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PHL 104
December 13, 1999

Four Accounts of the Discovery of DNA's Molecular Structure

Theoretical models for the molecular structure of DNA can be likened to scientific theories. DNA's structure was determined largely because scientists scrutinized the relationship between theory (a particular theoretical model of DNA) and observation (x-ray crystallographic patterns, or bonding patterns between bases and sugar-phosphate groups, for example). Inductivists, falsificationists, Kuhn, and Feyerabend all have different accounts of how scientists have related theory to observation. These accounts are important because, not only do they delineate frameworks scientists use to develop their theories, but because these frameworks subsequently became important in developing a theory for the molecular structure of DNA.

The inductivist account of science recognizes five steps that are essential to scientific progress, and consequently, the discovery of the molecular structure of DNA. First, scientists compile a large body of facts from observation and experiment. Using the principle of induction, these facts can, often with severe logical difficulties, be generalized to form the basis for a theory or law. Then, once a theory has been developed, scientists can use the theory as part of a valid logical argument to make new predictions or explanations of phenomena. According to Chalmers, the inductivist account has "a certain appeal" to it, namely, that all of scientific progress can be seen as the result of a linear, highly structured inductive scientific method (54). "Its attraction lies in the fact that it does seem to capture in a formal way some of the commonly held intuitions about the special characteristics of scientific knowledge, namely its objectivity, its reliability, and its usefulness" (57).

An inductivist account of the discovery of DNA's molecular structure might proceed in the following way. First, early molecular biologists compiled a large body of facts from observation and experiment, such as Rosalind Franklin's findings on the structure of DNA based on her x-ray crystallography work. From these facts, a theory of DNA structure was developed. Watson demonstrates, in <u>The Double Helix</u> how one aspect of DNA structure was determined from factual experimental observations. In the β-model of DNA,

> …the meridional reflection at 3.4 A was much stronger than any other reflection. This could only mean that the 3.4 A-thick purine and pyrimidine bases were stacked on top of each other in a direction perpendicular to the helical axis. In addition we could feel sure from both electron-microscope and X-ray evidence that the helix diameter was about 20 A (110).

Once a theory of DNA structure had been developed, the next step in the inductivist account of science is the formation of predictions and new explanations. Through a valid logical argument, the theory of DNA structure can then be used to explain the transmission of genes, which are responsible for heredity. This explanation, in fact, happens to be paramount to the science of modern genetics. The inductivist account, in this case, is a simple and easy-to-follow one: make observations from experiments, link them together through induction to form a theory of DNA structure, then use a valid logical argument to make new explanations or predictions from this theory. Essential to theory formation in this account of science is induction. Given that induction is foolproof from errors, the inductivist account of the discovery of DNA structure would be very close to describing how this discovery actually took place.

However, this account of science happens to be riddled with flaws. An inductivist philosopher knows that having a large body of facts to draw upon is essential to theory development, because there is always the chance that a new observation can conflict with the theory. A second flaw is exposed by Chalmers when he discusses why inductivism is an attractive account of science. He cites "objectivity" as being one of the "special characteristics of science" (54). Inductivists consider a large body of facts to be essential to developing a theory using inductive argument, but they assume that subjective factors never influence this process. They believe that "observation statements that form the factual basis for science can be securely established directly by careful use of the senses" (57). However, the senses can often be deceived, and there is always a certain degree of subjectivity imposed on science from human behavior and the historical background of the scientists making observations and developing theories from induction. While induction is only one of the five steps in the inductivist account of science, it is one of the most important steps. Induction is the process by which scientists make a leap of thought from observation to theory, and if induction has flaws, then the new theory must unquestionably contain flaws. Regardless of these errors, a scientist, according to an inductivist philosopher, will still accept a particular scientific theory if it can be validly induced from factual observation and experiment.

Unlike inductivists, falsificationists believe that there is no way to conclusively prove that a theory is true. Consequently, they will resist stating that they've proved a theory to be true. Instead, falsificationists will consider a theory to be true so long as it has not been proven to be false. Unlike the strict five-step process held by the inductivist account of science, falsificationists hold that scientific progress comes about "by trial and error, by conjectures and refutations" (Chalmers 60). In the falsificationist picture, theory change happens constantly, and this process is what falsificationists believe constitutes scientific progress. "It can never be said of a theory that it is true, however well it has withstood rigorous tests, but it can hopefully be said that a current theory is superior to its predecessors in the sense that it is able to withstand tests that falsified those predecessors" (Chalmers 69).

