THOMAS KUHN: ON THE 50TH ANNIVERSARY EDITION OF *THE STRUCTURE OF SCIENTIFIC REVOLUTIONS*

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ABSTRACT

Kuhn draws a distinction between normal science and revolutionary science. Normal science refers to "puzzle-solving" science that scientists carry out on a daily basis. Revolutionary science, as the name implies, consists of those much rarer occasions when a significant shift is made in scientific thinking. Essentially scientific revolutions mark the acceptance of a new paradigm in place of the old theories. This is perhaps most plainly illustrated by the Copernican revolution whereby the Ptolemaic view of an earthcentered universe was replaced by Copernicus' heliocentric theory. Scientific revolutions are characterized by the controversial rejection of the old theory, effectively rendered incompatible with the new theory, and the proliferation of a new set of scientific problems for scientists to reflect on. Revolutionary science does not just spring from nowhere or out of the unprecedented brilliance of one or a few scientists. It is the result of a continual process of "anomaly accumulation", "novelty recognition", and "crisis". This paper is interested in Kuhn's The Structure of Scientific Revolutions so as to describe shortly the scientific cycle of normal science and revolutionary science through these terms on the 50th anniversary edition of the book.

Keywords: *Anomaly accumulation, novelty recognition, crisis, scientific revolutions*

THOMAS KUHN: BASKISININ ELLİNCİ YILINDA *BİLİMSEL DEVRİMLERİN YAPISI*

ÖZ

Kuhn, olağan bilim ve devrimci bilim arasında bir ayrım yapar. Olağan bilim, bilim adamlarının günlük olarak yürüttükleri "bulmaca çözme" etkinliği olarak bilim anlamına gelmektedir. Devrimci bilim, adından da anlaşılacağı gibi, bilimsel düşünmede önemli bir değişikliğe gidildiğinde, çok nadir durumlarda görülen bilimin adıdır. Esasen bilimsel devrimler, eski kuramların yerini yeni bir paradigmanın almasıyla belirlenirler. Bu durum en açık bir biçimde Batlamyos'çu yer merkezli bir evrenin yerini Kopernik'çi güneş merkezli bir evren kuramının almasıyla görülmüştür. Bilimsel devrimler yeni kuramla uyumsuz tartışmalı eski kuramın yadsınması ve bilim adamlarının üzerlerinde düşünmesi için bir dizi yeni bilimsel problemler getirilmesiyle ıralanırlar. Devrimci bilim, durduk yerde hiç yoktan ortaya çıkmaz veya bir ya da birkaç bilim adamının parlak zekasından fışkırmaz. Bu durum devam eden "aykırılık birikimi", "yeniliğin farkına varma" ve "bunalım" sürecinin bir sonucudur. Eldeki *mevcut çalışma, bu kavramlar aracılığıyla, Kuhn'un Bilimsel Devrimlerin Yapısı adlı eserinde irdelediği olağan bilim ve devrimci bilim bilimsel döngüsünü, kitabın baskısının ellinci yılında, kısaca gözler önüne sermeyi amaçlamaktadır.*

Anahtar Kelimeler: *Aykırılık birikimi, yeniliğin farkına varma, bunalım, bilimsel devrimler*

INTRODUCTION

Thomas Samuel Kuhn was born in Cincinnati, Ohia, in 1922, into a non-practising Jewish family. He attended progresive schools in New York City, New York State and Pennsylvania, before his parents moved him to a school in Connecticut, in preparation to enter Harvard University. Having done well at this school, especially in maths and science subjects, he went on to Harvard in 1940, intending to major in physics. Although concentrating on electromagnetism and electronics during his undergraduate studies, he also took some history and courses on classical and modern philosophy. The Second World War disrupted his curriculum, but he graduated in only three years. After the war ended in 1945, although Kuhn enrolled as a graduate student in theoretical physics at Harvard, he soon expressed doubts about his intended course of study and received permission to take courses in other disciplines also, including philosophy. This period confirmed his interest in the subject and around this time he became convinced that a book like *The Structure of the Scientific Revolutions* needed to be written. However, he decided to finish his doctorate in physics before changing disciplines (Preston, 2008: 1).

