T. C.

MUĞLA SITKI KOÇMAN UNIVERSITY

THE GRADUATE SCHOOL OF SOCIAL SCIENCES

DEPARTMENT OF PHILOSOPHY

BIOLOGICAL LAWS AND PHILOSOPHICAL ACCOUNTS OF SCIENTIFIC THEORIES

A MASTER THESIS
IN
DEPARTMENT OF PHILOSOPHY

SİNAN ŞENCAN

ADVISORS

ASSOC. PROF. NEBİL REYHANİ
PROF. DR. AYHAN SOL

JANUARY 2014
MUĞLA

T.C.
MUĞLA SITKI KOÇMAN UNIVERSITY
INSTITUTE OF SOCIAL SCIENCES

DEPARTMENT OF PHILOSOPHY

BIOLOGICAL LAWS AND PHILOSOPHICAL ACCOUNTS OF SCIENTIFIC THEORIES

SİNAN ŞENCAN

A THESIS SUBMITTED TO
INSTITUTE OF SOCIAL SCIENCES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF ARTS

Thesis Submission Date : 05/02/2014
Thesis Defense Date : 16/01/2014

Advisor	:	**Assoc. Prof. Dr. Nebil REYHANİ**
Advisor	:	**Prof. Dr. Ayhan SOL**
Committee Member:		**Assist. Prof. Dr. Buket KORKUT RAPTİS**
Committee Member:		**Prof. Dr. Hüseyin Gazi TOPDEMİR**
Committee Member:		**Assist. Prof. Dr. Belgin GÖÇMEN TAŞKIN**
Institute Director	:	**Prof. Dr. Namık Kemal ÖZTÜRK**

JANUARY 2014
MUĞLA

TUTANAK

Muğla Sıtkı Koçman Üniversitesi Sosyal Bilimler Enstitüsü'nün 12../12../2013.. tarih ve .13/44 sayılı toplantısında oluşturulan jüri, Lisansüstü Eğitim-Öğretim Yönetmeliği'nin **24/6** maddesine göre, Felsefe..........Anabilim Dalı Yüksek lisans öğrencisi Sinan SENCAN..........................'ın "Biological Laws and Philosophical Accounts of Scientific Theories..." adlı tezini incelemiş ve aday 16.../01../2014.. tarihinde saat 14:00'da jüri önünde tez savunmasına alınmıştır.

Adayın kişisel çalışmaya dayanan tezini savunmasından sonra 80...... dakikalık süre içinde gerek tez konusu, gerekse tezin dayanağı olan anabilim dallarından sorulan sorulara verdiği cevaplar değerlendirilerek tezin **kabul** edildiğine oy birliği... ile karar verildi.

OFFICIAL REPORT

According to the Graduate Education-Instruction Regulation's **24/6** article, the jury impanelled in 13/44 meeting of Mugla Sitki Koçman University Institute of Social Sciences on 12 / 12.. / 2013 read the thesis titled Biological Laws and Philosophical Accounts of Scientific Theories of the graduate student Sinan Sencan from Department of Philosophy and the candidate defended his thesis on 16./ 01../ 2014. at 14:00 infront of the jury.

After the candidate's defense of the thesis which is dependent on his personal studies, it is agreed with agreement that his thesis was successful in the light of the answers he gave to the questions related either to the subject of the thesis and to departments on which the thesis is dependent in 80.. minutes.

Tez Danışmanı	Tez Danışmanı
Doç. Dr. Nebil REYHANİ	Prof. Dr. Ayhan SOL
Üye	Üye
Yrd. Doç. Dr. Belgin GÖÇMEN TAŞKIN	Prof. Dr. Hüseyin Gazi TOPDEMİR

Üye

Yrd. Doç. Dr. Buket KORKUT RAPTİS

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Sinan ŞENCAN

Signature :

YÜKSEKÖĞRETİM KURULU DOKÜMANTASYON MERKEZİ
TEZ VERİ GİRİŞ FORMU

YAZARIN **MERKEZİMİZCE DOLDURULACAKTIR.**

Soyadı : Şencan
Adı : Sinan **Kayıt No:**

TEZİN ADI

Y. Dil : BIOLOGICAL LAWS AND PHILOSOPHICAL ACCOUNTS OF SCIENTIFIC THEORIES
Türkçe : BİYOLOJİK YASALAR VE BİLİMSEL TEORİLERİN FELSEFİ ANALİZLERİ

TEZİN TÜRÜ: Yüksek Lisans	Doktora	Sanatta Yeterlilik
x	O	O

TEZİN KABUL EDİLDİĞİ

Üniversite: MUĞLA SITKI KOÇMAN ÜNİVERSİTESİ
Fakülte : FEN- EDEBİYAT
Enstitü : SOSYAL BİLİMLER
Diğer Kuruluşlar:
Tarih :

TEZ YAYINLANMIŞSA
Yayınlayan :
Basım Yeri :
Basım Tarihi :
ISBN:

TEZ YÖNETİCİSİNİN
Soyadı, Adı : REYHANİ, NEBİL
Ünvanı : DOÇ. DR.
Soyadı, Adı : SOL, AYHAN
Ünvanı : PROF. DR.

TEZİN YAZILDIĞI DİL: İNGİLİZCE (23.05.12 tarih ve 553/3 sayılı karar ile)
TEZİN SAYFA SAYISI: 89

TEZİN KONUSU (KONULARI) :

1. BİLİMSEL YASALAR

2. BİYOLOJİK YASALAR

3. AKSİYOMATİK GÖRÜŞ

4. SEMANTİK GÖRÜŞ

TÜRKÇE ANAHTAR KELİMELER:

1. BİYOLOJİ YASALARI

2. İSTİSNALAR

3. AKSİYOMATİK GÖRÜŞ

4. SEMANTİK GÖRÜŞ

İNGİLİZCE ANAHTAR KELİMELER:

1. BIOLOGICAL LAWS
2. EXCEPTIONS
3. AXIOMATİC VIEW
4. SEMANTİC VIEW

1- Tezimden fotokopi yapılmasına izin vermiyorum	**O**
2- Tezimden dipnot gösterilmek şartıyla bir bölümünün fotokopisi alınabilir	**O**
3- Kaynak gösterilmek şartıyla tezimin tamamının fotokopisi alınabilir	**x**

Yazarın İmzası : **Tarih : ..../....../..........**

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. First and foremost, I would like to express my special thanks and sincere gratitude to Prof. Dr. Mehmet ELGİN, who always encouraged me to study, helped and guided me in completing my thesis through his invaluable suggestions, deep interest, endless assistance, constructive feedback and patience.

I am deeply indebted to my advisor, Assist. Prof. Dr. Nebil REYHANİ, whose help, suggestions, comments and encouragement helped me in all the time of research for and writing of this thesis.

I would like to thank my advisor, Prof. Dr. Ayhan SOL, for supporting me to carry out a research in philosophy of biology and for his valuable suggestions and contributions to this thesis.

I am thankful to my friends and colleagues Efe, Kubilay and Dinçer for their all kind of help and support. Without their efforts it would not be possible to complete the study.

I owe my special gratitude to my parents Kadriye and Hayrullah, and my brother Murat for their infinite love, motivation and support.

Last but not least, my biggest thanks are to my beloved Zümrüt. Without her courage and emotional and professional support, I would not have completed this work.

To my dearest parents, Kadriye and Hayrullah Şencan…

TABLE OF CONTENTS

TABLE OF CONTENTS i
ÖZET iii
ABSTRACT iv
CHAPTER I 1
Introduction 1
CHAPTER II 4
Philosophical Accounts of Theories and Laws of nature 4
2.1. Introduction 4
2.2. Regularities and Laws of nature 5
2.3. Axiomatic View of Theories and Laws of nature 8
2.3.1. Universality 9
2.3.2. Theoretical Laws and Empirical Laws 13
2.3.3. Correspondence Rules 15
2.3.4. Explanation 17
2.3. Semantic View of Theories 18
2.3.1. Scientific Models and Laws of Nature 20
2.3.2. Semantic View without Laws of Nature 23
2.4. Conclusion 24
CHAPTER III 26
Status of Biological Generalizations and Different Approaches 26
3.1. Introduction 26
3.2. Biological Generalizations and Exceptions 28
3.3. The Role of Biological Practice 33
3.3.1. Biological Dispositions and Hidden Universal Laws 33
3.3.2. Restricted-Scope Biological Laws 38
3.3.3. A priori Biological Laws 46
3.3.4. Semantic View and Biological Laws 48
3.4. Conclusion 52
CHAPTER IV 54
Biology as Exception Ridden Practice 54
4.1. Introduction 54
4.2. Importance of Exceptions in Biology 54

4.3. Case Studies 56
4.3.1. Mendelian Principles 56
4.3.2. Structural Genes and Regulative Genes..................................... 64
4.3.3. Blood Groups and Bombay Phenotype...................................... 66
4.4. Conclusion.. 70
CHAPTER V..72
Evaluation 72
BIBLIOGRAPHY 74

ÖZET

Bilimsel yasaların ne olduğuna dair bir fikir birliği varsa, bu fikir birliğinin bilimsel yasaların evrensel ve empirik genellemeler olması gerektiğine dair olduğunu söyleyebiliriz. Bu kriterlerden yola çıkarak bazı bilim felsefecileri biyolojik genellemelerin bu kriterleri sağlamayacağını öne sürmüşlerdir. Bu iddiayı savunanlar biyolojik genellemelerin tarihsel olarak olumsal olmaları ve karmaşık olamaları nedeniyle evrensellik kriterini ihlal edeceğini düşünmektedirler. Öte yandan, bazı felsefeciler bilimsel yasaların empirik olması koşuluna karşı çıkarak biyolojide bazı a priori genellemelerin bilimsel yasa olarak düşünülebileceğini savunmaktadır. Bazı diğer bilim felsefecileri kimi biyolojik genellemelerin evrensellik kriterini tamamen yerine getirmeseler bile bilimsel yasaların işlevini yerine getirdikleri için evrensellik kriterinden vazgeçilmesi gerektiğini savunmaktadır. Bununla beraber başka bilim felsefecileri semantik teori görüşünün daha verimli bir biyoloji anlayaşı geliştirmekte kullanılabileceğini öne sürmektedir. Ben bu çalışmada biyolojideki istisnai durumların konumuna odaklanarak bu farklı görüşleri karşılaştıracağım. Semantik yakalaşımların genelleme odaklı yaklaşımlardan daha verimli bir zemin oluşturduğunu iddia edeceğim.

Anahtar Kelimeler: Biyoloji Yasaları, İstisnalar, Aksiyomatik Görüş, Semantik Görüş,

ABSTRACT

If there was ever any agreement at all on the question of what laws are, we could say that this agreement was on the claim that whatever else must be true about laws they are strictly universal and empirical. Given these conditions, some philosophers of science argued that distinctively biological generalizations cannot satisfy this requirement. Supporters of this idea defend that biological generalizations violate strict universality criterion because organisms are both historically contingent and too complex. On the other hand, some philosophers think that scientific laws do not need to be empirical; in fact, they argue that life sciences have some a priori generalizations which can be considered as law. Some others suggest that since there are non-strictly universal biological generalizations that can fulfill functions attributed to laws, universality requirement should be reconsidered. Yet others insist that semantic view of theories can be used to develop more fruitful conception for life sciences. I focus on biological exception as an overlooked concept examining biological practice to compare these different positions. I argue that semantic approaches can provide a more fruitful ground than generalization-based approaches.

Keywords: Biological Laws, Exceptions, Axiomatic View, Semantic View

CHAPTER I

Introduction

It is usually believed that there are physical laws. But, the debate on the existence of biological laws is still ongoing. Optimistic approaches to existence of biological laws focus on the actual biological practice. However, there is no consensus among philosophers and scientists that how the existence of biological laws is possible. Nevertheless, they all share the idea that some biological generalizations are proper candidates for laws of nature. I have two fundamental aims in this thesis. My first aim is to examine whether there is a superior position among optimistic approaches that explains the existence of biological laws. My second aim is to examine whether focusing only on biological generalizations can reflect the entire biological practice. By following these aims, I will argue that the semantic view of theories can offer a more fruitful ground than other approaches if we consider the status of biological exceptions together with biological generalizations.

Philosophers usually enjoy to deal with perennial problems, such as the appearance and reality problem. The problem of appearance and reality refers to the tension between two contrary answers to one question: is there any ultimate reality beyond perception? Of course, to know where all the bodies are buried is pretty difficult. Nevertheless, someone can investigate the concept of law of nature in order to pursue the problem of appearance and reality that can be traced back to Ancient Greece:

> Philosophy begins in ancient Greece with a simple hypothesis: nature *(phusis)* is or has an order *(kosmos)* or structure. If nature has an order or is structured, that order is intelligible. It is subject to reasoning or argument or understanding, in short, to *logos*. The idea of a *kosmos* is closely related to the idea of a universe or world. The idea that nature is a *kosmos* appears to sit closely alongside the idea that there is a single or unique order to nature. In this sense, ancient *cosmological* speculation from its inception bears the

> hallmark of scientific reductionism, that is, the operating assumption that multiple explanations are themselves ultimately reducible to or derived from a single explanation. Thus, the understanding of one system or phenomenon is not, ultimately, unrelated to the understanding of any other, but rather, there must be minimal or even one single law or set of law-like facts underlying it which provide the basis for explanations of the discrete data.
>
> (Gerson, 2009, p.14)

Then, it is expected that laws of nature can explain a number of individuals even though these individuals seems to be unrelated to each other. In other words, the function of laws of nature is not merely to give a description of a particular event, but laws of nature can provide a genuine explanation as well. In order to provide a genuine explanation, both philosophers and scientists intend to deal with "why questions" instead of "what questions". An answer to a "what question" provides a description of a single event, whereas an answer to a "why question" points out how similar events come into existence:

> To explain the phenomena in the world of our experience, to answer the question "why?" rather than only the question "what?", is one of the foremost objectives of all rational inquiry; and especially, scientific research in its various branches strives to go beyond a mere description of its subject matter by providing an explanation of the phenomena it investigates.
>
> (Hempel & Oppenheim, 1948, p.135)

By following the distinction between "what questions" and "why questions", it can be argued that there are at least two kinds of scientific knowledge; namely "knowledge what" and "knowledge why"[1]. Since laws of nature are considered as scientific propositions that have explanatory power, they are also considered as an important part of "knowledge why", and so as a crucial part of scientific explanation. Therefore, laws of nature are accepted as indispensible components of scientific theories. Nevertheless, philosophers of science do not reach a consensus about characteristics of laws of nature.

---

[1] See also Salmon 1989 and Hardcastle 2002.

In Chapter II, I will examine the two rival understandings of scientific theory; namely, the axiomatic view of theories and the semantic view of theories. I will emphasize the differences between these two views of scientific theories with regard to the laws of nature. In Chapter III, I will introduce different approaches to the status of biological generalizations. I will discuss the both pessimistic and optimistic approaches to existence of biological laws. In Chapter IV, I will argue that biological exceptions are also important for biological practice. I force this idea by appealing to three case studies. There will be an evaluation of my work in Chapter V.

CHAPTER II

Philosophical Accounts of Theories and Laws of nature

2.1. Introduction

Generalizations in science are considered to play a special role in explanations and predictions. However, generalizations in science seem to differ markedly. For this reason, philosophers of science (e.g. Goodman 1947, 1965; Hempel 1948, 1965; Reichenbach 1947, 1952; Nagel 1961; Armstrong 1983; Drestke 1977; Tooley 1977; Lewis 1983) try to distinguish generalizations that have a great range of applicability and a status of lawhood from those that don't to have this status. The project can be called distinguishing lawful generalizations from contingent accidental generalizations. For example, the sentence "all French novels include the letter E" is a true generalization; however, this sentence does not have the force of a lawful statement because it is possible to write a novel without using the letter E in French[2]. On the other hand, the sentence "all metals expand when heated" is proper candidate for a law statement because there is some kind of necessary (and causal) relationship between to be metal and to expand when heated. What distinguishes accidental generalizations from generalizations that seem to have a status of a law statement?

Since physics has been the model science in philosophy of science until very recently, philosophers mainly focused on typical laws in physics and tried to come up with a set of criteria that these physical laws satisfy but obvious contingent generalizations fail to satisfy. Although, there is a widespread agreement that none of these attempts have fully succeeded in providing necessary and sufficient conditions for laws of nature, there is also a widespread agreement that at least some of the necessary conditions for them are correctly identified and these are: 1. Laws must be strictly

---

[2] Actually, *La Disparition* (1969) which is written by Georges Perec does not contain the letter E in French, moreover it was translated (2005) in Turkish without using the letter E by Cemal Yardımcı. The letter E is the most frequently used letter in French, and the second in Turkish.

universal and 2. They must be empirical. These two conditions are not sufficient but any generalization that fails to satisfy any of these two conditions will not be a candidate for a law statement. Therefore we can call these two conditions as minimum conditions of law of nature.

