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**BLAISE PASCAL: PHILOSOPHER OF SCIENCE**

**JOSEPH WILLIAM**

**Master of Arts thesis presented to the Department of Philosophy  
in the Faculty of Arts of the University of Ottawa**

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## BLAISE PASCAL: PHILOSOPHER OF SCIENCE

### Introduction

During and immediately following his lifetime Blaise Pascal was recognized as a philosopher, theologian, mathematician, logician, inventor and scientist. As a mathematician and logician, Pascal addressed a variety of issues within geometry, probability theory and number theory. His studies on both the problem of the cycloid and of conic sections were particularly significant to the growth of seventeenth century mathematics. As an inventor, Pascal conceived and helped to construct a number of machines and instruments of which the arithmetical machine, a predecessor to the modern calculator, was among his most famous inventions. As a scientist, Pascal conducted brilliant and decisive experiments to establish both the existence of the vacuum and the existence of atmospheric pressure as an unobservable force in nature. It was the formulation and execution of such innovative experiments that marked the significance of Pascal's scientific studies, both among his contemporaries and in wider scientific circles. Indeed, Pascal's scientific studies established Paris as a leading centre of scientific research within Europe in the latter half of the seventeenth century.

This commendatory portrayal of Pascal's scientific studies has diminished over time. In recent times, the contributions of Pascal to the growth of modern science have been well documented, although not well understood among contemporary philosophers of science. Although there are a variety of excellent studies on the scientific

contributions of Pascal, limited systematic or critical study has been undertaken which provides philosophical analyses of his scientific works. The scarcity of critical studies has resulted, I believe, in misconception of both the philosophical aspects of Pascal's own scientific works and of his approach to philosophical issues pertaining to science.

In this thesis, I will provide the historical context to Pascal's innovations in science, set out Pascal's views on the philosophy and nature of science and then situate them in contemporary discussion of the philosophy of science. I will draw out the importance of Pascal's innovations and show how their value has been traditionally under-estimated for their philosophical insight. Indeed, I will demonstrate that a contemporary critique of the methodological approach of Pascal to scientific inquiry has been completely misconceived. Furthermore, I will demonstrate that a contemporary sketch of the approach of Pascal to the validation of scientific knowledge is also misconceived, while his approach to the pattern of development of scientific knowledge has yet to be addressed. With this in mind, I shall try to provide the framework from which to understand the fundamental contributions of Pascal to the philosophy of science. In doing so, I hope to contribute to the restitution of Pascal as an important contributor to modern scientific thought.

## CHAPTER ONE

### 1. Historical Context

In this section I want to set out in some detail the historical context to the scientific studies of Pascal. The contributions of Pascal to the philosophy of science are contained in several short treatises. The treatises are concerned with the formulation and defence of his views both on the nature of the vacuum and on his approach to scientific inquiry. They were intended as reflections on, or to be part of, a larger treatise that was never completed by Pascal.

The first of such treatises, entitled *Les Experiences Nouvelles Touchant Le Vide*, was published in the fall of 1647 and was intended as a preliminary report on experiments conducted earlier in the year. We now recognize these experiments as a series of pilot studies on the vacuum. In the physical sciences, the undertaking of pilot studies represent the initial testing of hypotheses which have been formulated to explain phenomena and processes under scientific investigation. Pascal's experiments were based on Torricelli's experiment on the vacuum conducted sometime in 1644. Torricelli had constructed a baroscope in order to observe the creation of a vacuum. He had not however, conducted more elaborate experiments to arrive at physical proof for his hypothesis that atmospheric weight was related to the creation of a vacuum. Pascal's pilot studies, on the other hand, initially served to test hypotheses arising from the accepted or received view on the vacuum that was defended by various influential

scholars, namely that the vacuum was an impossibility in nature.

