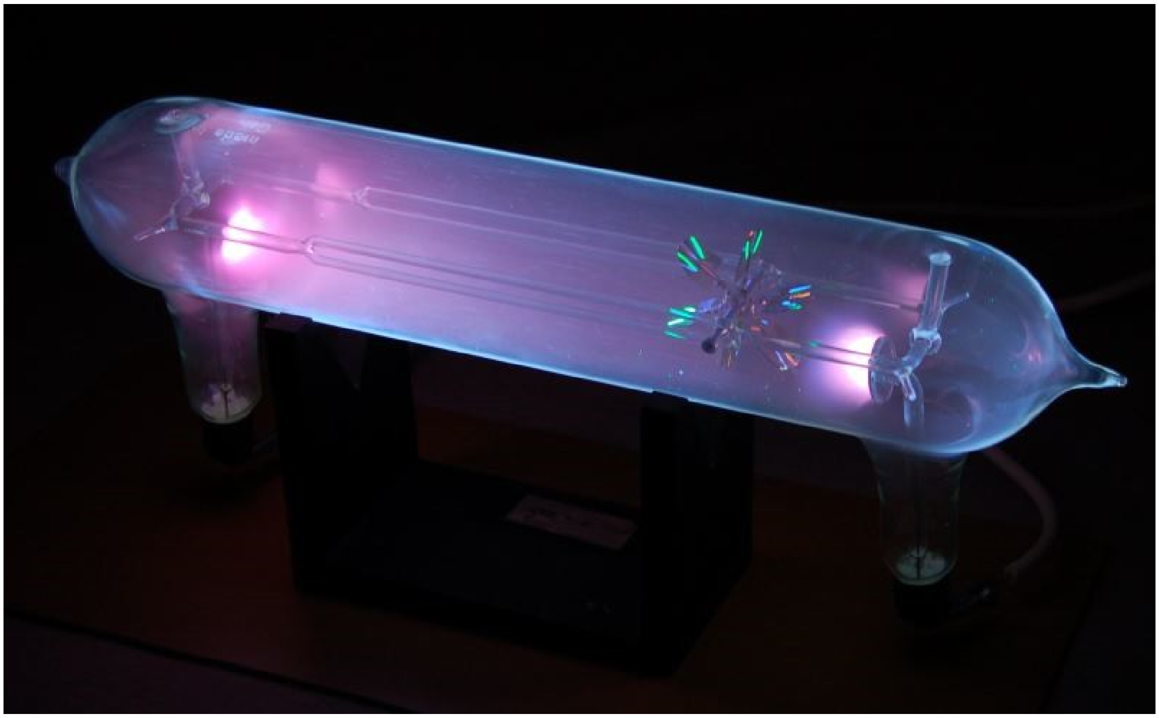
CHAPTER 6

The Origin of the Concept of the Atom



He had never seen anything like this before – if you could call it "a thing." Not only was the space inside the tube glowing, so was the space outside. As he removed more of the gas from the tube, the tube began to glow even brighter. It was as if matter had suddenly become formless. Could matter really pass through the walls of a glass tube? What was the nature of this "radiant matter" anyway? Perhaps he was asking the wrong question. Maybe the most important question was: What is the nature of matter? What was an atom anyway?

The atom has become one of the most powerful concepts of our time. Every*thing* is made of atoms. From a modern reductionist point of view, atoms are what every aspect of our existence is created from. As you sit here reading, you may think you have a certain level of freedom in the activity you are engaged in. You could choose to read the rest of this chapter in one sitting. You might decide that you would like a snack after this sentence and go to the refrigerator and see what it contains. You have many free choices in your life. From a reductionist point of view, no*thing* could be further from the truth; what you consider to be yourself or your personality is simply the result of a series of biochemical interactions. These reactions are then considered to be simply the result of a series of interactions of other biochemical interactions, biological processes, and a series of preprogrammed DNA tendencies. All of these biochemical interactions are then thought of as a lawful expression of material interactions, which ultimately devolve into a series of atomic interactions. When we get to the atoms or the subatomic particles, reductionist thinking assumes the processes stop. For a reductionist, we have found the basis of all existence: a series of material interactions. This is the basis for a material based worldview, the view that most of us spend our days unconsciously adopting. While many of us may be repulsed by such a view, and claim that we think of the world as otherwise, in the end, the materialistic worldview is the one we habitually fall back to in our unconscious moments.

