ON THE SIGNIFICANCE
OF
IDEALIZATIONS IN SCIENCE

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ABSTRACT

ON THE SIGNIFICANCE OF IDEALIZATIONS IN SCIENCE

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The aim of this thesis is to investigate the problems that use of idealizations in science leads to. Idealizations are simplifications and therefore false descriptions of how actual objects behave. Presence of idealizations in scientific theories is the reason for the problems in our understanding of confirmation of theories and also of scientific explanations. Nevertheless, idealizations are ubiquitous especially in natural sciences. Scientists have to employ idealizations because of the complexity of the real world and our limited capacity of computation. The roots of the methodology of modern science are in Cartesian philosophy. I propose that Descartes also employed idealizations in his theory of motion in the universe. Idealized worlds can be regarded as simplifications of the real world. Scientific theories are literally false but they are approximately true in the possible worlds which are similar to the real world. Models provide the connections between idealized laws and the real world. Construction of models of the actual world is based upon idealizations which are indispensable in the theoretical sciences. Theories can be indirectly confirmed by models denoting different aspects of the phenomena.

Keywords: Idealization, simplification, counterfactual, possible world and model.

ÖZ

BİLİMDEKİ İDEALLEŞTİRMELERİN ANLAMI ÜZERİNE

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Bu tezin amacı bilimde idealleştirme kullanılmasının yaratmış olduğu problemler üzerine bir inceleme yapmaktır. İdealeştirmeler basitleştirilmiş ve bu yüzden nesnelerin nasıl davrandıklarını yanlış betimleyen ifadelerdir. Bilimsel kuramlarda idealleştirmelerin varlığı kuramlarımızın doğrulanması ve açıklama yapabileceğine dair olan inancımızda sorunlar oluşturmaktadır. Buna rağmen, idealleştirmeler doğa bilimlerinde yaygın olarak kullanılmaktadır. Bilim adamları, gerçek dünyanın karmaşık yapısı ve bizim sınırlı hesap kapasitemiz nedeniyle idealleştirme yapmak zorundalar. Modern bilimin kökenleri Descartes'in felsefesine dayanmaktadır. Descartes da evrendeki hareket üzerine kurduğu teorisinde idealleştirme kullanmıştır. İdealleştirilmiş dünya, gerçek dünyanın basitleştirilmiş biçimi olarak kabul edilebilir. Bilimsel kuramlar mutlak anlamda incelediğinde yanlış ancak gerçek dünyaya benzer dünyalarda doğruya yakındır. Modeller idealleştirilmiş yasalarla gerçek dünya arasındaki bağlardır. Gerçek dünyadaki fenomenlerin modellerini yapma teorik bilimlerde kaçınılmaz olan idealleştirmelere dayanır. Bir teorinin genel kabul edilebilirliliği o teorinin modelleri aracılığıyla sağlanır. Yani, bilimsel teoriler fenomenlerin değişik yönlerine işaret eden modeller tarafından dolaylı olarak doğrulanırlar.

Anahtar Kelimeler: İdealleştirme, sadeleştirme, olgu karşıtı, mümkün dünya ve model.

To My Parents

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CHAPTER 1

INTRODUCTION

The received view of theories affirms that theories explain the empirical laws. The most basic claim of this view is that theories are generalizations of empirical facts revealed by observations. Truth of scientific theories depends upon the relation between theories and reality. Scientific theories are confirmed by observational data. Confirmation of theories is commonly accepted as a sign for theories to be true. In other words, if predictions derived from the theory are true, then the theory is confirmed. That is, every true prediction provides us with confirmation of the theory.

The notion 'scientific truth' is a problematic relation between scientific theories and reality. The Realistic understanding of science acknowledges that knowledge of the reality is possible and science mirrors the reality. However, the presence of idealizations and their use in scientific theories endanger the classical understanding that scientific theories describe the reality. In other words, scientific realism is false in its claim that science gives true representations of the real world.

Use of idealizations in science has been discussed as a problem in the methodologies of science. Some methodologists ignore the problem of idealizations, and they do not state methodological programs dealing with idealizations in science. Their attitudes do not abate the importance of the problem. This debate has an essential importance for both sides of the discussion, that is, for both Realists and Anti-Realists. What the role of idealizations in scientific theories is occupy the center of that debate.

Use of idealizations in science gives rise to problems in our understanding of confirmation of theories and also of scientific explanations. Idealizations are simplified and therefore false expressions employed in descriptions of how actual objects behave. How are idealizations used in explanations? Although idealizations are false statements, how is it that they can have any explanatory power? Also, how is the confirmation of idealized laws possible?

In Chapter 2, my aim is to introduce different denotations of the concept 'idealization'. First, I mainly discuss idealizations as simplifications. Scientists commonly use idealizations in order to simplify the complexity of the actual situations they need to deal with. An idealized world as a simplification of the real world is a possible world. To formulate a scientific law, scientists employ idealizations to construct possible worlds which are models of physical systems. A model is an idealization of the real world. For, models are not literal description of the actual world.

I will discuss syntactic features of idealizations in Chapter 2. Are idealizations predicates or are they statements? Are there any distinct structural characteristics which an expression must possess in order for it to be an idealization? William Barr emphasizes three forms of idealization which are called *ideal condition, ideal cases,* and *idealized theories*. I will mention Barr's claim concerning these three different kinds of idealization.

I shall stress upon important examples of idealizations in science, especially Boyle's gas law and Galileo's law for falling bodies. These two laws are very good examples of idealized laws. Kuokkanen and Tuomivaara oppose the view that Boyle's gas law is an idealization. I shall argue that they misunderstand the point that the law is valid for perfect gases.

In Chapter 3 I intend to clarify the reasons for use of idealizations in science, which seems inevitable in science. *Ubiquity of idealizations thesis* asserts that most scientific theories involve idealizations. Cartwright claims that most theories are false because they are held to be true only under idealized conditions. She says that fundamental laws are true only when they are qualified with *ceteris paribus* modifiers, that is, they are true only in a model since the conditions they involve can never be satisfied in the real world.

The overwhelming complexity of reality makes scientists simplify the reality or employ idealizations. Although this complexity is a barrier to our understanding of nature, to overcome the complexity, scientists have to limit the parameters they deal with. In order to simplify the world, scientists remove properties, relations and individuals from it, and by doing so they replace the real world with one of its models. That is, models are simplifications of the real world. They are just a description of only one aspect of the real world.

Also, in this chapter, I will discuss the problem of the relation between mind and nature, because mind-nature confrontation requires idealizations. Knowledge can be defined as the end result of an interaction between a subject and an object. The modern understanding of knowledge arises from Descartes' conception of mind-body relation. His epistemological principle implies that mind is really distinct from the body. In the *Meditations*, especially Sixth and Second, Descartes mentions the existence of physical objects which can be conceived as the objects of pure mathematics. For him, scientific knowledge of the external world depends on the quantitative properties of the objects in the real world.

I want to argue that Descartes also employs idealizations in his mechanics when he explains the behavior of material bodies during the collision. He introduces seven rules to calculate the quantity of motion in the universe. He believes that if there were two bodies which are perfectly hard and isolated from impacts of other bodies, then the calculation would be easy. I will explain the rules of Cartesian physics in brief.

Besides all this, I will try to answer questions like how it is possible for us to know the external world in terms of mental acts, such as conceptions and perceptions. Do perceptions involve a modification of the mind? Mind deliberately simplifies the complexity of nature by focusing on certain parameters. Idealizations and abstractions are the essential active transformations and refashioning activities of the human mind.

In Chapter 4 I deal with the problem of confirmation of idealized laws. Scientific realism claims that theoretical laws are true or false, and their confirmation is possible. Philosophers like Cartwright, Hacking and

Van Fraassen maintain that theoretical laws cannot be confirmed because they involve conditions that are never satisfied in the real world, and they are held only in a model.

I will carry on a discussion concerning Cartwright's understanding of fundamental laws and models. She claims that idealizations cannot be approximately true and confirmable. However, I think she is wrong at this point. There is no contradiction in the claim that fundamental laws are true in highly idealized models and also approximately true in the actual world.

In my concluding chapter, I will give a brief summary of what I have said in the previous chapters. The genesis of modern methodology of science owes a lot to using idealizations in science. The problems arising from use of idealizations can be solved by models. This makes it necessary that we modify our theory of truth. Idealized laws are literally false but they are close to being 'exactly true' of empirical phenomena. That is, a law is approximately true on the condition that the model or the possible world in which it is true is sufficiently close to the actual world.

CHAPTER 2

THE CONCEPT OF IDEALIZATION

2. 1. The Connotations of Idealization

Scientific theories are developed in order to explain or predict how the objects in the nature behave. Simplicity, economy and being general are essential characteristics of such theories. In order to attain simplicity in the formulation of the scientific theories, scientists apply theoretical entities to simplify the complexity of nature. Theoretical entities are used to arrange the parameters which have primary influence on the phenomena. They provide certain abstractions from the real world. In other words, scientific theories are developed to characterize the behavior of the phenomena under the idealizations.

In their formulations, scientific theories involve a set of parameters having influence on the phenomena.

> The theory does not attempt to characterize the phenomena in all their complexity, but only attempts to do so in terms of a few parameters abstracted from the phenomena…. In point of fact, however, other unselected parameters usually do influence the phenomena; so the theory does not characterize the actual phenomena, but rather characterized the contribution of the selected parameters to the actual phenomena, describing what the phenomena would have been had the abstracted parameters been the only parameters influencing them.[1]

They do not describe the phenomena as a whole. The parameters included by the theory are taken to be the relevant factors.

For example, scientists do not claim that the classical particle mechanics describe the real nature of an inclined plane. They are all aware that the theory describes what the behavior of an inclined plane would be under idealized conditions, i.e., frictionless plane. That is to say, the theory describes the behavior of the physical system which depends on the relevant

[1] Suppe, 1989, p. 82.

parameters. In brief, theories indirectly demonstrate counterfactual characterizations of the actual world.

Certain characteristics of laws which are the essences of a law provide us with a differentiation between scientific laws and accidental generalizations. In order to clarify the difference, Achinstein gives a detailed account for what kinds of characteristics differentiate a scientific law from an accidental generalization. A common characteristic of laws is that they all describe or aim to describe the regularity in the behavior of the objects in the nature.

> (1) Laws express, or purport to express, regularities underlying other regularities in such a way that the latter can be analyzed and explained in physical terms by the former.
> (2) Laws express, or purport to express, regularities with a certain amount of completeness by isolating various factors that are involved and indicating the manner in which they are related.
> (3) Laws express, or purport to express, regularities in a precise manner, frequently using technical concepts with precise meanings, and they are often formulated quantitatively.
> (4) Laws express, or purport to express, regularities, where simplicity is a function of the number and the kind of terms or factors the law contains and the relationships between them which the law postulates.[2]

The above quotation summarizes certain characteristics of a real scientific law. Achinstein argues that the essential features of a law of nature are its generality, preciseness and simplicity, and also its capability of supporting counterfactuals. For the sake of simplicity, scientists may ignore certain factors when they formulate a law; it is not important whether they are aware of them or not. For example, “Galileo was aware that his law ignored the air resistance, Boyle was not aware that his law ignored the rotation of molecules as well as intermolecular attractive forces.”[3] A law which ignores some factors is called an idealized law or idealization. So, Galileo’s law is an idealization because it ignores air resistance and also assumes that the body falls in vacuum.

Empirical sciences use commonly certain concepts such as ‘perfectly rigid body’, ‘point mass’, ‘perfect gases’, ‘frictionless media’, etc. These

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[2] Achinstein, 1971, pp. 13-14.
[3] Ibid., p. 12.

concepts are accepted as idealized concepts and theoretical concepts. There are numerous examples of idealizations in natural science, like Galileo's law of falling bodies, Galileo's law of inertia, Boyle's law, and Kepler's laws of planetary motion, and so on. Use of idealizations is ubiquitous in the natural sciences.

Idealizations are simplified and therefore false statements concerning the descriptions of how actual objects behave. The Anti-Realist point of view believes that use of idealizations would be illegitimate if we claimed that scientific theories represent the behavior of objects in the real world. On the other hand, the Realist point of view claims that scientific theories give literally true descriptions of the world. Although some methodologists ignore the problem of idealizations and do not state methodological programs dealing with idealizations in science, this does not solve anything and the problem is not abated. Presence of idealizations in theories makes scientific realism false. Realists must explain how use of idealizations is legitimate although idealizations are never satisfied in the real world, i.e. empirically false.

