

Scientific Knowledge and Faith

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topic, and I hope that the framework I have chosen makes sense, but I'm sure you'll tell me, and if not, my colleague Eben here will tell me if it makes sense. He usually does that.

To start, we have to define the notion of scientific knowledge and the notion of faith. Usually, when we think of faith, we think of religious faith, but I have used a definition, which is broader and includes it. "Faith is a firm belief in something for which there is no proof." Faith is used very broadly and in many contexts, and of course, the problem always is that it can be used so broadly that it loses meaning and loses principally luminosity. There is one quote from *New York Times*, March 1 this year – "Buying stocks in a market like this takes a healthy dose of faith." This is not the kind of faith I am envisioning, although perhaps that is really maybe a more profound faith.

Faith seems to be a basic human trait, and it is in essence, optimistic. We do not usually say, "I have faith that mice will chew up the wires in my house." We usually say, "I have faith my house will be protected from mice." In other words, there is an optimism involved in having faith. What I would like to show you is that science, at the forefront of its activity, is essentially-faith based, and that is where we're going.

First, I'd like to just talk about science. I want to point out that all scientific knowledge is empirical. It is based on observation, based on experiments, without any exception. We make observations and then we form a hypothesis, and then we test the hypothesis, and if it withstands the testing in the domain in which the experiments were conducted, then the attempt is to fit the hypothesis into a broader theory. These are generalities, and I hope to give examples of this. The other important thing to understand is that a hypothesis or a theory, which is sort of a broader range of hypothesis, is only applicable in the domain where the experiments and observations were performed. It doesn't extend outside of it. A very old example is Ohm's law. (In the 20

th century, science stopped using the term laws. They now called theories, principles, hypotheses, but laws were still used in the 1800s.) And Ohm's law – you may have studied it in basic physics in high school—just says that the current through a wire increases as the voltage increases. And this holds for a wide range of materials and conditions. But then in 1920s, as lower temperatures were obtainable, the experiments were extended beyond where Ohm did his experiments, and it was shown that we have such things as superconductors, which don't obey Ohm's Law. That's a great example where you have to stay within the context of the experimental observations.

The theory that we form must be predictive, testable, and any contradiction to it in the domain of its assumed applicability invalidates the theory. Here is a quote from Thomas Huxley, a prominent scientist in the late 1800s.. He said, “The great tragedy of science is the slaying of a beautiful hypothesis by an ugly fact.”

As an example of a scientific enterprise, I bring it to you Emilie du Chatelet, a brilliant scientist, very little known, from the 1700s. She was married to a nobleman, a rich woman. She had two children, and then, as was not unusual in those days, they agreed to go their separate ways. They did not get divorce. Divorce was not acceptable, but they did their own thing. Emilie du Chatelet hired tutors and learned all the science that was known in her day. She translated Newton's *Principia*, but not only did she translate it, she wrote commentaries and made it accessible to the French scientific community. She also did experiments. She dropped balls into a sandbox and measured the depth of the holes they made, and she showed that the kinetic energy, the depth to which the ball penetrated, was proportional to the velocity squared, not to the velocity as Newton had proposed. And this she tested over a wide variety of objects, sizes, and materials, and this became a hypothesis, and later on, it became part of a more, a broader theory called the kinetic theory. Du Chatelet had four lovers. One of them was Voltaire, and at the age of 43, she became pregnant. She knew at that time, being pregnant at that age, it was very likely that she would die. So, throughout her pregnancy, she worked feverishly completing the comments on the *Principia* and then she died at the age of 43 in childbirth. So, that's Emilie du Chatalet.

Now, what is the relationship between faith and science? For the purpose of our discussion, I would like to categorize faith into three classes – faith that contradicts science, faith that is tangential to science – that is, it does not interact with science. It's not testable by the methods of science. And the third, faith that drives science.

As you walk along Beacon Street, you come across St. Jude's gate, and there you see a quote from Luke, “For nothing is impossible with God.” You can obviously give deep, profound, and vibrant meanings to this quote, but one of the possible interpretations is that miracles are possible. All religions I know, report miraculous events that contradict solidly established scientific principles – splitting of the Red Sea, stopping the sun. So, a faith that leads a person to believe in such miracles is in contradiction to science. But I would like to point out, there are many superb scientists I know that have great faith in precisely these type of miracles, miracles as described in the Bible or other Holy documents, and they do excellent science, but they keep the two areas of their lives separate. They are fenced off. This is a cartoon I like illustrating this. [Cartoon of two scientists at a blackboard covered with a long and complex equation. Two the two parts of the equation are linked by “Part 2: Miracle Happens Here. One says to the other, “At this part I think you need to be more explicit.”] This is where that kind of faith in miracles does not mix with science.

Type two faith, faith that is tangential to science. Now, generally, the constructs centered around this type of faith pose the big questions. Is there a meaning to life? Is there a guiding, cosmic purpose? These are questions that are not in the domain of science. They are in the domain of certain aspects of religion, and this type of faith is associated usually with constructs that are designed to reconcile or merge science with religion.

