe that, "for better and for worse, this may be one of the most dramatic moments to observe evolution in action since evolution began." Now that humanity has changed the face of the planet and pressurized certain selection and evolution events (such as in the case of the Manchester moths), it can absorb the gravity of its actions. Humans shouldn't only feel guilt—they should marvel at the planet's capacity to change, and work to take actions that will nurture positive selection and change rather than continuing to feign ignorance as to how human activity impacts the planet's many species.

After Britain enacted clean-air legislation in the mid-20th century, the moths in Manchester began to morph back to their original forms—the frequency of the black mutant dropped from seven in ten months to fewer than one in ten. *The Beak of the Finch* makes the case that humanity has the power to assume responsibility for how its activities impact nature, and to ensure that we are conscious, careful, and deliberate in our actions.

EVOLUTION, THE MODERN ERA, AND NATURE'S "RESISTANCE MOVEMENT"

"Wherever we aim at a species point-blank, for whatever reason, we drive its evolution, often in the opposite direction from what we ourselves desire," writes Jonathan Weiner in *The Beak of the Finch*. The book, written in the early 1990s, calls attention to how humanity's impact on the globe impacts evolution of the planet's animals, plants, bacteria, and viruses, but often in ways that are problematic for humanity itself. The book shows through multiple examples how humanity has tried to assert its dominance over nature, and yet nature, through a series of evolutionary processes, continues to resist the modern era's innovations. By highlighting how the processes of evolution naturally work to resist human dominance, the book suggests that, in fact, human dominance is not as clear as it might seem at first glance: nature is still able to resist the modern era's technological, entrepreneurial, biological, and medical innovations.

The book explores how the "resistance" of many life forms to human attempts at control is, in and of itself, a form of evolution at work. In one example, author Jonathan Weiner discusses how bacteria are developing increasing resistance to the antibiotics that human have developed to kill them off. The bacteria that survive a dose of antibiotics are, naturally, those that carry the most resistance to the drug. Those surviving bacteria then pass that resistance to their offspring, and those offspring multiply rapidly because they face no competition since the non-resistant bacteria have all been killed off. In this way, colonies of bacteria can rapidly gain resistance to the drugs designed to control them, because the drugs themselves act as a selection pressure for bacterial resistance. In another example, the book explores how insects like moths that feed on cotton crops have developed resistance to pesticides like DDT. The moths that survived initial encounters with these pesticides passed their genes along to their offspring—and in each subsequent generation, the moths have, through pressurized selection, developed hereditary resistance to a huge variety of pesticides. The farmers spraying their crops with harmful insect repellents, then, drive natural selection in a way that produces insects immune to the farmer's efforts to control them. Evolution is a powerful force—powerful enough, it turns out, to thwart humanity's attempts to best nature.

Because many different species are evolving to resist humanity's direct (or inadvertent) targeting of them, the book suggests that humanity is better off conceiving of itself as being a part of nature rather than transcending and dominating it. Charles Darwin himself wrote of how "man in his arrogance thinks himself a great work". In reality, Darwin supposed that humanity's capacity for consciousness was simply a random, yet miraculous evolutionary trait that evolved just as his finches' **beaks** did. Humanity's "admiration of ourselves," Darwin cryptically predicted, would be humanity's downfall. Humanity occupies its current position of power, the book suggests, because our capacity for heightened consciousness has allowed us to "carve out more adapted niches more rapidly than any other species on the planet." But the book posits that there is just "one degree" of difference between humanity and other species. For instance, blue tits—small birds found throughout the United Kingdom, Europe, Asia, and some northern parts of Africa—have learned to peck holes in the lids of milk bottles left out on people's doorsteps overnight. Ornithologists have observed the phenomenon of blue tits teaching others of their kind how to copy their behavior. And a young female macaque monkey named Imo, native to an island of Japan, learned to wash her food before eating it—and, like the blue tits, taught others of her kind to do the same.

Ultimately, *The Beak of the Finch* is not interested in trying to diminish what makes humanity unique. The book is clear that the leap to consciousness in humanity is the most profound evolutionary change in the history of the planet. But the book does make the case that humanity, like every other living thing on the planet, lives in relationship with every other living thing. And that arrogant or unheeding efforts by humanity to control nature are likely to end up with unintended, and perhaps disastrous, consequences.

THE INTERCONNECTEDNESS OF SPECIES AND ECOSYSTEMS

Throughout *The Beak of the Finch*, author Jonathan Weiner shows how deeply entwined the fates of living things that share the same spaces truly are. By highlighting how the subtlest changes in weather to more extreme changes like the introduction of a new species into an environment can throw an ecosystem into chaos, the book makes clear the intricate and far-reaching impact of this interconnectedness.

The book examines how natural disasters and weather phenomena—floods, droughts, and extreme singular weather events—can change a species' development significantly. After an alternating period of a serious drought followed by a torrential flood on the Galápagos island of Daphne Major at the end of 1982, researcher Lisle Gibbs was stunned to find that the finches of Daphne were evolving before his eyes: "[Lisle] checked and rechecked. It was true. Natural selection had swung around against the birds from the other side. Big birds with big **beaks** were dying. Small birds with small beaks were flourishing. Selection had flipped." This rapid "flip" of natural selection—from prioritizing the traits of big birds with big beaks who weathered droughts well to small birds with small beaks who could thrive in a wetter, rainier environment—illustrates that a species' development depends on its ecosystem. By highlighting the rapidity of this "flip"—and how over the course of just a couple of extreme-weather seasons, an entire species changed—the book shows that the development of any given species is directly tied to the environmental pressures its ecosystem exerts upon it.

Weather and other natural phenomena can also impact species in less obvious—but equally meaningful—ways. During the heavy rainy season in the Galápagos in 1982 and 1983, adult finches on the island of Genovesa would abandon their nests—or their newly-hatched young—when the weather got too cold or intolerable for them. In an attempt to preserve themselves in the face of an environment in flux, these adult finches sacrificed their offspring—or, in some cases, lost them accidentally when heavy winds and rains snapped the tree branches where they made their homes. To hammer home this point, the book turns to an example from the extremely rainy season in the Galápagos in 1982 and 1983. As El Niño wreaked havoc on the area, local mockingbird populations on the island of Genovesa became sick with pox. The pox didn't spread to many finches—but because the disease wiped out so many of the mockingbirds' elders, the juveniles who normally stayed close to their tight-knit family groups were suddenly left to roam and wander. While migrating between different parts of the island in newfound patterns, the mockingbirds began attacking and eating the finches who were their neighbors (as well as those finches' young.) This episode illustrates how external changes within a given ecosystem can have ripple effects within that ecosystem. Not only were the mockingbirds' social groups more or less destroyed—but many members of an entirely new generation of finches, too, were wiped out, impacting the finches' population counts, social organizations, and future mating patterns.

The book also illustrates how certain things introduced to an environment—new plants, pollinators, or animals—can forever change that environment. As one example, the book uses a thought example that Charles Darwin himself devised: he suggested that introducing more cats into an English village would forever change that village's ecosystem. The cats would eat the mice. The mice, which often eat the honey and combs of bees, would diminish in numbers, and so the bees would flourish. As the bees grew in number, they'd pollinate more flowers and perhaps even introduce new species of flowers to the area. Ultimately, the village could see a complete change in its landscape through this chain of events, which illustrates the delicate interconnectedness of different species within a single ecosystem. Another example the book brings up is the arrival of polar bears in Iceland via a floating iceberg. Because polar bears weren't native to the region, the animals who existed there already—deer, foxes, seals, and more—didn't recognize them as predators, and were thus more vulnerable to them. The bears ate all of these creatures. Fewer deer meant the flourishing of the local plants they deer had previously feasted on—and the proliferation of the insects that fed on the plants, too. Fewer foxes meant more ducks, which meant fewer fish. "What havoc the introduction of any new beast of prey must cause in a country," Charles Darwin wrote in his *Journal of Researches*, predicting even in his era the upheaval and change that even a slight change in an ecosystem might create and illustrating the interconnectedness of species and the systems around them.

HYBRIDIZATION AND SPECIALIZATION

The study of evolutionary biology seems, from an outsider's perspective, as if it serves to bring strict "order to the riotous diversity of the natural world." But in reality, the processes of hybridization and specialization—the processes by which different species are crossed, combined, and set on new evolutionary pathways—are processes that in many ways defy order. As fusion and fission compel species to fuse together to create new hybrids, then specialize those hybrids so intensely that fission again separates the hybrids from their relatives, biologists can watch evolution in action. Throughout *The Beak of the Finch*, author Jonathan Weiner uses the topic of hybridization and specialization to suggest that while nature is indeed fragile and vulnerable, organisms of all species are determined to find ways to innovate and change in order to survive.

By examining how the forces of fusion and fission lead to hybridization and specialization, the book illustrates how hardy and resilient the Earth's species truly are. "The two forces of fission and fusion fight forever among the birds," Weiner writes of the development of Darwin's finches on the island of Daphne Major. Peter and Rosemary Grant, evolutionary biologists who've been studying the finches for decades, have observed that the finches on Daphne Major are "perpetually being forced slightly apart and drifting back together again" in an ongoing tug-of-war between specialization and hybridization. Alternating spells of dry and wet weather are the primary drivers of these forces. During periods of drought, one beak size is favored over another. This splits the population, forcing it onto two slightly adaptive peaks—in other words, fission creates a new, specialized trait that, if allowed to evolve, might eventually represent a new species. But, more often than not, these newly specialized birds don't quite make it across the species barrier. During wet and rainy periods of abundance, frenetic and random mating often means that individuals that have developed specialized traits will mate with those that haven't—and thus the species fuses once again, bridging the beginnings of a species divide. This constant push and pull shows that animals are ready, in difficult circumstances, to change and evolve new traits that will allow them to survive through difficult times. But when circumstances aren't so difficult and pressurized, it's more advantageous for these species to revert back to the traits they'd begun to evolve out of. This illustrates the power of the concept of the "survival of the fittest"—in other words, different species will undergo rapid and sometimes fluctuating changes and adaptations in order to survive.

Humanity—and human-hastened climate change—are rapidly changing the planet, yet, through hybridization and specialization, plants, animals, and microorganisms are able to carve out new niches for themselves and increase the likelihood of their survival. Even though Darwin himself hypothesized that hybridized animals and plants were, more often than not, unfit for survival, the Grants' research on the Galápagos has challenged this line of thought. While some animals do produce hybrid offspring that are sterile and thus unfit (for example, mules, the offspring of horses and donkeys that mate), other species, like the finches, place themselves at an advantage rather than a disadvantage by hybridizing. In the modern era, the droughts and rains that dictate the finches' evolutionary patterns are more unpredictable than ever. Climate change, a direct effect of humanity's ever-increasing output of pollution that impacts the environment, is changing the weather around the world. Places like the Galápagos are especially vulnerable. Because the weather in places like the Galápagos is increasingly unstable, the periods during which a hybridized lineage is more likely to continue building itself out into a new species are more unpredictable, too. With longer periods of specialization, or fission, required of these birds in order to ensure their survival, it might be harder or less advantageous for these new lineages to reintegrate into the species from which they're branching off in times of plenty. Humanity's impact on the natural world is intense and undeniable. Judging by the new lineages that are being created in places like the Galápagos among the finches and in places like the American South among insect populations, organisms throughout nature will continue specializing in order to survive the effects of the pressures humanity has placed on the natural world.

Hybrids that are variable and adaptable because their lineages are so new are more sensitive to the pressures of natural selection. And because natural selection allows the "fittest" individuals within any species to survive, change, and multiply, it makes sense that these hybrid individuals are, somewhat counterintuitively, better primed to survive the unpredictable ways in which humanity is continuing to change the face of the planet. Thus, even as selective pressures become more unpredictable and intense, there is lots of evidence that life forms in the wild will, against all odds, find ways to survive and thrive in the face of uncertainty and instability.

SYMBOLS

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

THE BEAK OF THE FINCH

The highly variable beaks belonging to the different species of Galápagos finches—animals that are often called "Darwin's finches"—symbolize the power of natural selection and evolution. The book suggests that the enormously different beaks of the finches found throughout the Galápagos, and specifically on the volcanic island of Daphne Major, are proof of evolution. But, as the book explains, people throughout history—from Darwin's era in the mid-1800s all the way up to the modern day—resist subscribing to the belief that life is constantly evolving, sometimes claiming instead that all of life was created in an instant by God (this belief is called Creationism). The beaks of Darwin's finches, though, symbolize the powerful and remarkable ways that evolution diversifies life on Earth not just over thousands or millions of years, but sometimes from hour to hour or day to day. Everything on Earth, the book posits, from bacteria to plants to animals, is always changing due to a steady stream of unseen selective pressures that force life to adapt favorable traits in order to survive. The ever-changing beak of the finch is one of the most easily observable pieces of evidence for evolution that any species on Earth possesses. Thus, the author Jonathan Weiner uses the beak of the finch to symbolize how powerful and omnipresent evolution really is.

QUOTES

Note: all page numbers for the quotes below refer to the Vintage edition of *The Beak of the Finch* published in 1995.

Chapter 1 Quotes

[T]hese new studies suggest that Darwin did not know the strength of his own theory. He vastly underestimated the power of natural selection. Its action is neither rare nor slow. It leads to evolution daily and hourly, all around us, and we can watch.

Related Characters: Jonathan Weiner (speaker), Charles Darwin

Related Themes:

Page Number: 9

Explanation and Analysis

In this passage, author Jonathan Weiner lays out the central thesis of his book *The Beak of the Finch*: the argument that natural selection and evolution are ongoing, everyday processes rather than rare events.

This passage is significant because it lays the groundwork for Weiner's investigation into the complex science of evolution, which is at present best observed on the isolated Galápagos island of Daphne Major, where Darwin's finches live. The finches are a highly variable, highly adaptable group of species that coexist throughout the Galápagos archipelago. From season to season and year to year, field scientists like Peter and Rosemary Grant, who have dedicated their lives to studying the finches, can watch evolutionary change happen by observing and measuring how the finches' behaviors and physical traits change. The finches show that evolution isn't something that happened long ago and is now over, or that evolutionary events are rare and triggered only by cataclysmic changes. Rather, the finches prove that the Earth's species are constantly in flux. Pressurized by environmental changes, human intervention, and the demands of mating, all manner of plants, animals, and microorganisms—indeed, even humans—are in a constant state of change.

This passage also introduces the concept of natural selection, the process through which evolution takes place. As nature selects "for" advantageous traits and "against" traits that weaken or threaten a species' survival, members of that species will either live to pass on their favored traits, fail to mate, or perish. Natural selection is, in the book's estimation, the primary force that drives the evolutionary process, and this passage calls particular attention to how powerful a force natural selection really is.

Chapter 2 Quotes

❝ The whole family tree of Darwin's finches is marked by this kind of eccentric specialization, and each species has a beak to go with it. Robert Bowman, an evolutionist who studied the finches before the Grants, once drew a chart comparing the birds' beaks to different kinds of pliers. Cactus finches carry a heavy-duty lineman's pliers. Other species carry analogues of the high-leverage diagonal pliers, the long chain-nose pliers, the parrot-head gripping pliers, the curved needle-nose pliers, and the straight needle-nose pliers.

Related Characters: Jonathan Weiner (speaker), Charles Darwin

Related Themes:

Related Symbols:

Page Number: 18

Explanation and Analysis

In this passage, the book describes the highly variable beaks of Darwin's finches. The beak of the finch is the book's central symbol, illustrating the unbelievable observability of evolution in action. As author Jonathan Weiner describes the tool-like nature of the finches' variable beaks, he is telling his readers how essential differently formed beaks are to the many species of finch found throughout the Galápagos. Based on the unique pressures of their similar but minutely different environment, these finches have evolved bills that will help them survive and thrive in their particular conditions. Because the finches have, over time, evolved different beaks to do different tasks, they're now considered separate species: they are one of the most clearly observable examples of evolution's power found in the world today.

This passage also proves that the finches are intimately interconnected with their environments: the things in their surrounding environment dictate how the finches will develop. As the finches create particular niches for themselves—for example, cactus finches who specialize to eat and drink from cacti, or ground finches whose beaks resemble "gripping pliers" and allow them to pry open hard seed-pod cases—they stay out of one another's way, allowing the other species to evolve around them, as well. So this passage confirms that the finches' specialization and independent evolution is both a product of their environment—and the key tool that allows them to thrive within that environment.

❝ Only varieties. If so, they would fit comfortably within the orthodox view of life. But what if they were something more than varieties? […] What if there were no limits to their divergence? What if they had diverged first into varieties, and then gone right on diverging into species. new species, each marooned on its own island?

"—If there is the slightest foundation for these remarks," Darwin wrote, "the zoology of Archipelagoes—will be well worth examining; for such facts undermine the stability of Species." Then, in a scribble that foreshadowed two decades of agonized caution, Darwin inserted a word: "would undermine the stability of Species."

Related Characters: Charles Darwin, Jonathan Weiner (speaker)

Related Themes:

Related Symbols:

Page Number: 27

Explanation and Analysis

This passage describes the ideological challenge that Charles Darwin faced as he realized that the finches he'd collected from the Galápagos all belonged to different species.

This passage shows Darwin, in his own words, expressing his anxiety about the fact that his amazing discovery of the distinct, speciated Galápagos finches threatened to "undermine the stability of Species." Darwin, who'd studied evolution, hybridization, and specialization by observing flocks of pigeons and the work of dog breeders in his native England, had some groundbreaking theories about evolution and natural selection that were downright heretical for his time. But Darwin, a learned scholar, knew that while Creationism was the accepted doctrine at the time, there had to be an explanation for the variations between species like the finches, which all seemed to have evolved from a common ancestor, branching out from a larger tree trunk. By illustrating the anxiety and excitement Darwin felt as he verged on creating the works that would illuminate the processes of natural selection and evolution, the book shows how remarkable it was for the man to see proof of evolution's ongoing processes in the real world.

Chapter 4 Quotes

According to [Darwin's] theory, even the slightest idiosyncrasies in the shape of an individual beak can sometimes make a difference in what that particular bird can eat. In this way the variation will matter to the bird its whole life—most of which, when it is not asleep, it spends eating. The shape of its particular beak will either help it live a little longer or cut its life a little shorter, so that, in Darwin's words, "the smallest grain in the balance, in the long run, must tell on which death shall fall, and which shall survive."

Related Characters: Charles Darwin, Jonathan Weiner (speaker)

Related Themes:

Related Symbols:

Page Number: 51

Explanation and Analysis

This passage details why the beak of the finch is so important to the finch's survival—and, therefore, why the beak of the finch is the most adaptable, variable trait the finch has. The size and shape of a finch's beak determines almost everything about its life. This passage calls attention to the fact that the size, strength, and shape of the finch's beak determines what it can eat and how efficiently it can eat it—and because so much of a finch's life revolves around the intake of food, even the smallest mutation could be a game-changer (or a liability). Finches born with beaks that are just a millimeter too small or too large may suddenly find themselves struggling to survive—or, on the other hand, they might become the most successful forager of their generation and live to pass on this advantageous trait to many offspring, who will then enjoy the fruits of their parents' luck.

This passage illustrates the profundity of the process of evolution and natural selection. Evolution isn't random—it's the product of a finch's lineage, environment, and genes. Centuries of struggle, death, and change are behind the beak shape of every new finch born in the Galápagos. By highlighting how involved and ever-changing the processes of selection and evolution are, the book seeks to illustrate how incredible the finches' capacity for change really is.