The minimum conditions of law of nature is strictly related with axiomatic view of theories. According to the axiomatic view, laws are directly related to the explanations and predictions and therefore they function as the main element in explanations and predictions (Hempel, 1948, 1965). On the other hand, according to the semantic view of theories, laws are only indirectly related to explanations and predictions. Therefore, laws of nature do not have to satisfy the minimum conditions of law of nature. It is the models that can properly be called the main element in explanations and predictions (see Suppe 1979, 2000; Van Fraassen 1980, 1989, Giere 1999). Thus, the axiomatic and the semantic view of theories disagree over the function of laws in explanations and predictions. I focus on this debate between these two approaches about the status of laws in a theory because they have different implications for the question of how theories in biology such as evolutionary theory should be understood[3].

Axiomatic view of theories and semantic view of theories are two rival philosophical approaches to the issue of the structure of scientific theories. There are different aspects of the debate between these two approaches; however, here I will only focus on their differences about the question of how the status of law statements in a scientific theory should be understood.

2.2. Regularities and Laws of nature

Marc Lange (2008) argues that both accidental generalizations and laws of nature are physically contingent statements and they express neither logical nor metaphysical

[3] For example, some philosophers of biology argued that the semantic approach rather than the axiomatic approach is better fitted for this job (e.g. Beatty, 1981; Thompson 1989; Lloyd, 1984). I discuss this issue in the chapter III.

necessities (p.489). Logically or metaphysically necessary statements always make true assertions and negation of them entail a contradiction. Since, laws of nature express relations between events or things which actually exist in the world; they cannot include logically or metaphysically necessary claims. Therefore, laws of nature make possible assertions about the world and so they are contingent facts.

The idea put forward in Lange goes back to Hume. Hume (1854/1996) argues that *a priori* reasoning is not sufficient to show that consecutive events follow each other necessarily in nature:

> I shall venture to affirm, as a general proposition which admits of no exception, that the knowledge of this relation is not, in any instance, attained by reasonings *a priori;* but arises entirely from experience, when we find, that any particular objects are constantly conjoined with each other.
>
> (Enquiry, p.32)

Even well mathematized laws of nature (e.g. the law of motion) are inadequate to show the existence of necessity in nature, because “abstract reasoning” merely helps when we discover laws of nature and apply them to single instances:

> …all the abstract reasonings in the world could never lead us one step towards to knowledge of it [law of motion]. When we reason *a priori*, and consider merely any object or cause, as it appears to the mind, independent of all observation, it never could suggest to us the notion of any distinct object, such as its effect; much less, show us the inseparable and inviolable connection between them.
>
> (Enquiry, p.37)

A priori reasoning fails to show the existence of necessary connection between successive events. Hume also argues that observing single events do not produce the impression of causality. Put it differently, to find a cause of event is impossible by only observing this event:

> From the first appearance of an object, we never can conjecture what effect will result from it… In reality, there is no part of matter,that does ever, by its sensible qualities, discover any power or energy, or give us ground to imagine, that it could produce any thing, or be followed by any other object, which we could denominate its effect... The scenes of the universe are continually shifting, and one object follows another in an uninterrupted succession; but the power or force, which actuates the whole machine, is entirely concealed from us, and never discovers itself in any of the sensible qualities of body

(Enquiry, pp.72.73)

Moreover, Hume thinks that observing reoccurring events is not sufficient to prove the existence of causality in nature:

> All events seem entirely loose and separate. One event follows another; but we never can observe any tie between them. They seem conjoined, but never connected … there is nothing in a number of instances, every single instance, which is supposed to be exactly similar; except only, that after a repetition of similar instances, the mind is carried by habit, upon the appearance of one event, to expect its usual attendant, and to believe, that it will exist … Contemplate the subject on all sides; you will never find any other origin of that idea. This is the sole difference between one instance, from which we can never receive the idea of connection, and a number of similar instances, by which it is suggested.

(Enquiry, pp.84-85)

Therefore, causality is not necessary relation which can be demonstrated by *a priori* reasoning or can be perceived; rather it is merely psychological habit. In other words, necessary connection between events does not exist in nature, but our mind has a capacity to produce such an impression. Hume thinks that this psychological tendency is an outcome of the “constant conjunction”. The impression of causality is produced by our mind even though this impression looks like it exists in nature. Thus, all statements which are about causal relations in the world only express regular events (or constant conjunctions).

Even though Hume does not mention directly, we can infer that laws of nature are also regularities. Since laws of nature look like to explain or describe relations in nature, they are not more than regularities (Mumford, 2004, p.28). Laws of nature express contingent relations in the world. But accidental generalizations are also regularities. In addition, all laws of nature are regularities, but not *vice versa*. Therefore, Humean analysis of law of nature cannot distinguish laws of nature from accidental generalizations without any modification or addition[4]. Thus, if there is a genuine difference between laws of nature and accidental generalizations there should be some criteria to separate laws of nature from other regularities[5]. One possible way to remedy the defect of regularity view of laws of nature is to show that laws of nature are universal but accidental generalizations are not. In fact, adherents of axiomatic view of theories come up with this solution and I discuss the universality requirement in the next section.

2.3. Axiomatic View of Theories and Laws of nature

Axiomatic method is an important method, which has been widely used in formal sciences such as mathematics and geometry, in natural sciences like physics and even in philosophy[6]. Axioms are self-evident propositions and they are accepted as true without proof. Pyotr Sergeyevich Novikov (1988) defines an axiom in *Encyclopedia of Mathematics* as "A fundamental assumption, a self-evident principle. In deductive scientific theories the axioms are the fundamental primitive assumptions of the given theory from which its remaining contents is derived by deduction, i.e. by purely logical procedures" (p.314). Axioms are essential parts of axiomatic system because propositions cannot be proven in the absence of the other propositions. However, if proof of any proposition requires the existence of proved proposition, then there should be infinitely many propositions. To prevent the infinite regress, axioms are introduced into the system:

---

[4] Sometimes early modified version of Hume's regularity view of laws is called Naïve Regularity view of Laws (Carroll, 1994; Psillos, 2002).
[5] See more detailed discussion about Hume's regularity view of laws in Psillos, 2002; Mumford, 2004; Carroll, 1994; Faye et. all 2005 and especially for critics of it Armstrong, 1985.
[6] For instance, Spinoza's Ethica and Giovanni Battista Vico's New Science are two known philosophical works which are written by using axiomatic method. Moreover, Wilder (1967) mentions that Leibniz also used axiomatic method while he was writing a political book. Descartes and Hobbes are also some famous philosophers who used axiomatic method in Euclidean sense while they were studying philosophy (p.123).

> The nature of mathematical truth can be understood through an analysis of the method by means of which it is established. On this point I can be very brief: it is the method of mathematical demonstration, which consists in the logical deduction of the proposition to be proved from other propositions, previously established. Clearly, this procedure would involve an infinite regress unless some propositions were accepted without proof; such propositions are indeed found in every mathematical discipline which is rigorously developed; they are the axioms or postulates (we shall use these terms interchangeably) of the theory.
>
> (Hempel, 1945: 7)

The function of axioms is to provide a safe ground for proof of other propositions. Therefore, there are at least two kinds of propositions in axiomatic systems; namely axioms which are assumed true without proof and theorems which are proven by means of axioms.

The usage of axiomatic method is not restricted by formal sciences. In fact, axiomatic view of theories[7] is a philosophical theory, which adopts the idea that scientific theories (of natural sciences) are also axiomatic systems and laws of nature are axioms of scientific theory.

Since, laws of nature are axioms of scientific theory, other statements of a scientific theory can be derived from laws of nature. It means that laws of nature are more fundamental statements than other statements. If laws of nature are different from other statements in this way, it can be considered that laws of nature point out necessary relations or events in nature, however, laws of nature only point out contingent events as I discuss in the next subsection.

2.3.1. Universality

Especially adherents of "the early logical empiricist tradition" embrace the idea that laws of nature can meet some formal criteria but accidental generalizations are not adequate to meet them. They argue that laws of nature should be "true universally

[7] Received view of theories and syntactic view of theories are also used for axiomatic view.

quantified statements". By this requirement, they also defend the idea that to demarcate laws of nature from accidental generalizations is possible by means of "purely syntactic" analysis. Indeed, the universally quantified means that the statement can be expressed by the logical formula (Psillos, 2002, pp.137-138):

$$(\forall x)\ (Fx \longrightarrow Gx)$$

According to this approach, laws of nature are universal propositions but accidental generalizations are not.

However, some accidental generalizations can also be expressed as universal propositions. For instance, both "all metals expand when heated" and "all people are amazing in Taksim" are universally quantified statements. In other words, both statements can be expressed by logical formula: all *Fs* are *Gs*. Yet, scopes of these generalizations are different, because the former is universal (i.e. spatiotemporally unrestricted) but the latter is not. The difference between universal scope and restricted scope can be explained by the distinction between "local" terms and "non-local" terms. On the one hand, local terms refer to specific space-time coordinates. For instance, Taksim is a local term because it refers to a special location in space and time (e.g. being in Turkey or being in the 20^{th} century). Thus, a statement including "Taksim" or other local terms does not make truly universal assertion. On the other hand, non-local terms do not refer to specific space-time coordinates. For example, when we say "metals expand upon heating", we are not referring to any specific metal or expansion in a specific space-time coordinates; we are talking about metals and expansions anywhere and anytime in the whole universe. Therefore, statements that are proper candidate for laws are statements that contain only non-local terms. Put it differently, although a generalization have a universal form, a scope of generalization can be restricted because of local terms. Therefore, existence of accidentally true statements that satisfy the formal requirement of universality shows that this criterion alone is not sufficient to distinguish contingent generalizations from laws.

Reichenbach (1954) proposes two further conditions to overcome this difficulty.[8] The first requirement is that all laws of nature should be universal statements. Universal statements cannot include any local terms[9]. A local term "is a term which is defined with reference to a certain space-time region, or which can be so defined without change of meaning" (p.32). However, this requirement is not sufficient because some terms may implicitly refer to particular space and/or time. For instance, Reichenbach argues that "H. v. Helmholtz" and "any man who saw a living human retina before any other man saw one" refer to the same individual. But, the latter makes a reference to H. v. Helmholtz indirectly. Thus, Reichenbach offers a second requirement to eliminate local terms from scope of laws of nature; namely, to be unrestrictedly exhaustive statements. Unrestrictedly (exhaustive) universal statements do not include terms which refer to finite number of individuals. Therefore, laws of nature cannot include terms which refer to particular objects even implicitly:

> By a restricted space-time region we understand an undivided part of the universe, which however is not identical with the universe. Such a region might be given by a part of the earth's surface during a certain time, or by a galaxy. The condition of being unrestrictedly exhaustive rules out all-statements which are verified by examining all individuals of a certain kind within such a region.
>
> (Reichenbach, 1954, pp.37-38)

Carl G. Hempel and Paul Oppenheim (1948) also argue that scope of laws of nature should be universal. They call the predicates, which refer to limited number of instances, "designations of particular objects". Laws of nature cannot include these kinds of predicates, like *Ailurus fulgensor* or centriole. However, sometimes some predicates in a statement may formally look properly universal predicate but may contain hidden

[8] According to Reichenbach (1954), only original nomological statements are proper candidates for laws of nature. There are three other requirements for original nomological statements. First, original nomological statements should be all-statements. This means that they should include at least one universal quantifier (p.29). Second, original nomological statements should be general. Generality refers that parts of original nomological statements should be also all-statements (p.32). Third, original nomological statements should be highly confirmable (pp.18-19). For detailed discussion see Lauter, 1970; Jobe, 1967; and Hempel, 1955.

[9] Reichenbach uses individual term instead of local term. I use them interchangeably.

references to particular objects in a specific space – time region. Therefore, they also suggest that laws of nature should include only "purely universal predicates" which do not contain hidden references to particular objects like prokaryote (pp.153-156). Similarly, Nagel argues that laws of nature should be "unrestrictedly universal" which means that laws of nature should not refer to a specific "spatio-temporal region" (1979, pp.57-59). I call the terms that refer to particular space or time indirectly (or implicitly) hidden local terms.

According to adherents of the axiomatic view, laws of nature can be separated from other regularities, if laws of nature are unrestrictedly universal. In other words, a true scientific statement is a genuine candidate for a law of nature if and only if;

(i) It has at least one universal quantifier

(ii) It includes only non-local terms

(iii) It does not include hidden local terms

Therefore, restricted scope generalizations are not proper candidates for laws of nature. In other words, a proper candidate for a strict law of nature should satisfy these conditions.

Adherents of axiomatic view agree that to be universal[10] and to be empirical are two essential hallmarks of laws of nature. Nevertheless, to generalize singular events are not sufficient to construct laws of nature. For instance, the law of nature that describes the behaviour of objects in motion would include some theoretical terms such as inertia

[10] While some philosophers of science think that scientific laws are merely regularities, the others (e.g. David M. Armstrong (1983), Fred Drestke (1977) and Michael Tooley (1977)) embrace the idea that scientific laws can make ontological commitments about causality and necessity. This approach usually is called as Necessitarian account of scientific laws. According to necessitarian view, scientific laws are not regularities, rather they are statements that represent necessary relations among universals. Although their approach to laws of nature is different, they think that laws of nature should be universal. According to Necessitarian account universality is attained by a certain relation between objects (or their properties). For instance, Armstrong argues that universality cannot be captured by means of logical relations or contingent relations (1983, p.85).

or gravitation. Since, laws of nature include theoretical terms, I briefly explain the distinction between theoretical terms and empirical terms in the next subsection.

2.3.2. Theoretical Laws and Empirical Laws

In philosophy of science, there is a distinction between unobservable terms and observable terms. Unobservable terms refer to scientific entities which cannot be observed by unaided sensory organs or very simple devices such as allele, force or gravity. Observable terms refer to entities which can be directly observed or can be investigated by simple tools such as a microscope. By following this distinction, Rudolf Carnap (1966/1995) makes one more distinction between laws of nature; namely empirical laws and theoretical laws. On the one hand, empirical laws are laws of nature which describe and explain behavior of observable entities. On the other hand, theoretical laws are laws of nature which include unobservable terms. For instance, a generalization about tissue or cell can be a candidate for empirical law because to detect tissue or cell is possible by means of simple devices such as microscope. But, a generalization about allele frequencies is a more proper candidate of theoretical law because it contains unobservable terms and it is a more abstract generalization. Theoretical laws are more general (and so fundamental) than empirical laws. He thinks that the relation between singular facts and empirical laws are similar to the relation between empirical laws and theoretical laws[11]:

> An empirical law helps to explain a fact that has been observed and to predict a fact not yet observed. In a similar fashion, the theoretical laws helps to explain empirical laws already formulated, and to permit the derivation of new empirical laws. Just as the single, separate facts fall into place in orderly pattern when they are generalized in an empirical law, the single and separate empirical laws fit into the orderly pattern of a theoretical law.

(Carnap, 1995, p.229)

[11] The distinction between observable and non-observable terms (sometimes entities) is not absolutely clear. Carnap says that there is a continuum between these terms (p.226). In addition, Nagel also makes a similar distinction and he agrees that the distinction is not so sharp. Moreover, Nagel also thinks that there is a distinction between the laws of nature which include non-observable entities and the others. But, he calls the laws of nature which include only observable entities as experimental laws (pp.79 - 85).

So, theoretical laws are relevant to explaining singular events because theoretical laws explain empirical laws.

Theoretical laws are different from empirical laws in terms of their vocabulary. While empirical laws include only observable terms, theoretical laws include theoretical terms like force or gene. According to axiomatic view, any scientific theory can include different kind of terms such as mathematical terms, non-observable terms and observable terms. Frederick Suppe underlines this issue when he characterize what is an axiomatic view in his *The Structure of Scientific Theories*:

> A scientific theory is to be axiomatized in mathematical logic (first-order predicate calculus with equality). The terms of the logical axiomatization can are to be divided into three sorts: (1) logical and mathematical terms; (2) theoretical terms; and (3) observational terms which are given a phenomenal or observational interpretation. The axioms of the theory are formulations of laws of nature, and specify relationships holding between the theoretical terms. Theoretical terms are merely abbreviations for phenomenal descriptions (that is, descriptions which involve only observational term).
>
> (Suppe, 1977 p. 12)

Laws of nature are propositions which describe the relationship between theoretical terms. From an axiomatic point of view, theoretical terms are not vague concepts but they are established by means of observational terms. Although laws of nature include mathematical terms and/or theoretical terms, they can still remain empirical propositions. Because the function of mathematical terms is to help representing laws of nature quantitatively. Mathematical formulations of laws of nature represent the relationship between theoretical terms which are abbreviations of observable entities.

At first glance, to exhibit the relation between the theoretical laws and the empirical laws looks like easy to handle. Yet, there is a difficulty: while the theoretical laws explain the properties of non-observable entities, the empirical laws explain the behavior of observable entities. Therefore, there should be some rules or statements which tie the concepts of theoretical laws and the concepts of empirical laws (p.229).

Therefore the concept of correspondence rule is offered by adherents of axiomatic view of theories to construct a relation between theoretical laws and singular events.