In philosophy of science, it is controversial how idealized theories could be confirmed. The problem arises from the fact that these laws are taken to hold only under idealized conditions. The universe is not simple as assumed in Newton's derivation of Kepler's Laws, that is, there are not only two bodies in the universe. Newton claims that any change in velocity and motion requires a force. The planets would move on a straight line if there were no force. There is a universal force which keeps the planets in elliptical orbits with the sun as a focus. Velocities and motions of the planets are deflected toward the sun. However, the planets do not really go on in ellipses because they are not only attracted by the sun, but also attracted by each other. The universal law of gravitation is that two objects exert a force upon each other which changes inversely as the square of their distances and directly as the product of their masses. The orbit of a planet is a perfect ellipse when other forces exerted by other planets are ignored

2. 1. 1. Idealizations as Simplifications

Idealization is a deliberate operation of simplification.[4] The actual world is so complex that scientists could not formulate a scientific theory without employing idealizations. Scientists sometimes deliberately simplify the world which they deal with in order to reduce computational complexity.

> No-one– not even scientists–ever studies reality in all complexity. The way in which we come to (scientific) knowledge is determined by acts of abstraction and simplification. Thus rather than focusing on the colorful richness of reality, scientists typically will decide to focus on a particular aspect or system of reality. Moreover, intensifying their initial selective actions, scientists will also decide to concentrate only on particular features of the real system they have picked out.[5]

Most scientific theories are formulated as a model which is based upon one or more idealizing or simplified conditions because of the complexity of the world. For example, Boyle would not be able to formulate his law concerning gases if he did not use any idealizing conditions, i.e., idealizations. For the nature of the interaction between the molecules of gases is complex, Boyle simplified his description of their natures by assuming that there is no interaction between particles.

The human mind naturally has a process of selection of relevant parameters. Scientists feel forced to abstract relevant factors in order to deal with the complexity of nature. They deliberately limit their attention to the relevant aspects of physical events. For example, in Galileo's law of free falling bodies, Galileo selectively limited his attention to *the time of the fall, the distance fallen.* He did not consider for the color of a falling body in the case of free fall. He employed idealizations by neglecting air resistance.

According to Shaffer, idealization is an operation of counterfactual simplification. A counterfactual statement is a characterization of *what would have happened if certain conditions had been satisfied* for a phenomenon. It is a conditional statement (A →B) which asserts if A were

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[4] Shaffer, 2000, p. 16.
[5] Ruttkamp, 2002, p. 23.

to happen, then B would happen. Lewis claims that counterfactuals can be evaluated as true or false on the basis of whether B is true in the most similar possible world to the actual world in which A is true. Scientists give a simplified description (counterfactual) of how the object would behave under idealized conditions when they eliminate all irrelevant factors. By simplifying the conditions, the scientist purports to use our computational and descriptive powers effectively for formulating the situations, or relations. For example, we simplify the case when we examine the motion of projectiles. In the case of projectile motion, the moving object is regarded as a point mass or particle. We introduce the projectile as a point mass or particle that is a body which has finite volume and a definite surface configuration. Such an assumption decreases the complexity of the actual situation and also of the equation which represents the phenomena.

2. 1. 2. Idealizations as Simplified Worlds

Lind defines an idealization as an assumption, a proposition or a statement which is believed to be false for the objects and the situations of the actual world. Scientists reconstruct the actual world by using idealized situations and transform it into a simplified world. That is to say, the actual world is reconstructed as a simplified or idealized world. An idealization of the real world becomes a possible world.

> Idealized worlds are just those worlds that are arrived at by successively removing properties, relations and individuals from complete or real worlds. So idealizing is a world relative concept…. Adding properties, relations or individuals counterfactually just is not idealization. Idealization essentially involves simplification and so expansions cannot be instance of idealization.[6]

Idealized worlds can be thought of as simplifications of the real, complete world. A possible world helps us analyse and also understand idealizations and counterfactuals.[7] Semantics of idealizations can be based upon possible

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[6] Shaffer, 1989, pp. 18-19.

[7] A possible world can be defined as a world which is different from the actual world in at least one aspect. The similarity between the actual world and a possible world is important

worlds. Scientific theories are not directly applicable to the actual world. There is an indirect and mediated relation between theories and the real world. Most theories are accepted as counterfactual conditionals whose antecedents are not satisfied in the actual world. "…they apply to some appropriate possible worlds where such entities as frictionless planes, point masses, ideal gases, etc. exist. Thereby, the framework of possible world semantics enables us to understand the counterfactual character of scientific laws."[8]

According to Lewis, a possible world is a form the world might have been. It cannot be reduced to something more basic. Possible worlds refer to both imaginative constructs of human beings and also the nature's dictation of the way things are. They are composed of a *state of affairs physically possible relative to another state of affairs.* The way things are is not identified with the actual world itself, but a property of the actual world. Scientists simplify the systems which they deal with in order to reduce the computational complexity of the real systems. In other words, scientists counterfactually replace the actual world with an idealized world by removing some individuals, relations or properties in the actual world.

An idealization of the real world involves counterfactual representations that omit certain conditions in the real world. Scientists selectively omit some negligible factors and limit their attention to relevant factors in order to assert theoretical claims which hold only under idealized boundary conditions. They admit that idealization is an operation of finding a special kind of relation between the real world and the idealized world. They believe that possible worlds or idealized worlds have informational relevance with respect to the actual world. That is to say, idealized worlds are physically similar to the real world; therefore, they provide us information about the real world.

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for the semantics of idealizations. The more similar possible world will give more information about the actual world.

[8] Kuokkanen, 1994, p. 81.

> Idealizations are simplified worlds, including initial and boundary conditions, in the precise model-theoretic sense…. Mass points are often used as idealizations of both planets and of particles…. In any case, we say that the world of the mass points is an idealization of the real world of planets and particles or that the mass point is an idealization of a planet or particle, and it is understood what property or properties are being idealized away. In this case three dimensional objects are being treated under the idealizing assumption that they are zero dimensional objects. Theoretical claims, claims about the behavior of the objects in a world, that hold only in idealizations will be termed simply theoretical claims that depend on idealizing conditions.[9]

Scientific laws support counterfactuals. Achinstein, like some other philosophers of science, believes that although accidental generalizations do not support counterfactual statements, theoretical laws support them. Supporting counterfactuals is one of the essential characteristics of the real laws of nature. The relation between idealized laws and the actual world is thereby revealed. That is to say, scientific laws do not purport to describe how the objects of the real world behave, but rather how the objects of possible worlds, which are highly idealized pictures of the actual world, act.

Scientists mentally have to rearrange inconvenient factors in order to formulate the regularities in a simple form. It is impossible to delete those factors. Scientists are aware of this impossibility and replace them by idealized conditions which are easy to deal with or to calculate. They could not study all the complexity of the real world. That is, they focus on some relevant factors and ignore all other parameters. By doing such a selection, scientists construct a possible world involving the selected parameters.

2. 1. 3. Idealizations as the Models of the Actual World

Use of idealization is the hallmark of modern science and it is usually identified with Galileo's understanding of science. Models are not generally accepted as literal descriptions of nature. Scientists, especially physicists, believe that a model is useful to make a relation of analogy to the real world.

[9] Shaffer, 2000, pp.34-35.

> To say that a model is in general an analogue and not a literal description of nature may in certain cases mean no more than that the model is an idealization of nature. In classical mechanics, the entities discussed, such as smooth planes, perfectly rigid spheres, and the like, are not literal descriptions of anything to be found in nature, but are simplifications of natural objects arrived at by neglecting all but a few properties of objects–properties which are selected because they are amenable to mathematical treatment.[10]

The term 'model' must be carefully used because it has different meanings. Van Fraassen defines it as a specific structure, in which all relevant parameters have specific values.[11] Achinstein divides models into three categories: iconic, analogue and symbolic models.[12] Nevertheless, the concept 'model' that I use refers to analogue or theoretical models. A model is a set of assumptions concerning some objects or phenomena. It is used to describe inner structures or mechanisms in behaviors of objects exhibiting certain regularities. A model is a simplified approximation to the real phenomena which is used for certain purposes. For example, billiard ball model of a gas is a set of assumptions concerning the interactions between the gas molecules. This model attributes a molecular structure to the gases and their representation as composed of tiny elastic spheres is very useful to formulate the law of ideal gases. That is to say, the set of assumption helps us to derive some principles for pressure, temperature, and volume of an ideal gas.

Models provide the connection between idealized laws and the real world. Construction of the models of the actual world is based upon idealization which is indispensable in the theoretical sciences.[13] In *How the Laws of Physics Lie* Cartwright says that a model is a simplification of the real world, that is, it usually refers to a simplification that scientists select some relevant factors and omit other factors. However, the omitted factors

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[10] Hesse, 1952, p. 202.
[11] Van Fraassen, 1980, p. 44.
[12] Achinstein, 1968, pp. 209- 220.
[13] Liu in 1999 argues that the complexity and variability of natural phenomena and our desire to explain them with a set of simple and invariant laws demand the use of idealization, whose ultimate aim is to *carve nature at its joints.* That is, we select relevant parameters to simplify the actual world. Formulation of laws of nature is possible only when the actual world is simplified by idealization (p. 244).

have influences on what occurs in reality although their effects are insignificant.

Cartwright argues that models are the links between fundamental laws and the phenomena of the actual world. She claims that fundamental laws are false in reality but they have a great explanatory power. However, there is no guarantee for their truth although they have great explanatory power, because the truth is related with the models of laws. That is to say, a fundamental law is true only in one of its models. For this reason, scientists use the models in order to construct a link between the fundamental laws and reality.

Models differently manifest certain aspects of the phenomenon according to Cartwright. That is, models which are constructed for different purposes give different relevant factors for the same phenomenon. They all have different equations to describe the phenomenon because each model limits its attention to different parameters. Nature enforces scientists to simplify the complex structure of the nature and to choose only the relevant factors having influence on the nature. Construction of models depends upon selection of the relevant factors and ignoring the negligible factors. So, models are idealizations of the complex structure of nature.

Physical systems are developed by assuming certain idealized conditions which are never satisfied in the actual world. Suppe defines the concept of physical systems as follows:

> A physical system is an abstract replica of a phenomenal system if for each t, its state stands in the counterfactual replicating relation to its corresponding phenomenal system. This replicating relation obtains only if the defining parameters of the physical system are parameters abstracted from the phenomenal systems in the theory's intended scope or else are idealizations of them.[14]

Physical systems are counterfactual models of the actual phenomena. Causal parameters are made use of when constructing possible worlds or models. That is to say, a model involves certain parameters related with one

[14] Suppe, 1989, p. 97.

aspect of the actual phenomenon. Theory will be true in relation to causally possible models.

According to Achinstein, models are the simplifications and the approximations about the physical system. By constructing a model, scientists demonstrate the similarity between certain aspects of phenomenon and that of idealized systems. For example, in the billiard ball model of the gases, the gas molecules are described as similar to the billiard balls. The gas molecules randomly collide with each other and the walls of the container. This model manifests certain aspects of how the gases behave under idealized conditions. The billiard ball model limits the relevant parameters with the scope of the size, shape and mass of the molecules. It is an idealization because it asserts that the billiard balls are rigid although the actual bodies are not perfectly rigid.[15]

Construction of a model of phenomena amounts to an assertion that only selected parameters influence the phenomena under the study. In order to construct a model, scientists make observations both in highly idealized conditions and less idealized conditions. These experiments help the scientists to decide the set of relevant parameters which have influence on the behavior of the physical systems under the study.

[15] Hesse asserts that a model is not a literal description of nature and also the model is commonly an idealization of nature. For example, no one asserts that the entities, like smooth planes, perfectly rigid spheres, and the like, are literal descriptions of anything to be found in nature, but are simplifications of natural objects arrived at by neglecting all but a few properties of objects– properties (p. 202).

2. 2. Types of Idealizations

Many scientific laws and theories in natural sciences involve idealizations which do not present any difficulties as far as the syntax of the law is concerned. In a scientific law or a theory, idealizations may function as predicates or statements or statement functions.[16] If an idealization stands for a statement function, it can be treated as a predicate. Therefore, there remain only two possibilities for idealizations, i.e. either predicates or statements.

Barr contributes a useful terminology for dealing with the problems of idealizations. According to him, there are three different kinds of idealization used in science. Ideal conditions, ideal cases and idealized theories, Barr suggests, are commonly used types of idealizations in natural sciences. He claims that commonly discussed example of idealizations are laws which are taken to hold under *ideal conditions.* However, this does not mean that the claim "Some idealizations are predicates" is false.