Where there are many finches, each mericarp has fewer seeds, but it has longer and more numerous spines. In the steep, rugged, protected place, the mericarps have more seeds and fewer, shorter spines. Peter [Grant] suspects that the caltrop is evolving in response to the finches. Where the struggle for existence is fierce, the caltrop that is likeliest to succeed is the plant that puts more energy into spines and less into seeds; but in the safer, more secluded spot, the fittest plants are the ones that put more energy into making seeds and less energy into protecting them. The finches may be driving the evolution of caltrop while caltrop is driving the evolution of the finches.

Related Characters: Jonathan Weiner (speaker), Peter and Rosemary Grant

Related Themes:

Page Number: 64-65

Explanation and Analysis

This passage describes the interconnected evolutionary relationship between the Galápagos finches and one of their primary food sources, the caltrop plant.

This passage emphasizes that all the various parts of any given ecosystem aren't just interconnected: in fact, they directly influence one another's evolutionary patterns. The finches have had to evolve their beaks from generation to generation in order to get better at extracting the fruit from the hard, spiny outer shell of the caltrop's mericarp. There has been observable change, from generation to generation of finches, as the finches' beaks have become stronger and better-equipped for this difficult and draining work. But as the finches have become more adept at prying open the mericarps, the caltrop has evolved tougher, more impenetrable mericarps in response. This illustrates that the two are "driving [one another's] evolution." This concept is significant, because it shows that evolution is an ongoing process that constantly shifts and changes based on what's happening in the environment. Species adapt to their environments in order to survive—and it doesn't matter whether that species is an animal, like the finches, or a mere weed like the caltrop. In evolution, survival is the only end game, and a species will change and specialize accordingly.

Chapter 5 Quotes

Now it became of great significance that variations of body and beak are passed on from one generation to the next with fidelity. As a result, the males' unequal luck in love helped to perpetuate the effects of the drought. The male and female *fortis* that survived in 1978 were already significantly bigger birds than the average *fortis* had been before the drought. Of this group the males that became fathers were bigger than the rest. And the young birds that hatched and grew up that year turned out to be big too, and their beaks were deep. The average *fortis* beak of the new generation was 4 or 5 percent deeper than the beak of their ancestors before the drought.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Related Symbols:

Page Number: 81

Explanation and Analysis

This passage illustrates how a period of prolonged drought on the island of Daphne Major engineered an observable evolutionary event amongst the ground finches that lived on the island.

During the period of drought on the island, it became extremely difficult for all of the finches on the island—but most especially the ground finches who fed on tough seed pods and other fruits that had fallen to the ground—to find food and survive. The ground finches with the biggest beaks, who could wrench open seed pods and crack tough, dry seeds while expending the least possible amount of energy, did the best and survived the most. So the biggest males and females were the ones to survive and pass on their genes to the new generation. This next generation had even bigger beaks than the one before it, because natural selection and sexual selection were both favoring bigger beaks well-suited to the work of popping open tough seeds. This shows that the finches were pushed to evolve because of the demands their environment placed on them. They specialized intensely in one direction because of the intensity of the drought itself. This example illustrates how evolution takes place in observable ways from generation to generation in response to environmental pressure.

So the birds were not simply magnified by the drought: they were reformed and revised. They were changed by their dead. Their beaks were carved by their losses.

In most places on this planet, the sight of a dead bird is so rare that it shocks us, even scares us. [...]

But on the desert island of Daphne Major, dead birds are commonplace. They are everywhere. [...] Each generation lies where it falls, and the next generation builds on the ruins of the one before.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Related Symbols:

Page Number: 82

Explanation and Analysis

In this passage, Jonathan Weiner examines the unique role that death plays in the ongoing evolutionary processes happening each day throughout the Galápagos.

While in "most" parts of the world, dead birds are shocking sights to behold, a dead bird on the Galápagos signals something larger than just the loss of one single individual. As birds on the Galápagos die—which they do at a more frequent rate, this passage suggests, than birds in most places—they "reform" and "revise" the living. The birds that survive learn valuable lessons from those that die. As birds who are unfit to a certain set of environmental conditions or unable to keep up in the race to secure food and mates die off, the birds who are fit pass on the very traits that made them stronger than their peers. So each generation "builds on the ruins" of the one that preceded it, instinctually learning from the "losses" of those who didn't make it. By placing the process of evolution in these profound terms, Weiner seeks to highlight how intricate and remarkable the process of selection and evolution is. It is a constant, ongoing process, and it connects different species of plants, animals, and bacteria in a continuous parallel struggle to "carve" out new ways of surviving.

Chapter 6 Quotes

In the dry season, natural selection metaphorically scrutinizes these birds, "daily and hourly," as they strive to keep body and beak together. Some birds make it, and some don't. In the wet season, which is also the breeding season, the survivors are scrutinized daily and hourly by one another, not metaphorically but literally, as males begin jousting for territory building nests, and singing from the highest cactus in their territories, while females troop by and inspect the males' nests and plots of lava and listen to their songs.

In other words, as soon as nature stops selecting among these birds, the birds start selecting among one another. Again, some make it and some don't.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 86

Explanation and Analysis

This passage examines how the forces of natural selection and sexual selection act together to influence evolutionary events among the Galápagos finches.

In the dry season—when it's more difficult to find food and survive—natural selection is acting on the birds. This means that their environment is pressurizing them to make certain changes in their behavior (and sometimes even in their anatomy) in order to survive. But in the wet season, which is traditionally the birds' mating season, a new force enters the ring: sexual selection. During sexual selection, it's not the environment that's pressurizing change: it's the drive to find a mate. So as the females of the species choose the mates that seem fittest, certain advantageous traits determine whether a male will be able to find a mate. These forces combine to ensure that only certain traits are passed down to the next generation. The big-beaked birds that survived the drought of the late 1970s, for instance, were more likely to find mates, so the forces combined to influence a new generation of bigger-beaked birds.

This passage examines in fine detail how different forces play significant roles in the evolutionary process. The finches of the Galápagos are pressurized to change and evolve by their environment, but also by one another. The ecosystem of the Galápagos, then, becomes a kind of pressure cooker in which the birds must constantly keep up with the evolutionary stresses placed upon them from season to season.

The answer is that a male guppy has more to do in life than merely survive. It also has to mate. To survive it has to hide among the colored gravel at the bottom of its stream and among the other guppies of its school. But to mate it has to stand out from the gravel and stand out from the school. It has to elude the eyes of the cichlid or the prawn while catching the eyes of the female guppy.

Related Characters: Jonathan Weiner (speaker), John Endler

Related Themes:

Page Number: 91

Explanation and Analysis

This passage describes how the competing forces of natural selection and sexual selection act upon a species of guppies found in northeastern South America.

John Endler is to these guppies as the Grants are to Darwin's finches in the Galápagos—he is an expert in their lineages, their behaviors, and their evolution from season to season. The guppies, though, are even more unique than the finches in terms of how they respond to the tug-of-war between the pressures of natural selection and the pressures of sexual selection. The guppies live in the gravel at the bottom of South American riverbeds, and they share their ecosystem with predatory fishes and prawns. So in order to live longer, they must disguise themselves and blend in the with the drab gravel. But in order to pass on their lineages, they must mate—and to mate, the males must develop bright spots that attract females. So this passage illustrates how the guppies are constantly torn between the drive to stand out in order to mate and the drive to blend in order to survive.

By highlighting how these competing forces pressurize every aspect of a guppy's life, this passage illustrates how intricately interconnected any given species is with the ecosystem in which it lives. The guppies have to contend with an onslaught of differing pressures that shape how they change from generation to generation. Natural selection and sexual selection are constantly dictating how the guppies behave, how they look, and how they evolve—and these ongoing processes are intimately intertwined with the guppies' physical environment.

Chapter 7 Quotes

Natural selection had swung around against the birds from the other side. Big birds with big beaks were dying. Small birds with small beaks were flourishing. Selection had flipped.

Both big males and big females were dying, [Gibbs] noticed, but many more males than females—again, the reverse of the drought. Everything the drought had preferred in size large—weight, wingspan, tarsus length, bill length, bill depth, and bill width—the aftermath of the flood favored in size small.

Related Characters: Jonathan Weiner (speaker), Lisle Gibbs

Related Themes:

Related Symbols:

Page Number: 104

Explanation and Analysis

In this passage, Jonathan Weiner describes a remarkable evolutionary event that took place on the island of Daphne Major in the early 1980s: after a long period of drought, which selected for bigger birds with bigger beaks that could more easily harvest tough seeds from the ground, the ground finches of Daphne Major faced a stark reversal of fortune. A torrential El Niño brought on a period of wetness and new growth: plants around the island flourished, there was a mating frenzy among the finches, and the ground became filled with tiny seeds dropped by all the new plant life. So suddenly, the big birds who'd evolved to thrive in dry conditions were struggling to keep up with the smaller birds with smaller beaks who were better suited to foraging in the wet soil for tiny seeds. The environment flipped—and so did the traits that nature was selecting for among the finches.

This passage is significant because it highlights the mercurial, ever-changing nature of selection and evolution. Because selection and evolution are tied to the environment, even subtle shifts can influence how a species changes from generation to generation. And when a major environmental shift like this one comes along, it has the power to really alter the population of any given ecosystem.

The fossil record is just too primitive a motion-picture camera to capture the fast-moving life. Rapid motion disappears like the whir of a hummingbird's wings. In such a record, the two wonder years of Darwin's finches would disappear as surely as a wing-beat up and a wing-beat down, canceling out in the blur.

Related Characters: Jonathan Weiner (speaker), Charles Darwin

Related Themes:

Page Number: 111

Explanation and Analysis

In this passage, Jonathan Weiner illuminates why it's often hard to conceive of evolution as an ongoing process: the fossil record is ill-suited to capture the tiny changes that take place in a species from generation to generation.

Because Darwin and his contemporaries were constrained by the technological and practical limitations of their given time periods, they had trouble seeing evolution as an ongoing process. To Weiner, this explains why so many people believed in Creationism: the idea that God had created the universe, and all its species, in one fell swoop. The fossil record appeared to be stagnant—or to show that evolution took place very slowly over a long period of time. But contemporary researchers like Peter and Rosemary Grant have proven that the opposite is true: evolution is a rapid, perpetual process. And, their research shows, one can observe evolution in motion if only they know where to look. But it makes sense that Darwin and his contemporaries would only have been able to see evolutionary shifts like the ones that take place each year on Daphne Major "canceling [each other] out". Ironically, evolution moves so fast that if one isn't looking in the right place at the right time, it might seem like change isn't taking place at all because selection events often reverse so rapidly.

Chapter 8 Quotes

Half a millimeter can decide who lives and who dies. Since these slight variations are passed down from one generation to the next, the brood of a small beak and a medium beak would be likely to have intermediate beaks, equipment that would sometimes differ from their parents' not by one or two tenths of a millimeter but by whole millimeters, maybe by many millimeters. [...] Daphne Major is not a forgiving place. A line of misfits should not last.

[...]

That is why the Grants are so puzzled now.

Related Characters: Jonathan Weiner (speaker), Charles Darwin, Peter and Rosemary Grant

Related Themes:

Related Symbols:

Page Number: 123

Explanation and Analysis

This passage is significant because it introduces one of the major thematic concerns of the second half of Jonathan Weiner's *The Beak of the Finch*: hybridization, specialization, and survival in the face of change.

In a place like Daphne Major, hyper-specialization is the key to survival. Finches must develop highly specialized beaks and then pass along those advantageous beaks, within a margin of a fraction of a millimeter, to ensure that their offspring are well-equipped to survive in exactly the same way their parents were. But as a new crop of hybrid finches with beaks that differ greatly from either of their parents' begins to rise on the island, the Grants begin to suspect that some kind of major evolutionary event is taking place. Hybridization means that the offspring of two different kinds of finches won't be as specialized as either of their parents—and that seems like it should be a liability, given everything that specialists know about natural selection and evolution. But the evidence that emerges in this half of the book seems to suggest that hybrids might actually be the best-suited breed of all: because they're not too specialized, they won't suffer if a weather event or a strange mating season renders a highly-specialized beak obsolete or useless. Because they're not at the top of an "adaptive peak" or struggling in the valley below, they can land somewhere in the middle—and thus become a jack of all trades rather than a master of one.

Chapter 10 Quotes

Selection will act in this way on all neighboring varieties, [...] and the effect will be continually to move varieties apart and repel them. Even if they never actually jostle and joust, [...] natural selection will gradually magnify their differences.

At last the two varieties will move so far apart that competition will slack off. It will slack off when the two varieties have evolved in new directions: when they have diverged. Natural selection will have led in effect to another adaptation—the mutual adaptation of two neighbors to the pressures of each other existence. And the result of this sort of adaptation would be forks in the road, partings of the ways, new branches on the tree of life: the pattern now known as an adaptive radiation.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 142

Explanation and Analysis

This passage explains how the evolutionary force called "adaptive radiation" helps many species to survive and thrive rather than just allowing one to succeed. As selection "magnif[ies]" the differences between neighboring varieties of animals or plants, they slowly begin to evolve in opposite directions. For example, cactus finches evolve narrower beaks to become better at drawing out cactus flesh and water from the cacti around them, while ground finches evolve bigger, deeper beaks to become better at cracking open tough seed pods and nuts. So the two varieties eventually diverge enough that they're not competing for the same food sources: a ground finch would be no good at eating cacti, and a cactus finch wouldn't be able to crack open a tough caltrop husk. So through "adaptive radiation," these species essentially move out of one another's way. By filling a specific, adaptive niche, these species allow one another to grow and thrive.

This passage is significant because it examines how specialization—a form of hybridization—allows for the greater good of all varieties of a single species. Because the second half of the book seeks to examine why there are so many different kinds of plants and animals on Earth in the first place, this passage helps to develop a narrative that's centered around why different varieties contribute to the larger evolutionary process.

Chapter 11 Quotes

The conclusion is inescapable: the feature that makes the finches most interesting to us is also the feature that makes them most interesting to each other. When they are courting, head to head, making decisions that are fateful for the evolution of their lines, Darwin's finches are studying the same thing as the finch watchers. They are looking at each other's beaks.

Related Characters: Jonathan Weiner (speaker), Charles Darwin

Related Themes:

Related Symbols:

Page Number: 168

Explanation and Analysis

This passage takes a closer look at the "invisible coasts," or instinctual boundaries, that keep species apart and contribute to the process of specialization and adaptive radiation.

In this passage, Jonathan Weiner describes an effective but grotesque experiment that Peter and Rosemary Grant, along with their research assistants, pioneered on the island of Daphne Major. By using finch corpses of different species whose heads and bodies were swapped, the Grants and their team were able to determine that a finch will ignore the fact that a decoy has the body of a different species than its own. This illustrates that mating finches are, in choosing a partner, looking only at the beaks of the finches around them. The finches instinctually know that the beak is what separates the different species around them—and they instinctually know to seek out the beaks similar to their own in order to keep their line distinct.

This passage suggests that individual species generally want to mate with others of their own species in order to remain specialized and thus metaphorically out of the way of the other species within their ecosystem. This passage speaks to how intricate and multilayered the processes of selection and evolution are. Species seek to remain with their own kind not just so their own line will flourish, but so that their adaptive specialties will remain intact—and thus not encroach on the territory of another species, creating a sense of competition that could ultimately be detrimental to both species.

Thus the Grants suspect that the finches here are perpetually being forced slightly apart and drifting back together again. A drought favors groups of one beak length or another. It splits the population and forces it onto two slightly separate adaptive peaks. But because the two peaks are so close together, and there is no room for them to widen farther apart, random mating brings the birds back together again.

These two forces of fission and fusion fight forever among the birds. The force of fission works toward the creation of a whole new line, a lineage that could shoot off into a new species. The force of fusion brings them back together.

Related Characters: Jonathan Weiner (speaker), Peter and Rosemary Grant

Related Themes:

Related Symbols:

Page Number: 176

Explanation and Analysis

This passage explains how the forces of fission and fusion play a key role in the evolutionary process of any given species. During periods of fission—such as a drought that requires a species to specialize intensely—similar species are driven further apart as they burrow into their respective "niches" within their shared ecosystem. But during periods of fusion—such as a rainy season where food is plentiful and mating frenzies flourish—the various pressures on any given species is relaxed a bit, and random mating combined with a plateau in specialization means that any populations that were ready to branch off into a new species might fuse back into the "tree of life" they share with their neighbors.

By highlighting how these forces work, Weiner further elucidates how delicate a process evolution is. Natural selection, sexual selection, and adaptive radiation are constantly driving changes within the populations of any given ecosystem. So while the forces that drive evolution are constantly at work, evolution itself remains a process that requires a very specific set of conditions. By understanding the many competing process that drive the daily functioning of any given ecosystem, we can better understand the delicacy of the environments around us, and we can learn to think of evolution less as a slow, painstaking process and more as a continual, ongoing wave.

Chapter 12 Quotes

So there is a simple trade-off here for a stickleback. If the fish specializes in the muck, it cannot compete in the open water; if it specializes in the open water, it is outclassed down in the muck. The fish is in much the same position as a finch in the Galápagos, where specializing in big seeds unfits you for the small ones, and specializing in the small seeds unfits you for the big ones.

To Dolph all this evidence powerfully suggests that the colonists in these lakes have altered the course of each other's evolution, just as the finches have altered each other's courses in the Galápagos.

Related Characters: Jonathan Weiner (speaker), Dolph Schluter

Related Themes:

Page Number: 187

Explanation and Analysis

In this passage, author Jonathan Weiner describes an experiment undertaken by Dolph Schluter, a former mentee of Peter and Rosemary Grant.

In Schluter's experiment with the stickleback fish, Schluter sought to show how competition and specialization drive evolution. There are two species of sticklebacks—benthics and limnetics—and the two occupy different "niches" of the ecosystems in which they live. Benthics are bottomfeeders, while limnetics feed in the waters nearer to the surface. But placing two hybrid species in a test pond will result in one animal specializing to feed at the bottom of the pond, while the other specializes to feed in the waters above. These species, then, are driving one another's evolutionary processes and the filing of an adaptive niche. This illustrates how interconnected different species are with the ecosystems in which they live—and it shows that specialization plays a major role in a species' chances of survival. By occupying separate niches, these species find "adaptive peaks" they can thrive on—while leaving room for the other species within their ecosystem to find their own "adaptive peaks" and thrive, as well. With less competition, everyone does better and lives longer.

Chapter 13 Quotes

These two oscillations are driven by the same events. They are both governed by the same changes in the adaptive landscape. In an adaptive landscape that is wrinkling and rolling as fast as Daphne, a landscape in which the peaks are in geological upheaval, it can pay to be born different, to carry a beak 3, 4, or 5 millimeters away from the tried and true. Since the super-Niño, some of the old peaks have turned into valleys, and some of the old valleys are peaks. Now a hybrid has a chance of coming down on the summit of a new peak. It can luck onto a piece of the new shifting ground.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Related Symbols:

Page Number: 193

Explanation and Analysis

This passage illustrates how changing conditions within any given ecosystem can lead to major evolutionary changes in that ecosystem's population. For instance, on the island of Daphne Major, the "adaptive peaks" that species are incentivized to reach are always changing. In times of drought and scarcity, it helps to be highly specialized—but in times of plenty, when random mating leads to increased hybridization, it might be a liability to be highly specialized to only one food source or task. So by metaphorically suggesting that the "adaptive peaks" that species are pressurized to reach are in "geological upheaval," Weiner points out that being somewhere on the midpoint of that metaphorical mountain of suitability to one's environment might be a more valuable trait. In an environment that's constantly shifting—or is in a brand-new process of rapid change—being adaptable is more valuable than being specialized. Thus, the hybrids that are now being born all over Daphne Major are doing better than researchers ever suspected they would. These new hybrids can weather more kinds of metaphorical storms that comes their way than their highly specialized ancestors. They are changing based on the patterns emerging within the ecosystem around them.

