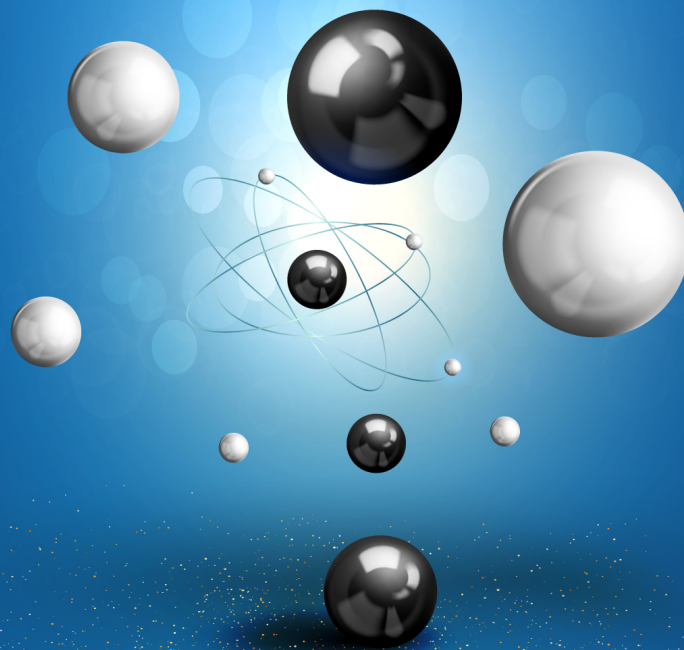


SUMMARY

REALITY IS NOT WHAT IT SEEMS

CARLO ROVELLI



Summary of “Reality is Not What it Seems” by Carlo Rovelli

Written by Lea Schullery

Take a journey through history that leads to today's theory of quantum gravity and the modern physicist's view of the universe.

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Introduction

In the world of physics, much has yet to be discovered. Therefore, Carlo Rovelli seeks to present his perspectives and knowledge in quantum gravity, the region at the boundary between what we understand and what we do not yet understand. Many other physicists will agree with the ideas presented here, while others won't. This is the world of physics. Therefore, Rovelli doesn't aim to write to you about the certainties, rather he aims to take you on an adventure of moving toward the unknown. But he's not going to take you on just any journey, it'll be the most spectacular journey that humanity has ever taken: the journey toward an increasingly vast understanding of the world.

Scholars have been searching for the answers to their questions about the world for centuries, and in some ways, have answered those questions; however, in other ways, their answers have only led to even more questions! The more we discover, the more we understand that we don't yet know all there is to know. Our knowledge of the elementary grammar of the world continues to grow, and we can no longer believe what was once taught to us in school. Therefore, Rovelli seeks to give his account of the current state of the search for our new image of the world, as he understands it today. At the end of the day, this book is Rovelli's answer to the question, "So, what do you think is the true nature of things?"

Ancient Scholars Attempt to Explain The World

Since the beginning of time, or at least since humanity has left written texts, men have wondered about the world. How did the world come into being? What is it composed of? They've even wondered about natural phenomena, asking questions concerning the wind and the rain. For centuries, man has tried to explain the world surrounding them and sought answers through elaborate stories of spirits, deities, imaginary and mythological creatures, and more.

Then, at the beginning of the fifth-century, scholars of ancient Greece began searching for more answers, different answers. Thus began a revolution of scientific thought. One such scholar was Anaximander, who understood that the Earth floats in the sky and that rainwater did not come from the gods, instead, the rain was produced by an accumulation of evaporated water from the Earth. He understood that plants and animals evolve and adapt to changes in the environment, and that man must have evolved from other animals.

Advancements continued in the following years as a scholar named Democritus sought to answer how the world was created. With help from his mentor, Leucippus, the two discovered that all substances were made up of building blocks called *atoms*. Additionally, they believed that empty space lay between each atom; therefore, atoms must have a certain size and there must be an infinite number of them. They believed that there “was no finality, no purpose in this endless dance of atoms,” taking a romantic spin on science. In other words, these philosophers believed they were a part of nature, not separate. Of course, advancements didn't stop there as philosophers Aristotle and Plato came on the scene.