Not all scholars however, were pleased with the publication of the pilot studies. Pere Etienne Noel, teacher and friend of Rene Descartes, correctly interpreted the results of the pilot studies as an attack on both Aristotelian philosophy and Cartesian physics, since each of these views denied the existence of the vacuum. Noel composed a semi-public letter, stating his disagreement with Pascal's views by asserting that the vacuum was actually filled with a special matter posited as *purified air*. On this view, the alleged observation of a genuine vacuum was merely the observation of an apparent vacuum. Furthermore, on appeal to Aristotelian authority, Noel asserted that the term *empty* was synonymous with *nothingness*. On this view the vacuum, as an empty space, was an impossibility since the existence of nothingness was an impossibility in the world.

These views implied that a vacuum was not a natural phenomenon and that Nature, as an animated or emotional creature, either prevented or, on a weaker view, actively resisted the creation of a vacuum. Such views on the vacuum were well accepted among scholars, since they carried the stamp of both Aristotelian and Cartesian authority although, as we shall see, Descartes rejected the existence of the vacuum for different reasons than classically-minded scholars. Thus, the denial of the existence of the vacuum, that Pascal termed the "received" view, was almost universally held among scholars, despite the fact that, historically, insufficient

physical evidence had been provided in its defence.

Pascal answered with his own semi-public letter, *Lettre A Pere Noel*, in the fall of 1647. In it we find his critique of both the Aristotelian and more particularly of the Cartesian tradition of scientific inquiry. We also find in this letter his statement on the importance of experimentation in the physical sciences and a statement of some kind of falsificationism among other things.

Pascal believed that appeal to the authority of either of these two respective traditions was not sufficient to arrive at an understanding of the world, at least not without further appeal to experimentation from which to evaluate hypotheses in question. He wrote, "...we do not base anything on the authorities: when we cite authors, we cite their demonstrations, and not their names; we have no regard for them other than as historical data;..."<sup>1</sup> According to Pascal, both scientific methodology and scientific hypotheses were based on reason alone in these two respective traditions. More positively, Pascal believed that three types of scientific hypothesis could be posited from which to acquire an understanding of the world. The first type of hypothesis was one which could be verified by virtue of any inconsistency or contradiction derived from its denial. The second type of hypothesis was one which could be falsified by virtue of any inconsistency or contradiction derived from its affirmation. The third type, on the other hand, remained doubtful on the appeal to reason alone, as an inconsistency or contradiction could be derived neither from its affirmation nor from its denial.

Of the above types of hypothesis, it was the third that required testing by phenomena and processes in the world. On Pascal's view, the use of both reason and the senses were required to assess hypotheses of the third type. Furthermore, it was the appeal to scientific practice, in particular, as the appeal to experimental methodology based on both reason and the senses, that would determine the plausibility of hypotheses of the third type. On this view, it was not enough for verification that phenomena were said to be in accordance with hypotheses by appeal to reason alone, or by appeal to the authority of influential scholars, without further appeal to scientific practice. Thus, with this letter, Pascal outlined his preliminary statement on the importance of scientific practice in relation to evidential reasoning in the physical sciences.

Acknowledging Pascal's critique of his first letter, Noel composed a second letter that contained an alternative formulation of the received view. Appealing to the authority of Descartes in particular, Noel asserted that *subtle air* filled the apparent vacuum. On this hypothesis, the special matter entered the laboratory apparatuses through the pores of the various tubes, thereby filling the empty space. Furthermore, Noel relied heavily on religious authority stating that God filled the apparent vacuum if no other matter could be detected. Pascal did not reply directly to Noel since for him the debate had clearly gone beyond the confines of physical science.

Pascal addressed his reply of the second letter of Noel to a

family friend Le Pailleur. This was also intended as a semi-public letter to indicate the poverty of Noel's latest views on the vacuum. Later, in a treatise concerned with the vacuum, Noel provided honourable mention of Pascal's scientific activities. However, because of the resistance displayed by proponents of the received view, Pascal went on to formulate the methodology for an experiment that would provide conclusive proof of the implausibility of the received view. This decisive experiment would also provide initial proof for his own research hypotheses on the vacuum.

