15 Kuhn and the Nature of Science and Scientific Revolutions

We have looked at two accounts of scientific method--Popper's account and the older inductivist account. We have seen that they do not throw much light on what we know about the history of science. Scientific change, debate and work is more complicated, for social and political reasons, than those stories tell us. The conclusion we have reached is an artificially constructed version of the situation that pertained in the field of HPS, 25 or 30 years ago. At that point work in our own field of history of science and philosophy was very much affected by the appearance of Thomas Kuhn's book *The Structure of Scientific Revolutions* (1st ed.1962; revised ed.1970). This Fifth Section of the Book, takes time out from the historical account to pursue the issue of Kuhn's theory of scientific change.

Kuhn's work on the nature of scientific change has affected thinking in many areas - not only the history of philosophy of science but general history, sociology, political science, anthropology and even art history. Although an educated person today can afford to be ignorant of Popper, one cannot afford to be ignorant of Kuhn. Popper was moving in the wrong direction and Kuhn was moving in the right direction, although very little of what he actually says will be agreed to today even by his followers. Already in this book, although you did not know it, you have been introduced to some Kuhnian ideas. In this Chapter I will be outlining his views in detail. They may provide a useful starting point for thinking in a non-mythological way about scientific change and the dynamics of science.

Kuhn, who was born in 1922, was a physicist turned historian of science and then philosopher and sociologist of science. He was aware of the difficulties of theory-loading and the problems that it posed for the story of traditional method. He was aware that Popper's method story does not really grasp the dynamics of scientific change. As an historian of science he was also aware of some of the complexity and detail in cases such as the one we have been dealing with this book.

Kuhn's project is to develop a general theory of how natural science works and developes. But, unlike most general theories of how science works, Kuhn's theory does not depend upon believing that there is some sort of scientific method that gives the answers. Kuhn is not constructing a philosophy of science or method, for he is trying to examine the *dynamics* of scientific change: how any given science *changes* over time.

One of the main things to grasp about what he is trying to do (whether you accept it or not) is that Kuhn believes that he has discerned or outlined a common pattern (dynamics or life story) that each individual science undergoes. In other words, the reason we can have a general theory of science is that each science has a life history that bears analogies and resemblances to the development of the other sciences. Its the common pattern that he is trying to elucidate. Not as a common pattern of method, but as a common pattern of social and political behaviour among scientists which produces the similar life histories or patterns of development and change of the different sciences.

There are a number of premises in Kuhn's viewpoint and it is important to remember them. If you try to explain Kuhn to anyone and don't keep these premises in mind you will make mistakes about what he is saying.

The first premise is that there is no such thing as Science (capital S). You cannot say "Science began with the Greeks" or "Modern Science started in the 17th century". If you talk in this way you do not achieve a decent history. Kuhn is interested in the **histories of the sciences**. He is not interested in Science (capital S) which he views as an invention of public relations and rhetoric. If you like, it is also an invention of the method story. There is no 'Science' there are only 'sciences'. Next point (which has already been mentioned), Kuhn does not believe there is **a** scientific method; he does not believe that the sciences work to a scientific method. His theory partially explains how they can work and yet not have any *common* method. The third point he makes is about a common pattern of development and change which we see in the history of each science.

Let us work our way into his position. Kuhn starts by being impressed by what he considers to be an important historical fact which is this: In any science you look at you find that its history alternates or appears to alternate between two qualitatively between two different types of phases or periods. (fig. 1) One kind of period which Kuhn calls a 'normal' period is characterised by great stability and agreement about the basic theory. During a 'normal period' the basic theory is used and applied but not questioned or undermined. We have periods like that according to Kuhn in the history of astronomy and the history of the other sciences. But there are also other kinds of periods which he calls 'revolutionary' periods or 'scientific revolutions'. In scientific revolutions there is no consensus or agreement about basic theory for there is debate and conflict and disagreement--the fundamentals are under question. According to Kuhn, such periods of scientific revolutions end when one theory (a new and very different one from what was accepted previously) emerges out of the revolutionary 'ruck' and is accepted on an agreed basis so a new period of normal consensual scientific work eventuates. Until, of course, there is another revolution.

