On the Origin of Species Study Guide

On the Origin of Species by Charles Darwin

Contents

Plot Summary

The Origin of Species is an extended argument for the belief that species that are now living were not created independently by God, but evolved from other, past species through the process of natural selection. The text of the book is divided into two purposes: first, explaining what natural selection is and how it could produce species; second, responding to the objections of those who do not agree with it.

The book opens with an introduction that provides an outline of the book and its general purpose. The first chapter discusses how plants and animals exhibit variations in physical traits and behavior when kept domestically and how breeders use these variations to improve their stock. The purpose of this chapter is to provide an analogy to how nature gradually changes and improves forms of life living in the wild. For the analogy to work, however, variations must also occur in nature, and proving this is the purpose of the next chapter. Now, all forms of life are engaged in an endless struggle for existence with one another. This is the result of two facts: all organisms reproduce very rapidly and there are far too few resources to support all of them. Therefore, only the strongest organisms that are best adapted to the circumstances in which they live will be able to survive and reproduce. This also implies that when an organism is born with a variation that gives it some advantage in surviving (or reproducing) that it will, by that fact, have a greater chance of surviving, reproducing, and passing on that trait. This is known as the process of natural selection, whereby helpful variations are gradually accumulated. Over time, natural selection can greatly modify organisms to such a point that they no longer belong to the same species, and this is how all species came to be.

However, many objections can be and have been raised against this. For example, if one species descends from another species through a series of small, gradual steps, why are there not existing creatures that show all of these small steps? The answer to this objection is that the very process of natural selection assumes that the weakest organisms die out and become extinct. While the variations which some creatures developed gave them an advantage in surviving, since resources must be competed for, they must also have put other creatures at a disadvantage, particularly those creatures which were not as well adapted to their circumstances, such as their parent-species. As a result, they went extinct. Certain complex traits of organisms also seem difficult to explain through natural selection, like an organ as complex as the eye or behavior as complex as hive-building. However, these objections are based mainly on the limits of imagination and not on any sold scientific basis.

While many objections can be raised, and some even appear very serious, there is a lot of positive evidence for the theory of natural selection, such as evidence found in the similarities between related but still very distinct organisms, such as humans and dolphins. Similarities of this kind are difficult to explain on the belief that God created the dolphin and man independently, but easy to explain if it is believed that both descended from a common ancestor.

Natural selection does not at all diminish the role of God in creating the world, but rather elegantly places his role at the beginning in creating life and then allowing it develop into the many forms of life which exist today.

Introduction

Introduction Summary and Analysis

The Origin of Species is a biological work that challenges many of the beliefs that were common in the field, particularly, the belief that the species of life on Earth were all individually created by God. In place of that belief, Darwin offers the theory that the species descended from other species, and through a process of gradual change, were significantly changed.

In the introduction, Darwin outlines the reasons for his work, establishes his credibility in writing on the subject, and anticipates some possible objections to his work. He begins by describing his voyage on the H.M.S. Beagle, a ship that traveled to South America and surrounding islands. Here he took interest in how living creatures varied from one location to another and wondered about the relationship between the currently living beings and the now extinct beings which lived before. He then relates that, over the next several years, he spent a large amount of time and effort collecting facts related to this subject. This work is imperfect because considerations of space do not allow for the inclusion of all of the factual details necessary to prove the theory. While some facts will be provided to illustrate the general points of the theory, a full collection of facts will have to wait for the publication of another work. While, in the absence of a complete account of facts, it would be easy to object to the theory, a rational conclusion can only be reached after both sides of the argument have been fully considered.

Before outlining the contents of the book, he expresses his gratitude to those who have helped him in his research, which include "very many naturalists, some of [whom] are personally unknown to me" as well as Dr. Hooker who he says has helped him in "every possible way" over the fifteen years prior to the book's publication.

The general plan of the book and its general conclusions are provided next. In light of the evidence gathered from studying different geographical locations, embryonic development, and fossil records, it is plausible to think that the various species of life were not independently created, but descended from other, previously existing species. However, this theory cannot be accepted unless it can be shown how exactly this process of descent works. Many naturalists—that is, scientists who study living creatures—attribute the change in species to external conditions, such as climate, terrain, and food. These external factors play a role in the development of different species, but concrete cases tell against their being the sole determinate of change in species. The woodpecker, for example, is adapted perfectly for catching insects underneath the bark of trees and it is implausible to think that external factors alone could account for such exact adaptation.

Since external conditions are not enough to account for the adaptation of living things to their environments, it would be useful to first look at how animals and plants that are bred and cultivated domestically change and adapt to the intentions of their owners. For this reason, the first chapter of the book is devoted to this subject. Even though the context is greatly different from animals and plants living in the state of nature, the study is useful because it shows that "hereditary modification"—that is, change from one generation to the next—is possible. The next chapter considers briefly the question of variation in the state of nature that is necessarily brief since it can only be truly studied in the context of a large collection of facts, which cannot be included. The next chapter considers the fact that far more organisms are produced than can survive and this leads to a struggle for existence among them. Those organisms that do survive are "naturally selected" and will tend to pass on their traits and characteristics, while those organisms that do not survive will not pass on their traits.

The next chapter discusses in more detail how natural selection works and how it leads, necessarily, to the extinction of species whose traits do not allow them to survive. The following chapter discusses the "laws of variation"—that is, how exactly species change over time. Over the next several chapters, several objections to theory are discussed. The final chapter summarizes the book and includes some concluding remarks.

Chapter 1: Variation Under Domestication

Chapter 1: Variation Under Domestication Summary and Analysis

Among the many differences between domesticated organisms and wild organisms, the most striking difference is that domestic organisms tend to differ more from one another more than wild organisms do. This difference is in part due to the fact that the conditions of domestic animals tend to be less consistent than for wild animals and to the fact that domestic animals generally do not have a difficulty in obtaining food, while wild animals are constantly in search of it. In addition, once an organism begins to start varying over several generations, it usually does not stop varying.

There are two types of variations, definite and indefinite variations. A definite variation is a variation that is exhibited by most or all of group of organisms. Examples of definite variation would include changes in size due to increased or improved diet, changes in color due to the type of food consumed, and so on. Indefinite variations, on the other hand, are changes that affect only individuals and which are not inherited from a parent or other ancestor. Indefinite variations can range from very slight changes, such as a slightly longer beak, to what are known as "monstrosities"—radical changes in the structure or behavior of an organism. There is no difference between these two kinds of variation except for degree. Indefinite variations are the more important kind of variation in creating the differences between the different types of domestic animals and plants. Indefinite variations result in part from changes to the reproductive system, which is especially susceptible to changes in conditions. This point is illustrated by the fact that it is often difficult to get animals kept in captivity to mate. Some claim that this is due to the instincts of animals being suppressed; however, even cultivated plants often do not produce seed or potent pollen.

Another cause of variation is the disuse of certain characteristics. For example, domestic ducks have lighter wings and heavier feet compared to wild ducks since they tend to fly less and walk more. In addition, in some cases, the variation of one feature is correlated with the variation of another. Cats that are entirely white with blue eyes tend to be deaf, for example. Inherited variations are the only relevant kind of variations for the study of the origins of domestics species and varieties, however this includes most variations, as is shown by the practice of breeders, which do not hesitate to think that, for example, a strong cow is more likely produce a strong cow. This can be seen easily in extreme examples—for example, when both a parent and child share a very rare characteristic, such as being albino.

The laws of inheritance are little understood, however, and naturalists of the time do not know why sometimes traits are passed on and why they are sometimes are not. Nor do they understand why sometimes a child will "revert" and take on characteristics not shared by its immediate parents, but by a more remote ancestor. However, on the subject of reversion, he notes that there is little evidence to support the view, held by some naturalists, that domestic species, if let loose in the wild, would revert to their wild ancestors over the course of a few generations. This view is impossible to confirm since in many cases the ancestor of domestic species is not even known nor could an experiment be done in a controlled fashion that would ensure that inter-breeding with wild varieties of the same animal would not occur.

It is sometimes difficult to determine whether a given domestic species of plant or animal descended from a single common species or from several different species. For example, in the case of the domestic dog, it is difficult to see how all of the differences between, say, a pit bull and a terrier could be accounted for solely through domestication. It is much more likely that there are several wild ancestors to the modern varieties of domestic dog. In other cases, however, such as the goose or mule, there is good reason to believe that all of the varieties descended from a single ancestor.

Some naturalists believe that every race or variety of plant or animal has descended from a different wild species, but this view is obviously an exaggeration. For example, at this time in England, there existed many varieties of cattle and sheep that did not exist in continental Europe. However, there were no wild varieties of animals in England that did not also exist somewhere else in Europe. If all of the English varieties of cattle descended from unique wild varieties, it is not clear what happened to those wild cattle, since they clearly do not exist anymore.

The example of the pigeon is instructive in showing how a great amount of variation can exist within a species that descended from a single ancestor. Though varying greatly in physical appearance, ability, and behavior, there is great reason to believe that all the varieties of domesticated pigeons are descended from the rock pigeon, because of certain similarities it has with all the domesticated types as well the ease with which it is domesticated in foreign lands. Furthermore, when two different types of domestic pigeon are bred together, the offspring will occasionally show signs of reversion and express characteristics that are unique to the rock pigeon. Nonetheless, despite this common ancestry, the pigeons exhibit a great amount of difference from one another, in size, plumage, flight patterns, diet, and so forth. This evidence should be enough to convince those who are doubtful of the claim that even greatly different domestic plants and animals could have descended from a common wild ancestor.

The process of selection is an ancient one that was practiced even by the ancient Egyptians and Romans. In its simplest forms, all that needs to be done is to breed those plants or animals which have traits that are more desirable and to not breed other plants or animals that do not possess those traits. The importance of the role of humans in this is obvious. While external factors might account for some of the changes of species, the fact that there exist many breeds of animals and plants which are tailored specifically for human usage shows that the intentions of breeders and cultivators has a very large effect. For example, changes in climate or diet could hardly account for the fitness of a racehorse for running, or the fitness of a workhorse for pulling heavy loads. The development of these varieties is obviously the effect of purposeful breeding by humans. This effect can even be seen in relatively short periods when done by experienced breeders. Within a single lifetime, a trained person can achieve noticeable improvements in a plant or animal.

The practice of breeders also shows that the development of different varieties is not due to the crossbreeding of different species, since breeders generally avoid this practice. That different varieties are the products of purposeful selection can also be seen in the case of cultivated plants. In many cases, certain plants will differ from one another only in one or at most a few characteristics while remaining the same in all others. For example, if a plant is valued for its fruit, the fruit might be much larger than other related plants, but the leaves, stem, and flowers remain the same. This casts doubt on the view that the differences in the plant are the result of anything but purposeful selection. Furthermore, the practice of selection is obvious historically, as many relics from ancient civilizations attest to laws and practices which show that attention was paid to breeding from only the best of the stock.

Evidence for artificial selection can be found in many other places, as well. For example, there are varieties of a single animal species that will often differ greatly in external and behavioral traits but are very alike in internal traits. Since breeders are unlikely to know very much, or care, about the internal traits of an animal or plant they are breeding, it is not surprising that different varieties that have been bred for different purposes would not vary greatly in these respects. Likewise, the theory that artificial selection is to be credited with the usefulness of many plants and animals also explains why there are not very many useful plants or animals in areas where there is not a great amount of civilization, such as in parts of Africa or in Australia.

Chapter 2: Variation Under Nature

Chapter 2: Variation Under Nature Summary and Analysis

This chapter is dedicated to showing that variations occur in the wild, not only in domesticated conditions. He proves this in several ways. First, it is simply well-known and obvious that wild organisms do vary, often significantly, from one another and these differences are often inherited. Though these variations often affect what might be considered less essential parts of the organism, there are known cases of variation in what are certainly very important parts of the organism. For example, Darwin cites the case of research showing that the nervous system of insects can vary greatly from one individual to the next. While some might argue that "important organs" of animals are precisely those organs that do not vary, this is just a circular argument that could be easily dismissed. Any more open-minded view would be forced at accept the evidence of variation in all parts of an organism, regardless of the importance of the variation.

In further support of this claim, the so-called "polymorphic" species can be brought forward. These species are specifically known for the great amount of variation seen among the individuals. Furthermore, the variation does not appear to depend on the external circumstances in which the individuals live, since the variation takes place equally even when individuals are studied in very different geographical locations. Therefore, these polymorphic species may be considered as a kind of extreme illustration of variation that takes place in all organisms, even if to a lesser degree. Variation can also be seen in species in which there are different forms of the genders. For example, certain species of butterflies produce very different kinds of males and females.

It is very difficult to determine exactly what a species is, what a sub-species is, and what a variety is. The distinctions are for the most part arbitrary, and evidence of this can be seen in the fact that naturalists frequently disagree about whether a given organism is a species or a variety. The distinction between a variety and a species is one only of degree—they are terms that are used to group together organisms, which resemble each other to greater or lesser degrees.

There is a strong correlation between the number of varieties of a species and the number of species in the genus. Genera that have a large number of species also tend to have species with a large number of varieties. This suggests that variations are the causes of species, since, if they were not, it is not obvious why species that are part of large genera should produce more varieties. In other words, it seems likely that the genera that produce many variations and therefore produce many species would also produce many varieties of species.

It might be argued that one definite distinction between a species and variety is the geographical range of each. Species tend to exist over larger areas and have wider ranges while varieties tend to be much more geographically confined. However, this is simply a matter of definition. What naturalists tend to define as the species is simply the one that has a larger geographical range and what they tend to define as the variety is the one that has a smaller range.

Chapter 3: Struggle For Existence

Chapter 3: Struggle For Existence Summary and Analysis

This chapter discusses the fact that all organisms are engaged in a constant competition with one another, with their habitats, and with their climates, for survival. The primary cause for this struggle is the fact that organisms produce at rapid rates and the world could not possibly sustain all of the organisms that were thus produced. Therefore, some—in fact, even most—must die off.