Barr states that idealizations can be employed in scientific laws or theories as either predicates or statements. Although there are idealizations which are in the form of statements, this does not imply the claim that some idealizations are predicate is false. Idealizations may be either predicate or statements. On the other hand, Rudner claims that idealizations can be only statements. He rejects the possibility of idealization in the form of predicates. Idealizations are statements and theoretical terms refer to complex set of conditions, or more precisely, they refer to the set of statements describing such ideal conditions. For him, idealizations are expressions of nonanalytic statements. He also maintains that if a universal statement is either (i) an analytic statement or (ii) a statement whose corresponding existential statement is false, then this universal

[16] A statement function is known as a map or mapping. It refers to a function with domain Φ and range ψ or mapping from Φ to ψ, and written as $f\ \Phi \rightarrow \psi$. A concept may be similar to a function and a predicate may be analogous to an expression for a function. The sentence 'The apple is red', for example, can be written as 'Fx', where 'x' ranges over apples and 'F' refers to the predicate 'is red'; or it can be written as 'f(x) = y', where 'f' stands for a function mapping any apple 'x' onto its color value 'y'.

generalization will fail to describe anything in the real world. For example, "All swans are white" is a universal generalization and its existential statement will be "There are swans". This generalization will fail to describe anything in the real world just incase there is no swan in the world. An idealization, Rudner says, is contingent statement but its existential closure is empty.

Science aims to discover the laws of nature which describe exceptionless regularities. However, some special sciences are incapable of producing strictly universal generalizations or their laws. Such sciences have to impose a kind of modifier called *ceteris paribus* (hereafter, CP).[17] Some philosophers, like Hempel and Cartwright, argue that actual physical theories also implicitly contain such modifiers. For example, in the case of Kepler's law, the planets travel in elliptical orbits. In order to be true, the law must involve the condition that assumes there is no force other than the force of gravity exerted by the dominant body on the orbiting body.

Cartwright emphasizes that the fundamental physical laws are not true unless they are qualified by a *ceteris paribus* clause.[18] CP clauses have an indispensable role in science. The existence of CP clauses in actual physical science is accepted as problematic because there are no acceptable semantics for them and yet no acceptable account of how they can be tested. However, this does not show they cannot be tested.

CP clauses provide us with a kind of simplification in the complexity of nature. This is because assuming the CP clause ('other things are equal') implies that some factors having influence on the phenomena are kept constant. For example, when the universal generalization 'Smoking causes cancer' is qualified by a *ceteris paribus* clause, other things being equal, it becomes a law or a lawlike generalization. However, the conditions kept constant by the CP clause are not clearly defined. The only difference

[17] Sklar (2000) defines *Ceteris Paribus* conditions as a number of unspecified, and, perhaps never fully specifiable, background conditions (p. 41).
[18] Cartwright claims that her understanding of *ceteris paribus* is different from other philosophers'. She takes such clauses as definable in a certain way.

between a CP clause and an ideal condition is that the first one does not clarify the conditions under which the universal generalization holds.

> When Boyle's law was discovered, for example, scientists must have understood its *ceteris-paribus* clause. But they did not know all of the factors that can cause gases to deviate from $PV = k$. They had not yet justified the kinetic-molecular theory of gases. They did not know that the forces exerted by gas molecules upon each other, the molecules' sizes, their adhesion to the container walls, the container's shape, and a host of other petty influences cause departures from $PV = k$. So in discovering that $PV = k$, *ceteris paribus*, scientists couldn't have discovered that $PV = k$ holds when the gas is 'ideal' in the above respects.[19]

Boyle's law is qualified by the CP clause, 'there are no disturbing influences'. Besides qualifying it by a CP clause, Boyle employs an ideal condition assuming the temperature is constant to his law for ideal gases.

CP clauses vaguely qualify the universal generalizations; for this reason, a generalization qualified by a CP clause cannot be accepted as a law and also they cannot be tested according to Earman. A law qualified by a CP clause implies a generalization describing a regularity which holds for the most part.

> *Ceteris paribus* generalizations are true for a case, a circumstance, a situation, if the appropriate value for the indexical antecedent for that case results in a true conditional, that is, if there is some appropriate instance of *normally X* that is true for the case. *Ceteris paribus* generalizations are true if they are true for every case.[20]

The syntactic function of the CP clause is similar to ideal conditions. Scientists formulate the laws in a conditional form. Both CP clause and the ideal condition are located at the antecedent of the generalizations. However, there is a difference between the generalization whose antecedent is an ideal condition and the generalization whose antecedent is a CP clause. That is, an ideal condition assumes a change in the values of parameters, generally, giving them zero value, whereas a CP clause implies a vague abstraction by eliminating relevant parameters. For, by a CP clause, we assume that all factors are equal. However, we do not mention about these factors that are kept constant.

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[19] Earman, 2002, p. 411.
[20] Ibid., pp.400-401.

Cartwright introduces the CP clause as a bridge between fundamental physical laws and phenomenological laws. The laws qualified by a CP clause cover the phenomena.

> Many phenomena which have perfectly good scientific explanations are not covered by any laws. No true laws, that is. They are at best covered by ceteris paribus generalizations–generalizations that hold only under special conditions, usually ideal conditions. The literal translation is ‘other things being equal’; but it would be more apt to read ‘ceteris paribus’ as ‘other things being right’.[21]

The fundamental laws of physics do not describe the actual situations but only describe counterfactuals, i.e. ideal situations.

According to Rudner, a law fails to describe the actual phenomena if and only if its existential statement is false, that is, it involves an idealization. An idealization is a nonanalytic statement whose existential statement is false. Any logical equivalence of

(A) $\forall x\ (Fx \supset Gx)$

will fail to describe, because (A) fails to describe anything. That is, if the existential statement of (A), ‘$\exists x\ Fx$’, is false, then both (A) and its logical equivalences fail to describe anything. Idealizations are contingent statements and also a universal generalization which takes in an idealization can fulfill the condition (ii). “For any true universal conditional statement there is a logically equivalent form of the statement such that the appropriate corresponding existential statement is false. Hence, any true universal conditional statement would fail to describe”.[22]

According to Barr, Rudner’s syntactic analysis of idealizations is not adequate. For, idealizations can be assessed as either predicates or statements. Rudner does not accept the possibility of an idealization in the form of a predicate. According to Barr, Rudner’s account is insufficient for at least three reasons. It excludes the possibility that idealizations are taken to be predicates.

> Secondly, a necessary semantic condition—namely, that idealizations fail to describe anything—as Rudner interprets it excludes or includes statements as

[21] Cartwright, 1983, p. 45.
[22] Barr, 1971, p. 261.

idealizations when they are stated in a particular way, but not when they are stated in a logically equivalent way. And, finally, any nonanalytic statement can be made to describe anything simply by putting it in a logically equivalent form so that the corresponding existential statement is true (and, indeed, logically true). If we were to alter Rudner's analysis of 'fails to describe' by stipulating that a contingent universal conditional statement fails to describe if there is a logically equivalent form of the statement where the corresponding existential statement is false, then, as we have seen, any true universal conditional statement would fail to describe.[23]

Barr refutes Rudner’s claim by demonstrating that Rudner’s account is implausible. As stated above, Rudner assumed that any nonanalytic statement fails to describe if its existential statement is false. Two logically equivalent statements whose existential statements have different truth value can be considered. That is, any logical equivalence of (A) may not fail to describe although (A) fails to describe anything.

In his article, Barr clarifies what he means by the concepts ‘ideal condition’, ‘ideal cases’ and ‘idealized theories’ by giving the definitions of these concepts as follows:

An ideal condition is a formula in which state variables occur, whose existential closure is false, and for which there is another formula that can be constructed out of the original formula such that the existential closure of the new formula is true. An ideal case is a statement which is logically equivalent to a universal conditional which has an ideal condition as its antecedent. And an idealized theory is a set of false universal conditional statements.[24]

Barr discusses his concepts ‘ideal condition’ and ‘ideal case’ with the example of Galileo’s law which is in the form of both ideal condition and ideal case.

(B) “Given any x, if the friction acting on x equals zero, the buoyancy of air acting on x equals zero, and the deflecting magnetic forces acting on x equal zero, then the distance that x falls divided by the square of the time that it takes x to fall equals a constant.”[25]

This formulation of the law is an instance of a contingent universal conditional statement.

[23] Barr, 1971, p. 261.
[24] Ibid., p. 268.
[25] Ibid., p. 261.

Barr continues to discuss the law by transforming it into the more general form of a universal conditional statement. He claims that given any x, if x satisfies certain conditions, then x is so and so, and x is thus-and-so, and…, then x is such and such. This form of Galileo's law can be substituted by the form stated in (B). The important point is that the antecedents of both forms refer to conditions which are never fulfilled in the real world. The antecedents of these conditionals are called *ideal condition* and the whole conditional will be called *an ideal case.*

The ideal conditions are imposed to demonstrate the deviations between the actual situation and the ideal situation. Scientists use the ideal conditions in order to simplify the complexity of the actual world. For example, in the case of Galileo's law of free fall, it is assumed that the bodies fall down in a vacuum. That is, the resistance of air is ignored by attributing to it a zero value.

We generally use the first order predicate calculus in order to mention the theoretical concepts (or terms). Such a calculus involves symbols of disjunction, conjunction, individual constant, individual variables, and predicate of any finite degree, and so on. When doing experiments concerning falling bodies, the amount of friction, buoyancy of air, and deflecting magnetic forces can change from one situation to another. For that reason, such terms are accepted as variables. Such variables are named 'state variables' and they must be represented by applying an n (≥ 1)-place operation expressions. These cannot be represented like the predicate as a simple one predicate term.

In order to be an ideal condition, any formula C must satisfy the following conditions. C must be a formula whose existential closure is contingently false, and also C cannot be logically equivalent to any formula which does not involve any state variables.

> With Galileo's Law, the state variables representing 'friction acting on x', 'the buoyancy of air acting on x' and 'deflecting magnetic forces acting on x'- i.e., 'f (x)', 'b (x)' and 'd (x)', respectively–are assigned the value '0',

> but there is always in fact some friction, buoyancy of air and deflecting magnetic forces acting on bodies.[26]

Then, the existential closure of the formula is false, because the antecedent conditions of the formula are almost never satisfied in the actual world.

Then, both Galileo's law and Boyle' law become the instance of ideal case. For, Barr defines the ideal case as the formula which is a contingent universal statement and logically equivalent to a universal quantification of a conditional whose antecedent is an ideal condition. That is to say, any situation Φ is an ideal case when Φ is described by a contingent universal statement whose antecedent involves at least one ideal condition.

The ideal case is an idealization of the actual phenomena by constructing a model of the phenomena. To construct a model, scientists select certain relevant factors and then formulate their laws which hold only under ideal conditions. That is to say, models are the abstract replicas of the actual world. They are constructed to demonstrate certain aspects of the phenomena in the real world. The ideal cases are simplified models of the actual systems and the ideal cases like Galileo's law and Boyle's law are unrealizable in the actual world. Ideal cases depending upon ideal conditions express how the objects would behave in such conditions.

Barr defines the idealized theory as follows: "A set of statements *T* is an *idealized theory* only if (i) each statement in *T* has the syntactic and semantic characteristics of a universal law and (ii) the conjunction of the statements is contingently false."[27] The first condition implies that in order to be a universal law, a statement must satisfy the conditions such as logical contingency (having empirical content), universality (covering all space and time), truth (being exceptionless) and natural necessity. However, the problem is how we can decide what sentences are to be considered as universal laws. The second condition is satisfied when a statement whose antecedent is an ideal condition is in the conjunction of the theory. As stated before, the ideal

[26] Barr, 1971, p. 263.
[27] Barr, 1971, p. 266.

conditions are contingently false because it is a condition which is never satisfied in the actual world.

2. 3. Historical Examples of Idealizations in Science

2. 3. 1. Galilean Idealization

Galileo is commonly regarded as a revolutionist for his understanding of science. The old assumption which asserts that knowledge comes from the deductions derived from the writings of the authorities was given up and replaced by the modern method of physical sciences. Traditional studies on the motion depended upon the Aristotelian physics which studies the qualitative aspects of motion. That is, the relevant question concerning motion is why-questions in accordance with the Aristotelian physics. However, Galileo wished to study the quantitative aspects of how motion occurs.

Galilean methodology has three essential characteristics: mathematical language, experiments and idealization. Galileo is blamed for the problem of idealization by some philosophers of science. Galilean idealization reveals that scientific theories do not describe the objects of the real world. It separates idealized conditions from the actual conditions. That is, Galileo employed idealizations in order to reduce the complexity of the nature.

Galileo was responsible for the beginning of scientific mechanics. Although his contributions to mechanics were relatively few, the intellectual attitude he had developed started to be used in science. Galileo believed that mechanics is the study of the entire world. He took mechanics to be the geometrical representations of perceived phenomena. Also, mathematics was accepted as the principal tool of the knowledge of the universe.

> Galileo's physics was not *impregnated with interpretation*, just like every other description: what it did was invent new, experimental relations to the facts. It was because Galileo was convinced that he had to go beyond the phenomena in order to grasp their essence, and because he believed that only mathematics could express this essence, that he was able to formulate the laws of falling bodies.[28]

[28] Serres, 1995, p. 292.