Chapter 15 Quotes

In times of stress, when the temperature shoots up or down, for instance, or the environment goes suddenly more wet or dry colonies of bacterial cells in a Petri dish will begin to mutate wildly. This is known as the SOS response, for the international distress signal Save Our Souls, Save Our Ship. It increases the chance that at least a few of the cells in the Petri dish will survive the disaster of the new conditions.

The SOS response has been observed in the DNA of maize when it is shocked by hot or cold temperatures. Recently it has been discovered in yeast. Apparently many different kinds of living cells can switch up their mutation rate under stress and relax it again when the stress dies down.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 221-222

Explanation and Analysis

In this passage, author Jonathan Weiner describes the SOS response that can engender a new period of evolution in any given species. When a species is threatened—such as a colony of bacteria dosed with a regimen of antibiotics, or a group of finches threatened by an extreme shift in weather—that species will sometimes reproduce in a frenzy, aiming to create as many new offspring as possible in order to ensure the survival of the species. These offspring will often be highly varied, and this fact further increases the likelihood that the offspring will be able to survive a wide variety of unpredictable contingencies and threats.

This passage illustrates one of the many ways in which species all over the world respond and adapt to chaos and havoc in their environments. By hybridizing, expanding, and multiplying, a species can ensure that the selective forces that will inevitably act on their offspring might be thwarted in their ability to significantly thin or even eradicate a new generation. Evolutionary forces within any given species are working constantly and invisibly in order to ensure that species' proliferation and survival, even in difficult or uncertain times.

Chapter 16 Quotes

A "web of complex relations" binds all of the living things in any region, Darwin writes. Adding or subtracting even a single species causes waves of change that race through the web," onwards in ever-increasing circles of complexity." The simple act of adding cats to an English village would reduce the number of field mice. Killing mice would benefit the bumblebees, whose nests and honeycombs the mice often devour. Increasing the number of bumblebees would benefit the heartsease and red clover, which are fertilized almost exclusively by bumblebees. So adding cats to the village could end by adding flowers.

Related Characters: Charles Darwin, Jonathan Weiner (speaker)

Related Themes:

Page Number: 225

Explanation and Analysis

Here, author Jonathan Weiner describes the complex nature of connection between different species in any given ecosystem. To explain the complexity of nature's "web[s]," he uses an anecdote that Charles Darwin himself thought up. By tracking how the introduction of cats into an English village would, through a complicated chain reaction, theoretically lead to the proliferation of more flowers throughout that village, Weiner reveals the deeply interconnected nature of the world's ecosystems. The smallest change can have massive consequences—consequences that might not be immediately evident, but that will reveal themselves as time goes by. Weiner uses other examples in this chapter, too, to hammer home his point: he shows how introducing polar bears to Iceland led to smaller fish populations there, because the bears killed foxes—and because there were fewer foxes to eat the country's ducks, the ducks thrived and ate up lots of fish. The "gigantic experiment" this chapter speaks of, then, is the experiment of testing how ecosystems respond to change and new contingencies.

If animals can influence one another this strongly, the book suggests, humans can do even more damage. By this logic, Weiner implies that human beings have a responsibility to the world around us to be careful and judicious about how we (and the byproducts of our colonization of the planet) interact with our environments.

Chapter 17 Quotes

The arrival of human beings means a new phase in the evolution of Darwin's finches, and its directions are still unclear. [...] Rosemary and Peter do think they see something odd about the finches of Santa Cruz. The birds around the research station, and in the village, seem to be blurring together. The Grants have never made a systematic study of this: but to their eyes the species almost look as though they are fusing. "They just sort of run into each other," says Rosemary. There is no difference between the largest *fortis* and the smallest *magnirostris*.

Related Characters: Peter and Rosemary Grant, Jonathan Weiner (speaker)

Related Themes:

Page Number: 239-240

Explanation and Analysis

In this passage, author Jonathan Weiner describes a conversation he had with the famed naturalists Peter and Rosemary Grant during which the Grants conceded that the species of finches on islands within the Galápagos populated by humans have begun to "run into each other."

This passage is significant because it illustrates how humanity is creating an increasing level of hybridization, or fusion, amongst the once highly specialized populations in our ecosystems. Species are much different from each other when survival is dictated by a species' ability to specialize and find a "niche" in the environment—like on the island of Daphne Major, where food is so scarce and conditions are so tough that even a millimeter's difference in beak size can be a matter of life or death. But in places where food is plentiful—as it has become on islands that are populated by humans throughout the Galápagos—the birds don't need to carve out those adaptive niches for themselves and their offspring. So they stop specializing, and the ongoing processes of natural selection and evolution come to a bit of a halt.

This passage is significant because it illustrates, as the chapter's title suggests, "the stranger's power". Humanity, through sheer presence alone, can wreak havoc on a natural ecosystem. It's important, then, the book suggests, for humanity to recognize our power over the other creatures with whom we share the planet—and to do our best not to interfere with their delicate natural processes. Otherwise, entire species might be lost forever to the forces of hybridization and fusion.

You don't find situations that chaotic under natural conditions, but you do find them in the havoc that human beings bring in their train. [...] Thus, our disturbances hybridize both the environment and the species.

We are hybridizing the planet.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 242

Explanation and Analysis

In this passage, author Jonathan Weiner makes the bold assertion that humans are hybridizing the planet. Weiner arrives at this conclusion after examining several different ecosystems in detail. First, he discusses how finches in certain parts of the Galápagos that are populated by human beings are changing. With the humans feeding them or dropping food that they can eat all over the place, the finches have little need to continue evolving toward the intricate, hyper-specialized "adaptive peaks" that will allow them to fill one particular niche in their ecosystem. Similarly, farmers who are planting new crops in areas where certain plants, flowers, and weeds thrive are changing the pollination patterns of that plant life, creating new hybrids that need increasingly strange conditions to thrive. Weiner—along with many other evolutionary biologists and botanists—believe that the "havoc" humanity has brought to the world is directly and profoundly changing the evolutionary patterns of all kinds of organisms.

This is significant because one of Weiner's central arguments throughout the book centers around humanity's responsibility to recognizing its role in the evolutionary processes of the species that share our ecosystems. By continuing to wreak "havoc" over the course of the planet, humanity may be killing off or forever changing the life forms that benefit our environment in ways we don't consider significant enough to see or understand. But if this pattern continues, the continuing hybridization of many of the Earth's species will alter the course of much life on this planet—and it will be too late, then, to recover the unique species and variations that will be lost in the process.

Chapter 18 Quotes

A pesticide applies selection pressure as surely as a drought or flood. The poison selects *against* traits that make a species vulnerable to it, because the individuals that are most vulnerable are the ones that die first. The poison selects *for* any trait that makes the species less vulnerable, because the least vulnerable are the ones that survive longest and leave the most offspring. In this way the invention of pesticides in the twentieth century has driven waves of evolution in insects all over the planet.

Related Characters: Jonathan Weiner (speaker), Martin Taylor

Related Themes:

Page Number: 253

Explanation and Analysis

In this passage, Jonathan Weiner describes how a phenomenon of pesticide-resistance insects in the American South is evidence of a "resistance movement" taking place in ecosystems all over the world. The "resistance movement" that Weiner describes in this passage is taking place globally as plants, animals, insects, and microorganisms, like bacteria, react to humanity's attempts to change their ecosystems or eradicate them altogether. Weiner describes how antibiotic-resistant bacteria threaten to become an "epidemic" of vast proportions and how animals vulnerable to hunting and fishing are evolving to make themselves less appetizing or desirable to those who are hunting them.

And here, as he discusses the remarkable immunity of a group of cotton-eating moths to the various pesticides farmers keep trying to use against them, Weiner illustrates how human intervention can drive a species' evolution. The moths are evolving in ways they might never had if humans hadn't aimed pesticides at them—and because each generation of quickly-spawning insects passes along their resistance to the next, it's becoming nearly impossible for these farmers to outpace the insects' evolution. So not only does this instance illustrate how natural selection and evolution are constantly at work in the world around us—it also shows that until humanity recognizes this idea more broadly, we'll continue to wage war against the organisms with which we share our ecosystems rather than accepting responsibility for the unique role we play within those ecosystems.

❝❝ In the world's oceans, Norwegian cod, chinook salmon, Atlantic salmon, red snapper, and red porgy are getting smaller, very likely through the selection pressures of the net. Fishermen are not happy with the trend toward small fish, any more than elephant poachers are pleased with the trend toward tusklessness. But both resistance movements are direct results of Darwinian law.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 264

Explanation and Analysis

This passage illustrates how nature's "resistance movement" is driving evolution in the natural world in visible ways. As Weiner describes how animal populations all over the world are changing, there is no denying that humanity's often predatory relationship to the animals around us is defining what future generations of many species will look and how they will act. Whenever humanity shoots "point-blank" at a species, Weiner argued in an earlier part of this chapter, that species will find a way to move out of humanity's sight, so to speak. So as elephants watch large-tusked elephants fall victim to poacher's guns and as smaller fish find themselves spared due to their diminutive size while the bigger members of their species are caught in fishermen's nets, it stands to reason that these animals would adapt protective measures to make themselves less appealing to the humans who prize certain traits in them.

This passage illustrates the idea that humanity is driving the evolution of animals all around the world. Animals are changing, specializing, and hybridizing on their own due to the pressures of natural selection, sexual selection, and adaptive radiation. But, the book argues, there's no denying that humanity plays a large role in dictating how certain species will evolve in order to survive in a world increasingly overrun by human beings.

Chapter 19 Quotes

❝❝ The black mutants swept up through the mort populations wherever the air was black with the soot of the industrial revolution. Their numbers did not rise in rural parts of Cornwall, Scotland, and Wales. In rural Kent, Darwin's adopted county the black form of the moth was not recorded during his lifetime; but by the middle of this century, nine out of ten *Biston betularia* were black in Bromley, and seven out of ten in Maidstone.

Manchester, of course, was one of the grimy hubs of the industrial revolution.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 272

Explanation and Analysis

In this passage, Jonathan Weiner uses an anecdote from the mid-1800s to illustrate how powerful humanity's influence on the evolutionary processes of the species all around us truly is. In it, Weiner describes how a certain species of moth native to England changed and evolved based on the environmental pressures it faced at the height of the Industrial Revolution. The moths were white with dark stripes—but as the soot-stained, grimy buildings of cities like Manchester became darker and harder to camouflage themselves against, these moths began to evolve to become black in color so as to better blend in with their changing surroundings. Only city moths underwent this selective process—moths in the country had no need to evolve to fit in with their surroundings, so they didn't. This illustrates how sensitive the moths were to their environment, and how quickly natural selection selected for darker moths that would be more likely to blend in and survive in their changing ecosystem.

This example highlights how humanity is pressurizing unprecedented evolutionary events among the plants and animals in our ecosystems all the time, sometimes without even realizing it. And while the dark soot that was a symptom of the Industrial Revolution produced a visible change in the moths, many current human innovations such as carbon dioxide output aren't visible. So humans have no idea of how our present actions are changing the other life forms around us—perhaps for good. This passage suggests that humans must understand the role we play in the evolutionary processes of the species around us and learn to work with our ecosystems rather than against them.

Epilogue Quotes

“ They rise, they are discovered by seeds and birds, they support Darwinian chains of action and reaction, and they sink again to the bottom of the sea, while new islands rise in their place. This rise and fall may have gone on here in the middle of the sea for as many as eighty or ninety million years. […] We know [that Daphne Major is] a place that was here before we came and will remain when we are gone. The very island will sink someday, and another will rise when it is drowned.

Related Characters: Jonathan Weiner (speaker)

Related Themes:

Page Number: 303

Explanation and Analysis

In the final lines of his book *The Beak of the Finch*, author Jonathan Weiner uses this passage to meditate on the continuous nature of evolution and change on our planet.

Just as the Galápagos islands as we know them today were once at the bottom of the ocean, the formations researchers have found at the bottom of the ocean today are believed to have once been islands of their own. The continual (though slow) rise and fall of these islands highlights the impermanence and constant fluctuation of life on Earth. Just as the finches of the Galápagos are formed by their dead, so too are many aspects of life on earth centered around loss and struggle. But life always finds a way to survive. The rise and fall of the islands mimics the rise and fall of Darwinian evolution. This passage implies that there are still many untold, unimaginable evolutionary events in store for life on Earth—and while we may not be here to see it, just as Darwin was not able to see how the Grants expanded upon his theories, change, loss, and growth will continue to define our planet long after we are gone.

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.

CHAPTER 1: DAPHNE MAJOR

It is January 25, 1991, and author Jonathan Weiner is on the island of Daphne Major—one of the Galápagos Islands—along with famed naturalists Peter and Rosemary Grant, and 400 of the finches that live on the island. The Grants know each individual bird on sight—the two of them have been studying the finches for two decades, or about 20 generations of finches. Looking out from the upper rim of Daphne Major, a desert island formed from a dormant volcano, one can see the neighboring islands of the Galápagos clearly. The islands are where Charles Darwin began his groundbreaking research on evolution in the mid-19th century—but Darwin could not easily return to these islands year after year. The Grants, however, can—and they do, measuring and charting the growth and change within the islands' diverse finch population.

In the opening lines of the book, author Jonathan Weiner gives his readers a sense of what the island of Daphne Major is like—and, in spite of its small size, how large a role it has played in the study of evolution over the years. Peter and Rosemary Grant are Weiner's guides through the world of evolutionary biology, and he makes it clear right away that they are skilled, passionate, and deeply involved in carrying on the legacy Darwin began here over 150 years ago. This illustrates that the field is still developing in many ways—and that the Grants take their responsibility to their work and to the natural worlds seriously.

The Grants are continuing the work that was begun in the mid-1800s by the English naturalist Charles Darwin. Darwin's famous text *On the Origin of Species* was about the process of natural selection and evolution—but Darwin himself never saw evolution take place. In other words, he theorized that natural selection—the "survival of the fittest"—led to evolution, but the connection between the two mechanisms remained a mystery to him throughout his lifetime.

Charles Darwin is considered the founding father of evolutionary biology, but he was constrained by the technological and practical limits of the time period in which he lived. So in taking up the mantle of his research, the Grants are honoring Darwin's work while at the same time covering the ground he could not. The Grants' work continues to prove that natural selection and evolution are ongoing processes: they can see, through return trips to the islands, what Darwin never could.

Even as late as 1990, naturalists lamented the lack of programs that actually conducted tests of natural selection that could prove the connection between natural selection and to evolution. But by the 21st century, more and more evolutionists had begun to undertake new studies on the evolutionary process, filling in the gaps that Darwin and his contemporaries never could. These studies have shown that Darwin himself underestimated the power of natural selection—they have proven that natural selection leads to evolution, "daily and hourly, all around us." And the Grants' ongoing research with Darwin's finches is at the forefront of this expanding field.

Darwin could only hypothesize about the link between the process of natural selection and evolution. But modern technology is able to zoom in on what's happening in the natural world and prove that natural selection is constantly at work in nature. And if nature is selecting for certain traits, encouraging species to adapt and change, it means that the evolution of many species around the world is ongoing.

Studying the evolution of life over the course of several generations requires an isolated, fixed population that doesn't migrate or mate with others. Islands—and specifically the isolated volcanic Galápagos islands—are perfect for this purpose. The Galápagos islands are relatively young, having broken the surface of the ocean about 5 million years ago. And because the islands are so young, the creation of new things is still happening there very rapidly.

This passage shows that while it might be hard to witness evolution in one's own backyard, there are still many places around the world where the circumstances are just right for people like the Grants to put Darwin's theories to the test. Nature is delicate, and some places are even newer and more delicate than others.

Even though getting to Daphne Major is quite difficult, the Grants' experiences living and working there have helped them to see the island less as a "prison" and more as a "treasure-house" of precious information about the process of evolution. The Grants work together to trap, measure, weigh, and tag the finches with small metal bands. The Grants—both natives of Britain who are now lecturers and researchers at Princeton University—are spry and toned for a couple in their mid-50s, and they approach their work, Weiner writes, with wonder and enthusiasm. Though the tools they use to complete their work are simple and rudimentary, the Grants are observing evolution in action—standing on the shoulders of Darwin, they can see "farther than [Darwin] ever dreamed."

This passage illustrates how the Grants see their work. They understand that they have a responsibility to the planet, and they view nature's challenges as opportunities rather than nuisances. While the Grants' humility is palpable, Weiner takes this opportunity to point out the enormous scale of the work they're doing. Weiner is seeking to remind his readers of how groundbreaking the Grants' work truly is—and how it stands to elevate and illuminate the great works of Charles Darwin himself.

CHAPTER 2: WHAT DARWIN SAW

In the Galápagos, there exist 13 species of finches—and some of them look so alike that they're nearly impossible to tell apart. Yet in spite of their similar appearances, the birds are amazingly diverse. There are cactus finches that live and mate in the island's cacti, drink their nectar, and pollinate them. There are vampire finches that feast on the blood of the blue-footed boobies that live on the islands. Each finch is highly specialized—and each species has a unique **beak** to go with their behaviors.

This passage introduces the book's central symbol: the titular beak of the finch. The finches' beaks are highly specialized and highly varied: some beaks are big and deep, others small and shallow. These beaks symbolize the fact that it is possible to see evolution in action: each species of finch has evolved their unique beak over the course of millennia in order to survive.

These finches have become more and more sophisticated in their uses of their tool-like **beaks** over time, thanks to the forces of evolution. The Grants' research on the evolution of these finches—which takes place from season to season, year to year—is widely recognized as groundbreaking and completely unique in their field.

Darwin discovered the finches, which is why they're often called "Darwin's finches". But this passage shows that the Grants are also playing a major role in determining what the finches' unbelievable evolutionary history means for the modern era.

Darwin arrived in the Galápagos in September of 1835. He had joined the voyage of the ship the *Beagle* four years earlier, at just 22, serving as a companion to ship's Captain FitzRoy. Though Darwin would become famous for analysis of the finches on the island, he mentioned them in his early diaries of his time in the Galápagos very infrequently and casually. He collected all kinds of specimens—fish, reptiles, insects, and nine kinds of finches, though he did not think the birds were particularly important. He didn't realize at the time that they were all products of evolution and natural selection.

This passage provides some context about Darwin's life and illustrates how, before Darwin had any sense of how or why the Galápagos islands were unique), he was still compelled to participate in and understand the natural world around him. Weiner uses examples of how Darwin and the Grants—though they lived a century apart—are united in their senses of responsibility to nature.

