Wonderful Life: The Burgess Shale and the Nature of History Study Guide

Wonderful Life: The Burgess Shale and the Nature of History by Stephen Jay Gould

BOOKRAGS

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Plot Summary

Wonderful Life: The Burgess Shale and the Nature of History focuses on a limestone quarry high in the Canadian Rockies known as the Burgess Shale. The Burgess Shale formed 530 million years ago and contains fossils of creatures from an incredibly ancient sea, where a plethora of frighteningly alien creatures lived and died. Stephen Jay Gould, the famous paleontologist, evolutionary biologist, and science journalist uses the Burgess Shale as a method of teaching the reader about the animals found therein and the evolution of our understanding of these animals' relationships to the organisms of today. However, he has a further purpose as well. He believes that the story of how scientists came to classify the animals of the Burgess Shale can shed light on the nature of history.

The man who discovered the Burgess Shale in 1909, Charles Doolittle Walcott, understood evolution as a gradual, steady progression from primitive, precursor forms of life to more advanced forms of life. Diversity of life increased steadily over time. Thus, evolution climbed a "ladder" of complexity and increased in diversity in the shape of a "cone." This preconception led Walcott to classify the animals of the Burgess Shale incorrectly as precursors to many of the arthropods that we see around us today. However, later paleontologists were forced to make the "Burgess revision." Throughout the 70s, a paleontologist named Harry Whittington and two of his students were forced to conclude that many of the animals of the Burgess Shale were evolutionary dead ends. Entire new phyla and groups were created in order to place these animals in their proper taxonomy. It turns out that the Cambrian "decimation," in which 96% of all sea life died, wiped out most of the animals of the Burgess fauna but apparently for only contingent reasons. Thus there was great diversity, which then was largely decimated. This showed paleontologists that the nature of evolutionary history was far from gradual and progressive. The image of the ladder and the cone was misleading. Instead, evolution is guided loosely by the laws of nature and something Gould calls Contingency—or the hand of chance and incredibly improbable events.

He uses this lesson, the lesson of Contingency, to argue that the Burgess Shale teaches humans that their evolution was an incredibly improbable event with no evolutionary significance. We should not understand ourselves as the "top" of the evolution ladder or that evolution would lead inevitably to our development. Instead, we should take a less arrogant and anthropocentric view of humanity's place in the universe, a view that Gould finds liberating. Gould's writing is classic and tells many stories, not only of the complexities of the Burgess fauna but of the life and work of the men who discovered and analyzed these creatures. In the middle of the book we are treated to five acts of what Gould calls "the Burgess Drama," an incredible illustration of what Gould considers one of the most important scientific discoveries in human history, a discovery that has gone largely unnoticed.

Chapter 1, The Iconography of an Explanation

Chapter 1, The Iconography of an Explanation Summary and Analysis

The Burgess Shale is the largest collection of fossils ever discovered. It is composed of invertebrates, found in the Canadian Rockies, within Yoho National Park, which is close to the eastern border of British Columbia. It is perhaps the most important collection of fossils that scientists have uncovered and it offers unique insight into the nature of life and the evolution of life forms. Stephen Jay Gould proposes to use the Burgess Shale to illustrate the nature of history, not only to tell the reader the tale of human evolution but to draw some philosophical points from it. The first chapter explains the original interpretation of the development of life communicated by the Burgess Shale and the subsequent, distinct interpretation. Gould draws some deep methodological and philosophical lessons from the shift.

The Burgess Shale represents the "Cambrian Explosion" of new life forms around 570 million years ago. It contains within it the precursors of practically every form of animal life, and within the small scale (from an evolutionary perspective) of a mere few million years. The Burgess Shale was discovered in 1909 by a man named Charles Doolittle Walcott, America's "greatest paleontologist and scientific administrator" who was then the secretary of the Smithsonian Institute. Walcott provided the first interpretation of the shale, classifying the Burgess animals into particular groups and then listing subsequent animals as "improved" versions of the original. The new interpretation was given in 1971 by Professor Harry Whittington of Cambridge and his colleagues. They showed that the Burgess animals do not fit into a single category, nor do they reflect gradual, progressive development. Further, many of the general types (phyla) of the Burgess Shale animals no longer exist.

Gould has three aims in the book—to recount the intellectual drama that led to rejecting Walcott's interpretation, draw out the statement the reinterpretation makes about history's nature and the improbability of its occurrence. Finally, Gould will focus on how this new research paradigm has not been communicated to the public.

The original interpretation is represented by Gould as "the ladder" and "the cone." "The ladder" refers to the older view of human evolution and development that was linear, progressive and inevitable. Evolution follows a stable path towards more complex forms of life and if the process was "reset" at the beginning, similar creatures would arise at the end. Thus, human evolution represents a "ladder" with a small, primitive beginning expanding towards a wide degree of progressive diversity at the end. This wide degree of diversity is the "cone." In stark contrast, the new interpretation emphasizes that human evolution has no single order. Instead, the results of evolution are just the contingent result of innumerable extinctions, upheavals and adaptations. Were the tape

of history "reset," the same results would almost never be reproduced. Further, evolution by no means always involves progress. Many developed animals simply die out; in fact whole classes of animals do.

Accepting this picture has an enormous psychological cost. Humans are no longer the most progressive animals in history, nor is the universe centered around them, nor are they the inevitable outcome of evolution, but instead developed out of an extremely improbable series of accidents. We can respond to this discovery either with despair at our loss or joy in the new challenge of a truer and more complex world. The evolution of life contains "decimation and diversification." Decimation involves the destruction of whole classes of animal life, with diversification occurring in response. The Burgess Shale represents something far more complex, more contingent, and more improbable than Walcott could have imagined. It contains dramatic diversity but also contains a great "disparity" between anatomical types. We do not have to accept that our development was "random" though. Instead, the Burgess shale—in Gould's view—offers us an understanding of history as "contingency," not randomness. Its development is not purely random, but shaped by real factors, despite the outcome not being guaranteed or repeatable. Ultimately, this picture of reality will prove to be more satisfying, more realistic and more honest than the alternative.