Galileo applied geometry in order to simplify and purify the natural situation. For him, by doing this, we do not only eliminate the irrelevant factors but also make the natural situations manageable. The actual situations in the real world are idealized with the tools of mathematics after Galileo's mathematization of nature. That is to say, application of the pure geometrical entities to nature is an idealization.

> Then whenever you apply a material sphere to a material plane in the concrete, you apply a sphere which is not perfect to a plane which is not perfect, and you say that these do not touch each other in one point. But I tell you that even in the abstract, an immaterial sphere which is not a perfect sphere can touch an immaterial plane which is not perfectly flat in not one point, but over a part of its surface, so that what happens in the concrete up to this point happens the same way in the abstract… The errors, then, lie not in the abstractness or concreteness, not in geometry or physics, but in a calculator who does not know how to make a true account. [29]

Galileo was the first scientist who correctly defined acceleration for modern physics and also introduced it into the laws of free fall. Galileo's contribution to modern science is indisputable because in order to demonstrate his importance, it is sufficient to mention the importance of idealization in the physical sciences. By inspiration from Platonism, he affirmed that nature can be described by using mathematics. Modern science purports to explain the phenomena in the real world by number, figure and motion.

Galileo rejected the a priori dogmas of Aristotelian physics. Aristotelian theory was in agreement with common sense experience. Aristotle suggested two types of motion: natural and forced. Natural motion is that bodies naturally move towards the center of the earth. For any motion other than natural motion, a moving force is required.

> A body moves as long as the moving force operates; when the force ceases to act, the body falls down to the Earth or finds itself in the state of rest. Observation of moving objects teaches us that two factors influence the movement of bodies: external force and resistance of the environment. In order to make objects move, external force has to be greater that resistance. If the resistance of the environment is constant, then the velocity of a body will be directly proportional to the moving force. [30]

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[29] Galileo [1632] 1967, p. 207. Quoted from Pitt, 1988, p. 99.
[30] Nowak in Kuokkanen, 1994, p. 112.

It is a historical fact that Aristotle had never investigated any counterfactual characterization of motion. That is, he did not ask the question how the object would behave if there was no air resistance. Although Galileo knew that there is no vacuum in the physical world, he did not refrain from asking this question.

To eliminate all external and accidental impediments, Galileo employed several idealizing assumptions. These assumptions deform the empirical reality for simplification. He explained his law of inertia as follows: for a moving object, if there is no external force affecting it, then its movement will be limitless and hence infinite. If the rolling ball is perfectly round and it moves on a perfectly smooth plane and if the resistance of the environment equals zero, then the ball continues to move.

> If x is a rolling ball which is perfectly round, projected along an ideally smooth and perfectly spherical but limited and elevated plane so that x is carried with a naturally accelerated vertical motion and the resistance of the environment exerted upon x equals zero, then the path of motion of x is semi-parabola.[31]

Galileo described the motion of an ideal body rolling infinitely on a perfectly smooth surface. He stated that the body moves with a constant velocity if there is no external force.

Galileo also studied the nature of the motions of ordinary objects on the earth, and looked for the laws of motion of the objects of the real world. He formulated his laws which are concerned with the quantitative aspects of the regularity in motions of the ordinary objects. In other words, he approached motion as an exemplification of an equation, which is one demonstration of the quantitative aspects of natural phenomena.

The motions of actual bodies, Galileo says, could be expressed in mathematical terms. In the Galilean method, the phenomena are accepted as describable by mathematical equations. That is, Galileo's understanding of science stresses upon the importance of discovering how the objects in the actual world fall in accordance with mathematical relations.

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[31] Nowak in Kuokkanen, 1994, pp. 114-115.

Galileo argued that the definition of the simplest form of motion could be given in terms of mathematics. He stressed upon rectilinear and uniform motion. He assumed that the behavior of free fall is similar to that of uniformly accelerated motion. That is, he used an idealization when he assumed that free fall is a kind of uniformly accelerated motion. By doing this, he opened the way for us to comprehend many phenomena and to increase the number of experimental questions.

> This was the core of the scientific endeavor to which Galileo would henceforth devote himself. To the extent that he succeeded in it, he transformed the initial datum of experience into a sort of elementary yet fundamental system of basic experiments, which would henceforward continue to underlie all scientific thought.[32]

Galileo used the inclined plane in order to investigate the nature of free fall and to define what natural acceleration is. He firstly discovered that when a body freely falls, its velocity constantly increases. He developed his hypothesis on the relation between the velocity acquired and the descent fallen. He formulated this hypothesis as that the velocity acquired is proportional to the time of descent. He defined the regularity in the behavior of the freely falling bodies in terms of the relation between velocity and time.

Galileo thought that the inclined plane confirms the law of free fall empirically. To eliminate the interference of friction, the smooth inclined plane can be useful in his rolling ball experiments. Although in the technical Newtonian sense, he did not have any idea concerning friction and force, he tried to express how a body falls in vacuum media.

> The theoretical structure of this dynamics is built on two postulates: (1) the central feature of natural motion is that it possesses a uniform speed, proportional to the specific gravity of the moving object; (2) nonnatural motions are a result of a *virtus impressa*, an impressed force.[33]

Galileo considered whether specific gravity has any influence on the free fall. According to Galileo, in a vacuum, the motion of the body occurs in a specific speed associated with a given specific gravity. That is, he

[32] McMullin, 1967, p. 309.
[33] Ibid., p. 319.

ignored the all effective density in the medium and selected the speed and the gravity of a body.

In his *Dialogues,* Galileo deals with an early form of his law concerning falling bodies. He introduced his laws of free fall with the formulation $s = ½gt^2$ in which s = distance, t = time, g = a constant. Barr formulates Galileo's law in a general form as follows: "Given any x, if the friction acting on x equals zero, the buoyancy of air acting on x equals zero, and the deflecting magnetic forces acting on x equal zero, then the distance that x falls divided by the square of the time that it takes x to fall equals a constant."[34]

Galileo thought that idealization is the process of reducing the problems to their basic essential form. To formulate the phenomena, a distinction between primary and secondary parameters must be drawn. That is to say, scientists are required to select and focus on certain parameters and to ignore secondary parameters. He ignored friction, resistance and the certain characters of all physical objects which cannot be described by mathematical equations.

This formulation of the law is in the form of conditional statement whose antecedent involves idealization. In Galileo's law for freely falling bodies, an ideal antecedent condition is used. "When we apply this law to actual situations, we are able to attribute slight deviations in the acceleration of many freely falling bodies to influences such as friction, interfering magnetic forces, and buoyancy of air".[35] The values of the variables 'friction acting on x' and 'the buoyancy of air acting on x' and 'deflecting magnetic forces acting on x' are assumed to equal to '0'. These conditions are almost never fulfilled in the actual world.

Galileo studied uniformly accelerated motion and found its properties. According to him, uniformly accelerated motion can be regarded as the simplest type of the natural motions of freely falling bodies.

[34] Barr, 1971, p. 262.
[35] Ibid., 1974, p. 57.

> Galileo puts forward, as the only explicit postulate necessary for his proof, that the speed of a falling body will be the same for all inclinations of the plane on which it moves, provided the vertical height of fall be the same. From the definition of uniformly accelerated motion, he deduces that the velocity depends on the square of the time of fall, and goes on to develop a theory both of free fall and of fall on inclined planes. He shows that the speed acquired by a falling body will suffice to allow it to ascend again to the same height.[36]

As stated before, in order to formulate his law of free fall, Galileo employs idealization by isolating two factors: the time of the fall and the distance fallen. He ignores the air resistance which has influence on the body fallen. Galileo's law of free falling bodies describes a regularity with certain completeness. That is to say, this law describes how the objects fall when they are unsupported.

> … to formulate and demonstrate his law of free fall, Galileo assumed that the fall was taking place in vacuum, without the disturbing effect of the resistance of air. Bodies condensed to geometric points, perfects spheres, and frictionless planes are other standard imaginary creatures that allow the scientist to study physical phenomena in their pure form.[37]

Galileo's law counterfactually describes how ordinary objects would fall under idealized conditions.

Galileo tried to prove his theory by demonstrating that the objects which are made up of the same material but different weight fall at the same rate. Also, he claimed that if a perfectly round and smooth ball was rolled along a perfectly smooth horizontal endless plane there would be nothing to stop the ball (assuming no air resistance), and so it would roll on forever. "As a direct empirical test of Galileo's ideal law was not possible, he used his inclined plane experiment to show that as the angle of incidence approximated 90° (free fall), the acceleration of objects rolling down an inclined plane increasingly approximated a constant."[38]

Galileo used idealizations to describe the nature of the motion. It can be claimed that his idealization is fruitful, because he reached many

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[36] McMullin, 1967 p. 164.
[37] Niiniluoto, 1999, p. 136.
[38] Niaz, 1999, p. 145.

essentially correct results which could not have been reached without appropriate idealizations.

Galileo made a revolution in the understanding of experience. He was aware of the fact that his law of falling bodies does not hold precisely. The law of free falling bodies is a legitimate idealization since the antecedent of the law involves ideal conditions stated by Galileo. Unlike the Aristotelian methodology, Galileo intended to give a mathematical description of the phenomena rather than giving a philosophical knowledge of nature. Some historians of science emphasize that many experiments Galileo performed were accepted as impracticable or inconclusive. That is to say, Galileo performed *thought experiments*.

2. 3. 2. Boyle's Idealization

Boyle's gas law is another excellent example of idealization in science. Boyle formulates his analyses and explanations for the behavior of gases in physical terms. That is to say, Boyle selected the relevant parameters to study gases and introduced the ideas of pressure, volume and compressibility of a gas. Barr formulates Boyle's gas law as follows:

> (BGL) Given any x and any y, if all the molecules in y are perfectly elastic and spherical, possess equal masses and volumes, have negligible size, and exert no forces on one another except during collisions, then if x is a gas and y is a given mass of x which is trapped in a vessel of variable size, and the temperature of y is kept constant, then any decrease of the volume of y increases the pressure of y proportionally, and vice versa.[39]

Derived version of Boyle's gas law is an idealized law because it is valid for perfect or ideal gases. Also, the antecedent of the law contains the idealized variables. In the antecedent of the conditional, the gas molecules are described as perfectly elastic and spherical. Temperature and volume and pressure are assumed to be constant. To derive it from the kinetic theory of gases, gases are composed of point-mass molecules, and there is no interaction among them. In other words, Boyle's law holds for only the ideal gases which possess the following properties: their molecules or particles are material points, and they exert no forces on one another except during collisions; so for those gases, there is no inner pressure. Boyle paid attention only the factors which are relevant according to him, neglected all negligible factors.

Boyle performed some experiments in order to formulate his law for the ideal gases. After performing the experiments, he concluded that the pressure and the volume of a gas are inversely proportional, since experiments demonstrate that if the volume of the gas is decreased to a quarter of its original value, then the pressure of the gas becomes four times as great. He detected regularity between pressure and the volume of a gas.

Boyle formulated his law for ideal gases as $pV = RT$ where 'p' is the pressure of the gas, 'V 'denotes the volume, 'R' is a constant, and 'T' is the

[39] Barr, 1971, p. 259.

temperature of the gas. Boyle's original formulation of the law for an ideal gas demonstrates the regularity in the behavior of the gas when its pressure and volume are inversely proportional. However, there are no ideal gases such that all molecules of the gas are perfectly elastic and spherical. Besides having negligible size, the molecules of the gas have equal mass and volume. Also, there is no interaction among the molecules of the gas.

Boyle's law does not describe the behavior of the actual gases in their complexity. By keeping the temperature constant and ignoring the interaction of the gas molecules, it simplifies the complexity of the phenomena. Boyle's law characterizes the phenomena with a few selected parameters. The behavior of the gases is described by means of the parameters pressure, temperature and volume. Boyle's law is a good idealized law because it allows to be improved upon the ideal conditions which assume zero value for some parameters.

On the other hand, Kuokkanen and Tuomivaara oppose the claim that Boyle's law is an idealized law. Their argument to defend their claim depends upon the formulation of Boyle's law. They claim that this formulation demonstrates that we cannot accept Boyle's gas law as an idealized law.

According to Kuokkanen and Tuomivaara, Boyle's law can be stated as follows: "if $G(x)$ and $T(x) = t$, then $p(x\ ).\ V(x) = c$, where

$G(x)$ … x is a body of a gas

$T(x) = t$ … the temperature of x is a constant t

$p(x)$ … the pressure of x

$V(x)$ … the volume of x

c … the universal gas constant" [40]

According to Kuokkanen and Tuomivaara, this formulation demonstrates why Boyle's law cannot be accepted as an idealizational law, because, the idealized antecedent condition, which is typical for an idealized

[40] Haasse, 1997, p. 360.

law, is missing in Boyle's gas law. Moreover, Boyle believed that his law is factual.