Having studied scripture at Cambridge, Darwin was still largely a Creationist—he believed that God had created all animals as the now were. Darwin drew on the research of the Swedish botanist Carolus Linnaeus, who had visited the Galápagos islands a century earlier in hopes of "glimps[ing] the plan of the Creator." Linnaeus was the first to divide life on Earth into kingdoms, classes, orders, genera, and species—a system many know now as the "tree of life," branching ever outward. But Linnaeus believed that life forms on Earth hadn't changed at all since their divine creator made them. Even observable variations between different kinds of plants didn't convince him that life on Earth changed from generation to generation.

This passage introduces one of the central tensions of Darwin's life and work. During Darwin's time, it was largely believed that God had created the world and all its inhabitants in a single instant—that every life form on Earth was perfect and complete. And yet the organization of nature and the variations between species spurred Darwin (and other thinkers like him) to question whether life as they knew it was truly static and fixed.

Darwin's time was full of scholars and thinkers who debated whether life was fixed or not—Charles Lyell, one such man, suggested a then-heretical view that while species were fixed, the Earth itself was ever-changing. Darwin had a sense that species could create variants of themselves, though he did not then imagine that the varieties of finches would become so important. But as he studied the specimens he had taken on the voyage back to England, he began to believe that the finches could "undermine the stability of Species"—they could plausibly show that species are changing over time.

Darwin realized early on into his research in the Galápagos that he was sitting on potentially explosive information that could undermine the stability not just of the concept of "Species," but of how people around him understood the world. Such an idea was a potentially dangerous one—yet Darwin felt a great responsibility to understand the natural world.

In 1836, Darwin returned to London—and by early 1837, specialists at the Zoological Society there were already marveling at the 14 species of finches that had been created by the conditions in the Galápagos. The birds Darwin had brought back, the Society found, weren't just varieties—they were a new, isolated species unique to the island. Though all of the specimens of birds and reptiles Darwin brought back bore a resemblance to their mainland counterparts in South America, they were all undeniably distinct from anything that had ever been found there. The society came to believe that these birds had diverged from their ancestors and "broken the species barrier."

When Darwin began sharing his findings, other scientists and naturalists in his community immediately recognized that what he'd discovered in the Galápagos was unique and groundbreaking. The idea that there had been a divergence of species between mainland South America and the outlying Galápagos islands showed that the "species barrier" wasn't fixed—it was permeable, and it could change.

Darwin also brought back from his journey fossils of giant, extinct species of armadillo, llama, and capybara which proved that there was a "law of succession" linking living animals to their dead predecessors. Darwin had proof that species gradually changed over time—and he was "haunted" and thrilled by his own discovery. In the summer of 1837, he began writing about what he called the "Transmutation of Species". Though he lamented having failed to label his specimens based on the islands where he'd found them, he began working toward a theory that selection was driving evolution.

The "law of succession" that Darwin discovered was groundbreaking. But the fact that he was "haunted" by his own findings shows that he understood how unprecedented and potentially damaging coming forth with such a discovery could have been. Darwin wasn't just on the cusp of overturning other people's beliefs—his own beliefs were also changing to accommodate the story that his specimens were beginning to tell.

Darwin knew that dog breeders could select for certain traits that would change the "character" of an animal. This process was already referred to as "selection"—so Darwin termed the phenomenon as it occurred in nature "natural selection." In 1855—more than 20 years after his initial voyage—he began breeding pigeons, and soon wound up with 15 breeds that were technically the same species, though they'd been made distinct by nothing other than the process of selection. Darwin began to write about his findings. He knew that what he'd discovered in his own backyard implied that the power of nature could, over the course of millions of years, accomplish far greater things.

The idea that the "character" of an animal—its personality and certain physical traits—could be changed through purposeful breeding wasn't new to Darwin: he knew dog breeders and pigeon fanciers. But seeing the process occur in nature suggested that there were extremely powerful forces at work in the natural world. Not only could humans manipulate animals—but animals, plants, and other organisms could adapt based on the pressures within their environment.

Darwin's realization about evolution wasn't a single "eureka" moment—contrary to popular belief, even Darwin himself underestimated the mechanism of natural selection. And though Darwin himself never returned to the Galápagos, many naturalists who traveled there after him collected specimens of their own—and Darwin's finches quickly became proof of evolution in action. Still, the Grants are the first people to actually watch the process of natural selection happen before their eyes.

This passage shows that humanity's understanding of the natural world—and of the processes that govern it—has been a long work in progress. Darwin presented the theory that has allowed naturalists like the Grants to deepen their understanding of the species all around them, and of how the different parts of the natural world are interconnected.

CHAPTER 3: INFINITE VARIETY

Peter and Rosemary Grant were both interested in the variation of animals and plants from a very young age. Darwin, too, studied variation from a young age, focusing on a study involving barnacles in 1846. While a colony of barnacles might appear homogenous (or the same), Darwin found remarkable variations between his specimens. He became frustrated, wondering where he should draw the lines between different species. The study confirmed for Darwin that "there is no species barrier"—in other words, that one species can shade into another. Darwin assumed that this shading (or splitting) of species was a process too slow for him to observe. But in reality, it's a process that can indeed be seen happening each day in places like the Galápagos.

This passage shows how Darwin's initial understandings of the process of selection, speciation, and evolution paved the way for newer generations of naturalists to understand more about the world around them. Darwin provided the theory—but, again, constrained as he was by the resources available to him, he could not observe it in practice. But further generations of researchers have been able to observe this process in action—and develop a greater understanding of the interconnectedness of all aspects of the natural world.

As ornithologists studied Darwin's finches, some split them into species—others lumped them together. Today, most taxonomists consider the 13 species of Galápagos finches to be a single family or subfamily, divided into four genera. In the first genus, the birds live in trees and eat fruit and bugs; in the second, they live in trees and are herbivores; in the third, the birds live in trees but look and act like warblers (another species of bird entirely); in the fourth, the birds live on the ground. Within the ground finches, there are three distinct species (*G. magnirostris*, the largest; *G. fortis*, the medium; and *G. fuliginosa*, the smallest). Within each of those species, there are variations in the finches' **beaks**, but it is said at the Galápagos research center that only God and Peter Grant can tell the finches apart on sight.

This passage illustrates the Galápagos finches' intricate development. While all of the birds might appear the same to the untrained eye, there is a vast network of biological, social, and behavioral differences underlying their apparent similarities. The beaks are evidence of how the finches have evolved to become different from one another time—and, again, symbolic of how evolution is a real, observable, ongoing process.

In the 1970s, Peter Grant had begun to wonder why some species of animals and plants were hypervariable (prone to lots of variation), while others weren't. In order to study this phenomenon, he needed to observe a hypervariable species over a long period of time—and Darwin's finches were ideal for his purposes. Peter and Rosemary first traveled to the islands in 1973, bringing along their young daughters. There, they found the birds to be extremely tame—the birds did not recognize humans as predators due to their isolation, and they would perch on the Grants' shoulders or eat out of their hands. The finches, it seemed, were studying the Grants, too.

The Grants were fascinated by the finches—but as they began spending more and more time among them, the Grants began to realize that the finches were still learning about their environment. They knew that they would have to be careful in their study of the finches, because any small disturbance could change the course of the finches' ongoing evolution. This illustrates the delicate balance between the natural world and the humans who long to better understand it.

That first year, the Grants hopped between seven different islands, meticulously measuring the finches. They found that while most species of birds elsewhere in the world have **beaks** that are so identical in shape and size that only four in 10,000 might have beaks that deviate from the mean, on the Galápagos, about four in 100 finches had beaks of different sizes. Even Darwin, the Grants quickly learned, had not realized how extremely variable his finches were.

When the Grants discovered how incredibly variable the Galápagos finches' beaks were, they knew that they'd have a unique opportunity to study selection and evolution in action. A species that is highly variable—meaning that there are plainly observable differences between different individuals of the same species—is a species that is still figuring out what its final form will be. Thus, evolution is in progress on the island of Daphne Major.

CHAPTER 4: DARWIN'S BEAKS

Having studied natural theology at Christ's College, Cambridge, Darwin was inspired and influenced by religious thinkers. So when he and his fellow crew members on the *Beagle* saw the finches of the Galápagos, they viewed the finches' adaptive traits to life on the harsh islands as "admirable provisions of Infinite Wisdom"—that is, that God had made them well-suited for their environment. But Darwin also had the idea that if living things were well made, then even the slightest variations must make a difference, even perhaps helping an organism to find a new spot in the larger organization of the natural world.

This passage illustrates the tension between Darwin's religious background and the scientific, real-world implications of his research on the Galápagos finches' development. This tension between Darwinism and Creationism would continue throughout the modern era. Darwin sought to find a way of thinking about the processes of evolution and selection that didn't negate the idea of things being formed or made by something larger than themselves.

Because a bird's **beak** is the most important part of its anatomy—it is the tool a bird uses to eat, dig, and defend itself—there are many different kinds of beaks. Egrets have spear-like beaks, herons' beaks are like tongs, and so on. Neither Darwin nor his contemporaries doubted the "adaptive value[s]" of these tools. But many of Darwin's colleagues *did* doubt that individual variations in these different sorts of beaks meant that much at all.

The book describes the stark variations between different birds' beaks, emphasizing how a species' environment largely dictates how selection and evolution play out. This illustrates how connected different species are to the ecosystems in which they live—and how adapting to one's environment ensure that a species will survive and thrive.

Darwin saw variations as essential to the longevity of a species. For instance, in a long dark winter with few deer around for prey, the slimmest wolves in the pack would be expected to do best. The same idea, then, applied to all animals: the fox with the best sense of smell or the rabbit with the longest legs would fare the best in tough conditions and pass its traits along. Yet Darwin himself never tried to produce an experiment that would confirm this point—though it was a "logical" hypothesis, it was a difficult one to prove.

Darwin knew that there had to be a connection between a how a species looked and how it interacted with its environment. But as the book has illustrated, it was difficult for Darwin to find a way to concretely prove his hypothesis. Though his idea made logical sense, finding a way to prove a theory that contradicted the accepted understanding of his time was a daunting task even for Darwin.

A British ornithologist named David Lack arrived in the Galápagos in the late 1930s to research Darwin's finches—and at first, his research seemed to suggest that the birds' **beaks** offered "no scope for natural selection." But upon returning home to England and looking over data, he noticed stunning anomalies which suggested the opposite: the birds, as they bred, seemed to be "consciously trying to get out of each other's niches." They were making themselves as different as possible from one another in order to survive. In 1947, Lack published a monograph called *Darwin's Finches*, proving that there was enough difference between the beaks of individual finches on the islands to confer competitive advantages that would in turn power natural selection.

In this passage, the book introduces the work of a researcher who was able to do what Darwin could not: observe the finches more closely to see whether they were indeed adapting and evolving based on pressures from their peers and their environment. Lack built on Darwin's work to show that the finches were "consciously" and deliberately evolving to reduce competition between themselves and other species and ensure the survival of their offspring. The finches' varying beaks were ultimately the greatest evidence for the forces of natural selection that were shaping them from generation to generation.

To illustrate the finches' "bitter struggles for existence," author Jonathan Weiner describes one of their food sources: a weed called caltrop, Latin name *Tribulus*. The weed defends its fruits, or mericarps, with sharp spines. When the mericarps fall to the ground, the finches eat them—but the mericarps are awkward in a finch's **beak**, and some species don't even try to open them. The finch species *Magnirostris* crushes the mericarp in its powerful beak, but *fortis*, whose beak is weaker, must slowly pry the mericarp open. Finches' lives depend on how efficiently they can forage—and their specialized beaks can help them save precious energy as they do so.

This examination of how the finches of Daphne Major are continually pressurized by their environment and its food sources to change reveals that there are selective forces working on the finches at all times. The finches who evolve to better handle their food sources are more likely to survive efficiently—and so any change toward specialization of a given task makes the species stronger.

The tiny variations between the species, then, are critical, and finches with stronger **beaks** survive better. And, at the same time, the caltrop is evolving in response to the finches: spinier plants with less fruit survive longer and proliferate more. The finches and the caltrops are driving one another's development. Darwin himself commented on the "trifling difference[s]" that can determine whether a species survives, or whether it perishes. Peter and Rosemary Grant can see how these "trifling differences" pan out on the islands of Daphne Major and Genovesa—how those differences decide which individual birds live, and which die.

This passage illustrates how different organisms within a single ecosystem are bound to one another: they evolve around one another and drive each other's evolutionary processes. While the changes that take place across species may seem small or insignificant, in an environment as delicate and contained as the Galápagos, any variation can mean a world of difference to the plants and animals within that environment.

Darwin argued that favorable variations would be more likely to be passed down, spread throughout the population, and benefit the survival of the entire species. But not all of his contemporaries—or even evolutionists working in the early 20th century—believed him. Peter Boag, a contemporary of the Grants, decided to undertake a study measuring relationships between parent **beak** size and offspring beak size in Darwin's finches to see how accurately favorable variations are passed down, and he found that they did. However, Boag didn't get to perform an experiment in which he switched eggs from different nests to see whether the inheritance of beak size was a function of genetics or upbringing. But another scientist, Jamie Smith, did, and he found that foster birds took after their biological parents rather than their adoptive ones. Smith showed that the smallest details are heritable, passed down through the generations.

This passage shows that questions of selection and heritability have been at the forefront of the field of evolutionary biology for well over a century. It also illustrates that Darwin's theories still aren't always taken as fact—many evolutionary biologists working today are still trying to prove some of the more difficult-to-observe hypotheses Darwin posed.

While the Grants first traveled to the Galápagos, they planned to stay for just a few months and take a "snapshot" of the environment. But soon they began to understand that it was worth watching the finches over a long period of time so that they could see in real time how the variations between finches impacted their survival, and offspring, and how those variations were passed on from one generation to the next.

The Grants realized that on Daphne Major, evolution was happening at a rate they could observe, if they just stayed long enough to watch it happen. The unique environment of the isolated island allowed them to see things that no one had ever seen before and understand selection, heritability, and variation in brand-new ways.

CHAPTER 5: A SPECIAL PROVIDENCE

The Galápagos islands have suffered four years of drought, and there are now fewer *Tribulus* plants on the island than there used to be. Peter and Rosemary have to struggle and hunt in the dust to find them. And even those they do find aren't fully eaten—this shows the Grants that the struggle for existence on Daphne Major is intensifying. During years with a lot of rain, the insect and plant populations are plentiful, the birds breed more prolifically, and their young prosper. But in years of extended drought—such as the years Boag spent on the island in 1976 and 1977—there are fewer birds that mate, fewer chicks that survive, and fewer insects and seeds for the finches that do make it to eat.

This passage illustrates how the ever-changing conditions on Daphne Major directly impact the finches' capacity to survive. As nature changes around the finches, they must adapt to their surroundings or die. This illustrates how delicately, profoundly interconnected any given species is with its ecosystem. The smallest environmental shifts can have devastating impacts on the living organisms within that environment—and thus nature is in constant flux.

The drought of 1977 changed the behaviors of many different kinds of finches—some learned new ways of attacking the mericarps to extract fruit, while some began relying on Boag and his team's camp for sustenance, drinking water and scavenging food from their tents. Some finches began eating the tails of the small lava lizards that ran around the island. Yet birds kept dying—and many skipped over their mating season.

This passage shows that changes in the finches' environment directly and immediately impacted their behavior. The finches were learning to find new ways of securing food, stepping out of their territories and eating in ways they'd never eaten before in order to survive. A change in behavior is the first step in specialization—and the finches were, by this point, well on their way to being changed by their environment.

Boag went home dispirited, his data ruined. When he and his team returned in January of 1978, they found that just one in seven finches had made it through the drought—85% of *fortis* perished, 60% of the cactus finches died, and of the smallest ground finches, only one single bird survived. The biggest birds with the biggest **beaks** survived the drought the best—which meant that, though not in the way they hoped, Boag's team had in fact seen natural selection in action, and they'd documented the most intense period of it on record. The tiniest variations in the birds' characteristics had become a matter of life and death.

The smaller birds that were ill-suited to the drought's demands—demands that they learn to attack the biggest, toughest seeds on the island or die—did not survive. But the birds who were already well-suited to the harsh drought conditions found a way to survive and pass on their advantageous traits. This passage illustrates how delicate life is—and how the smallest variations can end up making an enormous difference when an environment places selective pressures on the organisms within it.

Natural selection in and of itself, however, is not evolution—it is just a mechanism that leads to evolution. The finch watchers didn't know whether the event they'd witnessed would lead to a real evolutionary change. But on January 9th of 1978, it rained more than 50 millimeters on Daphne Major. Within a week, the island was green and lush—and the finches began to seek new mates, since not a single coupled pair had survived the drought intact. Because more males than females had survived, the breeding season was skewed and only a small subsample of the largest males with the most intact plumage were able to mate. The new generation of finches on the island would be bigger and stronger than the last. Evolution was happening.

This passage shows how while selection had already acted on the finches, they hadn't yet been pressured to evolve. But yet another environmental shift created conditions that would spur evolution. As the hardiest, most resilient birds mated with one another, they were passing on their favorable traits to their young—thus ensuring that future populations would be well-suited to handle tough, dry conditions. This shows that the beginnings of evolution can take place within just a couple of generations.

In the 1980s, researchers with access to new kinds of technology further analyzed the data gathered during both the Galápagos droughts of the late 1970s and of the rainy season that followed. They found that selection was clearly, specifically favoring birds with the kind of beaks that would best allow them to twist and bite the mericarps of *Tribulus* plants apart. The finches on the island were forever "changed by their dead."

In this passage, Weiner suggests that even the birds who are unable to survive in difficult conditions and end up dying off play a significant role in their relatives' evolution. Death at the hands of natural selection isn't meaningless; instead, Weiner suggests, it is full of great meaning. In a place like Daphne Major, no specimen, no matter their fate, is insignificant.

On Daphne Major, dead birds are commonplace, as opposed to other parts of the world where a dead bird is considered a shocking sight or even a bad omen. On this island, "the next generation builds on the ruins of the one before." Evolution shows that there is meaning in death—and that there is, as William Shakespeare once said, "special providence in the fall of a sparrow."

By invoking the words of William Shakespeare, Weiner is looking for the poetic or dramatic meaning in the "ruins" of a dead generation of birds. The author is awed by the interconnectedness of life on Daphne Major and the delicate nature of this particular ecosystem. He is trying to help his readers understand that evolution is a large and remarkable puzzle in which every part of a given ecosystem is a vital piece.

CHAPTER 6: DARWIN'S FORCES

The next "watch" over Daphne Major fell to the researcher Trevor Price, a student of Peter Grant's who landed on the island early in 1979. Because of the research of those who came before him—Boag, the Grants, and their teams—Price could follow Darwin's finches more closely than anyone else. He banded finches quickly and came to know them by sight, as a shepherd knows members of his flock. He quickly learned that the smallest of the young *fortis* were surviving—they were the most likely to succeed. Because juveniles must hunt and peck for small seeds—yet need the most food of all—big soft **beaks** don't help them get it. Instead, smaller, beaks are favored amongst younger birds. Price set to work measuring these "conflicting waves of natural selection" as they moved through the finch population.

While a previous selection event had caused the finches to pass on the trait that was then in favor—big, strong beaks that could wrench apart tough seed pods—a new selection event was taking place. The rains had created an environment in which small seeds embedded in the soil were so plentiful as to now be the primary food source on the island—and the big beaks of the ground finches were suddenly a liability. This passage illustrates how "conflicting" and mercurial natural selection can be in an ecosystem as small and intimate as Daphne Major. Even the smallest shifts have the potential to create profound, lasting change.