Obviously all I'm doing is describing the most superficial descriptive level in Kuhn's work. We have to work our way inside these periods or stages. I want to describe this pattern he is talking about. In figure 2, we have pictured the alternating patterns of normal and revolutionary stages in the sciences of astronomy, physics, biology and chemistry. If we take astronomy, Kuhn would map it something like this: There was a time before which there was no technical, theoretical, serious astronomy --in Antiquity--when there may have been some things that looked like bits and pieces of astronomy but there was no theoretical, technical astronomy. Kuhn calls that kind of period--before you have any kind of thing that looks like a workable agreed theory in the science--calls this the Pre-Scientific Period in that given science. In Astronomy that Pre-Scientific Period ends with the Greeks but you could take it to the end with the work of Ptolemy. (I've simplified this -- you would maybe want to end with the School of Plato). What you have after Ptolemy (for a very long time) is a consensually agreed basic theory that is not questioned and that is merely applied and developed. But, we have been studying a period of turbulence and disagreement which is commonly called the Astronomical Revolution. Kuhn would call it the first Astronomical Revolution. Out of this period of turmoil and conflict emerges (broadly speaking) a way of doing Astronomy that is accountable to Copernicus (and which is actually much more due to Newton but we haven't got that far yet), basically a Copernican-- Newtonian astronomy. This applies from the 17th century down to the end of the 19th century for the theory was not questioned and was applied until there came new problems, difficulties, turmoil and disagreement which out of all of that came another Revolution, perhaps not so much in Astronomy but in celestial mechanics and cosmology. Out of that later revolution came Einstein's General Theory of Relativity which gives us a different theory for doing cosmology and celestial mechancs.

To take a different example--chemistry--according to Kuhn, the pre-scientific stage in chemistry is very long. It last all through the period of the Greeks, all through the Middle Ages, even up to the 17th century and the first really serious technical and theoretically sound chemistry (according to Kuhn) only comes about around 1720 or so--the so called phlogiston chemistry of the 18th century. The chemistry built around the idea that when something burns there is a substance, phlogiston, given off by the burning or flammable substance. Kuhn would say that that was the first normal period, but rather soon, the phlogiston chemistry would be challenged and be overthrown, and there was a new revolution and a new theory based on the concept of oxygen replaced the old chemistry, which in turn lead on to further revolutions in chemistry having to do with atomic theory and in this century with quantum mechanics and chemistry.

Physics is the study of motion and causation. According to Kuhn, the first science of Physics in which a normal period of research was under the guidance of Aristotle's physics. Pre-Science in physics ended about the 4th BC with Aristotle and it was a very long time until we got *the* Scientific Revolution in the 16th and 17th century when Aristotle's physics was challenged and overthrown and a new and completely different physics replaced the so-called Classical Physics of Galileo and Newton. Newton's physics reigned supreme for 200 years until it suffered a dual defeat and displacement in the early 20th century with the advent of Einsteinian physics and quantum mechanics.

This is how Kuhn tends to see the map of the history of science. These are the basic facts that Kuhn is working with and how he sees the basic history. Now comes the problems of explanation and understanding.

Following Kuhn, obviously we have two tasks to understand this: We want to know what he means by a 'normal' period of science. What goes on in the 'normal period' of astronomy from Ptolemy to Copernicus/Newton. What are the social and institutional mechanisms and dynamics of science in such normal periods. Secondly, what is a 'Scientific Revolution'? Why do they happen? How do they relate to the normal science that comes before them? How do they relate to the normal period that always seems to follow them? Kuhn's answer to those questions, along with figure 2, is Kuhn's theory. It is quite a different way of asking the questions and setting up the questions than the Whiggish or methodological way, where the story of Science is the story of some method.

We will now talk about the 'normal' periods. In general what is a 'normal' period of science like? What do scientists do in their field when they are in a period of 'normal science'? This is what you do *not* do--you do not go around collecting facts about theories: you are not an Inductivist. Another thing you do *not* do is desperately run around trying to falsify the theory that you hold. According to Kuhn, scientiists do not behave the way Popper says they behave (at least in normal periods of science and in fact he does not believe that they do when in a Revolutionary period either). As a scientist in a normal period of your science you operate within an all-embracing theoretical framework which is peculiar to your science at that point in time. If you do not believe in the prevailing theory, then you do not count as a professional member of the community, and will not be accredited by members of the community and your work will not be part of that particular science at that stage.