Following the pilot studies and the ingenious experiment of the vacuum-within-a-vacuum, Pascal composed a letter, in November 1647, stating his intentions to his brother-in-law Florin Perier. Perier was to conduct the experiment which would provide the conclusive proof on Pascal's behalf. Of the proposed decisive experiment, Pascal wrote,

"I have conceived of one which alone will be able to suffice to give us the illumination we seek, if it can be carried out carefully. It is to perform the ordinary experiment of the vacuum several times a day, in the same tube with the same quicksilver, now at the bottom and now at the top of a mountain, with a height of at least five or six hundred fathoms, in order to test if the height of the quicksilver suspended in the tube will be found to be similar or different in

these two situations. You already see without doubt that this experiment is decisive for the question, and that, if it happens that the height of the quicksilver be less at the top than at the bottom of the mountain (as I have reason to believe, although all those who have thought about this matter are opposed to this view), it will necessarily follow that the weight and pressure of the air is the only cause of this suspension of quicksilver, and not the abhorrence of a vacuum, since it is quite certain that there is much more air that weighs down at the foot of the mountain than at its summit: whereas it cannot be said that nature abhors a vacuum at the foot of the mountain more than on its summit."<sup>2</sup>

The formulation and execution of the Great Experiment of the Equilibrium of Fluids aroused even greater scientific interest than the earlier pilot studies. It was to be the first controlled experiment conducted in a natural setting and was regarded as a decisive experiment on the vacuum. The pamphlet, containing the letter sent to Perier and an account of the Great Experiment, entitled *Recit De La Grande Experience De L'Equilibre Des Liqueurs* was published sometime in 1648, and was the last physical treatise published in Pascal's lifetime.

Pascal left three other physical treatises which bear his views on both the nature of the vacuum and of his approach to

scientific inquiry. The *Preface Sur Le Traite Du Vide* was also written in the fall of 1647. This treatise contains a more precise account of the views of Pascal on scientific methodology. Pascal believed that the methodology proper for the physical sciences was and should be distinct from the methodology proper to other disciplines, including those of the social sciences. He believed that the appeal to experimental methodology was the proper and only reliable means to reach an understanding of the nature of the physical world. On the other hand, the appeal to memory, authority and reasoning was proper for disciplines such as history, linguistics, geography, jurisprudence and theology which, in Pascal's time, were regarded as human or non-physical sciences. In addition, this preface contained Pascal's views on verification, problem of induction and scientific progress among other things.

The two other treatises, entitled *Traite De L'Equilibre Des Liqueurs* and *Traite De La Pesanteur De La Masse De L'Air*, were drafted in 1648 and completed in 1651, although not published until 1663, a year after Pascal's death. In the first treatise, Pascal formulated specific scientific propositions about the process of fluids held in equilibrium within various experimental apparatuses. Firstly, Pascal showed that a sustained force, posited as the pressure of the surrounding air, was necessary to prevent liquids from flowing out of the aperture of a tube. Secondly, as a means of measurement, it was shown that such a force was equal to the weight of the liquid contained in a column of the height of the liquid, given that the column extended to the cross-section of the

aperture of the tube. Thirdly, as a result, Pascal proposed that liquids weigh according to their height, by the above formula, and not their volume. It thus followed that a liquid with a small column and aperture could hold, in equilibrium, liquids with a larger column and aperture. Fourthly, and by extension, Pascal's law, as it has come to be known, correctly asserted that the force or pressure exerted on the surface of a liquid was conveyed equally and undiminished to all other parts of that particular liquid's surface.

In the second treatise, Pascal established the relation between both the equilibrium of fluids and the creation of a vacuum to the behaviour of the surrounding atmosphere. Pascal was the first to demonstrate that air was compressible, although various scholars before him had indicated this much. According to Pascal, the elasticity of air was comparable to that of liquids, save for the fact that air was compressible in a way that liquids were not. Concerning the equilibrium of fluids in particular, he asserted that the pressure of air was responsible for the suspension of fluids within the column of a baroscope. The limited pressure of air held liquids of varying weight and density in suspension to varying heights within apparatuses under varying experimental conditions. As a result of this process, a vacuum or empty space was created between the liquids in suspension and the surface of the experimental apparatuses.

