Ancient Greek Ideas on the Nature of Reality and Their Influence on the Discovery of Quantum Mechanics

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Abstract: The discovery of quantum mechanics in the 1920s would not have occurred without the influence of ancient Greek ideas. Beginning with Pre-Socratic thought, and the subsequent formalization of Aristotelian logic historians can trace the chronological chain of ideas that began with the debate on the particulate or continuous reduced nature of reality. These ideas shaped how scientist think, and the debate set the tone for how modern scientific evidence would be interpreted. This paper explores how the ancient debate directly enabled the quantum pioneers in their discovery of quantum mechanics, and by consequence, how the ancient particle/continuum debate was resolved.

On October 27, 1924 physicists and mathematicians met at the Fifth Solvay Conference to discuss the significance of quantum mechanics and its transformative impact on contemporary physics. In the decades prior to the conference, mounting evidence of sub-atomic processes demonstrated that the physics behind the preeminent Newtonian mechanical view of the universe was no longer sufficient in its explanation of light and subatomic phenomena. Most surprisingly, the desire to fix the inadequacies within classical physics led to evidence that seemed to suggest that electrons possessed qualities that were particulate and wave-like in nature; a duality which violated logic. This duality puzzled scientists who struggled to make sense of how an electron could both display the mutually exclusive qualities of a continuum and a discrete unit.

The impassioned debates surrounding the significance of subatomic behavior at the Solvay conference legitimized quantum mechanics as a new field in physics, but its discovery did not occur in a vacuum by a handful of modern scientists. By understanding Anaximander, Heraclitus, and Parmenides's ancient ideas regarding the reductive nature of the universe, their attempt to resolve opposites, and the subsequent emergence of Aristotle's law of Noncontradiction, one can see how these ideas set the foundation for quantum scientists. Quantum mechanics should not only be credited to a few quantum pioneers in the 1920s; rather, viewed as the apex of the persistent and cumulative historical inquiry into the reduced nature of reality.

Science depends on rational thought. A shift in thinking Greece during the sixth century BCE created an environment in which intellectuals asked questions without assuming theological explanations. Prior to this century, natural phenomena were mechanically thought of consequences caused by divine impulse.[1] A single individual helped transform western thinking from metaphysical explanations to rational analysis. Thales of Miletus abandoned divine influence in his explanation of earthquakes by theorizing that the shaking was caused by water rather than the whims of an angry god. The importance of this intellectual shift from theological explanations to natural cause cannot be overstated; it set off a chain of ideas that directly influenced later thinkers to support their ideas with rational thought rather than reliance on metaphysics.

Anaximander continued the rational discussion and reasoned his way to conclude that the universe is reducible to a continuous primary substance. This he referred to as *apeiron*, or that which has no boundaries.[2] He did not rely on sense perception in order to formulate his theory; *apeiron* cannot be observed nor can it be defined. A fragment of his surviving writing states:

> The Non-Limited (*apeiron)* is the original material of existing things; further, the source from which existing things derive their existence is also that to which they return at their destruction, according to necessity: for they give justice and make reparation to one another for their injustice, according to the arrangement of Time.[3]

This was the first instance in which the fundamental nature of reality was thought to be reducible to a continuous form. More importantly, Anaximander began to question the fallibility of the human senses. His theory held that there is an underlying nature of reality unobservable to the human eye, therefore only being comprehensible through the use of reason. In contrast to the other Milesian materialists who believed that the universe is reducible to a primary element, he insisted that reality is reducible to a substance that cannot be defined due to the fallibility of the senses. Anaximander's theory is relevant because his idea would be revisited by atomic theorists of the 19th century, who theorized that an unobservable microscopic substance is at the heart of all matter.[4] In addition, *apeiron* is the fundamental substance that is responsible for the creation of complex macroscopic objects through the mitigation of opposites. Anaximander implies that contradictory forces are not mutually exclusive. It is a cooperative duality that is necessary for the universe's existence. This concept would be evidenced by the electron's simultaneous particle and wave-like behavior, as discovered in the beginning of the twentieth century. An electron's dual nature being an essential property of the atomic structure, from which all things are created.