The reason it is necessary to discuss the "struggle for existence" is that it is the primary force behind natural selection, which will be discussed in later chapters. In the case of artificial selection, which was discussed in Chapter 1, the intentions of humans were the primary forces that caused plants and animals to accumulate certain kinds of traits and change gradually over time into different forms in life. Obviously, in the wild, this kind of purposeful selection does not exist. However, since there is a constant struggle to live and reproduce in the wild, an organism which possesses traits that help it survive and reproduce will generally be at an advantage over other organisms and those traits will be passed on, while traits that are not helpful will not be. Over time, these traits will accumulate and large changes can occur in species.

The struggle for existence is caused primarily by the fact that organisms reproduce at very quick, geometric rates. That is, if one organism gives birth to four offspring, and each offspring gives birth to four more offspring, in just two generations one organism has produced sixteen new organisms. Over the course of time, any organism could produce so many offspring that they could not support all of them. It is similar to the doctrine of Malthus, who believed that the human population would eventually fall into a period of starvation when the needs of the population exceeded the amount of food that could be produced. However, in the case of plants and animals, food cannot be artificially increased, as in the case of humans, and therefore the point at which there becomes a serious struggle for food (and for other necessities) occurs much sooner.

While every species naturally tries to increase its number through reproduction, what slows down this process is different for each. In some cases, it is the destruction or eating of seeds or eggs, which slows down reproduction. In other cases, it might be that the organism serves as prey for another. Ultimately, a species can only grow to such a size that can be supported by the amount of food available to it, if there is no other check on its growth. Thus, the number of carnivorous wolves in a forest could only grow so large before some would starve due to a lack of prey. Climate plays a limiting role on species as well, although in a slightly different way. In extreme climates, such as towards the tops of mountains or in the Arctic, competition tends to be less between different organisms and more with the climate itself. Furthermore, as climates and terrains become more hostile, there tend to be fewer species.

The checks on the growth of populations of species can be very complex and interwoven with other species. For example, a certain parasite lives in South America that infects and often kills young cattle. These parasites are likely eaten by birds that thrive on insects. In turn, those birds are hunted by birds of prey, such as hawks. Therefore, if there were an increase in the number of birds of prey, this would mean a decrease in the number of birds to hunt the parasites and, in turn, an increase in the number of parasites. This would cause a corresponding decrease in the number of cattle that reach maturity. However, as complex as relationships can be between organisms as remote as birds of prey and cattle parasites, the most significant checks to the growth of a species generally come from organisms that are most similar to it. The reason for this is that they will generally tend to interfere with one another in the most realms of life.

These reasons explain why foreign plants and animals introduced into new regions often do not prosper, even if certain external conditions are the same, such as climate or terrain. They do not prosper simply because they are not adapted to compete with the specific organisms that inhabit the new land.

Chapter 4: Natural Selection

Chapter 4: Natural Selection Summary and Analysis

Natural selection is a process that is the result of the ideas expressed in the previous two chapters: variations that occur in the wild and the struggle for survival among all organisms. While perhaps most variations that occur are not helpful for surviving, very rarely, a variation does occur which helps an organism to survive and reproduce. Given that many more organisms are produced than can survive, those traits which are helpful in surviving will tend to be passed on, while those traits which are not helpful will tend to be weeded out. If a variation is neither helpful nor unhelpful, it is not subject to natural selection.

The process of natural selection can be illustrated by considering a region that undergoes a dramatic change in climate. The result of this would surely be to drastically change the populations of organisms. Some species might go extinct. Other species might enter the newly changed region from others. Additionally, as was argued previously, dramatic changes to the circumstances of organisms increases the likelihood of variations occurring in a given population. Therefore, natural selection would act very quickly to adapt the various species better to the new conditions in which they live.

The scope of natural selection is much broader than domestic selection by humans. While domestic selection only targets those features which are important to humans, and generally only those which are observable by humans, natural selection applies to every change in trait, whether it be internal or external. Natural selection also favors some traits that may seem unimportant and trivial to observers, but, in fact, are very important for the survival of the species.

There is a sub-class of natural selection called sexual selection. In sexual selection, the relevant struggle is not among animals all struggling to simply survive. Rather, the struggle in sexual selection is among members of one gender vying for the ability to reproduce with members of the other gender. The kinds of traits favored by sexual selection include better physical ability and other adaptations to physically fight sexual competitors. The force of sexual selection is greater among animals in which the male mates with multiple females. In animals that mate with only one partner, there is relatively less competition. Sexual competition does not always take the form of physical conflict. In birds, for example, the competition often takes the form of males attempting to attract the attention of females by singing or by displaying their feathers. In these cases, the female, after being courted, so to speak, by many males, will pick the one they find most attractive. By this selection, the female is favoring certain traits and passing them while preventing other traits from being passed on. Just as with other forms of natural selection, the result is an accumulation of traits over the course of time.

Sexual selection is also the main reason for differences between the various genders of organisms. For example, in most species the competition mainly occurs among males trying to mate with females. Therefore, those males which are best-equipped to physically fighting other males will tend to have their traits passed on. This leads to males tending to be physically stronger and more dangerous than their female counterparts are. However, not all differences between the genders can be explained in this way.

Natural selection also explains the separation of the sexes in organisms to begin with. Naturalists generally agree that biological functions tend to be more efficient when they are done by different parts of an organism. For example, a plant tends to thrive more when one part produces pollens and another part, once fertilized with pollen, produces seeds. This is similar to the economic theory of the division of labor, the notion that human economies tend to be improved when individuals specialize in a certain trade, rather than attempting to do everything themselves. Therefore, as plants become more specialized in certain functions, over the course of time, there may be such a great distinction as to produce two altogether different genders.

Natural selection generally works by accumulating very small, even imperceptible, traits over the course of a very long time. While this notion might at first be counterintuitive to people who are skeptical that such tiny changes can add up to entirely new species, it is comparable to the theory of geology that large valleys or mountains are the result of waves eroding them over the course of thousands of years. If natural selection is accepted, it will undermine the belief that new species are continually being created from nothing or that great changes happen suddenly to species.

Natural selection also explains why organisms tend to pair with other organisms in reproduction. This principle applies not only in the case of animals that have two genders, but also applies to those plants and animals that are hermaphrodites—that is, which do not have distinct genders. While there are some exceptions, most hermaphrodites do pair with other organisms for reproduction regularly. It is likely however that even those hermaphrodites which do not regularly pair with other organisms for reproduction do pair with others occasionally. The reason for this is the general rule that organisms which are distinct from one another tend to produce stronger and better offspring. On the other hand, organisms that are the result of close inbreeding tend to be weak and have a difficult time surviving. Therefore, natural selection will favor traits that lead to pairing in reproduction.

Certain conditions tend to favor the action of natural selection. Larger populations tend to be favored more by natural selection, simply for the reason that in larger population, the likelihood of variations—and, therefore, positive variations—is increased. Larger populations will tend to adapt more rapidly to changed circumstances and smaller populations will adapt more slowly and be more likely to be extinct altogether.

Inter-crossing between individuals of the species can also play a role in helping or hindering natural selection. While having large populations is useful in producing positive traits, free inter-breeding between individuals of the species can make it difficult for positive traits to be selected for, if individuals of the species live in very different circumstances. For example, if there is a population of insects which lives in both a very hot climate and a very cold climate, natural selection will work much more effectively if the insects living in the hot climate are not able to mate with insects living in the cold climate. The reason for this is that if a variation favorable to living in the cold occurs in an insect it may not be favorable to living in the heat and, therefore, once it is passed to an insect living in the hot climate, it will no longer be selected for.

Therefore, isolation plays an important factor in natural selection. If, in the above case, the two populations of insects were isolated from each other in such a way, it would be much easier for natural selection to change the two populations in ways more suited for their climates. Furthermore, isolation also allows smaller populations to change and adapt. Isolation limits the amount of competition the species will face and, therefore, the chance of going extinct will be lessened. This reasoning may explain why there are so many unique species on small islands. If the same populations were to exist on large continents, they would necessarily encounter many more species, any of which might have caused them to go extinct. However, on a relatively small island, the competition is much less intense. This also means, however, that the gradual change of species on small islands (or other very isolated regions) will occur more slowly. Some biologists have speculated that the plants of certain islands, for example, resemble what the plants of Europe used to be like. This phenomenon could easily be explained by the forces of natural selection acting more slowly on the plants of the island.

Natural selection is a very slow process and it depends upon there being room for improvement of animals in a given region. These opportunities for improvement can be brought about by physical changes, such as rising or lowering of the sea level causing regions to be connected or separated. However, the opportunities will also arise simply from other inhabitants of the same region changing and causing the circumstances for all of the other species to change. This slow process accords with the findings of geology which show that the earth has very slowly and gradually changed over thousands of years.

Varieties of a species are, in a way, the predecessors to new species. Over time, the differences between various varieties will become so pronounced that they will no longer belong to the same species. In domesticated animals, breeders tend to favor those animals with extreme characteristics. For example, a bird with a very long beak might be favored by one breeder and a bird with very colorful tail feathers might be favored by another. However, a bird with an average-sized beak and plain tail feathers will generally be favored by no breeder. Therefore, if different individuals of a species of bird were to have one of these traits, it will generally be bred and preferred, while those birds with average characteristics will tend to be ignored. Thus, over time, a variety of this bird will emerge which has a long beak and another variety will emerge that has colorful tail feathers. However, it is unlikely that a very average variety, which has no extreme or interesting characteristics, will emerge, simply due to the lack of attention from breeders.

A similar phenomenon happens with natural selection. Organisms survive and reproduce by finding specific niches in the state of nature. A bird that is very good at hunting insects beneath the bark of trees, for example, will tend to prosper more than a bird that is only moderately good at hunting those insects and only moderately good at hunting flying insects, for in both areas it will be at a disadvantage against its competition. Therefore, just as human breeders tend to favor extreme characteristics, so too does natural selection.

Natural selection produces new species over a very long, gradual period, and before a new species is produced, many intermediate varieties first must occur. As was argued previously, there is no difference between a variety and a species other than degree of difference. As natural selection gradually accumulates certain traits, the difference between two forms of life will increase, so long as interbreeding does not occur and they are isolated in some way. After a certain period, the organism will become a variety. Then, after another long period, it will become a more distinct variety. The process will continue until the organism is an altogether different species. In fact, over a sufficiently large period, the process of natural selection can even create new genera of organisms. Nor does the process stop with genera. Over a sufficiently long period, even large divisions of life can be created, such as new families, classes, and orders.

However, the process of natural selection does not always produce two distinct species that live alongside one another. Given the necessary similarity between the two species once they are made distinct, it is likely that the newer and better-adapted species will replace the old species and cause it to go extinct.

Chapter 5: Laws of Variation

Chapter 5: Laws of Variation Summary and Analysis

Variations in organisms are not the product of chance. They are caused, at least in part, by the external conditions of the organisms as well as changes to the reproductive systems of parents bearing offspring. However, it is not understood why changes to reproductive systems would produce specific changes in the offspring.

The amount of variation that can be attributed to external conditions such as climate and food is likely small. While biologists have certainly found examples of the same species having different appearances in different climates or regions—such as some birds being differently colored when near the ocean—these variations tend to be less significant than other differences between organisms. However, the fact that species do vary in this why from external factors helps demonstrate the point that the species were not independently created, but rather change frequently.

It is impossible to tell whether a variation is the result of accumulated changes from natural selection or from the climate. For example, mammals living in cold climates often have thick pelts and fur. However, it is impossible to determine whether this is due to nature selecting for animals that have stronger and warmer hair or whether the coldness causes the animals to grow thicker fur. However, many examples could be given of species remaining the same even in very different climates and habitats and for this reason it is reasonable to think that the external conditions play a minor role in variation.

However, one must be careful to not attribute to disuse what may actually be caused by natural selection. Thus, for example, a study of beetles on a certain island revealed that most of them were unable to fly, despite possessing wings. While this might first be understood as the consequence of the beetles not using their wings, it is likely that it is even more the result of natural selection. Many beetles on the island die by being blown to sea, a risk that is greatly increased when the beetle flies. Therefore, nature would tend to select for those forms of beetles that do not fly and are, therefore, less susceptible to this risk of death.

In some cases, however, natural selection cannot explain certain traits and they, therefore, must be attributed to disuse. For example, there are certain crabs which dwell in dark areas which appear to have lost their eyes altogether. However, even if they are not very useful in dark areas, it would never be bad to possess eyes, and therefore natural selection would not favor crabs without eyes over crabs with eyes. These changes, therefore, must be the result of the crabs not using their eyes.

Caverns on different continents are likely to be the most similar habitats of those two continents. On the view that the species were independently created, it might be thought, therefore, that the animals inhabiting European caves and the animals inhabiting American caves are very similar. However, study shows that the animals are no more alike than any other species. Natural selection can explain this fact by supposing that cave-dwelling animals originated from species that lived outside. Gradually, species adapted to living deeper and deeper within the caves and, over the course of time, due to disuse, lost their power of sight but, due to natural selection, gained other modifications to help them survive in the caves, such as large antennae.

Organisms often possess a great ability to acclimate, or adapt to different climates. It is often thought that plants brought from hot climates will be unable to survive in cold ones, but often this is shown not to be the case. This suggests that the reason that the plant in question only naturally occurs in hot climates is not due to its inability to survive in colder climates but because of the other organisms with which it would have to compete. However, it should not be thought that natural selection does not at all favor organisms that are better adapted to living in the specific climate they live in.

Many variations often cause variations in other parts of the structure of an organism. This is known as the "correlation of growth." In such cases, changing one part of the structure causes another part of the structure, often seemingly completely unrelated, to change in some fashion. One example of this would be the way in which minor changes to embryos can lead to large changes in adults. However, in other cases, the connection is less clear. For example, deafness in cats is often associated with having blue eyes.

However, just as in the case of disuse, it's easy to attribute variations to the correlation of growth when, in fact, they are simply inherited traits from a common ancestor. For example, if a large group of species all possess a set of common traits, it might be supposed that the traits are correlated in such a way that changing one changes the others. However, this possession of traits might actually be the result of the organisms sharing a common ancestor that possessed all of them and passed them all on to the various species. This is, in fact, a consequence of the view that even divisions as large as genera are the result of changes accumulated by natural selection.