In the two years prior to the conclusive discovery of DNA's structure, models for DNA had been proposed and rebutted many times. For example, Linus Pauling announced the α-helix, which he believed to be the structure of DNA. Watson realized that this could not be the proper structure of DNA, since atoms seemed to be unnaturally forced too close to one another in this model. However, the pattern of the B-model was

> …unbelievably simpler than those obtained previously ("A" form). Moreover, the black cross of reflections which dominated the picture could arise only from a helical structure. With the A form, the argument for a helix was never straightforward, and considerable ambiguity existed as to exactly which type of helical symmetry was present. With the B-form, however, mere inspection of its X-ray picture gave several of the vital helical parameters (Watson 107).

This is an example of how one theory of DNA structure (the α-helix) was falsified because of the observation that atoms were being unnaturally forced too close to each other than chemistry would allow. In its place, Watson found a new theory, the B-model, that proved superior to the α-helix theory. Chalmers claimed that scientific progress occurs by trial and error (60). This is exactly what we see here; one theory was falsified and another took its place. Later the B-model would be shown to stand up to numerous tests, withstanding falsification many times by independent scientists.

One factor a falsificationist believes is essential to science is the notion that science is no more than "a set of hypotheses that are tentatively proposed with the aim of accurately describing or accounting for the behaviour of some aspect of the world or universe" (Chalmers 61). In analogy, the discovery of the molecular structure of DNA consisted of nothing more than models of DNA structure proposed to describe its actual structure. A scientist will accept a particular scientific theory only as long as it has withstood attempts to falsify it, but as soon as the theory has been falsified, a new theory must be accepted in its place. We saw this when the α-helix theory of DNA structure was discarded due to falsification, and the B-model took its place. Another key factor in the falsificationist account of science is the idea that scientific theories must be falsifiable. If not, then science would be very similar to the Freudian and Marxist theories studied by Karl Popper, a falsificationist who said these theories "could in fact explain nothing because they could rule out nothing" (Chalmers 59). Because scientists want to explain phenomena, a theory must be falsifiable so that it can be replaced by another when an unsupported, anomalous observation is made. This is why the α-helix model was considered to be a theory. It was a useful theory, but only until observations were made that falsified it.

Kuhn's account of science is remarkable in that it places emphasis on the "revolutionary character of scientific progress, where a revolution involves the abandonment of one theoretical structure and its replacement by another, incompatible one," and "the important role played by the sociological characteristics of scientific communities" (Chalmers 107). Whereas all philosophers of science are concerned with the relationships between theory and observation, Kuhn is additionally concerned with how these relationships come about. In the discovery of DNA's molecular structure, a primary thing of interest to Kuhn is the scientific community. After all, the scientific community is the body responsible for creating new theories; how the members of a scientific community interact with one another therefore will have great influence on the kinds of theories generated during a period of normal science.

The structure of Kuhn's account of science is given in a chapter by Chalmers. First, there is a period of pre-science during which there is "disorganized and diverse activity that precedes the formation of a science" (108). When a scientific community adheres to a single paradigm, defined as "the general theoretical assumptions and laws and the techniques for their application that the members of a particular scientific community adopt," then the community establishes a normal science. Within a normal science, scientists do three things. They articulate and develop the science's paradigm, they solve problems using their science, and they encounter anomalous observations that begin to destabilize their paradigm. When the paradigm becomes riddled with anomalies, the community enters a crisis stage, similar to the stalemate that occurred between supporters of the Aristotelian and Copernican theories of the universe. When a new paradigm emerges, the crisis ends. The process of developing and adhering to a new paradigm constitutes scientific revolution, which Kuhn likens to religious conversions, gestalt switches, and political revolutions. These changes in thought can happen overnight or can take decades, and can involve both changes in observational interpretation or changes in ideology based on human behavior or the historical background prior to a revolution. When the community embraces a new paradigm, a new normal science is formed. Then, a new crisis may emerge, and the process of theory change continues indefinitely.