2.3.3. Correspondence Rules

To consider scientific laws as axioms of scientific theory require defining correspondence rules which have fundamentally three essential functions. First function is that correspondence rules define theoretical terms which are considered as abbreviations of empirical terms. Second function is that correspondence rules guarantee that theoretical terms are empirically meaningful. Third function for correspondence rules is “specifying admissible experimental procedures for applying a theory to phenomena” (Suppe, 1977). Correspondence rules make it possible for us to relate our theories to empirical phenomena.

Since scientific laws represents the relations between theoretical entities, there should be a link or connection between theoretical terms and empirical terms in order to show that scientific laws directly refer to observable entities. At first, correspondence rules are considered as explicit definitions which can be represented by a certain by logical form:

$$(\forall x)(Fx \leftrightarrow Gx)$$

In this formulation *F* and *G* denotes to theoretical terms and observational terms respectively. The logical operator ‘if and only if’ provides that if both theoretical term and observational term are true at the same time, theoretical term will be meaningful. In other words, theoretical terms can be defined by purely observational terms. Moreover, conjunction of theoretical law *T* and correspondence rule *C* provide proper structure to make empirical assertions.

However, Carnap (1936) realized that dispositional terms are also cognitively meaningful even if they cannot be defined explicitly. Since dispositional terms are not definable explicitly, the initial logical formula of correspondence rules does not suit them; rather we need another logical formulation to represent dispositional terms:

$$(\forall x)\ (\forall t)[Fx \leftrightarrow (Sxt \longrightarrow Bxt)]$$

In this formulation *F* is still a theoretical term but the observational result is represented by a conditional statement where *B* is observed when *S* is observed. However, the conditional statement will still be true when *S* is not observed because of the logical structure of a conditional statement. In other words, truth of *S* is not necessary condition for the truth of conditional statements (because of material condition); therefore, the universal sentence could be true by a property which is not possessed by dispositional term *F*. Carnap offers to use bilateral reduction sentences to overcome this problem that does not provide complete interpretation of a theoretical term, rather these sentences provide only partial interpretation of a theoretical term under certain conditions:

$$(\forall x)\ (\forall t)[\ Sxt \longrightarrow (Fx \leftrightarrow Bxt)]$$

The statement tells that what will happen when S is satisfied, when there is an *x* at time *t*. In other words, the reformulation of statement guarantees that F would not be satisfied by instances which do not have a property of *S* and *B*. This modification on correspondence rules provide a proper analysis to define dispositional theoretical terms which cannot be defined explicitly (440-444).

By this modification, the idea that correspondence rules should give a complete relation between theoretical terms and empirical terms is changed by the idea that any correspondence rules provide only partial interpretation of theoretical term under a specific test condition. Therefore, correspondence rules give only partial definitions of the theoretical term. The role of scientific laws in this analysis is providing the proper relation between theoretical terms. In other words, theoretical terms could be partially specified by certain experimental vehicles for particular phenomenon under particular conditions.

2.3.4. Explanation

The function of law of nature is not limited by providing description for natural phenomena, laws of nature should provide explanation and prediction as well. As Wesley Salmon (1989) says that Hempel and Oppenheim's Studies in the Logic of Explanation is the best starting point to discuss the role of laws of nature in scientific explanation. The distinguishing feature of Hempel's deductive nomological model of explanation[12] (D-N model) lies in the idea that scientific explanation can be constructed as an empirical argument: "it does not demand anything beyond the sphere of empirical knowledge" (p.5). In addition, the consistency of scientific explanation is attained (only) by logical rules in D-N model (Salmon, 1989, pp. 3-5).

Hempel and Oppenheim (1948) argue that there are two kinds of requirements for any genuine explanation, namely: empirical requirement and logical requirements. Empirical requirement is the truth condition: "[t]he sentences constituting the explanans must be true, [t]hat in a sound explanation, the statements constituting the explanans have to satisfy some condition of factual correctness is obvious" (p.137). Simply, explanans are propositions which explain the conclusion, or the explanandum. If a scientific explanation is an argument, the premises of an argument will be explanans and the conclusion of an argument will be explanandum. Logical requirements are the formal conditions which help us to construct a valid deductive argument[13]. The second condition of logical criterion is about general laws which guarantee the deductive inference:

> The explanans must contain general laws, and these must actually be required for the derivation of the explanandum. We shall not make it a necessary condition for a sound explanation, however, that the explanans must contain at least one statement

---

[12] Covering law model of explanation is also used to name this explanation model: "The laws invoked in a scientific explanation will also be called *covering laws* for the explanandum phenomenon, and the explanatory argument will be said to subsume the explanandum under those laws" (Hempel, 1966, p.51).

[13] There are also inductive arguments in scientific activity. Hempel offers the inductive statistical (I-S) model of explanation to cover the inductive explanations. According to Hempel, the laws of nature are also essential part of I-S model of explanation. Yet, probabilistic laws are used in the I-S model of explanation instead of universal laws.

> which is not a law; for, to mention just one reason, we would surely want to consider as an explanation the derivation of the general regularities governing the motion of double stars from the laws of celestial mechanics, even though all the statements in the explanans are general laws.
>
> (Hempel & Oppenheim, 1948 pp.136-137)

This condition shows that any scientific explanation should be based on general laws, otherwise the deductive nomological model does not work. Therefore, existence of laws of nature are necessary requirements for genuine scientific explanation in D-N model. Although D-N model is not only a philosophical account of the scientific explanation, it is the most important explanation model of axiomatic view of theories.

The axiomatic view of theories may be the most influential theory conception of philosophy of science. Yet, it is not the only theory conception. On the contrary, the semantic view of theories offer a rival theory conception that rejects the very fundamental assertions of the axiomatic view.

2.3. Semantic View of Theories

According to the semantic view of theories[14], scientific theories are abstract systems that include several idealized models. Although there are different versions of semantic view of theories (e.g. Suppe, 1977; van Fraassen, 1989; Giere 1999), all these different views "share a core commitment to viewing theories as an abstract specifications of a class of models" (Craver, 2002, p.65). Since, the disagreement about the essential characteristics is not relevant, I will focus on the function of laws of nature and scientific models. Therefore, I will not discuss different forms of semantic view and their conception of models either. Furthermore, I do not compare axiomatic view and semantic view in all details. In fact, I have a more modest aim in this section, which is to investigate the basic commitments of semantic view, which helps me to examine the application of semantic view to life sciences.

---

[14] Model theoretic approach and semantic view of theories are sometimes used interchangeably.

One important difference between semantic views and axiomatic views is about the formalization of scientific theories. Supporters of semantic view do not agree that the first order predicate logic, which is embraced by the supporters of axiomatic view, is (always) the best way to formalize scientific theories. For instance, Patrick Suppes (1957) says that “when a theory assumes more than first-order logic as already available for use in its statement and development, it is neither natural nor simple to formalize the theory in first-order logic” (p. 248). For Suppes, “more than first-order logic” refers to set-theory. One advantage of the set-theoretical approach is connected with the difference between set-theoretical entities and linguistic entities: “[l]inguistic entities are, of course always part of some language, whereas set-theoretical entities in general are not” (p.232). Choosing axiomatic method to formalize a scientific theory requires using linguistic entities such as formulas and quantifiers. However, according to Suppes, a scientific theory can also be formalized by using set-theoretical entities such as relations, functions and sets as well. Bas Van Fraassen (1972) agrees that axiomatic method offers limited understanding about the nature of scientific theories: “an axiomatic formulation of a theory presents its body of theorems in one of many possible alternative ways: it presents the theory, so to speak, from a single perspective” (p.305). Since mathematical entities, like set-theoretical entities, are not part of particular language, accepting to use mathematical structures such as set theory to formalize a scientific theories means that scientific theories are extralinguistic entities:

> Theories are extralingusitic entities which can be described by their linguistic formulations. The propositions in a formulation of a theory thus provide true descriptions of the theory and so the theory qualifies as a model for each its formulations. This suggests that the semantic techniques of model theory (in the sense of Tarski [1936]) will be useful analyzing the structure of scientific theories. This suggestions gains further plausibility when it is noted that in actual practice the presentation of a scientific theory often takes the form of specifying an intended models for the sentence used to formulate the theory; this is especially so when more complicated theories of the sort encountered in the physical sciences involved.
>
> (Suppe, 1977, p.222)

Such difficulties led some philosophers of science such as Patrick Suppes, Bas van Fraassen, Frederick Suppe and Ronald Giere to develop an alternative view of scientific theories. These philosophers all agree that theories are extralingustic entities such as set-theoretical entities (Suppes, 1957) or state-spaces (Suppe, 1977; 1989, Van Fraassen 1980).

If scientific theories are not linguistic entities, then laws of nature also are not axioms of theory. The role of laws of nature is to specify an abstract system that can be applied to nature via certain interpretations. In that respect, laws of nature are abstractions which describe an ideal situation. To put it differently, laws of nature are definitions of a theory and an empirical model is an interpretation of these definitions under certain circumstances. In other words, there are two important concepts in semantic approaches: The first one is a law of nature which describes an ideal situation. The second one is a model which involves the specification of definitions for a given empirical situation. I examine these concepts in the next section.

2.3.1. Scientific Models and Laws of Nature

For semantic view of theories, universality and unrestricted scope are not essential properties of laws of nature, because laws of nature are not axioms of scientific theory which provide a basis for derivation of other propositions: "[l]aws do appear in this view – but only laws of models, basic principles of theory, fundamental equations. Some principles are indeed deeper or more fundamental than others" (van Fraassen 1989, p.188). Laws of nature are basic principles, equations or definitions of scientific theory and they only describe an ideal situation. According to van Fraassen (1970) and Suppe (1977), there are three kinds of laws of nature which can be either deterministic or statistical; namely law of coexistence, law of succession and law of interaction. Laws of coexistence describe a part of phase space which represents physically possible states. Laws of succession describe trajectories which specify possible states in the phase space. Laws of interaction describe interaction between different systems that are already specified by either laws of coexistence or laws of succession. Since, these three kinds of laws can be deterministic or statistical; there are six categories for laws of nature (van Fraassen, 1970, pp.330-334; Suppe, 1977, p.226-228).

Despite all differences, any law of nature has a certain function in semantic view: to describe the behavior of the physical system that represents all possible states in intended scope of theory: “[r]egardless what sort of law is involved, the laws of theory impose configurations on the phase space, and each of these configurations specifies the behaviour or configuration of a particular physical system” (Suppe, 1977, p.227). It is not the function of a theory or laws of nature to realize all possible states. In other words, “the theory tacitly assumes that the only factors influencing the behaviour of system are those which show up as state parameters in theory” (Suppe, 1989, p.153). If the parameters of a theory are realized in nature, then the theory can make predictions or provide explanations.

The question is whether laws of nature are empirical is not also fundamental question for semantic view because the function of laws of nature is not about providing empirical description for certain phenomena. Instead, the function of law of nature is to describe ideal models[15]. Indeed, the difference between axiomatic and semantic

[15] The term model is used differently in the semantic view. From the point of axiomatic view, scientific models are conjunction of theory and correspondence rules. In this view, universal propositions range over individuals. In fact, this is a natural outcome of using first order predicate logic to describe scientific theories. Therefore, a model of a theory is a partial model of a law of nature. Each correspondence rule has a certain function to link one feature of theory and individuals. Then, correspondence rules are components of scientific theory. On the contrary, according to semantic view, universal propositions do not range over individuals but range over properties of individuals. In fact, this is a natural outcome of using set theory to describe a scientific theories. In this approach, universal propositions explain the behavior of abstract entities, extralingusitic entities such as sets or models. Then the function of correspondence rules is to construct a link between models and theory. To put it differently, correspondence rules are considered as a component of scientific theory in axiomatic view and they serve as experimental procedures that provide a partial application of scientific law (to empirical results). Since correspondence rules are part of the theory, partial interpretation of theory is attained by conjunction of scientific laws and correspondence rules: *TC* (*T* stands for scientific law *C* stands for correspondence rule). This partial interpretation *TC* can be considered as partial model of theory which gives the true description of empirical results. In other words, a model for theory in axiomatic view is partial interpretation of theory which is constructed as *TC*. In addition *TC*, there will be a set of auxiliary hypothesis, initial and boundary conditions in order to apply the model to empirical results. If there is a new experimental procedure in order to apply the scientific law to phenomena, the modification of auxiliary hypotheses or initial and boundary conditions could not provide a satisfactory model because there should be a modification on *C*. Modification on *C* means that the model *TC* should change into

conceptions of laws of nature is related with scope of laws of nature. According to the axiomatic view, universal laws range over objects or properties in the world but according to the semantic view, they range over ideal objects or properties in the model. Therefore, there is an indirect relation between laws of nature and empirical propositions in semantic view.

Let’s analyze the sentence summarizing the role of laws of nature in semantic view to see the relationship between empirical propositions and laws of nature: “[laws of nature] impose configurations on the phase space, and each of these configurations specifies the behavior or configuration of a particular physical system” (Suppe, 1977, p.221). A particular physical system refers to a group of parameters selected to define some aspects of behavior of phenomena even though there are also different sorts of behavior of phenomena. In this sense, any physical system is an abstract system in which phenomena is considered as not affected by other parameters. A scientific theory includes all physical systems and any physical system is an idealization to represent different behavior of phenomenon. If parameters of a particular physical system are measurable, this particular system can be a phase space which is “n- dimensional space where the n parameters of the theory are the coordinates of the space” (p.226). In other words, phase space includes all possible states of physical system. Laws of nature are rules that describe the physical system by determining the different states on the phase space. Since physical systems are idealized “replicas” of particular properties of phenomena, laws of nature are not empirical propositions, rather abstract propositions.

In some versions of the semantic view of theories, laws of nature can be omitted. In fact, I will examine Ronald Giere’s position in the next subsection.

---

something like *TC′* which refers to the new experimental procedure. Since *C* is the component of theory, replacing *C* with *C′* means that the theory also changes with the modification on *C*. On the other hand, correspondence rules are auxiliary hypothesis that serve applying experimental procedures to phenomena in semantic view. In this respect correspondence rules are not part of scientific theory, rather they guarantee that idealized models can be applied to empirical results. See also Suppe, 1977, pp. 86 -110)

2.3.2. Semantic View without Laws of Nature

Ronald Giere offers a version of semantic view which does not stipulate using laws of nature to construct scientific theories. Giere (1999) examines Newton's equations of motion and equation of gravity. He says that he prefers to use the term equation instead of "law" because he thinks that using the etiquette of law for equations means that these equations have empirical meaning. However, he follows the idea that the relationship between a scientific theory and the world is indirect:

> On my alternative interpretation, the relationship between the equations and the world is indirect. We need not initially presume either a universal quantifier or empirical meaning. Rather, the expressions need initially only be given a relatively abstract such as that m refers to something called the mass of a body and v to its velocity at a specified instant of time t. The equations can then be used to construct a vast array of abstract mechanical systems, for example, a two-body system subject only to mutual gravitation attraction. I call such an abstract system a *model*… For the purposes of understanding the relationship by which the model represents the real system, the concept of truth is of little value. A model, being an abstract object rather than something linguistic, cannot literally be true or false. We need another sort of relationship altogether
>
> (Giere, 1999, p.92)

According to Giere, the function of basic principles of scientific theory such as equations is providing abstract models. In this picture, laws of nature do not have to be universal and empirical because they do not describe or explain the phenomena directly. In other words, laws of nature which are supposed to be universal and empirical are not necessary to construct scientific theories. Instead, abstract equations or basic principles can be used to establish scientific models: "Principles, I suggest, should be understood as rules devised by humans to be used in building models to represent specific aspects of the natural world" (p.94). Giere uses the term "fit" to explain the relationship between a scientific model and the world: "[t]he question for a model is how well it "fits" various real-world systems one is trying to represent" (p.93). If a scientific model describes a real world event correctly, then we can assume that our scientific model represent (part of) the world. The relation between a law of nature (i.e. principles of theory) and phenomena is indirect relation because explanation or description of phenomena is provided by scientific models. Since, scientific models are similar to real systems, they can be used for scientific prediction, explanation or description.

While some supporters of semantic view argues that laws of nature do not have to satisfy minimum conditions of laws of nature; namely to be universal and to be empirical (e.g. Suppe and van Fraassen), some other supporters embrace that laws of nature are not essential to construct scientific theories (e.g. Giere). Nevertheless, there are commitments of semantic view:

> (i) Theories specify or define abstract or idealized systems.
>
> (ii) Models are the structures that satisfy (or instantiate) these specifications or definitions (the abstract and idealized system is itself a model of the theory).
>
> (iii) These models are more or less similar to, or homomorophic, with real systems, and so could be used to control and predict real systems if the real systems were sufficiently similar to the model.
>
> (Craver, 2002, p.65)

The key idea is that very basic principles of scientific theory explains the phenomena indirectly and scientific theories are abstract entities.