Pascal's discovery of the pressure of air was generated by reflection on experimentation and by analogy. Referring to a bulk

of wool, an analogy used by Descartes and Torricelli, although they limited the analogy to the weight of air alone, Pascal asserted that the bottom layers were compressed by the pressure exerted from both the top and middle layers. By analogy he wrote, "This would prove that air has weight; that the mass of the air is heavy; that its weight presses all the bodies it contains; that its pressure is greater on the lowlands than on the highlands;..."<sup>3</sup> It was the pressure from both the top and middle layers of air, exerted on the lower layers that provide for an unobservable force in the atmosphere. On this analogy, Pascal provided a clear expression of the behaviour of atmospheric pressure and its relation to both the creation of a vacuum and the equilibrium of fluids as natural phenomena and processes in the world. In these treatises then, Pascal attempted to formulate and answer views on scientific inquiry.

In summary of what can be found in his scientific works, the following important features are to be recognized:

(1) The notion of a pilot study for the physical sciences, within the context of seventeenth century, originates with Pascal. As mentioned, a pilot study is a small scale study undertaken to determine initially which hypotheses about phenomena and processes under investigation are plausible, if any, and which hypotheses are not plausible.

(2) The notion of a "received" view about phenomena and processes resembles the modern formulation of the null hypothesis in experimental science. The received view or the null hypothesis is

that hypothesis or set of hypotheses that is endorsed among a community of scholars, although challenged by other scholars.

(3) Three kinds of hypotheses can be posited, although there is only one kind of hypotheses relevant to the physical sciences. This kind of hypothesis must be open to scientific testing only, in order to determine its affirmation or denial.

(4) Experimentation, as a means of investigating phenomena and processes in the world, is given epistemic priority over and above the appeal to reasoning alone.

(5) A distinction is made between methodology suitable for discovering evidential relations in the physical sciences and methodology suitable for discovering evidential relations in the non-physical or human sciences.

## **2.The Modern View Of The Scientific Works Of Pascal**

I turn now from the historical context to a consideration of the orthodoxy of the contributions of Pascal to the physical sciences. Modern scholars of science have recognized the contributions of Pascal to the history of the physical sciences. Indeed, Pascal is recognized for having proved the existence of the vacuum. He is also recognized for establishing evidence that atmospheric pressure is related to both the equilibrium of fluids and the creation of a vacuum. Furthermore, he is recognized for establishing the practical application of the barometer as a measuring instrument. Pascal demonstrated that the barometer could be used to measure varying altitudes above sea level at different locations throughout the world, as well as aiding in the prediction

of impending weather conditions.

Despite such contributions, it is the orthodox view to argue that Pascal ranks lower in the hierarchy of important contributors to natural science. That is, scholars of science usually assert that Pascal does not rank with such names as Copernicus, Galileo and Newton in the history of physical science. In defence of this view, one could cite the fact that Pascal did not complete the extensive and comprehensive work that he had promised or intended to complete on the physical sciences. The *Treatise On The Vacuum* was never completed and his *Treatise On Mechanics* has been lost. As such, Pascal did not provide a larger theoretical perspective about phenomena and processes in the world as Copernicus, Galileo and Newton respectively had done. Pascal's failure, however, to complete the *Treatise On The Vacuum* is directly attributable to both his physical health and to the significance of his second religious conversion. Nevertheless, what we have, I think, is enough to reconstruct his important views on science.

Pascal suffered from a variety of illnesses throughout his life of thirty-nine years, of which mercury poisoning is among the most likely contributing factors to his death. It is well known that Pascal conducted experiments while in direct contact with the toxic mercury. Whatever the cause of death, Pascal suffered from acute illnesses throughout later stages of his life. Such illnesses had left Pascal bedridden for prolonged periods of time, thereby interrupting any work in progress. Furthermore, on November 23, 1654 Pascal underwent the second of two religious conversions. This

second conversion effectively concluded Pascal's brief but intense exploration into the physical sciences although he continued, for a short time, his work in mathematics.

