

William Whewell's Theory of Scientific Discovery

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과학적 발견에 관한 윌리엄 휴웰의 이론

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요 약

윌리엄 휴웰(1794-1866)은 존 허셀, 존 스튜어트 밀과 동시대의 사람으로서, 그들과 더불어 귀납적 과학의 본성에 관한 연구에 깊은 관심을 가졌던 과학자이자 과학철학자였다. 그는 그의 과학철학을 과학사에 대한 깊은 통찰에 기초치으려 하였다. 그는 특히 과학적 발견에 있어서의 관념과 직관의 중요성을 강조하였으며, 과학적 이론의 성장의 문제에 깊은 관심을 기울였다.

오늘날 과학철학이나 과학사의 연구에서 그의 과학철학에 대해 새로운 관심이 주어지는 것은 과학적 발견의 유형으로서 그가 제시한 '귀납의 동조(the consilience of inductions)'라는 개념이 과학사가나 과학철학자들이 주목하지 못하였거나 그 중요성을 간과한 과학의 국면들을 새롭게 조명해 줄 수 있다고 믿어지기 때문이다.

이 논문의 목적은 휴웰의 대표적인 저작인 『귀납적 과학의 철학』(1842)을 중심으로 과학적 방법론에 관한 휴웰의 이론을 재구성해 봄으로써, 과학적 발견에 관한 그의 견해의 중심이 되는 '귀납의 동조'라는 개념을 해명해 보려는 데 있다. 특히 필자는 휴웰의 '귀납의 동조'를 다음과 같은 세가지 물음을 중심으로 고찰해 보려 한다. (1)귀납의 동조란 정확히 무엇인가? (2)귀납의 동조를 가져오는 가설의 가치는 무엇인가? (3)귀납의 동조는 이론에 대한 어떤 의미의 테스트인가?

이러한 논의를 통해서 필자는 먼저 과학적 발견의 과정에 관한 휴웰의 주장은 잘 확립된 가설-연역주의의 입장임을 밝히려 한다. 또한 휴웰에 있어서 귀납은 과학자의 창조적 직관에 의해 언어된 개념에 의해 사실들을 총괄(colligation)함으로써 가설을 발견하는 과정이라는 것이 밝혀질 것이다.

귀납의 동조에 관해서는 다음과 같은 사실이 분명해 질 것이다. (1)귀납의 동조는 두 가지 혹은 그 이상의 일반화를 보다 포괄적인 이론으로 통합하는 과정으로서, 그것은 가설을 과학적 이론으로 수락하는 기준으로서의 역할을 한다. (2)귀납의 동조를 가져오는 동조적 가설은 별개의 종류로 보이는 데이터들 하나의 종류로 환원시켜 주는 가치를 지닌다. (3)귀납의 동조가 이루어질 수 있는가의 여부가 이론의 적합성의 기준이 되며, 그것은 과학이론에 대한 사실적 테스트인 동시에 심리적 테스트이다. 아울러 필자는 휴웰이 자신의 방법론을 뉴턴의 물리학과 같이 과학사적으로 중요한 발견 과정을 해명하는 데 적용하는 실례를 보여 주려고 하였다.

I. Introduction

William Whewell figures prominently in 19th century philosophy of science. Looking back we can say that he anticipated central issues of the philosophy of science of our days, such as the importance of bold ideas, the role of intuition in induction, and the conception of progressiveness. Throughout his scientific and philosophical career Whewell had a deep concern for methodological issues. His own positive methodological theories were developed in the three editions of *Philosophy of the Inductive sciences*¹⁾.

Whewell is of interest to modern readers because he, *inter alia*, based his philosophy of science on a study of the history of science. Many recent writers have attempted to understand William Whewell's philosophy of science because they think that Whewell's notion of 'the consilience of inductions' is able to shed a new light on the recent issues in the philosophy of science, and it can show some important but neglected aspects of the practice of science with which no contemporary work by philosophers of science deals adequately.

The main concerns of recent papers on Whewell's philosophy of science can be divided into three categories. First, some writers like Larry Laudan and Mary Hesse have examined Whewell's notion of the consilience of induction with the concern on the problem of confirmation.²⁾ They have attempted to reconstruct the concept of consilience within the context of confirmation theory. Secondly, some writers like William Harper and Malcolm Forster apply Whewell's philosophy of scientific discovery to the problem of understanding the nature of unification and explanation by the composition of causes in Newtonian mechanics.³⁾ Forster's paper was written with the conviction that Whewell's account of scientific discovery would provide us with a philosophical theory of scientific explanation and inference that would hold middle-ground between the anti-realism of the logical positivists and the modernday radical realism.⁴⁾ Thus these attempts can be thought to be related with the issue of scientific realism. Thirdly, some writers like Robert E. Butts and Menachem Fisch are concerned with Whewell's employment of the contention that in the course of scientific investigation necessary truths are actually arrived at and recognized.⁵⁾ What Butts has been mainly concerned with in a series of

1) William Whewell, *Philosophy of the Inductive Sciences*, 2 Vols (London: John W. Parker and Son, 1842). I shall refer to this work as PIS.