2.4. Conclusion

Up to now I have discussed the basic commitments of axiomatic and semantic views of theories about laws of nature. On the one hand, from the axiomatic point of view, laws of nature should satisfy the minimum conditions of laws of nature which are to be universal and empirical. On the other hand, from the semantic point of view, laws of nature do not have to satisfy the minimum conditions because their function is not to provide a description, explanation or prediction. Instead, according to the semantic view, the function of scientific laws is to provide the relevant scientific models. Laws of nature describe models, not the actual world, and we compare our models with the world not with our laws of nature. Therefore the relationship between a theory (also laws of nature) and the world is indirect.

CHAPTER III

Status of Biological Generalizations and Different Approaches

3.1. Introduction

The function of scientific theories is to provide explanation and prediction. According to axiomatic view, theories fulfill this function via laws that satisfy certain conditions. Even though there are disagreements about the issue of what a law of nature is, there are at least two minimal conditions they need to satisfy. Thus, any generalization that does not satisfy these two conditions cannot be laws and therefore cannot fulfill the two important tasks, explanation and prediction, required of a genuine scientific theory. It is somewhat uncontroversial that whatever else laws may be, they must be strictly universal and they must have empirical content. Given these two necessary conditions, some philosophers of science argued that distinctively biological generalizations cannot satisfy this requirement (e.g. Smart 1963; Gould 1970; Ruse 1970; Beatty 1995). Supporters of this idea defend that biological generalizations violate strict universality criterion because biological entities are both historically contingent and too complex. The incompatibility between successful biological generalizations and their violation of the universality condition encouraged some philosophers of science to reconsider the status of biological generalizations and the status of two necessary conditions widely accepted in philosophy of science. Some philosophers of science (e.g. Press; 2009) argue that biological laws can be traced by biological dispositions. Some others (e.g. Elgin; 2006) insist that there are already some examples of biological laws that satisfy these two such as allometric scaling laws. Yet, others argue that the distinction between historical generalizations of biology and causal biological generalizations (e.g. Waters; 1998) or normative biological generalizations (e.g. Bock; 2007) should be reinvestigated.

On the one hand, some philosophers of science (Sober 1984, 1997; Elgin 2003, Woodward 2000, 2001; Mitchell 1997, 2000; Cooper 1996) argue that the minimum criteria for scientific laws are too strict for biological generalizations. Sober (1984) and Elgin (2003) think that scientific laws do not need to be empirical; in fact, they assert that life sciences have some a priori generalizations which can be considered as laws. Mitchell (1997) and Cooper (1996) argue that since the contingency comes in degree, the strict distinction between scientific laws and accidental generalizations cannot be useful to examine biological generalizations. Woodward (2000) thinks that the concept of invariance offers more proper evaluation for biological generalizations than the criterion of strict universality. Mitchell and Cooper agree that strict universality condition should be loosened because some biological generalizations can fulfill functions attributed to laws even though they do not exactly satisfy this condition. Moreover, others insist that complexity and contingency are no reason to think that biology cannot have strict laws (Sober 1997; Elgin 2006; McIntyre 1997).

On the other hand, several philosophers of science (e.g. Beatty, 1980, 1981, 1987; Thompson 1987, 1989; Lloyd 1984, 1994) defend the idea that semantic view of theories can be used to develop a more fruitful conception of life sciences. The relevant idea of semantic view is that that explanation and prediction are provided by scientific models instead of scientific laws (see Suppe 1979, 2000; Van Fraassen 1980, 1989, Giere 1999). In other words, the fundamental statements of scientific theories specify or characterize intended models that are used in explanation and prediction. By following semantic view, Beatty (1981) argues that central statements (basic principles) of evolutionary theory serve as definitions or mathematical abstractions used to specify systems which make empirical claims on behalf of scientific theory. Lloyd (1984) thinks that population genetics could be understood in terms of mathematical models related each other with coexistence laws and laws of succession. Thompson (1989) emphasizes that since the evolutionary theory is the collection of multiple theories, semantic view can handle to explain these different theories like population genetics and sociobiology together.

This chapter is mainly concerned with different approaches the status of biological generalizations.

3.2. Biological Generalizations and Exceptions

In contemporary sense, John Jamieson Carswell Smart (1963) introduces the first powerful objection. Smart argues that neither biological laws nor biological theories exist because biological generalizations refer to historical events; therefore, they cannot be “omnitemporally” and “omnispatially” true. Although Smart believes that biology is not applied science like engineering[16], he claims that biological explanations depend on “historical structure” rather than scientific laws. According to Smart, the scientific laws should be spatiotemporally unrestricted, however, the scope of biological generalizations are always restricted. In other words, the objects of biology like organisms or genes are historical entities because any biological generalization must refer to the evolution of life on Earth viz. the history of Earth. Thus, in principle, if there are other life forms in the universe, they could be organized differently from Earth:

> If 'cell' is defined in relation to terrestrial organisms, then these propositions about cell division are not laws in the strict sense. If 'cell' is defined without explicit or implicit reference to the planet Earth, then we have no reason to suppose that these propositions are true. Is it not very likely that in planets of remote stars there are cells which divide according to rather different methods?
>
> (Smart, 1963, p.54)

Since biological objects are products of random evolutionary events; they would be organized differently under different circumstances (pp. 50-61).

To explore Smart’s point about historical structure of biological explanation is possible by examining the evolutionary contingency thesis. John Beatty (1995) develops the evolutionary contingency thesis according to which biological generalizations are either historically contingent or deductive derivations of non-biological generalizations.

---

[16] Smart thinks that there are similarities between biology and engineering, but he accepts that biology is not merely application of physics and chemistry to organisms.

Following Stephen Jay Gould, Beatty argues that contingent "details" of evolution could be different and therefore every time one rewinds the tape of evolution and replays, one would get different evolutionary outcomes. This, according to Beatty, threatens the possibility of formulating universal laws in evolutionary biology. Furthermore, neither biological objects nor their properties are fixed because they can change as a result of evolutionary mechanisms and environmental conditions. Although some generalizations used in biology seem to satisfy minimum conditions for scientific laws, properly understood these generalizations are not distinctively biological but either physical, chemical or purely mathematical laws. (pp. 46-58):

> All generalizations about the living world:
>
> a. are just mathematical, physical, or chemical generalizations (or deductive consequences of mathematical, physical, or chemical generalizations plus initial conditions),
>
> b. or are distinctively biological, in which case they describe contingent outcomes of evolution. Whatever laws are, they are supposed to be more than just contingently true. Therefore, there are no laws of biology
>
> (Beatty, 1995, pp. 46-47)

The first part of the argument emphasizes that some mathematical, physical and chemical generalizations are also true in biology. Since, they are not biological generalizations, they cannot be a candidate for biological laws. The second part of the argument underlines that "rule making" agents of evolution such as random mutation and natural selection are also "rule breaking" agents. For instance, Beatty examines Krebs cycle to show the impossibility of distinctively biological laws. Krebs cycle is biochemical process which is essential for aerobic respiration. Although, many pathways of Krebs cycle can be explained by molecular chemistry, some processes depend on organism's genetic structure such as enzyme synthesis. Therefore, Beatty argues that the truth of generalization, which describes aerobic organisms' carbohydrate metabolism, depends on certain evolutionary outcomes, i.e. "the matter of evolutionary history". Since, scientific laws should not be restricted by contingent facts to manifest "natural necessity", biological generalizations cannot be scientific laws even though they are true propositions (pp. 47 - 53). In other words, once we formulate it in a way that it satisfies the conditions of lawhood, it is not distinctively biological, but once we formulate it in a way that is distinctively biological then it does not satisfy the conditions of lawhood.

According to Beatty, agents of evolution does not permit to formulate biological generalizations that are strictly universal and distinctively biological. There are two reasons for this: The first reason is that "mutation and natural selection in changing environments" cause to alter traits in population; therefore, the discontinuity between dominant traits in population(s) leads to contingency problem. In other words, since dominant traits always change, the biological generalizations remain local. The second reason, is related with "random mutation" and "functional equivalence". While random mutation or chance mutation means that "probability of occurrence of a mutation is no way proportional to the advantage it confers", functional equivalence means that "there are very different ways to adapting to any one environment". Both random mutation and functional equivalence show that although the same evolutionary processes affect organisms, the outcomes of evolution could be different. Therefore, neither biological objects, e.g. *Ailurus fulgens*, nor properties of biological objects, e.g. to reproduce sexually or having 36 diploid chromosome, are necessary outcomes of evolution (pp.53-58).

Smart (1963) underlines the complexity problem of biological generalizations. According to Smart, the complex properties of physical entities can be reduced to basic components of physical entities; for instance, proton, neutron and electron are simple components of atom. However, he argues that complex biological properties cannot be reduced to basic components. Thus, biological generalizations cannot be strict biological laws: "[t]here are, I would submit, no laws in the strict sense about organisms, because organisms are vastly complicated and idiosyncratic structures" (p.55). Alexander Rosenberg (1994) also discusses the complexity problem. He argues that physical phenomena can be explained by limited set of simple "mechanisms or processes" and "a small number of different types of things". However, "biological systems" are product of natural selection. Although, the identity between molecular level and functions (and regularities) can be captured in physical sciences, the same molecular structures can cause different functions and the same functions can be explained by different molecular structures in biological systems. Hence, the "smooth reduction"[17] is not possible for life sciences because of the lack of identical relationships between micro level and macro level in biological systems. In other words, while the complex phenomena can be reduced to more simple level[18] in physical sciences; functions and regularities selected by blind natural selection cannot be explained by small number of laws in biology (pp. 25 -35).

All different objections seem to share the same idea: biological generalizations are not exceptionless. Let's formulate a biological generalization which would explain reproductive strategies. This generalization will be evolutionarily contingent because all reproductive strategies depend on the history of life on earth. If the "tape of evolution" were replayed, the reproduction strategies could have been different. In other words, if the generalization about reproduction were true, the truth of this generalization would depend on the limited set of information about life.

The generalization will be complex because there are different organisms, which reproduce differently. Moreover, there are several mechanisms for different types of reproduction. For instance, asexual reproduction is observed among domains of Archaea, Bacteria, and Eukarya, i.e. asexual reproduction can be found among all six kingdoms: Bacteria, Archaea, Protista, Plantae, Fungi, and Animalia. Although asexual reproduction is a widespread reproductive mechanism, it cannot be explained by a simple generalization. In fact, there are several types of asexual reproduction in nature. For example, while the species of kingdom Archaea can reproduce by means of binary fission, budding, constriction and fragmentation; binary fission, budding, formation of

[17] Smooth reduction is direct reduction to explain complex theories via more basic theories in scientific activity. Rosenberg use this term for the complete and successful reduction between complex above level and basic ground level (molecular level).
[18] Molecular level which makes possible to explain all phenomena with small number of laws (Ibid. pp.54-55).

spores and fragmentation are types of asexual reproduction, which can be detected in kingdom Bacteria. Furthermore, species of the kingdom Protista use binary and multiple fission, budding, formation of spores and fragmentation. Although formation of spores is major asexual reproduction type for species of the kingdom Fungi, fragmentation, fission and budding are also observed among different species. Moreover, it is possible to discover formation of spore, vegetative reproduction, fragmentation, apomixis and parthenogenesis among species of kingdom Plantae. Sexual reproduction is more general among species of the kingdom Animalia, but budding, apomixis and parthenogenesis can also be observed among animals. Therefore, although *Geoglobus ahangari*, *Vampirovibrio chlorellavorus*, *Trypanosoma brucei*, *Schizosaccharomyces pombe*, *Antennaria alpine* and *Hydra viridissima* all reproduce asexually, it is impossible to explain reproductive strategies of all by a simple generalization. In addition, especially species of the kingdom Bacteria use special processes to defeat disadvantage[19] of asexual reproduction such as conjugation, transformation and transduction, which can be evaluated as type of sexual reproduction[20] and there are species, which use both asexual and sexual mechanisms to reproduce. Furthermore, there are also many sexual reproductive strategies, which are observed in the kingdom of Plantae and the kingdom of Animalia, therefore; it seems hard to formulate a single generalization to cover all cases of asexual reproduction. In other words, any biological generalization which tries to explain asexual reproduction seems to admit exceptions.

To sum up, biological generalizations cannot satisfy the strict universality condition. Since this condition is required of any generalization to be a law of nature, it follows that there could not be any strict biological laws in biology. This conclusion is reached from two main, seemingly uncontroversial, theses about evolutionary processes and the received consensus about what makes a statement a law[21].

[19] The generation of genetic diversity depends on merely mutations in asexual reproduction. Since parent and offspring are usually identical in asexual reproduction, genetic diversity would be very low.
[20] Of course, these mechanisms cannot be examined as sexual reproduction but genetic material exchange is observed among Bacteria via these mechanisms (Narra & Ochman, 2006, R705).
[21] Let's look at an argument form of this conclusion:

3.3. The Role of Biological Practice

Biology is a successful science nevertheless; it provides successful explanations and predictions. Following this fact, some philosophers argued that biological dispositions can perform the function of strict scientific laws in D-N model of explanation. Moreover, focusing on biological practice instead of philosophical assumptions about laws, some philosophers argued that the requirements for laws are too strict for biological regularities even though the consensus is not provided about which requirement is unnecessary among philosophers of biology. Furthermore, some others offered that the semantic view of theories can better accommodate the biological theories.

3.3.1. Biological Dispositions and Hidden Universal Laws

According to D-N model, laws of nature have a certain function in scientific explanation[22]. Although there can be other functions of scientific laws, I believe that their function in scientific explanation deserve extra attention because, some suggestions to overcome problems of biological generalizations depend on the idea that biological generalizations are capable of performing the role of strict laws in D-N model of explanation. For example, Joel Press (2009) thinks that biological dispositions can fulfill the function of laws of nature in D-N model of explanation. Furthermore, he pursues an idea that existence of biological dispositions can imply the existence of underlying biological laws even though the existence of underlying laws has not been proved explicitly yet.

---

1. Evolutionary mechanisms change organisms, populations and properties of them.
2. Biological generalizations are historically contingent.
3. Biological properties, events and objects are too complex to be described by a single generalization.
4. Empirical biological generalizations are not exceptionless (and would not be). (1) (2) (3)
5. Empirical biological generalizations are not strictly universal. (4)
6. There are some universal biological generalizations but they do not have an empirical content (a priori generalizations).
7. Truth of a priori biological generalizations does not depend on any empirical content. (6)
8. If any biological generalization is empirical, then it is not universal. (5)
9. If any biological generalization is universal, then it is not empirical. (7)

∴ 10. Biological generalizations cannot be scientific laws. (8) (9)

[22] According to D-N model of explanation, there is a symmetry between scientific explanation and scientific prediction. Therefore, laws of nature have a certain function in also scientific prediction.

Press (2009) argues that there may be hidden universal generalizations in biology. He states that some biological dispositions can give us a clue about the existence of the hidden biological laws. After he examines the example of prehensile tails of monkeys, he says that "[s]ince these claims are all claims about a particular population and a particular trait, they lack the generality of laws. If this explanation contains empirical biological laws, they are hiding" (p.370). In other words, he argues that some biological dispositions can imply the existence of underlying laws, because dispositions are not simply coincidences[23]. Thus, according to Press, if some biological generalizations represent the biological dispositions and these biological generalizations are more than coincidences, biological dispositions can accomplish the function of strict scientific laws in D-N model of explanation:

> Clearly, if known, these unspecified laws would allow us to construct covering law explanations of the dispositions themselves, and these explanations could then be substituted into whatever higher-level explanations refer to those dispositions… The attribution of dispositions thus acts as a sort of placeholder for the unspecified laws in a covering law explanation by placing outer bounds on which natural laws might be true… Since the explanation relies on these laws without specifying them, we can explain why it looks as though the biologist's explanation makes no reference to laws at all, even though it in fact conforms to the covering law model…So long as our knowledge of dispositions constrains the ways that the underlying laws might be sufficiently that, however they actually are, the phenomenon to be explained was to be expected, this purpose will have been fulfilled… Wherever explanations rely upon claims about dispositions, they rely upon laws, and this satisfies the covering law model.
>
> (Press, 2007, p.371)

So, Press argues that the genuine biological explanations can be based on biological dispositions such as that heritability, adaptation and fitness. According to Press, if

[23] Press (2007) makes his assertion about the existence of hidden laws clearly: "So, if there are empirical generalizations at work in this explanation, they must be hiding in the explicitly stated premises…We would not call some object's tendency to behave in a certain way a disposition if we believed that this tendency were a mere coincidence or miracle. These implied natural regularities are empirical laws if anything is" (p.371).

biological dispositions can satisfy the D-N model of explanation, biologists (and philosophers of biology) do not need to worry about the existence of universal laws because biological dispositions imply the existence of underlying universal empirical laws. Moreover, Press thinks that underlying empirical laws do not have to be distinctively biological laws: “[i]n the case of heritability, for example, we now know enough about the underlying genetic processes to at least sketch a (bio-chemical) covering law explanation” (p.371). In other words, Press thinks that if biological dispositions imply the underlying empirical laws (even biochemical laws), biological dispositions can satisfy the D-N model of explanation: “The biologist’s assertion that this disposition exists places bounds on the laws that might exist, and this is enough to satisfy the covering law model” (p.372).