The key questions one might ask are: Is such a materialistic view of the world wrong? And, if the world is not based solely on material interactions, on what else might it be based? If you investigate this question thoroughly, you may be quite surprised at the origin and history of the concept of the atom. A very brief history follows below.

The first historical mention of the atom took place around the 6th century, BCE. While many students learn that the concept originated with the Greek Philosopher Democritus, it was mentioned slightly earlier by the Indian Philosopher Kanada. According to Kanada, all existence was made of small eternal particles that were in continuous motion. While Kanada had no direct evidence to suggest that all of matter was ultimately made of discreet bits, he nevertheless stated that this was the case. Likely, Kanada was influenced, as we are, by the concept of separate objects that are large, small or tiny in size. A large rock may wear away into smaller stones, into pebbles, into grains of sand, and finally into the discrete elements of nature that are the smallest entity that can be imagined.

Shortly after Kanada recorded his ideas on the atom, the Greek philosopher Democritus, around the 5th century BCE, also conceptualized that the ultimate essence of existence was the atom. The word atom comes from the Greek word *atmos*, which generally means, *"that which can not be cut."* This implies a finality with respect to the ultimate smallness of material objects. To Democritus all existence was made of atoms. The shape of the atom determined its quality or, more rightly said, Democritus speculated that the quality of the atom was a result of the atom's shape. Democritus continued to speculate that sour food must have sharp atoms, that water's atoms must be round and smooth. Even the human soul was thought to have contained fine, mobile atoms. Once again, Democritus asserted that all material existence was made of discreet particles and that these particles, although unseen, were similar in nature to the larger objects that make up the world of our everyday experience. It is critical to note that both Kanada and Democritus did not have an experimental means of validating their stated views about the nature of the material world. They were neither the first nor the only ones who made this assumption. They were also certainly not the last.

Much of the scientific and philosophical traditions held this view or contrary views for a number of centuries. As Western science became more developed with the aid of such scientists as Galileo and Newton, the idea of an atomistic or corpuscular worldview continued to gain followers. However, the next time this view achieved real prominence was in the early 1800's, with an Englishman named John Dalton. Dalton was a teacher, chemist and meteorologist. He was greatly interested in the composition of the atmosphere and in determining if air was a compound or a mixture of gases. Dalton was able to deduce that the atmosphere was made up of a series of gases that could be isolated given the proper conditions. More importantly for our study, Dalton was also able to determine that many of the gases as well as other compounds were the result of chemical interactions that appeared in fixed mathematical proportions. Dalton spent a number of years investigating the mathematical nature of the proportions by which chemicals react. In time, his analysis suggested that each of the chemical elements of nature appeared to react with other elements in fixed whole number ratios. Dalton was aware of two relationships that had been found between the products of a chemical reaction and the reactants that yielded the products: the law of constant composition and the law of definite proportion.

The Law of Constant Composition – all chemical compounds when put through a destructive chemical process will always yield the same chemical elements.
For example, if one subjects sodium chloride (common table salt) to the right chemical process, one can obtain elemental sodium and chlorine gas. Note that one never obtains any other element, say copper, from sodium chloride (unless there are impurities in the original compound).

The Law of Definite Proportion – all chemical compounds when put through a destructive chemical process will always yield the same chemical elements in the same mathematical proportions.
Using the above example of table salt again, one will find that the ratio of sodium to chlorine gas will be 23 parts of sodium to about 35 of chlorine gas by weight. If you repeat the experiment using larger or smaller qualities of pure sodium chloride, you will continue to get the same proportional results.

Through experimentation, Dalton also found the following to be true.

