A Study Guide for The Structure of Scientific Revolutions by Thomas Kuhn

In 1962, Thomas Kuhn wrote one of the most influential books of the last half of the twentieth century. He was inspired to write this book, The Structure of Scientific Revolutions, upon reading another book, The Great Chain of Being by Arthur Lovejoy. Lovejoy' book was one of the most influential books of the first half of that century and was an important seed for the development of what came to be called Intellectual History, that branch of history which deals with the effect of key important ideas on the flow of historical events. Lovejoy sub-titled his book The History of an Idea. To understand the link between these two books better, it is helpful to give a brief review of The Great Chain of Being.

In Lovejoy's view, the way the universe was perceived by the Western world through much of its history was driven by the dominance of one idea over all of Western thought. This idea originated with the philosophical views of Plato and Aristotle and entered Christian theology through Saint Augustine's synthesis of Christianity and Greek Neo-Platonist philosophy. Augustine's synthesis brought the more mystic thought of Plato and Aristotle into Christianity .The burning of the great library at Alexandria through a fire occurring during Roman occupation of Egypt resulted in a loss of Aristotle' more scientific writings to scholars of the western world, although these works did still remain in other libraries such as the one at Antioch. After about 600 AD, these libraries came under Islamic control and helped initiate and support a flourishing period of scientific and technological discovery by largely Arab and Persian scholars in Islam.

By the start of the eighth century C.E., Islamic conquest had spread over most of the Iberian Peninsula, including most of modern day Spain and Portugal. This created an Islamic reign characterized to a large extent by religious and intellectual tolerance that allowed Islamic, Jewish and Christian peoples to co-exist to an extent not often seen in the rest of either the Islamic or Christian worlds. In this environment we saw Jewish scholars, who had long interacted with both Islam and Christianity, serving as a bridge between Islamic and Christian scholars, translating Islamic scientific, technological and literary works from Arabic into Latin, the language of Christian scholarship, and translating Christian works from Latin into Arabic. Among the manuscripts translated from Arabic into Latin were the lost scientific works of Aristotle that had not been available to Western scholars for some 700 to 800 years. At this time, Aristotle was the most revered of the ancient Greek philosophers. When his scientific works, which utilized human reason as a tool for understanding the universe, became available to Christian theologians, they began to change their way of looking at their world and began to integrate Aristotle's perceptions on the value of reason into theological debate, along with his perceptions of the material (or natural) world. This line of thought led to a second synthesis of Greek philosophy and Christian theology, that of Saint Thomas Aquinas.

Thomist theology, by elevating the value of reason as a means for resolving theological questions, opened the door for the development of science as a tool for understanding the universe. Eventually, science and reason replaced religion and revelation as the primary authorities for understanding the material universe in the Western world. The universe was still seen through the eyes of The Great Chain of Being, however. Scientific questions were formulated within the framework of possibilities defined by the assumptions inherent in the chain. These assumptions were:

1. Everything that can exist does exist;
2. Everything exists in its place, beginning with inanimate objects, going up to humans as the highest form of material being, up through the Angels and culminating with God as the highest of all; and
3. The Universe is static and unchanging in any significant way. It exists as God created it, with the stars where he placed them and all the species of living beings as he formed them.

The concept of a static universe as described by the Great Chain does not apply just to the material universe. It applies to social organizations as well. The concept of the Divine Right of Kings and of the right of the Aristocracy to govern is an extension of the concept of a static universe. Such a perception places severe limitations on the opportunity for upward mobility, and contributes to the need to justify revolutions by seeking ecclesiastical support as evidence that the acts of revolution reflected the will of God, or, in some cultures, to identify divine kinship with the gods as justification for displacement of a ruler previously considered to be legitimate.