The correlation of growth may be explained by the fact that natural selection tends to favor economizing as much as possible in the structure of an organism. Thus, for example, when one part of an animal becomes larger, in order to preserve biological resources, the organism will be better off reducing another part. In fact, this also explains why natural selection might favor diminishing any part of organism that it does not use. If an animal does not use its wings very much, for example, natural selection will favor smaller wings since then it does not need to consume as much food to support them.

Variations will tend to be greater and more frequently kept by natural selection when they affect parts of an organism that are not very specialized. An analogy can be seen in the case of a knife compared with a specific woodcutting tool. A knife need only be to cut whereas a specific type of saw needs to be able to cut wood in a certain way. The knife could take on many different forms and still accomplish its function effectively, but the saw needs to be specifically formed for its purpose. For this reason, parts of an organism that are specifically adapted for a special purpose are likely to change less than other parts. This also explains the general observation that parts of an animal that occur in it many times tend to vary in number more than parts which do not occur many times. For example, the vertebrae in a snake's spine tend to vary significantly in number whereas the number of arms of a human does not. This is because having exactly two arms is useful for humans and having one would be a hindrance and having three would be excessive. On the other hand, having one or two more vertebrae would not cause a significant difference in the life of a snake.

Variations tend to be more common in the parts of an organism that distinguish it from other, closely related species. An example of this can be seen in secondary sexual characteristics—those traits associated with one particular gender but not directly related to reproduction. However, the rule does not only apply to these traits, as it can be seen in the case of certain hermaphroditic species.

This fact cannot be explained if one believes that the species were created independently from one another. It would simply be a strange coincidence that the most distinct parts of an animal would also happen to be the parts which to vary the most. However, on the view that natural selection changes the species over time, this fact can easily be explained. For, the trait of an organism that is most distinct is, on the theory of natural selection, the most recently changed feature. This would also mean that in recent generations, that feature has been varying enough for natural selection to modify it. Therefore, it is not surprising that the trait continues to vary. The most striking example of this is, once again, secondary sexual characteristics. For reasons unknown, these traits tend to vary the most between closely related species and, correspondingly, they vary the most within a species.

Closely related species also tend to share common variations and show tendencies to revert to common ancestors. Thus, the Swedish turnip and ruta baga both occasionally show a variation in which the roots are enlarged. That this variation should affect both would be difficult to explain on the view that the species were independently created, for similar variations should no more occur among closely related organisms than among distantly related organisms.

A more striking example can be given in the case of equine animals—that is, four-legged hoofed animals, such as the mule, horse, and zebra. It has often been noted that when a horse and mule are bred together, the offspring has stripes on its legs, very similar to the striping of a zebra. This shows a connection between the horse, mule, and zebra species, despite their great geographical distance. Once again, this is a fact that cannot be explained by those who believe in the independent creation of species.

To summarize, while knowledge of variation is limited, what little is known all tends to conform to the theory that natural selection has gradually produced the species in existence today. The most profound evidence for this is the similar variation among related species. This provides strong evidence for believing that there is a historical tie between the species, namely, that the species are descended from other species.

Chapter 6: Difficulties on Theory

Chapter 6: Difficulties on Theory Summary and Analysis

Four objections may be raised to the theory of natural selection. The first is that, if the species have descended from others by small, gradual changes, there should exist a large number of intermediate, transitional organisms that link the various species together. However, these do not exist. Second, there are many organs and traits of organisms that seem far too complex for natural selection to produce, such as the eye, which is an incredibly complex and fine-tuned organ. Third, how can natural selection account for the complex instincts of animals that are often capable of producing behavior that even humans cannot understand? Finally, according to the theory of natural selection, species are only separated from varieties by degree of difference. However, when varieties are interbred, the offspring is generally stronger and healthier than its parents, but when two species are interbred, if it is possible to do so, the offspring is usually weak and infertile. This would appear to show that there is a significant and meaningful distinction between species and variety. The first two are treated in this chapter and the second two have their own chapters dedicated to them.

To the first objection, it may be responded that natural selection works by eliminating the less fit forms of life and preserving the most fit forms of life. Thus, when a species undergoes modification over a period of generations, only those individuals who have the best chance for survival will be preserved and all other forms that have not adapted will be weeded out. This includes the individuals of the species that have not inherited the best adaptations and as such would include the transitional forms and more distant ancestors of the species that does survive. Therefore, it is not surprising that the transitional forms are not found in nature.

It might further be argued that, even if the transitional forms no longer exist, they should at least be preserved in the fossil record and be found there. However, such is not the case. This objection will be discussed in further length in a later chapter, but the reason these fossils are not found is because fossilization is a very rare process and only a tiny percentage of living creatures are ever found as fossils.

Another objection along these lines is to question why transitional forms of species do not exist in regions geographically between two related species. For example, if it is supposed that a species of deer living in a northern region and a species of deer living in a southern region descended from the same species, why are there not deer that represent a link between the two species in the middle region?

In response to this, it must first be pointed out that, since natural selection is a very slow process, it is not safe to assume that regions that are physically connected in the present day were connected in the past. Changes in sea level can cause the geography a region to change significantly, causing islands to become part of a continent or to cause parts of continents to be separated by water and become islands. Therefore, it is difficult to identify exactly what the intermediate regions between two species are. It is also true that, in general, species tend to inhabit discrete areas and do not tend to exist in gradually decreasing numbers over a large range. This fact cannot be explained simply by considerations of climate, since climate tends to change gradually. Rather, it is the result of the species' interrelation with other organisms that, as was discussed in the chapter on the struggle for existence, is the most important check on the production of individuals of a given species.

As a result of the range of a species being distinctly defined, to some degree, this will tend to lead to circumstances similar to geographical isolation, such as two kinds of rodents being separated by a large body of water. What will occur is that the animals in one region will tend to interbreed with one another and, through inheritance, will possess very similar traits, while the animals in the other will not inherit those traits. Therefore, the result will be the development of two, homogeneous species and no intermediate varieties linking the two.

The second objection requires a longer and more detailed response. It may be stated in several ways. First, it can be asked how natural selection can account for gradual changes as dramatic as changing a land mammal into an aquatic mammal. According to the theory of natural selection, each individual change in an organism must be beneficial to be preserved, but it is unclear how an animal could gradually change from living on the land to living in the water.

However, there are actual examples of mammals that exist in this in-between state. There is a kind of wild cat, for example, which possesses webbed feet but only hunts fish in the water during one season of the year and hunts rodents on land during the other seasons. Such a creature represents a kind of middle ground between a fully aquatic animal and an animal that lives entirely on land.

A more difficult case is that a flying mammal, such as the bat. How exactly a wing could gradually be created through natural selection, and be useful to the animal in each stage of development, is harder to see. However, there are cases in nature that suggest answers to this. For example, there exist squirrels in the wild that are not fully capable of flight, but are capable of gliding. These are known as flying squirrels. Between their arms and their bodies are pieces of flesh, which in some ways resemble a wing. The use of these wings is to quickly escape from predators. It can be imagined that gradual increases in the size of this flesh between the arms and body would be helpful in facilitating gliding and letting the squirrel more easily escape being eaten.

There is also the example of the flying lemur, which was previously mistaken to be a bat. The flying lemur does not possess wings but possesses flaps of flesh between its limbs and body similar to the flying squirrel, but much larger. Unlike the bat, however, the flying lemur is not capable of actual flight by flapping its wings, but only of gliding. However, in the structure of the bat there are signs that the wings developed from structures similar to those of the flying lemur. In particular, the bat possesses flaps of flesh between its legs and body that could be used for gliding, but are no longer used for that purpose, as the bat possesses actual wings.

Another analogy can be seen in the case of birds. Wings need not be capable of flight to be useful and therefore the bat could develop wing-like structures that would be useful to it even before they were large enough or strong enough for actual flight. Penguins, for example, are incapable of flight and use their wings only for swimming. Ostriches use their wings in a similar way to the sails on ships—to increase their speed while running. While the species that existed between the modern day bat and its flightless ancestor might not have used their wing-like structures in this way, this does illustrate that there are many ways in which such structures could be useful to the intermediate species.

It is also worth noting that when a species perfects a certain structure—such as, for example, when a bat's wing is improved to the point of actual flight—that it will have such an advantage over similar individuals that cannot fly that the extermination of the less fit species will happen quickly. This helps explain why there are few records of transitional species in the fossil record—they simply would not exist for very long or in very large numbers.

Cases also exist of animals that change their habits without a corresponding change in structure. On the view that the species were each independently created, it is difficult to understand how this could be the case. For, if each organism were created to live in a specific environment and never change, why would it not be properly equipped for doing so? However, on the theory of natural selection, this can be understood as simply an example of a species transitioning. Examples of this include species of geese, which, though possessing webbed feet, only very rarely goes near water and spends most of its time on land. Why these geese would possess feet better fit for an aquatic life cannot be explained if they were specifically created to live on the land.

It is difficult to understand how an organ as complex as the eye could have developed by individual, gradual steps each beneficial to the organism. This difficulty is made worse by the fact that of all living creatures that possess eyes, there do not appear to be many that possess eyes in any kind of transitional or imperfect state. Fossil records also cannot provide much information about the mechanism of ancient eyes as such detail is not preserved.

However, there are some cases of imperfect forms of eyes in some animals. In crustaceans, for example, some possess eyes that are more accurate and complex than the other, less accurate and more simple eyes possessed by other species. Small changes to the lens or optic nerve could produce gradual changes that would enable the crustacean to see better and, at least in some conditions, give it a greater chance of survival.

Even if one is not capable of constructing a series of reasonable steps in the development of the eye, this does not mean that the theory of natural selection is wrong, necessarily. It may simply mean that the progression from ancient eyes to modern eyes has not yet been discovered. In light of the many facts which natural selection does help to explain, it would be rash to abandon it altogether simply because how exactly it works in one area cannot be fully understood. In other words, there is no reason to believe that natural selection could not produce an organ even as complex as the eye, even if a convincing explanation for how it did in fact produce the eye cannot be proposed. If, indeed, there were some compelling argument to show that it would be impossible for natural selection to produce such an organ, the theory would fall apart.

The development of an organ can be very complex and involve the same organ performing very different functions at different times. Therefore, in the case of the eye, it must not be imagined that from its most basic form it was intended to visually perceive its surroundings; the structure that later developed into the eye could very well have performed a variety of other functions. There are examples of organs in fish that perform one function for one species and quite a different function for another species. For example, an organ known as the swimbladder is used by some fish for the purpose of flotation—it fills with air to keep the fish on top of water. However, in other fish, the same organ is used for breathing. This shows that an organ that developed for one purpose may, through the course of improvement by natural selection, take on a very different function.

While some organs or traits are difficult to explain with natural selection, this only shows ignorance on the subject and not that no explanation is possible. In fact, in the case of the vast majority of organs, gradual steps in their development can be found in living creatures and this is something that would be difficult to explain on the view that the creatures were independently created by God. If that were so, it is difficult to see why the same organ would serve different purposes in different species, when it would be just as easy for God to design and create an altogether unique and different organ.

A final difficulty is that of very simple and seemingly unimportant organs. Some organs do very little, or nothing, to help the survival of the organism. Since natural selection only preserves those traits of structure that are beneficial to the survival and reproduction of the organism, it cannot explain such organs.

However, in such cases it may be that biologists are simply ignorant of the purposes of structure and think that they are unimportant when, in fact, they are not. An example of this would be the tail of the giraffe, the seeming purpose of which is to swat flies, a task which it performs very efficiently. This would appear to be a very trivial and useless function that could not aid very much in furthering the species. However, in the case of South American livestock, the ability to fend off insects and parasites is very important for their survival. Therefore, the giraffe's tail could serve a similar purpose.

Further, in the case of some seemingly unimportant organs, it could be that they are slightly modified forms of organs that previously served other, more important organs. Take, for example, a land animal that descended from a water animal, as seems likely in many cases, due to the similarities in structure, especially the lungs. For a creature living in the water, the tail is very important for movement. As the water creature gradually was modified into a land creature, the tail would persist and some slight changes could gradually turn it into something more useful for the new way of life.

These organs can also be explained by causes other than natural selection. As has already been noted, the structure of a creature can be modified in several ways. For example, the organ or trait that appears to be useless may be the result of climate of food. It may also be the result of sexual selection—that is, the trait may not be useful in survival, but in fighting other males or charming a female. Examples of this could be seen in the colors of many animals that probably serve little or no purpose as far as survival but are more likely used to attract females.

Finally, there may very well be some organs or traits in organisms that are of little or no use to the organism, but were of use to its ancestor. According to the theory of natural selection, each species descended from a prior species, inheriting the vast majority of its parent's traits. In this case, it is possible that an organ that was of use in previous circumstances is no longer of use in later circumstances but, nonetheless, was not a burden to the creature in the new circumstances. As a result, there would be no pressure from natural selection to remove this organ.

While many of the objections presented in this chapter may at first seem very serious, in light of the various facts and arguments given, their gravity is reduced significantly. Many of the objections do more to reveal science's ignorance of many facts about organisms than to undermine the theory of natural selection.

Chapter 7: Instinct

Chapter 7: Instinct Summary and Analysis

The complexity of instinct is grounds for a serious objection to the theory of natural selection, because it seems that behavior as complex and amazing as the skill of bees in building their hives is far too complicated for natural selection to have produced. The term instinct itself is not well-defined, since it covers many very distinct behaviors. It is often used to describe behavior that is done for a purpose that is not intended or understood by the organism doing it. However, there are examples where this would not appear to be the case, but, nonetheless, the behavior is still considered instinctive.

Instinct in some ways can be compared with habit, and this comparison has some evidence in nature. Many activities that are habitual in humans are done almost unconsciously without any clear purpose in mind. In the case of many habits, the performance of the habitual activity depends on doing it in a certain rhythm. For example, a person who is familiar with a certain song often cannot begin singing the song in the middle, but must start at the beginning and then work his or her way through it. In a similar way, experiments have shown that a caterpillar when building its cocoon cannot work ahead of itself, so to speak. In one such experiment, a caterpillar was allowed to build its cocoon up to the third stage, after which point it was moved to another cocoon that had already been constructed to the sixth stage. Instead of working from the sixth stage towards finishing it, the caterpillar began afresh from the third stage and worked its way up to the sixth stage.

