HISTORY OF THE 19TH CENTURY CELL THEORY IN THE LIGHT OF PHILIP KITCHER'S THEORY OF UNIFICATION

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ŞAHİN ALP TAŞKAYA

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Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Arts

Prof. Dr. Ahmet İnam
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Arts

Assoc. Prof Samet Bağçe
Supervisor

Examining Committee Members

Assoc. Prof. Barış Parkan (METU,PHIL)

Assoc. Prof. Samet Bağçe (METU,PHIL)

Assoc. Prof. Erdoğan Yıldırım (METU,SOC)

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ABSTRACT

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Taşkaya, Şahin Alp
M.A., Graduate School of Social Sciences
Supervisor: Assoc. Prof. Samet Bağçe

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In the turn of 19th century, Biology as a scientific discipline emerged; focused on every aspect of organisms, there was no consensus on the basic entity where the observed phenomena stemmed from. By the half of the century, the Cell Theory stepped in and unified the sub-disciplines of Biology under a few, but encompassing statements. In this thesis, the history of Cell Theory is handled through Philip Kitcher's Theory of Unification and it is claimed that the idea of unification, in accordance with Kitcher's conception of science, was actively sought and promoted by the scientists, and that a better reading of history of Cell Theory is possible through Theory of Unification.

Keywords: philosophy of science, cell theory, history of biology, theories of scientific explanation

ÖZ

PHILIP KITCHER'IN BİRLEŞTİRİMCİ TEORİSİ IŞIĞINDA 19. YÜZYIL HÜCRE TEORİSİ

Taşkaya, Şahin Alp
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19. Yüzyıl'ın başlarında Biyoloji bir bilimsel disiplin olarak ortaya çıktı. Canlıların tüm özellikleriyle ilgilenilmekle birlikte, bu özellikleri ortaya çıkaran temel birimin ne olduğu konusunda uzlaşı bulunmamaktaydı. Yüzyılın ortalarında, Hücre Teorisi'nin gelişiyle birlikte Biyoloji'nin alt çalışma alanları birkaç kapsayıcı önermenin çatısı altında toplandı. Bu tez çalışmasında, Hücre Teorisi'nin tarihi Philip Kitcher'ın Birleştirimci Teorisi yardımıyla incelenmekte, birleştirim fikrinin dönemin bilim insanlarınca Kitcher'ın bilim anlayışına denk düşen biçimde arandığı ve teşvik ediliği ve Hücre Teorisi tarihinin iyi bir okumasının Kitcher'ın teorisi yardımıyla mümkün olabileceği savunulmaktadır.

Anahtar Kelimeler: bilim felsefesi, hücre teorisi, biyoloji tarihi, bilimsel açıklama teorileri

To My Family

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

19th century witnessed the rise of Biology as a scientific discipline and flourishing of its branches as fruitful research areas. With the fast paced improvements in optics and chemistry, the micro world once inaccessible became a playground for curious minds. By the half of the century, the endeavors bored their prize and the basic principles of Cell Theory were at hand revolutionizing the understanding of living world. Through it, it was now possible to stitch together a great variety of phenomena once thought to be belong different realms and was prized for unifying power. Philip Kitcher, in providing a model of scientific explanation, attaches priority to degree of unification which is achieved by consuming and explaining a variety phenomena via small number of encompassing statements. For this reason, I decided to use history of Cell Theory as a case study for showing that it is as a matter of fact devised and promoted in line with unificationist understanding.

In the preceding lines I will first provide a survey of Karl Hempel's Deductive-Nomological and Inductive-Statistical Explanations, then continue with unificationist understanding of explanation. In the second part, I will give an historical account of Cell Theory in line with John Baker's propositions regarding Cell Theory, followed by reassessment of propositions. Lastly, I will try to look at Cell Theory from an unificationist perspective.

CHAPTER 2

CARL G. HEMPEL AND THE RECEIVED VIEW

In this chapter, I will first introduce the landscape of philosophy of science, before the 1948 article written by Hempel and Oppenheim that laid the basis of Deductive-Nomological Model of Explanation which in turn influenced and provided more or less departing point for other theories of explanation to this day. Then, I will give a brief account of Hempel's D-N model and prominent counter-examples pointing out various weak points of it, and I will proceed with Hempel's second model of explanation, Inductive-Statistical Model which is aimed at laws with statistical nature.

2.1 Philosophy of Science Before 1948

The first half of twentieth century witnessed the shake of mankind's world view in the hands of Einstein's Theory of Relativity. Once taken for granted for millennia, it is understood that the universe was non-Euclidean in essence and time that is thought to be absolute was relative with respect to reference frames. Together, those notions as such being the pillar stone of Newtonian Theory, gave way to idea of “space-time” continuum. Theory of Relativity had repercussions beyond the domain of physics and philosophy was no exception. The success of natural sciences spearheaded by physics led philosophers to devise ways for philosophy to function akin to science. Being influenced by works of Bertrand Russell and Ludwig Wittgenstein, two groups of philosophers residing in Vienna and Berlin, of which some with a background in natural sciences as well as social sciences, gained influence for years to come. Being empiricist in nature and with a scientific attitude, they aimed to “dissolve” everlasting philosophical problems with logical analysis and explications of philosophical concepts, and to come up with a philosophical theory that would not involve any “metaphysical” commitments and that would provide an objective basis for assessing claims of truth of theories, a feat that was highly sought in the upheaval being witnessed in German speaking part of the world in 1930's. Being affiliated with Berlin Society and having the aforementioned ideas with respect to science and philosophy, Carl Hempel was first to tackle on problem of scientific explanation which I will recite in the next section.

2.2 Carl Hempel and Scientific Explanation

Hempel starts his venture of explication of scientific explanation with a particular idea of science and a particular idea of how scientific questions are posed. For him, science is a twofold activity. One stemming from practical nature of mankind which seeks to enhance his knowledge of nature it is in, in order to enhance its position in it. For this end, it is vital to be able to predict future events or digging out laws from observed regularities. The second source of scientific activity is sheer intellectual curiosity which is inherent to mankind and which in the absence of attainable knowledge of events applies to myths to fill the blanks, only to give way to scientific knowledge by time. Be it the former or the latter, this activity has to comply with the criterion of objectivity. In other words, it has to be rest on testable empirical data and the results obtained should be readily disposable in the face of a contrary evidence or of a more adequate theory.

Defined in this fashion, it is possible to ask two kinds of scientific questions, namely that “explanation-seeking-why-questions” and “reason-seeking (epistemic)-why-questions”. The first kind is posed as “Why is it the case that p?” where “p” is the event to occur in a particular fashion and the answer has to involve an explanation accordingly; the second kind is posed as “Why should it be believed that p?” where the answer pertains on to not an explanation, but the reasons that leads the event p to occur just as it is. Hempel claims that the main difference between those two questions is that in the former the statement that conveys the event p is taken to be true whereas in the latter it is asked the very reason to accept the truth value of the statement regarding the event p; so, the answers differs accordingly and the former provides the explanation for the event whereas the latter the justifying grounds. (Hempel, 1965) However, every “explanation-seeking-why-question” is also involves a potential answer to “reason-seeking-why-questions”; and Hempel with his theory of scientific explanation tries to shed light to this situation.

2.3 Deductive-Nomological Model of Explanation

2.3.1 Pattern of Scientific Explanation

According to Hempel, any scientific explanation is composed of two constituents, namely that, "explanandum" which is the statement of the phenomenon that is to be explained and "explanans" through which the explanandum is explained and which is composed of sentences of any antecedent conditions and of any general laws used. This type of explanation is called "Deductive-Nomological" by Hempel, since it involves laws -hence, nomological- and the explanandum is deduced from explanans -hence, deductive. (Hempel, 1948) The schema, accordingly, looks like this where preceding part is explanans and subsequent part is explanandum:

$C_1, C_2, \ldots, C_k$ Statements of antecedent conditions

$L_1, L_2, \ldots, L_r$ General Laws

———————————————— Logical Deduction

E Description of the empirical phenomenon to be explained

For this inference to be adequate as an explanation, three logical conditions and one empirical condition are set forth by Hempel. First, the explanandum must be deducible from the explanans; second, explanans must involve general laws which are necessary for the deduction of explanandum and whose absence would render inference invalid; and last logical condition, the explanans must have empirical content, so that it is testable. The empirical condition is that the sentences constituting the explanans must be true or at least highly confirmed with respect to available relevant evidence. The explanation made through deductive-nomological model is also considered to be "casual" by Hempel, since it involves regularities that are expressed by general and unexceptional laws showing that given such and such conditions, the explanandum is to be expected and when these laws are accompanied with the condition statements in the explanans, they can be said to "cause" the explanandum jointly.

2.3.2 Explication of Laws

Hempel chooses truth as the tenable property for laws, since being highly confirmed would lead to a “relativized concept of law” as the truth-value of laws with regard to confirmation degree will be prone to change in the face of new evidences, a situation which is not acceptable given the understanding of law. For laying out general characteristics of law, Hempel introduces the term “law-like” that is coined by Nelson Goodman and that other than being true carries all properties of a law, which in turn makes it possible to delve into properties of law independent of its truth value, and tries to explicate the concept of law-like sentences without referring to the concept of law. (Hempel, 1965)

The first property that is attributed to all law-like sentences concerns form, law-like sentences might be generalizations of either universal or existential sorts depicting quantitative relations between different variables, and when universal having conditional form; while being universal is considered indispensable, having conditional form can be dropped since all conditional sentences can be turned into a non-conditional sentence via logical operations. (Hempel, 1965) In order to bar generalizations that have the universal form, yet hardly can be viewed as law, two more properties are added, namely that having an infinite scope of objects, which is tantamount to not being expressible through conjunction of finite set of individual sentences, and having no designation of particular objects, time or place, since it is possible to come up with accidental generalizations which would satisfy the former rule by not indicating the scope of objects it encompasses whereas still being particular.

For the property of having an infinite scope, a differentiation between “fundamental laws” and “derivative laws” is introduced, as without it some established laws would have to be left out. So, derivative law is described as a law which deduced from some fundamental law that have far larger applications than the derivative laws and which has a universal form. Fundamental law-like sentences, on the other hand, other than being universal, are constructed in the sense that their constituents' meanings entail non-limited scope. (Hempel, 1965) To satisfy the second property that of having no designation of particular objects, policy of not using any predicates which are not purely universal (qualitative) i.e. not bounded by a particular time and particular place, is adopted. This restriction which holds for fundamental law-like statements only, in turn, strengthens the first condition, since purely universal predicates act on an unlimited scope of objects.