The two ancient philosophers largely fought against Democritus' ideas, they instead, sought explanations in favor of trying to understand the *purpose* of the world. Therefore, they took to the idea that mathematics could be used

as a tool to explain the world around them. Ptolemy then expanded on these ideas and sought to predict the movement of planets by creating formulas to calculate such movements.

Speaking of the Earth's movements, it wasn't until over a thousand years later that scholars like Copernicus and Galileo expanded on the mathematical tools and revolutionized the way humans understood the world. Copernicus, for example, proved that the orbits of the planets could be calculated once he understood that the sun was at the center of the solar system, not the Earth. Around that same time, the invention of the telescope transformed the way humans viewed the celestial objects in the sky. In the sixteenth century, Galileo discovered the rings of Saturn as well as the many moons around Jupiter.

Galileo expanded upon Copernicus' hypothesis surrounding the orbit of the planets and created what is now known as the scientific method. He also sought to prove the rate at which objects fall. Do all objects fall at a constant speed? His experiments resulted in the discovery of the first mathematical law of motion while simultaneously disproving Aristotle's theory of gravity. Because of scholars like Galileo, Aristotle, and Democritus, scientists today have an even better understanding of the world around them and continue to revolutionize the way we think.

Newton's Contributions Lead to Revolutionary Ideas

We then travel to seventeenth-century England where we meet “the greatest scientist of all time,” Isaac Newton. Newton expanded on Galileo’s calculations and sought to discover how long it would take for a very small moon to orbit the Earth. He discovered that the hypothetical moon’s acceleration would equal the acceleration of falling objects on Earth. In other words, the force affecting the speed of the orbiting moon was the same force that Galileo discovered. So what is this force?

Suddenly, Newton was bringing together multiple observations into a single theory. No longer was there a separation between the heavens and Earth, instead, the gravity on Earth became the same as gravity elsewhere. Now, he understood that space wasn’t just filled with floating objects, these bodies were being drawn toward one another by the force of gravity. Newton used this theory to create the first coherent picture of the world, separating the world into three categories: *space, time, and particles*. While Newton successfully painted a new picture of the universe, there was still much to be discovered.

Now traveling to the nineteenth century, Michael Faraday and James Clark Maxwell expanded on Newton’s ideas and discovered the concept of *electromagnetism*. Electromagnetism is the force that binds atoms together to form molecules, as well as the electrons that are within atoms. Additionally, the two British scientists demonstrated that electricity, light, and magnetism are all different manifestations of the same phenomenon. This discovery divides Newton’s concept of particles into two separate parts: *fields and particles*. Faraday and Maxwell suggested the idea of an invisible “field” throughout space that allows these electromagnetic forces to act.

After this unification of terrestrial and celestial mechanics, Einstein came onto the scene to contribute more ideas of his own. In 1905, Einstein

suggests that space and time are the same things, they “fuse together in a single concept of spacetime.” In other words, Newton’s idea of space and time came together. This became known as Einstein’s theory of special relativity and while it was a radical idea, it began a series of discoveries that would change the way people viewed the world.

Einstein's Theory of Relativity

As mentioned previously, Einstein discovered that Newton's space and time were fused to become one. Well, just ten years later, Einstein suggested an even more radical and revolutionary idea. The idea that Newton's space is the gravitational field discovered by Faraday and Maxwell. This theory of general relativity brought together the ideas of Newton, Maxwell, and Faraday proving that breakthroughs occur when scientists combine their ideas with the learning of others.

With this unification of ideas and scientists, Einstein redefined the concept of space and its contents. Now, space was no longer an empty and mysterious mass surrounding Earth, instead, space became a gravitational field that affects every single object. Additionally, Einstein proved that mass could bend the space around it, creating a curvature that caused bodies to be pulled toward one another. His theories then led to an explanation of how the universe was created with the "big bang theory."

One question still remained, "Is the universe finite or infinite?" Scientists sought to answer this question for years, but now, Einstein was able to suggest a new theory. Perhaps, the universe was both! While this seems confusing, surely something couldn't be both finite and limitless, let's look at the Earth, for example. Imagine walking in a single direction on the surface of the world, how long would you be able to walk for? Technically, you could walk forever, you would never "fall off" as the Earth never ends. So while the Earth is limitless, it is still finite as the planet has a certain amount of surface.