While some actions that are learned through habit are sometimes passed onto offspring, this cannot explain the complex habits that pose the most serious objections to natural selections, such as the spider's ability to construct its web. As with any trait, natural selection can only modify instincts through small, gradual steps. As a result, just as biologists can find examples of variation in physical structures of organisms, so too should there be examples of variation in instincts. These, indeed, can be found, even within a single organism, whose instincts may vary over the course of its life. Likewise, there are examples of organisms within the same species varying slightly from one another in instincts. For example, in birds that migrate, minor variations can be found in the exact timing or direction in which they migrate.

One consequence of the theory of natural selection is that every trait of an organism must be primarily or entirely for the benefit of the organism itself and never for the benefit of another. However, a counterexample of this can be found in the behavior of the aphid, an insect, which allows itself to be milked by colonies of ants. This behavior appears to be entirely voluntarily, as experiments show that the aphid cannot be induced to excrete its milk unless it perceives the presence of ant. However, there may be good reason to think that the aphid also benefits from this instinct by removing the thick fluid from its body, which is perhaps an unwanted byproduct of some other biological function. While natural selection did not develop this adaptation in the aphid for the purpose of feeding ants, it is possible, and likely, that natural selection did develop the instincts of ants to take advantage of the aphid in this way.

Once again, cases of domesticated animals can be used to show how natural selection might develop and modify instincts in the wild. In domesticated dogs, certain behaviors and instincts are closely associated with certain breeds. Pointers, for example, all possess the instinct of pointing at perceived prey and the tendency to retrieve what is perceived to be killed prey is common to all retrievers. All of these instincts are completely natural the various breeds and do not require any training on the part of the owner. Intermingling of various breeds of dogs also show that the instincts are inherited.

There is evidence that some habits acquired in the life of a parent are inherited by its offspring. For example, the children of a wild rabbit are notoriously hard to tame, while the children of a tamed rabbit are usually tame themselves. This cannot be explained by any process of selection, as there is no evidence that domestic rabbits were ever intentionally developed to be tame. Likewise, some natural instincts seem to be lost in the process of domestications. While wild dogs and cats instinctively attack and try to eat chickens, domesticated dogs and cats rarely show these tendencies.

How exactly natural selection could develop instincts gradually can be best seen in considering specific cases. The European cuckoo is distinctive in that it lays its eggs in the nest of other birds that then, mistaking them for their own children, raise them as if they were their own. The reason naturalists give for this behavior is that the cuckoo lays its eggs over a very long period and tends to migrate at an early time. As a result, many of the young would need to be raised by the male cuckoo alone and would therefore suffer as a result. The American cuckoo, on the other hand, behaves similarly to other birds in laying eggs in its own nest and raising them itself. Unlike its European counterparts, it lays its eggs at roughly the same time. Supposing that the American and European cuckoo shared a common ancestor, as the theory of natural selection suggests, the development of the European cuckoo's behavior can be easily explained. If the cuckoo began with the more normal habits of the American cuckoo but on rare occasions laid its eggs in the nest of other birds, this practice was found to be beneficial either to the mother or to its offspring, natural selection would favor any variations that led to the cuckoo engaging in this practice more frequently. It could, for example, be beneficial to both mother and child by reducing the burden of the mother by having one fewer child to raise and beneficial to the child by allowing it to be raised in an environment in which food is less scarce. Over time, after the accumulation of several modifications of instinct in this way, the cuckoo could develop to perform this instinct nearly always.

Another example of instinctual behavior that can be explained by natural selection is the slave-making instinct of some types of ants. One species of ant known as Formica rufescens is entirely dependent upon the slaves it makes of other species of ants. The other ants do nearly all of the work for them, even feeding them. Experiments showed that when the Formica rufescens were isolated without any slaves that many starved to death. When a single slave was introduced, however, it immediately went to work in feeding and tending to those ants that survived. The dependence of the Formica rufescens on the slave at first seems very difficult to explain through natural selection. In particular, it seems difficult to see how such behavior could develop through the gradual steps necessary in natural selection.

However, there exist other species of ants that also take slaves but do not have the same degree of dependency on them and, as a result, can give some hint as to how the slave-taking instinct in the Formica rufescens developed. The Formica sanguinea is one example of such an ant. In this species, the slaves are much fewer in number and perform only some of the tasks necessary for the survival of the colony. For example, the slaves are usually not seen leaving or entering the nest. The ants of the species itself hunt for food and bring materials for building the ant's nest. The slaves work appears to consist mainly of tending to tasks within the nest, such as moving food and tending to larvae. Observation shows how exactly the slave-making process occurs. Occasionally, a large group of Formica sanguinea will attack another colony of ants and kill any adults that they meet and carry their bodies back to the hive for food. If any ant larva is found, they will also be carried back to the colony, but will be allowed to hatch and be made into slaves.

Now, one possible way in which natural selection could have developed this instinct is this. In other species of ants that do not make slaves, larva of rival species are carried back to nests for food. If a variation occurred which allowed some of the larva to be hatched, the newly hatched ant might follow its instincts and begin to work around the hive performing various useful tasks. If the ant performing these tasks proved to be more useful to the colony than serving as food, natural selection would promote this trait and, over the course of time, modify this instinct to make it more common. Over the course of a long period, this instinct could become so developed that the ants could become so entirely dependent upon slaves as the Formica rufescens.

The final example is the hive-building instinct of hive-bees, which is one of the most amazing instincts found in nature. When constructing cells, the bees instinctively construct them in such a way as to enclose the most amount of space with the least amount of material, a problem which mathematicians only recently have been able to solve. Such a complex instinct seems like it would even more difficult to explain with natural selection than an organ like the eye. However, there is evidence to believe that it could be explained as originating from simpler, more basic instincts.

A spectrum of sophistication in hive-building can be found in nature. On one end is the simple honeybee that constructs the cells of its hive in an irregular and inefficient manner. On the other end is the hive-bee that produces them with the precision already mentioned. In between these two extremes, some intermediate forms can be found. The species of bee known as Melipona, for example, constructs cells in a very similar fashion to the hive-bee but does not space them as efficiently, not creating as much space as the hive-bee but still using the same amount of material. It would not be difficult to imagine a series of gradual modifications to the instincts of the Melipona that would make its hive as efficient as those of the hive-bee. The reason why natural selection would favor efficient building of cells is that they are used to store the food for the hive, and the more food that can be stored, the greater chance the bees have for survival. Furthermore, the wax used in constructing the hive is a scarce resource, and so using the wax in the most efficient way possible will benefit the hive.

While many other instincts could be brought forward as possible objections to the theory of natural selection, the preceding three should be some evidence that even very complex behavior can be understood as the result of many, small changes over several generations. Moreover, as was the case with objections in other areas, the fact that an explanation cannot be given now does not mean that no explanation is possible, but perhaps only that science is too ignorant now to provide one.

In summary, it can be seen that instincts do not differ in a significant way from other traits of animals and work under the same general laws that physical traits do. While some difficult examples do exist, many can be explained, and others indicate only scientific ignorance of the subjects involved, and not prevent difficulties that could never be solved.

Chapter 8: Hybridism

Chapter 8: Hybridism Summary and Analysis

When two organisms of distinct species are interbred, the resulting hybrid offspring is sterile. It is often thought that this intended in nature to prevent all of the various species from intermingling and, as a result, losing the distinctions between them. If this were so, this would support the belief that the species were independently created and, therefore, undermine the theory that the species were produced by natural selection.

It should first be noted that two different facts are often confused when studying this subject, namely, the sterility of two species when breeding with one another and the sterility of the resulting offspring. In other words, there is the question of whether two distinct species can produce offspring at all and, second, whether the offspring of two distinct species is itself capable of producing offspring. Now, studies that attempt to show the infertility of either type are seriously flawed, for, as was noted in a previous chapter, the reproductive systems of organisms are very delicate and sensitive to changed circumstances. Therefore, when put in experimental conditions, it is difficult to tell whether the inability of a given organism to reproduce is due to it being a hybrid or due to the strange circumstances in which it exists. As a result, it is difficult to determine exactly what the boundaries are for producing fertile offspring. In other cases, the interbreeding of hybrids is the cause of some doubt of the results. Interbreeding has been shown in other cases to decrease the fertility of an organism over successive generations and, as a result, an experiment, which attempts to show the general infertility of hybrids by breeding hybrids together that are closely related, is seriously flawed. Moreover, there exist experimental cases in which organisms of distinct species have been shown to produce fertile offspring.

There are some general rules that govern whether or not two species will be able to produce offspring and whether the offspring is fertile. While there are some exceptions, there is a general correlation between the difficulty of two species producing offspring and the infertility of the resultant offspring. That is, if two species can only rarely successfully produce offspring, it is likely that the offspring will be infertile. Furthermore, it is generally true that two species that are similar in structure will be more likely to successfully produce fertile offspring, while two species that differ significantly in structure will be less likely to produce fertile offspring, or offspring at all. However, to all of these rules there are exceptions.

All of these facts considered together seem to undermine the belief that the infertility of species when crossed is the result of Divine institution to prevent the mixing of species. For, if that were the reason for infertility, it is strange that there would be such a large degree of difference in the ability to produce fertile offspring between some species. Why, for example, are some species that are very closely related unable to produce fertile offspring, while other species that are more distant able to produce perfectly fertile offspring? Furthermore, if the goal were to prevent the intermingling of species, it is difficult to explain why the production of hybrids is possible at all.

That said, it is still important to determine and understand what exactly causes this infertility. In the case of two species that are unable to produce any offspring, the reason may simply be some kind of physical incompatibility. For example, if the pistils of a flower are too long the pollen of another plant may not be able to reach the reproductive organs. Alternatively, there may be some physical incompatibility between the male and female elements preventing an embryo from being formed. Furthermore, in some cases a child might be conceived but die before being born. As a hybrid is only half-related to its mother, its constitution might not be suited to surviving in the environment of its mother's womb.

The theory of natural selection depends upon the claim that there is no essential difference between species and varieties and that they only differ from one another in degree. This is because the theory of natural selection claims that distinct species were once varieties that, through gradual changes, became species. However, the fact that the offspring of species are generally infertile while the offspring of varieties are generally fertile and, in fact, quite robust, seems to undermine this claim.

However, this objection has several flaws. The perfect fertility of varieties is only observed in the case of domesticated varieties and therefore cannot be extended as a general rule that would apply to all varieties. Furthermore, in the case of domestic varieties, as breeders select only for external differences, there is no reason to suspect that the reproductive systems of the organisms are significantly changed and, therefore, it should not be surprising if the production of fertile offspring is still possible. In the wild, however, natural selection modifies all aspects of an organism, therefore it is possible that varieties that develop in the wild would not be able to reproduce. Finally, biologists often determine whether an organism is a variety of a species or a distinct species simply by testing whether it can reproduce. Therefore, it is simply circular to argue that all varieties can reproduce if the test for whether an organism is a variety is the fact that it can reproduce.

Furthermore, it is not even always the case that distinct domesticated varieties can reproduce. There is, for example, a species of maize that occurs in several different varieties and, nonetheless, the different varieties cannot reproduce, or at least, their fertility is greatly diminished. There is also a species of a flowering plant known as the Verbascum that occurs in several varieties that cannot produce offspring among themselves.

Therefore, all of these facts considered, the ability to reproduce cannot be taken as a kind of essential difference between species and varieties. As has already been mentioned, some species can interbreed with other species and produce fertile offspring, while some varieties cannot interbreed. Rather, the inability to reproduce would appear to be the result of differences in the reproductive system, which differences accumulate gradually over the course of many generations.

Finally, some naturalists who wished to show that there is a bold line between species and varieties have attempted to show that hybrids and mongrels—that is, the offspring of two distinct species—differ in significant ways. In this way, the distinction between species and varieties could be shown to be more than just a matter of degree of difference. The most important difference is that first generation mongrels tend to show greater variations than first generation hybrids. However, as has already been noted, most observed cases of varieties interbreeding occur in domesticated organisms. However, in cases of domestic breeding, there has recently been variation, otherwise attempting to breed would be useless. Therefore, it should be surprising that the offspring of two frequently varying varieties should also show many variations. On the other hand, when two species are crossed, they are usually not in a state of particularly frequent variation and, as a result, it is not surprising that the offspring shows relatively few variations.

Other differences have been pointed out, but none proves that there is a significant distinction between species and variety. For example, some naturalists claim that mongrels are more likely to resemble one parent or the other than hybrids. However, this is only a matter of degree, as hybrids do in some cases resemble one parent closely. Moreover, the ways in which they resemble the parent are generally in certain extreme ways, such as being albino or having excessively large appendages. That is, they generally do not resemble them in ways that would be the result of natural selection.

Chapter 9: On the Imperfection of the Geological Record

Chapter 9: On the Imperfection of the Geological Record Summary and Analysis

One of the most serious objections to the theory of natural selection is the lack of organisms that link together the various species. If, for example, a species of cattle descended from a distinct species, it might be objected that there ought to at least be evidence of cattle that represent the transition from the one species to the other. The fact that there are no existing organisms that represent this transition was discussed in previous chapters. The process of natural selection causes the extinction of those forms of life that do not adapt, and, therefore, only the species of cattle that is most fit for surviving and reproducing in its circumstances will survive. However, this does not explain why the geological record—that is, the record of fossils found in the earth—does not show this great variety of species linking together the existing ones.

It should first be understood exactly what sort of transitional forms one might expect to find in the geological record. Consider the case of the rock pigeon and the fantail, one of many varieties of pigeons that are thought to have descended from the rock pigeon. According to the theory of natural selection, one would expect that there was a series of pigeons linking the two, each differing from the next in only a very slight way. However, if one were to consider a third pigeon descended from the rock pigeon, for example the pouter, one should not expect to find a series of pigeons that directly link together the fantail and pouter; rather, both can be linked to the rock pigeon. Therefore, it will usually not be possible to find species of animals directly linking together two existing species, since natural selection tends to cause the extinction of the parent species. What is possible, however, is to find geological evidence that two now-existing species shared a common ancestor.