On conversion, he became deeply involved in moral and religious issues that led to the publications of the *Lettres Provinciales* and, following his death, of the *Pensees* which is widely regarded as his unfinished, literary masterpiece. Indeed, most of Pascal's literary and non-literary works were left in fragmentary form, although he intended to complete these works. His preoccupation, first with mathematics and then with science and finally with philosophical and religious issues, made continuous scholarly development in any one area of inquiry difficult. On foregoing his scientific activities and on establishing his literary reputation, Pascal's favourable characterization as a noted scientist has faded with time. Summarizing the orthodox view, it somewhat plausible to argue that in the sense of not providing a larger theoretical perspective, Pascal is not as important as Copernicus, Galileo and Newton in the history of the physical sciences.

### **3. Contemporary Views Of The Scientific Works Of Pascal**

More recently, the significance of the works of Pascal have been further downgraded from the modern view. I will argue that recent literature on the contributions of Pascal, scarce as it is, has failed in its understanding and presentation of the approach of Pascal to scientific inquiry. More specifically, I will show that contemporary philosophers of science who have discussed his

works, have misconstrued the approach of Pascal to both the formulation of scientific methodology and to his approach to the validation of scientific knowledge.

For example, in one influential text entitled *Science As Social Knowledge*, Helen Longino dismisses the significance of the contributions of Pascal to the history and philosophy of science in one short passage. Discussing the nature of evidential relations in scientific practice, Longino writes, "One solution would be to restrict the hypothesis and theories proposable in scientific contexts to propositions expressing only relationships among observables. This was the course taken by Blaise Pascal in his work on aero- and hydrostatics. It is also one of the reasons his name does not appear in short lists of the seventeenth century founders of modern science. Pascal urged and followed a rigorously empiricist program, which effectively prevented him from distinguishing atmospheric weight from atmospheric pressure."<sup>4</sup> The third chapter of Longino's text is entitled 'Evidence and Hypothesis'. In it we find the above criticism of Pascal under the sub-title 'The Positivist Tradition'.

Longino contends that the positivist tradition, and therefore Pascal, had failed in the attempt to provide adequate methodology for establishing evidential relations in scientific inquiry. More specifically, her critique of positivism is (1) that scientific knowledge is the only valid knowledge and (2) that observable facts are the only possible objects of knowledge. Her claim is that this was also characteristic of Pascal's experimental methodology.

Reconstructing Longino's critique we can create the following argument. (1) Pascal limited the relation between evidence and hypotheses to observables among phenomena under study. (2) Such methodology for evidential relations is consistent with a rigorous empiricist approach characteristic of the positivist tradition. (3) This approach prevented Pascal from distinguishing atmospheric weight from atmospheric pressure as an unobservable force in nature. (4) Pascal's failure to make such a distinction prevented him from providing fundamental contributions both to the history and philosophy of science. On Longino's reading, his science suffers from failing to distinguish between atmospheric weight and pressure. His philosophy of science suffers from being too rigorously empiricist in the positivist tradition. Longino's critique is one contemporary view about Pascal which I shall be addressing. There are other views.

Another recent text, entitled *Pascal Selections* by Richard Popkin, provides a translation of the main treatises of the scientific and non-scientific works of Pascal. Popkin, in the introduction, asserts that the approach of Pascal to the validation of scientific knowledge bears close resemblance to the approach of Sir Karl Popper to the validation of scientific knowledge. That is, he asserts that the approach of Pascal was based on the "principle of falsification", as formulated in a contemporary perspective by Popper.

Referring to a passage in the *Lettre A Pere Noel*, Popkin correctly identifies the following statement about the appraisal

of hypotheses as some version of the principle of falsification. In this letter Pascal wrote, "...in order to make it the case that a hypothesis is evident, it does not suffice that phenomena follow from it, instead, if something contrary to a single one of the phenomena follows from it, that suffices to establish its falsity."<sup>5</sup> This statement of the principle of falsification bears some resemblance to Popper's brand of falsification. However, the contemporary philosopher of science Imre Lakatos, argued, correctly I think, that the approach of Popper to falsification has been marked by three distinct stages of development. When I proceed to an analysis of the scientific works of Pascal, I will try to determine which stage of development Popkin intends to identify with the approach of Pascal to the validation of scientific knowledge.