Press seems to emphasize an important point. However, I think that his position offers limited understanding (at least to evaluate the status of biological generalizations), because he fails to notice the fundamental obstacle for the existence of biological laws. According to Press, the existence of biological disposition cannot guarantee the existence of universal biological laws, but the existence of biological dispositions can guarantee that D-N model of explanation works in biology. In fact, the major obstacle is not the absence of successful biological generalizations or successful biological explanations. Instead, the obstacle is that either successful biological generalizations admit exceptions or they are not distinctively biological generalizations. Biological dispositions do not necessarily imply the existence of universal biological laws even if biological dispositions can offer successful biological explanations.[24]

I want to also underline an important issue about the D-N model of explanation to make more apparent my criticism to “hidden laws”. Some physical generalizations are considered as genuine scientific laws even though their scopes include local terms. For instance, Hempel and Oppenheim (1948) make the distinction between fundamental

---

[24] Moreover, successful biological generalizations can be constructed without appealing to strict laws or D-N model of explanation. For instance, see Giovanni Boniolo (2005), James Woodward (2001) and Gregory Cooper (1996) for different accounts of biological explanations.

laws and derivative laws[25]. According to Hempel and Oppenheim, the scope of the former can only include non-local terms. On the contrary, derivative laws may have limited scopes like Kepler's laws[26]. But, all scientific generalizations within restricted scope are not derivative laws because derivative laws should be derived from fundamental laws: "[a] statement will be called a derivative law if it is of universal character and follows from some fundamental laws" (p. 154). In other words, Hempel and Oppenheim argue that some genuine laws of nature can have a restricted scope but in this case restricted scope laws of nature should be derived from fundamental laws. Furthermore, Hempel underlines that some empirical laws[27] or empirical regularities can give us a clue about the existence of more fundamental theoretical laws. In this case, we can assume the existence of theoretical laws:

> Theories are usually introduced when previous study of class of phenomena has revealed a system of uniformities that can be expressed in the form of empirical laws. Theories then seek to explain those regularities and, generally, to afford a deeper and more accurate understanding of phenomenon in question. To this end, a theory construes those phenomenon as manifestations of entities and processes that lie behind or beneath them, as it were. These are assumed to be governed by characteristic theoretical laws or theoretical principles by means of which the theory then explains the empirical uniformities…
>
> (Hempel, 1966, p.70)

Therefore, it may seem reasonable to argue that biological generalizations can imply the existence of more fundamental laws. Of course, this assertion can also be true for some biological generalizations or dispositions. However, we cannot simply assume the existence of universal biological laws because, as I mentioned above, some biological generalizations can imply the biochemical generalizations. In other words, we cannot be

[25] Hempel and Oppenheim says that his distinction is different from Reichenbach's distinction between original nomological sentences and derivative nomological sentences.
[26] However, Nagel (1979) argues that it is not so easy to show that derivative laws can be derived from fundamental laws by merely using rules of logic (even for Kepler's law). Nagel thinks that there should be extra premises, which include local terms, to make such a derivation (p.58). On the other hand, Neil Tennant (2010) offers a logical proof to derive Kepler's three laws of planetary motion from Newton's laws of motion and law of gravitation (with the addition of an empirical assumption about the total energy of a planet).
[27] Empirical laws are also derivative laws in D-N model of explanation. See the distinction between theoretical laws and empirical laws in section 2.2.3.

sure about the character of underlying mechanisms before we discover them. Therefore, I think that empirical regularities, which look like to provide a clue of the existence of theoretical laws, cannot imply the existence of universal biological laws. To argue that there are universal biological laws requires to show explicitly the existence of such universal biological laws.

Moreover, I think that biological dispositions can also lead us to wrong assumptions about underlying laws. For instance, George Wells Beadle and Edward Lawrie Tatum proposed an idea that each gene controls the expression of a specific enzyme. They conducted an experiment by using mold *Neurospora crassa* and its mutant forms. They hypothesized that if the synthesis of specific enzyme is controlled by specific gene, genetic mutants of *Neurospora crassa* cannot synthesize a specific gene products. To test their hypothesis, they created some genetic mutants of *Neurospora crassa* by means of x-ray techniques. While the wild-type of *Neurospora crassa* needs only a few components to grow, they realized that mutant strains need richer mediums. Furthermore, they determined that each different mutant needs specific nutrients which can be synthesized by the wild type. In other words, they discovered that mutant strains cannot carry out the specific biochemical pathways such as synthesizing vitamin B_6. Therefore, they concluded that each gene is responsible of producing a specific enzyme[28]. However, researches have shown that this hypothesis is not true. Because two or more genes can work together to synthesize a specific enzyme or a particular gene can have number of functions.

Although biological dispositions can offer a useful framework to understand a specific phenomenon, they may also lead us to wrong assumptions. Therefore, we cannot simply assume that successful biological dispositions imply the existence of underlying biological laws.

---

[28] This hypothesis is known as one gene one enzyme hypothesis. See Beadle and Tatum (1941) for original article, see also Hickman and Cairns (2003) for historical discussion, Fruton (1999) for a discussion about the relationship between gene and biochemical pathways (pp. 430-434).

To sum up, Press's hidden universal law argument seems to overlook the fundamental problem for biological laws. On the other hand, he has an important motivation that is taking biological practice as an initial step. In the next subsection, I examine the restricted scope biological law approach. Adherents of this approach also share the same motivation, but they argue that the universality condition is not proper to evaluate the status of biological generalizations.

3.3.2. Restricted-Scope Biological Laws

Sandra Mitchell defends the idea that biological laws do not have to be strictly universal. Since most of the biological generalizations fall into a category between strictly universal generalizations and accidental generalizations and yet can perform the function required of laws, strict universality condition for laws should be questioned. She, therefore, suggest that contingency comes in degrees not in kinds.

Sandra Mitchell has developed a pragmatic strategy about the status of biological generalizations (e.g. 1997, 2000, and 2003). Mitchell's pragmatic strategy depends on the idea that normative conception of laws of nature should be reconsidered: "Taking a pragmatic approach to scientific laws replaces a definitional norm… with an account of the use of scientific laws. How do they function in experiment, in explanation, in education or in engineering?" (Mitchell, 1997, p.S475). Mitchell primarily focuses on the function of scientific generalizations in scientific activity. With this motivation, she argues that some biological generalizations can perform the function of strict laws even though the applicability of these generalizations is limited:

> The function of scientific generalizations is to provide reliable expectations of the occurrence of events and patterns of properties. The tools we design and use for this are true generalizations that describe the actual structures that persist in the natural world. The ideal situation would be, of course, if we could always detach the generalizations gleaned from specific investigations from their supporting evidence, carry these laws to all regions of spacetime, and be ensured of their applicability. Such generalizations would be universal and exceptionless. But some causal structures-in particular those studied by biology-are not global. Thus the generalizations describing them cannot be completely detached from their

> supporting evidence. Nevertheless, we can and do develop appropriate expectations without the aid of general-purpose tools-laws that govern all time and space without exception or failure. To know when to rely on a generalization we need to know when it will apply, and this can be decided only from knowing under what specific conditions it has applied before.
>
> (Mitchell, 1997, p.S477)

According to Mitchell some restricted-scope generalizations can also be useful in scientific practice even though they cannot satisfy the universality condition. By focusing on the function of scientific generalizations, Mitchell (2000) rejects that only universal generalizations can be proper candidates for laws of nature: “[i]t is my view that to reserve the title of ‘law’ for just one extreme end is to do disservice to science by collapsing all the interesting variations within science into one category, non-laws” (p.254). Moreover, Mitchell also thinks that the sharp distinction between accidental generalizations and laws of nature can prevent noticing the importance of some restricted-scope generalizations: “Indeed, by doing so we are unable to differentiate them from the least useful of the so-called accidental generalizations” (p.254). Therefore, she prefers to use a concept of stability to distinguish less useful generalizations from more useful generalizations instead of using the concept of strict universality. Mitchell (2003) chooses the concept of stability, because she argues that the contingency comes with degrees among generalizations: “[t]he difference, then, between the two is not that one functions as a law and the other does not, nor that one is necessary and the other is contingent. Rather, the difference is in the stability of the conditions on which the relations are contingent” (p.139). If a contingency of generalization is not a proper demarcation criterion for laws of nature, contingent generalizations (e.g. biological generalizations like Mendel’s laws) can be stable enough to perform the function of laws of nature in special sciences like biology.

Mitchell argues that the pragmatic role of some non-global biological generalizations and universal physical generalizations are the same. If biological generalizations accomplish the mission of strictly universal generalizations, then the problem of contingency can be ignored. In other words, although strictly universal generalizations are more stable than biological generalizations, some biological generalizations are stable enough to perform the function of scientific law. Therefore, she claims that to be strictly universal is not a fruitful criterion to evaluate the status of scientific generalizations. The main question should be whether any generalization is stable enough to provide explanation and prediction. If stability is replaced by the strict universality condition, then it is possible to defend the idea that there are biological laws.

On the other hand, James Woodward (2000) thinks that invariance is more suitable condition than universality to explain success of biological generalizations. His argument depends on the idea that an invariant generalization can provide a successful explanation whether it is lawful or not:

> When is invariance so characterized some laws turn out not to be invariant because they are not change-relating. Hence some laws are not explanatory. More importantly, there are many examples of invariant relationships that are not laws. Appeal to laws is thus neither sufficient nor necessary for successful explanation. In contrast to the standard notion of lawfulness, the notion is well suited to capturing the distinctive characteristics of explanatory generalizations in the special sciences. A generalization can be invariant within a certain domain even though it has exceptions outside that domain. Moreover, unlike lawfulness, invariance comes in gradation or degrees
>
> (Woodward, 2000, p.199)

He argues that focusing on the concept of lawfulness may be misleading to realize the importance of more useful concept, namely; invariance. According to Woodward, an invariance of generalization depends on the stability of generalization: “[t]he general idea of invariance is this: a generalization describing a relationship between two or more variables is invariant if it would continue to hold – would remain stable or unchanged – as various other conditions change” (p.205). So, if a generalization keeps to describe a particular relationship under intervention, the invariance of generalization will not change.

Woodward states that invariance comes with degrees. In other words, there is not a sharp distinction to be invariant and to be vulnerable against interventions. Woodward suggests that some generalizations are still explanatory even though they do not satisfy the minimum conditions of laws of nature: “generalizations may differ in the range of changes or interventions over which they are invariant and that these differences are connected to differences in their explanatory status” (p.215). Since explanatory status of a generalization depends on the invariance of a generalization in invariance-account, whether or not a generalization satisfies lawful conditions is not a crucial issue (p.213-214). To put it differently, according to Woodward, some biological generalizations remain stable under very different circumstances. In this respect they have an explanatory power even though they are not strictly universal. In fact, the scope of generalization is not a proper demarcation criterion to separate the useful generalizations of special sciences from other generalizations (p.225). Therefore, he argues that the traditional views about generalizations of special sciences should be abandoned.

Despite minor differences, both Mitchell and Woodward agree that restricted scope biological generalizations can perform the function of strict scientific laws. I think that there are some difficulties with their approaches. The first difficulty is that Mitchell’s stability concept leads to *ad infinitum*. The problem emerges because any biological generalizations is stable enough to offer genuine explanation. For instance, Mitchell compares Mendel’s law of independent assortment with less contingent physical laws to argue that Mendel’s law of independent assortment is stable enough to offer a genuine explanation:

Ideal Laws: Contingent, Universal, True

- Law of conservation of mass-energy
- Law of conservation of mass
- 2nd Law of Thermodynamics
- periodic law
- No uranium-235 sphere has diameter greater than 100 meters
- Galileo's law of free fall
- no gold sphere has diameter greater than 100 meters
- Mendel's law of independent assortment
- All the coins in Goodman's pocket are made of copper.

Accidental Generalizations

(Mitchell, 2000, p.253)

It is clear that Mendel’s law is more contingent than physical laws such as 2nd Law of Thermodynamics. However, Mitchell thinks that the contingency is not a big deal, because Mendel’s law is stable enough to perform the function of physical laws. But, I think we can construct a similar table for only biological generalizations to show that Mitchell’s stability concept leads to *ad infinitum*. Let’s G_1 be a biological generalization and Mendel’s law be more stable than G_1. Let’s G_2 be a biological generalization and G_1 be more stable than G_2. So, let’s G_{n+1} be a biological generalization and G_n be more stable than G_{n+1}. By this motivation, it is possible to construct a table for biological generalizations:

Minimum contingency

Mendel's Laws

G_1

G_2

.

.

.

G_n

G_{n+1}

Maximum contingency

Figure 3.1

In this table, a contingency of generalization decreases when it approaches to the minimum contingency. If less contingency means more stability, then stability comes also with degree (like contingency). So, explanatory power of generalization will also come with degree. Therefore, the lesser stability (of a generalization) merely means that applicability of generalization is more limited than more stable generalizations. In other words, application of less stable generalization to particular domain requires more information than to apply a more stable generalization. If we know that when we apply a biological generalization to a particular domain, we can argue that this generalization is stable enough to offer an explanation. Therefore, the difference between less stable generalizations and more stable generalizations is that more stable generalizations can explain more instances than less stable generalization. So, all true biological generalizations can satisfy the stability condition when the applicability conditions are known[29]. Then, all biological generalizations can fulfill the function of laws of nature, if to fulfill the function of laws of nature depends on the stability. Therefore, I think the concept of stability goes to *ad infinitum*, because biologists can/may detect the application conditions of all biological generalizations.

The second difficulty is that Mitchell is not clear on the function of laws of nature. She only says that stable biological generalizations can perform the function of laws of nature. But I do not think that there is a consensus about this function. For instance, adherents of semantic view and supporters of axiomatic view do not share the same idea about the function of laws of nature. While, adherents of semantic view think that the function of laws of nature is providing an intended scientific models, supporters of axiomatic view argue that, the function of scientific laws is to explain empirical laws[30]. Furthermore, laws of nature may have multiple functions in scientific enterprise. For instance, while the function of Hardy-Weinberg law is to specify how the system would behave in the absence of any forces acting on that system but the function of Mendel's law of independent assortment is to specify how the system would behave during sexual reproduction. Therefore, I think if the intention is to compare the two different generalizations in order to show that they have the same function, the function of laws of nature should be clearly introduced.[31]

The third and the most important difficulty is that neither Mitchell's account (pragmatic law account) nor Woodward's account (invariance law account) can explain the status of exceptions. I think to overcome the aforementioned difficulties may be possible, however, if we follow the pragmatic law account, we cannot offer a solution to the problem of exceptions. Let's Z is a restricted scope generalization and *é* is an

---

[29] For example, a generalization about conjugation or binary fission would be stable enough if we knew which species use these asexual reproductive strategies and when particular species use these asexual reproductive strategies.

[30] See the conclusion of second chapter.

[31] The ambiguity about the function of laws of nature leads to different views. I think Sandra Mitchell does not defend the idea that stable biological generalizations can fulfill the function of strict laws in the D-N model. But, for instance, Jani Raerinne (2013) underlines that Mitchell's pragmatic account can entail the D-N model: "It appears that the motivation for the pragmatic account is adherence to a covering law model of explanation" (p.848).

exception to Z. By following the pragmatic law account, when *é* is discovered, there can be three strategies:

> (i) if it is possible to explain why *é* has emerged, then the applicability conditions of *é* can be added to the antecedent of Z, and *é* can be added to the consequent of Z.
>
> (ii) if *é* is stable enough to offer a generalization, then *é* can also be a pragmatic law.
>
> (iii) *é* can be ignored for the sake of the truth of Z.

I argue that (i) and (ii) do not offer proper explanation for *é*, because there can be infinitely many exceptions in biology. So, it seems not practical to revise pragmatic laws or to increase the number of pragmatic laws. Since the strategy (iii) does not offer an explanation for *é*, it cannot be good candidate to evaluate the status of exceptions. Furthermore, I think the invariance account would also embrace the strategy (iii). Therefore, I argue that both pragmatic account and invariance account can offer only limited understanding for biological exceptions even though both approaches can provide a fruitful framework to evaluate the biological generalizations.

I agree with the idea that the concept of law of nature should be reinvestigated in the light of actual scientific practice. Nevertheless, I think that a proper theoretical framework for biological generalizations should have a capacity to explain also the status of biological exceptions.

Both the pragmatic law account and the invariance law account underline that the universality condition can be reevaluated. I examine the a priori biological law approach that comes with the idea that, by eliminating the empirical condition, some biological generalization can be named as laws of nature.