If the theory of natural selection is true, the number of transitional forms of life between the species now living and ancient, extinct species must be very large. If so many existed, however, it is difficult to see why the fossil record does not provide more evidence.

However, before this objection can be dealt with, another objection is worth considering. Some argue that the process of natural selection could not account for the species since there has not been enough time to generate all of the organic change necessary to account for the variety of species found on Earth. As natural selection is by its nature a very slow process, it would require an enormous amount of time to generate the existing species. This objection is undermined by the great amount of geological evidence suggesting how old the Earth is, such as the amount of erosion found in certain rock formations.

With that objection aside, it is now possible to discuss the fossil record and explain why it does not appear to provide the evidence that the theory of natural selection seems to depend upon. First, it should be noted that the collection of fossils gathered by paleontologists is very poor. Only a tiny portion of the Earth has been searched and even those areas that have been searched are frequently found to have more fossils when later digs revisit them.

Furthermore, it should be understood that the majority of organisms will never be fossilized to begin with. Soft creatures without any kind of shell or skeleton cannot be fossilized and even creatures with hard parts will not be fossilized unless sediment accumulates over their bodies before they die. It is common to think that sediment is always accumulating at the bottom of the sea quickly enough to preserve records of living creature, but this is not the case. In most regions of the sea, the water is too pure for sedimentation to fossilize the remains of an organism.

However, the best explanation for the lack of fossils is that fossils will generally only be preserved in between periods of great geological change. Evidence suggests that landmasses undergo great amounts of change even in relatively short periods. Within the span of tens of thousands of years—which is not much in geological terms—new rock and sedimentary formations may emerge and old ones may be eroded away. The process of erosion naturally would destroy any fossils that were contained within the formation. Therefore, only those fossils preserved in very thick and large formations are likely to survive.

Furthermore, as previous chapters have argued, large shifts in geology will generally tend to promote the development of new varieties and species of organisms, as the previously existing organism must adapt to new environments. This also means, however, that fossils of these newly emerging forms will tend to be scarce as it is difficult for a fossil to survive through great geological changes. Likewise, fossils will be most likely to survive in those times in which geological change is relatively slower and more rare but this also means that organisms will be better adapted to their environments and will, therefore, have less need to vary. Therefore, the fossil record is even less likely to contain a great record of forms of life that represent a transition from one species to the next.

The movement of one species from one region to another provides more problems for leaving behind a fossil record that shows transitions from one species to another. In order for a single formation to show a gradual change in a species over time, the species must have lived in the same area for a lengthy period. However, as biological evidence suggests, it is uncommon for most species to stay in the same region for any significantly long period. Furthermore, if a species moves to a new region, it is likely that the region it moves to will not be one that is conducive to producing fossils or at least conducive to preserving them. Therefore, it is not reasonable to believe that a complete fossil record, which documents the gradual evolution of the species, could ever be found.

The definitions of the terms "species" and "varieties" has an important impact on the discussion also. Paleontologists often distinguish two fossil species from one another on very slight differences and therefore even if a fossilized species was discovered which linked together two other species, it might be classified as an altogether distinct and unrelated species by paleontologists unless further varieties were found which made the link abundantly clear. In addition, if one species is the ancestor of two others, it does not necessarily mean that its form was exactly between the two species. It may have some features or traits that were never passed on to any species that descended from it. This would form another obstacle to identifying transitional species.

The difficulty of establishing that two now-living creatures belong to the same species shows how difficult it would be to establish relationships between creatures found in the fossil record and now-living creatures. It often takes the discovery of dozens of intermediate forms for naturalists to agree that two varieties belong to the same species. Since the fossil record is so inconsistent and incomplete, it should be not be surprising that clear transitional forms have not been found in great number.

A more serious form of this objection is to point out the sudden emergence of groups of species at the lowest known levels of the earth - that is, groups of species that seemed to emerge all at once in periods so distant that many do not believe any forms of life existed before them. For example, fossil records show that a group of crustaceans known as trilobites existing in very ancient times. According to the theory of natural selection, any group of related organisms is related to one another by sharing a common ancestor. However, the trilobites could not share a common ancestor if life did not previously exist, which geological evidence supports.

No definitive answer can be given to this objection, but there are some possible speculative responses to it. First, geological evidence shows that landmasses and bodies of water change, sometimes dramatically, over long periods. For example, the small islands that exist in the ocean show no geological evidence of existing very long. Since the trilobites existed very long ago, it might not be unreasonable to assume that oceans existed where continents now exist and that land masses existed in many places where oceans now exist. As a result, therefore, the fossil records of creatures existing prior to the trilobites might be at the bottom of the ocean. Furthermore, the fossils underneath the ocean might not even be intact due to the great amount of pressure exerted on the formations beneath the ocean.

Chapter 10: On the Geological Succession of Organic Beings

Chapter 10: On the Geological Succession of Organic Beings Summary and Analysis

There is much evidence in the geological record which supports the theory of natural selection and which undermines the belief that the species are unchanging and were created independently. First, the geological record show that new species consistently appear at a gradual rate throughout the fossil record. Species that now exist do not generally appear in any ancient fossil records, but only in the most recent. This shows a gradual succession of different species over the course of the world's history. Furthermore, this succession of species is gradual, as some formations show the extinction (or appearance) of a given species at earlier or later dates than other formations. In addition, variation of species is not always consistent or equal among different types of species or genera. In some very ancient fossil beds, there are many extinct, ancient animals found alongside the shells of species that exist in a more or less unchanged form to this day.

These facts all support the theory of natural selection. As was discussed in the chapters on variation, not all species vary to the same degree. Furthermore, the pressure to adapt is not equal for all creatures. As was discussed in a previous chapter, organisms living on small islands generally face less competition than creatures living in large reasons, simply because they encounter fewer competitors. Therefore, it is not surprising that the geological record should show that some species change more slowly over time than others. In more complex organisms, such as primates, it should not be surprising that variation seems to be more common and that more changes are recorded in the geological record, since these creatures tend to have more complex relationships to their environments and, therefore, face much greater pressure to adapt when circumstances change even slightly. The fact that species do not reappear after disappearing is also fully in accord with the theory of natural selection since all organisms of the same species are thought to descend from a common ancestor.

The species found in the fossil record form an integrated system of organisms that can be classified into various groups, in a similar way that existing organisms can be classified. Furthermore, the more ancient an extinct species is, the less it tends to resemble modern forms of life. Conversely, the more recently extinct species tend to frequently resemble existing forms of life. Furthermore, extinct animals often link together existing groups of animals, "falling between them." Thus, for example, Pachyderms and Ruminants, two groups of mammals, were once considered different orders. However, fossil records showed so many forms of life that linked the two orders together that the classification was completely changed and the two groups were classified in the same sub-order.

A clearer example of this pattern of ancient forms of life "falling between" existing groups can be seen in the case of ancient reptiles and fish. While there do not exist any fossil records of animals which were exactly between reptiles and fish (and the theory of natural selection would not require that such an organism ever even existed), it is generally true that when one compares ancient fish and reptile specimens, they tend to resemble one another much more than they do today.

This phenomenon (of ancient species resembling distinct, currently living groups) can be easily explained by the theory of natural selection. According to natural selection, all organisms belonging to any given classification, whether it be variety, species, genus, or order, descended from a common ancestor and were distinguished from one another through gradual changes over many centuries. If reptiles and fish shared a common ancestor, then it would be make sense that more ancient forms of fish and reptiles tended to resemble each other more than they do today. For in ancient times, there had been less time for natural selection to accumulate gradual changes and, as a result, the two types of organisms would retain more of the traits of their common ancestor. This fact cannot be explained by anything but natural selection.

Natural selection also explains the relationships that exist between different extinct species. There is a general pattern found in the fossil record that related species tend to show a gradual transition from one species to an intermediate species to another species. It should be noted, however, that the species found in the middle do not always equally resemble the older and the younger species. First, fossil formations, as was discussed in the previous chapter, are inconsistent and intermittent and therefore there is no reason to suspect that a fossil exists of an organism that existed exactly between the other two species. Furthermore, species change at different rates at different times.

There are exceptions to this rule, but these exceptions do not undermine the general theory. There are cases of forms of life which are intermediate between two extinct species in terms of characteristics (in other words, they resemble both species) but exist later than either. For example, the elephant can be considered a transitional form between some ancient land mammal and the mastodon, but the mastodon is extinct and the elephant is not. However, this is not a serious objection, as the theory of natural selection does not exclude the possibility of the parent-species of a new species outlasting that new species. On a smaller scale, this can be seen in the case of the rock pigeon, which has produced numerous varieties, some of which have even gone extinct. This fact gives rise to a more general rule: The further apart chronologically two fossils are, the less they tend to resemble one another. All of these facts support the view that the species have gradually changed over time.

The geological record also shows that in more recent times, the same types of organisms are generally found in the same areas. Thus, for example, in the tertiary geological period (the most recent geological period) there can be found extinct species of armadillos in South America, where armadillos still to this day exist. This fact is difficult to explain on any theory but that of natural selection. If the older species of armadillos are not related to the modern-day species of armadillos, it is difficult to see why armadillos tend to be found exclusively in America, when other regions, such as

Australia, have very similar climates and the armadillo would, presumably, be well-suited to surviving in such a habitat. However, armadillos are not found in Australia, but they are found in a wide variety of climates and habitats in America. This phenomenon could only be sensibly explained on the theory that the modern-day armadillos found in South America descended from the ancient armadillos found in fossils.

This chapter and the previous chapter have attempted to show that the geological record does not undermine the theory of natural selection and, in fact, on many points supports it. The fact that few transitional links between various species can be found in the fossil record is explained by its great imperfection. Due to the delicate nature of fossilization and the very specific circumstances necessary for a fossil to be preserved over a long period of time, only an extremely tiny portion of organisms are fossilized. Furthermore, geologists have only studied a very small portion of the Earth and have found only a relative few fossils. As a result, the fossil record as it exists today cannot be taken to be representative of the history of life on Earth.

However, those trends which the fossil record does demonstrate tend to support the theory of natural selection by showing that new species gradually develop over time, that species do not reappear after going extinct, and that very ancient animals tend to fall in between now existing groups, suggesting that the groups share a common ancestor. Furthermore, ancient forms generally tend to resemble modern forms less, suggesting that modern forms have undergone significant change. This rule also holds true of species found in fossils themselves, as fossils tend to resemble one another more the closer they are together chronologically. All together, the fossil record is too incomplete to undermine the theory of natural selection, but those general rules that it does seem to suggest about the history of life on Earth all tend to confirm that creatures have changed over time due to natural selection.

Chapter 11: Geographical Distribution

Chapter 11: Geographical Distribution Summary and Analysis

It is obvious that differences in climate and terrain are not sufficient to account for the differences in organisms from one region to the next. This is a conclusion admitted by almost all naturalists who have studied the subject. This point can be illustrated by considering North America and Europe. Very few climates on either continent do not have a counterpart in the other. Nonetheless, the variety of plants and animals in each is completely different. The same is the case with South America, Africa, and Australia.

The existence of barriers within regions is also correlated with a difference in the creatures that inhabit that region. Thus, for example, the kinds of land animals that are found to exist on one side of a mountain often differ greatly from those that live on the other side. The difference between the organisms is, however, of a lesser degree than the difference between organisms that live on different continents. Many examples of this phenomenon can be given. For example, the marine life near the Equator around South America differs radically from one another and yet they are only separated by the small stretch of land at Panama.

A final relevant correlation between geography and the type of organisms found in a region can be seen in the resemblance organisms which live in the same region have, compared to how dissimilar they are to organisms in regions which are very distant or somehow a barrier to them. For example, South America is home to two species of American ostriches that belong to the same genus. The ostriches found in Africa at the same latitude, however, are members of a different genus. Similarly, rodents found in America resemble other American rodents much more than they resemble European or African rodents.

These three facts are easily explained by natural selection. In all of these cases, similarities can be explained by the species having descended from a common ancestor somewhat recently; dissimilarity can be explained by the species having descended from a common ancestor much longer ago. It is a general rule that the offspring of parents generally resemble them, or vary from them slightly. Thus, as more generations pass, more differences are accumulated and the more distinct an organism becomes from its more remote ancestors. Without the ability to interbreed freely, organisms will develop in different ways, and over time, these differences will be significant enough that two new species exist. This explains why there is such a great similarity among organisms on the same continent or on the same side of a mountain chain, and why creatures on different continents, or different sides of a mountain chain, are dissimilar.

From this it follows that if there are many species of the same genus found in different spots in the world, that all of those species must have originated from the same geographical location and that their ancestors, at some point, migrated to where they now live. This is not difficult to believe in the case of those species that exist in very similar forms in different places. It also follows that individuals of the same species must have, at some point, originated from the same location, since natural selection could not independently produce the same species twice.

There are some cases where it seems difficult to hold this view. In order for that position to be true, there must be some explanation of how an organism migrated from one point to the point that it now inhabits. However, the claim is such a simple one that it is difficult to reject. In the majority of cases, the region that a species inhabits is continuous, creating no difficulty in explaining its migration. One of the greatest limiting factors for the migration of a land animal is the sea and there exist no cases where the same species of mammal is found to inhabit two regions that are separated by ocean. In the case of some land bodies that are very close to one another, similar or identical mammals are found, but this can easily be attributed to the previous existence of land between them that allowed for migration, as in the case of those animals common to both England and France. There are some known cases of plants living in very distant areas, but this can possibly be understood because of seeds more easily traveling than animals.

There are many possible ways to explain how a species migrated from one region to the next. In some cases, changes in climate can cause regions to be connected when they were formerly disconnected. For example, if climate becomes significantly colder, a lake could freeze over and allow animals to walk over it. Changes in the level of land or the sea level can also cause two landmasses to become continuous when they were not so before, as is supposed in the case of continental Europe and Great Britain. Some geologists even suggest that all of the islands in the Atlantic near Europe were once attached to it. All of these facts could possibly explain situations which seem to contradict the rule that all of the individuals of a species or genus originated from a common location. There are also what are called "accidental means of dispersal," which are ways by which an organism could spread to a new area which might happen only very rarely, which would include cases where a plant's seed are carried by logs or birds to a distant island. While such cases are rare, over a long period, they are guaranteed to occur at least sometimes.