2.3.3 Deductive-Nomological Model as Prediction

For Hempel, what differentiates prediction from explanation is not logical, but rather pragmatic and there is a “structural identity” between explanation and prediction. The prediction also has the logical form of explanation and utilizes both general laws and antecedent conditions as premises, yet the antecedent conditions involve a reference to time i.e. they have to be about before the time that event takes place and should also specify certain conditions that would affect the outcome throughout the time the event takes to realize. (Hempel, 1948)

2.3.4 Criticism of Deductive-Nomological Model

Counter examples against the D-N Model can be grouped under three themes. First, there are the problems arising from “temporal relations” between events or lack of it in explication of D-N Model. Although, in the formal definition the mention of antecedent conditions occurs, Hempel shies away delving into details of those conditions in his account. This in turn leads way to explain occurrence of an event with conditions of related phenomena in later time frame; as such a case of a lunar eclipse which can be explained through relative motions and positions celestial bodies combined with laws governing their motions, can also be explained with the positions of celestial bodies long after the occurrence of the mentioned eclipse, yet it would be hardly an explanation. (Kitcher&Salmon, 1990)

In relation with the problem of temporal relations, another front Hempel's model receives criticism is lack of emphasis on causal relations. One counter example relies on the interchangeability of explanandum and antecedent conditions involved in explanans where with help of optics and geometry, it is possible to explain the particular length of a shadow of pole, it becomes possible and is in accord with the conditions of D-N Model that to deduce an explanation of particular length of the pole through the relevant laws and the length of the pole's shadow. (Kitcher&Salmon, 1990)

Another counter example deals with events with common causes such as the drop of barometer readings accompanied by a storm, which can be explained with a pseudo-law positing a relation between drops in barometer value and the occurrences of storm without mentioning the atmospheric conditions that in fact cause of both events. This sort of false, valid explanations emerge since it is not possible to root out correlated events which are not casually connected with the conditions offered by Hempel. (Kitcher&Salmon, 1990)

Lastly, another batch of counter examples exploits explanatory relevance where two irrelevant events can be thrown together in a fashion that one can be used as an explanation; the case of a male not being pregnant can be explained through his regular use of birth-control pills and it will still count as a valid explanation as it complies with conditions of D-N Model of Explanation.

I will return to problems posed later after laying out the Kitcher's model of explanation and discuss solutions provided through it.

2.4 Inductive-Statistical Explanation

The first mention of inductive-statistical explanation by Hempel occurs in his 1958 article Theoretician's Dilemma. (Hempel, 1958) There, he separates explanations where the laws involved are of a different kind and where the explanandum follows from explanans not deductively, but inductively; a divergence from the deductive-nomological type of explanation which was previously covered by him.

2.4.1 Explication of Statistical Laws

Another kind of law Hempel examines is the “laws or theoretical principles of statistic-probabilistic form”, or with its known label “statistical laws”. The very basic form of a statistical law is $p(G,F)=r$ which is read as proportion of those instances of F are also G is approximately *r*. According to Hempel, laws of this sort can be regarded as less stringent counterparts of universal conditional laws. So, both being similar, they are both about potentially infinite number of cases and like universal conditional laws, statistical laws are not juxtaposition of statements about singular cases with conjunction operator. (Hempel, 1965) Therefore, any law having form of statistical law asserts a relation probability between infinite class of occurrences that are subject of the law; in the form $p(G,F)=r$, F is both the class of actual and potential instances. Moreover, like its counterpart statistical laws supports counterfactuals and thanks to it, what it is implied by r is a disposition in the long run rather than a conclusion attained through any occurrences of F. One possible source of confusion Hempel tries to dispel is the view that since all laws of universal form rely on a finite set of evidence, they may be considered as laws of statistical form, since they might have undetected instances of exception. However, because the difference between laws with statistical form and laws with universal form is not the evidential support, but the claim made by the laws, i.e. latter is about all members of set whereas the former is about certain members of a set, the mentioned view above misses the point. (Hempel, 1965) The statement that has the universal form of "All F's are G's" is not logically equivalent to the statistical form $p(G,F)=1$ as the former makes it certain that any observed F will also be G whereas the latter puts forward that in the long run virtually all instances of F are also instances of G.

2.4.2 Deductive-Statistical Model

Before dealing with Inductive-Statistical explanation, Hempel first handles a more straight forward type of explanation that involves statistical laws where the inference is based on a law of statistical form and pertains to mathematical theory of statistical probability. In a nutshell what is achieved through Deductive-Statistical Model is "a general uniformity expressed by a presumptive law of statistical form". (Hempel, 1965)

2.4.3 Inductive-Statistical Model

The main difference between Inductive-Statistical Model and duo of deductive explanations is that when taken with explanans the statistical law does not imply the explanandum with deductive certainty, but with high likelihood. However, one pitfall to be eschewed, for Hempel, is thinking that modal qualifiers used in inductive inferences have truth-values by themselves; in contrary their truth-values are dependent on the evidence available at hand through the induction. (Hempel, 1965) This again differentiates Inductive-Statistical Explanation from deductive counterparts since in deductive arguments when modal qualifiers marking certainty is used their truth-values are dependent on the truth of premises and the wording here is relational with respect to premises. Making this clarification, Hempel lays basic formulation of Inductive-Statistical Explanations as `$R_j$` is practically certain (very likely) relative to explanans containing sentences `$p(R,S•P)$ is close to 1` and `$S_j•P_j$ `; which is schematized as such where the double line and the value in square brackets in which the degree of support is shown indicate the inductive nature of the inference:

$$\begin{array}{ll} P(R,S•P) \text{ is close to } 1 & \\ S_j•P_j & \\ \hline\hline & \text{[makes practically certain (very likely)]} \\ R_j & \end{array}$$

2.4.4 Problem of Explanatory Ambiguity

One particular problem in Inductive Statistical Explanation, which does not have a counterpart in deductive explanation types, is the “ambiguity of inductive-statistical explanation” which stems from the fact that there can be more than one reference classes, which would yield to the different statistical probabilities for a given particular event. (Hempel, 1965) This situation in turn causes, for every explanation with true explanans and near certain probability, to have another explanation with likewise properties of the former, yet which would indicate the non-occurrence of that particular event with near certain probability. That kind of ambiguity is not observed in deductive explanation models since in those as the name implies, the inference is through deductive means and having two arguments with true explanans, yet with opposite conclusions are not logically possible.

Hempel draws a distinction between the ambiguity just laid off and another kind of ambiguity, which is called “epistemic ambiguity of inductive statistical explanation” which differs from the former by the fact that in the first case of ambiguity, the explanans are true whether it is known or not, whereas in the epistemic ambiguity the statements in the explanans –independent of its truth value- are accepted –as true- by empirical science. (Hempel, 1965)

To further define epistemic ambiguity of inductive statistical explanation, Hempel sets forth some preliminary concepts. K_t is introduced as the class of all statements accepted or asserted by the empirical science at the particular time t, whose members are prone to change in the face of new researches, and can be modified or dropped out already, or where new members are included. Moreover, K is logically consistent and contains every statement that is implied by its subsets. With help of those, the epistemic ambiguity of inductive explanation is put as such (Hempel, 1965):

> The total set K of accepted scientific statements contains different subsets of statements which can be used as premises in arguments of the probabilistic form, and which confer high probabilities on logically contradictory ‘conclusions’.

This, in turn, causes somewhat unacceptable result of being able to provide explanations via statements belonging to K, in cases of occurrence or of non-occurrence of a particular event. This outcome is not confined to explanation, but also affects prediction since it would be possible to come up with to predictive arguments whose premises belong to K, yet predict opposite outcomes.

2.4.5 Requirement of Maximal Specificity

In order to overcome this problem, Hempel, taking his cue from the “requirement of total evidence” which is proposed by Rudolf Carnap and according to which in a knowledge situation, when it is due to determine degree of confirmation, the total evidence should be taken as basis and which is a maxim that has to be taken into account in knowledge situations, rather than being a theorem or postulate. (Hempel, 1968) In searching ways to incorporate "requirement of total evidence" into statistical explanations, Hempel writes off including all and only available evidence in explanans since, when all evidence is included, all explanans in a particular time would be tantamount to K_t for every probabilistic explanation, and when only available evidence is included, since it might be the case that a bit of information which is not thoroughly tested to be add in K_t might be useful to provide an insight about the explanandum. Then, what to be included in explanation attempts is the "narrowest reference class" that accommodates the particular occurrence that is to be explained. Therefore, "requirement of maximal specificity for inductive-statistical explanations" can be put for basic form of statistical explanation as (Hempel, 1965):

> Let s be the conjunction of the premises, and, if K is the set of all statements accepted at the given time, let k be a sentence that is logically equivalent to K (in the sense that k is implied by K and in turn implies every sentence in K). Then, to be rationally acceptable in the knowledge situation represented by K, the proposed explanation [$p(F,G)=r$ and F_b then G_b (with probability of r)] must meet the following condition: If s and k implies that b belongs to a class F_1 and that F_1 is a subclass of F, then s and k must also imply a statement specifying the statistical probability of G in F_1, say $p(G,F_1)=r_1$. Here r_1 must equal r unless the probability statement just cited is simply a theorem of mathematical probability theory.

Here, the unless clause is included to bar theorems of pure mathematical probability theory off, since they fall short of explaining empirical data.

Hempel's claim is that by employing requirement of maximal specificity, it is possible to overcome the problem of epistemic ambiguity as whenever there are two arguments whose statements belong to K and which assign high probability to opposite outcomes respectively, -at least- one violates the requirement of maximal specificity, as demonstrated here (Hempel, 1965):

> Let,
>
> $p(G,F)=r$ and Fb therefore Gb [r_1] and $p(\bar{G},H)=r_2$ and Hb therefore $\overline{Gb}$ [r_2] where r_1 and r_2 is close to 1.
>
> Let, both arguments satisfy the requirement of maximal specificity, then:
>
> $p(G,F\bullet H)=p(G,F)=r_1$ $p(\bar{G},F\bullet H)=p(\bar{G},H)=r_2$ But $p(G,F\bullet H)+p(\bar{G},F\bullet H)=1$
>
> Therefore $r_1+r_2=1$
>
> Since the conclusion is an arithmetic falsehood, it cannot be implied by consistent class K.

