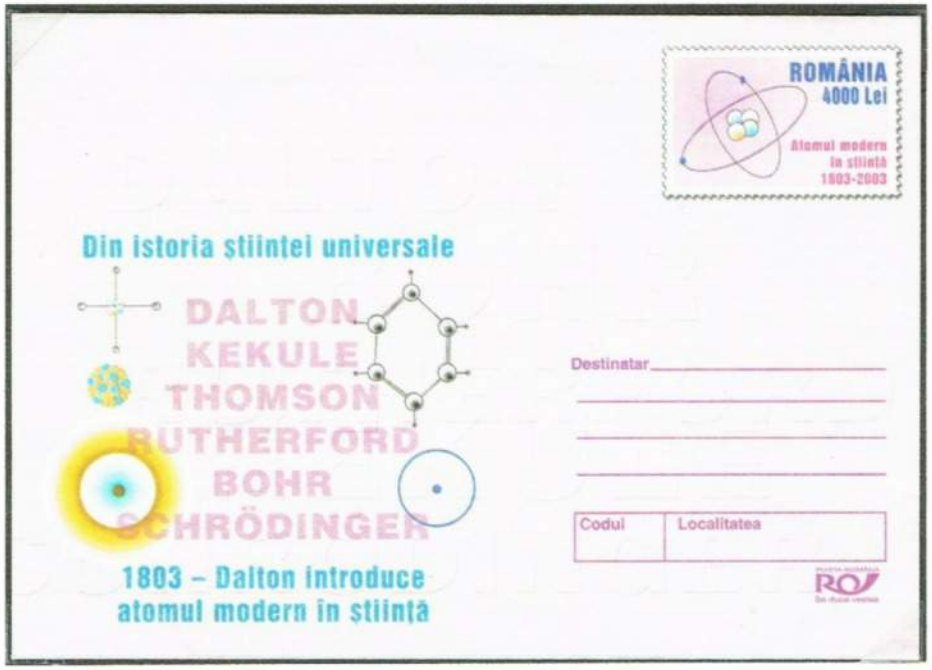
What Can The Matter Be?

The Science and the Scientists behind Man's Search for the Fundamental Nature of Things



PLAN

1. The Ancient World	Chinese and Egyptian philosophers considered that different forms of matter comprised combinations of a few Attributes
2. 17th Century	Robert Boyle adopted a practical approach; he concluded that matter is made of tiny atoms and introduced the idea of Elements
3. Early 19th Century	John Dalton determined the relative weights of atoms of different elements.and devised symbols for them
4. 19th Century	Dmitri Mendeleev realised that elements could be arranged in a Periodic Table. Ernest Rutherford established that atoms consist of a central nucleus surrounded by electrons
5. 20th Century	Neils Bohr and others developed a model of the atom which had both particulate and wave-like characteristics. Recently a mathematical approach has been pursued

Rutherford said *"All science is either physics or stamp collecting"* - here we have both !!

1.The Ancient World

Feng Shui

The Chinese concept of Feng-Shui with origins dating to **4000BC** considered that different forms of matter had one of five different attributes.

木 火 土 金 水

wood fire earth metal water

The Zodiac

From around **1000BC** in Mesopotamia it was thought that the alignments of the stars had an influence on earthly things

These ancient ideas had a philosophical rather than physical basis.

1.The Ancient World

Greece

In the **5th C BC** the Greek philosophers conceived the idea that all matter consisted of four fundamental **elements** in different proportion, each element having a different combination of the 'Qualities' of dry, wet, hot and cold..

Earth - dryness and coldness

Air - wetness and hotness

Water - wetness and coldness

Fire - dryness and hotness

Democritus

Democritus (460-370BC) took the view in ca **400BC** that if matter could be subdivided sufficiently, it would be shown to consist of discrete particles, called **Atoms** (from the Greek ατομος - indivisible')

. . . BUT THE STRUCTURE DEPICTED HERE WOULD NOT BE KNOWN FOR A FURTHER 2500 YEARS !!!

Paracelsus

Views of the fundamental nature of matter remained broadly unchanged for centuries.

