The discovery of the Higgs Boson required over fifteen years of preparation, billions of dollars in funding, and thousands of scientists to achieve. This lecture series aims to explain why and how all of that time, sweat and money were spent in pursuit of this elusive particle. We begin by setting the stage for the discovery through examining the Standard Model of particle physics.

The Standard Model describes the known fundamental particles and forces existing in the universe much like the periodic table describes known atoms. Particles in the Standard Model are organized by how they interact through the forces. There are four fundamental forces of nature that we know of: the electromagnetic force, the weak nuclear force, the strong force and gravity, which does not have a place in the Standard Model. More on that later. We are most familiar with the electromagnetic force, which is responsible for making our hair stand on end in winter, for allowing us to transmit information over long distances in the form of radio waves or through transatlantic fiberoptic cables, and governs our ubiquitous electronic devices. The weak nuclear force is most known to us for its role in nuclear processes such as radioactive decays used in nuclear power plants and cancer research, as well as nuclear fusion, which powers our sun. The strong force binds the protons and neutrons of atomic nuclei together, overcoming the electromagnetic repulsion of having many positive charges in a small space.

Each of these forces has at least one force carrier which is its physical manifestation. The electromagnetic force is transmitted by the massless photon, which we know as light. The weak nuclear force is mediated by the W & Z bosons. (Boson is a type of particle, we'll go over that later). These particles are very heavy and decay quickly to other particles. The strong force is transmitted through the gluon, a strange, massless

http://hep.uchicago.edu/~tompkins/
particle. Gluons come in eight, indistinguishable types, and are very powerful, but only over short distances.

There is a hierarchy of the Standard Model forces. The weak force is, appropriately, the weakest. Because the W&Z bosons are so massive they can only interact over short distances and therefore are relatively weak. The electromagnetic force is much stronger because the photons are massless and have much farther range. The strong force, as its name suggests, is the strongest. It is peculiar because it gets stronger as the separation between two particles increases. Gravity doesn’t fit in the standard model because it is $10^{36}$ times weaker than the electromagnetic force! It’s completely irrelevant in the world of subatomic particles. Think about the fact that you can hold a pen between your fingers, held up only by the friction between it and your skin (electromagnetism), while the entire mass of the earth is pulling down on it gravitationally!

The force carriers in the standard model are called bosons and have the special property that many of them can exist in the same state simultaneously. The other particles are called fermions, and cannot occupy the same state simultaneously. Fermions are further subdivided into quarks and leptons, each of which comes in six types. Quarks are particles with electric charge +/- 1/3 or +/- 2/3 which interact via the strong, electromagnetic and weak forces. Because they interact via the strong force, you can never find a single quark–they are always paired with 1 or 2 more quarks. Two up-type quarks and one down-type quark make up a proton. The most famous lepton is the electron. Half of the leptons carry electric charge, like the electron, and interact via the weak and electromagnetic forces. The other half, which are named neutrinos, have no charge and don’t interact via the electric charge. They are only visible through weak interactions.

Now, onto the Higgs Boson. The Higgs boson is the physical manifestation of the Higgs Field. We talk about the Higgs mechanism as a field rather than a force because the Higgs field is always present everywhere in the universe, whereas the electromagnetic field is only present when there are electromagnetic charges are around, so we call it a force. But, really it’s a field too. The Higgs field is responsible for giving fundamental particles mass and how strongly they interact with the field determines how massive they are. In a classical sense, a particle’s mass is how much energy it has when it is isolated not moving. If a particle didn’t have mass, it would always have a velocity equal to the speed of light. And if particles always moved at the speed of light atoms would not form. And we would not exist. So, the Higgs is really important. Which is why we went looking for it!

For more information about the Standard Model: http://www.particleadventure.org/

http://hep.uchicago.edu/~tompkins/