One result of problem of ambiguity and requirement of maximal specificity is that inductive-statistical explanations are relative to the particular class of K in the time of explanation; hence there is the characteristic of “epistemic relativity of statistical explanation” which does not arise in deductive explanations (Hempel, 1968).

CHAPTER 3

THE IDEA OF UNIFICATION

In this chapter, before continuing with Philip Kitcher's Unificationist Model of Explanation, I will refer to Michael Friedman's attempt at providing a theory of explanation involving the idea of unification and criticism of it by Kitcher. In the last section, I will give an account of Kitcher's model and of a case from genetics provided by Kitcher, and will discuss how it overcomes counter-examples posed against Hempel.

3.1 An Early Attempt: Michael Friedman

Friedman starts his 1974 article with two basic questions about scientific explanation, namely that what is the relation between two phenomena that lead one to explain other, and that how come that aforementioned relation enhances and is connected to our understanding of the world. (Friedman, 1974) For the task, he sets forth to examine theories of explanations proposed to the date.

According to him, proposals given for scientific explanation are roughly divided into two camps of which one putting the emphasis to the first question i.e. the relations between phenomena and is advocated by K. Hempel and E. Nagel, whereas the second camp is more focused on understanding. (Friedman, 1974)

Before coming up with his model which, according to him, would remedy the disparity and provide a comprehensive picture of scientific explanation and scientific understanding, he surveys the prominent models to point out their shortcomings, starting with Hempel's Deductive-Nomological Model. Although concurring with Hempel on the idea that any criteria for a scientific explanation should rest on an objective ground, Friedman points out that it is possible to carry out an explication of “understanding” which is casted out as pragmatic, hence psychological, by Hempel, eschewing pitfalls of psychologism by providing criteria which would hold for a large class of people. (Friedman, 1974) He is also not satisfied with the extent that Hempel lets understanding into his D-N Model of explanation, since, for Friedman, contrary to Hempel's claim, having rational grounds to expect a phenomenon to follow another given the prior conditions, is not identical with understanding the relation that holds between them as illustrated by counter-examples like “Koplick spots” which occur more or less two days before measles, and known for a long time before their cause was unknown.

Second thesis Friedman tackles is that scientific explanation, thus understanding, is aimed at reducing unfamiliar phenomena to familiar ones. After promptly refusing “naive” version of it by applying to Electromagnetic Theory where familiar daily occurrences of light are explained through somewhat unfamiliar electromagnetic waves, Friedman turns his attention to Michael Scriven who proposes that in order that any phenomena included in an explanation to add up to understanding, it has to be related to some set of phenomena that is already understood. (Friedman, 1974) However, Friedman argues, there are “fundamental processes” such as particle physics that are used in scientific phenomena, so it is still possible to talk about understanding without relating those processes to already understood ones.

Third thesis Friedman handles is the historicist idea that what constitutes a satisfactory explanation and its relation to understanding is subjected to change with respect to historical conditions as what is thought to be intelligible is also determined by historical period. Here, Friedman's objection differs from the former two as this stance leaves out the criterion of objectivity, whereas Friedman sets forth with the very idea of objective answers to the questions of scientific explanation and scientific understanding. (Friedman, 1974)

Weighing pros and cons of prominent theories, Friedman proposes three criteria for and adequate theory of explanation. First, it has to hold as universally as possible, so that a theory that is deemed to be explanatory turns out to be one via theory of explanation. Second, it has to be objective and independent of social and psychological factors. Lastly, it has to provide a link between explanation and understanding. (Friedman, 1974)

With those criteria in mind, he lays the pillar stone of his version of theory of explanation as that it is through reducing total number of independent phenomena that has to be accepted as given, that science increases understanding of world, which in turn what aimed with scientific explanation is. (Friedman, 1974) His elaboration starts with representing independent phenomena with law-like sentences and total number of independent phenomena with total number of logically independent law-like sentences. K, is introduced as deductively closed set of logically independent law-like sentences that are accepted by scientific community on a given time and S is defined as law-like sentence that is a member of K, if it is entailed by K. So, the aim becomes as to find suitable law-like sentence S that would reduce the number of independent law-like sentences in set K. The problem that follows is to find a viable way to avoid and to bar superficial reductive sentences composed of formerly single law-like sentences, which are still logically equivalent to conjunction of their parts. In order to overcome it, Friedman introduces notion of "independent acceptability" (Friedman, 1974):

(1) If $S \rightarrow Q$ then S is not acceptable independently of Q.
(2) If S is acceptable independently of P and $Q \rightarrow P$, then S is acceptable independently of Q.

With aid of notion of independent acceptability, Friedman lays out notion of "reducing the number of independent sentences". First, Γ is introduced as the partition of sentence S, where Γ is logically equivalent to S and in which every sentence S` belonging to Γ is acceptable independent of S. Second, S is to be "K-atomic" if there is no pair S_1, S_2 such that S_1 and S_2 are acceptable independently of S and their conjunction is logically equivalent to S. Third, let K-Partition of a set of sentences Δ be a set Γ of K-atomic sentences which is logically equivalent to Δ. K-cardinality of a set of sentences Δ is defined as inf{card (Γ): Γ a K-partition of Δ}. Therefore, it is argued that S reduces the set of Δ iff $K - card(\Delta \cup S) < K - card(\Delta)$. From here, it follows that for any S to explain a S' in K, S has reduce the set of independently acceptable consequences of $S(con_k(S))$:

(D1) S_1 explains S_2 iff $S_1 \in con_k(S_1)$ and S_1 reduces $con_k(S_1)$.

However, this definition is dropped swiftly by Friedman, since it turns out to be too strong as it is possible that for S_1, S_2 and S_3 where S_1 explains S_2 and S_3 is an independently acceptable law, the conjunction of S_1 and S_3 won't be considered as explaining S_2 since that conjunction will not reduce $con_k(S_1 \& S_2)$. As this undesirable, Friedman offers a loosened up definition (Friedman, 1974):

(D2) S_1 explains S_2 iff there exists a partition Γ of S_1 and an $S_i \in \Gamma$ such that $S_2 \in con_k(S_i)$ and S_i reduces $con_k(S_i)$.

Thanks to (D2), since $\{S_1 \& S_3\}$ is a partition of $S_1 \& S_3$ and S_1 reduces $con_k(S_1)$, if S_1 explains S_2, so does $S_1 \& S_3$. Furthermore, Friedman notes that through this definition the problem of trivialization of explanation by conjunction of two laws and using this conjunction in explaining one of the conjuncts disappears when reducing number of independently acceptable consequences is taking as a maxim since it wouldn't reduce this number.

3.3 Philip Kitcher's Criticism of Friedman's Model

Kitcher's claim is that there are two types of counter-example against Friedman's theory of explanation both of which are valid against both versions of Friedman's definition of explanation. (Kitcher, 1976) By providing a definition that would banish any sentence which is not K-atomic with his first definition, although Friedman overcomes the Hempel-Oppenheim problem which deals with the conjunction of otherwise unrelated theories in explanation schemes, according Kitcher, he also bars otherwise acceptable scientific explanations where two laws which are part of the same theory are used in conjunction so that not K-atomic. (Kitcher, 1976)

Kitcher uses Friedman's example regarding Boyle-Charles law which is derivable from kinetic theory of gases and Newtonian assumption that gas molecules are minute particles interacting through collisions, and the assumption that gas molecules are evenly distributed and have the same average speed. (Kitcher, 1976) Calling the former conjunction *(K1)* and the distribution of gas molecules *(K2)* and the assumption of speed *(K3)*, it becomes readily available that $\{(K1\&K2), (K1)\&(K3)\}$ is partition of the explanans since $(K1)\&(K2)$ is acceptable independently of $(K1)\&(K3)$ and vice versa. The second type of counter-example Kitcher offers relies on the explanations where different laws from different theories where both the laws and the theories are independently acceptable, such as working of eyes where laws from diverse disciplines such as Biology, Physics are employed. (Kitcher, 1976)

Friedman's second proposal for definition of explanation fares no better than the first against the arguments offered by Kitcher where it is brought forward that S_1 explains S_2 if and only if there exists a partition Γ of S_1 and an $S_i \in \Gamma$ such that $S_2 \in con_k(S_i)$ and S_i reduces $con_k(S_i)$. (Kitcher, 1976) Kitcher sets forth to test the modified definition by the law of adiabatic expansion which deals with expansion of gases and derivable from first law of thermodynamics and Boyle-Charles law. *T* being first law of thermodynamics, *B* being Boyle-Charles law and *A* being law of adiabatic expansion, from the definition it follows that *A* is derivable from $T\&B$

only if there is a partition Γ of $T\&B$ and an $S_i \in \Gamma$ such that $A \in con_k(S_i)$ and S_i reduces $con_k(S_i)$ where S_i is K-atomic. Assuming there exists a pair of Γ and S_i as required, and taking the set $\{(S_i \vee T), (S_i \vee B)\}$ which is equivalent to $S_i \vee (T\&B)$, it follows that $T\&B \vdash S_i$ since Γ is partition of $T\&B$. Thus, the set $\{(S_i \vee T), (S_i \vee B)\}$ is equivalent to S_i. Therefore, either $(S_i \vee T)$ or $(S_i \vee B)$ (in other words T or B) is not acceptable independently of S_i since S_i is K-atomic and has no partition. Kitcher argues, it is not possible to find an S_i as there is no law L such that the sufficient ground for accepting T (or B) is also sufficient grounds for accepting L and that $L \vdash A$. (Kitcher, 1976)

Kitcher concludes that unlike what Friedman argues the understanding is not attained when the set Γ with a suitable set S_i reducing number of independent phenomena is at hand, but via having small number of laws which are used through and through in unifying seemingly diverse phenomena.(Kitcher, 1976)

3.3 Philip Kitcher's Model of Explanation as Unification

3.3.1 Summary and Key Concepts of Unificationist Account of Explanation

Taking his cue from Hempel's "unofficial view" with regard to explanation i.e. explanation as an attempt to arrive at "... an objective kind of insight that is achieved by a systematic unification, by exhibiting the phenomena as manifestations of common, underlying structures and processes that conform to specific, testable, basic principles.", Kitcher shares the idea that an account of scientific explanation should show how scientific explanations enhance our understanding of the world with Friedman and like Friedman proposes it as a criterion. (Kitcher, 1981) Moreover, he argues that newly emerged theories are defended and adopted with respect to their explanatory power and a theory of explanation should be suitable to task of assessing mentioned merits of scientific theories, and be available in this sense not only for present, but also for historical cases. (Kitcher, 1981)

Kitcher claims his approach to explanation differs from Hempelian one by the fact that in Hempel's model, the candidates of explanations are assessed individually whereas in the model he lays out the candidates of explanation are evaluated among with the set of other successful explanations which are in turn a part of "explanatory store" that is being used in providing a systematized and unified landscape of beliefs held at a particular time.