2) See Larry Laudan(1971), "William Whewell on the consilience of Inductions"; Mary Hesse(1971), "Whewell's Consilience of Inductions and Predictions". As Butts has pointed out, "Laudan's task was to show that Whewell's concept of consilience entails that the most important consiliences occur where a certain maximally acceptable level of corroboration of a theory has been reached": Robert E. Butts(1977), p.72. Hesse's interest has been in seeing whether she can reconstruct something like Whewell's consilience in the context of normal probabilistic confirmation theory" (*Ibid.*)

3) See Malcolm Forster(1988), "Unification, Explanation, and the Composition of Cause in Newtonian Mechanics"; William Harper(1989), "Unification, Explanation, and the Composition of Cause in Newtonian Mechanics"; William Harper(1989), "Consilience and Natural Kind Reasoning."

4) Harper also expresses his similar conviction with Forster that "Newton's reasoning in support of universal gravitation is a vivid illustration of non-empiricist aspects of scientific practice": William Harper(1989), p.117.

5) Butts(1965), "Necessary Truth in Whewell's Theory of Science"; (1973), "Whewell's Logic of Induction"; (1977), "Consilience of Inductions and the Problem of Conceptual Change in Science".

publications on Whewell, I think, is the problem of how consilience can warrant necessity. In his recent paper, ⁶⁾ Butts has tried to show that the history of science is in some important way the justification of science with a more accurate reconstruction of Whewell's employment of the concept of consilience. Fisch has pursued the question of how we should understand Whewell's notion of consilience as an evaluative criterion for the truth of scientific theory.⁷⁾

The aim of this paper is twofold. First, this paper is concerned with Whewell's account of scientific method. I shall try to show that Whewell's idea of scientific method is an well-established form of hypothetico-deductivism. Secondly, I would like to clarify Whewell's notion of consilience of inductions as a criterion of theory appraisal. For doing that, I shall consider the following three questions about the consilience of inductions: (1) Precisely what is consilience? (2) What is the value of a hypothesis by which consilience of inductions occurs? (3) What does Whewell mean by saying that consilience is a test of the truth of the theory?

After considering the above questions I shall argue that consilience of induction includes two kinds of test: on the one hand it is a evidential test of the truth of theory; on the other hand it includes the extra-evidential test like simplicity. Additionally, I shall argue that Whewell's notion of consilience shows us under what conditions there is a simplest theory that entails a given body of evidence statements, and under what condition a theory can have explanatory connection with evidence, by taking Newton's arguments for gravitation for examples.

To these ends, this paper will proceed as follows: First, I shall briefly mention some premises of Whewell's account of the scientific discovery; secondly, Whewell's hypothetico-deductivism on the scientific practice will be presented; thirdly, I shall examine Whewell's account on the notion of consilience and its relation to the simplicity and explanatory power of theories; meanwhile I will show how Whewell applies his account of scientific discovery to explaining Newton's case.

II. The Nature of Scientific Knowledge

Before explicating Whewell's main idea concerning the scientific method, I shall briefly review Whewell's conception of the nature of scientific knowledge.

1. Whewell's definition of the philosophy of science

Whewell begins his aphorisms concerning ideas with the statement that "Man is the Interpreter of Nature, Science the right interpretation." (PIS, II, p.443) Whewell thinks that the goal of science is to interpret nature, not to catalogue or describe it. For him, the goal of science is not to device compendious schemes for summarizing facts, nor is it the linguistic mirroring of the extra-linguistic.

According to Whewell, in all sciences "it is familiarly understood and assumed that their doctrines are obtained by a common process of collecting general truths from particular observed facts, which process is termed induction." (PIS, I, p.2) By that process, science has achieved the certainty and con-

6) Butts(1977), "Consilience of Inductions and the Problem of Conceptual Change in Science."

7) Menachem Fisch(1984).

stant progress. Thus, what Whewell thinks as the task of the philosophy of science is "examining the ground and nature of that certainty, the causes and laws of that progress." (PIS, II, p.15)

In other words, the subject of the philosophy of science is to find the general laws of the formation of sciences "from a contemplation of the Structure and History of those Sciences." (PIS, I, p.6) Therefore a philosophy of the sciences, for Whewell, "ought to be founded, not upon conjecture, but upon an examination of many instances." We can read Whewell's definition of the philosophy of science in the following paragraph: "The Philosophy of Science, if the phrase were to be understood in the comprehensive sense which most naturally offers itself to our thoughts, would imply nothing less than a complete insight into the essences and conditions of all real knowledge, and an exposition of the best methods for the discovery of new truths." (PIS, I, p.1)

From the above, that Whewell viewed science as the clearest examples of knowledge and of discovery, and as an historically developing process can be known. Whewell wanted his theory of method to capture the best mode of acquiring scientific knowledge and to explain the prized kind of historical event of scientific discovery.

2. The fundamental antithesis

In order to understand Whewell's entire theory of the structure and growth of scientific knowledge, I think, we have to understand what he refers to "an antithesis or opposition", (PIS, I, p.16) because it is the foundation to both his historiography and methodology of science.