Of course, Einstein wasn't finished. Einstein recognized that the universe certainly couldn't be finite. If the universe had a limited amount of space, it would eventually lead to an inward collapse of matter due to the strong gravitational pull. However, that hasn't happened so Einstein suggested that the universe must be expanding outward which led to the idea we now know as the big bang theory.

The Theory of Quantum Mechanics

Einstein's contributions of spacetime and gravitational fields would eventually lead to what is known as quantum theory, or quantum mechanics. Since the days of Anaximander and Democritus, philosophers and scientists have been building upon ideas to create what we understand today. So what exactly is this theory? Rovelli states that quantum mechanics is the theory that seeks to explain the motion of subatomic particles.

This theory began back in 1900 with German physicist Max Planck. When calculating the energy of electrical fields, Planck took a mathematical shortcut and believed that all energy in the field was broken up into small packets, called quanta. Shockingly, Planck's calculations were correct. So in 1905, Einstein realized that light was similar to energy in that it was also made up of small packets. Then, just a few years later, Niels Bohr, a Danish physicist discovered an atom's electrons have a finite amount of energy rather than the previously believed theory that atoms had a continuous spectrum of energy.

What all this means is that Planck, Einstein, and Bohr all discovered the fundamental theory of quantum mechanics, that the universe is made up of finite packets of both light and energy. Of course, the theory of quantum mechanics doesn't stop there. In the 1920s, German physicist Werner Heisenberg discovered that an electron's position can only be determined based on its interaction with another object. This discovery debunked the previous belief that electrons had a fixed position in space. Additionally, Heisenburg proved that an electron can only exist in relation to another object.

While quantum mechanics seeks to explain the microcosmic level of atoms and particles, there are still many questions surrounding the topic. One of those questions involves the aspect of indeterminacy which means the prediction of physical events cannot be predicted with certainty, only with

probability. Indeterminacy is the fact that there is always something unpredictable that allows us to obtain new information. In other words, “the future is genuinely unpredictable” but this fact enables us to discover more.

The Theory of Quantum Gravity

With the discoveries made by ancient and modern philosophers, there is now a twentieth-century paradox in modern physics. The theory of general relativity and quantum mechanics both have vastly different beliefs. You see, general relativity suggests that space is curved and continuous; however, those who accept quantum mechanics believe that space is flat and that everything, like light and energy, is granular and exists in small packets.

Today, modern physicists seek to come together and somehow combine these theories. Enter quantum gravity. When it comes to quantum gravity, the theory suggests that space is not continuous but also granular. This relates to Soviet physicist Matvei Bronštein's idea that space is not infinitely divisible similar to Democritus' theory about atoms and matter. Bronštein developed this idea in the 1930s; however, today's research supports this theory by suggesting that space can be divided into a unit of measurement that is a billion times smaller than the nucleus of an atom. This measurement is called the Planck length and is 10^{-33} centimeters.

Quantum gravity has one more fundamental claim that is perhaps the most important of all. This claim surrounds the notion of time. You see, Einstein's theory of special relativity persuaded people into believing that time passes the same everywhere. However, it has been proven that time passes slower or quicker in some places in the universe! For instance, time passes slightly faster in areas where gravity is higher. In other words, if you were to place a clock on a table and another on the floor, the one closer to the earth would run a bit slower.

So what exactly does this mean? Basically, physicists now understand that time is no longer a reliable scientific unit of measurement. If time can pass at different speeds based on its position in the universe, then how can time measure anything? The point is that it can't. Therefore, physicists in the field of quantum gravity no longer use time in their fundamental equations.

In other words, events no longer happen in time. In fact, in the world of modern physics, time doesn't even exist.

Final Summary

From the scholars of ancient Greece to the modern physicists of today, both of which have discovered revolutionary breakthroughs about the way we view the world. Beginning with Anaximander's discovery of the Earth floating in the sky and Democritus' discovery of the atom, scholars and physicists have built upon these ideas, essentially working together and unifying them. Even more, Newton and Einstein revolutionized the way we think about time and space. From Newton's theory about the absoluteness of time and space to Einstein's theory of general relativity and quantum mechanics, physicists today have resigned to come together about the different theories. Now, thanks to quantum gravity, physicists have created a world in which space is granular and where time may or may not exist!



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