This all embracing theoretical framework is what makes work possible in your field at that point in time. Your theoretical framework is what loads your experiments and observations and descriptions; it controls the problems you define; it is what controls the solutions you accept or do not accept to your problems. Scientists are accordingly very reluctant to give up their theoretical framework. Kuhn has a name for this all-embracing framework which defines work in a given normal period (which has now passed into literature) called a '**paradigm**'. So there was a Ptolemaic paradigm; an Aristotelian paradigm; Newtonian paradigm in physics. **A paradigm is an all embracing theoretical framework that defines scientific work in a given moment or period.**

What is in a paradigm? Basically there are three things in a paradigm:

> (1) The basic laws and concepts of the science at that time. Kuhn states this is not enough for philosophers have often talked about science just talking about the basic laws and concepts. They have missed the other elements that go into a paradigm and so have missed the real guts of how science works.
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> (2) All the experimental and instrumental procedures for attaching the concepts and laws to concrete situations. In a previous chapter we saw Galileo struggling to establish the telescope as an instrument of Copernican research and succeeding more than perhaps he deserved to. This is a very important insight involved in this remark by Kuhn that instruments are not neutral. Instruments are embodiments or materialisations of theory. Instruments are theory-loaded or if you prefer--instruments are paradigm-loaded.
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> (3) Any paradigm has a set of underlying deep cultural assumptions which have shaped it. The set of deep cultural assumptions is called the paradigm's metaphysics, (in the sense that introduced back in Chapter 11).

So each paradigm is defined by the basic laws or concepts, the paradigm-loaded experimental and instrumental procedures and the metaphysical background that has shaped that paradigm. By the way, in a scientific revolution what we *change* is the paradigm. Kuhn does not talk about changing theories, only paradigms. He means that the basic laws and concepts change, the instruments and experiments change or they are construed differently. And often, the metaphysical background to the new paradigm is different from the previous paradigm. The Newtonian and Aristotelian physics do not have the same metaphysical background.

Now we come to the final set of points that are important to grasp about normal science. We come to the question of what the scientists do inside the paradigm, where they seem trapped until the next revolution. Actually Kuhn recognises that point and states that scientists are happy to be trapped, because then they know what to do and what tools they have for doing it. If they were not 'trapped' they would be confused and would not know what to do. What you do inside a paradigm is you pose, and solve, problems. Your paradigm is your life-blood and life-line because it helps you to define problems, gives you the tools for solving the problems and gives you the standards or the criteria for judging whether you have done a good job in solving the problems. This sounds closed, or narrow and pretty tautological, but, according to Kuhn, there are important things to do. There are two broad categories of problem which are 'problems of fit' and 'problems of extension'. These are not Kuhnian terms but my own, for they interpret a lot of what Kuhn says.

The problem of 'fit': it could be problems of fit in Ptolemy's Astronomy in one period, or problems of fit Newton's physics in another. You have the paradigm and you try to make predictions from it and to explain things. What is a prediction matched up to? What is an explanation an explanation of? Predictions are predictions about 'data'. Explanations are explanations about data. Kuhn uses an inappropriate word here when he state that scientists try to make predictions that 'fit the paradigm to nature'. Now no-one is fitting any paradigms to *nature* for people are fitting predictions to *data*. Data is, of course, theory-loaded and selected and interpreted. In fact it could be that it is the paradigm that is loading the production of the data. (fig 3)

There is a gap between our prediction and the data--trying to make that gap smaller is a problem of fit. Anything you can do **within** the paradigm to make the gap smaller on a given problem is a 'successful' piece of work within the paradigm. So, you might juggle the paradigm a little and the predictions a little. Or you might alter your production of data: Select it differently, interpret it differently, alter your theory a little --anything to close the gap. Problems of fit are, as Kuhn says, problems of matching paradigms to nature; but as I said, they are more correctly problems of closing the gap between paradigm predictions and relevant selected interpretive theory-loaded data. The difference between those two remarks is the difference between 1962 and the 1990s. Kuhn still talks about nature, and that is the last thing you talk about in the history of science.