The fundamental contention of Whewell's theory of knowledge is that all real knowledges from common perception to science's most elaborate theories are antithetical. The simplest and most idiomatic expression of the antithesis is, for Whewell, the opposition between things and thoughts. Here thoughts are what we think, or actions of our minds; things on the contrary are something different from ourselves and independent of us. So Whewell says that "in every part of my knowledge, there must be something about which I know, and an internal acts of me who knows." (PIS, I, p.17) What Whewell means by the antithesis of thoughts and things are nicely expressed in the following statements: "Knowledge implies a combination of Thoughts and Things. Without this combination, it would not be knowledge. Without Thoughts, there could be no connexion; Without Things, there could be no reality." (PIS, I, p.18) In Whewell, these two elements are regarded as the two-fold foundation of all scientific knowledge. The distinction of necessary and contingent truth involves the same antithesis of thoughts and things. According to Whewell, "necessary Truths are derived from our Thoughts; Experiential Truths are derived from our observation of Things about us." (PIS, I, p.21) The antithesis of theory and fact also is based on the fundamental antithesis of thoughts and things. Whewell explains this as follows; "For a Theory(that is, a true theory) may be described as a thought which is contemplated distinct from Things and seen to agree with them; while a Fact is a combination of our Thoughts with Things in so complete agreement that we do not regard them as separate." (PIS, I, p.24)

Whewell thinks that facts involve thoughts, for we know facts only by thinking about them. He puts this fact as follows: "A theory is an Inductive Proposition, and the Facts are the particular observations from which, as I have said, such propositions are inferred by Induction." (PIS, I, p.24) To

understand this antithetical structure is quite important, I think, to understand Whewell's conception of the mode of scientific growth. According to Whewell, we can separate each members of the antithesis in order that the nature and structure of knowledge may be seen, yet we cannot distinguish and define the member of these antitheses separately because knowledge requires the union of these two elements. It is rather that "Theories become Facts, by becoming certain and familiar: and thus, as our knowledge becomes more sure and more extensive we are constantly transferring to the class of facts, opinions which were at first regarded as theories." (PIS, I, p.46)

3. The nature of scientific induction

Because the notion of consilience is so closely connected with Whewell's doctrine of induction, the nature of Whewellian induction should be clearly understood. According to Whewell, the nature of inductive process can be clarified by comparing it with deductive process. We can read his comparison of induction and deduction in the following passage:

The contrast of the Deductive and Inductive process is obvious. In the former, we proceed at each step from general truths to particular applications of them; in the latter, from particular observations to a general truth which includes them. In the former case we may be said to reason downwards, in the latter case, upwards; for general notions are conceived as standing above particulars. (PIS, I, p.23)

While deductive truths are the results of relations among our own thoughts, in Whewell, inductive truths are relations which we discern among existing things. Whewell takes Kepler's work as an example of inductive process as follows: "Kepler started from more exact observations of the sun, and compared them with a supposed motion in a certain ellipse; and was able to show that, not a circle about an eccentric point, but an ellipse, supplied the mode of conception which truly agreed with the motion of the sun about the earth." (PIS, I, p.22)

According to Whewell, in such case in which truths are obtained by beginning from observations of external things and by finding some notion with which the things agree, the truths are said to be obtained by induction. Therefore in Whewellian notion, induction is not simply the process by which we collect a general proposition from a number of particular cases. It is rather the process in which "a new element added to the combination by the very act of thought by which they combined." (PIS, II, p.48) Whewell says that "there is a conception of mind introduced in the general proposition, which did not exist in any of the observed facts." (PIS, II, p.48) Once by this process an inductive truth is obtained, it should be proved "like the guess which answers a riddle, by its agreeing with the facts described." (PIS, I, p.23)

Now we have to remark that in Whewell's notion induction is not terminated by itself, rather it continues to make a chain of inductive process of wider generalization. This character of inductive process comes from the very fact that by the fundamental antithesis theories become facts, by becoming certain and familiar.

According to Whewell, in the progress of human knowledge there are successive generalizations. Whewell explains this fact as follows.

The theoretical views which one generation of discoverers establishes, become the facts from which the next generation advances to new theories. As men rise from the particular to the general, so, in the same manner, they rise from what is general to what is more general. Each induction supplies the materials of fresh inductions; each generalization, with all that it embraces in its circle, may be found to be but one of many circles, comprehended within the circuit of some wider generalization.(PIS, I, pp.46—47)

Whewell claims that the whole of the history of science is full of suggestions and exemplifications of this course of things. One of the most conspicuous instance of this succession of inductive process is taken from astronomy, especially the wonderful advance from Kepler to Newton. Whewell puts it as follows:

Kepler's laws of the elliptical motion of the planets were established; and these laws immediately became the facts on which the mathematicians had to found their mechanical theories. From these facts, Newton, as we have related, proved that the central force of the sun retains the planets in their orbits, according to the law of the inverse square of the distance. The same law was shown to prevail in the gravitation of the earth. It was shown, too, by induction from the motions of Jupiter and Saturn, that the planets attract each other; by calculations from the figure of the earth, that the parts of the earth attract each other; and, by considering the course of the tides, that the sun and moon attract the waters of the ocean. And all these curious discoveries being established as facts, the subject was ready for another step of generalization.(PIS, I, p.48)

Recent discussion of the so-called deductive model of scientific explanation has drawn attention to certain features of hierarchical or subsumption types of scientific systems, in which statements in the observation language are subsumed under (explained by) empirical generalizations, which in turn are subsumed under(explained by) higher level theoretical generalizations. Whewell's theory of science as successive generalization is one early form of this kind of philosophy of science. That Whewell's theory of induction, in its full form, expresses what is now called the hypothetico-deductive character of well-developed will be shown in the next section.