The geographical distribution of certain organisms can also be explained by migrations made during glacial period, or ice age. In cases of such a dramatic climate shift, some migrations would be obvious. Creatures that were adapted for warm climates would naturally travel towards the equator where the climate would be closer to what they were used to. Creatures that were adapted to living in mountains, in very cold climates, would leave the mountains, which would possibly become too cold or too snowy for them, and live on the now much colder plains that had been abandoned by other organisms. Once the ice age was over, the creatures would return to where they had previously lived. The animals that migrated towards the equator would come back and the mountain animals would migrate back into the mountains. However, consider the case of two mountain ranges that are separated by a large distance of flat land. It is possible that the creatures living in one mountain range would have migrated in the direction of the other mountain range, and when the ice age began to recede, went up the other mountain range instead. This explains the difficult case of finding very similar plants and animals in mountain ranges that are very far apart from one another.

Climate change can also explain how there are certain similarities between organisms in Europe and North America. Though in moderate and cold climates, the two continents are more or less inaccessible to on another, if the temperature were to rise a significant amount, it is possible that plants and animals could have passed from one continent to the other over the land around the North Pole. However, since this event likely took place much longer ago than the ice age, the theory of natural selection would predict that the differences between the organisms would be much greater than the differences found in the mountain animals. In fact, this is the case. While the same species are sometimes found on separate mountain ranges, the lowest classification that is common to European and American animals is that of class, which indicates the species contained within are somewhat distantly related.

Geographical Distribution continued

Geographical Distribution continued Summary and Analysis

It would seem, on the theory that all organisms belonging to the same species or other classification originated from a single location, that freshwater organisms would generally be confined to relatively small areas. Rivers within a country are separated from one another by land and rivers in distant countries are separated by saltwater oceans, an environment in which freshwater creatures cannot generally survive.

This occurrence may be explained by a certain adaptation possessed by many freshwater creatures that allows them to migrate from one river to another or from one pond to another. In the case of fish, there is no known case of the same species of freshwater fish existing on different continents, a fact which would be impossible to explain if it were true. However, these species of fish are frequently found in other rivers and streams within the same continent. There are some accidental means of dispersal by which the fish could arrive in other water systems. For example, if a cyclone picked a fish out of one stream and dropped it in another. It is more likely that the wide geographical range of fish can be explained by changes in water levels and land levels, however. There is geological evidence to suggest that the Rhine River has varied considerably in height in the past several centuries. This could result in rivers that are now separated being joined and enabling migration with ease. There are some cases of closely related freshwater fish being found at very distant points of the world, and while it may not be possible to explain each case at the present, geological and climate changes might be able to provide at least a partial explanation. It is also possible for a freshwater fish to develop the ability to live in saltwater through natural selection and then re-adapt to freshwater once reaching a new location. This process would naturally take many generations.

Another case of difficulty in understanding the geographical distribution of animals within the theory of natural selection is that of islands in the ocean. There are many facts about these islands that support the theory. For example, there are often many more unique, native species on oceanic islands compared to the number of non-native species. This agrees with the theory of natural selection, since inter-breeding with other species would be difficult. As a result, the species that somehow arrived on the island would gradually change independently from their parent-species and develop into unique organisms.

Oceanic islands also frequently lack certain types of organisms. For example, many islands have no mammals. This is easily explained by the fact that it would be difficult for a mammal to migrate there. It also would suggest that the theory that all islands were once part of continents is false, since this would suggest that mammals would be on the island. However, despite the lack of mammals, many islands often have plants on them that possess seeds on their hooks, the purpose of which is obviously to hook onto the fur of a mammal to be transported somewhere. This fact does not undermine the theory, however, as it could easily be the case that the seed of such a plant was transported to the island by some other means and natural selection has found no reason to get rid of the hook on the seed.

In the case of oceanic islands that are somewhat closer to a continent, there is usually correlation between the distance of the island from the continent and how much the species on the island resemble the species on the continent. This suggests that the islands were once part of the main land and some time in the past separated. Over the course of this separation—which would be longer in the case of islands that are very far from the continent—the organisms were modified by natural selection and became more and more distinct from the species on the continent from which they descended. As natural selection would predict, the inhabitants of oceanic islands tend to resemble most the organisms of the continent to which they are closest. For example, the species that inhabit the Galapagos Archipelago, which is located about five hundred miles from the coast of South America, bears a strong resemblance to the species found on the continent.

All of these facts demonstrate the general rules that related species descended from a common ancestor and that, therefore, originated from a single location. If individuals of a species, or species of a genus, exist in multiple places, it must be the result of migration. While it is difficult, in some cases, to explain exactly how the migration could have occurred, it is important to keep in mind that natural selection takes place over a very long period of time, long enough to allow for significant geological or climate changes to occur. As a result, ways of migrating may have been possible which are impossible today.

Chapter 13: Mutual Affinities of Organic Beings: Morphology: Embryology: Rudimentary Organs

Chapter 13: Mutual Affinities of Organic Beings: Morphology: Embryology: Rudimentary Organs Summary and Analysis

Biologists classify organisms into various groups of resemblance that gradually get smaller and include fewer organisms. Thus, the organisms that belong to the same family resemble one another in some way, but not nearly as much as the organisms that belong to the same genus or even species resemble one another. These classifications are not as straightforward as simply identifying one group that walks on land, another which flies, and so on. Rather, the creatures within the various classifications often differ from one another dramatically in certain habits, while retaining other certain common characteristics. The theory of natural selection can make sense of this organization as a kind of outline of the history of the species. Those organisms that belong to the same species descended from a common ancestor relatively recently. Those species that are grouped together in the same genus descended from a common ancestor somewhat less recently. The species that are grouped together into the same family share a common ancestor that is even further back. In this way, natural selection can explain the relationships among creatures that other theories cannot.

On the view that the classification of living things is a kind of reflection of some divine plan or on the view that it is simply a way of classifying similar things, one quickly runs into many difficulties. In ancient times, the basis for classification was external similarities, but this view is obviously false in light of modern science. On this view, for example, the whale would have to be classed with the fish, but it is well-known today that the two animals are not at all related. To fix this difficulty, some try to classify organisms according to those traits that are not directly related to their specific way of life. The reasoning is that the whale is like a fish in certain ways because it must survive in a similar environment. In ways that are not directly related to being an aquatic animal, the whale differs significantly from a fish. While this method is much better, it is not exact. There are cases in which an organ that is not very important or adaptive for a species is nonetheless not given the same value as it is in other creatures.

Classification seems to be clearly influenced by recognizing resemblances among groups of organisms. While in the case of some organisms—for example, birds—some definite traits can be given to identify them, in the case of other animals, such as crustaceans, no straightforward definition can be given. Nonetheless, that crustaceans all belong together in the same group is something with which all naturalists agree. The different groups are, for the most part, arbitrary constructs that only point out various degrees of resemblance. This can be shown in the fact that classifications which were once considered genus have sometimes been raised to the level of family, simply on the basis that more members of the group were found to exist.

The only way to logically classify and organize the various forms of life is according to genealogy, that is, according to the relationship the organisms have to one another by descent. Those organisms which are closely related to one another will be in more specific groups (such as genus or family), while those organisms which are distantly related to one another will be in more general groups (such as class or order). It should be noted that the distance or closeness between relatives, which determines which groups are used in classification, should reflect degrees of modification and not simply blood relation. Thus, for example, over the course of many generations, one organism may change greatly and become a member of a different genus altogether, while another organism may change so little that it remains a member of the same species. Examples of this can be seen clearly in those ancient shells which have changed very little even over the course of perhaps millions of years.

This type of classification is used in classifying varieties. Naturalists frequently insist that two varieties that appear similar in some way should still not be classified together if they were known to have descended from a somewhat remote ancestor. This practice can be seen in the varieties of the tumbler pigeon. The tumbler pigeon has a habit of tumbling head-over-foot while it flies and this is where its name comes from. One might think that this tumbling action is the essence of its distinction from other pigeons, but there exist some varieties that have nearly or completely lost the habit of tumbling. Nonetheless, all naturalists still group these pigeons as tumblers. This suggests that it is natural to classify varieties—and therefore, species and all other groups—according to genealogy and not simply to certain traits.

Organisms that belong to the same class often resemble one another in certain points of structure, independently of the usefulness of that particular structure for their way of living. Thus, for example, the hand bones in a human closely resemble the bone structures in the wing of a bat or the paddle structures in the fin of a dolphin, despite the fact that these three appendages are used for entirely different purposes. This fact cannot be explained by the theory that the species were independently created by God, for there is not apparent reason for the structures to resemble one another in this way. It can, however, be explained by the theory of natural selection, for it starts with the basis that all creatures in the same class are descended from a common ancestor. As a result of this, they all inherit certain traits. Over time, natural selection modifies those traits to adapt the creature to its environment, but it does not necessarily altogether eliminate them. According to the theory, a common ancestor to the dolphin, bat, and human had some hand-like appendage. In the case of the dolphin, the structure was gradually changed to be more useful for swimming; in the case of the bat, the structure was gradually changed to be more useful for flying; in the case of the human, the structure was gradually changed to be more useful for handling objects. However, in all three of these cases, simple modifications of shape were sufficient and so the underlying structure remained, in some respects, the same. It is possible, however, that an organ or trait be changed so dramatically by natural selection that it loses any resemblance to the organ possessed by an ancestor.

Further evidence for natural selection can also be seen in the similarity of parts within the same organism. The bones in the human skull, for example, resemble in certain ways the bones that make up the spine. As was discussed in a previous chapter, natural selection can create a new purpose for an existing organ, and it would seem that in the case of so-called homologous parts—that is, parts that are similar in structure—this is the process that has occurred. On the view that God independently created the human body, it would be difficult to see why the skull would be composed out of a number of irregularly shaped bones that in certain structural ways resemble the spine.

Closely related species often resemble one another especially in the early stages of embryonic development. In fact, the resemblance is so extreme that it can be difficult to distinguish a lizard, bird, and mammal embryo from one another. In other animals, such as insects, embryos need to be more specifically adapted for their lives, and resemblance is less clear. For example, the larvae of certain insects often need to be adapted to specific conditions of life even when they are just born. Nonetheless, the larvae of these creatures resemble one another much more than the adults do.

The similarity of embryos cannot be explained by usefulness, since the circumstances of creatures with very similar embryos are often so widely different, as is the case with humans and frogs. The resemblance tends to end whenever the organism is forced to provide for itself and adapt to its environment, as is the case with the larva of certain insects. There is a general pattern in the development of an embryo to increase in the degree of organization, that is, in general complexity.

A more likely explanation for the similarity of embryos is that the variations that most animals develop and then pass on to their offspring do not appear until some point later in their life, depending upon when the trait would be useful. That traits do appear in this way is confirmed by the experience of breeders, who often find that the quality of a cow cannot be determined until it is fully-grown. In the case of most animals, while the individual is still an embryo, it has little interaction with the world and, therefore, little need to adapt and fight for itself. As a result, there would be little pressure for natural selection to promote traits that caused significant differences in the early stages of the embryo. Once the animal becomes old enough that it does need to fend for itself to some extent it begins to show traits that distinguish it from other animals. Thus, natural selection would tend to ignore the traits of the embryo in its earliest stages and, as a result, the embryo has remained more or less unchanged from the time of the ancient ancestor of all animals.

The existence of rudimentary organs—organs that serve no purpose—offer more support for the theory of natural selection. These rudimentary organs are very common among all types of animals. Unborn cattle, for example, possess a row of upper teeth that they never use. There are also many insects that possess wings that are too small to use for flight and which are often unmovable. Some rudimentary organs do not entirely lose their purpose. For example, the mammary glands in some male mammals have been found to develop and secrete milk, even though the function is useless to the animal.

Rudimentary organs are difficult to explain on the belief that the species were created independently. Some have tried to explain rudimentary organs as simply adding symmetry or "completing the scheme of nature." On the other hand, the theory of natural selection can easily explain the existence of rudimentary organs. If the circumstances of an organisms life changed such that a certain organ's function was no longer necessary, natural selection would gradually reduce that organ in size and ability until it no longer served that function and no longer wasted those resources. In some cases, this reduction could be extreme, especially if the rudimentary organ would be a liability, such as might be the case in beetles with wings that could pick up wind and cause them fly into the ocean.

Chapter 14: Recapitulation and Conclusion

Chapter 14: Recapitulation and Conclusion Summary and Analysis

Up to this point, many facts and arguments have considered, and when combined they form a single argument in favor of the theory that the species descended from others and were modified by the process of natural selection.

Against this theory, many objections have been brought up. However, the theory must be accepted if one accepts a few other beliefs. The first belief is that there exist in nature degrees of perfection. For example, while some bees show an ability to build incredibly efficient and well-made hives, others show an ability to construct only very crude and inefficient hives. Other bees are somewhere in the middle. The second is that all organs and instincts show the ability to vary to some degree. The final belief is that all organisms are constantly engaged in a struggle for survival and, as a result, those that possess variations in their organs and instincts that help them survive will have a better chance of surviving and passing on those variations than others. If one accepts these three propositions, then the theory of natural selection must be accepted also, because it logically follows from them.

Nonetheless, the objections to the theory still must be answered. First, it may be objected that organisms possess certain traits or instincts that are far too complex to be the result of natural selection, such as the eye. While some of these cases are difficult to explain, it should always be kept in mind that organisms exhibit so many different degrees of various traits that one should not underestimate what nature could produce through small, gradual steps.

The theory also relies on eliminating a strong difference between species and varieties. For the theory to be true, all species must have first begun as varieties and then gradually changed through natural selection to become unique species in their own right. Therefore, the difference between a species and a variety is only one of degree. However, given that species are usually not capable of interbreeding, while varieties usually are, it seems that there is a significant difference between varieties and species. However, this can be accounted for in a number of ways. First, it may be that the species changed so much that the act of reproduction becomes in some ways physically impossible for the two species. Second, many of the varieties that have been crossed to prove that varieties can interbreed successfully are varieties that have been produced in domestic circumstances. However, domestic varieties are usually bred for fertility and so it should not be surprising that, when two varieties are bred, they produce fertile offspring.