The Great Chain of Being, with its assumption of a static universe, dominated Western thought for almost 2000 years. This dominance was so strong that it was difficult to even formulate a question that did not incorporate the features of the Chain at the core of the answer. This is seen in the debates of the Scholastic philosophers of the Middle Ages, and even dominated the thought of most of the Renaissance philosophers as well. It also appears as a theme in many literary works of this period, such as Essay on Man by Alexander Pope. The Great Chain of Being began to lose its ability to influence scholarly thought as the Western world moved into the Age of Enlightenment.

The Enlightenment movement began in France as a reaction to the excesses of the absolute rule of the French monarchy and the leadership of the Catholic Church, both in the Church's social policies and in its suppression of knowledge attained by the exercise of reason through scientific investigation, such as that conducted by Copernicus and Galileo. Both the natural philosophers, as the scientists were called at the time, and the newly appearing social philosophers began to question the long-standing assumption of a static universe that was one of the core tenants of The Great Chain of Being. This led to the development of theories of government, such as those of John Locke, which emphasized the equality of men (but not yet women) and the enhanced value of the individual over that of the community. These ideas became the guiding principles for both the American form of republican government and the French republic that arose from the French Revolution. The new view of the universe, which replaced the static structure of The Great Chain of Being, is one of a dynamic universe in which both its material and social elements are in a state of constant change. This view of the universe as a dynamic system in a state of constant evolution has, for the modern Western world, replaced the static The Great Chain of Being as the primary influence for understanding the various facets of the universe.

When Thomas Kuhn read Lovejoy's The Great Chain of Being, he immediately recognized similarities between the historical account of The Great Chain of Being and what he had observed in studying the history of science. He particularly was struck by the way The Great Chain of Being had so thoroughly taken hold of men's minds that they could not entertain

thoughts of alternative views of the universe. We often attribute failure of the Western world to accept alternative views that were presented from time to time by scholars such as Copernicus and Galileo as due to repression by those in authority, both civil and ecclesiastical. In all reality, however, these alternatives simply didn't make sense to most of the people of the West, even the scientists of the time, because they didn't fit the accepted view of reality upon which our understanding was based. From Kuhn's perspective, our understanding of the universe through science has been guided through the same kind of influencing ideas that are represented by The Great Chain of Being. Kuhn named these guiding ideas paradigms.

A good working definition of a paradigm as it applies to science is that it is an organizing idea that makes sense of all the observations made of a given natural phenomenon. As he indicates in his postscript to the second edition to The Structure of the Scientific Revolutions, he uses the term in more than one way in the book. The definition given above captures the essence of his meaning as he uses it to describe the role of paradigms in the history of science.

The function of a paradigm is to provide a structure through which the phenomenon can be understood. Without the structure, our awareness of the phenomenon will consist of a family of disjointed observations with no recognizable connections among them. Imagine that you have been given a jumbled set of clues to a crossword puzzle, but not the puzzle itself. You can go through and guess at the meaning of some of the clues, but for many of them you will have no idea at all of their meaning, and for others you may have an idea, but can't decide among several equally possible alternatives. If you are given the puzzle and the numbers that associate the clues to individual squares in the puzzle, then you can begin to match letters with squares and through noting points where clues intersect in the puzzle structure, the identity of previously unsolvable clues becomes apparent. The paradigm in the understanding of a phenomenon of nature serves the same function as the puzzle structure in working the solution to a crossword exercise.

Kuhn describes our understanding of natural phenomena as proceeding through a series of stages. These are:

1. The pre-paradigm stage;
2. The paradigm recognition stage;
3. The paradigm reinforcement stage; and
4. The paradigm shift

The pre-paradigm stage consists of random observations that have no obvious relation to each other. This is represented by the jumbled set of clues in the crossword puzzle analogy given above. An example from nature would be the patterns of inheritance that we collected for 5000 years or more before we developed the science of genetics. These observations on inheritance were collected through selective breeding, a practice we have been performing since we first began the domestication of plants and animals for human use. During the pre-paradigm stage we can use the phenomenon, but we can't explain it. We have no organizing idea (paradigm) to guide us to an understanding of the phenomenon.