For Kitcher, "ideal explanations are derivations" whose conclusions describe the phenomena to be explained and which belong to explanatory store E(K) where K is the set of statements accepted by the scientific community of the time and best systematization of E(K) is pertinent to unification. (Kitcher, 1989) So, the task becomes to pin any E(K) in such a fashion that it is the best trade-off between number of patterns used for explanation and the number of types of facts that are accepted as ultimate.

For a better grasp of E(K) as unification, it is due to introduce few other notions, all related and successive. (Kitcher, 1989) "Schematic sentence" is defined as the expression where some, but not necessarily all non-logical expressions are replaced with dummy letters and "set of filling instructions" is defined as the set of instructions for replacing non-logical expressions with dummy letters occurring in schematic sentence -for each of dummy letters. A sequence of schematic sentences is defined as "schematic argument" and inferential characteristics according to which it is to be decided which roles of schematic sentences in the inference are decided and which rules of inference are made use of, is defined as "classification". Lastly, tripartite structure composed of a schematic argument, a set of sets of filling instructions for each of schematic arguments and a classification is called "general argument pattern".

Three criteria are imposed for a particular derivation to instantiate a general argument pattern, namely that, derivation has to have the same number of terms as the schematic argument of the general argument pattern; second, via filling instructions for every corresponding schematic sentence, sentences or formulas used in derivation should be obtainable, and lastly the terms of derivation should carry properties assigned to them by corresponding classification rules of the members of schematic argument. (Kitcher, 1989)

To differentiate derivations and determine the degree of similarity between those the notion of degree of "stringency" is introduced and a general argument which sets the bar higher for its instantiations to be derivable is asserted to be more stringent than its counterparts. (Kitcher, 1989) The degree of stringency is achieved through adjustment of classification (logical properties) and of the schematic sentences and the filling instructions jointly (non-logical properties). When both are relaxed, any remote instantiation becomes available and when both are made strict, the pattern at hand becomes unique instantiation of itself and lastly, when classification kept strict and conditions on filling instructions and schematic sentences are loosened up, the pattern ends up to be “logician's notion of pattern”.(Kitcher, 1989)

Any acceptable systematization of K, E(K), should contain all and only acceptable arguments relative to K where arguments are accepted relative to K, when derivations involved are deductively valid and each and every premise belongs to K. (Kitcher, 1989) The “generating set” is defined to be “...the set of argument patterns such that each derivation in the set instantiates some pattern in the generating set.” and a generating set G for a set of derivations D is complete when “...every derivation that is acceptable relative to K and which instantiates a pattern in G belongs to D.” The choice of E(K) with respect to K requires first the elimination of unacceptable sets of arguments relative to K and then the comparison of different “generating sets” that are complete with respect to K. After the elimination, comes the comparison of generating sets that are complete with respect to K, for each derivation set where completeness introduced to leave out the possibility of using patterns selectively only for particular instantiations. (Kitcher, 1989) Then, the “basis” of the systematization will be the best complete generating set that generates that systematization with regard to criteria of unification. Since what desired through unification was to come up with as many as conclusions with fewer patterns, “conclusion” set of a set of derivations D, C(D), is defined, by Kitcher, as “... the set of statements that occur as conclusions of some member of D.” As a result, for any given complete generating set for D, the unifying power increases with the size of C(D) and the stringency and decreases with the number of the patterns in the set. (Kitcher, 1989)

3.3.2 Unificationist Model at Work

By instantiating four successive explanatory schemata through the history of classical genetics, Kitcher seeks to demonstrate how those explanatory schemata answers the problem of identification of expected distribution of traits in generation of organisms from common descent. (Kitcher, 1989)

Mendel (1900):

(1) There are two alleles A, a. A is dominant, a recessive.

(2) AA (and Aa) individuals have trait P, aa individuals have trait P'.

(3) The genotypes of the individuals in the pedigree are as follows: i_1 is G_1, i_2 is G_2,... {(3) is accompanied by a demonstration that (2) and (3) are consistent with the phenotypic ascriptions in the pedigree.}

(4) For any individual x and any alleles yz if x has yz then the probability that x will transmit y to any one of its offspring is ½.

(5) The expected distribution of progeny genotypes in a cross between i_j and i_k is D; the expected distribution of progeny genotypes in a cross … {continued for all pairs for which crosses occur}.

(6) The expected distribution of progeny phenotypes in a cross between i_j and i_k is E; the expected distribution of progeny phenotypes in a cross … {continued for all pairs in which crosses occur}.

Filling Instructions: A, a are to be replaced with names of alleles, P, P' are to be replaced with named phenotypic traits, i_1, i_2, …, i_m are to be replaced with names of individuals in the pedigree, G_1, G_2, …, G_n are to be replaced with names of allelic combinations (e.g. AA, Aa, or aa), D is replaced with an explicit characterization of a function that assigns relative frequencies to genotypes (allelic combinations), and E is to be replaced with an explicit characterization of a function that assigns relative frequencies to phenotypes.

Classification: (1), (2) and (3) are premises; the demonstration appended to (3) proceeds by showing that, for each individual i in the pedigree, the phenotype assigned to i by the conjunction of (2) and (3) is that assigned in the pedigree; (4) is a premise; (5) is obtained from (3) and (4) using the principle of probability; (6) is derived from (5) and (2).

Here, Mendelian schemata in 1900 is limited to one locus, two allele cases with complete dominance or recessiveness with regard to traits in pedigree, through the refinement of premises variety of instantiations increases in the Refined Mendel.

Refined Mendel (1902-1910):

(1) There are n pertinent loci L_1 ,.., L_n. At locus L_i there are m_i alleles a_{i1} ,..., a_{imi}.

(2) Individuals who are $a_{11}a_{11}a_{21}a_{21} \ldots a_{n1}a_{n1}$ have trait P_1; individuals who are $a_{11}a_{12}a_{21}a_{21} \ldots a_{n1}a_{n1}$ have trait P_2; … {Continue through all possible combinations.}

(3) The genotypes of the individuals in the pedigree are as follows; i_1 is G_1, i_2 is G_2, … i_n is G_n. {Appended to (3) is a demonstration that (2) and (3) are consistent with the phenotypic ascriptions given in the pedigree.}

(4) For any individual x and for any alleles y, z, if x has yz then the probability that a particular one of x's offspring will have y is ½.

(5) The transmission of genes at different loci is probabilistically independent.

(6) The expected distribution of progeny genotypes in a cross between i_j and j_k is D; the expected distribution of progeny genotypes in a cross... {continued for all pair in the pedigree for which crosses occur}.

(7) The expected distribution of progeny phenotypes in a cross between i_j and j_k is E; the expected distribution of progeny phenotypes in a cross … {continued for all pairs in the pedigree for which crosses occur}.

Filling Instructions: Similar to Mendel (1900)

Classification: (1),... ,(5) are premises; (6) is derived from (3), (4), and (5) using principles of probability; (7) is derived from (2) and (6).

In addition to the instantiations of the 1900 schemata, the Refined Mendel also allows epistasis where a gene may suppress an unrelated gene, and is not bounded by complete dominance and recessiveness. Yet, it can't be used in cases with linkage where a group of traits is inherited as a bundle as they are linked together on a chromosome and recombination where a combination of traits present in ancestors are combined.

Morgan (1910-1920):

(1)-(4) As for the Refined Mendel.

(5) The linkage relations among the loci are given by the equations $Prob(L_i, L_j) = p_{ij}$. $Prob(L_i, L_j)$ is the probability that the alleles at L_i, L_j on the same chromosome will be transmitted together (if L_i, L_j are loci on the same chromosome pair) and is the probability that arbitrarily selected alleles at L_i, L_j will be transmitted together (otherwise). If L_i, L_j are loci on the same chromosome pair, then $0.5 \leq pij \leq 1$. If L_i, L_j are on the different chromosome pairs, then p_{ij} is 0.5.

(6) and (7) As for the Refined Mendel

Filling Instructions and Classification: As for the Refined Mendel.

With the Morgan schemata, by a change on sentence (5), it becomes possible to come up with an explanation for the traits that are observed together on most of the cases as it points out that alleles that are located on the same chromosomes have higher probability to end up together in progeny. Kitcher from this point on, introduces recent schemata in use where the sentence (4) has been dropped out for the sake of another sentence that employs meiotic drive which allows further instantiations.

Watson-Crick:

(1)There are n loci $L_1, \ldots, L_n$. At locus L_i there are m_i alleles $a_{i1}, \ldots, a_{imi}$.

(2)

(a) The DNA sequence of a_{11} is XYUV . . . , the DNA sequence of . . . {continue through all alleles}.

(b) Details of transcription, post-transcriptional modification, and translation for the alleles in question.

(c) The polypeptides produced by $a_{11}a_{11}a_{21}a_{21} \ldots a_{n1}a_{n1}$ individuals are $M_1, \ldots, M_k$, the polypeptides produced by . . . {continue for all allelic combinations}

(d) Details of cell biology and embryology for the organism in question.

(e) Individuals who are $a_{11}a_{11}a_{21}a_{21} \ldots a_{n1}a_{n1}$ have phenotype P_1, individuals who are . . . {continue through all possible combinations}.

(3) The genotypes of the individuals in the pedigree are as follows: i_1 is $G_1, \ldots, i_n$ is G_n. {Appended to (3) is a demonstration that (2e) and (3) are consistent with the phenotypic ascriptions given in the pedigree.}

(4) If an individual x has $a_{11}a_{12}$ at locus L_1 then the probability that a particular offspring of x will receive a_{11} is ½, if an individual x has . . . {continue through all heterozygous combinations}.

(5)-(7) As for Morgan

Filling Instructions: As for Morgan, with the further condition that X,Y,U,V, . . . in (2a) are to be replaced with names of bases (Adenine, Cytosine, Guanine, Thymine) and that the M_i in (2c) are to be replaced with names of polypeptides.

Classification: (2c) follows from (2a) and (2b); (2e) is derived from (2c) and (2d). Otherwise, as for Morgan.