Chapter 2, A Background for the Burgess Shale

Chapter 2, A Background for the Burgess Shale Summary and Analysis

The purpose of Chapter 2 is to prepare the reader for the tale of the Burgess Shale by providing her with the necessary background to understand the "drama" of the tale. Gould begins by explaining the way that paleontologists (and other scientists) divide up historical epochs. There are eras, which are composed of periods, which are themselves composed of epochs. The pre-multi-cellular-life era is known as the Precambrian Era and comprises the first 4 billion years of Earth's history. The boundary between the Paleozoic and Precambrian eras (570 million years ago) is marked by the "Cambrian explosion" or the diversity of life that arose from the first multi-cellular creatures. The Precambrian Era contains geological, non-biological time and the advent of single-celled life. The Burgess fauna follow the beginning of the Paleozoic Era. The boundary between the Paleozoic and Mesozoic eras (225 million years ago) occurs at the greatest extinction in history, where 96% of all marine life died. Finally, the boundary between the Mesozoic and Cenozoic eras (65 million years ago) is the famed "death of the dinosaurs" boundary which made possible the development of large mammals like humans.

The Burgess Shale left scientists with many questions. For instance, why did multi-cellular life take so long to evolve? Why do the Burgess fauna seem to have no intermediate precursors? Gould takes pains to notice that the evolution of multi-cellular life was not unmitigated progress, as the time between the first multi-cellular creature and the first multi-cellular animal is incredibly large. The difference between eukaryotic fauna (small, multi-cellular creatures) and the Burgess fauna is vast and leaves scientists with even more mysteries. Between the two faunas are three general stages of fauna. The progressive conception of evolution, when examined, collapses because scientists do not understand the mechanisms of change. We simply do not have enough evidence to justify such a view.

Gould transitions to tell the story of the discovery of the Burgess Shale. Much like the two interpretations of the Burgess Shale, the story of the Burgess Shale's discovery has an older, less accurate version and a newer, more accurate version. The old story holds that Wolcott miraculously stumbled upon the Burgess Shale after his wife's horse tripped and fell onto it, but the real story is that it was discovered in a more mundane fashion. Walcott, no matter which story is true, did evolutionary science a great service by collecting and cataloging tens of thousands of new species, despite giving rather superficial descriptions of them. Scientists now think that the Burgess Shale developed in a mud bed that was highly oxygenated. It thus contained great degrees of life and a high speed of decay. A local mudslide seems to have preserved the bed.

Following Walcott, Percy Raymond, a Harvard professor of paleontology, and some students, reopened the quarry that Wolcott built in the thirties; they collected a few new fossils but they followed Wolcott's interpretation. Gould first encountered the Burgess Shale in the 60s, as a graduate student at Columbia. In 1966 and 1967, Harry Whittington became the paleontologist-in-chief and made his own examination with ten to fifteen scientists, along with a geologist named J.D. Aitken. They worked in Wolcott and Raymond's quarries and extended them. In 1975, Des Collins, from the Royal Ontario Museum, organized a new search to find new fossils. In 1981 and 1982 he continued to explore it. Gould is writing his book in 1988 and Des Collins is still at it. Gould tells the reader that the Burgess Shale is of great fascination to all paleontologists, and in fact, Gould "cannot escape" it. He even wrote this book as an homage to it.

Chapter 3, Reconstruction of the Burgess Shale: Toward a New View of Life

Chapter 3, Reconstruction of the Burgess Shale: Toward a New View of Life Summary and Analysis

The standard understanding of discovery in science is destroyed by the Burgess Shale, so Gould begins with undermining some other myths. Field work is sometimes thought to bring about the most important changes, through shocking discoveries in the field; the same mistake is repeated with the myth of the laboratory. In fact, the revolution of the Burgess Shale did not come from a new discovery of some chemical or fossil but instead of a shift in mindset. The Burgess "revision" requires some new scientific tools, but in fact the discovery came from Harry Whttington's analysis of fauna that Walcott had already discovered decades earlier. In 1971, Whittington published his first monograph, Marrella. Soon afterward Whittington brought on two graduate students—Simon Conway Morris and Derek Briggs. Whittington was methodologically conservative whereas Conway Morris was a bit of a social radical. The differences between the three formed a kind of cohesion. They also adopted new methods of studying the fossils, extracting three dimensional images of the creatures through excavation, dissection, new orientations of the fossil, and comparing parts of the fossil with their counterparts in the rock. From these methods, Whittington's team could devise representations of the creatures that allowed for new discoveries to be made.

One of the first tasks of the paleontologist, after producing a clear specimen, is to classify the specimen in taxonomy. There are several levels of the taxonomy of life, ranging from the most general to the most specific: kingdom, phyla, classes, orders, families, genera, and species. Whittington attempts to classify many of the new species found in the Burgess Shale into an already existing taxonomy. He was already the world expert on trilobite fossils. Gould transitions into an explanation of arthropod types that Whittingdon used to classify the new species. The discussion is complex, so we will leave it to the reader. The Burgess Shale, oddly enough, contains twenty new arthropod designs, with only four designs that survived the first great extinction (representative of these four classes are the dragonfly, a fossil eurypterid, a crab and a trilobite). Whittingdon was focused on classifying a new genus, Marrella. However, he could not figure out which of the existing phyla to classify it in.