One key feature of Kuhn's account of science is that it is the first to acknowledge the contribution of human behavior and political, economic, social, and cultural factors to scientific progress. Unlike inductivists, who believed that these subjective factors were unimportant to science, Kuhn believes that these factors can have strong influences on scientists' objectivity when articulating their paradigm. In the case of discovering DNA's molecular structure, social factors played important roles in this discovery. Rosalind Franklin was one of the five key people in the discovery of DNA, along with James Watson, Francis Crick, Linus Pauling, and Maurice Wilkins. These scientists, amongst others in their scientific community, had been unreasonably critical of Rosalind Franklin's work because she was female. Although this factor itself had nothing to do with her professional performance, the prevailing social custom of viewing women as overemotional or inferior thinkers than men during the early 1950's had substantial influence on how Franklin was able to develop and present her experimental findings to her scientific community. On this, Watson comments,

> She spoke to an audience of about fifteen in a quick, nervous style that suited the unornamented old lecture hall in which we were seated. There was not a trace of warmth or frivolity in her words…The years of careful, unemotional crystallographic training had left their mark…It was downright obvious to her that the only way to establish the DNA structure was by pure crystallographic approaches (51).

Kuhn believes that scientific progress can only be made during periods of normal science, and not during the periods of crisis or revolution. There are two reasons for this. First, during a normal science, scientists are less apt to disagree or dispute principles within their paradigm. If they did, then there could be no articulation of the paradigm, since scientists would not be able to work jointly on solving problems. The second reason is that, during crisis and scientific revolution, a scientific community lacks a paradigm to work under. Since the "existence of a paradigm capable of supporting a normal science tradition is the characteristic that distinguishes science from non-science," only when a paradigm exists can scientific progress exist (Chalmers 109). Therefore, the only times when scientific progress is made, according to Kuhn, are during periods of normal science.

Feyerabend's account of science is an anarchistic, "anything goes" account. "He takes examples of scientific change which his opponents…consider to be classic instances of scientific progress and shows that, as a matter of historical fact, those changes did not conform to the theories of science proposed by those [opponent] philosophers" (Chalmers 150). The discovery of DNA's molecular structure could be taken to be a classic instance of scientific progress, since this piece of information was the basis on which modern genetics later developed. If so, Feyerabend would argue that this discovery, in some way, did not conform to inductivist, falsificationist, Kuhnian, or other accounts of science.

Inductivism, falsificationism, Kuhnian philosophy, and Feyerabend's philosophy are four accounts of science that can be used to describe the process of discovery of DNA's molecular structure. Of these, the Kuhnian account of science best describes the actual history of genetics. The inductivist and falsificationist accounts fail to consider many other important factors that contributed to the development of a theoretical model of DNA structure; namely, subjective factors such as social and political ideologies. Justification for this reasoning arises in remembering that the factors surrounding the development of a theory are just as important as the relationships between theories and observation that have been fundamental to philosophers of science. Since the discovery of DNA's molecular structure was a vital component of the later development of modern genetics, it can be concluded that the Kuhnian account most accurately describes the history of modern genetics.

Of the four accounts of science discussed so far, Kuhn's approach probably does the best job of justifying the discovery of DNA's molecular structure as scientific knowledge. This discovery took place during a period of normal science, evidenced by the fact that a paradigm of molecular biology had been in place for quite some time. In articulating this paradigm, scientists within the scientific community shared by Watson and Crick used tools available to them to answer questions relating to this paradigm (namely, what is the molecular structure of DNA?). The resulting answer, according to Kuhn, is a new piece of scientific knowledge.

All four of the accounts of science discussed so far have one factor in common when explaining the discovery of DNA's molecular structure. This factor is observation. This does not appear very surprising; observation happens to be the basis of all theories and the foundation on top of which all scientific thought is built. It does not matter how philosophers choose to account for the discovery of the molecular structure of DNA; inductivists will see scientists constructing a new inductive argument, falsificationists will see scientists begin trying to falsify other theories, and Kuhnian philosophers will see scientists going through a scientific revolution so that a new paradigm can be developed and embraced by the scientific community. No matter how philosophers of science choose to account for it, the fact remains that the molecular structure of DNA was discovered, and that this discovery was the basis for today's understanding of genetics.