Given the critical remarks of Longino and Popkin, it appears to me that there must be an inconsistency in identifying or in interpreting the approach of Pascal to scientific inquiry. For, on the one hand, we are told that the approach of Pascal to the validation of scientific knowledge resembles Popper's brand of falsification while, on the other, Pascal is labelled by Longino as too rigorous an empiricist in the positivist tradition. It is not at all clear to me that such claims are compatible or consistent. These are contrasting claims about the approach of Pascal to the validation of scientific knowledge and to scientific methodology in particular. That is, no philosopher of science has yet accused Popper of being too rigorous an empiricist. Similarly,

it is questionable whether Pascal was too rigorous an empiricist if, in fact, his approach to the validation of knowledge bears resemblance to Popper's brand of falsification as Popkin suggests. One or both of these views must be mistaken.

In order to settle the issue, as to whether Pascal was one or the other or neither, an extensive formulation of the approach of Pascal to the philosophy of science is required. Such a step suggests itself because the formulation of both of a scientific methodology and of a method for validating scientific knowledge are issues pertaining to the philosophy of science and issues which Pascal was one of the first to formulate views on. Thus, by determining the approach of Pascal we may dispel current misconceptions while showing, at the same time, the significance of the contributions of Pascal to the philosophy of science.

## CHAPTER TWO

### 4. Two Alternative Approaches To Philosophy Of Science

In this section I will try to develop the framework for discussing and evaluating approaches to the philosophy of science and link these to the scientific works of Pascal in order to evaluate the respective claims of Longino and Popkin. An approach to the philosophy of science may be understood as part of the background knowledge or framework from which to embark upon discussion or debate concerning a variety of philosophical issues, including a philosopher's particular approach. Unfortunately, if the framework is misconceived, the ensuing discussion or debate may be flawed from the outset. Indeed, the failure to account for the elements that characterize a philosopher's method of validating scientific knowledge, as distinguished from the elements that characterize a philosopher's approach to formulating reliable experimental methodology may result in fruitless philosophical discussion. I think this is the case for both Longino and Popkin's respective discussions of the scientific approach of Pascal.

The importance of formulating a given approach to the philosophy of science should be apparent and something less than controversial. The need to formulate the approach of Pascal is even more pressing, given what I believe to be current misconceptions of the approach of Pascal to scientific inquiry. In order to develop the approach of Pascal however, we need define more clearly what characterizes an approach within the philosophy of science. To this end, Ernan McMullin in an essay entitled *Alternative*

*Approaches To The Philosophy Of Science* provides what I think is a basic formulation of diverse elements that characterize alternative approaches.

On McMullin's view, philosophy of science may be understood as a second order discipline that is concerned with the world only on reflection and analyses of the various sciences concerned with investigating phenomena and processes in the world. For McMullin, there are at least two fundamentally different approaches to critical reflection on the nature of science or scientific knowledge. The first is an *external approach* to the philosophy of science, while the second is an *internal approach* to the philosophy of science. I will simply adopt his view.

The external approach is best characterized by the normative and ideal formulation of what science and its method should be like, independent of how science actually proceeds or has proceeded in the past. On this view, it is the appeal to a broader context that lies outside or beyond the more specific context of scientific practice itself that establishes what the method of science should be like. The broader context, in turn, is generally formulated on the basis of either a metaphysical or logical foundation or some combination thereof. A metaphysical foundation, for example, may give rise to a general theory of knowledge, as was the case for Descartes in formulating his *Discours Sur La Methode*. Indeed, as an illustration, I will show that the approach of Descartes on the foundation of scientific knowledge was essentially characterized by external elements. This will serve as a contrast to the

alternative approach which I take to be the approach of Pascal. The views of Pascal on the foundation of scientific knowledge are a departure in the seventeenth century from this widely accepted external approach of Descartes.

The alternative internal approach is best illustrated by contrast with the external counterpart. This contrast is illustrated by the direct emphasis paid to the development of scientific practice, if only in a general way. Such an approach takes into account the internal, descriptive and methodological procedures of empirical science. As internal, this approach may be concerned with the building of apparatuses or the formulation of units of measurement to determine the relation between evidence and hypotheses in experimentation. As such, an internal approach is concerned with the various influences and factors that affect or determine the outcome of experimentation. While an internal approach may still be normative, it is only from a specific critique of how scientific practice proceeds or has proceeded in the past.