III. Whewell's Hypothetico-deductivism

In Whewell, the whole process by which a scientific knowledge can be established may be divided into two contexts: the first is the context of hypothesis-construction; the second is the context of test of it.

According to Whewell, the context of hypothesis-construction consists of two processes: the Explication of conception and the colligation of facts. And the context of test of hypothesis consists in the consilience of induction. We can read this in the first aphorisms concerning science: "The two processes by which Science is constructed are the Explication of conception and the colligation of Facts."(PIS, II, p.466) We must examine these two elements of the inductive process to understand Whewell's insight on the nature of scientific procedure. We shall begin with the explication of conception.

1. The explication of conception

What Whewell means by conception is made clear in the following passage:

We have given the appellation of ideas to certain comprehensive forms of thought — as space, number, cause, composition, resemblance—which we apply to the phenomena which we contemplate. But the special modifications of these ideas which are exemplified in particular facts, we have termed Conceptions; as a circle, a square number, an accelerating force, a neutral combination of elements, a genus. (PIS, II, pp.5—6)

Whewell insists that such conceptions involve in themselves certain necessary and universal relations derived from the ideas which he just enumerated, and these relations are an indispensable portion of the texture of our knowledge. In other words, the explication of conceptions is the process by which we bring the clearness of our ideas to bear upon the formation of our knowledge. So the conceptions must be carefully unfolded, so as to bring into clear view of the elements of truth with which they are marked from their origin. This is one of the processes in which scientific hypothesis are constructed. Whewell goes on to say that the acquisition of the explication of conceptions has resulted mainly from controversies between men of science over the definition concerning the conception of force. What Whewell means by the explication of conceptions is the clear development from fundamental ideas expressed in the form of definitions or axioms.

Now Whewell examines how science is built up by the combination of facts. According to Whewell, “when we inquire what Facts are to be made the materials of Science, perhaps the answer which we should most commonly receive would be, that they must be True Facts, as distinguished from any mere inferences or opinions of our own.” (PIS, II, p.27) However, Whewell points out that “facts, when used as the materials of physical Science, must be referred to Conceptions of the only, all emotions of fear, admiration and the like, being rejected or subdued.” (PIS, II, p.31) Thus in collecting facts which are to be made the basis of science, Whewell says, “the Facts are to be observed, as far as possible, with references to place, figure, number, motion, and the like Conceptions; which, depending upon the Ideas of Space and Time, are the most universal, exact, and simple of our conceptions.” (PIS, II, p.32) Furthermore, “we are not to confine ourselves to these: but are to consider the phenomena with reference to other Conceptions also.” (PIS, II, p.33) For instance, in the science of mechanics, we are not to confine ourselves only to observing motions as they take place in time and space, but further, referring them to force as their cause.

Here another process which is closely related with the explication of conception is operated. This process Whewell terms the decomposition of facts. In this process, according to Whewell, “we resolve the complex appearances which nature offers to us, and the mixed and manifold modes of looking at these appearances which rise in our thoughts, into limited, definite and clearly understood portions.” (PIS, II, p.33) Moreover, in this process, “the facts which we assume as the basis of science are to be freed from all the mists which imagination and passion throw round them; and to be separated into those elementary Facts which exhibit simple and evident relation of Time, or Space, or Cause, or some other Ideas equally clear.” (PIS, II, p.33) This is the beginning of exact knowledge—the fir-

st step in the formation of all science. Thus the 'explication of conceptions' and the 'decomposition of fact' are the twin processes which are preparatory stages in the context of hypothesis-construction.

2. The colligation of facts

Now Whewell explains the process in which "Facts are bound together by the aid of suitable conceptions." (PIS, II, p.36) This part of the formation of our knowledge Whewell calls "the Colligation of Facts." Colligation of facts is a term that can be applied "to every case in which, by an act of the intellect, we establish a precise connexion among the phenomena which are presented to our senses." (PIS, II, p.36) Whewell's conception of this process is clearly shown in the following instances:

The Facts that the planets revolve about the sun in certain periodic times and at certain distances, are included and connected in Kepler's Law, by means of such conceptions as the squares of numbers, the cubes of distances, and the proportionality of these quantities. Aging the existence of this proportion in the motions of any two planets, forms a set of Facts which may all be combined by means of the Conception of a certain central accelerating force, as was proved by Newton. (PIS, II, p.36)

With the above conception of colligation Whewell defines induction as follows: "Induction is a term applied to describe the process of a true Colligation of Facts by means of an exact and appropriate Conception. An Induction is also employed to denote the proposition which results from this process." (PIS, II, p.468) According to Whewell, the two operations—the explication of the conceptions of our minds, and the colligation of observed facts by the aid of such conceptions—are inseparably connected with each other. Whewell goes on to say as follows: "When united, and employed in collecting knowledge from the phenomena which the world presents us, they constitute the mental process of Induction; which is usually and justly spoken of as the genuine source of all our real general knowledge respecting the external world." (PIS, II, pp.46–47) The mental process of induction here is, I think, the most original part of Whewellian induction. Whewell describes this mental process of induction as follows:

The particular facts are not merely brought together, but there is a New Element added to the combination by the very act of the thought by which they are combined. (PIS, II, p.48)

The facts are known, but they are insulated and unconnected, till the discoverer supplies from his own stores a Principle of Connexion. The pearls are there, but they will not hang together till some one provides the String. (PIS, II, p. 48)

It is evident from these passages that in Whewellian inductive inference, there is a conception supplied by the mind and superinduced upon the facts, and by the conception we can consider the phenomena before us as "mere exemplification of some Ideal case in which the relations are complete and intelligible." (PIS, II, p.49) Whewell suggests an example:

The distances and periods of the planets were so many separate facts: by Kepler's Third Law they are connected into a single truth; but the Conceptions which this law involves were supplied by Kepler's mind, and without these,

the facts were of no avail. The planets described ellipses round the sun, in the contemplation of others as well as of Newton; but Newton conceived the defection from the tangent in these elliptical motions in a new light—as the effect of a Central Force following a certain law; and then it was, that such a force was discovered truly to exist. (PIS, II, pp.48—49)

In his *Novum Organon Renovatum*, Whewell divides “the Colligation of ascertain facts into general propositions” into three steps:

- (1) the selection of the ideas;
- (2) the construction of the conception;
- (3) the determination of the magnitudes.

As Whewell explains it: “These three steps correspond to the determination of the Independent Variable, the Formula, and the Coefficients, in mathematical investigations, or to the Argument, the Law and the Numerical Data in a table of an Astronomical or other Inequality.”⁸⁾ In his recent paper Malcolm Forster offers some interesting examples to explicate how these three steps work in real sciences.⁹⁾ One of these is the empirical work on the tides. Tidology aims at discovering the laws governing the height of successive high waters, H , at a particular place. The first step is the determination of the independent variable.

In this example, one such variable is the distance from syzygy of the Moon, D (the angle of the moon solar conjunction), which increases from 0 to 360 degrees about once every 4 weeks. When the height of high waters, H , is plotted on a graph against this variable, D , a roughly sinusoidal variation in H is detected of a period of 180, with maxima at approximately $D=0$ ($=360$) and $D=180$. In this case (of fitting a sinusoidal curve to the data) the coefficients will be the amplitude, the period, and phase, of the fitted curve.¹⁰⁾

The second step is the selection of the best fitting formulas representing the variation of high tide with respect to this independent variable. The last step is the determination of the magnitude: the determination of values of coefficient of the above, and the numerical ratio between its high and low values. As special methods of induction applicable to determine the formulas and magnitude Whewell suggests the methods of curves, of means, of least squares, and of residues.¹¹⁾

We have so far examined Whewell's account on the context of hypothesis-construction. From this we can be aware that in this context the act of invention is requisite, and the output of that act is hypothesis.

However, as Whewell reminds us, “the framing of hypotheses is, for the inquirer after truth, not the end, but the beginning of his work.” (PIS, II, p.57) In other words, each hypothesis is not invented to be followed, but to be put into a course of active experiment. The following analogy would make his idea on the relation between the hypothesis and the observations clear: “The hypothesis is like the Captain, and the observations like the soldiers of an army! While he appears to command them, and

8) R.E. Butts(1968), *William Whewell's Theory of Scientific Method*, p.211. Hereafter Butts(1968).

9) M. Forster (1988), pp.67—68.

10) *Ibid.*, p.67.

11) I refer to Harper's version of Forster's interpretation: W. Harper(1989), pp.117—118.

in this way to work his own will, he does in fact derive all his power of conquest from their obedience, and becomes helpless and useless if they mutiny.(PIS, II, p.59) Therefore, it is important for scientist to “possess talents and means for rapidly testing each supposition as it offers itself”, because scientists have constantly to work their way onwards “by means of hypotheses, false and true.”(PIS, II, p.59)

From the above it is evident that in Whewell our choice of a formula in a colligation is an hypothesis which should be subjected to empirical tests. Next section will be devoted to explicating Whewell's tests of hypotheses.

3. Context of theory appraisal

Tests of hypothesis, in Whewell's view, seem to be the most important part of the inductive process. Whewellian tests of hypotheses come in three distinct categories.

1) Prediction of same kind of phenomena

The first category of test consists in its capacity to predict the phenomena of the same kind. Whewell speaks of this in the following terms:

The hypotheses which we accept ought to explain phenomena which we have observed. But they ought to do more than this. Our hypotheses ought to foretell phenomena which have not yet been observed; at least all the same kind as those which the hypothesis implies that it is held to be true of all particular instances. That these cases belong to past or to future times, that they have or have not already occurred, makes no difference in the applicability of the rule to them.(PIS, II, pp.62—63)

It is evident from this passage that in Whewell's view a hypothesis can be regarded to be verified as right and useful, only if we can predict the results of new combinations, as well as explain the appearances which have occurred in old ones with certainty and correctness.