The Law of Multiple Proportions – if two or more different compounds composed of the same elements are put through a destructive chemical process to yield their elemental products, the ratio of the resulting elements from one compound will have a small whole number relationship to the ratio of the same elements in the other compound(s). That is to say, if two elements form more than one compound between them, the ratios between the masses of the second element, which combine with a fixed mass of the first, will be ratios of small whole *numbers.*

This law is just a bit trickier to understand. Imagine you take one of the gases emitted by the incomplete combustion of charcoal and put it through a destructive chemical process. You will find that you get carbon and oxygen gas in a ratio, by weight, of 3 to 4 units, respectively. If you were to perform another destructive chemical process on one of the gases present in carbonated spring water, you would fine that carbon and oxygen are again found, but now in ratios by weight of 3 to 8, respectively. Note that the ratio of carbon in the elemental proportions of each compound is one of a small whole number (2), while the oxygen remains fixed.

These lawful relationships caused Dalton to reason that since the materials always obeyed the same mathematical relationships, perhaps this was due to the presence of some tiny infinitesimal constituent of material that was always matching up in fixed proportion in his experiments. This led Dalton to speculate the existence of a small entity called the atom. Once again, although the mathematical relationship was numerical, there was no direct evidence of some tiny bit of material that *“could not be cut.”* It is worth noting here that Dalton, being a school teacher, was very interested in helping his colleagues and students to have an understanding of his imagination. He proceeded to have a local carpenter make a series of wooden spheres that were then painted different colors to portray the different elements. Dalton was clear that this was simply *a teaching tool*. Two hundred years later, one can ask the question: How many people remember that this was simply a teaching tool and not a representation of “the real *thing*?”

Dalton’s mathematical relationships were later verified and their accuracy was improved upon. While much of this careful experimental work honing the mathematical proportions was completed by John Berzelius of Sweden in the early 1800‘s, Berzelius did not take as much interest in developing Dalton’s physical model, as his focus was the mathematical relationships themselves. It was a few decades before another key researcher took a direct interest in the nature of the atom.

William Crookes was also an Englishman and one of real means. Crookes was born into an aristocratic family in 1832. When he was older, and, recognizing his good fortune, Crookes decided to dedicate himself to the pursuit of science. As Crookes was also a part of the growing “Spiritualist” movement of his time, he took a great interest in electrical phenomena, the mysterious and somewhat new emanation that had only recently begun to be harnessed by the early to mid 1800s. It had been found that electrical effects could instill movement on animals and humans, even those that were lifeless. Mary Shelly’s Frankenstein had been recently published, in 1818, and was based on the fascination that people had with electrical phenomena at that time. If electrical effects could bring movement into lifeless beings, then perhaps the nature of all life resided hidden in the depths of electricity's secrets. Crookes' interest in science and the spirit had found a worthy subject of investigation.

In time, Crookes performed a number of different experiments. The key one we will focus on involves a glass tube, in which an electric current is placed across the ends of the tube in order to electrify the air or gas contained inside. This was developed in the late 1860's and early 1870's. When Crookes began these experiments, he noted a faint glow from the tube when an electrical potential was placed across it. He experimented by evacuating the tube so that less gas was present than would normally fill the space. To his surprise, the more gas he evacuated from the tube, the more brilliant the glow became. In fact, Crookes began to notice that the emanations were not simply confined to the tube, but actually appeared outside of the tube, as if they were leaving it . The behavior of the gas surprised Crookes greatly. How could any material escape an enclosed glass tube? No solid, liquid or even gas was capable of escaping such a space. Crookes felt that he had discovered a new type of matter. Given that the emanation appeared to radiate out of the tube, Crookes called his discovery "radiant matter." Crookes had made a discovery that was the first to challenge the so-called corpuscular theory of matter. Even more interesting, he had done so with actual experimental evidence and not simply stated a new thought or conjectured idea. While few recognized at the time the depth of the implications of his discovery, it was clear that the nature of the material world was far subtler than had previously been thought. Scientists were going to have to come to terms with Crookes' new observations. In time, looking for electrical effects and their manifestation in the material world would become a standard means for investigating the essence of the material world.

