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“Democritus’ Exploration of the Atomist Theory and its Influence on the World”

Look up who discovered the atom. One will find the name Democritus—a Greek philosopher who lived c. 460 BCE – c. 370 BCE. Actually, Democritus of Abdera discovered the atom theoretically, not physically, since he had no equipment or instruments to see something as small as an atom. Democritus had no idea how correct he had been with the idea of atomism, or how much of an impact it would create. He is responsible for transforming humanity’s ideas of the natural world forever, because Democritus’ exploration into the infinitesimal world of atoms led to unforeseen consequences—a theory that parts of last until today. Democritus exchange of his new theory via writings with others who followed him dramatically influenced the course of scientific history throughout time.

In fact, it was this pre-Socratic philosopher’s teacher, Leucippus, who first explored the concept of an atom, but since no writings of Leucippus survive to the modern day (past ancient times) and because Democritus is the one who really crystallized his teacher’s theories, it is Democritus who is credited with the first human being to theorize on the existence of the atom (Berryman, 1). Back then, scientists –be it biologists or physicists–were called philosophers, and no one ever heard the term theoretical physicist.

Most ancient peoples’ beliefs of the universe were based on their religion and the worship of gods. Before Democritus, no one except Anaxagoras (c. 510 – 428 BC) had any thoughts about the existence of substances smaller than those they could clearly see. Anaxagoras,

however, was more concerned with the original state of the cosmos than atomism (Curd, 1), and he was exiled from Athens for his association with Pericles. One hundred years after Democritus, Aristotle established beliefs in the four classical elements: fire, air, earth and water. Democritus' search for a new way to look at the physics of the natural world was courageous for its time.

It was a group of ancient Greek philosophers who explored the theory of atomism: Leucippus (flourished 5th century BC), Democritus, and their followers Epicurus (341–270 BC) and Lucretius (c. 99 BC – c. 55 BC). This group was influenced by Democritus, and through letters and books, Democritus' atomist ideas were subsequently exchanged and actively discussed with the following ancient Greeks and Romans for the next 1000 years: Aristotle (384 – 322 BC), Marcus Tullius Cicero (106 BC – 43 BC), Galen of Pergamon (129 AD – c. 200/c. 216), Sextus Empiricus (c. 160 – 210 CE), Alexander of Aphrodisias (flourished 200 AD), Themistius (317 – c. 390 AD), Simplicius of Cilicia (c. 490 – c. 560), Joannes Stobaeus (flourished 5th-century CE), and John Philoponus (flourished 6th century) (Taylor, 69-90). Into modern times, even today, the ancient atomist theory and Democritus are discussed by scientists in their books. Many new books on theoretical physics, string theory, and astrophysics start with a discussion of Democritus' atomist theory. For example, the most recent book to be written on astrophysics, metaphysics, and extraterrestrial life—The Copernicus Complex by Columbia University Professor Caleb Scharf—credits Democritus with the idea of matter being made up of smaller parts in the beginning of his book (Scharf, 13).

So why is this important? Why was Democritus so learned? He grew up in Thrace, which was on the edge of ancient Greece and bordered the powerful Persian Empire. His wealthy father received the Persian King Xerxes on his march through Abdera. In gratitude, Xerxes left behind some of his wise men, who taught Democritus astronomy and theology. Upon the death of his

father, Democritus spent his inheritance travelling to distant countries in a quest for further knowledge. He travelled to many parts of the known world in search of more education. Due to his travels, Democritus was considered one of the most knowledgeable persons of his time (Macfarlane, 5-13).

Democritus' most famous quote is "Nothing exists but atoms and empty space; everything else is opinion." (Bennett, 1) This shows just how much Democritus believed in the theory of atomism. When he explored his mentor, Leucippus' new theory, Democritus took a risk. This early theoretical physicist had no idea whether or not his theory was actually true, nor did he know what consequences may result from the spread of this revolutionary new theory.