What Whewell means by “to predict the phenomena” can be shown by the following passage:

But to predict what has not been observed, is to attempt ourselves to use the legislative phrases of nature; and when she responds plainly and precisely to that which we thus utter, we cannot but suppose that we have in a great measure made ourselves masters of the meaning and structure of her language.(PIS, II, p.64)

However, we should notice that on Whewell's view the prediction of the same kind of phenomena cannot guarantee the truth of a hypothesis.

We can take one example of Whewell to support the claim that on Whewell's view the prediction of result of the same kind is not a proof of real success of a hypothesis:

For example, the Epicyclical Theory of the heaven was confirmed by its predicting truly eclipses of the sun and moon, configurations of the planets, and other celestial phenomena; and by its leading to the construction of Tables by which the places of the heavenly bodies were given at every moment of time. The truth and accuracy of these predictions were a proof that the hypothesis was valuable, and, at least to a great extent true; although as was afterwards found, it involved a false representation of the structure of the heavens.(PIS, II, p.63)

On Whewell's view, for a hypothesis to be regarded as real success, it should pass two other categories of test.

2) The consilience of inductions: prediction of even different kinds

The second category of test, the consilience of inductions is the special case of successful prediction in which "apparently heterogeneous classes of phenomena turn out to be, both of them, deducible from one and the same hypothesis."¹²⁾ Whewell's definition of the consilience of inductions is as follows: "The consilience of Inductions takes place when an Induction, obtained from one class of facts, coincides with an Inducton, obtained from another different class. This consilience is a test of the truth of the Theory on which it occurs." (PIS, II, p.469) Whewell's characterization of the nature of cases on which the consilience of inductions can be seen in the following passage:

Accordingly the cases in which inductions from classes of facts altogether different have thus jumped together, belong only to the best established theories which the history of science contains. And as I shall have occasion to refer to this peculiar feature in their evidence, I will take the liberty of describing it by a particular phrase; and will term it the Consilience of Inductions. (PIS, II, p.65)

With these characterizations in mind, I want to consider the following three questions to be asked about the consilience of inductions: (1) Precisely what is consilience? (2) What is the value of a hypothesis by which consilience of inductions occurs? (3) What does Whewell mean by saying that consilience is a test of the truth of the theory?

Whewell gives various characterizations of the concept of consilience, but one of his brief statements will do for our purposes:

If we take one class of facts only, knowing the law which they follow, we may construct a hypothesis, or perhaps several, which may represent them; and as new circumstances are discovered, we may often adjust the hypothesis so as to correspond to these also. But when the hypothesis, of itself and without adjustment for the purpose, gives us the rule and reason of a class of facts not contemplated in its construction, we have a criterion of its reality, which has never yet been produced in favour of falsehood. (PIS, II, pp.67—68)

Here I want to introduce a formal mode of consilience suggested by Butts, because that, I think, is most faithful explication of Whewellian sense of consilience. According to Butts, Whewell's concept of consilience can be formulated as follows:¹³⁾

a) Given two evidence classes E1 and E2, and two laws L1 and L2, at time t_1 , L1 explains E1, and L2 explains E2, and there are no inductive reasons for supposing that L1 and L2 are connected: at t_1 it is thought that E1 and E2 are disjoint.

b) At some later time t_2 a theory T is introduced. L1 and L2 become consilient at t_2 with respect to T when they both logically derivable from T, when T hypothetico-deductively explains both L1 and

12) C.J. Ducasse(1960), p.212.

13) R.E. Butts(1977), pp.74—75.

L2, and, derivatively, explains E1 and E2. At t_2 , then E1 and E2 are no longer thought to be disjoint.

Suggesting the above formal model, Butts insists that Whewell clearly accepted the hypothetico-deductive method and insisted to the end that all proper scientific systems be cast in deductive form.

Let us put aside the discussion about Butts claim that a consilience has hypothetico-deductive character, and consider the second question above. Whewell's thought on the value of a 'consilative' hypothesis is given in the following passages:

But the evidence in favour of our induction is of a much higher and more forcible character when it enables us to explain and determine cases of a kind different from those which were contemplated in the formation of our hypothesis. (PIS, II, p.65)

But when the hypothesis, of itself and without adjustment for the purpose, gives us the rule and reason of a class of facts not contemplated in its construction, we have a criterion of its reality. (PIS, II, pp.67–68)

What these passages are saying, I think, is that the values of a consilative hypothesis are i) that it explains events of a kind different from those which were contemplated in the formation of our hypothesis, and furthermore ii) that it achieves the reduction of the apparently different kinds of data into one and the same kind.

At this point, I agree with Laudan's claim that "the real strength of such an consilative hypothesis is usually that it shows that events previously thought to be of different kinds are, as a matter of fact, the 'same' kind of event."¹⁴

For Whewell, the most prominent examples of consilative hypotheses are great scientific syntheses like the one achieved by Newton's inverse-square law. The following statements clearly show this:

Thus it was found by Newton that the doctrine of the Attraction of the Sun varying according to the Inverse Square of this distance, which explained Kepler's Third Law of the proportionality of the cubes of the distances to the squares of the periodic time of the planets, explained also his First and Second Laws of the elliptical motion of each planets; although no connexion of these laws had been visible before. (PIS, II, pp.66–67)

It is evident from the above that Newton's hypotheses have the two values of a consilative hypothesis.