The late 1800's were full of scientists probing more deeply into the nature of matter, trying hard to find the subtle basis of matter. While many steps were taken in this exploration, we will look at the work of the next Englishman in the series, J. J. Thomson. Thomson, like Crookes, performed much of his investigations and experiments using electrical apparatus. In time, Thomson was able to find that Crookes' "radiant matter" was not only electrical in production, but that its direction of streaming could be influenced by other electrical effects. The "radiant matter" was either deflected in a different direction as the result of external magnetic effects, or simply left in its original emanating directions if kept from any external effects. Between 1897 and 1904, Thomson was able to deduce that the electrical effects happening on a very small scale suggested that the electrical polarity of the field was not uniform. Thomson described the periphery of the fields as generally having negative polarity, while the center contained concentrated bits of positive polarity. Thomson likened his discovery to that of a plum pudding with a gelatinous outer layer with hard bits (plums) in the center.

Thomson's discovery was a huge breakthrough in the evolution of the concept of the atom. *"That which can not be cut,"* the atom, appeared to have qualities that were more subtle than the discrete ultimate entity that had been postulated by most scientists and philosophers. This was not to be the last time that “the atom” was to be cut, but given that it was the first, the concept of the atom as the ultimate nature of matter, as a fixed entity, was beginning to be challenged.

The research of Thomson was carried on be other individuals, most notably another citizen of the English Empire, Ernest Rutherford. Rutherford was born in New Zealand, and as a youngster was recognized early in his schooling as a boy of talent. He quickly made his way through advanced schooling, and ultimately began doing research at the Cavendish Labs in Cambridge, England under J.J. Thomson.

Rutherford’s key contribution to our study is what is referred to as the Gold Foil Experiment, which he developed with some students in 1911. In this experiment, Rutherford took a piece of gold foil that had been hammered into an incredibly thin surface. The surface was so thin that that it was essentially translucent. Gold has a unique ability to be worked in such a malleable way that a one ounce piece, approximately the size of a half dollar, can be hammered such that it covers an area of 100 square feet. Once the gold foil had been prepared, Rutherford took a device that produced “radiant matter” (the present name for the type of emission that Rutherford was working with is ‘alpha rays’), and placed the gold foil between the electrical device and a piece of special prepared film that would change color when exposed to the “radiant matter.” Rutherford further narrowed the scope of the area where the “radiant matter” could be produced, and did so in very tiny amounts. The result was that individual spots could be observed on the film, even though the gold foil was placed inbetween the film and the electrical device. However, in a few cases, the spot found on the film was at a noticeable angle from the scope of the area created by the electrical device. Furthermore, in a few cases, one in 8,ooo, no spot was registered on the film at all.

Eventually, Rutherford, with his graduate assistant, placed a piece of film behind the electrical device. It was then that he was able to record the missing signature of the “radiant matter,” though it appeared in the opposite direction from where it began. In Rutherford’s own words, “It was as if we had shot a bullet at a piece of tissue paper and it bounced back!” It appeared that in these rare cases, the “radiant matter” must have left the electrical device and come into close proximity with such a strong electrical interaction that it had been repelled backwards and was therefore picked up by the film behind the device. This was truly astounding. Most of the time the radiant matter simply passed through the gold foil but occasionally it was deflected or simply bounced back. Rutherford deduced from these experiments that most of matter must be empty space with small, localized areas of negative (deflected) or positive (repulsed) spatial qualities. They key here was that most of matter now consisted of “no*thing.”* The concept of matter was quickly losing its “thingness” quality and was now open to being replaced with a new concept.

Perhaps the best description of the excitement that existed at the leading edge of science at that time was given by Arthur James Balfour in an address to the British Association for the Advancement of Science at Cambridge on August 17, 1904. A short excerpt is given below:

> *But today there are those who regard gross matter, the matter of everyday experience, as the mere appearance of which electricity is the physical basis: who think that the elementary atom of the chemist, itself far beyond the limits of direct perception, is but a connected system of monads or sub-atoms which are not electrified matter, but are electricity itself …*

It is hard to overlook the work of Bohr, Chadwick, Einstein and Born, but in the interest of keeping to the essential elements of our theme we will press on. In 1925, physics was to begin a tremendously new attempt at defining the nature of matter. Spurred on by the many great minds of the time, only a few of which are mentioned above, three new approaches arrived on the scene.