The Burgess Drama, Act I. Marrella and Yohoia: The Dawning and Consolidation of Suspicion, 1971-1974

The Burgess Drama, Act I. Marrella and Yohoia: The Dawning and Consolidation of Suspicion, 1971-1974 Summary and Analysis

Harry Whittington would not willfully change paradigms unless he was forced to do so. His work begins with the most common organism among the Burgess Shale fossils—Marrella splendens. Walcott thought it was the foreshadowing of the trilobite. It turns out that Walcott's taxonomy had to be significantly updated to include new genera and even phyla that were not known to exist in his time. Many of these new categories are not directly related to modern groups. It is these categories that form Gould's story. In 1959, Leif Størmer described the Burgess Shale arthropods in his Treatise on Invertebrate Paleontology, which focused mostly on trilobites. He decides, in contrast to Walcott, to spread the Burgess arthropods widely among the groups in the arthropod phylum, whereas Walcott groups them narrowly. However, this only foreshadows where Whittington would take the classification system.

Harry Whittington writes Marrella in 1979. It is his monograph cataloging Marella splendens (Trilobitoidea) from the Burgess Shale. Whittington spends four and a half years on the monograph. It turns out that Marella have appendages that no trilobite share. Whittington struggles under the then dominant paradigm that the Burgess fossils are either "generalized members of large groups that later developed more specialized forms" or even earlier versions that combined features of distinct groups.

Whittington next turns to Yohoia, after assigning his students to work on some of the other genera. In 1974, he publishes a monograph on Yohoia. He cannot classify Marella with any known group of arthropods; with this conclusion in mind, he approaches Yohoia less conservatively. Whittington later notes that he labored under the idea of these genera as "primitive" and "precursor"—the two Ps. However, Yohoia pushes him beyond this idea. Yohoia is an entity to itself, specialized to an environment, with appendages that are simply unique. In 1975, Whittington concludes that Yohoia does not fit anywhere, just like Marrella.

The Burgess Drama, Act 2. A New View Takes Hold: Homage to Opabinia, 1975

The Burgess Drama, Act 2. A New View Takes Hold: Homage to Opabinia, 1975 Summary and Analysis

In 1975, Whittington begins studying Opabinia. Its structure is so strange that many paleontologists find it unbelievable. Walcott thinks that Opabinia is just another crustacean, but Opabinia possesses a bizarre frontal nozzle and five eyes, which makes it an object of fascination. There are only ten specimens of it in the Burgess Shale. At this point, Gould focuses to bring Whittington's insight into clear view.

Everyone thinks Opabinia is an arthropod. But armed with new techniques, Whittington reviews this claim. He uses his new methods to dissect the carapace of Opabinia in order to uncover its bodily appendages (something characteristic of arthropods). Shockingly, after dissection, he finds nothing underneath at all. Opabinia is not an arthropod at all, and it is not anything else. Marrella and Yohoia still appear to be arthropods, even if they are evolutionary dead-ends.

The evidence in favor of Opabinia's distinctiveness is considered decisive, from the fact that its frontal nozzle is not a proboscis, to the shape of its gut and the segments of its trunk. Opabinia belongs "nowhere among the known animals of this or any former earth."

The Burgess Drama, Act 3. The Revision Expands: The Success of a Research Team, 1975-1978

The Burgess Drama, Act 3. The Revision Expands: The Success of a Research Team, 1975-1978 Summary and Analysis

Opabinia represents the Burgess message. However, it remains to be seen how this message comes to be articulated. These new arthropods need new groups, and Opabinia needs a new phylum. Different paleontologists take on the new groups, but Whittington and his team focus on Opabinia.

Gould describes Whittington's team in more detail. For the most part, Oxford advisors do not pay much attention to their students and have a strongly hierarchical relationship with them. They also do not spend much time on their students' work. However, two brilliant students, Derek Briggs and Simon Conway Morris, are exceptions to this rule. Gould describes their distinct approaches and personalities. Morris is young, radical and "antisocial," Whittington, kind, conservative and mild-mannered. Morris pushes Whittington to be more radical, whereas Whittington restrains Morris from overreaching. The team decides to focus on the old category of "worms" to classify Opabinia. Until this time, "worms" are a kind of catch-all category for organisms that are hard to classify. Simon enjoys the challenge. Whittington moves forward with new monographs, remaining focused on arthropods. However, Simon wants a radical interpretation of the Burgess fossils and publishes five papers on the new phyla that Opabinia forces paleontologists to create, all while in graduate school.

Whittington is, at this point, still inclined to see Opabinia as an "oddball" stem from a main line of development. He labors under the two Ps of "primitive" and "precursor." However, Morris finds five oddball species that force a new view: Nectocaris, Odontogriphus, Dinomischus, Amiskwia and Hallucigenia, all animals that appear so alien that the mind finds them shocking and even a bit frightening. A worry even arises that Hallucigenia is a mere appendage of another creature.

Until this point, Gould has largely ignored Derek Briggs, the third member of the team. He apologizes for this. Briggs decides to focus on bivalve arthropods, the most conventional group among the Burgess Shale fossils. He makes two major discoveries —Branchiocaris and Canadaspis. Branchiocaris exposes the fact that the "bivalved arthropod" class is merely artificial and obscures important anatomical distinctions. Canadaspis receives a full monograph from Briggs. It turns out that Canadaspis is a crustacean. This may seem to make the animal boring, but Gould argues that the classification is crucial. Canadaspis causes evolutionary biologists to reinterpret the

Burgess Shale from an evolutionary dead end full of extinct species to an understanding of the Burgess Shale as containing both precursors and dead ends which gives a picture of the types of life evolution was then working with. The Burgess shale has familiar and unfamiliar anatomies in great quantities.

The Burgess Drama, Act 4. Completion and Codiication of an Argument: Naraoia and Aysheaia, 1977-1978.