Some objections may also be raised on the basis of the geographical distribution of certain organisms—that is, where individuals of a species are found around the world. According to the theory of natural selection, all animals of the same species or genus are related to one another by sharing a common ancestor. This implies that these individuals all originated from the same geographical location. However, there are many cases where it seems that related organisms could not have possibly come from the same geographical location, such as mountain animals of the same species that are found on very distant mountain ranges. However, situations such as this can be accounted for in many ways, such as changes in climates causing migrations.

While these objections do pose some difficulty to accepting the theory, it has been shown that some answer can be given to each of them. However, there is also a large amount of evidence that supports the theory. That variation regularly occurs in plants and animals is obvious from the experience of breeders and cultivators, who manipulate these variations to improve their stock and create new varieties. In a similar way, nature gradually changes organisms through natural selection, which is a result of the constant struggle all organisms are engaged in for survival. Since all organisms produce far more offspring than can possibly survive, only the strongest and most adapted will live and be able to reproduce. As a result, those organisms born with good variations will tend to pass them on, while those without them will tend to die off. Over time, these variations are accumulated and can amount to differences large enough to produce an entirely new species. Natural selection can also modify instincts as well as physical traits, as variations can be found in either.

While the fossil record is imperfect and incomplete, what evidence it does provide supports the theory of natural selection. Evidence suggests that new species developed slowly and gradually over time and that a large number of species have gone extinct. Further, once a species has gone extinct, it generally does not reappear. Fossilized animals found in a region are usually related to the living creatures that are still there. For example, there have been a number of fossils of Edentata (a group of organisms which includes anteaters and armadillos) found in South America, where a number of species of that family still exist. However, in similar conditions, such as Australia, these creatures cannot be found. This suggests that the modern-day Edentata descended from the now-extinct species found in the fossils.

The geographical distribution of organisms also supports the theory of evolution. While migrations have certainly occurred, many forms of life are confined to certain areas of the world. These forms of life tend to be closely related to other organisms living near them. For example, rodents found in America tend to be more closely related to other American rodents than they are to African rodents. On the theory that the two descended from a common ancestor, this seems obvious. However, if one believes that the species were independently created by God, this is impossible to explain. Very isolated regions also tend to be inhabited only by certain types of life. For example, land mammals are never found on very remote oceanic islands. Why God would choose to create land animals only on continents and not on islands is difficult to explain. However, if the theory of natural selection is accepted, then the explanation is straightforward. Mammals only exist where they have been able to migrate to, and the islands in the ocean are separated by far too great a distance to be crossed by any mammals but bats.

The similar structures in organisms also show traces of the process of natural selection. For example, the dolphin's paddle and the human hand are structurally very similar even though the purposes for which they are used are very different. If the two creatures are descended from a common ancestor, this can be understood, since offspring tend to inherit the traits of their parents. However, if the dolphin and human were independently created, it is hard to explain why they would possess such similar features. Likewise, the existence of rudimentary organs—organs that serve no purpose—suggests that the animal has changed from a past state in which the organ was of some use. Once again, if the species were created and never changed, it would be difficult to explain why some would be created with organs that served no function.

Despite all of the evidence in support of the theory of natural selection, the majority of naturalists reject it. That the species did not change seemed like an obvious belief when it was believed that the Earth has not existed for a very long time, but geological evidence has shown that the Earth is many times older than was previously thought. Others reject the theory because the fossil record does not provide enough evidence. However, the fossil record is incomplete and imperfect and should not be relied upon to accurately represent the history of the world.

If the theory of natural selection is accepted, it is difficult to say how far it should be extended. It is harder to accept the theory if it includes very different forms of life. For example, it is much easier to see how cats and dogs might have descended from a common ancestor than to believe that fish and humans did the same. However, there is reason to believe that natural selection might account for a great amount of the diversity of life. Even organisms as distinct as plants and animals share certain similarities, such as cell structure and similar reactions to poisons. There is some reason to believe, then, that all life descended from a single ancestor that originally possessed life.

When the theory of natural selection is accepted by scientists, it will revolutionize the field of biology. Much of the work done by naturalists involves arguing over whether an organism should be considered a variety or species, and these arguments would cease if it is no longer believed that the species were the product of an act of creation, but rather of natural selection. The relationships between organisms will also be understood as the result of descending from a common ancestor and this will shed much light on the history of life.

The theory of natural selection does not give a less noble or beautiful account of the history of the world than the belief that the species were independently created. It is much more elegant to think that all of the various species of the world descended from a single act of creation at the beginning of life and, through the physical laws of the world imposed by God, developed into what they are today. It also gives great hope for the future, for the fact that life still exists implies that there was no great disaster in the past that eradicated all life and, for the same reason, humanity might expect to continue for a great period. Further, the process of natural selection improves individuals and thus, over time, all organisms will gradually reach towards perfection.

Characters

Naturalists

Naturalists are the 19th-century equivalent to biologists in modern-day. Their primary object of study, therefore, was plants and animals. As Darwin characterizes them, naturalists of his period were especially wedded to the notion that the species were created in an unchanging form by God. Since the origins of the species were already explained, then, the naturalist appears to have spent most of time his painstakingly classifying organisms into varieties, species, genera, and higher levels. There appears to have been a large amount of bickering about whether one animal belonged to the same genus as another and, according to their methodology, disputes of this nature could never really be solved, as classifications were based entirely on external similarity. If scientists disagreed about the similarity, or dissimilarity, of two organisms, very little fruitful debate could be had.

The Origin of Species is directed at changing the view of naturalists on all of these points, specifically on the view that God created the species, as they exist today. The reason that naturalists had become so mired in classifications is because of their deficient view of the origin of species. On the view that natural selection produced the species, there would exist objective criteria by which to rank and classify the species, namely, according to common descent. While Darwin has little hope of changing the minds of the existing generation of naturalists—who he believes are too wedded to their views—he hopes that the new generation of young naturalists will be more willing to consider new ideas.

Geologists

Geologists are scientists who study the earth and its history, particularly its non-living aspects. Darwin relies heavily on geological evidence. It is used, for one, to prove that the earth has existed for a sufficiently long time for natural selection to produce the variety of species that exist today. Geology provides evidence of this by measuring the amount of erosion found on certain rock formations. Since the rate of erosion can be measured, the age of the cliffs can likewise be determined. In many cases, the erosion of cliffs suggests that the earth is millions of years old, at the youngest. Geology also provides for explanations of the migration of animals by showing evidence of islands breaking off from continents and the occurrence of an ice age in recent history.

Paleontologists

Paleontologists are scientists who study and search for fossils. Their work is closely related to the work of naturalists and is especially important for Darwin's work as his theory of natural selection makes a number of predictions about previous inhabitants of the earth.

Breeders

Breeders raise and sell large quantities of plants or animals and through the process of selecting only the best stock to breed from, gradually improving the entire stock. The practice of breeders is the basis for the first chapter on artificial selection.

Dr. Hooker

Darwin cites Dr. Hooker as his greatest aid and resource during the process of writing and editing the Origin of Species. Like Darwin, Dr. Hooker is a naturalist who, presumably, is interested in promoting the theory of natural selection.

New Generation of Naturalists

Darwin looks to the upcoming, young generation of naturalists to accept his theory and expand it. He truly sees the theory of natural selection as the future of natural science and laments that the current generation of naturalists are too wedded to the old, established notions to largely accept a new one like natural selection. However, he believes, or hopes, that the new generation will be more open-minded and critical in their thought.

Botanists

The breeding of plants provides much of the research which Darwin cites in the Origin of Species, and as such, Darwin relies heavily on the work of botanists. Since the plants can be bred together much more easily than animals, and reproduction is much quicker, experimentation is also easier.

Religious Objectors

Some people in Darwin's time objected to his theory on religious grounds. They believed that the theory of natural selection diminished or altogether destroyed the role of God in Creation. Darwin argues against this in the conclusion by arguing that God's Creation is more, and not less beautiful, in light of natural selection.

Edward Forbes

Darwin cites Edward Forbes, apparently dead at the time of the book's publication, for an insight into the geographical continuity animals belonging to the same species, resembling the trajectory of an object moving through space.

Hon. and Rev. W. Herbert

W. Herbert, apparently some kind of clergyman according to the titles which Darwin uses, provides important botanical evidence in the chapter on hybridism. While Darwin was unable to successfully breed two species of plants together and produce fertile offspring, Herbert was able to breed perfectly fertile offspring from the exact same two species.

Objects/Places

Artificial selection

Artificial selection is the process by which plants or animals kept by breeders are gradually improved. Minor variations in the organisms occur and perceptive breeders notice them and breed only from those organisms which show desired variations. Over time, these variations accumulate and significant changes can be made to the stocks.

Natural Selection

Natural selection is the process by which plants and animals in nature are gradually improved and adapted to their environment. As all organisms are engaged in a constant struggle for existence, those organisms that exhibit variations which increase their chances of survival will tend to survive and reproduce more than those against which they compete. As a result, natural selection will accumulate these helpful variations and, over time, great changes can occur. Darwin believes that natural selection is the means by which one species descends from another.

Geological Record

The geological record is the collection of fossils found in the earth. These represent a sample of creatures that have lived in the past, even the distant past. Critics of natural selection cite the geological record, as it does not appear to provide the evidence of transitional species that Darwin's theory predicts would exist. Darwin, however, believes that the geological record is very flawed since only a tiny percentage of organisms are represented in it and many are destroyed through natural processes, such as earthquakes or erosion.

Geographical distribution

Geographical distribution refers to where organisms are found to exist on the earth. According to Darwin's theory, all organisms of the same species descended from the same ancestor and, as a result originated from the same geographical location. When closely-related organisms are found in very different places, then, Darwin must find some way to explain how they all migrated from the same region.

Struggle for existence

The struggle for existence is how Darwin describes the competition among organisms for the scarce resources provided by nature. All organisms reproduce at a very rapid rate and resources can only support a small number of them. As a result, only the strongest of them survive.

Morphology

Morphology is the study of the physical properties of plants and animals. It is used by naturalists in Darwin's time to classify organisms. Darwin uses morphological similarities to provide evidence for common descent among various groups.

Embryology

Embryology is the study of embryos of animals. Darwin uses the fact that the embryos of all vertebrae animals—from humans to birds—are nearly identical at an early age to suggest that all animals share a common ancestor.

H.M.S. Beagle

The H.M.S. Beagle is the ship on which Darwin toured South American and its surrounding islands on. This exploration was one of the motivations for his theory of natural selection.

Galapagos Islands

The Galapagos Islands are the islands off of the coast of South America which was a primary inspiration for Darwin's theory of natural selection. Examples from the Galapagos are referenced throughout the book, and what struck Darwin in particular was the wide variety of organisms found on them which all seemed perfectly adapted to the circumstances of their lives.

Hybrid

Hybrids are the offspring of two distinct species. They pose a difficulty for Darwin's theory because his theory depends upon the idea that species and varieties are not distinct except by degree of difference. However, the offspring of distinct varieties are almost always fertile, while the offspring of species are almost always sterile. This suggests that there is, in fact, a significant difference between species and varieties. However, as Darwin argues in the chapter on hybridism, this difficulty is weaker than it may seem.

Themes

Struggle for Existence

Crucial to Darwin's theory of natural selection is the idea that far more plants and animals are produced than can survive. Plants and animals produce in very great numbers and would, within a short period, create very large populations. This applies both to those organisms that reproduce quickly, such as some species of insects, and to those organisms which reproduce slowly, such as elephants or humans. This is due to what Darwin calls the geometrical rate of reproduction. If a pair of elephants mates and produces four children, and each of those four children produce four more children, which each in turn produce four more children, after just three generations, two elephants will have produced sixty-four children. Over just fifteen generations, reproducing at this rate, the elephants produced from the single initial pair would number over one billion. These creatures must all compete with one another for scarce resources and if they are not successful, they will die off. Therefore, only a very small portion of all creatures born will survive.

Natural Selection

Natural selection is the process by which organisms in the wild adapt to their environment. Natural selection depends first upon the fact that plants and animals occasionally vary in some way from their parents. For example, an animal might be born with slightly longer legs or sharper teeth than either of its parents. While many of these variations will not be helpful to the organism, and in fact may actually be harmful, in some rare cases the variation would be helpful and give the organism a greater chance of survival. Since all organisms are constantly engaged in an intense struggle for survival, due to the large numbers born and the scarce amount of natural resources to support all of them, any time a creature exhibits a variation that is favorable to survival, it is likely the creature will survive and pass that trait on to offspring. In this way, over the course of many generations, organisms will accumulate traits which are favorable to their survival and eventually can change greatly enough for new species to develop.

Arguing Against the Creation of the Species

The main purpose of the book is to undermine the belief that the species were created exactly as they appear today by God and never changed. This belief, as is evident from the final chapter, was the most common belief among biologists at the time. Darwin's theory that the species descended from other species and were modified through natural selection is opposed to this, because it would mean that the species were not created by God and did change. Darwin hopes to change their minds both by providing evidence for his own theory as well as frequently pointing out flaws with theirs. One way he frequently does this is to show signs of natural selection and then pointing out that those who believe in the creation of the species cannot explain it. For example, the paddles of dolphins, the wings of bats, and the hands of humans all have similar bone structures, even though they are used for very different purposes. On the belief that the three organisms are not related, and were each independently created, it would be difficult to explain why God would do this if he could instead give the organisms bone structures that were more related to their habits of life. The final chapter ends with an attempt to show that the theory of natural selection does not detract from the beauty of the natural world that can be interpreted as an attempt to convince religious readers that there is no difficulty in accepting Darwin's theory.

Style

Perspective

The Origin of Species is written from the perspective of a scholar who realizes that he is writing to a largely skeptical and even openly critical audience. As he indicates in the introduction and conclusion, the majority of biologists in his time does not accept his theory and are perhaps even ideologically opposed to considering it. As a result, Darwin approaches the subject very carefully and tries not to alienate his audience by appearing too forceful or sure of himself. Nevertheless, Darwin is obviously certain that his theory is true, and even states this, once again, in the introduction and conclusion.