Nevertheless, Kuokkanen and Tuomivaara miss the important point that this law is accepted to be valid if it is related with ideal gases. In order to do this, the assumptions *'a(x) = 0' and 'b(x) = 0'* are added to the formalization of the law, "if *G(x)* and *T(x) = t*, then *p(x) . V(x) = c*." Then, the supplemented result can be called 'idealized gas law' when '*a(x)* = 0' refers to the denial of intermolecular forces between molecules and '*b(x)* = 0' refers to the assumption that the molecules have zero volumes. That is, the formulation of idealized gas law is that *if G(x) and T(x) = t and a(x)* = 0 *and b(x)* = 0*, then p(x) . V(x) = c* as a result of idealized conditions. The domain of ideal gases can be specified by adding these idealized conditions to "Boyle's gas law."

Haasse added some important remarks concerning idealized gas law.

> … The idealized gas law is a representation that expresses the behavior of idealized gases. This example demonstrates the knowledge-dependence of idealization procedures: It is necessary to have at least some–or to assume to have some–information about entities and their attributes which should be involved in the making of representations and their deformation: '… we know now that Boyle's law is an idealizational law which exactly fulfilled with an ideal gas and only approximately with real gases when a (x_i) and b (x_i) are low,…' [41]

Therefore, we can conclude that Boyle's law can be taken to hold only under idealized antecedent conditions that are part of the law. Hence, this law is an idealized law. It is not important whether Boyle was aware of his idealization or not.

[41] Haasse, 1997, p. 361.

CHAPTER 3

INEVITIBILITY OF IDEALIZATIONS IN SCIENCE

3. 1. The Ubiquity Thesis

Use of idealizations in scientific theories is accepted as the hall mark of the modern science. Idealizations are essential to scientific rationality and idealizing assumptions cannot be eliminated because of the complexity of nature and our finite epistemic capacities. The claim 'most theories involve idealization' is named as *ubiquity of idealizations thesis* by Laymon.[42]

The *ubiquity thesis* implies that use of idealizations is very common in the physical sciences, particularly physics and chemistry. Those sciences impose certain ideal conditions, which never hold in the actual world, to their laws. It is commonly accepted that the elimination of idealizing assumptions in a law or a physical theory is not possible because idealized conditions are ineliminable principles of scientific methodology.

Because of being ineliminable, idealizations can be taken to be certain counterfactuals assumptions which help us to understand the behavior of the objects in the real world. They can lead us to empirically information how the objects of the real world behave in more complex, less idealized, situations. Some counterfactuals refer to idealized assumptions which hold only under a model but not in the real world. That is to say, idealization is indispensable for the theoretical sciences because it makes the construction of models possible, in other words, models of theory can be constructed as a result of idealization.

In *How the Laws of Physics Lie*, Cartwright argues that most theoretical claims or most theories are false because they hold true only under idealized conditions. She uses the existence of theoretical entities as a proof for fundamental laws being false. Fundamental physical laws are false

[42] Laymon, 1989, p. 357.

because they do not describe how the objects in the actual world behave. She introduces two kinds of law called fundamental and phenomenological laws. Phenomenological laws only describe how the objects behave in the actual world. That is, they are indeed true in the actual world. Fundamental laws have a great explanatory power. They are used to explain the phenomenological laws. According to Cartwright, if Newton's laws are fundamental laws, Kepler's laws are phenomenological laws (and deducible from Newton's).

Fundamental laws are true only in a model because their truth depends upon satisfying the idealizing conditions. Cartwright argues that use of approximations and idealizations in science is merely accepted as distractions. Although the fundamental laws of physics are true if and only if appropriate *ceteris paribus* modifiers are added to them, such modifiers describe conditions which can never be satisfied. She concludes that if the fundamental laws are true, then they cannot hold in the real world, but only in highly idealized counterfactual situations.

When Newton's law of gravitation ($f = \mathrm{G}m_1m_2/r^2$) is literally interpreted, it is accepted as false because the value which is specified in the formula could not give the net force acting on a pair of objects. A *ceteris paribus* modifier like 'there are no forces other than gravity' is required. After such a modification, Cartwright names the formula to the fundamental laws and she claims that antecedent of any fundamental law will represent the conditions which are almost never satisfied. Therefore, they cannot provide us with the descriptions of how the actual objects behave.

Moreover, although fundamental laws are false, they have great explanatory power. They counterfactually describe the reality and explain the phenomenological laws. Cartwright believes that use of idealizations provides scientists with formulating fundamental laws. And these laws are used to derive the phenomenological laws. Use of idealizations is always required for the actual derivations.

On the other hand, while use of idealizations is problematic, idealizations are ubiquitously used in science because of simplicity, scope and economy they provide for theories. In other words, for comprehensively characterizing the behavior of the objects in actual world, theories employ ideal conditions. Thus, idealizations are ineliminable because of the complexity of nature.

3. 1. 1. Complexity of Nature

In the history of science, there are many examples of scientific rejection of the furniture of the universe. For example, the existence of crystal spheres was denied. We are not concerned with a kind of rejection but a kind of elimination of the things which are unnecessary for a scientific theory's goals. The new theory involves an ontological elimination.

> Critical reconstructions of Newtonian theory reject Newton's absolute space as reference object for all motion, adopting a space-time instead that has only the notion of a class or equally fundamental inertial reference frames, no one of which takes the place of the eliminated Newtonian base frame. In the transition from prerelativistic space-time to the space-time of the special theory of relativity there is elimination, based on critique, of the notion of absolute simultaneity for events at a spatial distance from one another.[43]

Scientific theories are committed to their ontology. An ontological elimination means an interpretation of the existing theory which purports to reduce undesirable complexity, that is, to reject a portion of ontology which is unnecessary for the theory. In the history of science, there are many theories which have been exposed to reinterpretations aiming at elimination. For one thing, the old theory is reinterpreted in order to formulate a new theory which provides novel predictions. For another thing, with the interpretations, a new theory derived from the existing theory by ontological elimination will be able to deal with unexpected data. The interpretations of quantum mechanics are the examples of ontological eliminations.[44]

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[43] Sklar, 2000, pp. 13-14.

[44] Sklar in 2000 argues that Critical arguments for ontological elimination can be found in many places in the history of quantum mechanics: in Heisenberg's original positivistic

Scientists do not study the reality in its overwhelming complexity. By the operation of idealizations, they achieve to decrease the computational complexity of the real world. It is an essential characteristic of modern science that in order to examine the complex objects, the complex objects or situations are reduced into their parts.

> Because of the complexity of the dictates of nature, the possibly relevant factors are innumerable, and a one-by-one exhaustive examination is simply impractical. Moreover, various factors are likely to possess differing degrees of relevance, requiring selective judgment and evaluation[45].

In order to formulate a law, scientists do not doubt to use idealization because of the overwhelming complexity. For example, both Descartes and Newton formulated a principle of inertia. These two versions of the principle involve idealization because it describes motion of a body isolated from all exterior influences.

The complexity of the real world is a barrier to our understanding of nature. In order to overcome this complexity, scientists have to limit the parameters which they deal. Such a selection implies the existence of negligible factors and abstracting the nature involving only essentially relevant factors. In classical mechanics, we are concerned with the parameters: *mass, velocity, distance traveled over time* in order to describe the behavior of the falling bodies. However, we do not consider the actual velocities but the velocities under idealizations. Frictionless media is an idealization and we simplify the actual world by attributing a zero value to one of its properties. We attempt to describe the phenomena in terms of selected factors.

The complexity of nature refers to a form of ontological complexity. The world consists of individuals, relations and properties. "It (the world) appears to include aspects of both compositional complexity, the number of types and individuals in an entity, and structural complexity, the variety of

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program, in the background of Schrödinger's demonstration of the equivalence of his version of quantum mechanics with that of Heisenberg, and very dramatically, in Bohr's Copenhagen interpretation of the theory with all its instrumentalist aspects. p. 14.

[45] Blackwell, 1969, p. 134.

relationships between the constituents of an entity."[46] Use of idealizations is an operation of simplification in the complexity of the world. That is, by removing properties, relations and individuals from the real world, scientists make the world manageable.

As stated previous chapter, an idealization is the process of constructing models of the real world. In order to deal with the complexity of the world, we counterfactually replace the real world with one of its models which is a simplification of the real world. In other words, the complexity of nature is reduced by removing properties and individuals of the real world. The world whose properties and individuals are decreased is called an idealized world.

Scientific activity requires experiments and the experiments consist of isolating the environment to find an answer for a particular question. Scientists decide what factors are relevant and what factors can be eliminated. That is to say, scientists design the experiments in which the parameters are kept constants. The experiments are an idealization of the natural phenomena.

Scientists attempt to capture simplicity in their formulation of natural laws and also their representations. However, the nature is so complex; for this reason, there is always a gap between what the actual phenomenon is and what theory represents. Aim of science is not examining the real world with its messiness.

> The complexity and variability of natural phenomena and our desire to explain them with a set of simple and invariant laws demand the use of idealization, whose ultimate aim is to *carve nature at its joints.* It is only when the actual world is carved up at its joints by idealization, genuine lawlike statements can be formulated. Therefore, the more complex and/or variable the phenomena and the deeper the posited mechanisms by which the lawlike are to be formulated, the wider the gap between the ideal conditions and the facts. And the gap should not affect the truth of the laws or theories in question. If one can conceptually (and sometimes even experimentally) cut the world apart at its joints, one can better understand how it actually operates – i.e., giving explanations – and predict how not

[46] Shaffer, 2000, p. 22.

yet existing phenomena may occur (out of a composition of causes which obey the laws).[47]

Scientists are concerned with only the quantitative aspects of the phenomena although they have both qualitative and quantitative aspects. Cartwright maintains that mathematical physics simplifies the nature. The actual phenomena are reduced to simple mathematical functions and geometrical representations. She discusses on Coulomb's laws in which the total 'resultant' force are produced by adding two forces: gravity and electricity. Nonetheless, nature does not, Cartwright says, add these two forces. Physics uses mathematics to analyze a physical situation and the mathematical analysis demonstrates how the factors behave under idealized conditions.

3. 1. 2. Mind-Nature Confrontation

The problem of the relation between mind and nature has historically two phases: respectively the Greek and the modern phase. For the Greek philosophers, in order to know the real, we have to abstain from the feelings and sense impressions because to be the real implies being stable and permanent. Sense impressions help us to penetrate the unchanging essences and relations manifesting themselves through these impressions.

In modern sense, knowledge comes from a kind of relation between subject and object and this relation is defined as real knowledge if it is concerned with spatiality or extension. The root of modern understanding of knowledge is based upon the formulation of Descartes' mind-body relation. The body-mind dualism is transformed into subject-object relation as an epistemological problem. This formulation divides the real world into two parts as *the thinking substances* or subjects (mind) and *the extended substances* or the objects.

In the Sixth Meditation, Descartes introduced his epistemological argument establishing that mind is really distinct from the body. The

[47] Lui, 1999, pp. 244-245.

modern discussion of mind-body relation can be linked to Cartesian philosophy by Descartes' epistemological principle. He mentioned his discoveries concerning the self and matter in terms of clear and distinct perceptions. His epistemological arguments can be firstly applied for establishing the possible existence of physical objects. The physical things can be conceived as the objects of pure mathematics. In the fifth meditations, the physical things have the quantitative properties which are clearly and distinctly conceivable. Knowledge of nature will be in part knowledge of its quantitative properties or of properties expressible in quantitative terms.

Descartes claimed that scientific knowledge of external world depends on the laws of matter and motion. He states that the universe is a plenum or full of substance and he rejects vacuum or total absence of bodies in the universe. Extension is an essential characteristic of corporeal substances. All bodies and the space which contains extended bodies have an extension. Descartes simply defines motions as the action by which a body travels from one place to another. He understands motion and rest as two different modes of a body. He argues that the universal and primary cause for all motions in the world is God preserving the same quantity of motion in the universe.

Although Cartesian physics is inconsistent, it is very important in terms of formulation of Descartes' laws of nature. Descartes employs idealizations when he explains nature of the impact of material bodies during the collision. He introduced his collision rules and law of conservation for quantity of motion. In his *Principles of Philosophy,* he mentions his seven rules.

According to Descartes, motion is simply mode of the matter which is moved. Also, its motion is determined in quantity. In the universe, there is always the same quantity of motion. He introduces first law of nature: *what is in motion always continues to move and what is in rest always continues to be rest*. That is, if there is no external cause, every particular matter remains at the same state. Second law asserts that a body or every piece of matter inclines to remain in motion in a straight line but if there is impact of other bodies, it has to change its direction and as a result of any motion, all matter simultaneously moves in a circle. For, God preserves motion in matter.