In the early 16th C the notable Swiss doctor Philippus von Hohenheim, known as **Paracelsus (1493-1541)**, believed like the Greeks that natural things were mixtures of just a few substances of which salt was one of the most important.

2 17th Century

Boyle

The 17th C saw a significant step towards a physically based view of matter.

A key figure at this time was the chemist, **Robert Boyle (1627-91),** the first to use experiment rather than argument to make discoveries - **"The Scientific Method"**
He was a founder member in **1662** of the Royal Society whose motto "Take no-one's word for it" captures this new approach.

Motto - 'Nullius in verba'

Using the newly invented air-pump, Boyle discovered that gases could be compressed and that volume is proportional to pressure - **'Boyle's Law'**.
He deduced that this was best explained if gases consist of tiny particles

He knew of substances like sulphur and iron which could not be separated into simpler components by chemical means and defined them as **"Elements"**

... And decided that the solid particles of elements differed from eachother in ways such as size, colour, or texture yet to be elucidated.

3. Early 19th Century

Dalton

John Dalton (1766-1844) an English chemist developed ideas of the nature of atoms

IN **1803** he formulated his Law of Multiple Proportions
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asserting that combinations of elements of matter occur in definite simple proportions by weight. From this he was able to determine the relative weights of atoms,

He devised a system of symbols for the elements

Berzelius

Jacob Berzelius 1779-1848) an Swedish chenist developed the nomenclature

He invented the system we now use, abandoning symbols and abbreviating the Latin names of the elements down to one or two letters.

hydrogen.

carbon.

sulphur

potassium (kalium).

3. Early 19th Century

Gay-Lussac

Joseph Louis Gay-Lussac 1778-1850) was a leading French scientist, one of 72 names inscribed on the Eiffel Tower.

Having found that 2 volumes of hydrogen reacted with one volume of oxygen to give 2 volumes of gaseous water, he proposed in **1808** that for any gases the ratio of reactants and products can be expressed in simple whole numbers - The Law of Combining Volumes

He also showed that chlorine is an element.

Avogadro

Amedeo Avogadro (1776-1856) theorized on the basis of Gay-Lussac's results, that equal volumes of gas contain equal numbers of molecules.
And so 2 molecules of hydrogen + 1 molecule of oxygen give 2 molecules of water.

This led to the diameter of an atom being estimated as 10^{-10} metres so small that 10,000 of these stamps would have a face-value equal to the number of atoms in just one perforation tooth.

4. Late 19th Century

Elements

An increasing number of elements were being discovered. .

Nickel -1751

Cobalt -1751

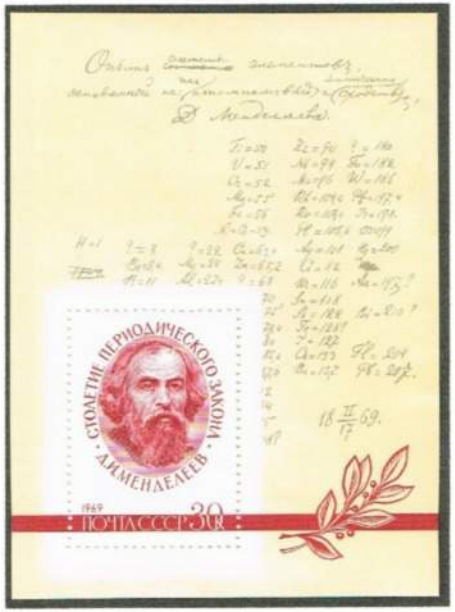
Aluminium -1825

There were several unsuccessful attempts to discover a pattern.

Mendeleev

Dmitri Mendeleev (1834-1907), a Russian chemist, made a break through in **1869**.