The heart of reality depends upon a necessary dichotomy, and Heraclitus of Ionia agreed. He continued Anaximander's work by favoring a prime universal continuum but

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1 G.E.R. Lloyd *Early Greek Science: Thales to Aristotle.* (New York: W.W. Norton & Co., Inc., 1970), 117.
2 J.L.E. Dyer, *A History of Astronomy from Thales to Kepler* (New York: Dover Publication, Inc., 1953), 13.
3 Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers* (Cambridge: Harvard University Press, 1943), 19.
4 Roland Omnés, *Quantum Philosophy: Understanding and Interpreting Contemporary Science* (Princeton:Princeton University Press, 1999), 135-136.

disagreed on its core essence; he believed that all material things are reducible to fire rather than *apeiron*. However, when we analyze his surviving written fragments–it seems like paradoxical nonsense. One surviving fragment states that fire, "rests from change."[5] He resolves this paradox by theorizing that two polarized states such as the states of rest and change are not mutually exclusive; rather, opposites are necessary because they exist in tension, and it is that tension that is a catalyst for change and material transformation.[6]

A second and third surviving fragment attributed to Heraclitus states, "Everything flows," and, "In the same river, we step and we don't step."[7] These simple phrases further support his belief of an ever-changing universe that is in constant motion. Scientist and mathematician, Werner Heisenberg further substantiates a continuously evolving universe in his Uncertainty Principle; a mathematical equation which proves that the position and momentum of a subatomic particle cannot be observed simultaneously. When an observer views an electron, they will only witness its blurred path,[8] and like a river that is constantly in a state of motion, an electron's inherent motionless quality cannot be observed by the human senses.

Parmenides of Elea agreed with Heraclitus and Anaximander. Reason alone should be used to seek objective truth. However, in contrast to Heraclitus's view, he rejected the existence of change and argued that any observable variation is an illusion of the senses. He argued that reality itself is a whole unfractured system, a universal particle that had no beginning or end. It was never created nor will be destroyed, and the only real thing is existence itself. He writes:

> For nothing else either is or shall be except Being, since Fate has tied it down to be whole; and motionless; therefore, all things that mortals have established, believing in their truth are just a name: Becoming and Perishing, Being and not-Being, and change of position, and alteration of bright color.[9]

Parmenides addresses opposing states such as Being and Not-being by reasoning that states of mutual exclusivity cannot logically exist within a universe that is an indivisible unit. Differences cannot exist because the universe is a unified state, and if it were subject to internal change it would exist as a fractured state of imbalance. His idea that the universe exists as a single unit suggests that although reality is not reducible to a single essence from the human perspective, the whole universe is reducible to a particle due to the universe's already reduced state. Furthermore, the idea of mutually exclusive concepts cannot exist in an undivided unit due to its unified state, despite human sense perception suggesting otherwise.

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[5] Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers*, 27.
[6] Werner Heisenberg, *Physics and Philosophy* (New York: Harper Collins Publishers, 1962), 6.
[7] Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers*, 28.
[8] Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: The University of Chicago Press, 2002), 104.
[9] Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers*, 44.

Much of Parmenides's theories were proven incorrect by future science. However, it is important to note that certain critical aspects of his ideas are relevant to modern science. For example, his assertion that the universe is one universal particle is not far off base. Erwin Schrödinger's work on wave function mechanics relies on a mathematical equation that only works in a universal closed system which suggests that the universe is a single unit despite perceptive change.

Anaximander, Heraclitus, and Parmenides's work were significant because they utilized reason in their analysis; however, according to Aristotle their conclusions were not acceptable because they could not be verified by observation. In his famous work *Physics,* Aristotle offers a balanced approach by concluding that the senses can be trusted to a certain degree, but one should use caution because observation or reason alone can lead the individual astray in the quest for absolute truth.[10] One must supplement observation with logical analysis; however, it is necessary to begin the process of deduction with a universally agreed upon fact. In the opening lines of *Physics,* he states, "The natural way to go about this is to start with what is more intelligible and clear *to us* and move from there to what is clearer and more intelligible *in itself."* Unlike Parmenides, Aristotle stressed that change within the universe is a self-evident truth because it can be observed. Although he agreed with Anaximander's prime continuum he disagreed on the *nature* of the continuum; the continuum cannot be defined as an unobservable primary substance because it cannot be observed. Rather, he used reason based on observation to conclude that the continuum is defined as an uninterrupted process of change caused by a process of mutual influence between all matter within the universe. Furthermore, he dismissed the belief of a particulate reality because it is logically inconsistent due to observed perpetual fluidity of change and mutual influence between material objects Dr. John Bell of Stanford writes:

> Aristotle defines continuity as a *relation* between entities rather than as an *attribute* appertaining to a single entity; that is to say, he does not provide an explicit definition of the concept of *continuum*. He observes that a single continuous whole can be brought into existence by "gluing together" two things which have been brought into contact, which suggests that the continuity of a whole should derive from the way its *parts* "join up".[11]

Aristotle's idea of a continuum based on the process of mutual influence has been validated by modern science. Werner Heisenberg discovered that the process of change is dependent on the probabilistic interactions of quantum objects which is essential in the continual creation of objective reality.[12] Reality is continually created through interaction. To ensure that an observation followed by reason does not lead to nonsensical assumptions, Aristotle outlined formal rules of logic. He believed his logical methods were

[10] G.E.R. *Lloyd Early Greek Science: Thales to Aristotle*, 99.
[11] Aristotle, *Physics*. A New Translation by Walter Waterfield. (New York: Oxford University Press, 2008), 9.
[12] John L. Bell, *Continuity and Infinitesimals*, The Stanford Encyclopedia of Philosophy.

necessary guidelines to access ultimate truth; most notably, The Law of Non-Contradiction. Nothing can both exist and not exist at the same time and in the same respect. Put more simply, no statement is both true and false.[13]

The law of Non-Contradiction is especially relevant to modern science because it created a rule that states that an object cannot simultaneously be in two states at the same time. Any fact must be either true or false. Quantum mechanics reaffirms this standard. Wolfgang Pauli's Exclusion Principle states that no two electrons can exist in the same space at the same time, and if Aristotle's logic was not correct then atoms would consequently collapse in on themselves.[14] Therefore, the structure of the atom depends on the Law of Non-Contradiction for its existence and further validates ancient Aristotelian ideas.

Aristotle invented logical methods that would be the foundation for future scientific research.[15] By criticizing Anaximander, Heraclitus, and Parmenides, Aristotle discovered that the search for universal knowledge should begin with logical relationships between axiomatic sense objects. The seventeenth century British mathematician and astronomer, Isaac Newton exemplified these core Aristotelian values in his explanation of motion. By observing planetary movement, he reasoned his way to explain their movements with his Three Laws of Motion.[16] It is key to note that like Aristotle, Newton relied upon observation supplemented by reason, without the use of experimentation. That he was able to invent his eponymous Laws of Motion serves to further validate the efficacy of Aristotelian logical process. However, unlike Aristotle who believed that the universe could be reduced to a continuum, Newton believed that reality is reducible to phenomenon that is particulate in nature due to his claim that motion and subsequent change were caused by the interaction and influence of macroscopic objects and fundamental particles therein.[17] It is important to emphasize, that Newton revised a two-thousand-year-old Aristotelian idea by modifying a core element. Change is caused by the interaction of particles rather than a continuum of objective mutual influence. Like Aristotle, Newton had no way of proving or falsifying his belief in a particulate reality, but his argument was accepted due to its foundation in Aristotelian logic which relied on observation supplemented by reason.

According to science historian Thomas Kuhn, despite Newton's inability to prove beyond a doubt a-particulate reduced nature of reality, the idea persisted due to his scientific brilliance in other aspects of physics.[18] For example, since he was able to predict the movement of the heavenly bodies through his invention of differential calculus he was seen by the scientific community as an authority in physics and his findings were rarely

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[13] G.E.R. Lloyd, *Early Greek Science: Thales to Aristotle*, 99.
[14] Aristotle. *Metaphysics*.
[15] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory,* (New York: Doubleday & Co.,Inc), 66.
[16] Edward Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century,* 6.
[17] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 104.
[18] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 104.