Now, why does Whewell think that consilience is a test of the truth of the theory? Whewell's answer for this question can be found in the following passage:

These instances on which this (consilience) has occurred, indeed impress us with a conviction that truth of our hypothesis is certain. (PIS, II, p.65)

As Laudan pointed out, this sentence can probably be taken as "a reasonably accurate description of the psychological force of consiliences." This psychological tendency of Whewellian concept of truth can be shown in the following passage also.

14) Larry Laudan (1971), p.374.

When such a convergence of two trains of induction points to the same spot, we can no longer suspect that we are wrong. Such an accumulation of proof really persuade us that we have to do with a *vera causa*. And if this kind of proof be multiplied; ...; we are still further confirmed in our belief; and by such accumulation of proof we may be so far satisfied, as to believe without conceiving it possible to doubt. In this case, when the validity of the opinion adopted by us has been repeatedly confirmed by its sufficiency in unforeseen cases, so that all doubt is removed and forgotten, the theoretical cause takes its place among the realities of the world, and becomes a true cause. (PIS, II, p. 286)

Therefore, from this passage, we can make two points. First, we should conclude that Whewell's references to consiliences as tests of truth should be read as suggesting that consilience, like simplicity, is an extra-evidential test of theories. Secondly, it is evident that when Whewell says that consilience is a "test of the truth of the Theory", he means that consilience increases the probability of the theory to a considerable extent and then increases the degree of confidence. Thus, in this respect, problem of consilience can be related with the problem of probabilistic confirmation theory. Therefore, Butts' claim that consilience has nothing to do with the confirmation or corroboration of hypotheses¹⁵⁾ is, I think, excessive and neglects this point.

In his recent paper, Malcolm Forster explicates what Whewell means by consilience of inductions as follows:

Here we must recall Whewell's insistence that every colligation of facts adds a new conception to the facts. Now, if we consider two separate domains of inquiry, then the colligations of facts within one domain will introduce conceptions unconnected (or not thought to be connected) with the conceptions introduced in the second domain. When these different inductions, i.e. colligations of facts, "jump together", Whewell means that the magnitudes independently measured within separate domains agree with one another, or are connected by some law-like regularity (i.e. connected by some formula).¹⁶⁾

Forster makes two points here. First, Forster claims that each case of consiliences is an high order induction. Second, he claims that by consilience Whewell means that the magnitudes independently measured within separate domains agree with one another, or are connected by some law-like regularity.

The first point of Forster is quite correct for the following reasons. For Whewell, as we have seen above, in the successive generalization, "the inductive proposition is a Theory with regard to the Facts which it includes, while it is to be looked upon as a Fact with respect to the higher generalizations in which it is included." (PIS, II, p.94) For example, that the planet Mars revolves in an ellipse about the sun is a theory to Kepler, employed in endeavouring to combine the separate observations by the conception of an ellipse; it is a fact to Newton, engaged in inferring the law of force from a knowledge of the elliptical motion. Therefore, consilience of induction can be regarded as the process of colligating the facts which has been theories in the lower level, by a new conception. On this point, Forster's first claim is, I think, a correct explication of Whewell's view.

15) R.E. Butts(1977), pp.73-74.

16) Malcolm Forster(1988), p.74.

However, Forster's second claim is controversial. According to Forster, Whewell understands the consilience of induction as a feature of the evidence demonstrated by the successful application of magnitudes determined by the facts of one domain in predicting facts in a different domain. Yet that magnitudes independently measured within separate domains agree with one another is not enough, I think, to capture the meaning of consilience, because in consilience the cases colligated have to be of different kinds. Forster's second point, therefore, I think, neglects the qualitative aspect of consilience. Thus, what we have to explicate is how consilience reduces two classes of phenomena to one general hypothesis. The character of unification of different kinds of phenomena by consilience has to be shown by explicating the third test of hypotheses.

3) Consilience and Simplicity

The third test of true hypotheses is introduced by Whewell in the following terms:

This being the mode in which theories are after framed, we have to notice a distinction which is found to prevail in the progress of true and of false theories. In the former class all the additional suppositions tend to simplicity and harmony; the new suppositions resolve themselves into the old ones, or at least require only some easy modification of the hypothesis first assumed: the system becomes more coherent as it is further extended. The elements which we require for explaining a new class of facts are already contained in our system. Different members of the theory run together, and we have thus a constant convergence to unity. In false theories, the contrary is the case. The new suppositions are something altogether additional;—not suggested by the original scheme; perhaps difficult to reconcile with it. Every such addition adds to the complexity of the hypothetical system, which at last becomes unmanageable, and is compelled to surrender its place to simple explanation. (PIS, II, pp.68—69)

In this passage, Whewell tells us that as the various suppositions are added in the course of its development a true theory tends toward greater simplicity and unification, while a false theory degenerates into complications.

Whewell's examples of false theories which have no simplicity of truth includes the ancient doctrine of eccentrics and epicycles and the Cartesian system of vortices. On the contrary, the theory of gravitation is, according to Whewell, the most convincing manifestation of simplicity and unity. Whewell explicates the simplicity and unity of the theory of gravitation as follows:

The theory of Gravitation, on the other hand, become more simple as the facts to be explained became more numerous. The attraction of the sun accounted for the motion of the planets; the attraction of the planets was the cause of the motion of the satellites. But this being assumed, the perturbations, the motions of the nodes and apheia, only made it requisite to extend the attraction of the sun to the satellites, and that of the planets to each other:— the tides, the nothing more than that the moon and sun should attract the parts of the earth, and that these should attract each other;— so that all the suppositions resolved themselves into the single one, of the universal gravitation of all matter. (PIS, II, p.70)

One of the controversial point here is of whether for Whewell the concepts of consilience, simplicity, and successive generalization mean the same thing. Butts suggests that for Whewell the three most prominent features revealed by the inductive tables—consilience, simplicity, and successive gen-

eralization—are concepts meaning the same thing. The following passage can be regarded as supporting Butts' claim:

The two last sections of this chapter direct our attention to two circumstances, which tend to prove, in a manner which we may term irresistible, the truth of the theories which they characterize;—the Consilience of Inductions from different and separate classes of facts;— and the progressive Simplification of the Theory as it is extended to new cases. These two characters are, in fact hardly different; they are exemplified by the same cases.(PIS, II, p.73)

It is evident from this passage that for Whewell consilience and simplicity are hardly different, and they are exemplified in the same cases.

However, Forster claims that consilience is not the same as simplicity: the former merely gives rise to a convergence towards the latter. Forster wants to show that a consilience of induction has led us to a simplification in our ontology, but we should not make the mistakes of conflation the two steps. He supports his claim by the following statements:

The goal—of simplicity and ontological unification—is only achieved once the observed consilience is deemed to be nonaccidental and is subsequently explained in terms of an identity. Consilience is the evidence for accepting the identity. After that, the unified theory can be further tested by its deductive consequences, but it is the discovery of the identities and unity in nature that is the admirable part of the process.¹⁷⁾

What Forster means by identity is the identity relation of apparently different kinds of phenomena, which explains the observed correlation between independent measurements. On this view, the consilience is the evidence for accepting the identity, and the consilience of inductions gives rise to the convergence toward simplicity and unity by providing the evidence for introducing an identity. The following passage seems to support Forster's claim: "The Consilience of our Induction give rise to a constant convergence of our Theory towards Simplicity and Unity."(PIS, II, p.74) From the fact given, we can conclude that while the consilience of induction is Whewell's second test, the convergence toward simplicity is his third test of a hypothesis, and the two are not "identical in their essence", even though both features are often exemplified by the same case.

However, Whewell does not tell us why the consilience can facilitate convergence toward simplicity and unity. What Whewell suggests is only that there is some close connection between consilience and the explanatory virtues of convergence toward simplicity and unity exhibited in successful theory. Thus, the question of whether consilience is the same as simplicity is not, I think, essential. What Whewell suggests is that the concept of consilience included two aspects: one is the substantial part in which the evidence for accepting the identity of apparently different kind of phenomena is provided by the measurements of the same magnitude; the other is the former part which has explanatory virtues of convergence to simplicity and unity which can function as another criterion of acceptability.

17) M. Forster(1988), p.79.

IV. Concluding Remarks

According to Forster, Whewell has provided the following picture of science.

At the phenomenological level a colligation of facts will generally introduce the means of measuring formulas co-efficient, which may be instances of variable quantities when viewed more globally. These 'theoretical' variables may themselves enter into higher-level colligations, which may then introduce further coefficients, and so on. This hierarchical procedure will eventually end when the coefficient introduced are no longer variables—as in the case of fundamental physical constants—or when the coefficient introduced are easily interpreted as conversion factors between the different scales of measurement.¹⁸⁾

With the fact that Whewell's emphasis is on the philosophy of scientific discovery in mind, Forster rejects the top-down emphasis of hypothetico-deductivism which seems to him to obscure the most important component of this process—the discovery that two, or more, coefficients invented to explain diverse phenomena actually represent a common "cause."¹⁹⁾ In Forster's view this feature is given its emphasis in the "bottom up" approach to the philosophy of science which his explication of Whewell's philosophy of scientific discovery takes. I agree with Forster that the bottom-up character of Whewell's philosophy of scientific discovery is shown well in his explication. However, as we have seen above, Whewell clearly accepts the hypothetico-deductive method and insists that all proper scientific systems be cast in deductive form. The hypothetico-deductive approach to his method can have the merit of explicating how consilience operates as a test of hypothesis. Moreover, it can clearly show us that consilience is an extra-evidential test of theories. Yet, Forster's interpretation of Whewell's conception of consilience is sufficient to show that consilience is an evidential test of theories. Therefore, accepting the merits of both approaches, I would like to conclude that consilience includes two kinds of test: on the one hand, it is an evidential test of the truth of the theory; on the other hand, it includes the extra-evidential test like simplicity.

18) M. Forster(1988), p.77.

19) M. Forster(1988), pp.77—78.

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