QUARKS

What are quarks?

They are three small elementary **particles** that compose a proton, one of the three elements of an atom (with electrons and neutrons)

Atom structure



But who did discover them? And when?

In 1964 **Murray Gell-Mann** and **Geroge Zweig** suggested that most of the known particles at the time could be explained as being combinations of these three fundamental parts: quarks. Fundamental because **quark doesn't have a substructure**, so therefore it cannot be split.

The name "Quark" was given from a quote from a James Joyce novel called "**Finnegan's Wake**": "*Three quarks for muster mark*".



Quark has a **fractional charge**, a new concept that had never been seen before!

At the **Stanford linear accelerator** electrons were fired at protons and found to bounce off of tiny particles inside them. It had taken four years but this was the first evidence for the existence of quarks:

At the time, there were **two basic quarks**:



- The "up quark", which has a charge of $+\frac{2}{3}$ of the charge of an electron.
- The "down quark", which has a charge of -1/3.

And how are they different?

They all have **different masses**, as well as charge, and another property called "**spin**". The up and the down quarks are the most common and least massive. The proton was found to be made up of two "up" quarks and one "down" quark.

Proton

We know that the charge of a proton is **+1**. If we were to look at this in terms of the fractional charges given to quarks, one "up quark" would have a charge of $+\frac{2}{3}$, so therefore 2 "up quarks" would have an overall charge of $+\frac{4}{3}$. Adding a "down quark" reduces the overall charge to **3/3** which is the equivalent of 1.





<u>Neutron</u>

A neutron was found to consist of two "down quarks" and one "up quark" which gave it an overall **charge of 0**.

Other types of quark

The discovery of the "up" and "down quark" was followed in the coming years by the "strange quark", the "charm quark", the "top quark" and the "bottom quark", which have quite strange names while "up " and "down" were named based on components of their spin.



- "Strange quark" were given the name
 "strange" because they were observed
 in particle decays that had slightly longer lifetimes than they should have done.
- **"Charge quark**" was given this name because of it's fascination. The way that it fascinated the physicists at the time.
- "Bottom" and "top quarks" were chosen by a famous physicist called Harari. He chose the names because they were the logical counterparts of the "up" and "down quarks"

Quarks are never seen on their own and their evidence for existence comes only from the particle accelerator.

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