3.3.3. A Priori Biological Laws

Elliot Sober (1984, 1993, 1997) and Mehmet Elgin (2003) argue that biological laws do not have to be empirical. By focusing mostly on population genetics, they defend the idea that some a priori biological generalizations can be considered as biological laws. For instance, Elgin (2003) thinks that both some physical laws and biological laws that describe "zero force state" fulfill the same function. He argues that both the law of inertia and the Hardy-Weinberg Law describe how the system would behave in the absence of other forces. On one hand, the law of inertia implies that the situation of motion or the situation of rest will remain unchanged in the absence of other effects. On the other hand, the Hardy-Weinberg law tells us that the genotype frequencies would exactly obey certain mathematical theorem given the relevant allele frequencies in the absence of evolutionary mechanisms. Therefore, function of both inertial laws is to specify how the system would behave in the absence of any forces acting on that system. If the function of these laws is the same, then the requirement that laws be empirical is unnecessary:

> What follows is that zero-force laws in physics and in biology function in a similar way in these sciences. They do not explain point values (save one exception-i.e., in zero-force state itself). They simply point out that there is (are) force(s) at work when the system deviates from the zero-force state. Zero-force laws form a starting point in explanations. Then, the singleton-force law can take over…The empirical requirement for laws entails that the law of inertia and the law of universal gravitation are both laws of nature, but the Hardy-Weinberg law in population genetics and the model of heterozygote superiority are not, because they are a priori. However, as we have seen, whether zero-force laws are a priori or empirical is irrelevant to how they function in the sciences to which they belong. Furthermore, whether the singleton-force laws are a priori or empirical is irrelevant to how they function in explanations. I take this to be evidence that the requirement that laws be empirical is mistaken.
>
> (Elgin, 2003, p.1387)

Therefore, Elgin argues that in the absence of any argument for the claim that laws have to be empirical and the fact that at least some a priori principles can function as the empirical laws of physics, the necessity of empirical content for laws should be questioned.

I agree with the idea that a priori biological generalizations can offer genuine biological explanations. I also agree that biological laws do not have to be empirical. Nevertheless, I think that the relationship between a priori generalizations and empirical biological phenomena is not clear. In other words, the question as to how a priori biological generalizations explain the biological data should be answered by adherents of a priori biological law approach. However, I do not agree with the objections that arguing the existence of a priori biological laws is somehow dangerous. For instance, Massimo Pigliucci (2012) thinks that to entitle some biological laws as a priori laws can cause misunderstandings about the role of mathematical principles in philosophy of science:

> [I]t simply seems strange to suggest that a scientific law can have no empirical content and instead simply be true a priori (as Hardy–Weinberg surely is, mathematically speaking). This risks embarking philosophy of science down the slippery slope of considering logical and mathematical principles themselves as ''laws,'' a usage that clearly does not accord to scientific practice at all.
>
> (Pigliucci, 2012)[32]

I do not think that existence of a priori laws is strange. If the existence of empirical physical laws is not strange for physicists who work with empirical generalizations, then the existence of a priori laws would not be strange for biologists who work with a priori models. As Sober (1997) states, the possibility of a priori laws is related with biological practice: "[p]erhaps it is time to investigate the possibility that biology has no empirical laws of evolution because of the strategies of model building that biologists have adopted" (p.S467). Nevertheless, Pigliucci's objection has a point that the relationship between a priori generalizations and empirical data should be investigated more deeply.

[32] I use the online first edition of this article, so there is no page number.

Furthermore, it is not clear what the function of a priori laws is. Of course, laws of nature provide scientific explanations and prediction, but it is still an important question as to how a priori biological generalizations accomplish to offer genuine empirical explanations.

I think that semantic view of theories can offer a starting point to explain the relationship between a priori generalizations and empirical phenomena[33]. Therefore, I examine the application of semantic view of theories to biological theories in next section.

3.3.4. Semantic View and Biological Laws

The status of evolutionary theory has already been interpreted according to the semantic view of theories. For instance, John Beatty (1981) states that the evolutionary theory should also be investigated in terms of the semantic view of theories because the axiomatic view of theories is not the only conception of theories:

> Philosophers' motives in defending Mendel's law and the Hardy- Weinberg law have been less questionable than their means of defense. They have wanted to show that Mendelian genetics and the synthetic theory of evolution are legitimate scientific theories. It's just that the only standards of appraisal available to them were those of the received view of theories, according to which the central statements of a theory should be laws of nature… But now that the received view has a rival in the semantic theory, the adequacy of the synthetic theory, as a theory cannot be judged simply in terms of received view standards.

(Beatty, 1981, p.410)

He thinks that evolutionary theory is a scientific theory even if there are no general laws of evolution. He suggests that central statements of evolutionary theory, such as Mendelian laws and the Hardy-Weinberg law can be considered as definitions. If these fundamental statements are considered as definitions, then they do not make any direct claims about natural populations:

---

[33] See Elgin (2010) for his view about the semantic view of theories.

> On the semantic view, a theory is not comprised of laws of nature. Rather, a theory is just the specification of a kind of system--more a definition than an empirical claim. In the case of the synthetic theory, an appropriate system specification is:
>
> > A Mendelian breeding group = [df] a breeding group whose members form gametes in accordance with Mendel's first law of inheritance.
>
> Since the Hardy-Weinberg law is a deductive consequence of Mendel's first law, we can also say of a Mendelian breeding group that:
>
> > A Mendelian breeding group = [by consequence of its df] a breeding group whose genetic frequencies obey the Hardy-Weinberg law.
>
> Whether Mendel's law or the Hardy-Weinberg law is really a law of nature is irrelevant from the perspective of the semantic view of the synthetic theory. The theory itself simply specifies a kind of system --it makes no empirical claims.
>
> (Beatty, 1981, p.410)

Yet, Beatty thinks that according to the semantic view, evolutionary theory is still an empirical theory because empirical part of a theory has to do with predicating these definitions to specific empirical cases:

> Rather, the empirical claims of science are made on behalf of theories. They assert that particular empirical systems are instances of the kinds of systems specified by theories. Empirical claims of modern evolutionary biology then include claims to the effect that particular breeding groups are instances of Mendelian breeding groups, and/or that particular breeding groups are instances of Mendelian breeding groups with respect to the particular loci under investigation.
>
> (Beatty, 1981, pp.470-471)

Thus, the function of definitions is to provide framework for specifying empirical models instead of making direct claims about nature. For instance, any particular breading group would behave as a Mendelian breading group if this particular group is an instance of empirical model specified by Mendelian laws. However, it is not compulsory that all breeding groups should be instances of a Mendelian breeding group.

Elizabeth Lloyd (1994) also embraces the semantic view of theories to evaluate the status of evolutionary theory. She offers a detailed account of evolutionary theory and she emphasizes the importance of scientific models in evolutionary biology:

> The main reason that models should be considered in any description of the structure of evolutionary theory is that models themselves are the primary theoretical tools used by evolutionary biologists. Biologists often present their theories in terms of models, and they often draw conclusions using these models. Conclusions arrived at purely through following the consequences of some mathematical model appear repeatedly in biologists' writings.
>
> (Lloyd, 1994, p.9)

Lloyd thinks that mathematical models are indispensible for evolutionary theory and she argues that the proper theoretical analysis of evolutionary theory should explain the status of mathematical models. Lloyd states that there is a difference between the axiomatic understanding of model and the semantic understanding of model[34]:

> Under the logical positivist approach, formulation of the logical calculus involves viewing the theories as sets of statements. Interpretations that make all the statements in the set true -- logicians call these "models"-- may be given for certain theories. In our discussion, a model is not such an interpretation, matching statements to a set of objects that bear certain relations among themselves, but the set of objects itself. That is, models should be understood as structures; in almost all of the cases I shall be discussing, they are mathematical structures, i.e., a set of mathematical objects standing in certain mathematically representable relations.
>
> (Lloyd, 1994, p.15)

Lloyd emphasizes that scientific models are not linguistic entities that can be represented by statements but, they are extralinguistic entities such as sets or mathematical structures.

Following van Fraassen's state space approach, Lloyd (1994) argues that the Hardy-Weinberg law can be used to develop both deterministic models and stochastic

[34] I already discuss the fundamental differences between the axiomatic view and the semantic view in Chapter II.

models of evolutionary theory. The Hardy-Weinberg law states that the allele frequency of particular population will remain unchanged from generation to generation if the population would not be influenced by other evolutionary forces such as genetic drift, migration, non-random mating, selection and/or mutation.

On the one hand the deterministic models can predict the gene frequency of population definitely when one or more force influence a population. For instance, if there is a dominance – recessive relationship for a trait in a population, then we can calculate the allele frequency of this trait for the next generation: "[t]his sort of model is a deterministic model because, given the initial conditions of the population and any set of parameters the precise condition of some future time can be predicted" (p.29). On the other hand, the stochastic models can predict the gene frequency of population relatively when one or more forces influence a population: "The need for stochastic models arises when it is necessary to know more than the average of a range of values, that is, when variability needs to be measured" (p.30). In other words, stochastic models can provide a prediction for "the relative chances of the occurrence of each of the possible results". [35]

The crucial idea is that the Hardy-Weinberg law is used to construct both deterministic models and stochastic models. Moreover, these different models can be used to predict a population's allele frequency after intervention of one or more genetic forces. But, the Hardy-Weinberg law is not empirical. Furthermore, deterministic models and stochastic models also are not empirical. Nevertheless, they offer a genuine explanation in evolutionary biology. The important point is that, the Hardy-Weinberg law provides relevant models without appealing to real populations. But, these models are beneficial tools for biologists when they face with real populations.

---

[35] Lloyd explains that the Hardy Weinberg law can also serve as both coexistence law and succession law. While the former "describe the possible states of the system in terms of the state space", the latter "select the biologically possible trajectories in the state space" (pp.37-40). I terminate to discuss Lloyd's position here because Lloyd follows a unique form of semantic view of theories; namely state-space approach. But, I focus on the basic commitments of semantic view. For instance Giere neither uses these kind of terminology nor follows the state-space approach. Therefore, I will not use a special terminology of state-space approach. The most relevant idea of semantic view is the indirect relation between scientific laws (or basic principles) and empirical data. I will return this issue in the Chapter IV.

3.4. Conclusion

To sum up, there are two general tendencies about the status of biological generalizations. One could follow the philosophical assumptions of the axiomatic view; alternatively one could give up to these assumptions, partly or totally, for the sake of biological practice. The price of the first tendency is the pessimistic approach to the existence of biological laws. The price of the second tendency is a more detailed biological study.

Although there are important differences between all aforementioned optimistic suggestions about the status of biological laws, they are similar in one respect: biology is a genuine science providing genuine scientific explanations. Moreover they agree that the general approach to the issue of whether there are biological laws is that to answer this question we have to take biological practice as primary and re-evaluate the status of our philosophical theories of laws. All views focus on the question of what the function of laws are, rather on the question of what laws are. The difference has to do with which of the two necessary conditions for laws (strict universality and empirical content) should be given up or with which of the theory conception should be embraced. Even then the positions are not necessarily incompatible as one can defend the idea that all positions should be given up (except the semantic approach) in favor of a more modest aim.

The debate about the status of biological generalizations can be concluded at this point or can be followed by a further discussion about the status of exceptions in biological practice. It may be theoretically interesting to show that at least some biological generalizations can satisfy the minimal conditions of traditional definition of lawhood. However, their number is very limited and therefore it does not help us to account for most of the biological practice to know that there are these very few special cases of biological generalizations. Most of the biological practice is carried out even in the absence of such special cases of biological generalizations. Therefore, I think it is important for philosophers of biology to give an account of how most part of biological practice is carried out.

CHAPTER IV

Biology as an Exception Ridden Practice

4.1. Introduction

I argue that a proper theoretical approach should have a capacity to explain both the function of biological generalizations and regularity-breaking exceptions together. Focusing too much on the nature of biological generalizations may cause to neglect the importance of how exceptions are dealt with in biology.

In this chapter, I will focus directly on the issue of exceptions in biology and its relation to issues concerning how scientific theories should be understood. I will argue that semantic approaches can provide better understanding for the status of exceptions in biology than the approaches. I will examine three case studies to argue for the view that exception ridden practice of biology can be explained by semantic view rather than axiomatic view or generalization-based approaches.

4.2. Importance of Exceptions in Biology

I already mentioned the one gene – one enzyme hypothesis[36]. According to this hypothesis, simply each gene has a unique factor that is synthesizing a specific enzyme. Although, we know that this hypothesis is not entirely true, even mostly false, it was a highly popular hypothesis in 1940s. Moreover, George Wells Beadle (1945), one of the founders of this hypothesis, thought that one gene – one enzyme hypothesis is almost universally true:

> If genes in some way direct the configuration of protein molecules during their elaboration, it is not necessary to assume that they function in any other way. . . . The protein components of enzymes. . . would have their specificities imposed fairly directly by genes and the one-to-one relation observed to exist between genes and chemical reactions should be a consequence. It should follow, indeed, that every enzymatically catalyzed reaction that goes on in an organism should depend directly on the gene

[36] See section 3.3.1.

> responsible for the specificity of the enzyme concerned. Furthermore, for reasons of economy in the evolutionary process, one might expect that with few exceptions the final specificity of a particular enzyme would be imposed by only one gene.
>
> (Beadle, 1945 in Fruton, 1999, p.434)[37]

Beadle thought that one gene – one enzyme hypothesis represents the relation between genes and cellular structures correctly. However, one gene – one enzyme hypothesis has been rejected as a result of novel experiments which was conducted on exceptional situations.

I assume that there are many similar cases in biology. I do not argue that biologists always study exceptional situations or that they always intend to find a genuine explanation for particular exceptions. I argue that biologists usually have to work with very local problems:

> [L]aws receive little attention in many well-developed areas of biology. There is no escaping the fact that biological systems (and their environments) are relatively complex and that this factor limits possibilities for developing general theories which allow explanation and prediction of behaviour in great detail. The emphasis is usually on antecedent conditions rather than on laws and the theories one encounters in the average biology text are almost always merely locally valid ones. We would regard the prevalence of such theories as a positive feature. In science one needs particulars besides generalities and in some contexts particulars may be very important, even if they are not covered explicitly by general laws… Although the old ideals of logical positivism have few adherents nowadays (unified science, laws of nature as a hallmark of science, coherence only by reduction, etc.), they still survive in a covert way. Science is supposed to aim primarily at generality, and research which puts generalities in a secondary role is often deprecated.
>
> (Van Der Steen and Kamminga, 1991, p.463)

Therefore, the philosophical accounts of local problems should be investigated. In the next section, I will discuss some case studies to show that exceptions deserve extra

[37] I could not find an original article.

attention. In addition, I argue that the semantic approach can provide more fruitful theory conception than other views to explain the status of these exceptions.

4.3. Case Studies

4.3.1. Mendelian Principles

One of the classical case studies for philosophy of biology is Mendelian inheritance principles. There are mainly two fundamental principles that are used in genetics:

> **Principle 1:** Genetic characters are controlled by unit factors (alleles) existing in pairs in individual organisms [P1]
> **Principle 2:** During the formation of gametes, the paired unit factors separate, or segregate, randomly so that each gamete receives one or the other with equal likelihood [P2]

P1 and P2 are Mendelian inheritance principles which are widely used to explain biological phenomena. Of course, we expect to apply these principles to any related biological phenomena. Monohybrid cross is one of the related phenomena that simply means that mating individuals possess different traits in one particular locus. Let's first apply P1 and P2 to monohybrid cross before discussing any particular empirical phenomenon.

According to P1 each individual possesses two alleles for any particular trait. We will use capital letter "A" to symbolize one of the alleles. For a given locus there can be more than one allele. The number of alleles can be many but we will consider a case where there are only two alleles. Let's suppose that the other allele that can occupy the locus that A allele can is 'a'. We will use AA for a particular trait and aa for another form of this trait. For instance, if having white flower is a genetic character which is controlled by a particular allele, we will represent this allele as A, and genetic trait as AA. Moreover, if having purple flower is other variation for this trait, we will represent this allele as a and genetic trait as aa. While white flower organisms will be represented by AA, purple flower organisms will be represented by aa. According to P2, any individual transmits only one allele to reproduction cells. It means that any offspring possesses only one allele from each parent. If we continue to use our symbolization, we will represent the gamete containing one allele as A or a. Let's use Punnett square to represent the result of mating of two individuals (Figure 4.1).

Parental Gametes	**A**	**A**
a	Aa	Aa
a	Aa	Aa

Figure 4.1

F_1 individuals have a different genotype from parents because they receive different alleles from each parent. However, all F_1 individuals have the same genotype Aa. Let's use Punnett square again to show what will happen if F_1 individuals mate (Figure 4.2).

Gametes from F_1	**A**	**a**
A	AA	Aa
a	Aa	aa

Figure 4.2

F_2 offspring does not have one genotype, but there are three different genotypes: AA, Aa and aa. Using figure 4.2, we can represent the genetic ratio for F_2 individuals like 1:2:1 respectively AA, Aa, aa.

Up to this point, we obtained a theoretical model that expresses the genetic ratio of F_1 and F_2 individuals in a monohybrid cross. However this model is not capable of describing or explaining empirical data because it is not interpreted by any empirical principle yet. Let's add another principle to apply our model to explain the phenotype. Our model describes only the genetic ratio so we need another principle to explain how genetic ratio affects relevant phenotype:

> **Principle 3:** When two unlike unit factors responsible for a single character are present in a single individual, one unit factor is dominant to the other. [P3]

The interpretation of P3 for monohybrid cross model is that both Aa genotype and AA genotype will exhibit the same phenotype because of dominance – recessive relationship. Therefore we expect to find the 3:1 ratio for different traits, respectively dominant trait and recessive trait, in monohybrid crosses (Figure 4.3).