questioned.[19] His work in optics suggested-that light is particulate in its most reduced form, because it behaved in a manner that as described by his three Laws of Motion. Most notably, the First Law which states that an object will move in a straight line unless acted upon by an outside force. By shining white light through a prism, he found that light moved in a straight line suggesting its particle-like quality. However, one notable scientist disagreed. In 1678 Christiaan Huygens proposed that light displays properties of a wave-like continuity, but the theory was largely ignored due to Newton's dominance in the scientific community.[20] Although Huygens's wave theory went largely unnoticed. It is important to emphasize his dissenting opinion because it demonstrates that the two-thousand-year-old particle/continuum debate that began two-thousand years ago in ancient Greece still had an impact on the science community in the seventeenth century. continued to make an impact on science during the seventeenth century.

Newtonian classical physics worked because it was intuitive. It made sense that the universe functioned similar to a giant universal mechanism, in which all particles influence each other. This process of mutual influence is responsible for motion and change, with every event caused by a preceding event in deterministic fashion. The process is observable and predictable through logic-based mathematics which further validated Aristotle's assertion that the senses can be trusted, and ultimate truth is accessible with logical analysis.

In the early 1800s, Newtonian ideas regarding the mechanical nature of the universe persisted. However, in the year 1800 Thomas Young challenged the Newtonian-particulate understanding of light when he conducted an experiment that would change future science. By shining light through a barrier containing two narrow slits he discovered that after the light traveled past the barrier the experiment resulted in bands of light as a consequence of constructive and destructive interference.[21] If light was particulate in nature it would not create bands of light because such interference can only be created by continuous wave-like phenomena similar to ripples in a pond.[22] It is critical to understand that although light's wave-like and continuous nature replaced Newton's prime particle, the Double Slit experiment further validated the Newtonian determinism because light's path through the double slit can be calculated to determine its final position. Another important feature of the experiment is that it reinvigorated the particle/continuum debate after a particulate reality was thought to be settled by Newtonian physics. Although the Newtonian model accurately described phenomena in its relationship to motion, as a consequence of particulate mutual influence; the conclusions of the Double Slit Experiment suggested that Newton's particle model was incomplete, despite its deterministic nature.

The Double Slit Experiment affirmed the continuous nature of light in reconciliation with the Newtonian deterministic universe. However, in the early 1900s classical mechanics was found to be problematic, because it did not accurately explain the heat spectrum. It

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[19] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 19.
[20] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 19.
[21] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 19.
[22] Roland Omnés, *Quantum Philosophy: Understanding and Interpreting Contemporary Science*, 38.

was discovered that the universe should be overwhelmed with infinitely high temperatures if light is both wave-like and infinitely divisible.[23] The struggle to solve the infinite temperature problem was the catalyst responsible for the discovery of quantum mechanics.[24] In 1901, theoretical physicist Max Planck found that the underlying issue within the infinite temperature problem, rested on the classical understanding that energy is continuous in nature. Planck formulated an equation that replaced light's continuous quality with a discrete, quantized unit. According to Planck, when an object radiates heat it actually emits energy in discrete packets, not a continuous wave. Planck's quantization of energy fixed the infinite temperature problem by accurately describing temperature limitations; however, quantized energy as proposed by Planck stood in contradiction to light's well-established continual nature. If light was particulate and continuous in nature it violates the ancient and proven Law of Non-Contradiction; therefore, the dual nature of light appeared to be logically impossible.

In the first two decades of the twentieth century, Planck's quantized theory of energy set in motion a major change in physics. Specifically, the desire to understand the true description of energy and resolve its ostensible paradoxical nature. According to Albert Einstein, there was no reason to assume that the classical physics behind light's continuous nature was incorrect, until Planck's discrete energy mathematically fixed the problem of radiation.[25] But it cannot be wave-like (as confirmed by Young) and simultaneously quantized in quality (as proposed by Planck). Therefore, in 1905 Einstein tested the dual nature of energy and conducted an experiment confirming Planck's quanta. By shining light on a metallic surface, he discovered that the interaction between light and matter ejected photoelectrons from the surface of the metal plate. This process was known as the *photoelectric effect.*[26]

The significance of the photoelectric effect cannot be understated. Although it seemed paradoxical that continuous light emitted a particle from a metal surface, Einstein found that the continuous nature of the shining light is composed of discrete photons. These were responsible for the displacement of photoelectrons on the metallic surface. The interaction of photons and the atoms that make up metallic surfaces demonstrates that change occurs through the process of mutual influence. The light *caused* the photoelectrons to be dislodged. The photoelectric effect, demonstrated that the dual nature of light is only paradoxical when not analyzed through its most reduced particulate form.