Descartes' third law is related with the collision of two material bodies. It explains what would happen when the body collides with another body which is stronger or weaker than it. This law implies that if the hard bodies in projectile motion collide with some other hard bodies, then they do not stop, but rebound in the opposite directions. In case of a soft body, the hard bodies will transfer all their motion to it. The transfer means conservation of quantity of motion because the quantity of motion does not change in the collision. According to Descartes, there is a difference between the motion of body and its direction. The direction of motion can be changed but the quantity of motion remains constant. The third law includes all changes in the motions of corporeal things.

All bodies in the universe have a tendency to persist in the same state. Descartes uses his first law in order to explain the nature of the power which all bodies have to act on or resist other bodies. The amount of power which the body uses to remain the same state depends upon the size of the body, the size of the surface separating it from other bodies and the speed of motion.

Descartes mentions seven rules to determine the quantity of motion. To calculate the quantity of motion, two conditions must be satisfied according to Descartes. Two bodies which collide must be perfectly hard and isolated. His seven rules for collision would be applicable the plenum if the bodies had perfect hardness and the impacts of other bodies in the plenum were ignored.

Descartes' seven rules for collision and quantity of motion includes idealization when they are examined.

> Our calculation would be easy if there were only two bodies colliding, and these were perfectly hard, and so isolated from all other bodies that no

surrounding bodies impeded or augmented their motions. In this case, they would obey rules….[48]

I intend to summary his seven rules and demonstrate idealizations in Descartes' mechanics. It can be calculated by means of the following rules. Assume that A and B are two bodies which collide each other.

First rule explains the case if two bodies (A and B) are equal in size and speed, then they continue to move opposite direction without anything in their speed when they collide each other.

Second rule describes the case if one body (A) is larger than other body (B) in size but they are equal in speed, then the body (B) bounds backward and two bodies travel same direction in so far as and they clash each other.

Third rule depicts the case if one body (A) is faster than the body (B); but they are equal in size, then the direction of slower body (B) is altered and A and B move to the same direction provided that the body A collides the body B.

Fourth rule asserts that if the body A is at rest and larger than the body B, then the body A does not move when they collide each other. Because, the power of body A to remain at the same state (or power of resistance) is larger than the power to move given by the body B.

Fifth rule expresses the case if the body A is at rest and smaller than the body B, then the body starts to move and they travel same direction when they hit each other. Since the body B transfer its motions to the body A.

Sixth rule represents the situation that if the body A is at rest and the bodies A and B are equal in size, the body B transfers certain quantity of speed and motion to the body A and it bounds backward with the body A or it pushes the body A and they travel same direction.

Seventh rule describes the condition that if the bodies A and B travel in the same direction and if the body B is slower than the body A, the body A transfers its speed to the body B. Descartes mentions certain possibilities

[48] Cottingham and Stoothoff, 1994, p. 244.

in terms of size of bodies. The main point in this rule is the transfer of speed and motion.

These rules are all idealizations because they assume that there are only two bodies in contact in the plenum (or universe). However, the universe which Descartes describes is full of bodies and each body is simultaneously in contact with many others.

The questions on relations of mind and nature were discussed as body-mind problem in the history of philosophy. How the knowledge of the external world is possible? Some philosophers claim that the reality is non-mental as the object of knowledge.

> The word "nature" has two distinct meanings in epistemological discussions, namely nature as external to mind and nature as internal to it. That is to say, contrary to all other discussions of reality, an epistemological discussion almost necessarily deals with nature as inclusive of minds and minds as inclusive of nature in the form of knowledge.[49]

Kant explains all experience in terms of mind's activities. For him, nature is a whole of phenomena. This assumption is required for the postulate 'the existence of the thing in itself' which underlies the data of sensory knowledge. From his point of view, the existence of reality is independent of mind, but the knowledge of that reality is mental. To be non-mental for an entity means that it can be perceived by more than one person.

We could indirectly get knowledge of the reality. Only thing we directly know is the images we hear or see and these images are not identical with the objects or events themselves.

> … in assuming an indirect knowledge of reality, we must not forget many perfectly normal limitations. Elements of selection, interpretation and distortion are found, doubtless, in both concepts and percepts. It is scarcely possible to see the A world precisely as it is and see it whole. The very nature of our minds prevents us from observing things in all their aspects at once. We are compelled by our position among things to look at them from a point of view, at a certain moment, in certain connections.[50]

The relationship between mind and external reality is an extra mental relationship. The existence of the external reality is independently recognized. The image of a body is not a faithful representation or

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[49] Winn, 1956, p. 44.
[50] Ibid., p. 42.

reproduction of it. Mind interprets it by means of a numerous elements of interpretation.

The concept of nature refers to two different meaning in epistemological discussion, namely *nature as external to mind* and *nature as internal to it*. The first meaning implies that the nature as external to mind can be different from the nature as revealed by our perception and also it is material. The second one asserts that the nature is mental.

The mind is a mediating agency between the actual world or nature and the world we conceive. The mind has an important and also indispensable role in preserving the influence of the nature upon mind and in understanding the behavior of the objects in their physical environment. Such a function implies two different aspects of the problem of knowledge. To understand how this function is possible, we must consider both how the external world can form and affect the internal world and how knowledge of the external world is possible.

All activities of the brain is not necessarily a mental activity having cognitive functions since every brain activity does not requires a phase of awareness and knowledge of external world. That is to say, most human reactions to stimulations are controlled by the automatic nervous system, for this reason, such reactions do not constitute knowledge at all. Since, the automatic nervous system has no capacity to make adaptation to external forces. Consciousness and knowledge depend upon a special nervous system called 'central' which is capable of making adjustment to external forces.

How is it possible for us to know the external world in terms of mental facts, such as conceptions and perceptions? The existence of the external world is established by perceptions. There is a pragmatic claim that if a normal person is able to indicate the presence of the phenomena he perceives and some individuals are in agreement on the perception, then the existence of the phenomena is established. Our knowledge of the external world comes wholly through perception. What is given in perception may itself belong to that world. That is, the content of the mind are produced by the sensations of the physical objects.

The problem is how perceptions produce knowledge. When we perceive an object, we are directly aware of the image of the object and indirectly aware of the physical object. The methodology of modern science accepts the possibility of knowledge of external world. Scientists believe that the existence of objects of the external world do not depend on our knowledge of them. We perceive the objects in the nature and the content of the perception is the material of knowledge concerning the external world. That is, knowledge is the end result of perceptions.

Do perceptions involve the modification of the mind? If we accept that sensations are the modifications of the mind, then how can we claim that the objects we perceive are independent of or external to the mind? The mind-body dichotomy is the reason for the concept of primary and secondary qualities of objects to be developed. The primary qualities are the essential qualities of the objects in nature. The secondary qualities are attributed to the objects by mind in perception.

Concerning knowledge of the external world, science uses mathematics in order to represent the nature. Idealizations and abstractions are two different processes of the mind to represent the nature.

> …in idealization we start with a concrete object and we mentally rearrange some of its inconvenient features- some of its specific properties- before we try to write down a law for it…. But in fact we cannot just delete factors. Instead we replace them by others which are easier to think about, or with which it is easier to calculate. The model may leave out some features altogether which do not matter to the motion, like the color of the ball.[51]

The secondary qualities are ignored when we write down a law of nature. As discussed before, human mind capacity is limited in terms of computation and analysis, for this reason, we use simplifying assumptions or idealizations on the description of the world. That is, the mind deliberately makes transformations of the real world to deal with.

[51] Cartwright, 1989, p. 187.

Abstractions and idealizations make the scientific knowledge of the real world possible. Without simplifying the complexity of the real world, scientist cannot study the nature in all its fullness at once.

The sciences concerned with the external world or empirical world begin with idealizations or a number of significant transformations.

> First, not all the available data is relevant to the solution of a given problem. A process of selection is involved. The color of a moving body plays no part in the laws of motion. The mind selectively limits its attention to those aspects of the physical situation which it perceives as relevant. Further, the physical realities with which science begins are often transformed into entities which are not physically real. We talk about point masses, instantaneous accelerations, conservative systems, which are deliberate idealizations.[52]

The genesis of human knowledge depends on the mutual relation between mind and nature, according to the methodology of modern science. When the methodology of modern sciences describes how we have knowledge of nature, it also describes the characteristics of the components of the relation from which knowledge comes. The essential property of the nature is its complexity or more clearly abundant richness of the nature.

The complexity of nature is an obstacle for knowledge. The mind defensively reacts to simplify the complexity of nature.

> Simply said, the complexity of nature is a barrier to human understanding… If the human mind were capable of gazing upon the whole of nature and at the same time of discerning the details of the components of nature, a comprehensive natural science would easily be attained.[53]

The mind focuses on certain parameters to limit the complexity of nature. Such simplification of nature increases the mind's ability to get knowledge of it. The criteria for choosing relevant factors are determined by the methodology of knowledge we have. That is, same phenomena can be examined differently if the methodologies require the selection of different parameters.

The methodology of modern sciences requires using idealizations in the formulation of theories or laws. It asserts that simplifications by

[52] Blackwell, 1969, p. 93.
[53] Ibid., pp. 124-125.

ignoring negligible factors do not affect the reliability of our knowledge. For a phenomenon, qualitative properties are secondary qualities which can be ignored. On the other hand, quantitative aspects of the phenomenon must be taken into consideration.

That is to say, the methodology of modern science directs the mind in selecting the factors. The relevant factors are determined by the methodology and the mind only selects these factors.

> Consider the problem of explaining the motion of falling bodies. The Aristotelian stance on this problem is dictated by Aristotle's demand that scientific knowledge consists in knowing the causes of an event. For Aristotle this means that the ontologically productive sources of motion with special emphasis on the final cause must be discovered. The mind is thus adapted to nature in a special way and the inquiry can begin. In contrast to this the treatment of the same issue in the seventeenth century, primarily in the hands of Galileo and Newton, begins with a considerably different perspective. The question is no longer of causal understanding in the older sense. Instead, the problem is formulated in terms of the proper functional relations between the descriptive properties of falling motion, independently of the ontologically productive causes, whatever they might be.[54]

That is, modern methodology requires selecting quantitative aspects of factors influencing the free falling. The problem is examined from different perspectives. Galileo was aware of that the resistance of the medium has influence on the rate of falling bodies and also he knew that the deviation from the actual situation is very small when it is ignored because the effect of the resistance is very minor.

The methodology of modern science requires the human mind to select quantitative aspects of parameters. That is to say, the human mind is conditioned by the methodology of science to choose certain factors and to neglect all secondary factors because of the richness of nature.

[54] Blackwell, 1969, p. 133.

CHAPTER 4

MODELS AS A SOLUTION TO THE PROBLEM OF CONFIRMATION OF IDEALIZED LAWS

Use of idealizations in science causes many problems in philosophy of science. Empirical testing or confirmation of scientific theories is one of the basic problems resulting from use of idealizations. According to the realist account, scientific theories make predictions and by means of these true predictions, theories can be tested. When idealized conditions or idealizations are accepted as premises, some premises are false because idealizations are true in only counterfactual situations or models. For this reason, there is no guarantee of predictions to be true. If predictions are results of derivations from the premises which are composed of general laws and initial conditions, then predictions will be true if and only if premises are true and entail prediction.

Scientific realism is the position which claims that science can give true and faithful picture of the real world. Statements of science describe the reality, that is, theories are true descriptions of the reality. Scientific theories aim to give descriptive, predictive and possibly explanatory accounts of the phenomena in the real world.

The realist account affirms that theoretical laws are factually true or false. However, use of idealizations makes this claim difficult to sustain. For idealized laws involve such conditions that will never hold in the real world. However, if idealized laws can be stated as conditionals whose antecedents are false, since those antecedents include idealizations, the conditionals are logically true.

Another problem implied by use of idealizations is about the relation between science and reality. Scientific realists claim that scientific laws describe the facts about reality. This assumption requires accepting that laws are true. On the other hand, Cartwright claims that fundamental laws of physics do not describe the real situations but only describe idealized situations. “The fundamental laws of the theory are true of the objects in the model, and they are used to derive a specific account of how these objects behave.”[55]

Cartwright accepts that the fundamental laws must have explanatory power and it is not necessary that to have explanatory power requires truth of fundamental laws. She claims that having a great explanatory power does not necessarily require the inference that the hypothesis is true. “… the falsehood of fundamental laws is a consequence of their great explanatory power.”[56] Philosophers like Cartwright and Van Fraassen, argue that a false theory would give an explanation of a fact. For instance, Newton’s theory elucidates the tides and many planetary phenomena although it is literally false.[57] He claims that ‘to say a theory explains a phenomenon’ is independent of the question whether the theory describes true facts about the nature. In other words, an explanation cannot be regarded as a relation between a theory and a fact. Van Fraassen is in opposition to the claim we have a good reason to believe in the truth of theories if they explain the phenomena. For him, explanatory power of theories cannot be reduced to their empirical adequacy, because explanation is purely conceived as a logical concept. It is not an entailment from the fundamental laws and initial conditions, but an answer for a why question.