One of the many "waves" of selection these birds must contend with is sexual selection. Put another way: in times of environmental stress, nature scrutinizes the birds, but in times of plenty, the birds scrutinize one another. Trevor Price watched as the island became a "comedy of sexual selection" rather than the "tragedy of natural selection" it had been just two years earlier during the drought.

When nature isn't selecting against the birds, they are selecting against one another. In other words, the finches, too, drive one another's evolution through how they choose their mates. Passing on certain traits is how a species slowly evolves—so mating plays a huge role in the finches' lineages.

Darwin assumed that in mostly monogamous species like his finches, the pressures of sexual selection would be less intense than the pressures of other kinds of selection. But after the drought, the skewed sex ratio between the finches meant that mating became a "winner-take-all" game. Many male finches were unable to mate—the biggest males with the biggest **beaks** were taking all the mates, and some females were mating with multiple males who had favorable traits.

During this particular sexual selection event, the female finches on Daphne Major were choosing the features that would allow their offspring to thrive in difficult times. Because the last major selection event had exhibited a preference for certain traits, the birds continued to select for those traits in their mating patterns.

Plumage color, territory size, and more play a role in the finches' mating process—but because males with the black plumage of sexually mature adults are often attacked by other mature males, some males will strategically hold off changing their plumage as they set up their territory under the radar.

While things like a bird's plumage color might seem fixed to the human eye, this episode illustrates that these things are not constant or solid at all—instead, they're heavily influenced by environment, situation, and circumstance.

The forces of sexual selection often wrestle with the forces of natural selection. The naturalist John Endler is one of the foremost experts on the intersection of these forces. Endler is to guppies what the Grants are to finches—he studies guppies that live in the streams of northeastern South America. The male guppies he observes are covered in spots of varying size, shape, color, iridescence, and location—the palette of colors and the size and brightness of a guppy's spots are all heritable traits. While the spots might seem like an insignificant trait, they are, like the finches' **beaks**, often a matter of life and death.

By introducing John Endler's work with guppies, the book begins to illustrate that the forces of natural selection and sexual selection aren't just observable within the population of finches on Daphne Major. These forces can be seen in action all over the world in all kinds of populations. No matter the organism and no matter the environment, what is consistent is that small variations between different organisms of the same species can be significant enough to drive the evolution of that entire species.

In the 1970s, Endler began watching the guppies and noticing that their spots helped them to camouflage themselves in the gravel at the bottoms of their riverbeds. The guppies are vulnerable to predators: both other fish and prawns. Guppies higher upstream face a lower risk, but those downstream are in a constant and intense battle with such predators, and therefore with natural selection. Endler developed a method of measuring guppy spots—and found that the spots are directly related to the number of enemies the guppies have. Those with fewer enemies have brighter spots, for attracting mates; those with more enemies have duller spots, so as to evade the notice of predators, because natural selection is a greater pressure than sexual selection. The gaudier the male, the more mates he attracts—but the more risk he attracts, as well.

This passage illustrates how profoundly natural selection and sexual selection intersect. Both forces are extremely powerful—and when they're in conflict with one another, remarkable things begin to happen. Endler's guppies are under the pressure of natural selection (the need to survive in the face of enemies by camouflaging themselves) as well as sexual selection (the need to develop bright spots to attract mates and continue the species line). When both of these forces compete with one another, even the smallest shift in appearance can make a world of difference for an individual guppy and its potential offspring.

Endler saw that the forces of selection were at work—but as he noticed more and more specificity in the coloring and patterning of the guppies' spots, he knew he needed to experiment on the guppies and see these selection processes in action. He built test ponds at Princeton and filled them with colorful gravel, guppies, and predators such as cichlid fish. Guppies can bear young at just five or six weeks of age, so it didn't take long to have enough guppies to stock each of his 10 ponds with 200 fish. By creating a huge assortment of guppies, he could see how they evolved.

This passage shows how Endler created an environment that would allow him to test his hypothesis. This passage illustrates the potential for humanity to witness evolution in action, but it also shows that humanity's interference with the natural world can create uniquely pressurized situations that impact evolution.

After many months (and many generations of guppies) had passed, Endler could see that the guppies placed into ponds with fewer enemies got gaudier—they had more spots that were bigger and in brighter colors, like blue, to which guppies' eyes are very sensitive. But the guppies with more predators to contend with stayed relatively drab. Even though Endler's experiment was taking place in a controlled setting, the data was plain: evolution was happening, daily and hourly, based on different pressurized selection mechanisms. Natural selection with the guppies, as with the finches, was "swift and sure."

This passage shows just how sensitive organisms are to their environments. The guppies who felt little pressure to protect themselves from enemies developed traits that would allow them to flourish in terms of mating, while the guppies who faced less pressure for sexual selection did a much better job of disguising themselves form predators. Environmental pressure creates natural selection—and selection leads to evolution toward the adaptation of more favored traits.

As Trevor Price's time on the island drew to a close, the members of Princeton's Finch Unit had spent nearly a decade on Daphne Major—and that decade had taught them that natural selection was making the finches bigger. But Price wondered why there were still, in spite of that fact, small birds on the island—he felt the trend toward selection for bigger birds had to come to an end soon. He believed the next heavy wet season would bring a new development.

Trevor Price had watched the pendulum of selection swing back and forth based on small environmental changes on the island, and he knew that there had to be a reason that the small birds were still surviving. These birds were vulnerable to their ecosystem's changing pressures, but they were clinging to life and continuing to pass down their traits for some reason.

But the rains didn't come—and Price traveled to the other islands of the Galápagos to kill time as he grew increasingly frustrated. When the rains finally came, in March of 1981, it was "too little too late"—not many finches bred. Price left, and Lisle Gibbs, another of Peter Grant's graduate students, took up the watch. A year passed with no rain. But in late 1982, as Lisle had left the island for Christmas, he got a postcard from a contact in the populated Galápagos village of Puerto Ayora—it was raining at last, and it was raining hard.

This passage illustrates nature's power to completely change an environment nearly overnight. Price went stir-crazy waiting for the rains to come—and, ironically, as soon as his watch ended, they arrived to prove the hypothesis he'd long been working on. Nature, this passage illustrates, is fickle, but its fluctuations can change the face of an environment completely.

CHAPTER 7: TWENTY-FIVE THOUSAND DARWINS

Lisle Gibbs and his field assistant rushed to Daphne Major to find nests all over the island crowded with baby finches—the wet season had come on fast and furious, earlier than any year on record since the founding of the Darwin Research Station in 1960. The rains over the next few weeks were torrential, leading to landslides and flash floods. The source of the storms was El Niño—the Child—a weather phenomenon that generally appears every three to six years. During El Niño, a patch of warm water appears in the eastern Pacific and spreads, warming the rest of the ocean. The warmer water creates uncommon winds and weather events all over the world.

This passage shows how a weather event essentially remade parts of Daphne Major's ecosystem. By flooding the island, causing landslides that changed the soil and topography, and encouraging birds to find shelter and mate, the rains began to pressurize a new kind of selection event on the island.

The El Niño that Lisle Gibbs and his assistant experienced was the strongest recorded in the 20th century. The desert island of Daphne Major was transformed into a veritable jungle; trees flowered, creating a "bumper crop" of seeds for the finches to enjoy. In contrast, neither the cactus nor the *Tribulus* plant could survive the wet weather. The birds "bred like hell"—even the juveniles—and, by June, there were over 2,000 finches on Daphne Major. On Genovesa island, though, the finches often abandoned their nests (or lost them to snapping branches). Juvenile mockingbird populations on the island, abandoned by their elders after a pox took most of them out, began roaming the island and terrorizing the finches by eating their eggs and attacking their young.

This El Niño was not just a regular storm—it was a major weather event. So if the island of Daphne Major, a closed ecosystem and thus an especially sensitive place, could be changed by a few rainy days, there was no telling yet what changes would happen throughout the rest of the archipelago as the massive storms shifted the landscape, the populations of the finches, and the health of other animals within the larger ecosystem.

The rains stopped eventually, and, by autumn, Daphne Major was dry once more. But the finch population remained huge, and the seeds left by the floods were still plentiful enough to support that population—for a while. But the following year, only 4 millimeters of rain fell, and the resources on the island could no longer support such a large group of finches. Their populations began to crash.

The population boom that the flood created couldn't last in the renewed drought that came to the island the next year. As the birds began dying off, yet another selection event was clearly in progress—the fittest would survive, and those ill-suited to the new conditions would not.

Back in the U.S., Lisle Gibbs looked at his research. It was September of 1985. What he found was astonishing: natural selection had swung back around. Now, big birds with big **beaks** were dying—and small birds with small beaks were flourishing. As it turned out, the traits that had been advantageous in a drought were liabilities in a wet season. More tiny seeds were buried in the island's soil—so smaller birds with narrower beaks could find them and get at them more easily than their larger counterparts, whose big beaks got in the way of the delicate work of seed-selecting. And as the seed supply ran low, these already struggling big-beaked birds found it even harder to compete.

This passage illustrates that traits that are advantageous in one set of circumstances might become a liability in another. Natural selection had pressurized the birds to develop bigger beaks in order to survive in periods of drought, but then, the population boom and changing food source made other traits more favorable. This shows how plants and animals' delicate relationships to the ecosystems in which they live can change on a dime.

The selection pressures of nature aren't static—instead they often oscillate, and sometimes, as in the case of the late 1970s and early 1980s in the Galápagos, they do so "violently".

Two once-in-a-lifetime events—first the drought, then the torrential rains—had put intense selection pressures on the finches in opposite directions.

A finch watcher (and student of the Grants) named Jamie Smith began watching sparrows on Mandarte, an island off the coast of British Columbia, and believed his research showed no selection amongst the population he was studying. But another Galápagos veteran named Dolph Schluter reviewed Smith's research. After breaking down the sparrows' lives on a closer level, he found that selection had actually been working on them "ruthlessly" from year to year—in other words, a lot of small changes were happening in the species. But on a longer timeline, these forces were invisible. The variations in the Mandarte sparrows were much harder to observe than those in the Galápagos finches, because "stabilizing selection"—a force that seeks to make all of the sparrows the same—is working on them.

The things that Jamie Smith and Dolph Schluter observed in the Mandarte sparrow population confirmed that it wasn't just the Galápagos finches who were changing and evolving from season to season based on selective pressures from their environment. The scientists' observations on Mandarte confirmed that natural selection—and the evolutionary process it begins—are happening everywhere, all the time, regardless of whether or not humanity is looking closely enough to notice.

Darwin believed that evolution was an extraordinarily slow process, because the fossil records he could observe were static and frozen for long periods of time. He had trouble seeing evolution at work on a large scale. But in reality, the forces of natural selection and evolution are happening each and every day—one just has to know where to look to see these minute forces in action.

On the Galápagos, weather events like the drought and flood of the late 1970s and early 1980s reveal that natural selection actually works very quickly. Darwin and his contemporaries didn't know where to look, or what to look for—but contemporary scientists have the resources to be meticulous in their observations and catch natural selection in action.

In 1949, an evolutionist by the name of J.B.S. Haldane suggested the rate of evolution be described in terms of a universal unit—he decided to call this unit the "darwin" and to define it as a rate of change of 1 percent per million years. Fossil records he looked at showed a rate of change of a single darwin, and so he concluded that the rate of evolution by natural selection was too slow to observe. But in the case of the drought and flood in the Galápagos in the late 1970s and early 1980s, the rate of change was 25,000 darwins during the drought and 6,000 during the flood. When seen in action, the evolutionary processes of the living world look much different than the ones recorded in stone.

The closer one looks, the faster the forces of natural selection and evolution seem to move. Looking at a fossil record that stretches back millions of years is, counterintuitively, the least useful way to observe natural selection and evolution in action, because the tiny minutiae of the process are lost. Natural selection and evolution are happening in real time all over the world—so ironically, looking extremely closely at a population's day-to-day life reveals more than a longer, more distant record ever could.

Ironically, if a species changes one way and then another in rapid succession, the official record would show little or no change at all. But things like the beak of the finch are in such fast evolutionary motion that all it takes is a careful observer to discover astonishing rates of change. "Life," Weiner writes, is in "perpetual readiness to take off in any of a thousand directions."

The fossil record can't capture the fast-moving reality of some evolutionary events. The species all around us are not fixed—they're in motion at all times, ready to change at an instant in response to the pressures that surround them at any given moment.

CHAPTER 8: PRINCETON

Jonathan Weiner is with Rosemary Grant in her office at Princeton. It is 1991, and Rosemary and Peter are planning on taking a sabbatical—a year without teaching so that they can analyze mountains of data from their time in the Galápagos. The Grants just got back from the archipelago a couple of weeks ago, and already they have begun to sift through it all. They can look through the data and see the mating patterns and family trees of every individual finch on the island. The Grants talk about the finches intimately, and they remember the most minute details of the finches' lives offhand.

The Grants' careful observations of the finches have led to a genuine interest in the minutiae of the finches' lives. The Grants are aware of how their presence on the island stands to affect the finches, and they take their responsibility to preserving the finches' habitat very seriously. This illustrates that humanity must resist the temptation to interfere with nature's processes—otherwise, the organic forces of natural selection and evolution might become compromised.

The Grants' data doesn't just cover their finches' lineages—they have data sets on vegetation, seeds, and transcribed birdsongs. All of this will help them, during their sabbatical year, to delve into the "secrets they were too close to see" while on the island. Here in Princeton, as they look at the mating patterns of a certain family of finches, they find themselves surprised and excited by an anomaly—the finches are pairing off with finches of different species. Hybridization—a crossing of species—is taking place. And what's even more exciting to the Grants is that the hybrid fledglings are surviving and going on to create their own family trees.

Just as Darwin was limited by the constraints of his time, the Grants, too, must operate within certain constraints on the island. But back on the mainland, they have access to exciting new technologies that help them to process and understand their data in order to comprehend the rapid changes that are taking place on Daphne Major. By introducing the concept of hybridization, the book opens up a new line of inquiry and begins to observe how the Grants will approach it. Change is happening on the island too fast for even the experts to see up close, and nature is doing surprising things.

Hybridization isn't unprecedented in nature, and in fact animals of different species breed all the time—such as horses and donkeys, the pairing of which creates mules and hinnies. But mules, for instance, are always sterile, and hinnies rarely breed (though they can). The Grants assumed that any hybridized finches born on Daphne Major would be unfit, and would not live long—but now, the hybridized finches on the island are thriving. These "misfits" are not suffering the disadvantage they might be expected to.

This passage further explains the concept of hybridization, illustrating why it's so strange and exciting that new hybrid finches are beginning to thrive on Daphne Major. Hybridization isn't a liability, as the Grants previously thought; instead, it seems to be strengthening these new finch populations in unexpected ways.

As the Grants work to analyze their data, they find that before 1983—the year of the flood—there were 32 fledgling hybrids on the island. None of them bred at all until the flood—they were unfit. But after 1983, the hybrids have done better and become more likely to breed. The purebred finches still haven't replaced their numbers on the island, but the hybrids have more than replaced themselves, by a factor of 1.3. "Something has changed since the flood," Weiner writes—and the Grants' research on the finches' hybridization has the potential to unlock the mystery of the origin of species.

Evolutionary processes aren't just ongoing—they're often mysterious while they're still unfolding. The Grants aren't sure, in this moment, exactly what has "changed since the flood," but they know that something significant is going on. This section of the book is pivoting toward a deeper understanding of what hybridization means for the world's species—and how it might influence ongoing evolutionary events all over.

CHAPTER 9: CREATION BY VARIATION

Peter Grant tells his classes at Princeton that "evolution is always happening." Grant often cites an example from Darwin's own life. Darwin built himself a Sandwalk, which he called his "Thinking Path," on a strip of land belonging to his next-door neighbor. He planted trees and created a trail, and soon, blackbirds came to roost along the path. One very cold March, Darwin noticed that many of the birds on his grounds had died off—over four-fifths of them. Darwin didn't document the process—but Grant supposes that if he had, he would've found something interesting about which birds lived and which died.

The Grants are now, in a way, retracing Darwin's Thinking Path, gathering the evidence he did not in order to solve the mystery of evolution. They can only speculate about the things that Darwin might have discovered if he'd done certain things differently. And they are careful, in their own work, to pay attention to every shift that takes place around them, no matter how insignificant it might seem, so that they don't miss out on a potential breakthrough, either.

How variation leads to the creation of new species is the question that has been at the forefront of many biologists' and evolutionists' minds since Darwin's time. Drawing a link between selection and evolution is one thing—drawing the link between evolution and the creation of new species is another entirely. Darwin's contemporaries struggled to accept Darwin's hypothesis that evolution could create entirely new species, writing it off as a "stimulating suggestion." Even as recently as 1981, the scientific community wrote the hypothesis off as conjecture. But the Grants have trained their eye on the mechanisms of natural selection and evolution—and they can see more than anyone who's come before them.

This passage shows how while many of Darwin's contemporaries dismissively discounted his "suggestions" about evolutionary processes, he was actually far ahead of his time. Science has taken a long time to prove what basic logic always pointed toward. As science has advanced, humanity has been able to take a closer look at the formerly invisible processes that are taking place all around us.

Yet even Peter Grant concedes that the step from variation to entirely new species is a puzzle that will confound people for years to come. Answers, though, seem to be found in the Galápagos. The islands are home to 13 species of finches found nowhere else in the world—not to mention unique species of sharks, mockingbirds, tortoises, iguanas, and more—and there are over 200 plant species unique to the archipelago. The Galápagos isn't even the most extraordinary hub of speciation on Earth—almost any location in the world, examined closely, reveals a huge variety of plants and animals. There are somewhere between two and 30 million species of animals and plants on the Earth today—and scientists are still asking why.

While it might seem unremarkable at first glance, scientists who take a deeper look at the extraordinary variation in species all over the world find that there are many mysteries to be solved in terms of asking why there are so many different kinds of the same animal (or plant). Variety, it seems, isn't just the spice of life, as the idiom goes—it's a necessary mechanism for deciding which species survive and thrive within their respective ecosystems. But scientists are still studying how the relationship between an environment and a living organism can lead to massive swaths of variation.

The process of evolution is not complete—it is still in action. The Grants continue to test the forces that shape adaptations—and the forces that put new species on the planet. Darwin thought of the branches of life as a massive tree that was grown long ago—but the Galápagos, for example, are so young that the process of animal and plant life's colonization and creation is still happening there. During their years on Daphne Major, the Grants could watch in real time as strange species of plants grew on islands where they'd never been before, having ostensibly traveled between islands (or even from the South American continent) via the ocean's current or carried by birds that travel from place to place throughout the archipelago.

This passage highlights the tension between schools of thought that suggest that evolution and speciation are already complete, and those that suggest that new species are still being created before humanity's very eyes. The Grants' research has shown that even Darwin's line of thinking on this matter was outdated. Nature is continuing to grow and change constantly, creating new species to fill new ecological niches all the time.

As natural forces—like the massive El Niño—encourage animals to hop between islands and carry new seeds to different places, hybridization continues to rise. And different species, flung together for the first time, begin to breed, producing new sorts of offspring.

Changes in any environment create changes in the organisms that inhabit that environment. Hybridization and variation are responses to these kinds of environmental changes—plants and animals are creating new forms that will be better-suited to an ecosystem's variable challenges.