But what was this theory? Atomism, at its most basic level, postulates two substances-- that which is, and that which is not. All of the objects, life, and everything in the world are made up of smaller parts known as atoms, based off of the ancient Greek word for uncuttable, atomos, (Thacker, Quinn and Cantrell-Briggs, Loree, 1) and these atoms travel through what is known as the void, which is simply the lack of stuff (ChemTeam,1). The attachment and detachment of atoms has been going on for eternity and will continue to do so. According to this ancient theory of atomism, everything around us is composed of atoms. These are tiny indivisible things which may vary in shape, location, rotation, and more, all of which change the properties of the atom. For example, atoms of fire are spherical, while atoms of water are cubes (Carpi, 1). In addition, in order to stick together and form larger things, atoms are theorized to have hooks on all surfaces to connect to other atoms. These hooks are, however, part of the atom itself. According to Democritus, atoms are partless, because if they had parts, they would be divisible into those parts. After all, an object is only divisible if it contains some void inside, but atoms have no void inside, while, when hooked together, there is some room for void (Taylor, 69-90).

Democritus was correct about much of this theory. According to some remaining fragments of the work of ancient Greek philosophers which still remain, Democritus is credited as the first to have discussed how things form and fade away, and he does this in a new way: while the other philosophers have no detailed accounts of what the creation and destruction of things truly are, Democritus and Leucippus hypothesized that atoms separate, join together, and change their arrangements to change the forms of things. Democritus was also correct when he theorized that if one small thing changes among the atoms, the result could be different from what would happen if other arrangements of atoms were used. This early Greek scientist postulated that the void, or space, is infinite, which modern day theoretical physicists believe could be correct according to current mathematical calculations. Democritus also correctly theorized that the most fundamental substances are too small to sense, and knew this to be true without the use of extra equipment such as modern day electron microscopes. In addition, everything (not only nonliving materials) comes together and breaks apart to form new things, which humanity now knows to be correct, because the same atoms are sometimes used to form different molecules. For example, charcoal and diamond are both made of the same atom (carbon). The only difference is that diamond requires much more energy along with the carbon to create it as compared to charcoal. Plus, the ingenious Democritus accurately theorized that atoms have weight, which is true, although the weight of an atom is very, very tiny relative to the weight of any larger object composed of millions of atoms (Taylor, 69-90). Democritus was right about many of his theories and very forward-thinking for his time.

One may now be left wondering, “How could one know all of this to be true about a theory developed so long ago?” Well, the word of atomism was spread through others around the known world, and it was further explored long after Democritus’ death--over 1000 years later, in

fact, via books and letters by other respected philosophers who valued Democritus' new ideas. Soon after his death, a new philosopher destined to become one of the most well known of his time, Aristotle, was born. Although he was a great philosopher, Aristotle was against the theory of atomism, because he believed that indivisible substances cannot exist. Hence, he wrote two books: *Against Democritus* and *Problems with Democritus*. During the next thousand years, other Greek and Roman philosophers, however, used logic to show how Aristotle's claims are invalid. They include: Marcus Tullius Cicero, Galen of Pergamon, Sextus Empiricus, Alexander of Aphrodisias, Themistius, Simplicius of Cilicia, Joannes Stobaeus, and John Philoponus. Most wrote commentaries on Aristotle's famous writings, for example, *De Generatione et Corruptione* and *Metaphysics* that included a discussion of atomism. Many wrote letters and books to exchange their understanding of the creative Democritus' exploration into the small world of atoms (Taylor, 69-90). Hence, through all of this discussion, scientists even up through today continue to preserve the innovative information included in Democritus' marvelous ancient theory.