Problems of extension can be illustrated this way: the problem of extension is a challenge to extend the paradigm so it makes explanations and predictions about new areas of phenomena. The term 'phenomena' here means relevant selected interpreted data. Let's say in figure 4 that we have a paradigm that explains or predicts this realm of data and people are struggling to get closer and closer fits. Someone may say that we haven't looked laterally at some other kind of phenomenon--can we use our paradigm to explain those? So scientists in this way would be looking to *extend* their paradigm. Of course as soon as you extend your paradigm, you then have new questions of 'fit' in the newly 'conquered' area of phenomena. So the ideal paradigm is one that creeps all over every realm of relevant data and phenomena and covers them with smaller and smaller gaps. In that sense, the most successful paradigm ever was probably Newtonian physics which went from strength to strength in explaining more and more realms of phenomena and explaining them on an increasingly accurate basis. This is Kuhn's prime example of a very successful paradigm.

Let us notice a few things before we finish. There is no scientific method and there is no general method for doing Ptolemy's astronomy or Newton's physics. The way to do Ptolemy's astronomy is to learn to do astronomy Ptolemy's way. You learn it and you do it and that is the 'method' of (Ptolemy's) astronomy. The 'method' of Newtonian Physics is entirely different because you learn Newtonian physics and then do it. The method of quantum mechanics is entirely different because you study quantum mechanics for 6 or 10 years then do quantum mechanics --This is Kuhn's viewpoint. There is no general method; there only are the paradigms of different sciences at different moments in their histories.

There is an analogy that I like to use to explain what normal science is all about. The normal scientist is to his paradigm as the trained professional tradesman is to his tool kit and techniques of his trade. Therefore, a scientist is like a trained master electrician or master carpenter in the sense that he only takes on problems that his tool kit and his techniques show can be solved. He only accepts and defines problems that are in the scope of his tools and techniques. He never changes his tool box and his bunch of techniques in a radical way *if he can help it* . He holds on at all costs to his tried-and-tested tools and techniques, for they are the very way that he defines and solves problems. And, if he does not succeed on occasions (if your plumbing leaks or your wiring developes a short) that does not mean that your electrician gets rid of his box of electrical tools, far from it, it simply goes down as a problem that was not addressed the right way on the day and that can be sorted out sooner or later using the same tools. The problem is almost never with the toolbox. You can draw the analogy to the paradigm: the problem is almost never with the paradigm; you're reluctant ever to reject the paradigm, for you live and die by the paradigm.

The question now is: If that is all true, why are there ever any Revolutions, for these normal scientists sound very boring, trapped by their own paradigms and involved in nit-picking little exercises of problem-solving. Kuhn's answer is that the very process of using the given paradigm ultimately helps to undermine it.