#### **5. The External Approach**

Broadly construed, the approach of Descartes to the foundation of scientific knowledge arose with his formulation of the Tree of Philosophy or Tree of Knowledge. By analogy to the growth of a tree, Descartes asserted that metaphysics was the root of the tree while physics represented the trunk of the tree. By extension, the various branches of science grew out from the trunk of physics. As such, metaphysics was the necessary foundation of scientific

knowledge, in that it represented a first philosophy concerned with first causes and/or first principles from which all other knowledge and inquiry must grow. On such methodology, the pursuit of certain or absolute knowledge could only be attained from metaphysical truths and principles that were logically prior to anything else. It was logically prior to the acquisition of metaphysical truths and principles preceded acquisition of truths arising from other disciplines. Thus, metaphysical inquiry did not take into account the truths or possible truths arising from scientific inquiry, although scientific inquiry necessarily took into account truths or principles arising from metaphysics.

Given this metaphysical foundation, Descartes proposed that the world could be known through the concepts of extension and movement respectively. Descartes believed that these two concepts were the only clear and distinct primary qualities of physical matter. He asserted that geometry was the science of extension, while mechanics was the science of movement. The use of these concepts provided Descartes with the means of deducing physical processes and phenomena from the first principles of metaphysics. That is, the science of the world reduced to geometry and mechanics, although its necessary foundation arose from the a priori concepts of extension and movement. On this view, the sense of physics arising from its foundation was not that of modern mathematics breaking away from ancient metaphysics; rather, mathematics progressed from metaphysics in a linear fashion.

The metaphysical and a priori foundation enabled Descartes to

formulate the meaning and definition of such physical concepts as body, movement, form, space and time independently of the appeal to experimentation or physical inquiry. In this way, physical inquiry took into account the proposed truths, definitions and meanings of concepts arising from metaphysical inquiry. Thus, while the physical sciences progressed in a linear fashion as extensions of a priori truths, metaphysics remained fixed and absolute once basic truths and principles had been discovered.

One obvious implication for Cartesian methodology, based on the above account, is that if deductive inference is understood in the strict sense, then the appeal to experimentation is not required in the physical sciences. Descartes asserted that there were various ways to deduce physical processes and phenomena from established first principles. Since, however, all paths of deductive inference are equally valid the appeal to experimentation is futile in the physical sciences. It is something less than controversial to assert that much of Cartesian physics is now regarded as false. Indeed, for Descartes, the mechanistic view of the universe was one, infinite, three dimensional, extended and continuous body, for which matter was infinitely divisible. On this view, there could be no vacuum or empty space within the world according to Cartesian physics. It is to Pascal's merit, I will show, that the view of Descartes on the nature of the vacuum was first proved false on appeal to elaborate means of experimentation.

Descartes proposed the formulation of ideal and complete system of philosophy as an alternative to the Aristotelian system.

In doing so, Descartes showed little concern for the history of scientific practice or experimental methodology, as rudimentary as it was prior to Pascal's scientific activities. The necessity of a metaphysical foundation for scientific inquiry was obviously an ideal, external and normative approach, given that scientists and scholars were required to take into account a priori truths and principles before proceeding to investigate various aspects of the world. This is especially apparent since results arising from scientific inquiry could never supersede nor displace metaphysical truths or principles. Descartes' goal to formulate an ideal and complete philosophical system that would solve both metaphysical and physical problems put his system widely at variance with scientific practice or the actual procedures of experimental science. Thus, it should be clear that the approach of Descartes to the philosophy of science is essentially external, given that he proceeds from a metaphysical foundation, independent of the history of scientific practice with limited appeal to experimentation.

#### **6.The Internal Approach**

Whereas the approach of Descartes to scientific knowledge was foundational, the approach of Pascal, in an important sense, was non-foundational. For Pascal, there could be no absolute, metaphysical foundation for the sciences. His rejection of Cartesian foundationism can be found throughout his scientific writings. Indeed, a clear statement can be found in the *Pensees*, in the section entitled 'Disproportion of Man'. There he asserted

that Cartesian foundationism was merely an ideal enterprise that resulted only in speculative physical inquiry. On this view, the approach of Descartes to physical inquiry, and its task of understanding the world, was doomed to failure because genuine foundations could not be discovered.