James Bryant Conant, The President of Harvard, was at that time setting up a ‘general education in science’ programme, designed to inform undergraduate students of non-science subjects about the nature of science. Kuhn, having made himself known to the faculty for editing the student newspaper and being prepared to write reports on matters affecting students, was invited by Conant to become an assistant on a history of science within this programme. The case study on the history of mechanics which Conant asked Kuhn to do helped further shift his interest from physics to the histoy of science. It was during the preparation for this course, in 1947, when Kuhn was reading about Aristotle’s physics, that he had a revelation about the way to do history of science. Thinking from the point of view of more recent physical science, he found, produced the puzzling consequence that Aristotle, a supremely talented observer of many of nature’s aspects, seemed instead to have made blatant errors when it came to physics. How could this have been so, and how then could his physics have been taken seriously for so long? A reading of the history of science which gave rise to such perplexities, Kuhn felt, had to have gone wrong. But one day those perplexities suddenly vanished. He all at once perceived the connected rudiments of an alternate way of reading the texts with which he had been struggling. By learning more about the universe as Aristotle conceived it, Kuhn came to see Aristotle’s physics in a different way, a way which was more like Aristotle’s than like the world-view of modern physics. Via a process that he later likened to a Gestalt-switch he had, as it were, got inside Aristotle's head. This kind of conceptual readjustment on the part of the historian, Kuhn felt, mirrored that which must have occurred to physicists themselves during the history of that discipline. There must have been a global kind of conceptual change within physics, a change that was not merely the addition of new material to what was already known or the correction of mistakes but rather putting on a different kind of thinking-cap. It was in 1947, then, that Kuhn stumbled upon the concept that would come to mean so much to him, that of a scientific revolution (Preston, 2008: 1-2).

Kuhn had already read and admired a well-known book by the philosophically-trained historian Arthur Lovejoy, *The Great Chain of Being*, one of the founding texts of the discipline known as the history of ideas. In the mean time, Kuhn's colleague, the Harvard historian of science I.B. Cohen, suggested to him that he read the *Etudes Galileennes* (*Galileo Studies*) by Alexandre Koyre (1892-1964), the famous historian of philosophy and science. Although this book had been published in 1939, it became known only after the war. Koyre's work and the *historiographic revolution* it initiated exerted a strong influence on Kuhn. Koyre showed Kuhn that what Lovejoy did with the history of ideas could also be done with history of science. Koyre also had a central role in establishing and clarifying the concept of the *scientific revolution*. He argued that the scientific revolution of the seventeenth century was one of the most important perhaps even the most important mutation in human thought since the invention of the Cosmos by Greek thought. As a matter of fact Koyre had already used the plural term "revolutions of scientific ideas", but it was Kuhn who explicitly took the concept of the scientific revolution and used it in what he calls an 'extended conception', characterizing several different episodes in the history of science as "scientific revolutions" (Preston, 2008: 3).

Kuhn, with Conant's sponsorship, was elected a junior Fellow in Harvard's Society of Fellows in 1948. This was his first opportunity not only to educate himself deeply in the history of science, the subject he had applied to do, but also to read in related areas, such as sociology, the history of ideas, psychology, anthropology and linguistics and it was also when he encountered the ideas of the Harvard philosopher Quine. Kuhn drew upon all these sources in constructing *The Structure of Scientific Revolutions*, but it resulted mainly from his sustained immersion in past science during the 1950s. This began to undermine the basic conceptions he had drawn from his own scientific training and his interest in the philosophy of science. Kuhn submitted his dissertation, which concerned a new way of measuring the cohesive energy of certain types of metals and was awarded a doctorate in physics in 1949. His first publications, in 1950 and 1951, were in physics and applied mathematics, but by the time they appeared, as he later put it, he had abandoned science for its history. When the well-known philosopher of science Karl Popper gave his William James lectures at Harvard early in 1950, Kuhn made his acquaintance. Popper pointed Kuhn towards the work of the Paris-based philosopher Emile Meyerson (1859-1933), whose approach to history Kuhn came to admire. Meyerson's philosophy of science, which had Koyre's support, was strongly opposed to the then popular approach known as positivism, but his tendency to see the rational structure of human thought (in the form of a small group of scientific conservation principles) operating throughout natural science caused him to overlook the issue of scientific change, which was Kuhn's concern (Preston, 2008: 4).

Kuhn travelled to Europe in the summer of 1950, meeting first with philosophers and historians of science at University College London where there was a history of science programme and at Oxford and then travelling to France. Koyre, who was based in Paris, but whom Kuhn had already met when giving lectures in the US, had provided him with a letter of introduction to the French philosopher Gaston Bachelard (1884-1962). While their meeting was apparently unproductive, Bachelard's concepts of 'epistemological break' and 'mutation', transmitted via Koyre, are relatives of and may even have been an inspiration behind Kuhn's idea of scientific revolutions. Hence, Kuhn's own writings were the route by which the work of these continental European historians and philosophers of science somewhat surreptitiously entered the Anglo-American scene. Kuhn's debt to these figures, whose work was not well known in the US and Britain is undoubtedly one of the main reasons why *The Structure of Scientific Revolutions* seemed so new and created such a fuss there. But the idea that became most familiar from his work, of discontinuities in the history of science, was already commonplace in France (Preston, 2008: 4-5). The year after he returned from Europe Kuhn delivered the 1951 Lowell lectures at Harvard on "The Quest for Physical Theory" and began publishing in the main history of science journal, *Isis*. The Lowell lectures anticipate some of the central features and concepts of *The Structure of Scientific Revolutions.* Notably, the conception of science featured there is a *dynamic* and *creative* one, opposed to the static conception which tends to emerge from science textbooks. Kuhn there takes what he variously calls 'preconceptions', 'prejudices', 'points of view', 'principles' or 'conceptual frameworks' to be essential to science and the underlying notion here (perhaps closest to 'conceptual framework') is undoubtedly a precursor of the looser sense of his later term 'paradigm'. But the sense of 'paradigm' as *achievement*, which was to be absolutely central to *The Structure of Scientific Revolutions*, was not yet present. The idea, which Kuhn derived from the work of the Swiss psychologist Jean Piaget, that although everyone operates within a certain 'perceptual' or 'behavioral world', different scientists operate within different behavioural worlds generated by their profession presages important ideas from *The Structure of Scientific Revolutions*, including the concept of 'normal science'. So too does the idea that scientific activity usually consists in increasing the scope and precision of an existing system. The idea that such behavioural worlds confront ‘anomalies’ which sometimes change those worlds by worsening into ‘crises’, is also present, as is the idea of scientific revolutions, destructive phases in which existing systems are replaced by new ones (Preston, 2008: 5).

In 1956, Kuhn left Harvard for the University of California at Berkeley. Among his colleagues in philosophy there, Kuhn befriended and had extensive discussions with Stanley Cavell and Paul Feyerabend. He also spent some time at Stanford University for preparing *The Structure of Scientific Revolutions.* The first edition of *The Structure of Scientific Revolutions* was dedicated to Conant, appeared in late 1962. This was the work that brought Kuhn to a worldwide audience. Having now sold more than a million copies, and having been translated into 27 different languages, it has become the most widely read and most influential work of philosophy written in English since the Second World War. In 1964, Kuhn left Berkeley for Princeton where he worked until the year of 1978. Kuhn eventually left Princeton in 1978, moving first to New York University and then joining the Massachusetts Institute of Technology (MIT). Kuhn retired in 1991 and he died in 1996, having beeen ill with cancer (Preston, 2008: 6-8).

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In his well-known book entitled *The Structure of Scientific Revolutions*, Kuhn starts with the phrase *normal science* that refers to the sort of routine science that is practiced everyday. It is defined by the so-called overarching paradigm which directs current scientific research. Paradigms provide the foundation for further scientific inquiry. They are the framework under. Kuhn also includes the work of Newton, Lavoisier, and Einstein as examples of scientific revolutions, which normal puzzle-solving science proceeds and particular traditions of science are born. In other words, the paradigm sets up a structure for science in which there are not only specific problems available for solving, but also the means and information required to solve them (Kuhn, 1970: 5-6, 35).

> … ‘Normal science’ means research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice. Today such achievements are recounted, though seldom in their original form, by science textbooks, elementary and advanced. These textbooks expound the body of accepted theory, illustrate many or all of its successful aplications, and compare these applications with examplary observations and experiments. Before such books became popular early in the nineteenth century … many of the famous classics of science fulfilled a similar function (Kuhn, 1970: 10).