	Genotype	Phenotype
	AA	Dominant Trait
	Aa	Dominant Trait
	aa	Recessive Trait
Expected Ratio	1:2:1	3:1

Figure 4.3

So far, we use P1, P2 and P3 to construct a monohybrid cross model (MCM) that can be applied to any organism. Finally, our assertion is that MCM can describe and explain the phenomenon of mating individuals possessing different traits. Two traits and one locus are constants for this model. It is also possible to construct other models for other constants like three traits or two loci with P1, P2, P3 and other related principles. Let's test MCM with empirical findings for two different organisms; namely *Pisum sativum* and *Antirrhinum majus*

Let's determine the trait which we test in monohybrid cross as flower color and use two flower colors for *P.sativum*: violet and white. After first cross between parents we obtain offspring that all possesses violet flower. Our conclusion is that violet flower trait is the dominant character and white flower trait is the recessive trait. Therefore, we expect 3:1 ratio among F_2 offspring respectively violet and white. As expected, we attain results which satisfy MCM that the number of violet flower individuals is approximately three times the number of white flower individuals. So far, the conclusion from this experiment is that MCM is capable of explaining the monohybrid cross for flower color in *P.sativum.* Moreover, this model works on other traits like form and color of pods and seeds. The conclusion is that MCM is a good model to explain monohybrid cross among peas.

Let's determine the trait which we test in monohybrid cross as flower color and use two flower colors for *A. majus*: red and white. After the first cross between parents we obtain offspring that all possess pink flower. The pink flower is new trait which is not observed among parents. The conclusion is that there is no dominant – recessive relation between red flower trait and white flower trait among *A. majus*. MCM does not offer acceptable explanation for monohybrid cross among *A. majus.* Therefore we should modify our model. Let's replace P3 with a new principle because dominance – recessive relation is not observed:

> **Principle 4:** When two unlike unit factors responsible for a single character are present in a single individual and one unit factor is not dominant to the other, then heterozygote genotype produces intermediate phenotype [P4]

The interpretation of P4 for monohybrid cross model is that each genotype represents different phenotypes. Therefore, we expect to find the 1:2:1 ratio for different traits, respectively parent trait (AA), intermediate trait (Aa) and parent trait (aa) in monohybrid cross (figure 4.4).

	Genotype	Phenotype
	AA	Dominant Trait
	Aa	Intermediate Trait
	aa	Recessive Trait
Expected Ratio	1:2:1	1:2:1

Figure 4.4

P1, P2 and P4 are used to construct the monohybrid cross for incomplete dominance model (MCMI) that can explain the phenomenon where there is incomplete dominance. The ratio of genotype is the same in this model, 1:2:1, but the genotype produces a different phenotypic ratio 1:2:1 which is covered by MCMI. Moreover, MCMI does not conflict with experimental results obtained from *A. majus* population. Our conclusion is that MCMI can describe and explain the phenomenon of monohybrid cross when incomplete dominance is observed among test subjects.

We start with two general principles of genetics and add more restricted-scope principles to them to explain a particular biological phenomenon. Neither MCM nor MCMI are false models. Rather, they are two different models that explain different biological phenomena. Therefore, we can only argue that MCM provide sufficient explanation for organisms that possess dominance – recessive relationship for particular traits. Besides, we can only argue that MCMI provides sufficient explanation for organisms that possess incomplete dominance relationship for particular traits. They are not the only models for monohybrid cross because we can construct a new model when we come across another case that cannot be explained by P3 or P4 (e.g. co-dominance).

Furthermore MCM or MCMI does not undermine P1 or P2 for two reasons: the first reason is that both of them are true in well-defined conditions. The second reason is that even if MCM and MCMI do not universally apply, we can still construct other models using P1 or P2 by specifying different empirical principles in place of P3 or P4.

One may argue that this case can also be accounted in the framework of Mitchell and Woodward's alternative strategy. According to this strategy, whether we call P1, P2 and P3 laws does not matter as long as they are capable of doing the job of strict laws. I think this would be true for the monohybrid cross with dominance/recessive relationship. However, when we come across a new exception to P3 like the case of incomplete dominance, this strategy will require that we come up with a new generalization such as P4 that will explain this case and this new generalization will again be said to do the job required of laws in its domain. However, this strategy should say that P3 is more stable or more invariant or has a greater scope than P4 because the recessive-dominance relationship is more common than the case of incomplete dominance. The trouble is that we should always have to increase the number of generalizations, because there are always exceptional situations. Let's think that there is a case for also co-dominance relationship and compare these three generalizations:

> (1) When two unlike unit factors responsible for a single character are present in a single individual, one unit factor is dominant over the other then heterozygote genotype produces dominant phenotype.
>
> (2) When two unlike unit factors responsible for a single character are present in a single individual and one unit factor is not dominant to the other, then heterozygote genotype produces intermediate phenotype.
>
> (3) When two unlike unit factors responsible for a single character are present in a single individual and both of them are dominant to other, then heterozygote genotype produces both phenotypes.

I think that (1), (2) and (3) can satisfy both stability condition and invariance condition with equal degree. Their contingencies are the same because their truth depends on the same conditions, namely the relation between two alleles at the same locus. Moreover, if we accept the idea that there are three different laws of nature, then there would be three laws of nature which try to explain the same phenomenon. I do not think this approach is so practical. Nevertheless, it may be argued that restricted-scope biological laws can be still a good approach, however, it offers less fruitful framework to explain all kinds of dominance relations. Moreover, if other cases of exceptions such as sex-linkage to P3 or P4 are taken into account, we will have to increase the number of generalizations with decreasing scope or with decreasing stability or invariance.

It is true that the very argument that Woodward and Mitchell put forward questions the sharp distinction between strict laws and less strict generalizations. However, to say that there is no sharp distinction between these two cases does not mean that no distinction is useful. It may be true that there is no sharp distinction between being rich and poor but that does not mean that there is no useful distinction between the two. Thus, even if we cannot come up with a sharp distinction between strict laws and less strict generalizations, we can still come up with a pragmatic criterion that will tell us what sorts of generalizations can do the job of laws. It does not seem right to suggest that a generalization that applies only few populations are invariant enough to do the explanatory or predictive function attributed to laws, not at least according to their own approach.

Let’s look at the strategy of Sober and Elgin. They seem to be silent on the question of what the exact relationship between these a priori mathematical models and specific empirical cases is. Although in their joint paper (Elgin and Sober 2002), they suggest that explanation by idealization does not work by either deducing explanandum from explanans or by even explanans conferring a high probability on explanandum, they are not specific enough about the nature of this relationship. Although their account is consistent with the semantic view of theories, they do not discuss their approach’s relation to this view[38]. However, according to the semantic view, Mendelian Principles

[38] Elgin (2010) is an exception, but he does not discuss the relationship between the semantic view and a priori law approach in details.

of inheritance describe idealizations that are used to specify empirical statements that apply to a specific phenomenon. Therefore, function of these principles is not to describe or explain the phenomenon at hand directly but rather provide suitable rules to specify empirical statements.

4.3.2. Structural Genes and Regulative Genes

Let's look at another case where the point I wanted to develop above becomes more apparent. There are two types of genes; namely structural genes and regulative genes. The distinction depends on the function of genes. While structural genes are used to synthesize functional units which help to control metabolic events; regulative genes control the expression of these structural genes. Not all gene sequences are used for expression at the same time. Regulative genes involve in the switching on/off of genes.[39] Regulative genes respond to environmental changes (e.g. heat shock or lack of lactose) by opening or closing structural genes. In Eukaryotes, mRNA molecules are synthesized from DNA and are released into cytoplasm. Biologists can determine the number of mRNA molecules by using DNA microarray techniques. Since to target specific gene is possible, DNA microarray experiment gives us relative activity of each gene. By identifying specific genes and by obtaining the total amount of mRNA molecules, biologists can determine which structural gene is active or can construct global maps for all cellular activities (Nguyen D.V et al., 2002, pp.703-705).

Wolkenhauer (2002) thinks that microarray measurements should combine with mathematical models to attain good representation of the gene expression activity. He argues that the best approach can be developed by state-space models. If the raw data is

---

[39] The idea is that some DNA sequences code trans-acting products which act anywhere in cell except affecting DNA. This type of sequences is structural genes. But, some DNA sequences do not code products such as proteins or RNA which are diffusible. It means these DNA sequences are cis-acting sequences which affect only DNA, therefore they are called as regulative genes. See François Jacob and Jacques Monod (1961) for original article, and see Benjamin Lewin (2004, Chapter 10) for detailed analysis. To conserve energy by doing essential jobs minimum effort is important for organisms. Since, to activate all gene sequences require a lot of ATP consumption, to minimize it gives an advantage for organism. Therefore, gene regulation mechanisms have a vital role for organisms

used[40] to construct a state-space model, this model describes a dynamic process[41]. He develops the idea that this construction requires to abandon "the classical approach to describe genome expression in terms of (material) objects or components and their spatio–temporal relationships" (Wolkenhauer 2002, 4). Instead, the proper model, which explains genomic regulation, includes mathematical objects. Therefore, the model is a representation which does not appeal to material objects. But it includes the mathematical abstractions of them: "when discussing genome expression, the power of mathematical modeling is due to the fact that we can deal with abstract, not necessarily physical or observable objects" (Wolkenhauer 2002, 6). He argues that neither mathematical models nor empirical generalizations can explain the phenomenon genomic regularity alone. On the other hand, mathematical models can represent "the (dynamic) processes that lead to observable changes" that are constructed by microarray data. The advantage of this conception is twofold: One is that accuracy of the model is attained by empirical findings. The other is that quantitative relationships are captured by simple mathematical models. The relation between empirical findings and abstract mathematical models will be indirect as a result of "relative measure of change":

> Genomics, in particular the study of genome expression and regulation, deals with complex interactive phenomena. Neither, it is possible to study quantitative relationships between relevant variables without reference to the context; nor it is possible to perform experiments or make direct observations that would isolate such relationships accurately. By constructing models for time-series we may hope to gain indirect access to the desired quantitative biological relationships, represented by the structure and parameters of the models
>
> (Wolkenhauer, 2002 pp.15-16).

Wolkenhauer argues that the use of mathematical models requires indirect relation between data and general abstract models.

---

[40] They are used "as set of independent input variables and one or more dependent (output) variables" (p.10)
[41] Mathematical model defines "a dynamic system as a family of time-series" (p.10)

I argue that semantic view provides more fruitful framework for Wolkenhauer's suggestion. First, Woodward and Mitchell's approach can only account for spatiotemporal generalizations to explain the gene regulation. Second, Elgin and Sober's approach is not specific about the relationship between a priori generalizations and empirical findings. Even though these approaches develop strategies to overcome mentioned problems, I argue that semantic approach offers unifying solution for both exceptions and the relationship between a priori models and specific empirical cases.

The key idea is to take scientific theories as a collection of idealized models. Biologists use not only different models, but also different types of models to explain gene regularity mechanisms. Ay and Arnosti (2011) examines different types of mathematical models constructed to explain gene expression phenomena. They underlie that biologists can select to use a new type of model when they face with a novel problem. The missions of models are various, such as: "to summarize experimental data, to infer new relations from complex experimental data, guiding the researcher to new testable hypotheses and to find properties of the system that are hard to measure directly but can lead to accurate modeling of novel elements" (Ay and Arnosti 2011, 138).

In other words, in every area of biological practice (when examining gene expression regulations), biologists use different types of models when they face a novel problem. Since biologists explain biological phenomena neither by one ultimate generalization, nor by one type of mathematical model; the actual biological practice can only be represented by a more inclusive theory conception. In that respect I argue that semantic view has a clear advantage over other alternatives.

4.3.3. Blood Groups and Bombay Phenotype

Antigens of ABO blood system determine the blood type: each individual has either the A antigen (A phenotype), B antigen (B phenotype), the A and B antigens (AB phenotype), or neither antigen (O phenotype). In human populations, these phenotypes are inherited as the result of three alleles of a single gene: I^A, I^B *and* I^O. I^A and I^B alleles behave dominantly to the I^O but codominantly toward each other:

Genotype	Antigen	Phenotype
$I^A I^A$	A	A
$I^A I^O$	A	A
$I^B I^B$	B	B
$I^B I^O$	B	B
$I^A I^B$	A, B	AB
$I^O I^O$	Neither	O

I^B I^O and I^A I^O genotypes produce A and B blood groups respectively because I^A and I^B alleles are dominant traits for I^O. I^A I^B genotype produces the AB blood group because I^A and I^B behave codominantly each other. If the genotypes of parents are available, we can predict the both genotype and phenotype ratio of offspring using Mendel's law:

PARENTS		POTENTIAL OFFSPRING			
Phenotypes	Genotypes	A	B	AB	O
A x A	$I^A I^O$ x $I^A I^O$	3/4	-	-	1/4
B x B	$I^B I^O$ x $I^B I^O$	-	3/4	-	1/4
O x O	$I^O I^O$ x $I^O I^O$	-	-	-	ALL
A x B	$I^A I^O$ x $I^B I^O$	1/4	1/4	1/4	1/4
A x AB	$I^A I^O$ x $I^A I^B$	1/2	1/4	1/4	-
A x O	$I^A I^O$ x $I^O I^O$	1/2	-	-	1/2
B x AB	$I^B I^O$ x $I^A I^B$	1/4	1/2	1/4	-
B x O	$I^B I^O$ x $I^O I^O$	-	1/2	-	1/2
AB x O	$I^A I^B$ x $I^O I^O$	1/2	1/2	-	-

AB x AB	$I^A I^B$ x $I^A I^B$	1/4	1/2	1/2	-

The A and B antigens are sugars and the specificity of the A and B antigens is based on the terminal sugar of carbohydrate group. I^A allele is responsible for an enzyme that can add the terminal sugar *N-acetlyglucosamine* and I^B allele is responsible for an enzyme that can add the terminal sugar *D-galactose*. Both terminal sugars bind to the complete H substance which has precursor substance and L-Fucose:

Blood Groups	H SUBSTANCE				
A Group	Red Blood Cell	Precursor substance	L Fucose	N-acetlyglucosamine	
B Group	Red Blood Cell	Precursor substance	L Fucose	D-galactose	
AB Group	Red Blood Cell	Precursor substance	L Fucose	N-acetlyglucosamine	D-galactose
O Group	Red Blood Cell	Precursor substance	L Fucose		

The H substance is bio-chemically produced by the binding of Fucose to the surface glycoproteins, the process being catalyzed by Fucosyl transferase. If N-acetylgalactosamine binds to the H substance, it forms the blood group A, whereas if galactose binds to the H substance, it forms the group B. Absence of any binding substance to H produces the O blood group.

Therefore, blood type is determined by A and B antigens. Chemically blood type A, B, AB or O is determined by terminal component of H substance. The people who possess A blood type or B blood type has either N-acetylgalactosamine or terminal galactose in H substance respectively. While the people who possess AB blood type can add "either one or the other sugar at many sites (substrates) on the surface of the red blood cell", the people who possess O blood type cannot add any terminal component to H substance. However, in 1952 interesting biological phenomenon was observed: a woman in Bombay had a B blood type but her blood cells were acting as if she had O blood type. The reason of this phenomenon is that she is incapable of synthesizing complete H substance because of recessive mutation in "a gene designated FUTI" (Klug et all., 2006, pp.71-72).

Bombay individuals lack all normal expression of the A, B, or O genes they inherited because of recessive genotype at the locus of H gene. The allele h is very rare and is not capable of producing the L-Fucose transferase which is necessary for formation of the H-Structure. Therefore, Bombay individuals have hh genotype at the locus of Hh.

I think that it is possible to follow two different ways to overcome this problem. Either we can argue that the generalization about blood types can be modified by adding Bombay phenomena or we can argue that the generalization about blood types is still strong enough to do the function of laws of nature. However, the most important issue here is not to save our generalization but to understand the meaning of this exceptional situation. For biologist, this exception is not an anomaly but data which are used for explanation and prediction.

A proper understanding of Bombay Phenotype and ABO blood groups can be offered by the semantic view. Bombay Phenotype and ABO blood groups are two different systems. Using Mendel's principle and biochemical pathways, someone can construct different models to offer a prediction and an explanation that are related with these two systems. Mendel's principles provide relevant genetic models and these models are applied to target system, such as human populations or parts of human populations by means of biochemical pathways. ABO Blood system can be considered as a biological model which includes:

– Inheritance Laws (idealizations or abstractions or definitions)

- Codominance and dominance principles (Empirical Rules)
- Gene expressions of ABO locus and H locus
- Empirical mechanisms show that the relation between related alleles and particular products (e.g. H allele expresses the L-Fucose)
- Biochemical pathways explain the particular relation between products and function (e.g. A and B allele products bind to H allele products and this substrate have a particular function for individual)

The proper explanation of ABO blood system should include all of these ingredients. It is important to underline that Bombay phenotype is not the only exception, for instance there is also the Para-Bombay phenotype. Moreover, ABO blood system is not the only possible model which is produced to explain blood phenotype. But, someone can also construct different biological models by changing the parameters such as gene expression of ABO genes or H genes.