First, a French physicist named Louis DeBroglie suggested that rather than focusing on a corpuscular model for matter, one could develop a model based on a harmonic wave form, similar to the notes in a musical composition, to distinguish the different qualities of matter. He developed a series of mathematical relationships and termed the resulting waves DeBroglie waves.

The second breakthrough came form a German physicist named Werner Heisenberg, who put forth his famous Uncertainty Principle. Heisenberg stated that, in short, whenever we try to know any particular aspect of a given experiment, simply the act of setting up the experiment or apparatus to observe that particular quality changes the context of the situation you are observing. This principle can be transposed into any aspect of our daily life. In the act of observing, it is impossible to remove the observer from the experiment. Much more will be said on this in later chapters.

Finally, the third big breakthrough came from an Austrian physicist Edwin Schrödinger. Schrödinger took a very pragmatic approach to what had resulted from the physics of the past twenty years. In short, Schrödinger became less interested in knowing exactly *what* matter is, and instead shifted the emphasis to predicting the likelihood (or probability) of a specific event or series of events happening. He, along with a number of other scientists, developed what has come to be known as Quantum Mechanics.

The year 1925 was a very productive year, so much so that all three of these physicists were eventually to receive the Nobel Prize for Physics (DeBroglie in 1929, Heisenberg in 1930, and Schrödinger in 1932). It took a few years for each of the ideas to be developed, accepted, and recognized (and we can assume each had to take a turn).

What is most important here is that in the mind of the leading physicists of their time, the concept of a material basis for the world had been totally overcome, and was no longer in contention as a worldview. This was to last only for a few years, until the mid 1930's. Once the threat of another war loomed on the horizon, most of the leading physicists were put on fast-track research projects to develop something other than an understanding of the nature of the physical world. The race to develop the atomic bomb, the ultimate form of destruction, was on, and each country was concerned that the other might achieve this goal first. This focus on "splitting the atom" was to dominate physics and continue through the Second World War and into the beginning of the Cold War. It wasn't until the 1960's that significant amounts of new research were begun, much of which centered around a whole new group of "subatomic particles." The atom, *"that which can not be cut,"* had already been cut into a nucleus, further cut into positively charged areas of space (protons) and neutrally charged areas of space (neutrons), and was surrounded by a negatively charged area of space-electrons. Now, each of these "particles," was formed from other entities. Other entities were postulated to exist and research was funded to find them. Positrons, hadrons, quarks and other entities were described and searched for. For a while, it appeared that the possibility for a new concept of matter was to be hopelessly caught up in a search for smaller and smaller "particles." To be sure, the leading scientists doing the research would often be able to describe their work as non-materially based, but the shift to a new worldview seemed to be present in very few, if any, of their daily lives. What was done in the lab was one 'thing,' what happened in their daily life was 'a different matter.'

Finally, toward the very end of the 20^{th} century and at the beginning of the 21^{st} century, a new view of the material world is beginning to rise again. One of these new views is based on the work of Higgs. The Higgs view contains both particles and what is called the Higgs Field. In the case of the latter, we once again stand at the edge of the possibility for a new conception of the material world. In the view of Higgs, there are a number of fields of activity. When the word "field" is used, do not think of a "thing" but rather conceptualize a spatial area in which one type of phenomena may arise. The Higgs Field way of looking at the world postulates that when the Higgs Field comes into the same spatial area as certain other types of fields, the quality of mass arises in matter. The key to this type of thinking is not to think of a 'thing,' but instead to imagine a new property or quality arising in a place where no quality existed before.

Thus, matter is ultimately not made of objects; instead, when the qualities of visual opacity and tangibility arise in the same spatial area, we describe the correspondence of qualities as matter. Other sensational qualities may also arise in the same spatial area such as sounds, smells, tastes, etc. Matter is not the cause of the sensations but rather the concept that unites the correspondence of sensational qualities. This is exactly the type of thinking that we developed in the previous chapter. The next chapter will begin to take it even further.