Duhem is another philosopher who claims that explanation is not the thing which science seeks for, or an aim of science. According to Duhem, science purport to simplicity in representation. He argued that an explanation has metaphysical aspects because it aims to clarify facts underlying the reality. “If we believe that physical theories can *explain* things, this can only be true if the physical science is subordinate to

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[55] Cartwright, 1983, p. 17.
[56] Ibid., p. 4.
[57] Van Fraassen argues in (1980) that ‘The theory T explains fact E’ does not implies that T is true and empirically adequate and also acceptable. He mentions examples of explanations given by theories which are empirically false. p. 98.

metaphysics."[58] He believed that a physical theory never explains empirical laws. It never makes known the reality. A theory is not regarded true or false according to how well it gives an explanation of reality. In other words, explanatory power of physical laws cannot be a reason for deciding that laws are true or false. A theory is judged to be true only when the predictions derived from it are in agreement with results of experiments. He also claims that laws of physics are essentially approximative. The anti-realists' challenge concerning the nature of explanation to scientific realism must be answered.

Cartwright says that fundamental laws are true only of objects in the model because a model constructs a link between the fundamental laws and the reality. Fundamental laws are applicable on the objects in the real world exactly when they are qualified by a CP modifier. Cartwright argues that Newton's law of gravitation is false if it is interpreted literally because the net force having influence of the objects are not correctly specified. In order to be true, this law must be qualified with an appropriate *ceteris paribus*: 'there are no forces other than gravity at work'. She claims that only phenomenological laws can describe the actual behavior of the bodies in the real world. However, these laws are less general and less exceptionless than fundamental laws. That is to say, phenomenological laws cannot be stated without exceptions whereas the fundamental laws are very general and simple and also can be stated without exceptions.

Elgin and Sober formulate Cartwright's arguments as follows:

(1) Interpret the law as including a *ceteris paribus* modifier (i.e., if there are no forces other gravity at work, then $f = Gm_1m_2/r^2$

(2) Interpret the law as describing a component force (i.e., the force due to gravity) $f = Gm_1m_2/r^2$.

(3) The fundamental laws of physics are true only when appropriate *ceteris paribus* modifiers are attached.

(4) *Ceteris paribus* modifiers describe conditions that hold only under ideal situations.

(5) When the fundamental laws of physics are true, they apply only to objects in ideal (counterfactual) situations.

(6) Therefore, the fundamental laws of physics don't apply to

[58] Duhem, 1905, p. 10.

objects in the real world

> We will argue that even granting the truth of premises (3) and (4), (5) does not follow (hence, neither does (6)).[59]

According to Elgin and Sober, Cartwright is mistaken when she claims that fundamental laws cannot be applied to the objects in the real world.

> Cartwright says that the statement "two bodies exert a force between each other which varies inversely as the square of the distance between them, and varies directly as the product of their masses" is false unless we attach the *ceteris paribus* modifier "there are no forces other than gravitational forces at work.[60]

When we examine what Cartwright says, we will notice that she mentions some features of true laws. First, laws must be in the conditional form, i.e., $C \rightarrow L$. And the laws must be qualified with an appropriate CP clause. She says that $C \rightarrow L$ is true if and only if the existential closure of C is false, that is, C is never satisfied in the real world because it is a CP clause. In other words, a law is true conditional whose antecedent is false. For this reason, the law cannot be applied to the real world because a model of the laws is required.

Elgin and Sober claim that Cartwright assumes that $C \rightarrow L$ is false and if $C \rightarrow L$ cannot be applied to the objects in the real world, then its contrapositive $\sim L \rightarrow \sim C$ can be applied. They formulate what Cartwright says, then following appear: (1) *If there are no forces other than gravity at work, then* $f = Gm_1m_2/r^2$. She claims that antecedent of the conditional (C) is false because it is never satisfied in the actual cases. Also, the consequent is false because of the presence of secondary forces although they are assumed as not present. If both C and L are false of the objects in the real world, then their contra positives $\sim C$ and $\sim L$ will be true of the objects in the real world. For this reason, $\sim L \rightarrow \sim C$ can be applied to the objects in the real world. That is, if $f \neq G\, m_1m_2 / r^2$, then

[59] Elgin and Sober, 2002, p. 442.
[60] Ibid., p. 442.

there are forces other than gravity at work. (1) is true law because it has a conditional form qualified with a CP.

On the other hand, Cartwright mentions the law of gravitation ($f= Gm_1m_2/r^2$) in the unconditioned form when she claims that fundamental laws do not apply to the real objects. (1) is the Feynman version of the law, that is, it has an implicit CP modifier according to Cartwright. After attached with a CP clause, the law can explain in only very simple or ideal circumstances. In other words, Cartwright contends that (1) can explain only "why the force is as it is when just gravity is at work."[61]

I want to argue that Elgin and Sober miss some crucial points in their argument. That is, Cartwright does not mention a conditional when she claims that the fundamental laws cannot be applied to the objects in the real world but only mentions from the L. That is to say, fundamental laws are false if they are not qualified with a CP clause. CP clauses are required for fundamental laws to hold. Moreover, Elgin and Sober ignores Cartwright's view on models. Cartwright argues that fundamental laws with CP clause can be applied to the phenomena by means of models, since she affirms that a CP modifier makes the test of a law possible. Cartwright accepts the fundamental laws as a tool which is used in the derivations of the phenomenological laws. Fundamental laws cannot be singly applicable to the objects in the real world. The law stated in (1) is not a fundamental law which does not describe anything in the real world, but it is the fundamental law qualified with CP clause. In other words, the law $f = Gm_1m_2/r^2$ in its unconditional form cannot apply to the real objects. Moreover, Cartwright claims that both C and L are false but she does not claim that $C \rightarrow L$ is false.

The second objection is based upon how the contrapositive of a law can be applied to the objects in the real world. Elgin and Sober maintain that the conditional and its contra positive are applied to exactly the same thing.

[61] Cartwright, 1983, p. 57.

However, the existential closure of *C* as antecedent is empirically false whereas that of ~*C* may not be false because of its existential closure. In other words, the existential closures of *C* and ~*C* are not identical.

In Newton's law of gravity, we all know there are forces other than gravity at work that is ~ C. To find $f \neq Gm_1m_2/r^2$ (or ~*L*) implies the result 'there are forces other than gravity at work' (or ~*C*). By using inference rule *Modus Ponnens,* ~*C* is derived from the contrapositive ~*L*→ ~*C* and ~*L*. Heuristically, the entailment of ~*C* does not say anything about the nature of forces having influence on the phenomena. For, the existential closure of ~*C* involves infinitely many forces in the universe. We cannot determine how much these forces affect the phenomena. Scientists could never take all forces into consideration because of computational difficulty. For this reason, they will never formulate the law of gravity which describes the actual phenomena. That is to say, scientist will never capture empirically *L*, i.e., $f= Gm_1m_2/r^2$, because they cannot deal with all forces at work. As a result of this difficulty, they employ idealizations. The application of the contrapositive to the objects in the real world may be possible but not useful. That is, to find ~*C* reveals that ideal conditions which the theory involves are false, but this is not something new that we do not know. For example, when the generalization 'Smoking causes cancer' is qualified with a CP modifier 'Other things are equal', it becomes a CP law according to Cartwright. It contrapositive will be that 'if smoking does not cause cancer, then other things are not equal'. Somebody who smokes may not get cancer just because he /she may do something which reduces the possibility of (or prevent him from) getting cancer like proper nutrition, doing sports, etc. To 'find other things are not equal' does not articulate the conditions which are different.

Cartwright claims that the fundamental laws give very little information or nothing concerning the actual phenomena. For this reason, they are false. In order to be true, they must state the actual phenomena. This is Cartwright's facticity requirement which must be satisfied by theories in order to be true. Cartwright argues that idealized laws cannot be confirmed because they are true only in a model which is a simplification of the actual situations.

> She claims in *How the laws of physics lie* (1983) that considering the truth of the (fundamental) laws of physics will force anyone to admit that almost all of these laws are strictly false, i.e. 'lie', because they are valid only under certain circumstances or given certain conditions *that do not strictly hold in reality*. However, it is interesting to note that the implication… is (logically) true even if the conditions (the antecedent of the implication) are not satisfied.[62]

On the other hand, Cartwright is wrong in assuming that the fundamental laws are true only in highly idealized models and they can not be approximately true and confirmable. For, there is no contradiction in the claim that the fundamental laws are true in highly idealized model and also they are approximately true. Use of idealizations makes the theoretical claims approximately true in a possible world being closest to the actual world. For this reason, Cartwright's challenge can be overcome. The realist account should be developed with modifications in identifying empirical truth or falsity with factual truth or falsity, as I shall explain below.

As stated before, the real world is really too complex to deal with. The gap in similarity of reality and its representations given by sciences cannot be disregarded. For this reason, scientists employ idealizations to counterfactually understand how the phenomena would happen in the idealized world. The idealized world is close to the real world. If the ideal conditions are true, the idealized laws describe how the real world would be.

> Some specific world (or subset thereof) is counterfactually simplified in the antecedent of such counterfactuals by treating the world as if it were idealized in the prescribed manner, and, typically, from this conditional and some set of factual claims, some conclusion, can be drawn concerning the (more) real world behavior of the entities quantified over in the theoretical claim that occupies the consequent position in the conditional. This is due to the similarity between the idealized world in which the theoretical claim holds strictly true and the (more) real world in which it is false or undefined.[63]

[62] Ruttkamp, 2002, p. 120.
[63] Shaffer, 2001, p. 105.

The relation between science and the reality is based upon idealizations because of the complexity of the real world. Models make scientific knowledge possible because each model gives partial information concerning the furniture of the real world. I believe that the counterfactuals or models can be approximately true of this world if and only if it is true of the best world resembling the actual world in the relevant parameters. The possible world implied by idealizations must be similar to the actual world in terms of including relevant factors. That is, both the idealized world and the actual world must involve the essential parameters having influence on the phenomena.

Idealizations are the method of producing approximately true theories. There is a relation between idealizations and approximations. Laymon introduces an account for the confirmation of idealized laws. To construct his account does not require having any definition of approximate truth or the notion of a true theory being idealization free. He needs only the use of more realistic boundary conditions which produce more accurate predictions.

> [According to Laymon,] idealized theories are confirmed if they improve upon the degree of approximation of the predictions they produce when the ideal conditions are relaxed towards the actual (or the real) on some scale of realness. This is taken by Laymon to support realism in that the truth of our laws and theories (and so the realness of the objects posited in them) is the *best explanation* for their having the approximation improving property.[64]

When the scientists simplify the complexity of the real world to deal with, a gap between the ideal conditions and the phenomena is set. However, this gap would not imply that theories lack of truth value. Many laws involving idealized conditions are only approximately true. But, the truth of the laws does not depend upon how much idealizations approximate the law to the phenomena. In other word, scientific laws are approximately true in the possible worlds which are similar to the actual world. In my

[64] Liu, 1999, p. 239.

concluding chapter, I will try to explain the notion 'approximately true' in details.

Models are heuristically useful in suggesting new ways to look at the phenomena. Models provide us with a relation of analogy to the nature. When we say that there is an analogy between scientific theories and their models, we claim that they resemble each other in terms of a number of characters and also differentiate each other in terms of a number of characters. Models make the theory close to the reality in terms of certain aspects. By the analogy of the fall of a body on the surface of the earth, Newton explains the motion of the moon and then formulates his universal law of gravitation. From Newton's laws of motion and his law of gravity, Kepler's three laws can be mathematically derived. However, Kepler's laws may only explain the motions of the planets. For this reason, Kepler's laws can be accepted as an interpretation or a model of Newton's laws. Nevertheless, the theory consisting of Newton's laws of motion and his law of gravity has different models in different applications.

Methodologists of theoretical science points out that a model has an important role to gain predictive and explanatory control of the phenomena in question. To understand nature and role of models in science are important because it give some important clues to find a solution for problem of confirmation of scientific theories. There may be more than one model for a phenomenon. For example, the billiard ball model for gases is not similar to the behavior of gases in all respects. When we use billiard ball model for gases, we affirm that billiard balls are similar to molecules of gases in certain respects. In other words, we do not claim that billiard balls are similar to molecules of gases because of their color, for example, but assert that motion of billiard balls are similar to that of molecules. The relation of analogy refers to that there are similar properties that belong to molecules of gases and billiard balls. On the other hand, this relation does not exclude some properties of billiard balls which are not found in molecules. This model provides us with an observable similarity between motion of billiard balls and that of gas molecules. By using this model, we learn a lot about molecules, their behaviors and their interactions. But we all know molecules of gases are different from the billiard balls in many respects.