4.4. Conclusion

Biological generalizations do not satisfy necessary conditions for lawhood; yet, they are successful providing good explanations. Therefore, several positions are developed to explain this success of biological generalizations. Some of them suggest that we should reconsider whether these purported necessary conditions are in fact necessary. I think the shortcoming of the sort of approach that Woodward and Mitchell have developed is that they do not provide explanation for the question of how exceptions are dealt with in biology. However, if we look at biological practice globally, exceptions are everywhere, so I think the proper account of how explanation works in biology has to account for this important aspect of biological practice. Although there are others who have argued that semantic view of theories (Beatty, Lloyd, and Thompson) better fits in the understanding of the status of evolutionary theory, they also overlook a quite common phenomenon in biological practice i.e. how exceptions in general are dealt with.

I tried to argue that semantic view of theories better fits to understanding biological practice in general not just to understanding the status of evolutionary theory.

The advantage of semantic view of theories is that it permits to construct related family of models without appealing generalizations that make direct empirical claims. I claim that this advantage universally applying to biological practice accounting both for the very common phenomenon of exceptions and the relationship between a priori mathematical models and specific empirical cases.

At the end of the day, as I mentioned in Chapter I, the problem of the existence of biological laws entails one of the perennial problems of philosophy; namely, the dichotomy of appearance and reality. In this respect, I believe that to embrace model-theoretic approach can have at least a heuristic role that open a new way of thinking to evaluate biological theories. I do not argue that the semantic view of theories is the most proper theory conception among all possibilities. I argue that the semantic view of theories can better accommodate the biological generalizations and the biological exceptions together. I believe that the better evaluation of biological theories can be introduced by means of a more detailed investigation of biological practice.

CHAPTER V

Evaluation

Are there any biological laws? I think that the answer is yes. But the answer comes with the price. The price is to replace the priority of philosophical assumptions with biological practice. I argued that when someone takes the biological practice at the center of philosophical investigation about the status of biological generalization, it is indispensible to deal with exceptions. I assume that exceptions are at the very heart of biological practice. Therefore, I pursue the idea that a proper account of biological laws should also be capable of explaining the status of exceptions. The semantic view of theories is a strong candidate for this mission, because the explanation is provided by scientific models instead of generalizations. The conception of scientific theories is based on scientific models that can open a way to explain the status of both biological generalizations and biological exceptions. In this picture, the fundamental principles of the theory provide scientific models, and scientific models provide an explanation for the scientific data. Therefore, the relationship between the fundamental principles, mostly named as laws of nature, and the empirical system is indirect.

Initially the semantic view of theories has been offered to provide a theory conception for physical theories. In that respect, I think that the semantic approach also has some defects. In fact, this is an expected conclusion of applying a theory conception that is constructed by taking physical theories as model, to biological theories. I hold the view that the most appropriate theory conception can only be constructed by focusing directly on biological theories and biological activity.

Taking biological practice at the center is not only important to find a proper theory structure for biological theories. Philosophers of biology usually find themselves in the middle of a tension between the philosophical assumptions and the success of biology when they deal with several issues in philosophy of biology, such as reductionism or species problem. There is an important point about the success of biology. If biology mostly fails to satisfy the traditional criteria of being a fundamental science, then biology may owe its success to something else that is not emerged by traditional evaluation of sciences. I think one example can help to clarify my idea. The sub-disciplines of biology may be considered as independent sciences that are different from each other. For instance, advanced mathematical models are mostly used in ecology and population genetics. Biochemistry is usually about the physico-chemical pathways that are found in biological entities. Taxonomy enjoys with classification of species. Very different tools, techniques and approaches are used in all these different sub-disciplines of biology. It is a philosophical question whether all these different biological disciplines can be gathered under the same etiquette or not. In other words, I wonder whether it is possible to explain all these sub-disciplines by one methodology or not. But there should be an extensive biological investigation to answer similar questions.

It is a philosophical endeavor to find what makes life sciences different from other sciences, but this endeavor should not be constrained by philosophical assumptions:

> Philosophy at its best is critical commentary upon existence and upon our claims to have knowledge of it; and its mission is to help illuminate what is obscure in experience and its objects, rather than to profess creeds or to repeat the battle cries of philosophical schools aiming as intellectual hegemony.
>
> (Nagel, 1957, p.3)

At the end of the day, I think that investigation of biological practice has a vital role to develop new approaches in philosophy of biology and philosophers of biology should be ready to abandon philosophical consensus when there is a clash between biological practice and philosophical assumptions.

BIBLIOGRAPHY

Armstrong, D. M. (1983). *What Is a Law of Nature?* Cambridge: Cambridge University Press.

Ay A. and Arnosti D. N. (2011) Mathematical modeling of gene expression: a guide for the perplexed biologist. *Critical Reviews in Biochemistry and Molecular Biology, 46(*2), 137–151

Beadle, G. W., & Tatum, E. L. (1941). Genetic control of biochemical reactions in Neurospora. *Proceedings of the National Academy of Sciences of the United States of America*, *27*(11), 499-506.

Beatty, J. (1980). Optimal-Designing Models and the Strategy of Model Building in Evolutionary Biology. *Philosophy of Science*, *47*(4), 532-561.

Beatty, J. (1981). What's Wrong with the Received View of Evolutionary Theory? In P. D. Asquith and R. N. Giere (Eds.), PSA 1980, Vol. 2, East Lansing, MI: Philosophy of Science Association, 397–426.

Beatty, J. (1987). On Behalf of the Semantic View. *Biology & Philosophy*, 2, 17-23.

Beatty, J. (1995). The Evolutionary Contingency Thesis. In G. Wolters and J. Lennox (eds.), *Concepts, Theories, and Rationality in the Biological Sciences: the Second Pittsburgh Konstanz Colloquium in the Philosophy of Science*. University of Pittsburgh Press, 45-81.

Bock, W.J. (2007). Explanations in evolutionary theory. *Journal of Zoological Systematics and Evolutionary Research*, 45/2, 89-103.

Boniolo, G. (2005). A Contextualized Approach to Biological Explanation, *Philosophy*, 80(312), 219-247.

Carnap, R. (1936). Testability and Meaning, *Philosophy of Science*, 3, 419–471.

Carnap, R. (1995). *An introduction to the philosophy of science.* New York: Basic Books.

Carroll, J. W. (1994). *Laws of Nature.* Cambridge: Cambridge University Press.

Cooper, G. (1996). Theoretical Modeling and Biological Laws. *Philosophy of Science*, 63, Issue Supplement: S28-S35.

Craver, C.F. (2002). Structures of Scientific Theories. In *The Blackwell guide to the philosophy of science.* Oxford : Blackwell, 55-80.

Dretske, F. I. (1977). Laws of Nature. *Philosophy of Science*, 44, 248-68.

Elgin, M., Sober, E. (2002). Cartwright on explanation and idealization. *Erkenntnis,* 57/3, 441–450.

Elgin, M. (2003). Biology and A Priori Laws. *Philosophy of Science,* 70, 1380 - 1389.

Elgin, M. (2006). There May be Strict Empirical Laws in Biology, after all. *Biology and Philosophy*, 21, 119-134.

Elgin, M. (2010). Mathematical Models, Explanation, Laws, and Evolutionary Biology. *History and Philosophy of the Life Sciences* 32(4) 2010:433-51

Faye at all. (2005). Introduction. In J. Faye, P. Needham, U. Scheffler, & M. Urchs, *Nature's Principle* (pp. 1-53). Dordrecht: Springer.

Fruton, J.S. (1999). *Proteins, Enzymes, Genes: The Interplay of Chemistry and Biology* Ithaca, NY: Yale University Press.

Gerson, L. P. (2009). *Ancient Epistemology.* Cambridge: Cambridge Universty Press.

Giere, R. G. (1999). *Science without laws.* Chicago: University of Chicago Press.

Goodman, N. (1947). The Problem of Counterfactual Conditionals. *The Journal of Philosophy*, *44*(5), 113-128.

Goodman, N. (1965). *Fact, Fiction, and Forecast.* Indianapolis: Bobbs-Merrill.

Gould, S. (1970). ‘Dollo on Dollo’s Law: Irreversibility and the Status of Evolutionary Laws’, *Journal of the History of Biology*, 3, 189-212.

Hardcastle, G. (2002). The Modern History of Scientific Explanation. In M. Heidelberger & Stadler, F. (Eds.), *History of philosophy of science. New trends and perspectives.* Dordrecht: Kluwer Academic Publisher.

Hempel, C.G. (1945). Geometry and Empirical Science. *The American Mathematical Monthly*, 52(1), 7-17

Hempel, C.G., Oppenheim, P. (1948). Studies in the Logic of Explanation. *Philosophy of Science*, 15, 567-579.

Hempel, C. G. Review of Reichenbach's Nomological Statements and Admissible

Operations. *Journal of Symbolic Logic*, XX, 50-54.

Hempel, C. G. (1965). *Aspects of Scientific Explanation.* New York: Free Press.

Hempel, C. G. (1965). *Philosophy of Natural Science.* Englewood Cliffs: Prentice-Hall.

Hickman, M., & Cairns, J. (2003). The centenary of the one-gene one-enzyme hypothesis. *Genetics*, *163*(3), 839-841.

Hume, D. (1854/1996). *The Philosophical Works of David Hume* (Vols. 1-4). Bristol: Thoemmes Press

Jacob F. and J. Monod (1961). Genetic regulatory mechanisms in the synthesis of proteins. *Journal of Molecular Biology* 3, 218-256.

Jobe, E. K. (1967). Some Recent Work on the Problem of Law. *Philosophy of Science, 34*(4), 363-381.

Klug W.S., Cummings, M.R., Spencer C. (2006). *Concepts of Genetics.* Upper Saddle River, NJ: Pearson Education.

Lange, M. (2008). Laws and Theories. In Sahotra Sarkar and Anya Plutynski (Eds.), *A Companion to the Philosophy of Biology*. Malden, MA: Blackwell, 2008, pp.489-505.

Lauter, H. A. (1970). An Examination of Reichenbach on Laws. *Philosophy of Science, 37*(1), 131-145.

Lewin, B. (2004). *Genes VIII*. Upper Saddle River: Pearson Prentice Hall

Lewis, D. (1983). New Work for a Theory of Universals. *Australasian Journal of Philosophy,* 61, 343-377.

Lloyd, E. (1984). A Semantic Approach to the Structure of Population Genetics. *Philosophy of Science,* 50, 112-129.

Lloyd, E. (1988). The Structure and Confirmation of Evolutionary Theory, New Jersey, Princeton University Press.

Mayr, E. (1988). *Toward a New Philosophy of Biology: Observations of an Evolutionist*. Belknap Press of Harvard University Press.

McIntyre, L. (1997). Gould on Laws in Biological Science. *Biology and Philosophy,* 12, 357-367.

Mitchell, S.D. (1997). Pragmatic Laws. *Philosophy of Science,* 64, 468-479.

Mitchell, S.D. (2000). Dimensions of Scientific Law. *Philosophy of Science,* 67, 242-265.

Mitchell, S.D. (2003). *Biological Complexity and Integrative Pluralism.* Cambridge: Cambridge University Press.

Mumford, S. (2004). *Laws In Nature*. London: Routledge Press.

Nagel, E. (1954 - 1955). Naturalism Reconsidered. *Proceedings and Addresses of the American Philosophical Association*, 28, 5-17.

Nagel, E. (1961). *The Structure of Science: Problems in the Logic of Scientific Explanation.* Indianapolis: Hackett Publishing Company.

Narra, H. P. & Ochman H. (2006). Of What Use Is Sex to Bacteria? *Current Biology*, 16, R705–R710.

Nguyen, D.V., Arpat, A.B., Wang, N. and Carroll, R.J. (2002) DNA microarray experiments: biological and technological aspects. *Biometrics*, 58, 701-717.

Novikov, P.S. (1988). Axiom. In *Encyclopedia of mathematics.* Dordrecht: Reidel, 314.

Pigliucci, M. (2012). On the different ways of “doing theory” in biology. *Biological Theory*, 1-11.

Psillos, S. (2002). *Causation and Explanation*. Chesham: Acumen Publishing Limited.

Press, J. (2009): Physical explanations and biological explanations, empirical laws and a priori laws. *Biology and Philosophy*, 24, 359-374.

Raerinne, J. (2013). Stability and lawlikeness. *Biology & Philosophy*, *28*(5), 833-851.

Reichenbach, H. (1947). *Elements of Symbolic Logic.* New York: Macmillan Co.

Reichenbach, H. (1954). *Nomological Statements and Admissible Operations.* Amsterdam: North Hollan Publishing Company.

Rosenberg A. (2001). *Instrumental Biology, or The Disunity of Science.* Chicago: The University of Chicago Press.

Ruse M. (1970). Are there laws in biology? *Australasian Journal of Philosophy*, 48, 234–246.

Salmon W. (1989). Four Decades of Scientific Explanation. In Kitcher P., Salmon W. (Eds.). (1989). *Scientific Explanation: Minnesota Studies in the Philosophy of Science,Vol. 13.* Minneapolis, MN: University of Minnesota Press.

Sarkar S. (1998). *Genetic and Reductionism.* Cambridge: Cambridge University Press.

Schaffner, K. F. (1969). Theories and explanations in biology. *Journal of the History of Biology,* 2/1, 19-33.

Smart, J. J. C. (1963), *Philosophy and Scientific Realism.* London: Routledge & Kegan Paul.

Sober, E. (1984). *The Nature of Selection.* Chicago and London: University of Chicago Press

Sober, E. (1993). *Philosophy of biology*. Boulder: Westview Press.

Sober, E. (1997). Two Outbreaks of Lawlessness in Recent Philosophy of Biology, *Philosophy of Science*, 64 (Proceedings), S458-S467.

Suppe, F. (Ed.) (1974). *The Structure of Scientific Theories*. Urbana, University of Illinois Press.

Suppe, F. (1989). *The Semantic Conception of Theories and Scientific Realism*. University of Illinois Press.

Suppe, F. (2000). Understanding scientific theories: An assessment of developments, 1969-1998. *Philosophy of Science* 67/3, S102-S115.
Suppes, P. (1957). *Introduction to Logic.* Princeton NJ: Van Nostrand

Thompson, P (1987). A Defence of the Semantic Conception of Evolutionary Theory, *Biology and Philosophy,* 2, 26-32.

Thompson, P (1989). *The Structure of Biological Theories*, Albany: SUNY Press.

Tooley, M. (1977). The Nature of Laws. *Canadian Journal of Philosophy,* 7, 667- 698.

van Der Steen, W. J., & Kamminga, H. (1991). Laws and natural history in biology. *The British journal for the philosophy of science*, *42*(4), 445-467.

van Fraassen, B. (1970). On the Extension of Beth's Semantics of Physical Theories. *Philosophy of Science*, 37(3), 325-339.

van Fraassen, B. (1972). A Formal Approach to Philosophy of Science. In R. Colodny (ed.), *Paradigms and Paradoxes*, Pittsburgh: University of Pittsburgh Press. 303–66.

van Fraassen, Bas C. (1980). *The Scientific Image.* Oxford: Clarendon Press.

van Fraassen, Bas C. (1989). *Laws and Symmetry*. New York: Oxford University Press.

Tennant N. (2010). The Logical Structure of Scientific Explanation and Prediction: Planetary Orbits in a Sun's Gravitational Field. *Studia Logica*, 95, 207–232.

Waters, K.C. (1998). Causal Regularities in the Biological World of Contingent Distributions. *Biology and Philosophy*, 13, 5-36.

Wilder, R. (1967). The Role of the Axiomatic Method. *The American Mathematical Monthly*, vol. 75, 115-127.

Wolkenhauer O. (2002). Mathematical modelling in the post-genome era: understanding genome expression and regulation - a system theoretic approach. *Biosystems*, 65/1, 1-18.

Woodward, J. (2000). Explanation and Invariance in the Special Sciences. *British Journal for the Philosophy of Science* 51/2, 197-25

Woodward, J. (2001). Law and Explanation in Biology: Invariance Is the Kind of Stability That Matters. *Philosophy of Science*, 68/1, 1-20.

ÖZGEÇMİŞ

Adı Soyadı : Sinan Şencan

Doğum Yeri ve Tarihi : İstanbul / 1985

Yabancı Dili : İngilizce

İletişim: sinansencan@gmail.com

Eğitim Durumu

Lise : Pertevniyal Anadolu Lisesi

Lisans : Ortadoğu Teknik Üniversitesi

Yüksek Lisans : Muğla Sıtkı Koçman Üniversitesi

Çalıştığı Kurum ve Yıl : Muğla Sitki Koçman Üniversitesi, Araştırma Görevlisi 2011