CHAPTER 10: THE EVER-TURNING SWORD

Darwin himself wondered, through his private writings, if the different strains of life in the Galápagos diverged by adapting to their isolated new surroundings. But Darwin's finches—at least in the modern era—aren't marooned: there is constant traffic of visiting finches between islands. While the birds might have started their divergences in isolation, they're not isolated now. Darwin's writings hold an answer to the question of what transpires when divergent lines of life meet up again after a long period of time.

While Darwin was often only able to wonder about the things he saw in the Galápagos on his lone journey there, modern scientists can actually seek out the answers to those questions. The relationships between species and the ecosystems in which they live—as well as neighboring ecosystems—are becoming clearer all the time.

Darwin believed that as natural selection acted on species that were still in the process of formation, it would drive wedges between them and push them apart. In other words, two varieties living side by side are in constant competition with one another—like the contest that's happening between ground finches for similar resources. In the struggle for existence, it's hard for two variations that are so similar to both survive. Any escape from this oppressive competition—a variety that finds a different seed or a new niche of territory—will get out from under that competition and begin to thrive and flourish. Eventually, the competition will slack off once the varieties have diverged. This process, Weiner writes, is known as "adaptive radiation."

This passage introduces the concept of adaptive radiation. It's a significant moment in the book, because it reveals a new step in the evolutionary process. When two species are too similar in behavior, food source, and other characteristics, both will struggle. But if one (or both) adapt new niches, they'll be able to coexist easily. This process is essential to the creation of new species—and it helps to explain why Darwin's finches are so specialized in their behaviors. By reducing competition with neighbors, any given species increases its own chances of survival.

Darwin himself never saw this process happen—but by studying pigeons, he came to believe that efficiency drove diversification. In other words, he discovered that natural selection organizes life by creating divergent species that fill separate niches.

This passage shows that natural selection is the driving force behind adaptive radiation. The selective pressures nature places on any given species are what drive them to change and evolve.

This theory of adaptive radiation, though, remains one of the "most contested questions" in Darwin's entire body of work—even the Grants, observing competition between the finches on the Galápagos, struggle to measure competition amongst species that are no longer actively competing with each other. But David Lack, who published *Darwin's Finches* in the middle of the 20th century, recognized that certain islands in the Galápagos don't hold two species of ground finch—he believed this was the "aftermath of a great war" across the archipelago. Lack's theory is that the species realized, over time, that when they were on the same island they were thrown into competition—so they began to seek other niches on other islands.

This passage shows that Darwin's legacy is still evolving itself. Darwin himself could not observe many of the theories he wrote about in action. And even the researchers who are taking up his work in the modern era struggle to observe some of the more obscure evolutionary processes in motion. But others have found interesting patterns in nature that seem to support the theories that Darwin presented to the world.

An American ornithologist named Robert Bowman visited the Galápagos in 1952—and after observing the contents of dead birds' stomachs, he found that many different species of finches were feasting at the same source. Bowman didn't believe that "the absence of competition is a proof of its power"—in other words, he wasn't certain that competition between species was enough to push them into such different niches.

Even though some specialists have found evidence that seems to support Darwin's theories, others have found evidence that shows Darwin's ideas weren't always right. This illustrates the fact that selection, evolution, and adaptive radiation are complex, ongoing processes that humanity must continue to observe closely in order to understand.

Yet the Grants observe, each year as the rains on Daphne Major end, how the finches move apart and specialize based on the level of competition with one another. Each year, in times of drought, the finches are, through specialization, "making room for one another"—which allows them to coexist on the island continuously. Even though in such cases it their behavior that is changing and not their anatomy, that change is still evidence of selection at work.

The same forces that led to the finches' creation continue to drive their behavior. Even if the finches aren't constantly evolving new physical traits from year to year, the observable changes in how they act around one another speak to the ongoing, constantly shifting evolutionary forces acting upon their environment.

The Grants, and researchers like them, are coming to understand that the hierarchy of nature—the "food pyramid" or food chain—isn't necessarily fixed. Within each level there are specialists, called "guilds"—leaf eaters, stem borers, root chewers, nectar sippers, and so on—and these guilds are frequently in flux. Harder times create smaller and smaller guilds, and the many pressures (like competition for food and mates) that are acting on guilds in tough times push those guilds further apart with each passing year.

This passage illustrates that in the face of scarcity, competition, or environmental change, Darwin's finches will carve out new niches for themselves in order to survive. The finches are part of a vast and constantly fluctuating ecosystem. So each finch finds a specialty both in order to stay out of the way of others who are also struggling to survive, as well as to ensure that no other finch will encroach on their own niche and thus threaten their *survival.*

Dolph Schluter, one of the Grants' former mentees, is one of the foremost researchers on Darwinian divergence in the modern era. While studying with Peter Grant, Schluter wanted to focus on the war between small-**beaked** and sharp-beaked finches on the island of Pinta. On Pinta, the small-beaks' and sharp-beaks' territories overlap—but their diets hardly do. Schluter found very little competition between the birds. He was disappointed in his inability to find competition between the finches to study, so he moved to several other islands, mapping how competition drove up beak size and influenced how the finches ate. He ultimately found that the small beaks and sharp beaks essentially divvied up the islands of the archipelago between themselves—they were staying out of one another's way.

This passage shows that species will find more large-scale ways, too, to stay out of one another's niches. This illustrates that the birds are finding small-scale and large-scale methods of lessening competition with other finches. The finches aren't seeking dominion over one another or claim on an entire territory—they know that their chances of survival are best when competition is reduced or eliminated entirely.

After a few years, Schluter had come up with a new way of visualizing Darwinian pressures on the finches. Adaptation and specialization, Schluter suggested, was a process similar to a long climb up to a mountain peak of "maximum fitness." A bird blown to a new island will hardly ever land at the top of this metaphorical peak right away because it is unlikely to be perfectly fit for that new environment. But if it lands somewhere on the side of the mountain rather than down in the valley at its foot (as it will likely die if it is so unfit as to be at the bottom), it can begin to climb, and its descendants will continue the journey until they reach their "adaptive peak".

This passage introduces the idea of adaptive peaks, illustrating how evolution pushes a species, with each new generation, toward the height of their respective niche. This demonstrates that evolution is an ongoing process with a clear goal: to help the evolving species survive no matter the challenges that come its way.

Schluter used his data to run experiments through a computer back on the mainland. By entering ranges of **beak** sizes available to the ground finches on the islands, as well as the range of seed sizes and their numbers, he calculated how many finches a hypothetical island could support—then he made the calculation again and again. The computer drew three peaks, with many deep valleys between them. The computer had, in effect, predicted the existence of three species of finches, each with a beak precisely the right shape and size to crunch the seeds available to it. There could be three adaptive beaks for ground finches on the island—which means that a single species arriving in a new land could, and likely would, diverge into three.

Schluter's computer presented him with three adaptive peaks, and because there are three sub-varieties of ground finches throughout the archipelago, it's clear that his experiment was a success. In other words, Dolph's research confirmed what the island had already shown him, the Grants, and the other researchers who'd traveled through. The computer confirmed that the forces of specialization and adaptive radiation would, in an imaginary scenario, act on the finches in the same way that they did in the real world.

Schluter has applied his research to different species of plants and animals throughout the Galápagos—he thinks that even distant branches in the trees of life are competing, each day, throughout the archipelago. Bees and birds are in competition for the nectar of certain flowers on certain islands; but on islands without bees, the finches have made themselves smaller to fill the bees' niche. Peter Grant believes that divergence is a consequence of the struggle for existence.

This passage illustrates that when different species are in competition one another, they diverge greatly in order to minimize that competition. This is significant, because it suggests that not only are organisms influenced to change and evolve by the environmental pressures of where they live, but also by the other living creatures that share their space.

CHAPTER 11: INVISIBLE COASTS

Darwin himself believed that "the possibility of making distinct races by crossing [or hybridization] has been greatly exaggerated." But the Grants now suspect that selection and crossing work together—that they are part of the same process of species creation. To explain this phenomenon, Weiner turns to the two kinds of shorelines in the Galápagos—visible and invisible. The visible shores are the rocks where volcanoes rise up out of the Pacific—the borders of air, sea, and land. But the invisible shores are the borders that exist between the birds themselves. These boundaries are not so easily seen. The boundaries between the species hold each one apart from the rest—each species is, with the exception of the hybrids, an island unto itself.

Darwin wasn't fully convinced that hybridization could create new species. But the Grants, who have seen many things that Darwin wasn't able to in his lifetime, now know that any force that pulls a species away from the "invisible coast" of its barrier with another species is a legitimate factor in the evolutionary process. These "invisible coasts" keep species apart from one another, but they are not entirely impermeable barriers—they can be approached and even crossed.

Darwin was confused by these invisible coasts between species. He did not fully survey the barriers that exist between them—and what makes those barriers easier or harder to cross. Modern ecologists and evolutionists now know that the isolation of species isn't just in the visible barriers between them, but the invisible ones. Instinct and behavior hold them apart—that is, the innate instinct to keep a line alive rather than blend with the lines around it, and thus disappear. The process of selection helps animals to abide by these invisible coasts, because the individuals that trespass between coasts will suffer a disadvantage: their offspring will have a harder time surviving.

The "invisible coasts" between species incentivize, or encourage, different species to remain with their own kind. Hybrids don't do as well in the wild as their purebred counterparts. So hybridization in nature isn't extremely common, but that doesn't mean that it doesn't happen.

The finches on Daphne Major have a talent for telling one another apart—even with the many shades of variation within each species. Even though their territories, mating habits, and plumage colors overlap, there are marked distinctions between these behaviors in each species. These variations are passed down, sometimes for good or for ill. For instance, finches that somehow learn the wrong mating calls (by, say, picking up a neighbor's call) rather than internalizing the mating songs of their progenitors find themselves in trouble, unable to attract mates.

To the naked eye, the finches that live in the Galápagos are extremely similar—but the tiniest differences between them, as the book has shown, can make a huge difference from an evolutionary standpoint. So, in order to survive, the birds have gotten very good at recognizing the differences among them. But, again, the system is not perfect—and sometimes, birds are influenced by other species in their ecosystem.

While the number of species of finches in the Galápagos is not eternally fixed, they are, right now, true species—they are distinct. So even while some hybrids breed, the species mostly remain apart. To test why birds rule one another out—and what they're looking for when they're seeking mates—Peter Grant and one of his associates, Laurene Ratcliffe, conducted some "ghoulish" experiments using finch corpses. By propping the decoys up and displaying them throughout different territories, they could watch the living finches' responses. The experiment showed that male finches chose the decoy of their own species—even when the heads and bodies of different species were switched, they gravitated to decoys that had the heads of their same species.

This passage illustrates that that when finches are mating, they are looking primarily at one another's beaks. And that fact proves that the quality and integrity of the beak is the main trait that these finches are looking to pass on. By passing on a specific beak type, the finches keep the "invisible coasts" between their different species intact, increasing the likelihood that their offspring will be able to successfully fill the narrow niche already carved out for them and thus thrive.

Mating patterns, though, can change and evolve just as quantifiably as the **beak of the finch**. Experiments with fruit flies bred in total darkness for 14 generations essentially erase the intricate mating patterns that flies usually engage in. All instincts but the instinct to keep the line going evaporate.

Just as the finches' beaks have evolved, morphed, and changed, so too do other things about a species' behavior that might initially seem fixed. Animals are influenced by their ecosystems and by the other organisms around them just as they're influenced by the instinct to mate with other members of their own species.

Sexual selection is a powerful force in the initiation of the speciation process—and researchers like Ken Kaneshiro, who works with Hawaiian flies (of which there are more than 700 species), are studying how sexual selection drives divergences. The pressures of sexual selection are acting fast on these insects—just as the pressures of sexual selection are changing the finch populations in the Galápagos. A preference for even the smallest details during mating can, over the course of a few generations, cause a major split.

During sexual selection, a species' mating patterns determine which traits survive and which traits do not. So if a species mates with its own kind, their most similar favorable traits will be passed down. But mating with a different species or selecting for a member of their own species with different or more variable traits can lead to hybridization, and begin the evolutionary process.

In 1978—the year after the great drought—the Grants began camping near a lagoon on the island of Genovesa. They found that among the cactus finches that surrounded them, there were two groups of singers—A singers and B singers. The As' **beaks** were narrow, shallower, and longer than the Bs'—even though the difference was just about a millimeter. The As drilled holes in the cacti to get at the fruit while the Bs ripped and tore fallen cactus pads. The Grants believed the drought had caused a split in the ground finches on Daphne Major—and that it could have caused a split among these cactus species on Genovesa, too.

The Grants were able to observe a species split in action—and they believed that the forces of natural selection were directly tied to the processes of sexual selection and hybridization that created the two different birds. While the birds were still the same species, their behaviors and physical traits had begun to diverge. In other words, evolution driven by fission was in process.

After observing the cactus finches, the Grants began to believe—based on mating pattern and **beak** size—that the drought had caused a disruption during which selection widened the difference between the beak size. The two groups had now become separate enough, such that they were not mating with each other and were showing signs of the potential for distinct speciation.

This passage shows that, contrary to what many might believe, evolution is a rapid process. Just one or two generations of difference can lead to a species beginning to branch off from its past and pass down new traits to its offspring.

However, by 1981, the link between **beak** shape and songs was completely gone—the birds stopped dividing. In 1985, another drought came, and this time the drought did not partition the birds. The island was a different place by then and many of the cactus plants were gone—and the pressures of selection had begun to favor the short, deep beaks for ripping up fallen cactus pads. There is no new niche—yet—for the finches to split and begin to occupy. Yet the Grants suspect that the finches are in a constant process of being forced slightly apart, then drifting back together. Fission and fusion, Weiner writes, "fight forever among the birds."

The forces of fission and fusion maintain the "invisible coasts" between species. A few generations of birds with variable traits or different behaviors from their forebears doesn't constitute evolution—the species must continue changing and specializing, adhering closely to the "coastlines" that separate them from others, in order to truly evolve. So while parts of the evolutionary process happen very quickly, true evolution can be quite involved.

CHAPTER 12: COSMIC PARTINGS

Nowhere in his writings does Darwin contemplate the moment of divergence itself—the moment when one line of a species splits into two. Weiner calls this "the cosmic parting." But today, as more and more naturalists study evolution in action, they keep an eye out for these "cosmic" splits. Researchers have been able to observe these splits in species like fruit flies and conclude the definitive fact that "each species first existed as a variety," as Darwin wrote so long ago. By observing many generations of fruit flies in lab conditions, evolutionists have watched "incipient species" arise—these new species are unable to produce fertile offspring with specimens that were, just a few generations ago, their kin.

Even though Darwin wasn't able to witness many parts of the evolutionary process in the wild during his lifetime, researchers today are far better equipped to capture these delicate moments in action. Because the process of evolution takes place gradually, it can be difficult to pinpoint the "cosmic" moment at which a species has diverged enough to constitute a new species entirely—but researchers have worked tirelessly to isolate and define that moment nonetheless.

The question of how new adaptations arise from gradual beginnings is one of the central questions of Darwinism. Darwin himself used the example of the evolution of the human eye to suggest that all the sophistications that exist within it grew gradually, in stages, through natural selection for advantageous traits, also called adaptive traits. Adaptive traits are more likely to be preserved—even though the process of creation is, essentially, "blind"—with the result that the advantageous traits build on themselves over time.

While evolution in an isolated place like the Galápagos can begin to take place quickly, evolution is very often a slow and painstaking process in which new, advantageous traits emerge gradually. This illustrates what an intense process evolution is: natural selection, sexual selection, and environmental pressures are all factors in the production and preservation of new traits that help a species to survive and thrive.

In 1991, two researchers at the University of British Columbia studied a genus of finches native to North America, Europe, and Asia called crossbills—their **beaks**, as their name suggests, are crossed. Their twisted bills are adaptive, because these finches eat pinecones and need twisted beaks that allow them to pry the cones open. The researchers clipped the bills of the finches—a harmless process akin to clipping fingernails—so that they were uncrossed. The birds struggled with their food sources, but as their bills grew back, they did better and better.

This experiment revealed something monumental about the evolutionary process. Any crossing of the bill at all helped the finches a little—so the crossed bill could have arisen gradually rather than all at once. This illustrates that the process of evolution is at work from generation to generation, weeding out individuals whose traits aren't different enough to survive while prospering those whose physical traits allow them to better interact with their environment.

Dolph Schluter has begun a new study near Mandarte Island, in the Strait of Georgia—a body of water which is full of three-spined sticklebacks, small salt-water fish who sometimes migrate into fresh water. For 12,500 years, the fish have been evolving in freshwater lakes—just like the finches on Daphne Major. Most lakes in the region hold just one species, but a few lakes hold two. One species (benthics) feeds along the bottom, and one (limnetics) above it. By carefully measuring the fish, Schluter and his team have mapped how selection is acting on the fish.

This passage sets up Schluter's experiment. By focusing on a genus of animal containing two specialized species, Schluter was able to predict how they would behave—and from there, he could watch how environmental differences would impact the fish.

In every lake that contains two species of sticklebacks, the team has found, the two species are divergent in the same way: one always feeds on the bottom, and one always feeds higher up. Benthics are bigger and fatter, while limnetics are small and thinner. The pattern has repeated itself in five different lakes. Even in one lake where all of the fish are technically the same species, the smallest difference in their sizes dictates where they'll feed. Speciation, in other words, is in progress. The populations are ready to respond, at all times, should selection pressure arise. And what's more: these species have altered the course of one another's evolution, filling niches that the other cannot.

This passage shows that the fishes' instincts and appearance drive their behavior. Bigger fish fill one niche, while smaller fish fill another. Just like the finches, the similar fishes have found out how to stay out of one another's way—and thus ensure their own survival. This experiment is also important because it shows that any given species is influenced heavily by its ecosystem, and that includes any neighboring species.

Schluter predicts that the species will continue evolving toward their respective peaks. Because the species are rare and protected, Schluter can't do the kinds of experiments he'd like to—but the ones he has done have made it clear that competition affects populations today, and that natural selection pressurized by competition can be observed. Schluter plans to create a hybrid of benthics and limnetics—then place those hybrids in two false ponds, one containing only benthics and one containing only limnetics, and see how the hybrids change in each pond to fill the niche exposed by their counterparts.

The next phase of Schluter's experiment promises to reveal how long it takes for a hybrid species to specialize. Schluter's work is significant because it carefully explores the process of specialization—even among hybrid populations that might not necessarily be suited for one specialty over another.

CHAPTER 13: FUSION OR FISSION?

Back in Princeton, the Grants are well into their sabbatical year. Their data has revealed that since the El Niño of 1982-83, the adaptive landscape on the islands has changed dramatically. There is far less *Tribulus* and cactus, but more soft, small seeds. So the ground finches who feast on those seeds are doing well, while the cactus finch population is suffering. There are only about 100 left—the lowest their numbers have been since the finch watch began in the 1960s. Yet the cactus finches themselves haven't changed or adapted—they have no other "adaptive peak" to fly to.

This passage is significant because it illustrates how hyper-specialization can sometimes become a liability for a species. When the cactus finches' food source dried out, there was no other "adaptive peak" or specialized niche for them to move toward. So their numbers began to crash. Sometimes, rather than ensuring a species evolves toward a new adaptive peak, specialization can box a species in.