Besides the involvement of meiotic drive, Kitcher, in the Watson-Crick schemata, points out that thanks to molecular biology, sentence (2) of Morgan now becomes a conclusion of placed under (2) of Watson-Crick as (2e), though it is not attainable in all explanatory cases as the details of sentence (2d) turns out to be scarce on most of the cases. (Kitcher, 1989)

Via those four successive explanatory schemata dealing with the problem of transmission of traits through generations, Kitcher draws three conclusions regarding laws, reduction, and unification. (Kitcher, 1989) First point, Kitcher makes is that, as observed through Mendel where it was assumed to be a "maxi-law" that would cover all transmission of traits, to Watson-Crick where transmission of traits are dealt with case-per-case, the generality of laws are dependent on the patterns of derivations brought forward by them and that the sentences regarded as laws turn out to be premises on an explanatory derivation. In case of reduction, Kitcher offers "explanation extension" which in turn can still account for the knowledge growth even in the cases where reductionist criteria are not fulfilled, ie. when the concepts of the extended theory (Mendel schemata) are not formulated in extending theory (Watson-Crick). Lastly, it is possible to observe, according to Kitcher, the single pattern of derivation that is used in arriving various conclusions through his examples; so that, there is concrete evidence of unification as he has proposed. (Kitcher, 1989)

3.3.3 Three Problems of Covering Law Model and Their Solutions

Three most cited problems with regard to Hempel's explanation model, as mentioned in earlier chapter, are the "asymmetry problem", "irrelevance problem" and "accidental generalizations". Kitcher's claim is that by means of Unification Model of Explanation and two corollaries posited it is possible to overcome those three problems. (Kitcher, 1989) The main strategy, Kitcher employed, is to show that the set of arguments which is not to be admitted to explanatory store that unifies the beliefs at hand, is either more limited than an equally satisfactory set of arguments, or fails with respect to numbers of most stringent patterns with regard to another set of arguments. This is achieved by the two corollaries as given by Kitcher (Kitcher, 1989):

> A.
>
> Let Σ, Σ` be sets of arguments which are acceptable relative to K and which meet the following conditions:
>
> (i) the basis of Σ` is as good as the basis of Σ in terms of the criteria of stringency of patterns, paucity of patterns, presence of core patterns and so forth.
>
> (ii) $C(\Sigma)$ is a proper subset of $C(\Sigma`)$
>
> B.
>
> Let Σ, Σ` be sets of arguments which are acceptable relative to K and which meet the following conditions:
>
> (i) $c(\Sigma) = c(\Sigma`)$
>
> (ii) the basis of Σ` is a proper subset of the basis of Σ.

The first problem Kitcher tackles is the irrelevance problem, which arise due to determine a lawlike connection between an accidental and irrelevant occurrence and an event, which would have realized without the existence of the former. In these cases, one is either to use more than one pattern of argument without extending the range of things that are explained or to leave out the cases where two occurrences seen together hence, lose unifying power. However, if the former is accepted, the choice will be in conflict with the corollary B and if the latter is accepted the corollary A. Therefore, in the face of a choice, it becomes possible to leave out the explanations based on irrelevant factors. (Kitcher, 1989)

The asymmetry problem is also tackled in the same fashion. The problem is due to logical form of general laws where the premises and conclusion can be used interchangeably while intuitively it is not possible. When a case where the statement that indicates condition C_1 is used to infer another statement indicating condition C_2 and vice versa is accepted to be an legitimate explanation pattern; either a new explanation pattern to be introduced to explain the cases where C_2 is present, but not C_1 or leave out those cases. Again, it becomes a choice between consequences of the corollaries A and B. (Kitcher, 1989)

It is no different for the accidental generalizations, which are intuitively non-explanatory, yet satisfying covering law model. Accepting accidental generalization in the face of another argument pattern with more unifying power, would lead to a conflict with the corollaries A and B, as there would be cases where the accidental generalization is not applicable, but the more general pattern is.

CHAPTER 4

CELL THEORY

In this chapter, I will first give a landscape of predecessor works done before 19th in Cell Theory. Then I will lay out the seven propositions provided by John Baker which more or less captures the essential principles of Cell Theory. I will continue with historical surveys of the first three propositions, and reassessment of Baker's propositions in light of the former.

4.1 Cell before 19th Century

The first description of plant cell -and cell as an entity- in literature appears in Robert Hooke's 1665 work “Micrographia” where he gives the details of “microscopical pores” he observed on a slice of cork and claims that those pores are not only present in cork, but can be found in a variety of other plants and that they are channels used in fluid conduction.(Baker, 1948) Later on, independent of Hooke's work, Nehemiah Grew made observations on plants and in his 1682 book “The Anatomy of Plants” presented drawings where cell structure is outlined, yet he took them to bladders woven from fibres which according to him, comparable to threads of a lace. Though not publishing a book, Dutch scientist Antoine van Leeuwenhoek also provides accounts of cells in different plant parts in letter correspondences with prominent botanists of his time. By the time of his death at 1723, the observation of cell like structure and knowledge of it becomes common among botanists. (Baker, 1948)

The discovery of cells and cellular nature of animals and its acceptance proved to be harder than its plant counterpart, as animal cells, unlike plant cells, don't have a cell wall readily observable. (Baker, 1948) The observance of cell-like entities in animals starts with works on blood. The first explicitly mention of cells in blood occurs in Jan Swammerdam's posthumous work “Biblia Naturae” where he mentions transparent globules in the blood of a dissected louse. Also, in his 1665 work Marcelo Malpighi although observing blood corpuscles, takes them to be globules of fat. Again, van Leeuwenhoek, in his letters to Royal Society delivers observations of blood corpuscles in human and frog bloods repeatedly and in 1717 becomes first to observe that they are not spherical, but concave disks. (Baker, 1948)

Before, delving into observations of "cellular tissue" and the Globule-Theory, in the next section, I will introduce John R. Baker's seven propositions with respect to Cell Theory and only after that section, I will use aforementioned ideas as precursors to arriving at statements expressed by Baker.

4.2 John Baker's Seven Propositions

John R. Baker, in a series of papers starting with his work at 1948, "The Cell-theory: a Restatement, History and Critique", undertakes an extensive research in history of Cell Theory in order to arrive at a clear formulation of it in terms of propositions. His work leads him to restate it in a series of seven propositions (Baker, 1948):

> I. Most organisms contain or consist of a large number of microscopical bodies called `cells`, which, in the less differentiated tissues, tend to be polyhedral or nearly spherical.
>
> II. Cells have certain definable characters. These characters show that cells (a) are all of essentially the same nature and (b) are units of structure.
>
> III. Cells always arise, directly or indirectly, from pre-existing cells, usually by binary fission.
>
> IV. Cells sometimes become transformed into bodies no longer possessing all the characters of cells. Cells (together with these transformed cells, if present) are the living parts of organisms: that is, the parts to which the synthesis of new material is due. Cellular organisms consist of nothing except cells, transformed cells, and material extruded by cells and by transformed cells (except that in some cases water, with its dissolved substances, is taken directly from the environment into the coelom or other inter-cellular spaces).
>
> V. Cells are to some extent individuals, and there are therefore two grades of individuality in most organisms: that of the cells, and that of the organism as a whole.
>
> VI. Each cell of a many-celled organism corresponds in certain respects to the whole body of a simple protist.
>
> VII. Many-celled plants and animals probably originated by the adherence of protist individuals after division.

Here, the proposition I deals with cell's most basic properties and more importantly incorporates the direct observations of it in organisms. The proposition II points out to the fact that they are “building blocks” with more or less uniform properties and deals with morphological properties. The proposition III is about the origins of cell which when taken with the proposition II cements the idea that cell is the unit of structure. Proposition IV dictates the fact that what underlies in metabolism of a many-celled organism is the processes taking place in cell level. Propositions V and VI draws on the resemblance of process between single celled organisms and single cells in many-celled organisms where cells may have specialized tasks in sustaining of organism as a whole and its functional properties. Lastly, proposition VII is about the genesis of organism as an whole and in reliance with the earlier propositions, asserts that it is thanks to interactions of single cells coming into being by division.

In the next section, I will provide historical backgrounds of first three propositions starting with proposition I. When the historical background is provided, propositions will be assessed again in another section.

4.3 Proposition I: The Existence and Shape of Cell

At the outset of 19th century, as mentioned before, the observations of cells were abundant. However, before the proposition I was realized as it is, “Globule Theory” reigned for some time, where the shape of cells, throughout in all parts of organisms, was thought to be globular. (Hall, 1969) The root of error can be traced back to late 17th century works of van Leeuwenhoek who in his letter written in 1686, reports the existence of globules in dissected brain of a turkey, which he says to be smaller than red corpuscles present, later on he reports to see the globules with varying sizes in different animals also. (Baker, 1948) Those letters proved to be influential in 18th century and observations of globules kept pouring in. In 1759, Christian Wolff came to conclusion that embryo cells are globular and was followed by Georg Prochaska who reaffirmed the existence of globules in nerves and brains in 1779. In 19th century, Prochaska's and globule theory's influence is felt in work of Josephus and Carolus Wenzel. By 1812, not only they repeated the results of former in nervous system, but also extended the theory to encompass whole organs of the organisms. (Baker, 1948) The globule theory appeared in a text book of anatomy by efforts of Meckel in 1815 and it is postulated that globules whose dimensions vary in different organs are embedded in plastic substance and that globules and aforementioned coagulable plastic substance are the basic constituents of organisms. Henri Milne-Edwards in

1823, made extensive studies on human and animal organs and was able to observe globules on arteries, membrane of intestines and again in brain cells. Later to change his idea, Henri Dutrochet was also committed to globule theory and claimed to observe globules on plants also.

However, the appeal of globule theory comes to a halt by the second half of the decade as the overall problem with the globule theory becomes apparent with the introduction of better microscopes. (Hall, 1969) With the newly introduced achromatic microscopes the effect of spherical aberration and the halo that surround minute particles observed are reduced. This in turn led to observations contrary to what globule theory suggests. Being a friend of Milne-Edwards, in 1827, Hodgkin with his colleague Lister searched for globules reported by Milne-Edwards with Lister's newly devised microscope, but was not able observe them; in brain tissue only small particles, in arteries fibers were present. Moreover, in human blood the corpuscles turned out to be not globular, but concave and the particles in pus to be irregular in shape. This result further reinforced by observations of Karl von Baer's work on embryo of chicken in 1828. In 1837, Dutrochet reported seeing cells in frog brain. Finally, Purkinje was able to observe cells on various parts of animals, once thought to be composed of globules. (Baker, 1948)

4.4 Proposition II: The Nature of the Cell

It has to be told that although the proposition II is composed of two parts, they are not successive in historical order; their processes and acceptances happen to be concurrent as the research on cell continues. However, here -following Baker- they will be examined separately starting with the first part that “cells are all of essentially the same nature”.