The Burgess Drama, Act 4. Completion and Codiication of an Argument: Naraoia and Aysheaia, 1977-1978. Summary and Analysis

The fourth act slows things down a bit. Act 3 teaches us that Opabinia is not an arthropod. Whittington next begins work on Naraoia, which also poses a problem. Whittington cannot classify it into an arthropod group. Initially, Whittington thinks that Naraoia is a unique form of trilobite, which excites him (he is the world expert on trilobites at the time). However, Naraoia helps complete the Burgess Drama because it leads Whittington to junk the entire class Trilobitoidea as artificial. He publishes his monograph on Naraoia and turns to Aysheaia. He now understands the new view that many Burgess fossils cannot be placed in any known taxonomy. Aysehaia is a further example, helping to round out the Burgess revision (although Gould actually dissents from Whittington on this point, arguing that Aysehaia should be retained in a known class, Onychophora).

The Burgess Drama, Act 5. The Maturation of a Research Program: Life after Aysheaia, 1979 - Doomsday (There Are No Final Answers)

The Burgess Drama, Act 5. The Maturation of a Research Program: Life after Aysheaia, 1979 - Doomsday (There Are No Final Answers) Summary and Analysis

After the fourth act, Whittington's heavy hand in the development of the new paradigm fades and his revisions become a research paradigm. 1971 through 1978 brings revolutionary changes and a new shift in perspective. This discovery does not happen gradually, but instead happens through sporadic leaps forced by clear, scientific reasoning. From 1978, the drama becomes denouement, a long one, but a denouement nonetheless. The chapter covers all the new classes, orders and genera from the Burgess Shale that have been analyzed over the ten years between 1978 and the publication of the book.

Derek Briggs, in 1981, begins to focus on Odaraia, the largest bivalve arthropod in the shale. It possesses a three-pronged tail with two lateral flukes and a dorsal projection. It is basically tubular. It is functionally unique. Also in 1981, David Burton publishes a monograph on Sidneyia. This is an important milestone since Sidneyia was often a focus of the fauna. It also rounds out the class of Burgess arthropods, the "merostomoids." In the same year, Whittington publishes a monograph on the rare arthropods in the Shale, such as Molaria, Habelia, Sartrocercus, Actaeus, and Alalcomenaeus. In 1983, Bruton and Whittinton analyze Emeraldella and Leanchoilia in a monograph. Leanchoilia, bizarrely, has two appendages that each split into three whip-like extensions. On its backside, it has a small triangular tail spine.

Frustratingly, Des Collins is prevented from excavating at Walcott's quarry for ecological reasons (which Gould generally approves of but deplores in this particular case). Collins finds another dig site five miles south of the original quarry. In 1985, he publishes a monograph on a large crab with an enormous number of spines known as Sanctacaris ("Santa Claws"). Sanctacaris is the last of the four surviving arthropod classes located in the Burgess Shale. Its discovery allows paleontologists to prove that all four surviving arthropod classes were indeed present during the formation of the Burgess Shale.

Other odd creatures abound. Morris decides to focus on a complex creature known as Wiwaxia, which appears close to a Mollusk but probably is not. Sidneyia is also discussed. The chapter then transitions into a series of quick descriptions, including

Peytoia and Anomalocaris, both analyzed by Briggs. Anomalocaris appears to represent yet another new phylum.

Gould notes that the Burgess work continues but that Whittington, Briggs and Simon have begun to work on other topics. Instead, the next generation must take up the Burgess Shale with new techniques and forms of analysis.

Remainder of Chapter 3

Remainder of Chapter 3 Summary and Analysis

The Burgess Drama has five acts. Now that Gould completes it, he has some comments that divide into three general classes.

First Gould analyzes this "disparity followed by decimation" by making a general statement. The Burgess Shale is such an amazing find because of its soft-bodied creatures. It contains a vast array of life but the Burgess Shale lesson is taught by the soft-bodied creatures. From the Burgess Drama, we acquire three general Burgess revisions—we now have new major groups within a phylum, we have new phyla and we have a distinct picture of multi-cellular animal life.

We also learn that the structure of evolutionary inference is quite complex. First, the classification of animal species cannot be made on the basis of similarities and differences alone. Instead, evolutionary biologists must specify types and sub-types of similarities and of differences so as not to become confused. They must attend to "deep" similarities and differences, not superficial ones. To give a commonplace example, bats are mammals, not birds, despite the fact that they superficially resemble birds. The problem with the Burgess Shale is that many of the similarities and distinctions are unknown and this made classification difficult. Whittington, Briggs and Morris have to construct one largely from scratch. The 'grab bag' of appendages and anatomical forms provided by the Burgess Shale prove to be an incredibly complex problem.

Next, Gould turns to understand the Burgess Shale as a "Cambrian Generality." We have a hard time grasping the level of diversity in the shale. In fact, there are many types of Burgess animals that have their own ecological function. They come in six types—predatory and scavenging benthos, deposit-feeding benthos, scavenging, and perhaps predatory, nektobenthos, deposit-feeding and scavenging nektobenthos, nektonic suspension feeders, and a miscellaneous category. The Burgess Shale is a cross-section of ecological types and does not follow the "precursor and primitive" model. It provides a picture of an entire Cambrian Era ecology.

Finally, Gould focuses on the two "great" problems raised by the Burgess Shale. First, how did the Burgess fauna's diversity arise? There has not been such a great explosion of diversity at any time in history. Second, what does the decimation of the species of the Burgess Shale teach us about the functionality of its creatures and of those that survived? Gould provides three general answers to the first question, none of which he regards as ultimately satisfactory—first, that the Burgess fauna developed out of the first "burst" of multi-cellular life, and since there were few limits on this expansion, great diversity resulted. Second, that various genetic systems tend to evolve in their early stages in diverse directions but become resistant to radical changes as they "age" and become more complex. Finally, models show that rapid and significant expansions in

disparity followed by decimation later are a common pattern of many evolving systems. All three hypotheses have problems.

The answer to the second question is complex. However, basically, we can infer nothing from which animals survived. Evolutionary biologists once thought they could show that the surviving creatures were more fit, but this appears to be a circular explanation because fitness is understood in terms of what survives. So the idea of fitness is developed to include a predictive element to where, were one present in an evolutionary environment, one could look at how well-suited animals were to their present environments and predict which would survive a change.

Whittington, Briggs and Morris accept this view, but later reject it. They now hold that there is no way anyone could know which animals were better suited to survive the decimation. Instead, evolution seems subject to a vast degree of contingency, as Gould notes in previous chapters. In fact, this is the lesson of the Burgess Shale.

Chapter 4, Walcott's Vision and the Nature of History

Chapter 4, Walcott's Vision and the Nature of History Summary and Analysis

The animating mystery of this chapter is why Walcott ever interprets the Burgess Shale according to the ladder and the cone in the first place. Walcott is easily one of the greatest scientists in American history, so this is a powerful question for Gould. Walcott has largely disappeared from memory, in large part because he was a well-known administrator at the Smithsonian and excellent administrators are quickly forgotten.

Gould reviews Walcott's biography. He is "an American success story." He is raised fairly poor near Utica, New York, and born in 1850. He becomes a professional scientist by selling some trilobite specimens he discovers on a farm to Louis Agassize, the greatest natural historian in American history. He then takes up a job in 1876, as assistant to a New York State geologist James Hall, and joins the US Geological Survey in 1879. He works his way up to director and is appointed head of the Smithsonian in 1907.

Walcott is a meticulous man, recording everything that ever happens to him, even the mundane details of his second wife's death (which is not to say that he did not grieve over her terribly). Gould is obsessed with Walcott's life because he wants to understand the root of Walcott's error. Walcott is a lifelong Presbyterian; he believes that God used the evolutionary process to bring about humanity, and so sees evolution as divinely guided and progressive, culminating with consciousness in humanity. So he brings these preconceptions to the table. He also, due to his great administrative duties, cannot spend the time with the Burgess fossils that he wants to. Walcott is an arch-traditionalist in temperament, a conservative and a Republican, but also a committed Darwinist. His diaries reflect this. This also shapes his preconceptions because he wants to understand history as progress toward science, spirituality and the dominance of bourgeois values. He also is partly influenced by Darwin towards a progressive view. While Darwin initially does not believe that evolution is generally progressive, he is partly pressured into this view by the spirit of the day, particularly the common understanding among the British at that time that the civilization encompassed by the British Empire was the greatest that had ever existed in human history.

Walcott is pained by the famous Scopes Monkey trial. He does not want to separate science and religion but believes that many use evolution as a bludgeon against people of faith, which leads to a reaction. His understanding of God pervades his scientific practice; God is to be found in the development of nature. Walcott's theological beliefs even influence his taxonomy and developmental charts.

The details of Walcott's life draw to a close. Gould comments that Whittington and his team do not dissent from this picture of development from the beginning but instead are forced out of it through the topsy-turvy practice of science (the actual practice of science, on Gould's view, is in striking contrast with the common understanding of the scientific method). Gould then transitions to draw a moral from this. The scientific method and the nature of history are not the result of inevitable progress and succession. Instead both are subject to Contingency. Natural history is extremely important in order to document and understand this crucial philosophical idea. Darwin sees Contingency but partly backs away from it. The laws of nature do not determine the course of history, but instead only lightly constrain it, leaving open a vast domain for Contingency and luck to have their way. We have to grant in our scientific explanations of the world equal weight to both contingency and the operation of the laws of nature. We must do so for three reasons: (1) to document evidence reliably; (2) to understand the true pattern of nature; and (3) to avoid giving the human too central a place in history, a place it does not deserve.

Gould transitions into documenting the idea of contingency in many great literary and cinematic works. Walcott has the traditional, progressivist view, but this is confused. History does not follow from the laws of nature or from God's hands. Instead, human existence is a "wildly improbable" event with no transcendental meaning save what we ascribe to it.

Chapter 5, Possible Worlds

Chapter 5, Possible Worlds Summary and Analysis

This chapter attempts to make concrete the lesson of the last. Chapter 4 argues that the story of history is Contingency. However, Gould realizes that this lesson is abstract and so he attempts to illustrate the contingency of evolution through alternative scenarios, which he realizes are difficult to describe (they did not happen, after all). He begins by describing various Burgess Shale animals, wondering what might have happened had they survived rather than the arthropods we know today. Contingency is powerful in the details of Darwin's theory, despite how well-adapted many creatures are to their environments. The Burgess Shale represents contingency due to the massive disparity of the Cambrian explosion and the apparent luck of those species that survive its eventual decimation. Maybe the Cambrian explosion did not have to happen that way. Perhaps diversity could have expanded evenly or even logarithmically. Things could have been different then as well. We do not know why the mass extinction worked as it did. It could have been random, or those creatures best suited to the pre-extinction environment may have been ill-suited for the environment that followed, the "different-rules model."

Gould turns to guide us through seven major contingencies along the path toward human development. The first is the evolution of the eukaryotic cell. It took billions of years. Prokaryotic cells exist at 3.5 billion years, and would exist alone for 2 billion years. What if eukaryotes had developed sooner? What if they tend to take much longer to evolve? Waiting much longer would lead to the death of our own sun! The second stage of contingency comes in the developmental path of eukaryotic organisms. There are other fauna besides the Burgess fauna. Evolution could have followed those paths. According to Gould's friend Dolf Seilacher, early eukaryotes exhibit a kind of complexity that could have led in many distinct directions. The third stage is the fauna of the Cambrian explosion. Again, there was no guarantee of its development. The subsequent Cambrian origin of modern fauna (the fourth stage of contingency) is no different. In fact, this is the stage of contingency the book focus on most. The fifth stage is the origin of terrestrial vertebrates, which rely entirely on one small sub-class of fish developing bone vertebrae, an unlikely event. The prevalence of mammals (the sixth stage) is widely known to be contingent, largely the result of an asteroid impact that decimated the dinosaurs. The seventh stage is the development of our species, homo sapiens. It was far from guaranteed. Many species of hominid existed hundreds of thousands of years ago. The Neanderthals could have survived. The Asian homo sapiens might have outlasted the African homo sapiens from which we are all descended. Gould includes a small epilogue on a forthcoming monograph by Morris concerning Pikaia, a small ribbon-shaped creation that is the first member known of the 'chordate' phylum - the phylum of organisms with spinal cords. It is located in the Burgess Shale. Without it, there would be no organism with a spinal cord, including us. Pikaia is the last argument in favor of contingency.

Characters

Charles Doolittle Walcott

Charles Doolittle Walcott (1850-1927) was one of the United States' greatest scientists. Specifically, he was an invertebrate paleontologist. He discovered the Burgess Shale in the Canadian Rockies in 1909 and was later secretary of the Smithsonian Institution.

Walcott was raised in Utica, New York, a small town in upstate New York. He never graduated from high school but had a strong interest in animals his whole life. He was also a meticulous cataloger and note-taker, writing in his diary practically every day of his life. Walcott met one of the great natural historians, Louis Agassiz, during a sale of trilobite fossils he had found at a local farm. Agassiz introduced him to the world of natural science and Walcott later pursued his professional education. He joined the US Geological Survey in 1879 and rose to director by 1894. He married his second wife Helena in 1888 and had four children. He was hired as Secretary of the Smithsonian institute in 1907 and discovered the Burgess Shale two years later. Walcott's administrative work kept him from analyzing the shale in detail but he did an extensive catalog of the fossils he found there and attempted to classify the fossils into the known taxonomy of the animal kingdom. Walcott understood the Burgess fauna as primitive precursors of current arthropods. This later turns out to be a mistake, one for which Gould rakes him over the coals. The entire book is shaped around the abandonment of Walcott's—then widespread—understanding of the nature of evolution.

Harry Whittington

Harry Blackmore Whittington (born 1916) is a world-renowned British paleontologist. He works at the Department of Earth Sciences at Cambridge University and received his geology PhD from the University of Birmingham. For many years, he worked at Harvard but was hired back to Cambridge between 1966 and 1983. During his time there, he had two major scientific achievements. First, he became the world expert on trilobites, and published a great work on their morphology, ecology and fossil structure. However, he may be most famous for the achievement that Gould discusses in detail; he is the man primarily responsible for the "Burgess Revision." Whittington decided to reanalyze the fossils of the Burgess Shale after little attention since Walcott's day. He labored under the same understanding of evolution as the ladder and the cone. By nature a conservative man, Whittington was forced by the evidence alone to conclude that many of the Burgess fauna were unrelated to any known group of arthropods. Starting with Marella and Yohoia, Whittington concluded that some of the Burgess Shale fauna were not part of any known group. However, Opabinia forced him to conclude that the Burgess Shale contained entire phyla that were not extinct. His reclassification of the Burgess Shale (along with two of his students) is considered—by Gould—to be one of the greatest achievements in scientific history because it forced paleontologists to

change their understanding of the evolutionary process from the ladder and the cone to the view that Gould calls Contingency.

Simon Conway Morris

Whittington's radical student assistant who correctly placed many of the Burgess fauna in the proper place within the animal kingdom taxonomy.

Derek Briggs

Another of Whittington's assistants, who rounds out the team of three scientists who classified the Burgess fauna and brought about the Burgess revision.

Marella

One of the first genera of the Burgess Shale that led to the Burgess revision. Whittington's monograph of Marella in 1971 began the Burgess Drama.

Yohoia

The second genus Whittington analyzed in detail, getting him closer to the Burgess revision.

Opabinia

The third genus analyzed by Whittington, which led him to understand that many of the Burgess fauna must be substantially reclassified.

Darwin

The famed creator of the theory of natural selection. He originally rejected the understanding of evolution as gradual and progressive but sometimes interpreted his work in this way due to the philosophical and historical ideas of his day.

Helena Walcott

Walcott's second wife, whose death deeply affected him.

Leif Størmer

A mid-20th-century biologist who aided in the early stages of the Burgess revision.

Pikaia

The final classified genus of the Burgess Shale, one of the first known chordates, Pikaia may be the early precursor to all chordate life, including humans.

Louis Agassiz

The Harvard natural historian that brought Walcott into paleontology.

James Hall

Walcott was assistant to Hall, then the State Geologist of New York

Objects/Places

The Burgess Shale

The limestone shale in the Canadian Rockies in British Columbia where the Burgess fauna were discovered.

Walcott's Quarry

The quarry Walcott built in the Burgess Shale to uncover the fossils located there.

The Canadian Rockies

The mountain range where the Burgess Shale was located.

The Smithsonian Institute

The series of famous museums in Washington. Walcott became Secretary of the Smithsonian Institute in 1907.

Cambridge

Whittington was a professor of geology at Cambridge and did most of his original research there.

The Cambrian Era

Beginning 570 million years ago, this Era marked the explosion of multi-celluar life forms.

The Burgess Fauna

The range of animal species located in the Burgess Shale.

Burgess Fossils

The Burgess fossils are the fossilized remains of the Burgess fauna.

Reconstruction Methods

The methods Whittington pioneers in creating three dimensional representations of the Burgess fossils.

Arthropod Appendages

The various arthropod appendages that Whittington expected to find on the Burgess fauna. Instead, many new appendages appeared.

Walcott's Diary

Walcott recorded nearly everything he ever did in his diary, including his discovery and cataloging of the Burgess Shale.

Themes

Contingency

The major theme of Wonderful Life is what Stephen Jay Gould calls Contingency. Contingency is the idea that evolutionary history is highly "path-dependent." In other words, it depends on wholly contingent factors in its path of development that were far from inevitable. The Burgess Shale fauna contain a host of unique phyla, groups, classes, genuses, and species. Many have gone extinct. Yet from Walcott forward, these fauna were classified according to already known taxonomical categories. Evolutionary biologists simply could not understand the evolution might produce broad classes of animals, completely obliterate them, and the survivors be the ones not who were most fit but that merely contingently survived. Gould goes to great pains to show that Contingency is the lesson of the Burgess Shale. The Burgess revision was so impressive precisely because it uncovered this fact. Instead of gradual increase in complexity and diversity, evolution is a wild, seemingly random ride.

The effect of this discovery has philosophical consequences. Humans can no longer conceive of themselves as the top of the evolution ladder, the inevitable consequence of increasingly diversity and complexity. Instead, the evolution of humanity was an incredibly improbable accident that means nothing from a cosmic perspective. We have no reason to rank ourselves as higher or lower than any other evolved being. The universe and the earth are not human-centric. For Gould, this view of humanity's place in the universe is both humbling and liberating.

The Ladder and the Cone

"The ladder" and "the cone" are terms of art that Gould uses together to describe the conception of evolutionary history that was widespread prior to the Burgess revision. "The ladder" is the perspective on evolutionary history which holds that evolutionary development is progressive. In other words, it moves from more primitive forms of life to more advanced forms of life. Evolution always proceeds towards the "higher" and "more complex." "The cone" compliments the ladder. It holds that the diversity seen in nature has always been gradually expanding. All the earliest creatures were relatively similar and were the precursors to all modern life.

Gould argues that the cone and the ladder did not dominate Darwin's conception of evolution. However, in the 19th century, views of history and development typically held that the development of history and culture had a certain orientation, towards greater and more complex stages of development. This view can be found in figures as disparate as Hegel, Mark, Cardinal Newman, and Herbert Spencer. Darwin was partly caught up in this view and sometimes expressed his theory in these terms. However, Walcott is the one who imposed the cone and the ladder on the Burgess fauna, "shoehorning" these unique creatures into a taxonomy constructed according to ladder-

and cone-shaped preconceptions. The view was so dominant in the twentieth century up until the Burgess revision that even Whittington labored under it for years. It was only close attention to the evidence that forced Whittington to make a revision and allowed him to break free from the "tyranny" of the cone and the ladder.

The Method of Scientific Discovery

Gould is fascinated by the distinction between the way most people conceive of scientific discovery and the way in which it actually occurs. First, many imagine those who follow the "scientific method" to be careful men in white lab coats who impartially apply reason to empirical data and thereby make gradual progress. Second, many understand scientific discovery as having a variety of "eureka" or "rubicon-crossing" moments. There are bursts of discovery made by individual men or women laboring over some important problem. Further, many see scientific progress as involving the discovery of new data with theories formed about the data and tested.

The Burgess revision defies all three of these conceptions of scientific discovery. The Burgess revision did not occur according to the common picture of the scientific method. While Whittington and his team worked carefully through the Burgess fauna, they were not expected to discover what they did. Discovering the nature of the Burgess fauna did not come through a gradual process of reasoning, but instead through a rough and tumble process of mistakes and ideas forced by the data that no one was expecting. In the same way, the second conception of scientific discovery was undermined. While Whittington did have a burst of insight, by and large the development of the Burgess fauna did not happen in a single moment. Instead, Whittington was forced to it over time by an accumulating set of mysteries. Finally, the Burgess revision involved the reinterpretation of data already possessed, the review of Walcott's fossils. The theories that Whittington and his team had about the fossils were not formed in order to account for the data they had. Instead, they labored under a paradigm that on further notice had little support.

Style

Perspective

Stephen Jay Gould (1941-2002) was a well-known evolutionary biologist, paleontologist and science writer. Throughout his work, he made a concerted effort to push a view of the universe often common to evolutionary biologists—that human life has evolved due to the contingent hand of a universe with no transcendent purpose. In other words, what moves Gould and creates the entire perspective of the book is his disposition as an agnostic Darwinist. Gould believes that seeing the order of nature as progressive, or as giving humanity pride of place within the hierarchy of the animals, is foolishness and the entire point of Wonderful Life is to make this point. The Burgess Shale, in Gould's view, taught the evolutionary biologist community that evolution does not have a gradualist and progressive structure. Walcott's original classification of the Burgess Shale reflected this false view, but Whittington was forced by the evidence to conclude that evolution had a quite different nature. To understand the book, then, one must understand this perspective, that Gould is out to dethrone humanity from the center of the universe, and instead seeks to "liberate" humanity from this false pride of place. In Gould's view, we are merely the products of contingency, an incredibly improbable development in history that would almost certainly not occur again were the evolutionary "clock" reset. Some may consider this view true, others false, but it is a bias that must be understood to grasp the essence of Wonderful Life.

Tone

Stephen Jay Gould is a famous science writer. He has written in any number of venues, from the most academic to the most popular. For this reason, he acquires the capacity to write about complex topics with the energy of a child opening presents for Christmas. Gould is wholly enamored with what he calls "the Burgess Drama." For him, the story of the drama is absolutely fascinating, from its beginnings with Walcott's discovery and misconception to the revision that came during the 1970s through the work of Whittington, Morris and Briggs. He begs the reader to pay close attention to the scientific details so that they can see the beauty of the Burgess revision as clearly as he does. He argues that the Burgess revision must be appreciated at a deep level in order to receive its full effect. Gould also has a philosophical tone, where he draws out deep lessons from the scientific experience of the Burgess revision. He seeks to draw a moral about humanity's place in the universe. For this reason, he often engages in broad, lyrical rhetorical flourishes, often citing poems alongside the anatomical details of Opabinia or some other Burgess fauna. Gould communicates a sense of excitement, creativity, spirituality and urgency throughout the text. However, it also bears noting that Gould expresses certain biases in his tone, such as the psychoanalytic approach he takes to Walcott. How could Walcott have possibly made such an error of interpretation, Gould wonders? He describes himself as "obsessed" with this question. He states that while he finds Walcott fascinating he does not "like the man."

Structure

The structure of Wonderful Life is unusual. At its most general level, it consists of five chapters. The first chapter, "The Iconography of an Expectation" covers the discovery of the Burgess Shale and the initial interpretation it was given. In chapter two we are given "A Background for the Burgess Shale" which explains much of the geological and biological background needed to explain its significance. Chapter three tells the story of the Burgess Shale's significance to modern evolutionary biology and the factors and events that led to the Burgess revision. However, Chapter 3 contains a mid-section that Gould calls "The Burgess Drama" which is the story of how the Burgess revision unfolded. It occurs in five "acts," just as a play would. Chapter IV is an extended discussion of Walcott, his life, and how he acquired the perspective on evolution that caused him to "shoehorn" the Burgess Shale into a taxonomy that reflected his preconceptions about the nature of evolution and history. The final chapter, "Possible Worlds" attempts to illustrate the general lesson of contingency by giving historical cases where human development took incredibly improbable steps forward.

The chapters, however, are full of illustrations and explanations of the various Burgess fauna. Beautiful pictures are sometimes displayed along with detailed scientific maps of their anatomical structure. Gould also gives brief "interludes" to explain the significance of some concept, such as the nature of natural history. Gould also transitions in and out of detailed scientific analysis and literary flourishes. Thus, as one "zooms in" on the structure of Wonderful Life, one finds an increasingly complex and variegated structure.

Quotes

"I state that the invertebrates of the Burgess Shale, found high in the Canadian Rockies in Yoho National Park, on the eastern border of British Columbia, are the world's most important animal fossils." (23)

"It [the book] is, first and foremost, a chronicle of the intense intellectual drama behind the outward serenity of this reinterpretation." (24)

"As a third theme, I grapple with the enigma of why such a fundamental program of research has been permitted to pass so invisibly before the public gaze." (24)

"The march of progress is the canonical representation of evolution ..." (31)

"Life is a copiously branching bush, continually pruned by the grim reaper of extinction, not a ladder of predictable progress." (35)

"We then view this twig as the acme of upward achievement, rather than the probable last gasp of a richer ancestry." (35)

"Why did life remain at stage 1 for two-thirds of its history if complexity offers such benefits?" (60)

"A lovely story, but none of it is true." (71)

"I cannot escape the Burgess Shale." (78)

"Oh why was I not made of stone like these!" (78)

"All the standard imagines of scientific discovery were violated by the revision of the Burgess Shale." (80)

"Don't accept the chauvinistic tradition that labels our era the age of mammals. This is the age of arthropods." (102)

"If Harry Whittington had known at the outset what a restudy of the Burgess Shale would require in time and commitment, he would probably not have started." (107)

"His favorite motto exhorts his younger colleagues to place fact and description before theory, for 'one should not run before one can walk.'" (107)

"Whittington had struggled with Marrella, and had come to the correct empirical conclusion—that this most common Burgess genus fits into no known group of arthropods." (121)

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"When an earlier version of figure 82 was shown at a meeting of the Paleontological Association in Oxford, it was greeted with loud laughter, presumably a tribute to the strangeness of this animal." (124)

"I am about to describe the key moment in this drama, but I am also committed to the historical principle that such moments do not exist, at least not as our legends proclaim." (129)

"Opabinia belonged nowhere among the known animals of this or any former earth." (134)

"Opabinia carries the full weight of the Burgess message for a new view of life." (136)

"Put these together with Simon's oddballs and Harry's orphaned arthropods and you have, by 1978, both a fully articulated and completely new account of how multicellular life evolved." (158)

"Three short years and a new world!" (172)

"Perhaps these necessarily dry papers conveyed a little of the excitement of discovery - it certainly was an intriguing investigation which had its moments of great joy when a new and unexpected structure was revealed by preparation." (207)

"Burgess disparity and later decimation is a worst-case nightmare for this hope of inevitable order." (233)

"Why not a Steven Spielberg film with a crusty seaman sucked into the cylindrical mouth of a sea monster, and slowly crushed to death by multiple layers of teeth lining a circular mouth and extending well down into the gullet?" (239)

"The inhabitants of each successive period in the world's history have beaten their predecessors in the race for life, and are, insofar, higher in the scale of nature; and this may account for that vague, yet ill-defined sentiment, felt by many paleontologists, that organization on the whole has progressed." (258)

"Homo sapiens, I fear, is a 'thing so small' in a vast universe, a wildly improbable evolutionary event well within the realm of contingency. Make of such a conclusion what you will. Some find the prospect depressing; I have always regarded it as exhilarating, and a source of both freedom and consequent moral responsibility." (291)

"We are a thing, an item of history, not an embodiment of general principles." (319)

"And so, for ourselves, I think we can only exclaim, O brave—and improbable—new world, that has such people in it!" (321)

"And so, if you wish to ask the question of the ages—why do humans exist?—a major part of the answer, touching those aspects of the issue that science can treat at all, must be: because Pikaia survived the Burgess decimation." (323)

Topics for Discussion

What are the three aims Gould has in Wonderful Life?

What is the Burgess Shale?

What is the contrast between the old view of evolution that Walcott had and the newer version pioneered by Whittington?

What was the significance of Marella and Yohoia?

What was the significance of Opabinia?

What is the Burgess drama? What is the Burgess revision? Who are the main characters (the human ones) in the drama?

What is Contingency?

What do you think about Gould's take on the place of humanity in the universe? Do you think it is the right lesson to take away from the Burgess drama? If so, why? If not, why not?