The medium ground finches, too, have been affected—they are flexible in what they can eat, but only to a certain point. *Fortis* with deeper, wider **beaks** are dying—but those born after the flood with narrower beaks were doing better. They have been able to adapt, survive, and nearly replace themselves. After the flood, hybrids, too have been thriving, showing that in a place that changes as rapidly as Daphne Major, it can be advantageous to be on the slope of an adaptive peak rather than firmly at the top.

Being too close to the peak of an adaptive niche was a liability for the cactus finches, who had nowhere else to go and nothing else to eat when their food source dried up. But a species that might not be hyper-specialized or perfectly suited to one specific niche will, in times of trouble or chaos, have an easier time finding a way to survive because they are more adaptive and more variable.

When an adaptive landscape changes dramatically—when a new species wanders into very different territory, for instance—the genetic changes that will allow that species to suitably adapt over time are very large. Two evolutionists, Richard Lewontin and L.C. Birch, published a study in 1966 concerning the adaptive capabilities of fruit flies who migrated from warmer weather to cooler weather. The flies changed as they moved farther from home—and Lewontin and Birch hypothesized that because the original species once lived side by side with a similar species, the two different species passed genes back and forth. The mixture of genes, the two researchers suggested, allowed the flies to expand their landscape.

This passage illustrates an experiment in which two researchers discovered that hybridized genes were actually advantageous for a species that was trying to migrate and change. Being a jack-of-all-trades is often better than being a master of one when it comes to evolution. If a species has genes or traits that allow it to survive well in multiple scenarios, it stands to reason that it will do better than its hyper-specialized peers.

The Grants have taken this research one step further—they've begun to believe that while hybrid offspring might not normally be fit for a given environment, a "rare event" like a drought, plague, or flood can so transform the adaptive landscape that which traits are favored shift immensely and there is a slow fusion of populations. The pendulum swings constantly: sometimes hybrids are at a disadvantage, other times at an advantage. It's hard for fusion to fully take place, though, before fission—environmental change—swings the other way. The Grants have witnessed these swings numerous times over the decades, and they've concluded that hybridization between species "provides favorable conditions for major and rapid evolution to occur."

As the ecosystem shifts around any given species, they might be pressurized to become hyper-specialized and fill a specific adaptive niche. But what this passage suggests is that environmental havoc might also create a situation in which greater variability and adaptability—traits that are conferred, as seen in the fruit flies, through hybridization—are most useful. This push and pull moves species toward and away from evolution over and over again. Again, while the smaller components of the evolutionary process can often happen very quickly, a species' full evolution is a careful process that must be sustained for a long time.

Hybridization among birds was once thought to be very rare—but among the 9,600-odd species of bird alive today, interbreeding is far more common than it once seemed. New hybridization most commonly takes place between different varieties of plants, and it's also been observed often among toads, insects, and fish—generally, within populations that stay in the same place. But in a case like the Galápagos finches, it's becoming clear that every so often, a certain lineage needs "an infusion of fresh variation".

A species that stays forever the same will have trouble adapting as its landscape and ecosystem change around it. And because change is the only constant—whether that change is fast and brief, like the changes caused by El Niño, or more slow-moving and ongoing—species that have "fresh variation" and a greater capacity for adaptability will do better than those that are concretely fixed and unable to interbreed.

"Reticulate evolution" is the name for a kind of evolution that appears more like a tangled thicket and less like the distinct branches of a tree. This kind of evolution doesn't bind lineages together forever—so it's been historically overlooked. But the Grants are taking care to call attention to how their finches engage in this kind of evolutionary behavior. This messiness creates the "bountiful diversity" that defines life on Earth. The forms of living things are constantly in flux—in spite of the invisible borders around them.

The term "reticulate evolution" seems to aptly describe the kinds of changes taking place among the Galápagos finches. Rather than constantly branching off onto new limbs and separating themselves from one another, the finches' evolutionary patterns are entangled and circuitous. The finches change based on their environment—and while new speciation doesn't always happen, the finches are able to find new ways to change and survive continuously based on the demands of their environment.

CHAPTER 14: NEW BEINGS

The Grants are meticulous in gathering, storing, and interpreting data. They've been able to verify, through computing, the hypotheses about evolution they've observed in action in the Galápagos. It is not, they've shown, impossible to test the theory of evolution by natural selection. And it's only through data that the Grants have been able to see the "coasts" and "pendulums" that are invisible to the naked eye.

While the Grants might observe something interesting in the wild, it's only through analyzing their data carefully that they're able to understand the minutiae of what's happening each day on the island of Daphne Major. This shows that while selection, hybridization, and evolution are indeed ongoing processes, they are intricate and ever-changing ones.

The Grants' discovery of the rise and fall of mixed breeds of finches doesn't take away from the theory of natural selection—in fact, it shows clearly that the finches are "new beings" on Earth, and that intense selection pressures continue to shape their creation. If natural selection weren't at work, the many species of finches would vanish into one.

While it might seem that hybridization means that natural selection isn't at work, the opposite is in fact true. This passage illustrates how selection keeps the species distinct and powers new species to branch off and develop specialized traits, again underscoring that evolution is constantly ongoing from generation to generation.

To observe the finches is to see the process of evolution at work—the finches are unfinished. Now, roughly one in 10 finches born on Daphne Major are hybrids—and the hybrids are doing better than any other species. This means that the individuality of the different species is threatened. The species still aren't completely, distinctly carved—so it is the delicate tension between fission and fusion that keeps them separate.

Hybrids are doing well on the islands because they're much more varied and adaptable than their highly specialized counterparts. So changes in the ecosystem and the weather are important in terms of keeping the species distinct. The finches remain heavily influenced by their environment in all aspects of their lives.

Adaptive radiation is part of the answer to why there are so many species of animals on the planet. In Hawaii, a single finch has radiated into more than 40 species with 40 different beaks. The same has happened with fruit flies there: some are predatory, some parasitic, some nectivorious (which means they eat nectar) and some herbivorious (which means they eat plants). Cichlid fish in East Africa, too, have evolved from one species into about 200.

All of these radiations taking place in nature prove that evolution is still in action, animating every moment in the history of life. The creation of new species allows a certain genus of animal, insect, or plant to survive, multiply, and thrive. So adaptive radiation, hybridization, and specialization are all key components of the evolutionary process and the sustenance of the world's ecosystems.

As the Grants' sabbatical year winds down, they marvel over the idea that new species of finches could still take off—an evolutionary response to the increasing hybridization could yet happen, and a new species could form. As Weiner listens to the Grants discuss this possibility, he observes that they become extremely excited by the potential for evolution—but then mutually decide that only more numbers and measurements will reveals for sure what eventually happens to the finches.

The Grants never put pressure on their research to show them a certain outcome—even if it's an outcome they're really excited about. The Grants know that as human beings, they have a responsibility to nature—and that responsibility informs how they conduct their research, their analysis, and the thinking and writing that allows them to draw conclusions about what the finches are showing them.

CHAPTER 15: INVISIBLE CHARACTERS

On the floor below Princeton's Natural History Museum is a drab basement corridor which leads to a subbasement—there, the Grants keep a Galápagos archive, containing hundreds of vials of the blood of Darwin's finches. In his day, Darwin imagined a secret code that might be used to explain what determines the variations of species—today, of course, biologists and evolutionists recognize this secret code as a being's genes.

This passage, once again, shows how while Darwin had a spot-on hypothesis about the evolutionary process, he was constricted by his era's technological limitations and unable to see it in action. But today, researchers can actually examine how the physical forces of selection and hybridization change an animal or plant's internal code, as well.

Weiner watches as Peter Boag extracts DNA from frozen finch blood, bathes the DNA in an enzyme solution which fragments the DNA, and then transfers the fragments into a nylon bag. Boag is just one of many former finch watchers to "go molecular"—in other words, his research now focuses on DNA. Once Boag X-rays the DNA, he will be able to zoom in on small fragments that interest him—he is one of the first people to look at the DNA sequences of Darwin's finches.

Peter Boag is a former field researcher who has narrowed his focus. His interest in the finches' evolution has brought him to the forefront of a new filed—one in which he can look on a much closer level at the exciting changes taking place in the finch populations from year to year. This passage suggests that this kind of research is essential—in other words, the kind of work Boag is now doing supplements and enhances the work the Grants and other field researchers are doing.

A Galápagos finch has about 100,000 genes—about the same number as a human being—and those genes are spelled out in a total of roughly 1 billion letters. Only four letters make up the sequence: G for guanine, A for adenine, T for thymine, and C for cytosine. The finches' genes are not fixed—they are shuffled and cut in each generation like a deck of cards, and each finch is completely unique. Mutations in the genetic sequence lead to variation: a mutation might cause cancer, or it might confer a small benefit on the finch, allowing it to survive and pass that favored mutation on again and again. Boag looks for slight differences in the sequences of letters that make up the birds' DNA.

The physical expressions of mutations are seen, for example, in the finches' changing beak sizes and shapes from generation to generation. But it's the finches' DNA that truly holds the answers to which mutations are happening and when. By zeroing in on these mutations, researchers can learn more about why some mutations or changes are advantageous, while others are life-threatening liabilities.

Evolutionists can learn more about "the lost history of life" from studying DNA. They can discover which animals are related, and how. Just as historians can now backdate Darwin's manuscripts based on spelling errors he made at certain points in his life, biologists can sort out how Darwin's finches have changed and when the most major changes took place. The finches that look most different—for instance, warbler finches—are those that have been evolving for the longest. Mutations spell out the answers to when certain species began to diverge—but because genes are like manuscripts that are being written and revised constantly, there are still many answers that evade Boag and his team.

Observing animals and plants in the wild isn't the only way to learn about hybridization, change, and evolution: looking at a species' DNA can reveal a lot about the specific, small changes they go through. And this is especially the case in a population that's changing so quickly and so constantly.

In times of stress, species like bacteria have been observed to start evolving wildly—it is a kind of SOS response, increasing the chance that at least a few cells will gain the variations necessary to survive the changing environment. This same response has been seen in plants—and many evolutionists, including the Grants, believe that the same thing has happened (and is now happening) to Darwin's finches. A major event seems to be taking place.

By spreading out the gene pool, intercrossing, and multiplying quickly, a species' variability increases—and this increases the likelihood that none of the species' gene pools will run too low. It is a careful and ingenious stress response, and it ensures that as the forces of selection move through a population, the fittest will be spared.

CHAPTER 16: THE GIGANTIC EXPERIMENT

From his very first moments in the Galápagos, Darwin knew that the birds of the archipelago had no experience with human beings—they didn't recognize Darwin and his team as predators, and they'd perch on their shoulders or on their cups. But Darwin did know that invaders always bring change—one of Darwin's contemporaries used the example of polar bears arriving in Iceland to illustrate this point. Polar bears, arriving in the country on an iceberg, began eating the animals like foxes, deer, and seals, who didn't recognize them as predators. With fewer deer on the island, the plants and insects prospered—and with fewer foxes, the ducks multiplied, thus reducing the fish population. Darwin could only imagine "what havoc the introduction of any new beast of prey must cause in a country".

Darwin knew that the introduction of any new species into an ecosystem—whether that new species was just visiting or became part of the ecosystem's population—could create utter chaos and set off a chain reaction that would forever change that ecosystem. This illustrates both the delicate interconnectedness of all the parts of any given ecosystem—and it also suggests that humans, in particular, are responsible for taking caution when entering any new ecosystem. Because we have consciousness of how our actions can affect the plants, animals, and biospheres around us, the book suggests, we must take responsibility for those actions.

Another example of this phenomenon Darwin referenced involved introducing cats into an English village. The cats would eat the mice, he predicted, and so a lesser population of mice (which ate honeycomb) would allow beehives around the village to thrive and expand. More bees would be able to pollinate more flowers—and so in time, Darwin predicted, the arrival of the cats would directly result in a flourishing of local flower populations.

Darwin argued that a complicated web of relationships bound all the living things in any region—and adding or subtracting even a single species from that web would inevitably cause chaos and waves of change.

Just as El Niño spurred an evolutionary event on Daphne Major, the introduction of a new species of plant or animal, too, could create conditions that would pressurize selection toward evolution. Darwinian pressures, Weiner suggests, are intensifying "everywhere we look."

In the fight for survival, it's clear that species are shaped by the plants and animals around them just as much as they are by soil, climate, and weather events.

In 1898, the evolutionist Hermon Carey Bumpus was living in Providence, Rhode Island when a strong blizzard killed hundreds of sparrows. Bumpus collected their corpses, took them back to the lab, and studied them—he determined that the sparrows had been through what's called a "stabilizing selection" event, because there were simply too many of them. The ones less equipped to survive—the ones that were largest and smallest—died quickly, which means that the rest of the species was pushed toward a more stable mean.

This stabilizing selection event shows how sometimes, the forces of evolution can select for a version of a species that hews closely to the middle of the road. Variations within the species are eliminated because while they might be in the process of specializing, they're not equipped to survive. So the hardy, average members of the species do best in harsh conditions, and they pass down their ability to weather difficult times.

The chain of events spurred by the introduction of a new species, too, can be seen in everyday life. An evolutionist named Scott Carroll is studying beaked bugs called soapberry bugs, and just as finches' **beaks** adapt based on the food they eat, so too do those of the bugs. The bugs are evolving rapidly in many different locations based on new plants that are introduced to their territories.

The bugs described in this passage are also being influenced to evolve by their environment. By specializing based on the demands of a certain food source, the bugs are ensuring that as long as that food source is around, they will be nourished and protected. Once again, this passage shows how interconnected species and the ecosystems in which they live truly are.

In the late 1860s, a British naturalist living in America, Benjamin Walsh, became inspired by Darwin's writings and decided to study the haw fly, a native American fruit fly that consumes hawthorn. But in Walsh's time, some of the flies had abandoned haws and begun to eat apples. This was only happening in certain parts of the country, but Walsh predicted the flies would multiply and expand their region. Sure enough, by 1902, the flies were not just in the Hudson River valley, but also in Vermont, New Hampshire, Maine, Michigan, and Georgia.

Walsh's prediction that the flies would be able to expand their range because they were adapting quickly to a new food source along the way came true. This example illustrates the evolutionary power of specialization and suggests that a very niche specialty allows even vulnerable hybrid species to survive and thrive.

Today, biologists have observed that the flies' lives continue to grow more and more entwined with the apple trees—the trees are where they feed, mate, and grow from larvae into insects. New technology allows modern-day researchers to study what's behind these changes on the molecular level—and it's clear that these flies are still in the early stages of divergence.

Even though the flies aren't finished with their evolutionary process, they're developing new behaviors and methods of survival that continue to specialize them. By becoming more specialized and connected to their food source, they increase their chances of surviving in an environment containing an abundance of that food source.

The same thing is happening, unseen, in thousands of other species around the world. For instance, as farms become more and more specialized, focusing on individual crops, the insects, too, are specializing, evolving to feed on specific types of fruit and becoming isolated based on that specialization.

This passage once again confirms that different organisms living within the same ecosystem are easily influenced and pressurized to evolve by one another. As an ecosystem changes, the animals within it will change, too, in order to keep up and survive.

CHAPTER 17: THE STRANGER'S POWER

Certain tracts of land throughout the more lush and verdant islands of the Galápagos have been cleared for farming and cattle pastures—all of these plant and animal species are new to the islands. In the village of Puerto Ayora, the biggest settlement in the archipelago, finches fly around amongst humans, eating crumbs dropped by people. A librarian at the Charles Darwin Research Station frequently throws rice to the finches that gather around the complex—sometimes, the birds eat right out of her hands, and once, she believes a wounded finch flew into her bedroom, seeking help with its affliction.

The habits of the finches that live in and around Puerto Ayora illustrate their variability—the finches' lives have intertwined with the humans'. The people of the village live in harmony with the finches, but their relationships are a testament to how easily influenced by environmental pressures and other living organisms these birds truly are. The book suggests that humanity needs to thoughtfully consider how their actions affect the other living things within their ecosystem.

The arrival of human beings in the archipelago has begun a new phase in the finches' evolution—but the direction of that phase remains unclear. There are changes taking place, but Peter Grant insists they're difficult to observe. The finches on the island of Santa Cruz, though, have started to appear more homogenous to the Grants—they seem to be fusing. The lessening pressure of the struggle to survive seems to be "turning [the birds] into a hybrid swarm." But on the uninhabited islands like Daphne Major and Genovesa, the struggle is still just as intense—the rapidly-changing weather conditions on those islands keeps the birds from ever really fusing.

This passage shows that in situations where a species' survival is relatively unthreatened, the evolutionary pressures on them will begin to lessen—and as a result, they'll stop making behavioral changes and developing such starkly different physical characteristics. But in places where environmental pressures continue to fluctuate, constantly encouraging a species to prize different traits at different times, divergence and evolution will continue to unfold at a rapid pace.

Decades ago, the botanist Edgar Anderson argued that human beings' presence in new places would lead to increasing hybridization of those places' plants and animals. The hybrids will require increasingly odd habitats for "optimum development," he suggested, predicting that the offspring of hybrids would be new and strange and would as such require new, strange environments to thrive.

Anderson's research suggests that humans had begun to hybridize the planet through their presence alone—and that the species they were causing to hybridize would forever change the world's ecosystems.

Botanists have observed this phenomenon from the Ozarks to the Mississippi Delta—farmers who treat their lands slightly differently can cultivate plants that won't thrive anywhere else. Wherever species that belong to different faunas and floras are brought together, the barrier systems between them break down—and in chaotic times, hybridization helps evolutionary mechanisms to work faster. Humanity is disturbing habitats and intensifying the pressures of selection—and so we're causing evolution to run "at its maximum rate."

This passage illustrates how the everyday activities that humanity takes for granted as unexceptional are actually creating unprecedented, exciting, and potentially destabilizing new evolutionary pathways for the plants and animals that share our ecosystems. Hybridization means that more species can survive in rapidly changing or unstable conditions—so the rapid, prolific hybridization of the species around us means that humans will have a harder time eradicating the species whose evolutionary processes we disrupt.

A giant finch specimen Darwin collected on his first voyage to the Galápagos was found to be extinct just three years after Darwin and his team visited. The birds died, it's hypothesized, because of the disruption that the arrival of human beings brought to their island. A prison colony had been erected on the island of Floreana, and as they cleared land, planted crops, and hunted wild pigs, the alchemy of the island changed. The large finches were suddenly vulnerable to rats, cats, and more—and at the same time, the cactus plants they fed on went extinct.

Though some species are quick to hybridize in order to survive changes, this passage illustrates a historic example of how human intervention can derail the evolutionary processes not just of different species of plants or animals, but of an entire interconnected ecosystem. Humanity must be more conscious of how its activities can interrupt or annihilate a species' entire evolutionary history.

Today, the scientists working at the research station know how fragile the ecosystem of the Galápagos is, and they're working to save the most vulnerable animals on the islands. The Grants and other researchers like them are careful to wash their belongings in salt water before stepping foot on an island like Daphne Major and Genovesa, where even a single pair of ants could, in a short time, destroy the entire ecosystem and spur evolution events that would forever change the island's populations.

This passage offers a tangible example of how even the tiniest change to a fragile, isolated ecosystem like those of the Galápagos islands of Daphne Major and Genovesa can have rippling effects throughout the entire biosphere. The Grants recognize the responsibility they shoulder in venturing to these places and inserting themselves into the local ecosystem—and all of humanity, too, should think more carefully about how we interact with vulnerable species in vulnerable places.