A model denotes a causally possible world which is similar to the actual world in terms of the parameters primarily influencing the phenomena. Models give the truth of theories but truth without universality. When we claim that Newton's theory is empirically true, we mean that there is at least one model in which the motions are similar to the actual ones in certain aspects.

The relation between models and reality is very important. To claim that models are realistic interpretations of the reality implies that models give an accurate description of the aspects of the phenomena modeled.

> To believe a theory is to believe that one of its models correctly represents the world. You can think of the models as representing the possible worlds allowed by the theory; one of these possible worlds is meant to be the real one. To believe the theory is to believe that exactly one of its models correctly represents the world.[65]

It is impossible that scientific theories always describe every detail of the phenomena. For example, Newton's laws do not explain the phenomenon of gravity but only describe its effects. However, fundamental laws involve different and also distinct aspects of the phenomena because of being so general. By constructing models, we interpret every distinct aspect of the phenomena within fundamental laws.

Cartwright affirms that models link fundamental laws and phenomenological laws and the reality. They are 'mediate' between theories and phenomena described by theories. Autonomy of models demonstrates diversity of models and their heuristic roles. Cartwright clearly states the nature of the relation between theories and models. Models are deduced from theories. Semantic account of theories affirms that theories are just collections or sets of models. "The route from the theory to reality is from theory to model, and then from model to phenomenological law. The

[65] Van Fraassen, 1980, p. 47.

phenomenological laws are indeed true of the objects in reality- or might be; but the fundamental laws are true only of objects in the model."[66] She claims that phenomenological laws can be interpreted by models and appropriate ceteris paribus conditions. Because, the phenomenological laws are explained by the fundamental laws being qualified with appropriate ceteris paribus conditions and models.

Scientific theories are abstract representations of the actual phenomena because of the complexity of the real world. That is, theories are isolated from negligible factors and by doing this, the models of the phenomena are constructed. If these models are sufficiently isomorphic to the actual phenomena, then the empirical truth of theories would be possible.

Use of idealizations provides scientific theories with a comprehensive characterization of the behavior of phenomena. Theory can predict what would happen if the ideal conditions are not satisfied. The transition from the real world to models is fundamentally made by the counterfactuals because we characterize what the phenomena would be under ideal conditions. That is to say, the relation between the actual phenomena and their models is based upon the condition that models are counterfactual reproduction of the phenomena. The essential feature of empirically true laws is that they have a counterfactual relationship with their phenomena.

In fact, models give partial information about the real world. Although they are simplifications, idealized conditions provide empirical information how objects behave in the real world.

> … in the context of physical sciences idealization is fundamentally a special kind of relation between worlds, between an idealization and a more real model. What is crucial in the physical sciences is that there is some important sense in which the idealization is physically informative with respect to the more real world… But as simplification is one of the main features of idealization simpliciter, worlds that are related as idealizations are at best partially isomorphic and so are at best partially informative with respect to less idealized worlds. As we have seen,

[66] Cartwright, 1983, p. 4.

idealizations leave out features of the worlds they represent, or we treat elements of the systems as structurally different than they really are.[67]

Scientific laws refer to isolated empirical generalizations. The confirmation of scientific theories can be done by means of highly controlled experiments in which only essential parameters are present. As in the constructions of models, in experiments certain factors are kept constant. Such an action provides us with examination of a specific aspect of the real phenomena. Then, an experiment is designed to observe the deviations when the secondary factors have influence on the phenomena. That is, scientific laws are qualified with appropriate ceteris paribus conditions, and then the laws are tested. We cannot test the theory because it has many aspects or different interpretations. We only test a model as an interpretation of the theory.

When discussing the acceptability of idealizations, Galileo suggests making two experiments for his law of falling bodies. He formulates his law as follows: "Given any *x* and *y,* if *x* and *y* move in a medium devoid of resistance, then the speed with which *x* falls equals the speed with which *y* falls."[68] In order to decide on the acceptability of the idealization, scientists should observe what happens in the rarest and least resistant media and compare the results with that of what happens in denser and more resistant media. Galileo proposed such a suggestion because he was aware that there is no media devoid of resistance.

Models provide us with a possibility to counterfactually test the theories. For example, assume 'if the planets were mass points, then their orbits would be such and such'. This counterfactual is true. Empirically, we all know that the planets are not mass points, but we know that their orbits are similar to that of mass points.

Laymon talks about the confirmability of theoretical laws involving idealized conditions. But their confirmation cannot be in virtue of predictions which are entailed from the theoretical laws. He claims that

[67] Shaffer, 2000, p. 31.
[68] Barr, 1974, p. 59.

explanations and predictions are derivations which require the use of idealization.

> Realists (in Laymon's terms) explain the practice of looking for increasingly more accurate and less idealized initial or boundary conditions in terms of the fact that idealizations are characteristically false and that they therefore have a distorting influence on derivations of predictions in such a way that, even if the fundamental laws are true, they will be able to produce only distorted or false predictions. In this sense, Laymon (ibid., p. 359) claims, realists see the aim of science as the construction of more accurate models because they believe that our theories, if true, will produce more and more accurate predictions when applied to these more and more accurate models.[69]

According to Laymon, elementary truth condition asserts that if a theory or a set of laws is true, then it must make at least one true prediction. The derivations producing the predictions must be sound and in order to be sound, they must be idealization free.

> But, since such soundly derived predictions are at best only possible in principle, it follows that the truth condition will be satisfied only in some *countefactual* sense. So, for example, to achieve confirmation it must be somehow determined that, if we had the requisite computational capabilities, then the law candidates when combined with true (and sufficiently accurate but currently unknown) descriptions of initial or boundary conditions would yield correct results.[70]

In order to defend the scientific realism, we define the aim of science as the constructions of more accurate models. Our scientific laws will produce more accurate prediction when they are applied to those models. Laymon mentions the piecemeal improvability of idealizations and approximations as the essential feature of actual science. That is, any improvement in idealizations and approximations brings about improvement in predictions. He contends that fundamental laws are confirmed when improved boundary conditions yield more accurate predictions. In this way, Cartwright's challenge to scientific realism is answered.

Scientific theories can be confirmed by means of models. Scientific theories consist of idealized laws or idealizations as constructing possible worlds or models of physical systems. Semantics of possible worlds provides us with the relation between reality and science. The real world is

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[69] Ruttkamp, 2002, p. 126.
[70] Laymon, 1989, p. 357.

transformed into a possible world by simplifying certain properties. The possible worlds contain partial information about the real world.

When we claim that there is analogy between a model and the phenomena, we affirm that models resemble the phenomena in terms of quantitative aspects. The assertion of analogies between models and reality implies the correspondence of between numerical consequences of models and quantitative properties of the objects. We can indirectly test the scientific theories by using models. The models are constructed from the relevant factors contained by the real world.

Models provide indirectly their confirmation of the scientific theories which are approximately true. As stated before, each model describes certain aspects of the phenomena and therefore it demonstrates the truth of the aspects of the phenomena modeled. "…the aim of science should be to construct more accurate models where the anticipation is that our theories, if true, will produce more accurate predictions when applied to these more accurate models."[71] Laymon argues that using less idealized initial and boundary conditions in theory results in more accurate predictions. Scientific theories are partially confirmed by their models. In other words, every model demonstrates that theory is true in terms of one aspect which the model denotes.

[71] Laymon, 1989, p. 359.

CHAPTER 5
CONCLUSION

I tried to explain the concept of 'idealization' and its connotations. Scientists commonly use idealizations because of our limited capacity in computation and the complexity of the actual world. The methodology of modern science requires ignoring some parameters and idealizing certain conditions for a phenomenon. It limits our attention in selection of quantitative factors. Both Descartes and Galileo who redound to growth of modern science use idealizations in their theories. As I proposed in Chapter 3, Descartes employs an idealization in order to calculate the quantity of motion in the universe. His seven rules for calculating the quantity of motion depend on the ideal condition '*there are only two bodies in contact in the plenum*' although all bodies in the universe are in interaction.

Because use of idealizations is unavoidable, we have to solve problems arising from use of idealizations. It is necessary for science since the complexity of the real world paralyses our mental capacities. Idealization is transformation of a discovered structure into theoretical entities. The structure of reality is simplified by assuming zero values for certain conditions. That is, our theories represent the reality with idealized concepts. Anti-Realists attack scientific realism with an argument based on presence of idealizations. They contend that if theoretical laws hold true only under idealized models, where they are not even approximately true, then they fail to describe the reality.

Classical realism must be modified in its claim that theories are committed to the existence of unobservable entities and idealized conditions. Use of idealizations does not require that idealizing concepts or entities do exist. That is, we can employ idealizations without being committed to their existence. Scientific theories cannot be regarded as lacking truth values just because they work with idealizations.

Empirical truth is different from truth in idealizations, because the former is related to the real world and the latter is related to a possible world, or an idealized world. Scientific theories are approximately true in possible worlds. I am not saying that scientific statements are approximately true in terms of measurement in the real world. In other words, I do not refer to a metric approximation like ‘x is 2 meters long’ although its actual value is 2.1 meters. Idealized statements are literally false but they are close to being ‘exactly true’ of empirical phenomena.

As stated before, idealized worlds are possible worlds. A scientific law is literally false in the real world if it involves an ideal condition; but it can be true in a possible world. If a law is true in a possible world, then it is approximately true in the real world. In other words, a law is approximately true if the model or possible worlds in which it is true is similar to the actual world. There will be no contradiction in the claim that a law is an idealized law and it is approximately true. General plausibility of scientific theories can be secured by a hierarchy of possible worlds ordered in terms of similarity to the real world. Scientific theories can be indirectly confirmed by models denoting different aspects of the phenomena. A model works in a possible world. That is, construction of a model requires idealized parameters which are satisfied only in the possible world. In other words, theoretical laws hold true only under idealized conditions while they are approximately true in real conditions.

Models can be used to decide which approximation is plausible, because there are many possible approximations for a phenomenon. Realistic models, which are constructed by the conditions close to the real world, will give confirmation for the theories. That is, to be realistic for a model requires that ideal conditions in the theory must be satisfied in the model and the model must be close to the real world. If a model is constructed by more approximated conditions, the idealized law is approximated. In other words, when the ideal conditions are made concrete in the model, the theory will be approximately true. For example, when a point mass is used in a law, we ignore dimension and shape of an object. In order to construct a model of the law, we replace a point mass with a body which is as small as possible. If the body has a sufficiently small dimension, then the law gives sufficient approximation. That is to say, this law is approximately true in the possible worlds in which the object has different dimensions. Use of different sizes produces different approximation in degree.

Some idealizations can be realized in the experiments. Experiments aim to realize the ideal conditions assumed in the antecedent of laws. In other words, in an experiment, if all idealized conditions of a law were satisfied, then we get an idealized result. For example, for the law of free fall ($S=\frac{1}{2}gt^2$), an idealized result is derived from the condition which the medium has no resistant. If the experiment is repeated in mediums which have different amounts of resistance, i.e., ideal conditions are realized only approximately, then we get some results approximated to the actual result. That is to say, the law is more approximately true in the possible world in which the resistance of the medium is close to its actual value. If a model captures a regularity by means of certain conditions which are similar to the conditions in the actual world, this model is more realistic than other models of law. Idealizations can be transformed into approximations by constructing models.

In order to defend scientific realism, like Laymon's understanding of the piecemeal improvability of idealizations and approximations, the aim of science can be defined as construction of more accurate model. Newtonian theory is utilized in physics to give explanations even though it has been falsified, since it is approximately true. In other words, it approximately handles the behaviors of many bodies in the real world. Although idealized laws are only approximately true, they can be used to provide explanations. Problems of confirmation and explanation can be solved by approximation.

As stated before, scientific laws are conditional statements and if antecedents of scientific laws are approximated, then their consequents are also approximated. That is to say, if we get more accurate models satisfying initial conditions, then we get more confirmation for theories and more approximated explanation for the phenomena. How we can decide one of the actual cases approximating idealized theories is problematic, because idealized theories can be approximated by many actual cases. To solve this problem, we can use semantics of possible worlds or models. That is, we prefer to choose the model which is most similar to the real world.

As a conclusion, the semantics of possible worlds can be used in the defense of scientific realism. Scientific theories are true of the objects in possible worlds which are similar to the real world. Presence of idealizations in science does not endanger confirmation of scientific theories and scientific explanation.

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