Some of these constructs are beautiful. One of them is that of Pierre Teilhard. Most of you may have heard of him. He was a Jesuit and an accomplished scientist, a geologist and paleontologist. Much of his work was done in China, and what he wanted to do was integrate faith and evolution. He believed there is a purpose to evolution. To paraphrase him, "there is an ever increasing complexity, that is the purpose of evolution, an ever-increasing complexity ascending towards increasing consciousness and unification drawn towards the supreme consciousness." He called it the Omega Point, which for him was God. Incidentally, there are a lot of people who are very taken by his construct and his faith in this construct and they see the World Wide Web as a manifestation of this increased consciousness. And there is certainly some truth to this. The Web has certainly increased our consciousness of each other and of the world.

I don't know how many of you know of Polkinghorne. Polkinghorne was a highly accomplished physicist at Cambridge University and a devoted Christian. For 25 years, he was a mathematical physicist, made brilliant contributions to particle physics, and then he left science and became a priest. He is now an Anglican Bishop. And this is from an interview he gave "I didn't leave science because I was disillusioned, but I felt I'd done my bit for it after about 25 years. Let me say, first of all, that I admire Teilhard – and one reason I'm quoting this because it kind of floats with what we said – as someone of integrity who sought to hold together his science and his religious experience, but the details of how he did it don't correspond to how I would try to do it myself. I think it's very important to maintain classical Christian distinction between creator and creation, and Teilhard does not. It is all one, sort of continuum."

Now, essentially, what Polkinghorne did was he described theological concepts, particularly Christian theological concepts, in the language of physics, and specifically, quantum physics, so here is just a little, I wouldn't call it a quote, an abstract of his thinking. Polkinghorne believes that mind, soul and body are different aspects of the same underlying reality, dual aspects of monism – there is only one stuff in the world, not two – material and non-material – but it occurs in two contrasting states. Those of you who know quantum mechanics can see in this an analogy to the particle wave duality. He wrote several books detailing his construct, and he again has a significant following.

There are several other prominent thinkers, among them, Freeman Dyson. He writes very often for the *New York Review of Books*, Alfred North Whitehead, who developed and believed in cosmic concepts and systems that are often beautiful and compelling, but in essence, cannot be tested or proved. So, they're outside the domain of science. These constructs depend on faith that is tangential to scienc

Finally, we come to the faith that drives science. (A picture of a mad scientist) This is from one of the great science fiction movies. On the simplest level, (and this is really just very simple and not what I really would like to focus on), any project you begin, one has to have faith that it will work, and sometimes it does and sometimes it doesn't. For example, 20 years of work, literally by thousands of scientists, has not led to a cure for AIDS virus or to a vaccine for it. But as I said, that's not what I want to focus on.

There is a deeper faith that has motivated science for the past 200 years, just about from its beginning. (The beginning of science is the beginning of enlightenment.) A faith that there is a unifying principle underlying the diversity of phenomena encounter in nature. Until recently, this kind of a faith that drove search such a unifying principle has been very successful.

One of the earliest successes was the demonstration that the same laws that govern motion of objects on our Earth, govern the motion of planets. Now, this quest for unification has hit a stone wall. About 10 years ago, there was a large measure of confidence obtained from measurements and observations, that there are four forces operating in nature – gravitational force, electromagnetic force, weak force, and strong force. We are all familiar with gravity and electromagnetic forces. The weak and the strong forces were necessary postulates to understand how the nucleus stays together, why the positively charged protons don't repel each other. Those are the weak and strong forces that keep the nucleus together. (I should point out the weak force is much stronger than the gravitational or electromagnetic forces. It is weak only when compared to the strong force.) The challenge and the belief was that it was possible to unify the four forces by finding one set of equations that would be applicable to them all. Einstein struggled most of his life to unify gravity with electromagnetism, with no success. It was one of his really great disappointments. Interestingly, having formulated two of the most brilliant theories construed, – the general and special relativity – towards the end of his life, his biographers who knew him personally said he felt like a complete failure, felt useless and left behind.

By the 1960s, the electromagnetic, the weak, and the strong forces were unified, by one set of equations. This model, unifying model is called the standard model. Since 1960, thousands of people have been working to squeeze the gravitational force somehow into this construct. No success. One of the most promising avenues was the string theory which is now looking less and less promising.

Then, 10 years ago, two fascinating complications developed, unrelated one to the other. Better observational techniques allowed the examination in greater detail of the expansion of the universe and the Big Bang. It was expected, with great certainty that the observations would show that the expansion of the universe is slowing down, just like when you throw up a stone, it slows down as it reaches greater heights. Much to everybody's amazement and initial disbelief, only 10 years ago, it was shown that the universe isn't slowing down, but rather it is accelerating. There is some sort of a mysterious anti-gravity force in action. It is a fascinating story how this discoveries was made.

The second discovery was that some unknown dark matter permeates the universe, called "dark" because we do not observe it directly, we only observe its unquestionable. And so, the net result is that 96% of the universe is composed of this

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mysterious dark matter and dark energy. The universe we can observe and know constitutes only 4% of everything, and maybe even less..

So now, not only is the gravitational force out of this unified picture, but we have two additional forces whose properties we don't even know. So, 96% of the universe is composed of this mysterious unknown. For some people, this is a source of frustration, but most people working in the fields, actually some whom I know are excited by this new fact, and they retain their faith that there is a unified principle governing the universe. Thank you for listening.