Kuhn explains, paradigms provide scientists not only with a map but also with some of the directions essential for map-making. In learning a paradigm the scientist acquires theory, methods, and standards together, usually in an inextricable mixture. The paradigm itself determines how science is and can be done. Once a paradigm is in place, normal science sets out to solve all the “puzzles” the paradigm has constructed. Effectively, normal science attempts to tie up all the loose ends created by the paradigm. From the scientist’s perspective, these puzzles are solvable under the paradigm so long as enough time, effort and resources are exhausted. This type of research comprises the everyday routine science that scientists carry out with the hopes of solving puzzles, or solving them more completely than anyone before them. Herein lays the scientists’ motivation. But if science is to progress, there must be a way for paradigms to change in order that inferior models be replaced (Kuhn, 1970: 42-50).

> … The term ‘paradigm’ is used in two different senses. On the one hand, it stands for the entire constellation of beliefs, values, technics, and so on shared by the members of a given community. On the other, it denotes one sort of element in that constellation, the concrete puzzle-solutions, which employed as model sor examples, can replace explicit rules as a basis for the solution of the remaining puzzles of normal science (Kuhn, 1970: 175).

As the process of normal science advances, says Kuhn, *a mass of anomalies* accumulates. Through the course of everyday science, scientists happen upon data notably dissimilar from the prediction made in the hypothesis. These data are inexplicable under the current paradigm; they are *anomalous*. Thus, anomalies are phenomena which resist explanation under the paradigm in place. They come in a variety of forms, from experimental results to fortunate accidents (Hacking, 1981: 24-25).

> … how changes can come about, considering first discoveries, or novelties of fact, and then inventions, or novelties of theory. That distinction between discovery and invention or between fact and theory will, however, immediately prove to be exceedingly artificial… discovery commences with the awareness of anomaly, i.e., with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science. It then continues with a more or less extended exploration of the area of anomaly. And it closes only when the paradigm theory has been adjusted so that the anomalous has become the expected (Kuhn, 1970: 52-53).

A collection of these anomalies prepares the way for the perception of novelty. *Novelties* often call forth new theories to help explain, for lack of a better word, their novelty. Novelty does not arise without resistance and difficulty, however. It is manifested against a background of expectation provided by the paradigm in place. Moreover, anomaly and novelty are often overlooked because of the influence of the anticipated results. Despite the difficulties, one or a few scientists will take notice of the novelties, perhaps recognizing a pattern in them which the current paradigm fails to explain. They begin to question the adequacy of current theories and even going so far as to formulate new theories in their place. Often new theories manifest themselves only implicitly at first, as a hunch. A scientist's intuition about anomalies can slightly alter his course of experimentation or interpretation of results. Kuhn explains that the mere awareness of anomaly opens up a period in which conceptual categories are tweaked until what initially appeared as anomalous eventually becomes appropriated as the norm. The novelty of anomalies does not transform into the expected all on its own. Then, anomalies earn acceptance through the proliferation of possible explanatory theories put forth by sympathetic scientists (Kuhn, 1970: 55-63).

As data begin to corroborate with a tentative theory, a discovery occurs. At that point scientists have the option of choosing between competing theories, including the old one. Ultimately the approval of a significant portion of the scientific community marks the inauguration of a new paradigm. The time between the recognition of anomalies and the adoption of an entirely new paradigm is marked by insecurity, debate and controversy within the scientific community. Kuhn notes that scientific revolutions are inaugurated by a growing sense, again often restricted to a narrow subdivision of the scientific community, that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature which that paradigm itself had previously led the way. Scientists begin to have the uneasy feeling that some of the most fundamental suppositions guiding their work may actually be flawed (Bird, 2000: 40-43).

In Kuhn's word, *crisis* has set in. During the crisis stage, the boundaries of the old, still reigning paradigm become increasingly blurred. The rules of everyday science's puzzle-solving become looser, ultimately permit[ting] a new paradigm to emerge. The scientific society divides itself into two parties, those traditionalists holding on to the old ways, and those revolutionaries seeking to institute a new view, a new paradigm. The two camps represent competing paradigms with incompatible modes of scientific life. Each camp, however, can argue for the supremacy of its paradigm only from within the paradigm itself. A particular scientist's hunch and subjective concerns will be lost on others. As in political revolution, change must be instated through mass persuasion rather than logic or probability. Because the scientific community decides the fate of scientific theories, the progress of science depends part and parcel upon the society in which it is instituted and the accompanying values. In terms of rivaling paradigms, the scientists become divided based upon their subjective opinions. Once a majority has been swayed, it is safe to say that the new paradigm rules and the old holdouts will eventually be left behind (Kuhn, 1970: 67-75, 78-90).

Kuhn thinks the initiation of a new paradigm signifies a *bona fide* revolution. Since the paradigm itself determines the structure of how science is thought about and done, that is, it defines the theory, methods and standards available, a change in paradigms causes significant alterations in the scientific program. The criteria determining the problems and solutions to be worked on in normal science and anticipated under the new paradigm must also change in light of the new model. Once a new paradigm has been instituted, the whole perspective of science necessarily shifts accordingly. The scientists' world *changes*. Therefore, a switch in paradigms is appropriately called a *revolution*. The changes instituted by a new paradigm take on a "global" level. Here Kuhn is not talking about a world-wide change, but an all encompassing shift in the way science is done. Not only do paradigms provide the basis for how scientific puzzles can be solved, but also determine what shows up as a scientific problem. The scientist may use the new theory nonetheless, but he will do so as a foreigner in a foreign environment, an alternative available to him only because there are natives already there. His work is parasitic on theirs, for he lacks the constellation of mental sets which future members of the community will acquire through education (Kuhn, 1970: 78-90-109).

Kuhn goes on to say that led by a new paradigm, scientists adopt new instruments and look in new places. Even more important, during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before.

> Examining the record of past research from the vantage of contemporary historiography, the historian of science may be tempted to exclaim that when paradigms change, the world itself changes with them… Even more important, during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before. It is rather as if the professional community had been sudddenly transported to another planet where familiar objects are seen in a different light anda re joined by unfamiliar ones as well… paradigm changes do cause scientists to see the World of their research-engagement differently (Kuhn, 1970: 111).

As Kuhn has it what were ducks in the scientist's world before the revolution are rabbits afterwards. A change in paradigms signals a scientific revolution whereby the inextricable mixture of theories, methods and standards that accompany a paradigm shift to match the new paradigm. So great is the shift that paradigms are said to be incommensurable. Of utmost importance to Kuhn's theory is the idea that the practice of normal science effectively allows for novelty and paradigm shifts to occur. While normal science does not directly aim at this goal, and even seeks to suppress novelties, it nonetheless produces the novelties which initiate paradigm shift. In this way "traditional pursuit prepares the way for its own change." The structure of science ensures its own advancement (Kuhn, 1970: 111-134).

In sum, Kuhn called into question the two proudest boasts of science: first, that science gives us the truth about what nature really is; and second, that science, unlike art, philosophy, religion or politics is progressive, securing an ever-greater store of truths about nature and building steadily on the work of past scientists. For Kuhn, science is something done by real men and women, to wit, people who are born into a particular culture at a perticular time, learn their science out of textbooks and in classrooms and then practice what they have learned in laboratories. Kuhn is interested in the human processes by which real scientests learn their craft and pass it on to others. It appears that Kuhn's picture of real-world science is as follows: in normal science period, which is based on paradigms or models that are precise and clear enough to tell scientists what the world should look like, scientists are puzzle solvers, working out answers to problems (Gutting, 1980: 41-46). Science is a human activity like any other. A theory succeeds, takes hold and becomes a paradigm for future work by attracting supporters, followers and adherents. Scientific revolutions, in this context, are noncumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one. Accordingly, this is how a paradigm shift occurs. It is extremely difficult for a scientist who has grown up in one paradigm to shift over to a new one. Those of us who are not scientists at all may have trouble understanding why this so difficult, but that is because we have not adopted the habits of thought, the manual skills, the very body language that characterize one paradigm or the other. It is hardly surprising then that during times of dramatic paradigm conflict in a branch of science, it is the young apprentices who most easily take up a newly proposed paradigm (Sharrock, 2002: 1-32).

All in all, Kuhn introduced the idea that science is a social practice, an activity carried on by groups of men and women whose interactions with one another in the classroom, in the laboratory, and through their publications shape who they are and what they believe. In a word, science; like politics, the economy, marriage, art and religion, is a social institution.

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