The emergence of the first part of the proposition is predated by works that establish the similarities on both animal and plant cells. At the time of its acceptance, it was understood that all cells have protoplasm as living parts accompanied with the presence of a nucleus and that they are separated from each other with a cell membrane. (Baker, 1949) As it is the case with the parts of proposition, these three attributes are parts of on-going simultaneous researches and not chronologically ordered and yet they will be examined separately starting with protoplasm.

The first mention of protoplasm like substance appears Abraham Trembley's 1744 work where he examines some granules he witnessed in Hydra genus, and mentions a matter resembling white-of-egg which keeps granules together and succeeds to isolate it, all the while not knowing cellular nature of his experiment objects. (Baker, 1949) In 1758, Henri-Louis Duhamel du Monceau mentions a fluid that fills cavities present in the plant tissues. Cyclosis, the movement of cytoplasm, is observed by Alfonso Giacomo Gaspare Corti in 1774 and the observation is repeated by Ludolph Christian Treviranus who didn't have the knowledge of former work of Corti in different plants. The idea was brought forward by Félix Dujardin in 1835 while he was examining a thesis concerning the food-vacuoles, cavities that are present in the cytoplasm, which proposed that those vacuoles among the ciliates, a protozoa with tiny hair like extensions, are connected via intestine like structure. Rather than refuting the idea, he comes up with the novel concept of Sarcode which he defines as a living jelly which is glutinous, transparent, insoluble in water and has mucus like behavior, and present in all the lower animals; thus, listing more or less the basic properties of protoplasm. (Baker, 1949) Matthias Jakob Schleiden in his 1838 work, witnessing protoplasm in plants, uses the word Schleim (mucus) for it and doesn't consider as an essential part. (Karling, 1939) The first use of protoplasm in a scientific sense and the first attempt to assign it to both animals and plants is made by Johannes Purkinje in 1839. (Baker, 1949) He claimed that in development stage both in the animal and the plant, there exists a jelly like granules that constitutes the elementary parts of the organisms which as the development continues changes into solids in plants and keeps its jelly like condition in animals. While in a sense the term protoplasm is reserved for the animal cells, he does not deny the correspondence between protoplasm in adult animal cells and the meristematic cells of plants that are present on the parts where the grow takes place. In 1841, Fredric Kützing through his studies on algae came up with the division of plant protoplasm into three parts which roughly corresponds to cell-wall (Gellinzelle), protoplasm lining the cell-wall on the inside (Amylidzelle), and lastly granular material enclosed by the second part (Gonidien). Carl Nägeli also observed the inner part of the cell-wall and starch-grain and chloroplasts attached to it and called it Schleimschicht (mucus layer) while being aware of Kützing's work, in 1844. His observation of Schleimschicht differed from Kützing's Amylidzelle (starch box) in the sense that Schleimschicht is neither box-like nor changes into starch when exposed to potash, a potassium compound. Again in 1844, the same part of the protoplasm is named as Primordialschlauch (primordial utricle) by Hugo van Mohl who expressed the idea that cell-wall is not the primary part of the plant cell. Later on, in 1846 unaware of Purkinje, he introduced the term "protoplasma" and posited that protoplasma is present even before the nucleus and predates solid structures in formation of new cells and that it initiates the process.

Although, by Purkinje, it was argued that there has to be a common constituent that underlies both in plants and animals in 1838, no progress was made in the preceding years. (Baker, 1949) It was Ferdinand Cohn in 1850, who claimed contractile substance of animal cells are the same with protoplasm of plant cells. After listing properties assigned to protoplasm of plants by botanists and comparing those to his work on animal cells and to properties assigned to sarcode, he infers that either those two be very similar or outright identical, only that former is enclosed by a cellulose membrane which restricts the movements of the contractile substance to internal mobility whereas the latter is not restricted in this fashion. This idea further supported with work of Franz Unger in 1855 where it is argued that movement wise protoplasm behaves like contractile substance of animal cells. Ersnt Haeckel also backed up Cohn's idea and titled it as one of the greatest achievements of the newer biology. Following observations of Heinrich Anton de Bary on Mycetozoa, slime molds, that again draws resemblances between aforementioned substances, by 1864 the identity of protoplasm and sarcode or contractile substance was accepted. (Baker, 1949)

The first recorded observation of nucleus appears in van Leeuwenhoek's letter to Royal Society in 1700 where he reports the little clear sort of light, lumen, in red blood corpuscles of salmon. (Baker, 1949) In 1744, Trembley gives an account of nucleus in Stentor, a genus of protozoa. Hewson was first to observe nucleus on blood corpuscles of an invertebrate in 1777, apart from his works on many vertebrates and Felice Fontana was first to it in tissues other than blood and makes first mention of nucleolus in 1781. Albeit there early observations, the proper study of nucleus had to be delayed until better preparation methods were devised. (Baker, 1949) Purkinje, in 1830, delivers the first report of nuclear membrane and nuclear sap while describing hen's ovarian egg and following works of Purkinje, Jean Victor Coste in 1833 and Adolph Bernhardt in 1834 were able to observe nucleus on various mammalians. Franz Meyen gave account of nuclei in Ephedra, a genus of shrubs, tough not regarding at as important. In 1833, Robert Brown after his work on epidermis cells of Orchidaceae, arrives at the idea that it is a basic constituent of plant cells and coins the term “nucleus” as used up to date. After half a decade, the reports of nucleolus appears in works of Rudolph Wagner again in 1835, which is named as Keimfleck (germ fleck). Recognition of nucleolus proved to be important as it is used in identification of nuclei. (Baker, 1949) The word nucleus carried over to animal cell research by works of Gabriel Gustav Valentin on epithelium of brain who draws comparisons between nerve-cells and cells of epidermis on plants in 1836. Jacob Henle observes nucleus on diverse tissues in humans, in 1837; by that year the concept of nucleated cell more or less carves its place in scientific literature. In 1838, Matthias Jakob Schleiden reports occurrence of nuclei in young cells of phanerogams, seed plants, and moreover becomes first to observe nucleolus in plant cells, but does not recognize the fact that it is Keimfleck of animal cells. It was Theodore Schwann to bring them together in with a series of papers in 1838. (Hall, 1969) Being an acquaintance of Schleiden, while working on animal cells, Schwann learned about Schleiden's work on phanerogams. Taking testimony of Schleiden's work on plant cells, Schwann in his first paper in 1838, draws a paralellism between larvae of spade-footed frog cells and cellular tissue of plants and claims that both have one or more Kernkörperchen (nucleus corpuscles, nucleolus). In his second paper, he contunies to provide examples of animal cells with nuclei and concludes that all animal body is composed of cells and structurally is not different than plant tissue. Through his last paper in 1838, he demonstrates that cartilage, nail, fat and unstriated muscle also composed of nucleated cells. By the work of Valentin in 1839 where the term nucleolus is coined, the idea of Schwann became fortified and from 1840's and onward there was little to none to doubt about it. (Baker, 1949)

The second part of the proposition II, namely that “cells are units of structure” will require to determine how they are separated from inter-cellular substance and how they interact with it where former required the observation of cell wall of plants to be double and thus cells can be isolated from each other. This was achieved by Gottfried Reinhold Treviranus who reported separating cells of buttercup flower by the point of a needle in 1805. Johann Frederich Link makes a explicit statement regarding cell walls in plants in 1809 and claims that cellular tissue looks like continuous just because cell walls are positioned so close to each other. In 1812, Johann Moldenhawer who was able to macerate plant tissue, reported observing single cells and claimed that use of cellular substance is more suitable than cell-tissue for plant structure. Dutrochet devising use of concentrated nitric acid as means of macerating, in 1837, was also able to show cell wall was double. (Nezelof, 2003) From there on with tools at hand, it was decided that plant cells were single entities. (Baker, 1952)

With influential work of Schwann, it was first assumed that there has to be a structure also in animal cells that would correspond to cell wall of plants. (Baker, 1952) So, following 1839 the attempts were aimed at to find one. In 1841, Karl Reichert claimed to see a surface membrane in late cleavage state of eggs of amphibians and used it as evidence of for cellular nature of blastomers. Robert Remak, in 1856, via his researches in blastomere was convinced to see counter part of cell wall in animal cells and that it was methods lacking that is needed to isolate them. It was Franz Leydig, in 1857, to oppose the necessity of cell wall like structure in animal cells and thus its status as a necessary constituent of cell, regarding membrane, cell contents and kernel as primary. Heinrich de Bary showed that Mycetozoa, slime molds, lacked cell wall and was followed by Max Schultze who claimed Protozoan cells are composed of protoplasm with nucleus devoid of membrane in 1860. Later, in 1861 with his works on striated muscle, he made the generalization that a membrane is not a necessary part of cell and that cells keeps their integrity intact by chemical properties of protoplasm. It was not until 1895 that Leydig's idea of cell structure was challenged. (Baker, 1952) Ernest Overton although not directly observing cell membrane, found through the works done on osmosis, that like plant cells, animal cells are selective in accepting in chemicals and later in 1900 after various experiments with different chemical substances and their intake rates by cell, he concluded that there is a lipoid-containing membrane on the surface of cells.

4.5 Proposition III: The Division of the Cell

The ideas on the origin of cells can be grouped in three camps, namely that they come to being by exogeny, outside and at near of existing cells; by endogeny, inside the existing cells and finally by binary division. (Baker, 1953) As it was the case with the proposition II those ideas were not in historical order and coexisted through 19th century, former two of which to be discarded with emergent evidences of cell division. I will start my discussion with ideas dealing with exogeny.

In turn, ideas about exogeny can be divided into three. (Baker, 1953) In 1807, Link proposed that cells multiply by exogenous partition while a space between cells enlarges and in the space through partition new cells occur and by growth fill it. The second idea, exogeny by vacuolation is expressed by Wolff in 1759 where he argued that there is pure glossy substance between cells where growth occurs which permits stream of nutritions and the minute holes in the intercellular substance grow into new cells. Lastly, more influential idea for cell origin by exogeny is exogeny from granules. Konrad Sprengel working on cotyledons, leafs on seeds, reported that new cells originated from granules that later enlarged in 1802. Gottfried Treviranus following Sprengel, argued that the intercellular fluid carries granules where new cell are to be formed.