Energy's simultaneous wave and particle duality proved to be false, Einstein's confirmation of light's reduced particulate nature through the photoelectric effect did not invalidate Young's Double Slit experiment. When Young shined a coherent light source through the Double Slit barrier, light was viewed through a macro perspective and

[23] Richard Olson, *Science as a Metaphor: The Historical Role of Scientific Theories in Forming Western Culture*, 296.
[24] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory*, 16-17.
[25] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory*, 16-17.
[26] Albert Einstein, Leopold Infeld, *The Evolution of Physics. From Early Concepts to Relativity and Quanta.* (New York: Simon & Shuster, Inc., 1938.), 253.

therefore continuous in quality and correct from the experiment's perspective. He was unable to further reduce the light source to its particulate state. This was due to the fallibility of his sense perception and the limited technology available during the early nineteenth century. Anaximander was right; there is an underlying micro reality within the macro world inaccessible to the human senses. Furthermore, energy's opposing particle/continuous state is only paradoxical when observed through comparative analysis of light through a micro and macro perspective. An observer must reduce light to its most fundamental form in order to invalidate its apparent opposing nature. The photoelectric effect further substantiated the foundational Aristotelian logic behind scientific principles.

After Einstein's experiment on the photoelectric effect, scientists turned their attention to the structure of the atom. Without the photoelectric effect's evidence that further validated Aristotle's law of Noncontradiction, it is doubtful that Niels Bohr would recognize the problematic structure of the contemporary atom. Bohr discovered that an electron's orbit does not behave like a planet orbiting the sun as suggested by classical mechanics, such orbital structure would result in the electron crashing into the nucleus due to gravitational pull.[27] By consequence, atoms would destroy themselves and the universe would not exist.[28] Bohr further theorized that since Einstein discovered light could dislodge electrons from a metallic surface, then perhaps the electron can only occupy orbits in discrete distances from the atom. This dual nature explains how an electron emits energy in discrete units, rather than in a continuous fashion. When an electron is emitted or absorbed, it jumps an energy level by absorbing or radiating energy that coincides with the distance between orbits.

Bohr was correct, but he discovered something surprising. As an atom absorbed or emitted energy, the electron immediately jumped to another level without following a well-defined transitional path; it seemed to pop in and out of existence from one orbit to another. As Bohr confirmed the electron's particulate nature, Louis De Broglie postulated that particulate energy within the atom should have wave-like properties akin to light, and it must follow the same dual quality as proved by the photoelectric effect. There was no reason to believe that electrons should behave any differently. He therefore theorized that the particle within the orbit can also be viewed as a circular standing wave. The Davidson-Germer Experiment confirmed De Broglie's standing wave theory which consequently reinvigorated the paradoxical nature of the electron due to its reductive contradictory dual state.[29] The paradox directly inspired Schrödinger, and Heisenberg's work to mathematically explain the duality.[30]

Schrodinger and Heisenberg approached the problem from two different perspectives.[31] Inspired by De Broglie's wave hypothesis, Schrodinger analyzed the

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[27] Albert Einstein, Leopold Infeld, *The Evolution of Physics. From Early Concepts to Relativity and Quanta*, 258.
[28] Roland Omnés, *Quantum Philosophy: Understanding and Interpreting Contemporary Science*, 137.
[29] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory*, 83-85.
[30] Werner Heisenberg, *Physics and Philosophy*, 14.
[31] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory*, 87, 99.

electron's wave-like property while Heisenberg analyzed the electron's movement from a particulate standpoint. Both created different mathematical formulas that expressed the same idea; the electron's final state cannot be determined with knowledge of its initial position and momentum. Schrödinger's Wave Equation and Heisenberg's Matrix Mechanics mathematically proved that an observer can only calculate the *probability* of the electron's final state based on wave or matrix mechanics.[32]