He realised that if the 60 elements then known were placed in order of their atomic weights a recurring pattern emerged and he produced for the first time a **Periodic Table** with similar elements arranged in vertical columns



Mendeleev and notes of the properties of elements

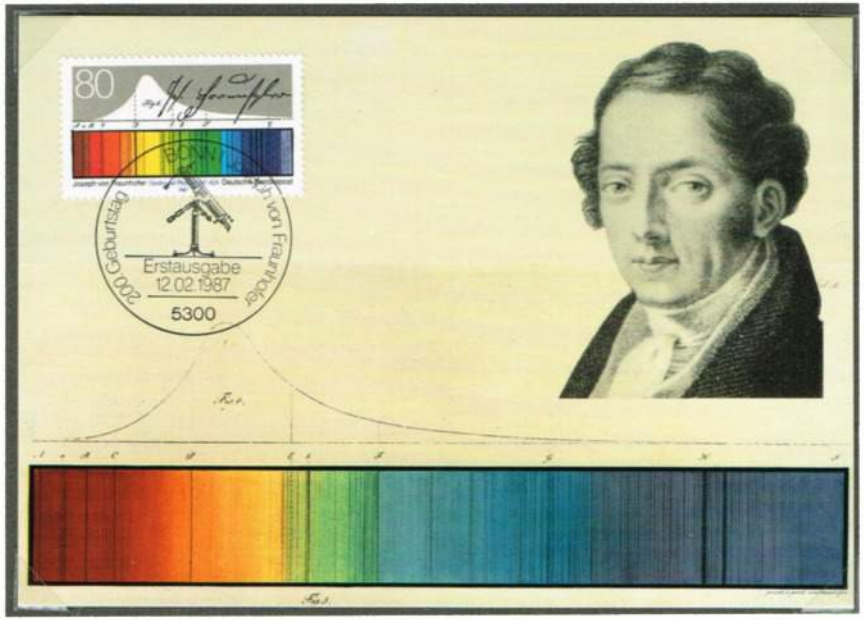
His major insight was to leave gaps in the table and to predict rightly that so far undiscovered elements would be found to fill them

The Periodic Table as now known

4. 19th Century

Fraunhofer

Josef Fraunhofer (1787-1826), a .German physicist, discovered in 1814 that sunlight when examined spectroscopically showed various dark lines



It was later realised that some of them were accounted for by the presence of a new element which they named Helium after the Greek word for the Sun

Ramsey

In 1895, Scottish chemist **Sir William Ramsay** (1852-1916) extracted a gas by treating a uranium ore with acid and found that its spectrum matched that of helium in the sun. He then discovered that nitrogen extracted from air contained other similar elements, argon, krypton and neon, which are very unreactive.

With this discovery, he realized that these 'noble gases' form an eighth group in Mendeleev's Periodic Table

4. 19th Century

Planck

Max Planck (1858-1947) a German physicist was the originator of the **Quantum theory**

He observed that the intensity E of the light emitted by hot bodies was proportional to its frequency ν, so that $\underline{E = h\nu}$ - we now know h as Planck's constant.

He postulated that light could only be transmitted in fixed amounts .or **'Quanta'**

Becquerel & the Curies

Henri Becquerel (1852-1908), observed in 1896 that, although giving off no visible light, some uranium salts blackened photographic plates.

He concluded that the salts were emitting radiation which became known as Becquerel rays. Subsequently they were named beta rays and were identified as streams of electrons.

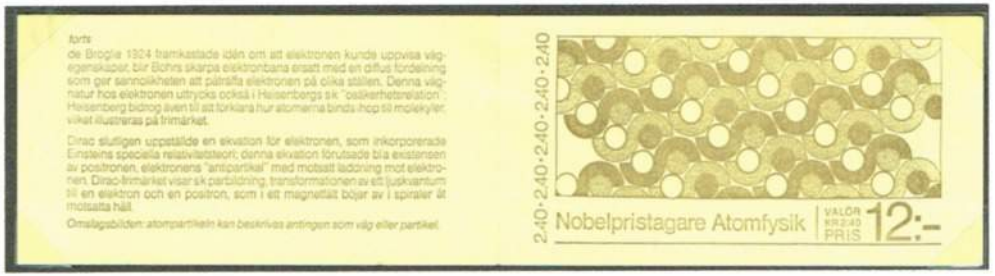
Marie Curie (1867-1934) and her husband **Pierre Curie (1859-1906)** looked for other sources of such radiation

After extraordinarily painstaking work they isolated two new elements, polonium and radium which behaved similarly.

They coined the term **Radioactivity** for this phenomenon

5. 20th Century

The first half of the 20th Century saw major advances in the field of sub-atomic structure, involving a succession of European physicists.