Although not all of Democritus' facts were completely correct, they still represented a great leap from the ancients' previous theories of the universe. Democritus was correct on many of his basic ideas of atomism but incorrect on most of his other, more specific ideas of atomism, perhaps due to his lack of ability to directly detect atoms. For example, he was incorrect on the following concepts. Leucippus and Democritus were wrong in saying that atoms are too small to be further divided and are partless, while Epicurus said that they do have parts but simply are unable to be affected. Democritus erroneously believed anything could be made from atoms and that atoms have parts and size, but they are incapable of being divided because of their solidity and fullness. Rather than combine, when atoms collide, they simply hook onto each other.

Democritus also had thought that atoms' appearances change when the observer moves closer to or farther from the atom, but this is incorrect. This "father of modern science" was also wrong in saying atoms are indivisible due to their lack of void inside; the void was said to be fine-textured. Democritus was also wrong in thinking the following: there are an infinite number of atoms with infinitely many shapes "since there is no more reason for them to be one shape than another" (Taylor, 69-90). The shapes of atoms determined properties of what they made up, for example, spherical atoms yield fire, while cubical yield water. Atoms form compounds by the fitting of their shapes, sizes, arrangements, and orders. Democritus erroneously believed the atoms are moved by mutual impact, but there is no stated natural origin of the motion → atoms are by nature immobile and moved by a blow (Freeman, 1). Furthermore, the cause of the atoms' weight is also not stated. The atomists incorrectly postulate "partless elements" as parts of the atoms which are also (according to them) weightless. Primary bodies (solids) had no weight but were rather moved by mutual collisions in the void (Garrett, 1). According to Democritus, there is no such thing as color and atoms are colored by their position. Democritus believed an atom may be as large as the world. Atoms have been doing this and will do this for eternity (Taylor, 69-90). While he was incorrect on the smaller details like the ones mentioned above, perhaps due to being born in the wrong time, Democritus was right about the larger picture.

If Democritus were around today, what would he be doing? He would likely be working in the field of theoretical physics. In particular, Democritus' ancient theories on time and other worlds relate to modern theoretical physicists' theories on the existence of a multiverse, which essentially would mean that the world is many universes together in one encompassing region, or meta-universe (Crume, 1). Possibly he might also be working on the challenging task of the theory of everything (ToE), a.k.a. master theory, one equation that explains everything in the

universe, which Albert Einstein and Stephen Hawking worked on. This is because theoretical physicists come up with and refine theories of what the world truly is, similarly to how Democritus' ancient theory of atomism explained how the world works at the deepest level. In the theoretical physicist field, in both modern and ancient times, Democritus would come up with a theory about a natural phenomenon which is unprovable and not verifiable, and subsequently try to gather data to prove it. The only difference between the modern and ancient definitions of a theoretical physicist is that in modern times, one must utilize math in the proof of their theory, while in ancient times, it was rare to see math proving a scientific theory (The Worst, 1).

Some, however, may argue that Democritus was not a theoretical physicist due to the lack of mathematics in his atomist theory. During Democritus' lifespan, not all areas of math were as developed as others. For example, algebra and calculus were not in existence for at least another 1,000 years. In ancient times, theories were not usually backed up using math and the field of science was still categorized as philosophy. Two millennia later, that all changed and hence appeared the modern day definition of theoretical physics that includes the use of math. For example, Albert Einstein came up with thought experiments that were later backed up by math, sometimes by other theoretical physicists' even decades later.

In his exploration of atomism, Democritus could have also used the modern day electron microscope. Just like in the early 20th century, Einstein could have used many observatories and data from around the world to prove his theory that there really are stars moving around black holes. Unfortunately, these amenities were not available in the lifetime of these great thinkers.

To conclude, Democritus had no idea how correct he had been by believing in atomism and how much of an effect his atomist theory had over the following 2000 plus years.

Throughout history, scientists have exchanged Democritus' ideas and utilized them to launch humanity ahead into a world full of knowledge and new theories. In just the past hundred years, humanity has even advanced far in the world of astrophysics, from our solar system to the edge of the visible universe. And Democritus is to be thanked; without his exploration of atomism, the path to proving the existence of atoms would have taken many years longer.

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