The Hawaiian islands, too, offer a prime example of how fragile ecosystems are. When human beings arrived—bringing species like pigs, goats, rats, mosquitos, roaches, centipedes, and scorpions with them—many native populations went extinct. In 1967, the U.S. Fish and Wildlife Service brought some endangered species of Hawaiian finches to Laysan, a small cluster of uninhabited islands north of the main archipelago—and within just 20 years of their arrival, they began to evolve in different directions.

This passage shows how fragile the planet's ecosystems truly are—especially those that are isolated, like the Hawaiian islands and the Galápagos archipelago. The introduction of even one new species would be enough to throw such an ecosystem into chaos—and the arrival of many new species at once will always have drastic, irreversible effects on how an isolated species evolves.

Human beings like the Grants and their fellow researchers are aware that projects like moving the finches to Laysan "tinker" with the course of evolution—it is difficult to preserve a species when human pressure inevitably steers that species toward selection. But there is beauty, as some researchers point out, in the astounding rate of change in places like the Galápagos.

This passage essentially states that there's no way to keep humanity's influences entirely out of the way of evolving species of plants and animals. Nevertheless, humanity should marvel at how interconnected, variable, and ever-changing plants, animals, humans, and the ecosystems that sustain us all truly are.

CHAPTER 18: THE RESISTANCE MOVEMENT

Martin Taylor, a researcher in the Grants' subterranean lab at Princeton, receives huge shipments of moth specimens every day from all across the U.S.'s Cotton Belt. He grinds the moths up in a mortar and pestle to extract their DNA. Taylor is studying the moths because they have, over the years, developed a peculiar and stunning resistance to pesticides. The moths that were able to tolerate initial sprayings of DDT in the 1940s passed on their genes to their offspring—and now, no matter how big the dose of DDT, the moths are able to survive it. The moths have developed resistances to other pesticides, as well. The pesticides' inability to kill the moths, which feed on cotton, is panicking farmers across the region. It's also an example of "visible evolution."

Evolution isn't just happening in the Galápagos—it's taking place around the world, especially in spots where humanity is putting intense selective pressures on the species around them. In the case of the Cotton Belt's moths, humanity's attempt to stop the creatures from being able to evolve is actually the very fuel the species needs to carve out new niches for itself and find new ways to survive. By ignoring the effects we have on the species around us, humanity is only frustrating itself.

Other insects, too, are rapidly developing complete immunity to commercially available pesticides. Some insects have evolved chemical antidotes to pesticides, or ways of dodging the poison such as by letting a poison-afflicted appendage fall from their body. These evolutionary mechanisms can develop over the course of a single growing season, which also spans multiple generations of the insects.

This passage depicts the process of evolution in action. By presenting a threat to a species' survival, humanity unwittingly ensures that the threat pressurizes the species in question to develop ways to survive. In other words, the more humanity does to control a species, the more adaptable and thus uncontrollable the species will become.

By studying the moths' DNA, Taylor is working to determine how, biologically, the insects are resisting—and what this might mean for other species with which they share DNA. The moth's gene that allows it to resist the pesticide is the same gene that many pesticide-resistant flies have—which shows that these "fixed categories" of different species are not as fixed as certain people (cotton farmers, especially) would like to think.

The physical and behavioral effects of evolution can be seen with the naked eye—but there are still stories to be told in an organism's DNA that reveal even more about the minutiae of the evolutionary process. By looking at animals like these moths on a molecular level, scientists can develop a greater understanding of how these extraordinary specializations are taking place.

"Resistance movements" like this one are happening throughout the natural world. After the arrival of antibiotics in western hospitals in the 1950s, antibiotic-resistant bacteria appeared within just a year. Now, antibiotic resistance is being termed a "global epidemic." Bacteria like *E. coli* grow so rapidly that when dosed with an antibiotic, the few surviving cells in the colony are able to replace their lost numbers within a day or two. The insides of a human body, then, becomes a site of natural selection and evolution in progress.

This passage shows that the forces of natural selection and evolution are strong enough to create a "global epidemic" that could one day change the course of the wider evolutionary process forever. Bacteria are simpler life forms that crop up in extraordinary numbers, so scientists can watch their evolutionary behaviors unfold even more quickly than naturalists can observe them happening in finches or guppies. Natural selection and evolution aren't just taking place in the wild—because of bacteria, they're processes that are even taking place within us. Again, this passage suggests that humanity must recognize the role we play in the evolutionary processes of the species around (and indeed within) us.

Investigators have fully mapped the genetic sequences of many kinds of viruses—but the sequences of viruses are always changing. Viruses evolve at a mutation rate of about a million times the rate of the human body—the weapon of the virus, Weiner writes, "is variation itself." And viruses are constantly evolving—they are "our only real competition for domination of the planet," says one microbiologist. The harder we attack bacteria through antibiotics, viruses through therapeutics, or cancers through chemotherapy, the more ably these rapidly growing resistance cells evolve. In other words, "whenever we aim at a species point-blank […] we drive its evolution."

The quotation that appears at the end of this passage is significant, because it illustrates that the natural world is evolving directly in response to humanity's attempts to control it. By "aim[ing]" at a species directly, humanity influences how that species evolves. The species will almost always try to get out of the way of humanity's range and thus ensure its survival—so anything we do to attack nature will, ironically, often result in nature growing stronger and finding new ways to evolve out of our metaphorical sights.

Elephants in regions of Africa where poaching is common have begun to evolve to be tusk-less. In order to protect the resource that humanity is "point-blank" trying to take from them, they are evolving in a way that's detrimental to their short-term well-being but essential to their long-term survival. The same kind of things are taking place in fisheries. Fish are becoming smaller, since bigger fish are the ones prized by fishermen and the consumers they sell to.

This passage confirms that animals are adapting and evolving in order to survive humanity's attempts to cull their numbers. Animals with traits that are less desirable are becoming more common, because being insufficient prey for humanity is now an advantageous trait.

The moths are evolving at a rate faster than what Taylor can keep up with. But farmers are still trying to shoot at them "point-blank." Ironically, the more preventative spraying these farmers do, the more capably they arm the evolving moths against their attacks. The more pressure humanity places on bacteria or moths or fish, the more we force them to evolve around that pressure. What humans call "control" is merely, to these organisms, a change that must be met, and a challenge to which they must rise.

The book underscores that evolution is real, and it will, given the chance, undermine any attempt to control it. Humanity must recognize that evolution is happening in order to work with and understand it. Only by realizing how our actions impact the species around us will we be able to work with rather than against the evolutionary processes happening all around us.

CHAPTER 19: A PARTNER IN THE PROCESS

Peter and Rosemary Grant have witnessed, together, the transformation of the idea of evolution from theory to fact. Now, they're witnessing something else: the transformation of the idea of climate change from theory to fact. Global warming began in Darwin's era—around the 1880s—and the 1980s were the warmest decade of the 20th century. The amount of carbon and other gases and pollutants in the atmosphere is rising, and heat is becoming trapped in our atmosphere. The Galápagos Islands are particularly vulnerable to the effects of warming, because the seasons there are driven by the ocean currents. When temperatures change, so too do the flows of the Earth's ocean currents.

Many people didn't believe Darwin's theories for a long time—but the book underscores that they were true all the same. Now, it is difficult to get lots of people to accept that climate change is real, and that it presents an existential threat not just to humanity but to the evolutionary processes that are unfolding each day all over the world. Humanity has a responsibility to accept our role in the climate crisis and do what we can to prevent the evolutionary processes of the Earth's species from being interrupted or derailed forever.

If the seasons in the Galápagos weren't so variable, the finches wouldn't need such variable **beaks**. A change in the ocean's currents—and thus the seasons on islands like Daphne Major—would mean an enormous, rapidly evident difference in the evolutionary patterns of the animals that call the Galápagos home. The freakish weather the Grants witnessed in the early 1980s, it turns out, might not have been coincidence. It could have been a casualty of warming (and a sign of more intense changes things to come).

Darwin's finches are the special and extraordinary animals they are because of the environment in which they live and the unique pressures it places upon them. If those pressures are thrown into overdrive, there's no telling what the damage to the fragile finch populations might be—especially among the new hybrid populations that are just beginning to thrive and branch out.

If global warming did cause the El Niño of 1982, and if the planet continues to warm, selection will create more fusion in the species of finches on Daphne Major. And the return of selection's role in keeping the species varied could take a long time to come. The harder and more frequently the Galápagos are hit by extreme weather, the more quickly the finches will fuse—that process, given climate change's current trajectory, could take only a century.

This passage illustrates how human-hastened climate crisis stands to erase millennia of intricate evolutionary processes around the world. The book stresses that if humanity doesn't recognize its role in the world's ecosystem, entire species could be wiped off the map.

Humanity's power to drive Darwin's process has been observed before: in 1848, a Manchester lepidopterist (a naturalist who studies moths and butterflies) named R.S. Edleston realized that a species of whitish-gray moths with black stripes were turning black. The moths, it turned out, were evolving to better camouflage themselves amongst the grimy, soot-stained buildings of the city, which was at the epicenter of the Industrial Revolution. The moths' relatives in the countryside weren't evolving—their color remained the same as they had long been. In the middle of the 20th century, after Britain enacted clean-air legislation, the moths began evolving back to their former states.

This passage illustrates just how profoundly the plants and animals that surround us are at the mercy of humanity's actions. Human activity can force major evolutionary events within the ecosystems around us—and often, we're not even looking closely enough to notice. Humanity, this passage suggests, has a responsibility to work to understand how our activities impact—and often threaten—the species with which we share the planet.

The carbon dioxide that drives global warming is just like the soot that turned the moths black—only it's invisible, and it's everywhere instead of concentrated in cities. In other words, it's pressurizing selection processes in ways we can't yet see. Another force influencing and accelerating evolution is genetic engineering. Some genetic engineers who work to create different strains of crops and (even different varieties of mice) in their labs call their work the Generation of Diversity, or G.O.D. for short.

Humanity is, in several ways, rapidly changing the environments of life without fully understanding the consequences our actions might create. By pointing out that many genetic engineers cheekily compare their work to God's, Weiner is point out humanity's hubris, or overabundance of pride and recklessness.

To understand our present, Weiner posits, we must look to the past. Darwin's finches, then, become symbols and heralds of the events taking place everywhere around us. The whole planet, now, is a demonstration of the power of Darwin's processes—and humanity is both the effect and cause of those processes, a relationship many might prefer not to contemplate. Only five times in the entire history of the world, the fossil record shows, has there been this much "havoc" on the planet—and all five times, most of life on Earth went extinct.

This passage suggests that we are presently in the midst of one of the most dramatic evolutionary moments since evolution began. The "havoc" on our planet suggests that something big is about to happen. But this moment isn't unprecedented in the fossil record—and, in fact, the big event that might be on the horizon could very well be a "stabilizing selection" event that threatens all kinds of life forms on the planet. Humanity must recognize the fragility of its environment.

CHAPTER 20: THE METAPHYSICAL CROSSBEAK

Humanity has long struggled to understand why we, as a species, developed consciousness and self-awareness—and the consequences of how this development has set us apart from the other species with which we share the planet. Evolutionists still debate what led to this split in development. Crossbills, hinged jaws, and specialized talons help certain finches to survive, but those adaptations are smaller than the leap from ignorance to consciousness.

This passage shows that this chapter will investigate the "metaphysical crossbeak" humans have developed. In other words, this chapter is going to delve into the unique specializations that have allowed humanity to grow and expand into new niches. Even though consciousness is a different kind of trait than a special beak, Weiner is attempting to draw a parallel between humanity's evolutionary advantages and the evolutionary advantages that appear in other species. Humanity must recognize that we, too, are only animals—and that we, too, are sensitive to the processes of evolutionary biology.

Humans walked upright for millions of years before our brains and skulls expanded in one of the most "dramatic evolutionary changes in the fossil record." The human brain tripled in size after that development. We developed opposable thumbs and our hyoid bone changed shape, allowing for speech. And somewhere in this series of evolutions, consciousness heightened. And it is this trait that sets humanity apart from other species most profoundly—so much so that we consider ourselves in a different family from other primates. But in reality, humans are as genetically close to chimpanzees as ground finches are to tree finches. Neurobiologists are still looking for the origin of consciousness in the brain: our "metaphysical crossbeak."

By drawing a connection between the "dramatic evolutionary changes" that humanity has gone through and the specialized "crossbeak" belonging to certain species of finches, Weiner is once again suggesting that humanity is more like the species that live all around us than we might like to think. He argues that our capacity for consciousness is not something divinely granted to us: it's just another advantageous evolutionary adaptation that has allowed us to fill a particular social and ecological niche.

Humanity's heightened consciousness has allowed us to carve out adaptive niches quite rapidly. But other species, too, are still evolving and learning: blue tit birds in England are learning to peck open holes in milk bottles left out overnight, monkeys in Japan are learning to wash their food before eating it, and octopi in Italy are able to observe one another's mistakes and learn from them, so as not to repeat them.

Humanity was able to radiate in so many ways because of our ability to pass along knowledge to our contemporaries and our offspring. Now that other animals have been observed engaging in this behavior, naturalists and biologists are wondering what might happen if natural selection starts to favor various animals' abilities to share knowledge with their own kind, and retain that knowledge from generation to generation.

Cultural evolution, these anecdotes show, is not unique to our kind. On Cocos Island in the Galápagos, where the finches are all one single species, they are not radiating into new variations. Neither is humankind—our environment has become too small. Humans are "specialized in our despecialization"—in other words, we aren't hyperspecialized like, say, cactus finches, but that very despecialization has allowed us to thrive in a variety of environments. And as we fill more and more niches, we pass on our learning through collective memory.

This passage shows that humanity has indeed evolved to reach an adaptive peak. We're different from the finches—but in many ways, we're still living examples of natural selection and evolution's power to force a species to evolve in a certain way. Humanity, the book suggests, must realize this in order to fulfill our responsibilities to the many species with which we share the planet.

Many believe that humanity is static, immune to the pressures of selection. But individual humans are much more like finches than we'd like to think: we all start out as fledglings, then enter a phase of "wild experimentation," then "narrow" our scope and seek trades in which we can successfully fill a niche. Humans are evolving, and, in the process, driving evolution around us. But a species that can only survive by causing such havoc is at risk of extinction—the whole planet, Weiner writes, is like a "twisted pinecone" we are trying to pry open.

By comparing humankind to Darwin's finches, Weiner is highlighting that humanity isn't necessarily special among the many life forms on Earth today. Humanity needs to learn in harmony with its fellow creatures in order to survive. By denying our own ongoing evolutionary processes—and by attempting to do things that create havoc for the rest of the planet, like expelling carbon into the atmosphere—humanity is dooming itself along with the Earth's plants and animals.

Just as cactus finches on Daphne Major sometimes accidentally snip the reproductive organs of the cactus flower in the process of eating it—thus cutting off their only food sources' ability to reproduce and nourish them—humanity is, in essence, "stealing from [our own] future[s]." Often, the needs of the individual clash with the needs of the flock. Yet Darwin optimistically called mankind "the wonder and glory of the universe."

Weiner suggests that Darwin's belief in humanity's unique, innate "wonder and glory" is useful for modern people to consider and internalize. There is always the chance that humanity will wind up negating its own future chances for survival through the struggle for power or hubris. But hopefully, as humanity continues to grow and evolve, we can add to what the generations before us have learned for the better, as we were born to do.

EPILOGUE: GOD AND THE GALÁPAGOS

It is March of 1993, and the Grants are back on Daphne Major. They are practically tripping over the numerous finches that are flying and darting everywhere, hopping on the ground before them and perching on their shoulders. There have been three El Niños in a row. It is the Grants' 21st year on the islands, and more birds are breeding on the island than ever before.

After several decades of research on the island, the Grants are still continually surprised, delighted, and baffled by the island's unique and unpredictable ecosystem. They remain connected to Daphne Major emotionally and intellectually, and they still often have no idea how the island will shock them next.

A 1993 poll showed that nearly half of U.S. citizens still do not believe in evolution. But scientists like Schluter insist that Creationists should understand that evolution is, indeed, Creation at work. When the Grants talk to strangers about their work without mentioning the word "evolution" those strangers are fascinated—but often, the minute the word enters the conversation, their faces turn cold. Darwin himself was surrounded by Creationists, yet he could not ignore the reality of evolution.

Here, Weiner points out the contradictions and setbacks that the field of evolutionary biology is still facing. Many people are unwilling to accept evolution as fact—but the book suggests that even those who believe in Creationism are able to see the undeniable facts that the Grants and their colleagues have brought to light. An ideological battle over evolution is still ongoing—yet it is, it seems, becoming more difficult all the time to ignore evolution's visible impact on the world.

Trevor Price, Lisle Gibbs, Peter Boag, Laurene Ratcliffe, and Dolph Schluter continue their research projects around the world. The Grants, meanwhile, have overseen two dozen generations of finches during their work on Daphne Major. No other human being has traveled as far along this line of research as the Grants and their many associates have.

The Grants and their students have made immense contributions to the field of evolutionary biology—they've achieved more than many even thought possible. Because these individuals understand key concepts about evolution's ongoing nature, the natural world's extreme sensitivity, and the impact of humanity on the world around them, the Grants and their former mentees have been able to watch the processes that govern life unfold with clear eyes and open minds.

The original meaning of the word *evolution* suggests the unrolling of a scroll. The scroll, in the Darwinian view of evolution, is never finished being written—it's still being inscribed as it unrolls, its letters composed moment-to-moment.

By looking at evolution as a process that is forever ongoing—not just in the fullness of time, but from moment to moment all around the world—humanity can perhaps understand how delicate and interconnected the world's organisms and ecosystems truly are.

Just as the finches were able to expand in so many different directions because they were the first to arrive on Daphne Major, humanity continues to radiate because we "stumbled into our new niche" first. Chimpanzees are making tools, though, and becoming more varied in appearance and disposition—and where there is genetic variation, there is room for selection and evolution. Life all over the planet, in fact, from primates to the inanimate molecules that live in the volcanic vents at the bottom of the sea around the Galápagos, continues to evolve.

This passage essentially suggests that humanity's success as a species comes down to chance. Having "stumbled" into a niche that allows us to thrive was pure luck—now, humanity must contend with its status as just one species within a spectrum of continually evolving organisms. Life is changing all around us, and some things may even be changing within us.

Now, humanity looks to the planets around us to see if we are truly the first—or just the first on this particular "island" that is our planet. We are constantly calculating our changes and our futures, gauging whether we will be able to travel to the next rock, the next peak—or whether we will stay where we are.

Humanity has long considered its evolutionary stage to be fixed and final—but there may yet be adaptive peaks for us to struggle against and summit. Humanity is not exempt from the ever-changing landscape of the natural world and all the continuously evolving organisms within it.

Geological surveys of the sea floor around the Galápagos show that there are lava cobbles, or stones of cooled lava, that formed above sea level clustered around sunken volcanic peaks. These lava stones, experts suggest, are 5 to 9 million years old. The volcanoes were once above the water, but they've now sunken back down—and new islands have taken their places. Daphne Major is a place that was here before us and will be here after us. But one day, it will sink, and something else will rise in its stead.

This passage demonstrates that the rise and fall of life is continuous, and it is taking place all around us. Through the book's final lines, Weiner impresses upon his readers that the only constant on this planet is change. Even the Galápagos islands are a living representation of nature's inevitable shifts over time.

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