FIGURE 1

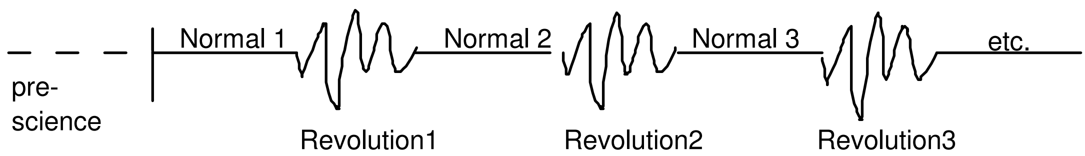

FIGURE 2

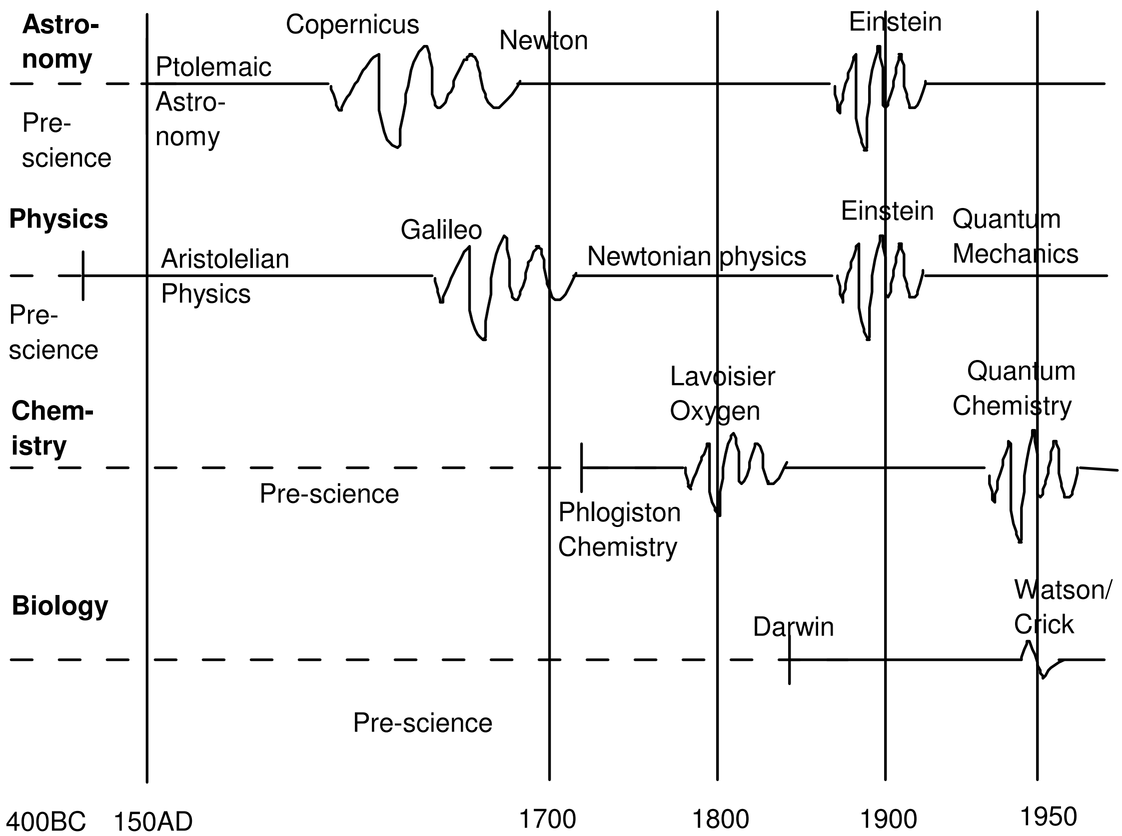

FIGURE 3

PROBLEMS OF FIT

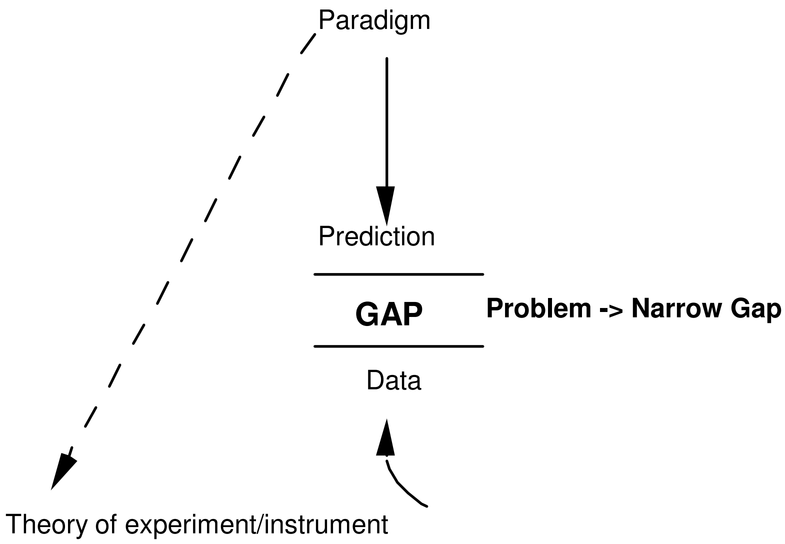

FIGURE 4