Exogeny from granules rose to prominence by the works of Schwann. (Baker, 1953) In 1839, he introduced Cytoblastema a structureless substance where new cells originate, often fluid and existent both inside and outside of the cells. He argued that in cytoblastema first nucleolus occurs, which then granules appear around it to dissolve and to provide nucleus and that when nucleus grows to a certain size it is provided a layer of substance that would turn into future cell-wall by cytoblastema. Karl Vogt, in 1842, proposed two types of cytoblastema, a primary one which constitutes the intercellular substance and does not become part of cell, and a secondary one that is formed from composed cells and is structureless and argued that a nucleus occurs in either of primary of secondary cytoblastema and cell forms around it.

The second school of thought about origin of cells is that they form inside cells. This idea also is proposed in two forms, endogeny with migration from the protoplast and endogeny without migration of which the latter found more circulation among scientists. (Baker, 1953) Endogeny with migration is proposed by Ludolph Treviranus, in 1806, who argued that new tube like cells of water net algae arose from granules that are located on the walls of older cells. Another mention of endogeny occurs in Dietrich Georg von Kieser's 1814 work where he argues the globules he was able to derive cells from, which he found in the intercellular space travels from within the cell to intercellular space. Endogeny without migration was put forward by François-Vincent Raspail in 1825. Working on germination of cereals, he concluded that new cells arise from starch grains in cell enlarging till they touch each other, bursting mother cell in process. Following footsteps of Raspail, Pierre Jean François Turpin, in 1827, argued that choromatophores, light-reflecting organelles present both in bacteria and higher organisms and colorless bodies he observed in plants are of the same nature and that he was able to derive cells from both of cells either they have choromatophores or mentioned colorless bodies. He took one kind of algae found on damp walls as an example of most primitive organism and a solitary choromatophore which is called by him as globuline which in turn contains smaller globulines to produce more of the kind. He furthermore claimed that plant cells also contains globulines while being colorless. In an 1828 paper, working on various microscopical plants and reproductive parts of higher ones, he reports that the cell reproduction occurs in powers of two and was unable to give a reason for this situation. Jean Louis Armand de Quatrefages de Bréau, in 1834, suggested that endogeny without migration is present in embryo state of gastropods. In 1834, Barthélemy Charles Joseph Dumortier working on Limnaea, fresh water snails, argued that in early embryo the cells arise after the first week which are called “cellules primitive” which in turn contains eight or more cells called “cellules secondaires” and that those secondary cells expands till the primitive cell is filled and that heads of snails are not composed of cells. Schleiden, in his 1838 work, examined the formation of cells in endosperm, tissue inside the seeds of plants, and in pollen tubes and reported that after appearance of small mucus granules, the nucleoli which is discernible among mucus granules appears which in turn is surrounded by a granular coagulum forming nucleus. Nucleus is considered to be responsible for producing the cell which grows larger in the process and on its surface a blister occurs that would become the new cell and encloses nucleus. This process is completed with the blisters walls having a jelly like form and the new takes its shape by the pressure of the other cells around it. Albert von Kölliker working on development of nematodes, roundworms, introduced Embryonalzellen (embryonal cells) which precedes the cells of later embryo and claimed that newer cells arises from those by producing a pair of cells inside and setting those cells free which in turn repeats the same process until later embryo is produced, in 1843. Last report of endogeny appears in 1865 with work of Lionel Smith Beale who claimed minute particles that would constitute the new cell inside of existing cells enlarges while other particles on them might keep enlarging also. (Baker, 1953) This argument failed to make an impact since by 1865 there was more or less a settlement of origin of cells, namely that they come to being by binary division. (Baker, 1953)

In reciting history of discovery of cell division, I will follow Baker's organization of history where accounts of observations of cell division are assessed separately for protists, filamentous algae, and blastomers to be followed by other observations in various organisms and tissues, and that ends with utterance of “Omnis cellula e cellula”, in a sense motto of whole Cell Theory.

The first account of multiplication by division in protists occurs in Trembley's 1744 work where details of division of Vorticella, a genus of Protozoa. He further gave accounts of division of cells of Synedra, a protist found in fresh waters. Yet, in both works the fact of cell division was missing, as his research was not on cell division, but on the possibility of spontaneous generation. (Baker, 1953) First conscious description of division of protists was given by Charles François Antoine Morren in 1830 work where he reports how a single algae cell forms to four cell and from four cells to sixteen. In the same year, Christian Ehrenberg provides reports of cell division in Actinophrys which differs from related Actinosphaerium that is involves many nuclei unlike Actinophrys.

In 1803, Jean Pierre Étienne Vaucher observed germination of a zygote in Spirogyra, a fresh water algae and reported the details of the process. However, his work does not contain any remark about binary fission of cells. It is in 1838, in Hugo von Mohl's influential paper in the research of cell multiplication that details of filamentous algae given explicitly.

The mention of cleavage-stage first appears in 1775 in the work of Maurice Roffredi, yet with no understanding of the occurrence. (Baker, 1953) In 1780, Lazzaro Spallanzani reports 4-cell stage in toads, but like Roffredi he can't figure out what is being observed. Description of cleavage in living embryo occurs in works of Jean-Louis Prévost and Jean-Baptiste André Dumas in 1824 where the upper pole of the egg, in later stage of cleavage, to raspberries. Von Baer working on eggs of frogs asserted that the furrows appearing in process of cleavage runs deep into egg that it divides it and that the parts observed are pressed against each other. Like in work of Prévost and Dumas, he also resembled the embryo to a blackberry and in a later stage to raspberry. Philipp Franz von Siebold was first to observe formation of furrows outside of vertebrates by his 1837 work on nematodes, roundworms where he calls blastomeres “Dottertheile” which he observes to be as they become smaller by cleavage they resemble a blackberry and he was able to spot nuclei on them. The description of blastomeres in mammals was done by Martin Barry in 1839 and in 1840 he refers to the blastomeres of 2-cell stage of egg as cells, a fact which was discovered independently of Barry by Reichert again 1840 with his studies of frog's eggs. Christian Bergmann distinguishes as the first scientist to point out to the relation between cleavage and cell formation and claimed that blastomeres are the cells themselves, in 1841. Kölliker once a proponent of endogeny, in 1847, changed his mind and came up with the generalization that blastomeres always multiply by division and never by endogeny and the problem of division of blastomers was at rest from then on.

Alongside with works mentioned above, other observations were made in different organisms cementing position of cell division. In 1827, Alexander Brongniart working with Polemoniaceae, a tropical flower observed the division of mother cells into four pollen-grains, yet didn't mention binary cell-division. Dumortier, in 1832, drew a parallelism between algae and fungi and filamentous algae with respect to cell division. Schleiden, endorsing endogeny as means of cell multiplication, although witnessing cell division, was able to also spot Cytoblast, nucleus, in both parts of the divided cells, so thought his observations were in accord with his theory. (Baker, 1953) In 1841, for the first time cell division is observed in many-celled organisms apart from cleavage by Robert Remak in the blood of chick embryo and Remak concluded that he had observed a stage in cell-multiplication by division. Vogt examined the cells on the notochord of the newt through stages of larval development and reported that division of cells into halves which continue to live as independent cells. Although considering cell wall as necessary component of cell and cell formation as formation of cell walls, Nägeli his various works provided accounts of cell division in plants focusing on protoplasm. In 1847, Reichert made observations on Stronglyus, blood worms, and compared the multiplication of sperm cells with pollen-formation.

By the end of the first half of 19th century, scientific scene was ready to embrace big generalization with respect to origin of cells and the efforts of years molded in the hands of Remak and Virchow. In his 1852 work, Remak outright rejects Schwann's idea of exogeny and compares it to Generatio aequivoca, spontaneous generation and further claims that botanist long discarded the idea of exogeny and pointing out to former studies concludes that animal cell multiplication like its plant counterpart is an intracellular process. (Baker, 1953) By 1855, Remak becomes convinced in his earlier view through his work on chick and frog development and by the end of his book concludes that what is to be considered as dividing is not the cell membrane, but the protoplasm itself and that all animal cells arise from the embryonic cells by progressive division. Virchow after his 1852 work where he lays out his view on multiplication of cells that are more or less the same with Remak, in 1855, makes the generalization that "Omnis cellula a cellula" meaning every cell originates from another existing cell like it with a leap from cells in diseased tissues to normal cells. Yet, it is still debatable whether Virchow arrived those conclusions by himself or used Remak's work as his own. (Baker, 1953)At last, Leydig assigned the same validity to "Omnis cellula e cellula" as "Omne vivum e vivo".

4.6 Baker Revisited

It might be argued that there is a systematical effort in numbering of propositions in Baker's series of articles. Of the seven propositions, the first three can be considered as basic premises and the other four as inferable or as dictating itself via the former three and successive use of the propositions IV to VII. The first part of the proposition IV, namely that transformation of cells into bodies not having all the characters of cells can be considered as a consequence of taking cells as units of structure in accordance with proposition II and of accepting proposition III which asserts that the origin and development of any organism pertain to cells and only cells, in combination with the knowledge that there are differences at least between plant cells and animal cells. The second part of the proposition IV involves a reference to proposition I and second part of proposition II. When it is accepted that organisms are composed of cells and that those cells are the units of structure, it becomes possible to claim the second part. Lastly, the third part seems to extend the proposition III with addition of interaction of organisms and of cells with environment including other cells around them. The proposition V makes a reference to last part of proposition IV where the interactions of cells was emphasized, so it becomes possible to assume the individuality of cells in microscopic level alongside the organism individuality. Proposition VI can be considered as straightforward as it was already claimed that all cells are essentially the same nature in second part of proposition II and via aforementioned proposition V individuality of cells in organisms was accepted. The last proposition proves to be more tricky as it is about the origin of the many-celled higher organisms and alone with earlier propositions cannot be shown. Here, there is a reference to another grand theory namely that Theory of Evolution and both provides means for it and also -in a sense- acts as a restrainer.