Darwin is a trained biologist (or "naturalist", according to the usage of his time) and very obviously deeply enmeshed within his field, as his frequent references to the works of others indicate. His own status in the field is indicated by the fact that he has evidently conducted a fair amount of original research (which he cites at several points) and published other books. Nonetheless, as immersed as he may be in the field, he is obviously at odds with it, especially with the most vocal proponents of the beliefs that God created the species individually and that the species do not change. This belief, he argues, does great harm to the study of the natural world by needlessly restraining research and thought. All in all, Darwin appears to be attempting to balance successfully asserting his theory and the evidence for it with the need to be tactful and not alienate his peers.

Tone

The tone throughout the book is very modest. Darwin frequently qualifies his statements by saying that it is "my theory" or "my view", rather than asserting that it is certainly a fact that others must simply accept. He also is very ready to acknowledge the seriousness of objections and possible flaws in his theory, even when he ultimately rejects them. Thus, for example, in chapter seven on instincts he acknowledges that the fact that drones and soldiers in ant colonies do not breed is a very grave difficulty for his theory, since the basis of it is that all creatures are improved in ways that make their chances of reproduction and survival the greatest. He provides some possible solutions to this problem, but gives no definitive answer. This shows a definite willingness to engage in a conversation with his opponents. His humility can also be seen his frequent citation of sources. While Darwin does provide some of his own original research in the book, he relies for the most part on the work of others. This tone is probably taken largely because he knows that the majority of people who are reading his work, at least at the time it was published were not sympathetic to his view.

It should be noted, however, that though he takes a humble tone in presenting his arguments for his theory, he is not unsure of his conclusions. This is obvious in both the introduction and in the conclusion. In the introduction, he expresses his confidence that one day all biologists will accept his theory. In the conclusion, he repeats this, but laments that many biologists working today may be too hardheaded to change their minds on a subject so central to their field. He hopes that younger biologists who are hopefully more open-minded will accept his theory.

Structure

The Origin of Species opens with an introduction that performs several useful tasks. First, it establishes Darwin's credentials for writing on the subject. It is important that the reader is aware of this from the beginning, since he is advancing a theory that contradicts many deeply held beliefs of other biologists. Second, it provides a brief overview of the content of the book, as well as a summary of the order in which the information is presented. As the opening chapters of the book mainly outline Darwin's own theory, it is useful for the reader to know that objections that may come to mind will be dealt with later and are not simply being brushed over. The introduction also contains a promise of a future work that will provide the scientific data that Darwin thinks is necessary to prove his theory; by including this promise in the introduction, he is largely undermining those critics who would criticize his lack of hard scientific facts.

The book is then divided into fourteen chapters. Chapters I through V explain Darwin's theory and the crucial premises it depends upon. Chapter I describes how plants and animals kept domestically exhibit variations and how breeders use these variations to improve their stock. This is provided first to give a familiar example that serves as an analogy for the process of natural selection. Chapter II formally establishes this analogy by arguing that variations do not only occur in domestication, but also in the wild. Variation occurs in the wild and is the first major premise in Darwin's argument. Chapter III establishes the second premise, that all organisms are engaged in a constant struggle for survival. Chapter IV combines the two premises and presents Darwin's basic theory: that the species that now exist were not independently created but descended from other species and were modified through the process of natural selection. Chapter V provides some speculation and observations on the exact nature of variation in nature.

Chapters VI through XIII deal with objections that have been or could be raised against Darwin's theory. The fact that the majority of the book is dedicated to responding to objections provides insight into the book's rhetorical context. As Darwin mentions explicitly in the introduction and in the conclusion, the majority of people in his field do not accept his views. The burden, therefore, is on him to try to respond to all of the objections raised against him and his theory. Chapter VI focuses on objections based on the lack of living organisms that link the various species together, as his theory seems to predict would exist, and objections raised on the basis of the complexity of certain organs. Chapter VII deals entirely with the subject of instinct and shows how certain very complex instincts, such as the hive-making instincts of bees, could develop through natural selection. Chapter VIII treats of the issues of fertility between distinct species and the fertility of their offspring, a point which seems to undermine his crucial claim that species are slightly more develop varieties. Chapter IX deals with objections based on the fossil record, to which he responds by arguing that the fossil record is very incomplete and imperfect. Chapter X examines the fossil record from the point of view of natural selection and attempts to show that what little evidence it does provide supports his theory. Chapters XI and XII discuss objections raised on the basis of where certain organisms are found, which seem to undermine a logical consequence of the theory of natural selection. Chapter XIII examines similarities found among distinct species and uses this as a basis for arguing for their common descent.

The final chapter of the book summarizes all of the arguments that have been made so far and ends with an appeal to the religious sympathies of his readers and critics. As many skeptics of his theory will disagree on religious grounds, he argues that his theory does not detract from the beauty of the world or from its Creator. This is perhaps included last as a final appeal to the reader who was unwilling to accept Darwin's arguments and to attempt to console the religious confusion some might be experiencing.

Quotes

"When on board H.M.S. Beagle, as naturalist, I was much struck with certain facts in the distribution of the inhabitants of South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to me to throw some light on the origin of species — that mystery of mysteries, as it has been called by one of our greatest philosophers." (p. 27)

"No one ought to feel surprise at much remaining as yet unexplained in regard to the origin of species and varieties, if he makes due allowance for our profound ignorance in regard to the mutual relations of all the beings which live around us. Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare? Yet these relations are of the highest importance, for they determine the present welfare, and, as I believe, the future success and modification of every inhabitant of this world." (p. 30)

"When we look to the individuals of the same variety or sub-variety of our older cultivated plants and animals, one of the first points which strikes us, is, that they generally differ much more from each other, than do the individuals of any one species or variety in a state of nature. When we reflect on the vast diversity of the plants and animals which have been cultivated, and which have varied during all ages under the most different climates and treatment, I think we are driven to conclude that this greater variability is simply due to our domestic productions having been raised under conditions of life not so uniform as, and somewhat different from, those to which the parent-species have been exposed under nature." (p. 31)

"Let us now briefly consider the steps by which domestic races have been produced, either from one or from several allied species. Some little effect may, perhaps, be attributed to the direct action of the external conditions of life, and some little to habit; but he would be a bold man who would account by such agencies for the differences of a dray and race horse, a greyhound and bloodhound, a carrier and tumbler pigeon. One of the most remarkable features in our domesticated races is that we see in them adaptation, not indeed to the animal's or plant's own good, but to man's use or fancy. Some variations useful to him have probably arisen suddenly, or by one step; many botanists, for instance, believe that the fuller's teazle, with its hooks, which cannot be rivalled by any mechanical contrivance, is only a variety of the wild Dipsacus; and this amount of change may have suddenly arisen in a seedling. So it has probably been with the turnspit dog; and this is known to have been the case with the ancon sheep. But when we compare the dray-horse and race-horse, the dromedary and camel, the various breeds of sheep fitted either for cultivated land or mountain pasture, with the wool of one breed good for one purpose, and that of another breed for another purpose; when we compare the many breeds of dogs, each good for man in very different ways; when we compare the gamecock, so pertinacious in battle, with other breeds so little quarrelsome, with 'everlasting layers' which never desire to sit, and with the bantam so small and elegant; when we compare the host of agricultural, culinary, orchard, and flower-garden races of plants, most useful to man at different seasons and for different purposes, or so beautiful in his eyes, we must, I think, look further than to mere variability." (p. 42)

"Again, we have many slight differences which may be called individual differences, such as are known frequently to appear in the offspring from the same parents, or which may be presumed to have thus arisen, from being frequently observed in the individuals of the same species inhabiting the same confined locality. No one supposes that all the individuals of the same species are cast in the very same mould. These individual differences are highly important for us, as they afford materials for natural selection to accumulate, in the same manner as man can accumulate in any given direction individual differences in his domesticated productions." (p. 59)

"Certainly no clear line of demarcation has as yet been drawn between species and sub-species that is, the forms which in the opinion of some naturalists come very near to, but do not quite arrive at the rank of species; or, again, between sub-species and well-marked varieties, or between lesser varieties and individual differences. These differences blend into each other in an insensible series; and a series impresses the mind with the idea of an actual passage." (p. 66)

"From these remarks it will be seen that I look at the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, and for mere convenience sake." (p. 68)

"From looking at species as only strongly-marked and well-defined varieties, I was led to anticipate that the species of the larger genera in each country would oftener present varieties, than the species of the smaller genera; for wherever many closely related species (i.e. species of the same genus) have been formed, many varieties or incipient species ought, as a general rule, to be now forming. Where many large trees grow, we expect to find saplings. Where many species of a genus have been formed through variation, circumstances have been favourable for variation; and hence we might expect that the circumstances would generally be still favourable to variation. On the other hand, if we look at each species as a special act of creation, there is no apparent reason why more varieties should occur in a group having many species, than in one having few." (p. 70)

"A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase." (p. 77)

"The elephant is reckoned to be the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase: it will be under the mark to assume that it breeds when thirty years old, and goes on breeding till ninety years old, bringing forth three pairs of young in this interval; if this be so, at the end of the fifth century there would be alive fifteen million elephants, descended from the first pair." (p. 77)

"The face of Nature may be compared to a yielding surface, with ten thousand sharp wedges packed close together and driven inwards by incessant blows, sometimes one wedge being struck, and then another with greater force." (p. 78)

"A corollary of the highest importance may be deduced from the foregoing remarks, namely, that the structure of every organic being is related, in the most essential yet often hidden manner, to that of all other organic beings, with which it comes into competition for food or residence, or from which it has to escape, or on which it preys." (p. 92)

"The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have tried to overmaster other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs; and this connexion of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. Of the many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear all the other branches; so with the species which lived during long-past geological periods, very few now have living and modified descendants." (p. 131)

"t is generally acknowledged that all organic beings have been formed on two great laws Unity of Type, and the Conditions of Existence. By unity of type is meant that fundamental agreement in structure, which we see in organic beings of the same class, and which is quite independent of their habits of life. On my theory, unity of type is explained by unity of descent. The expression of conditions of existence, so often insisted on by the illustrious Cuvier, is fully embraced by the principle of natural selection. For natural selection acts by either now adapting the varying parts of each being to its organic and inorganic conditions of life; or by having adapted them during long-past periods of time: the adaptations being aided in some cases by use and disuse, being slightly affected by the direct action of the external conditions of life, and being in all cases subjected to the several laws of growth. Hence, in fact, the law of the Conditions of Existence is the higher law; as it includes, through the inheritance of former adaptations, that of Unity of Type." (p. 220)

"But just in proportion as this process of extermination has acted on an enormous scale, so must the number of intermediate varieties, which have formerly existed on the earth, be truly enormous. Why then is not every geological formation and every stratum full of such intermediate links? Geology assuredly does not reveal any such finely graduated organic chain; and this, perhaps, is the most obvious and gravest objection which can be urged against my theory. The explanation lies, as I believe, in the extreme imperfection of the geological record." (p. 293)

"The inhabitants of each successive period in the world's history have beaten their predecessors in the race for life, and are, in so far, higher in the scale of nature; and this may account for that vague yet ill-defined sentiment, felt by many palaeontologists, that organisation on the whole has progressed. If it should hereafter be proved that ancient animals resemble to a certain extent the embryos of more recent animals of the same class, the fact will be intelligible. The succession of the same types of structure within the same areas during the later geological periods ceases to be mysterious, and is simply explained by inheritance." (p. 345)

"We have seen that the members of the same class, independently of their habits of life, resemble each other in the general plan of their organisation. This resemblance is often expressed by the term `unity of type;' or by saying that the several parts and organs in the different species of the class are homologous. The whole subject is included under the general name of Morphology. This is the most interesting department of natural history, and may be said to be its very soul. What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include the same bones, in the same relative positions?" (p. 420)

"The embryos, also, of distinct animals within the same class are often strikingly similar: a better proof of this cannot be given, than a circumstance mentioned by Agassiz, namely, that having forgotten to ticket the embryo of some vertebrate animal, he cannot now tell whether it be that of a mammal, bird, or reptile." (p. 430)

"Authors of the highest eminence seem to be fully satisfied with the view that each species has been independently created. To my mind it accords better with what we know of the laws impressed on matter by the Creator, that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of the individual. When I view all beings not as special creations, but as the lineal descendants of some few beings which lived long before the first bed of the Silurian system was deposited, they seem to me to become ennobled." (p. 459)

"Judging from the past, we may safely infer that not one living species will transmit its unaltered likeness to a distant futurity. And of the species now living very few will transmit progeny of any kind to a far distant futurity; for the manner in which all organic beings are grouped, shows that the greater number of species of each genus, and all the species of many genera, have left no descendants, but have become utterly extinct. We can so far take a prophetic glance into futurity as to foretel that it will be the common and widely-spread species, belonging to the larger and dominant groups, which will ultimately prevail and procreate new and dominant species. As all the living forms of life are the lineal descendants of those which lived long before the Silurian epoch, we may feel certain that the ordinary succession by generation has never once been broken, and that no cataclysm has desolated the whole world. Hence we may look with some confidence to a secure future of equally inappreciable length. And as natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection." (p. 459) "t is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." (p. 459)

Topics for Discussion

What is the main belief which Darwin is arguing against throughout the book?

Is Darwin being intellectually honest by explicitly leaving out the factual basis he believes is necessary to prove his theory and asking the reader to trust that he has researched the topic thoroughly? How does his promise to publish a future work with this data affect this?

Why does Darwin devote the majority of the book to answering objections rather than providing evidence for this theory?

When responding to objections based on the geological record, Darwin responds by saying that the geological record is imperfect and incomplete. However, in the following chapter, he uses evidence from the geological record to support his theory. Is he contradicting himself by doing this?

At several points in the book, Darwin raises an objection and admits that he cannot provide a definitive response to it. Does this weaken his argument and, if so, to what extent?

In the conclusion of the book, Darwin claims that the theory of natural selection does not detract from God's role in Creation, but makes it nobler. Is this true?

Why does Darwin spend so much time discussing the distinction between a variety and a species? In what way is undermining this distinction crucial to his theory?

How does the fertility between varieties and the sterility between species affect the theory of natural selection?

How do the similarities between organisms mentioned in Chapter XIII support the theory of natural selection?