Stephen Hawking
Cosmic Alchemy

How the universe began: stars and galaxies, time and space, began from a single point. Scientists believe they know the answer.

Medieval Europe had alchemists, who believed you could transmute one substance into another: the process could eventually make gold, the most perfect of all substances.

Thomas Daunt 7th one of a long line of alchemists. Search for fundamental forces and elements. Everything is composed of the 'four' elements: Earth, water, fire and air. Earth is the solid, water flows, fire is energy, and air is space. All things are combination of these to make them the way they are. If you change the proportions of the four elements, then you change what it is. Combining 'primal matter' like dung and urine, to try to make things.

Daunt lived in the 'age of reason' so he was not well respected, thought to be sort of a witch. Maybe his books were evil: decided to burn them. But the idea that you could rearrange the structure of matter is pertinent to modern science: accidentally a step in the right direction.

Alchemists were pioneers in modern chemistry. Mid 1800s: Demitry Mendeleev worked in a glass factory. Height of industrial revolution—understanding what things are made of was important to manufacture things. Needed a more sophisticated understanding of their components. Realized there are individual elements: maybe 65 of them. Called 'atoms': uncuttable in Latin. His family's glass factory burned down: his only hope was to become educated, because the business was gone.

Traveled to _____(Moscow?) to study at University. Became a notable chemist there. He investigated the repetition of patterns in the properties of the elements, if you arranged them in ascending atomic weight. Maybe it was indicative of an underlying order to their nature.

Wrote properties on cards, and arranged them on a tabletop. Sort in a logical order. Grouped those with similar properties. Arranged in rows with properties in columns. Some rows had gaps, and he surmised that there were elements in those places had yet to be discovered. His

work was insightful, and really started the concepts that were the basis for our modern science.

Marie Curie followed his work with her own investigations. She studied uranium, that released energy that exposed photographic emulsion. Needed to determine the power of the energy released. Very minute strength, so difficult to measure. Designed a scale to measure a small current, and compare it to one easier to quantify. Uranium was releasing a trillionth of an amp. She and her husband also tested pitchblende, the mineral the uranium was refined from. The current of the pitchblende was much greater than the refined uranium. Separated out the elements of the pitchblende: called one polonium (after Poland), and radium (which radiated light). Their specimens were dangerous: radioactive. She died of leukemia. But the Curies did not understand what radiation was.

Ernest Rutherford, New Zealand scientist, further advanced the understanding. Explored the nature of the rays of energy discovered by the Curies. He found vapor element emitted by the radium…not radium vapor, but a completely different element. As the alchemists had quested: making one element from another. There was, however, a genuine transformation taking place. One element was rising from another. Were all elements created from other primal ones?

Several years earlier, Einstein had developed the equation

$E = mc^2$

Energy= mass (speed of light)squared

Mass was like a battery: stored energy.

Rutherford wanted to further study this. Designed a machine to break the atom apart. Had student that followed Rutherford: Fred Niels. Collected junkyard material to make his gadgets. Found stuff in a military scrapyard. Rutherford bombarded gold with radioactivity. Knew radioactive particles were coming off at a certain speed. Found a few bounced back instead of passing through. Like shooting ballistics at a piece of tissue paper, and the ballistics bounce back sometimes. Niels wanted to work with this phenomenon, but wanted a less dangerous way to measure the radioactivity. Evacuated the apparatus of air, so they were not deflected by the air. There are deflections due to the nature of the atom's structure.

Perhaps the atom was NOT indivisible: it has building blocks of their own, with hugely electrically charged particles. Found more particles by increasing energy directed upon them. Built an electromagnetic device to contain the particles, due to their electrical nature, you can

cause beam of them to turn. Like the cyclotron particle accelerator in Cern, but smaller. Learn about the structure of the atom. Einstein's theory was correct: matter can be converted into energy.

Prediction of Einstein's theory included that if matter was converted into energy, there must be anti-matter mirror image. If matter and anti-matter meet, pure energy is the result. It defied common sense, but was logical prediction of the general theory of relativity. Anti-matter is very much like matter, but it is opposite in charge to its mirror image matter particle. If they come together, energy is result. And perhaps energy could be converted into matter and anti-matter.

Could you ever find anti-matter? Some radiation from space might reveal hints of anti-matter. Weren't looking for cosmic radiation, but found it in other investigations of radiation. Mountaintops had less atmosphere above them, so investigation started there. Created a 'cloud chamber' to see the cosmic radiation particles pass through: essentially a vapor chamber that the rays make vapor trails. They revealed on mountains, find one cosmic ray per centimeter per second, but much fewer at sea level.

Anderson used a lead bar to slow the particles down, so he could watch them better. Found that some particles deflected one direction by a magnetic field, and others deflected the opposite way. Electrons are negatively charged, but those that went the other way were … ?Positrons. No one had ever known about a positron before. And could detect particle collisions of photons, creating electrons and positrons. Debris of a 'little bang' creating matter from the energy of the collision.

So where is the antimatter? Physicists trust the laws of physics to understand the universe as it exists: gravity, mass, movement, etc. But at the beginning of the universe, there were numerous collisions creating energy, and energy creating matter. Universe began to create protons and neutrons: the nuclei of atoms. After that atoms formed mostly hydrogen. Clouds of hydrogen contract by gravity to become galaxies of stars. Some of the stars have solar systems.

A perfectly symmetric universe would not exist: it would cancel itself out. So it is not a perfect mirror image. But all the matter in the universe came from energy.