The realization of proposition I seems to differ from the other two in the sense that what under inspection was not cell itself, but its shape and that the source of error was in faulty observations due to inadequate means and the problem was settled somewhat peacefully with introduction of better instruments. As for the nature of cells handled in first part of proposition II, there were competing ideas on what constitutes the essential part of a cell and a gap to be filled was present between animal and plant cells, when former argument is solved first by introduction of nucleus and of protoplasm later, the latter also dissolved. The debate around the second part of the proposition II was seemingly solved with the solution of first part, but it resurfaced by the end of century and in turn made necessary to revise the answer for the first part of the proposition. The proposition III also riddled with three different approaches being neck and neck save exogeny, only to be settled with better observations freed from yoke of endogeny.

In the next chapter, via Unificationist Theory of Explanation those three propositions and their settlements sketched here will be reviewed more in depth.

CHAPTER 5

CELL THEORY AND UNIFICATION

The question that troubled the scholars of life sciences, even before the answer was understood as it is, was to find the underlying structure of life, a question which predates the 19th century. Yet, the answers brought in the 19th century proved to be vital. As shown in an earlier chapter, the odyssey was formidable and not free of errors. However, more or less in every step and in every claim of triumph, the mark of the question can be sensed. Finding this basic, underlying constituent, in turn, can be seen as attempts to unify objects of inquiry, the living organisms, and the attained knowledge of them in aspects of morphology, metabolism and reproduction, so far that history of those attempts can be reconstructed around the theme of unification.

This reconstruction of history of research in Cell and of the Cell Theory necessitates a suitable method which I believe to be Kitcher's Theory of Explanation as Unification. His theory, aside from providing an account of how scientific explanation is achieved, also supplies examples of theories dissected into statements that are used in arguments patterns of explanation. Moreover, by the theory, it is claimed that it is unification of diverse phenomena that enhances understanding and that unification, in this regard, can be used as an indicator of choice between theories, and in turn this unification is rated on ability to produce diverse explanations over and over again with the same argument pattern.

In a nut shell, Unification with regard to Cell Theory can be used in three fashions; first, as a tool to express Cell Theory as a set of statements and the explanations produced by it; second, showing the correlation between increase in understanding and increase unification; and lastly, in relation to second mean as a demarcation criterion.

The core of Cell Theory, summed up in statements is provided by Baker's series of papers. As argued before, the first three statements seem to be the most important as the following ones can be inferred from or are implied by the former three. These are existence of cells of spherical shapes in most of the organisms, cells having certain shared characteristics such as being essentially the same nature and units of structure, and cells arising from directly or indirectly existing cells by binary fission. Any explanation regarding observations of phenomena on the cellular level, after introduction of the cell, pertain those three statements. In other words, held ideas about cell and their iterations throughout 19th century were about the first three and the other four statements. If the Cell Theory were to be constructed in terms of argument patterns from which the conclusion sets to be generated, this set of statements would have occupied the pivotal point.

What is attained by unification is piecing together the phenomena which was thought to be unrelated and exposing the relations between them via showing how they can be accounted with use of the same statements, thereby providing insight. The correlation between understanding and unification and sense of advancement of insight is sensed by the scholars of the era and made evident by their testimonies.

By being able to provide an underlying structure, scientists were also able to assert the superiority of their ideas in the face of others which lack the unitive capacity. In relation to the point just made about understanding and unification, these claims of having the upper hand also can be seen in their comments. A fact which is to be expected, if science is taken to be a venture in increasing our knowledge, thus understanding, of natural phenomena, in this case the nature and role of cell.

As mentioned before three statements dealing with the most basic characteristics of cell can be viewed as the core of the theory. Those three statements in different forms were held throughout the 19th century and for each of those statements, when in their final forms, can be taken as efforts of bridging the gap between higher life forms of multicellular organisms, and in other cases the gap between plant and animal domains.

The choice of theories with regard to those three statements then, when the observational results are put aside, can be accounted to this gap bridging effort also. As for the first statement, for a time, scholars had to either accept that there are two distinct entities in underlying structures of plants and animals or that there are essentially the same. This leads to two argument patterns for the former and one argument pattern for the latter for the basis that will unify the set of scientific statements that are embraced by the scientific community of the day. So, for both parts of the former, for animals and plants, there exists a set of argument pattern in the latter, such that it has the same conclusion set, yet it is dependent on a number of argument patterns less than the former. So for every explanation brought by applying to two distinct entities for different domains, there exists another explanation relying on a single entity. Being able to describe and examine plants and animals with the same entity was considered as a remarkable feature by the community, as Dutrochet triumphantly states (Hall, 1969):

> This astonishing organ, when one compares its extreme simplicity with the extreme diversity of its intimate nature, is veritably the fundamental piece in the whole organization; all, evidently, derives from the cell in the organic tissue of plants, and now observation proves that with animals it is the same.

Second proposition is no different, attempts at unification when taken as Kitcher puts it, again become an attempt in reducing number of arguments patterns in an explanation generating set this time for the cell. This required pinpointing a common living part and common characteristics belonging to it and the cell. Sought common living part turned out to be protoplasm. Dujardin, when he introduces his theory of Sarcode, makes an emphasis on its feature of organizing the domain of living things. For him, Sarcode is "…susceptible of assuming a more complex degree of organization whereas in animals at the bottom of the scale it always remains a simple jelly, living, contractile, extensible…" and has potential to form specific structures that "… appears in higher animals to be the determining cause of the transformation of this homogeneous into a more organized substance." (Baker, 1949) Here, Sarcode acts as an agent that would account for both the processes of simple organisms and of the higher ones, being different on observational level, they are still to be explained with the same mechanisms. Purkinje, in turn, proposes his Protoplasm as a vessel of explaining diversity and claims that "The correspondence is most clearly marked in the very earliest stages of development –in the plant in the cambium (in the wider sense), in the animal in the Protoplasma of the embryo…" (Baker, 1949) Cohn with whom the debate on protoplasm comes to an end, remarks that (Hall, 1969):

> But all these properties are possessed also by protoplasm, that substance of the plant cell which must be regarded as the chief site of almost all vital activity, but especially of all manifestations of movement inside the cell. Not only does the optical, chemical and physical behavior of this substance correspond with that of Sarcode or the contractile substance… but also the capacity to form vacuoles is inherent in plant protoplasm at all times…
>
> Hence it follows with all the certainty that can be generally be attached to an empirical inference in this province, that the protoplasm of the botanists and the contractile

substance and Sarcode of zoologists, if not identical, must then indeed be in a high degree similar formations.

Here, not only that plant and animal domains are brought closer, but also all vital activity is accounted with the help of protoplasm. So, one argument pattern involving protoplasm, when employed, becomes potent to explain any phenomena observed regardless of the domain.

The common denominators for cell are decided to be the presence of a nucleus present in protoplasm and the cell membrane as the artifact that defines the borders of cell – tough after some time. Here, Schwann, after observing nucleus on animal cells and taking Schleiden's observation of it on plant cells, concludes that (Baker, 1948):

> Since therefore the serous and mucous layers of blastoderm consist of cells and the blood corpuscles are cell, the foundation of all organs that appear later is composed of cells.

When this fact is acknowledged, it follows that:

> So the whole animal body, like that of plants is thus composed of cells and does not differ fundamentally from the plant tissue.

By this suggestion, Schwann not only cements the idea expressed in the first statements, but also unifies the cell itself and makes it the same in all organism.

In an interesting turn of events, the other common characteristic, the cell membrane was regarded to be not an essential part of cell as there was no counterpart of it in plants. It might be argued that it is the result of far-fetched attempts in unification, a uniform and sole entity for both domains of organism. The cell membrane is reintroduced in the last decade of the century by careful experiments of Overton. This can be accounted by the Corollary A of Theory of Unification. The both argument sets are more or less the same with respect to (I), yet the conclusion set of theory that asserts that the lack of cell membrane is a subset of the theory that posits its existence. All explanations that are possible by the former is also possible by the latter, moreover the latter also provides explanations for other phenomena such as selective intake of chemicals through cell.

With regard to unification, the third statement, arguably, has the utmost importance. Through it, it is put forward the idea that all life, if ever to exist, stems only and only from cell. Virchow makes the boldest claim and utters the motto that would define the Cell Theory (Baker, 1953):

> Just as we longer allow that a roundworm originates from mucous slime, or that an infusorian or a fungus or an alga forms itself from the decomposing remains of an animal or plant, so also we do not admit in physiological or pathological histology that a new cell can build itself up from a non-cellular substance. Wherever a cell originates, in that place there must have been a cell before (Omnis cellula e cellula).

Accepting that cells originates from existing cells via binary fission, along with accepting cells are of uniform nature and simple blocks of organism, not only provides the necessary explanation patterns, but also changes the face of other sub-disciplines of life sciences. The cell reshapes almost every research question concerning organisms and provides a new entity to work on and to work with in every domain. Pathology is no longer bounded with spontaneous generation, developmental biology becomes able to demonstrate the same principles applies for all living entities, physiology starts its observation on the level of cell and provides explanations for higher different levels such as tissues and organs, it becomes possible to order organisms with respect to their structural complexity thus, in a sense, a pillar of Theory of Evolution is provided; being the simple, continual unit theory of heredity gets a readily available investigation point. In the end, in terms of theory of unification, Biology is provided with a basis that would generate the most number of explanations for a great variety of phenomena.

CHAPTER 6

CONCLUSION

Cell Theory and its history although having an utmost importance both in itself and its relation to other sub-disciplines of Biology, is relatively unexplored in terms of philosophy of science. My attempt of exploration has been on its role in unifying different parts of the discipline of Biology. Philip Kitcher's Theory of Unification, in that regard, proved to be a valuable tool as it places the idea of unification on its center. Moreover, it has not only provided the means of examination, but also the Cell Theory provided, arguably, good example that fits the model provided Kitcher. As mentioned earlier chapter, the researchers of the age were keen on the concept of unification and actively sought for it.

I believe that the history of Cell Theory provides insight both in how a scientific discipline flourishes and how it interacts with other disciplines and that it deserves an in depth research and reading as it is fertile in cases that can be facilitated in advancement of new ideas in philosophy of science.

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APPENDIX

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü	
Sosyal Bilimler Enstitüsü	x
Uygulamalı Matematik Enstitüsü	
Enformatik Enstitüsü	
Deniz Bilimleri Enstitüsü	

YAZARIN

Soyadı : Taşkaya

Adı : Şahin Alp

Bölümü : Felsefe

TEZİN ADI (İngilizce) : History of the 19th Century Cell Theory in the Light of Philip Kitcher's Theory of Unification

TEZİN TÜRÜ : Yüksek Lisans [x] Doktora [ ]

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. [x]

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. [x]

3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz. [x]

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: