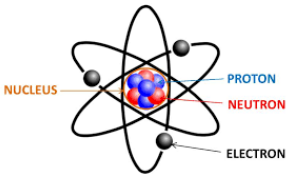
Name:_____
Date: _____

Elementary Particles - Quarks, Bosons, Leptons

You have already learned about atoms and their parts. Atoms are made of **subatomic particles**. The three types of subatomic particles are:

- Protons
- Neutrons
- Electrons.



But what are these particles made of?
They are made of (or *are*) **elementary particles**.

What is an elementary particle?

An elementary particle is a particle that is not made up of any smaller particles. Elementary particles are the building blocks of the universe. All the other particles and matter in the universe are made up of elementary particles.

History

For many years scientists thought that the atom was the smallest particle possible. Then they learned that the atom was made up of even smaller particles. When we studied the atom we learned about the basic particles of the atom including the electron, proton, and neutron. Today, scientists have found even smaller particles that make up the proton and the neutron.

Types of Elementary particles

We won't go into a lot of detail on these particles, but it is interesting to know the names of some of these particles and how they make up larger particles such as the proton and neutron. There are two main categories of elementary particles:

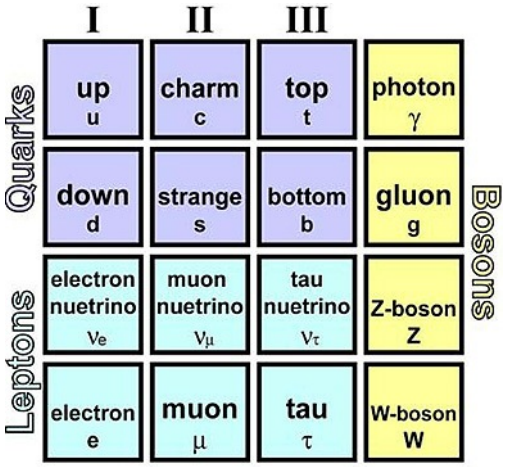
- Fermions
- Bosons

Fermions
Fermions are the matter particles. All matter is made up fermions. Fermions are divided into two types of particles:

- Quarks
- Leptons

Quarks - the basic building blocks for protons and neutrons. There are six types of quarks and they have pretty interesting names (**up, down, charm, strange, top, and bottom**). The different types of quarks are called "**flavors**" by physicists.

Leptons - One type of lepton that you have probably heard of is the **electron**. Electrons are important building blocks



for atoms. Other types of leptons include the **muon** and the **tau**.

Note: A proton is made up of three quarks

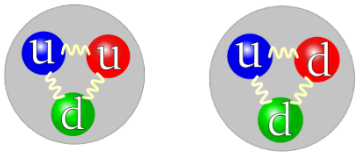
Bosons
Bosons are force-carrying particles. This means that they are made up of tiny bundles of energy.

Photon - Light is made up of a type of boson called a photon.

Gluons - Another type of boson is the gluon. Gluons act as the force-carrier between quarks in creating one of the fundamental forces of nature, the strong force.

Proton: A proton is made up of three quarks including two "up" quarks and one "down" quark.

Neutron: A neutron is made up of three quarks including two "down" quarks and one "up" quark.



Fun Facts about Elementary Particles

- Some scientists say that the electron is not an elementary particle and is actually made up of two smaller particles.
- Particles made up of quarks are called hadrons.
- A bunch of gluons bound together is called a glueball.
- A tachyon is a hypothetical particle that travels faster than the speed of light.
- Quarks and gluons are said to have a "color charge" as well as an electric charge.
- A proton is made from a blue up quark, a red up quark, and a green down quark

Four Fundamental Forces:

All interactions in the universe (YES THE UNIVERSE) are thought to arise from four different forces

Strong

- The strongest of the forces
- Holds the nucleus of an atom together
- Uses gluons to hold protons and neutrons together

Weak

- The second strongest force (only weak when compared to the strong force)
- Responsible for radioactivity in some elements

Electromagnetism

- Electricity and magnetism are interconnected
- Static electricity, like a balloon sticking to a wall, or magnetism, like magnets attracting or repelling each other are both the result of a *single* force
- Positively charged protons attract negatively charged electrons
- Holds the atom together

Gravity

- The weakest of the fundamental forces
- Holds you to the Earth, and the Earth to the sun (etc.)
- Very easy to overpower