The significance of quantum mechanics rests on evidence that proves that when an electron is in its continuous wave form it is in a state of continuous superposition of states, because prior to its observation or interaction with other matter it has the potential to materialize in a random position. There is no way to predict where the particle will materialize due to the probabilistic nature of Heisenberg's Matrix and Schrodinger's Wave equation. This hinges on the fact that it is in the act of observation, that causes an electron to materialize. In other words, an atom's interaction with other atoms, causes the wave function to collapse. This then results in causing the electron to transform, from a wave of probability to a discrete event. As a field of probability decoheres into an event it proves that the electron's dual particle and continuous nature is necessary for the universe's existence because the continuous probabilistic wave function causes a discrete event.

The evidence derived from the study of quantum mechanics is not a reflection of new ideas; rather, it is the scientific confirmation of ancient theories. Anaximander, Heraclitus, and Parmenides all questioned the reliability of the senses and theorized that there is a layer of reality that is not observable from the human perspective. Anaximander's idea was verified by the discovery of the atom and subatomic processes which are only accessible through the use of advanced technology. Furthermore, Anaximander believed that the unobservable and undefinable *apeiron* is the essence that causes growth and evolutionary processes like a living organism.[33] The underlying abstract wave function is not structurally defined nor can it been seen; however, like *apeiron,* the wave function is the influencing mechanism that is the underlying cause of material transformation and evolutionary progress.

Like Anaximander, Heraclitus's ideas are just as relevant although they are more difficult to understand; specifically, the paradoxical phrase, "It rests from change." With these four words he said that a necessary quality of the universe in its natural state is of change and transformation. The work of quantum theorists proved Heraclitus's idea to be correct. Change is a necessary characteristic of the universe that relies on the necessary duality of events governed by the probability that a certain event will occur. Like fire, the universe rests from change. The transformative nature of the universe depends on such duality. Parmenides denied the existence of opposites in his assertion that change and separation are an illusion within a universal single unit. Everything with the universe including all aspects of life and matter are one. Quantum mechanics verifies the interconnectedness of all atoms within the universe. From a micro perspective there is no

[32] Werner Heisenberg, *Physics and Philosophy*, 14.
[33] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory*, 28.

differentiation between atoms, and the tangible objects of our environment are merely an illusion.

Parmenides's theory of the of a universal whole was amended by Aristotle whose ideas were extremely critical in their influence on quantum mechanical theory. The desire to make sense of the mutually exclusive particulate and continuous nature of the electron drove scientists to dig deeper and solve this paradox. Without Aristotle's Law of Noncontradiction serving as an important foundation of science, the quantum pioneers would not have recognized the problem of an electron's dual nature and worked so fervently to solve what seemed to be a paradox. Furthermore, like Heraclitus Aristotle postulated that any substance is defined by its potential state, and any substance in the universe is created by the effects of mutual influence. This functions similarly to how atoms transform through interactions with other states of matter. Heisenberg stated that matter is never in a state of completeness, it is always transforming to become something else. It cannot be defined as it is in a single moment because it is always in a state of transition from potentiality to a new state of being.[34]

Quantum Mechanics resolved the particle continuum debate by discovering that the true nature of the universe is not a particle, nor a continuum. It is both, and the duality and opposing forces are necessary for the universe's existence. Without a wave function of potential outcomes there is no event; in other words, with the absence of change there is no reality, and change depends on opposing forces working in cooperation to perpetuate the creation of reality. The ancient Greek ideas of Anaximander, Heraclitus, Parmenides, and Aristotle set in motion a chain of ideas, whose tradition of rational analysis laid the groundwork for a modern understanding of the reductive nature of reality and opposing forces within the universe. Since an idea is dependent on antecedent ideas, we can credit the ancients in their direct influence in the discovery of quantum mechanics and the resolution of the particle/continuum debate.

[34] Shimon Malin, *Nature Loves to Hide: Quantum Physics and the Nature of Reality, a Western Perspective* (New York: Oxford University Press, 2001), 142.