Rutherford

Ernest Rutherford (1871-1937) a New Zealander investigated sub-atomic structure.

At McGill University in Canada he and **Frederick Soddy** (1877-1956) explored and identified two types of radiation - alpha and beta rays, the latter identified as electrons.

After moving to Manchester University his team investigated the effect of bombarding gold foil with alpha particles. Instead of passing straight through as the earlier concept of 'solid' atoms would imply, they found that some were deflected.

Rutherford concluded in **1911** that atoms consist of a tiny heavy core surrounded by a diffuse mass of electrons.

5. 20th Century

Rutherford initially calculated that the diameter of a nucleus was less than one three thousandth that of an atom, later refined to one fifty thousandth of that of an atom.

The common depiction of an atom grossly exaggerates the size of the nucleus..

1955 WATERLOW PRINTING - HORIZONTAL MARGIN 4 MM
NORMAL UPPER PERF

A better idea of the relative sizes may be to imagine a nucleus being the size of a football and the atom at least eight times the size of Windsor Castle.

1958 DE LA RUE PRINTING - HORIZONTAL MARGIN 3.5 MM
NARROWER UPPER PERF

5. 20th Century

Bohr

Neils Bohr (1885-1962) a Dane working in Copenhagen developed Rutherford's model of the atom and Planck's Quantum Theory

He suggested that the atom consists of a nucleus surrounded by electrons that travel in circular orbits. Classical mechanics predicted that the electrons would collapse into the nucleus. Bohr extended Planck's idea and proposed, in **1913**, that electrons could only orbit stably in certain orbits each with a definite energy

He surmised that different elements have different numbers of electrons.

2 electrons - helium

3 electrons - lithium

4 electrons - berylium

5 electrons- boron

6 electrons - carbon

17 electrons - chlorine

Furthermore, each orbit could contain several electrons *(rather than the stylised depiction above with each electron in a separate orbit)*

7 electrons - nitrogen

5. 20th Century

De Broglie

Louis de Broglie (1892-1987) a French physicist developed wave mechanics

In **1924** de Broglie surmised that, as Einstein had found with light, 'solid' matter could appear as either waves or particles depending on how they were observed. .

He expressed the relationship by the de **Broglie Equation** where λ Is wavelength m and v are the mass and velocity of the particle and h is Planck's constant.

Heisenberg

Werner Heisenberg (1901-1976) a German physicist worked with Bohr in Copenhagen.

In **1927** he realised that a property of wave-like systems is that it is inherently impossible at the atomic level to determine location and velocity at the same time - his **Uncertainty Principle**

5. 20th Century

Schrödinger

Erwin Schrödinger (1887-1961) an Austrian physicist studied **Wave Mechanics**

He developed de Broglie's wave interpretation of atomic structure further and formulated in **1925 Schrödinger's Equation** which represented the behaviour of these waves.

He could not accept the idea that fundamental particles appeared to be waves or particles depending on how they were examined.

Attempting to ridicule this idea he proposed in **1935** what is now called the Schrödinger's Cat Thought Experiment, A cat in a box was considered neither dead nor alive until someone looked at it.

Dirac

Paul Dirac (1902-1984) an English physicist discovered in 1928 the first particle of **antimatter**, the positron

5. 20th Century

Gell-Mann & Zweig

Murray Gell-Mann and **George Zweig** worked on sub-atomic structure.

In **1964** they independently proposed that the properties of the subatomic particles could best be explained if they consisted of even smaller particles, which were christened **'quarks'**

Several types of quark, bizarrely know as flavors, were discovered and given whimsical names

Charm

Down

Up

Strange

NZ 1d 1893
Underprint
2nd SETTING

5. 20th Century

Strings

Most recently, research has been directed at simplifying the increasingly complex mid-20th Century ideas about sub-atomic structure.

An esoteric mathematical approach has been adopted difficult for the non-specialist to comprehend, where particles of matter can be represented by minuscule 'strings' vibrating in different modes.

It seems we may be heading towards an almost metaphysical view of what matter is perhaps reminiscent of the 2500 year old ideas of the Greek philosophers.