The next stage is the initial recognition of the paradigm. In the crossword analogy, paradigm recognition would occur at the instant when we were given the puzzle and the numbered clues.

In the genetics example, the recognition of the first paradigm occurred when Gregor Mendel performed his experiment with colored peas and observed that inheritance of specific characteristics occurred in a quantitatively predictable manner, as if the characteristics were being transmitted as particles derived from each of the two parents. This observation made it possible to envisage any inherited characteristic being passed from generation to generation in the same way, and made sense of all the observations that had accumulated through centuries of selective breeding.

Once we have identified a paradigm for a natural phenomenon, we can properly be said to be in position to study the phenomenon scientifically. Once we have a paradigm in place, we have an explanation of how the phenomenon works. The paradigm provides the explanation. It also does two other things for us — it suggests other experiments or observations that may be carried out, and it predicts the outcomes of these experiments or observations within a reasonable range of possibilities. This is a reflection of the orderly nature of the phenomenon as a part of nature. Science is predicated on the assumption that nature is orderly, and that its behavior can be predicted if we can understand the rules and laws that govern this behavior. For any given phenomenon, the paradigm represents its natural order.

The third stage in our understanding of a natural phenomenon is the paradigm reinforcement stage. The paradigm, as mentioned above, will both suggest new observations to make and predict the outcomes of these observations. Every time we perform an experiment suggested by the paradigm and the results come out essentially as the paradigm predicted, we gain additional confidence that the paradigm represents an accurate description and/or explanation of the phenomenon. The work done during the paradigm reinforcement stage is what Kuhn refers to as normal science. Normal science does not mean average or pedestrian science. Rather it refers to the science that is most frequently done. Most of the Nobel Prizes have been awarded for work that would be considered normal science as Kuhn uses the term.

As we continue to perform experiments suggested by the paradigm, and these experiments continue to give results the paradigm predicts, we gain increased confidence in the paradigm as a descriptor for the phenomenon. However, as we continue to elaborate our understanding of the phenomenon, we eventually reach the point where a predicted result of a suggested experiment does not come out as expected. Kuhn calls such unexpected results anomalies. When an investigator encounters an anomaly, he or she attempts to rationalize the outcome in some way. The experiment may have been poorly designed, or the experimental apparatus may have been faulty. However, if anomalies continue to arise, the scientific community is forced to face the fact that this paradigm is no longer providing an adequate description of the phenomenon. Although the paradigm may be recognized as being inadequate, it can't be discarded out of hand because it represents order as we know it for that bit of nature. To discard the paradigm would be to discard the concept of order for the phenomenon, and without a perception of order, the phenomenon can't be investigated scientifically. We would have reverted back to the pre-paradigm stage.

We will continue our investigations of the phenomenon within the context of the accepted paradigm until some investigator comes along who is able to see the phenomenon in a new, different light and is able to recognize a new paradigm for the phenomenon. This leads to the

fourth stage of understanding, the paradigm shift. For genetics, the paradigm shift came with the discovery of the double helical nature of the structure of the DNA molecule. This allowed geneticists to ask a whole new set of questions, and explain elements of genetic behavior (for example, how genes are replicated and how genetic information is expressed in cells) that could not be formulated under the previous Classical Genetics paradigm. The current paradigm for genetics is called the Molecular Genetics paradigm.

Once a paradigm shift takes place, we return to the paradigm reinforcement phase. From that point onward our understanding of that phenomenon oscillates back and forth between paradigm reinforcement and paradigm shifts.

Reflection on the examples given above reveals the parallels that exist between understanding genetics through paradigms, and Western scholar's use of The Great Chain of Being as a structure for understanding the universe for over 2000 years. In both cases, the organizing idea identified the questions which could be asked, predicted the outcome of those inquiries and, when the organizing ideas no longer provided an adequate accounting of the observed reality, the paradigm went into a state of crisis and was replaced by another which provided a better explanation of the universe encompassed by the paradigm.