Pascal believed that Nature, or the universe, was infinite in comparison to individuals. It was not only the grandness of the universe that was infinite, the minuteness of some phenomena in the world were infinite as well. The minuteness and grandness of phenomena and processes represented the two extremes, or more properly, the two infinities of science. The disproportion of individuals, then, was to be placed between such extremes forever unable to gain thorough knowledge of such infinities. Of the disproportion of individuals, Pascal wrote, "What else can he do, then, but perceive some semblance of the middle of things, eternally hopeless of knowing either their principles or their end? The author of these wonders understands them: no one else can."<sup>6</sup> The pursuit of an absolute foundational enterprise for scientific inquiry was, for Pascal, an ideal pursuit that could not be attained because of the disproportion of individuals in relation to the two infinities of science. The disproportion of individuals represented natural human limitations whereby the use of reason alone resulted in mere speculation about the nature of phenomena and processes in the world.

More positively, as an internalist Pascal believed that we cannot elevate ourselves beyond the scientific practice or our own

scientific minds to find foundational principles or truths to justify our views of the world or universe. Just as the use of reason alone could not for Pascal lead to certainty about phenomena and processes in the world, neither could the use of the senses alone lead to certainty. As stated in the section 'Disproportion of Man', our senses are ill-equipped to guide us to certainty or to knowledge of the two infinities of science. What was required to guide us to possible truths of the world was the use of the senses in combination with the use of reason to give rise to reliable experimental methodology.

Just as a *geometric mind* was on his view required to arrive at demonstrations in mathematics, what was required was a similar *scientific mind* to arrive at possible truths in the sciences. The *geometric mind*, which was an ability to reason and solve problems, enabled man to grasp a large number of principles and keep them distinct in order to arrive at diverse demonstrations in mathematics. Pascal, however, did not provide for an extensive formulation of what characterized a similar although distinct *scientific mind*. He did assert that it required an accurate and precise mind from which to arrive at conclusions from a few arbitrarily determined principles. The ability to arrive at such conclusions arose, in large part, on appeal to distinct faculties of mind that all individuals possessed although not necessarily in same proportion.

The approach of Pascal to the foundation of scientific knowledge was fundamentally different from the approach of

Descartes. Pascal rejected foundationism on an external approach and substituted in its place an internal idea of the *scientific mind* and what it can prove and justify. The contribution of Pascal to this debate about foundationism in the physical sciences is to introduce the technical notions of a mathematical and scientific or exact mind.

The above contrast between their respective approaches, while relevant and interesting, is still too general for our purpose here which is to evaluate the different claims of Longino and Popkin and to draw out what I think to be the contributions of Pascal to the philosophy of science. In order to develop the internal approach of Pascal more clearly, I will now examine his approach to scientific inquiry in more detail. I will show that Pascal was essentially concerned with methodological and descriptive procedures of empirical science in order to establish reliable evidential reasoning on the nature of the vacuum. Thus, a study of his works will show that as an internalist, Pascal was not a positivist in any sense which Longino claims. Furthermore, this will show in which sense, if any, that he can be characterized as a falsificationist as Popkin suggests.

## CHAPTER THREE

### 7. Pilot Studies On The Vacuum And Their Analysis

In this section I want to examine my claim that Pascal was an internalist in more detail. I will do this by examining his scientific works. The pilot studies were conducted by Pascal with the express intention of testing alternative hypotheses arising from the received view about the vacuum. The alternative hypotheses were representative of three distinct forms of the received view, ranging from the strongest to the weakest form of this view. On the strongest view, Nature, as an active or emotional creature, would not allow the creation of either a small or large vacuum in the world. Proponents of the received view, in defence of this strongest view, posited the existence of special matter to fill the vacuum. The special matter was posited as either *purified air*, *subtle air* or *spirits* left from the fluids used during experimentation. On the weaker view, Nature prevented the creation of too large a vacuum, although allowing a small, momentary vacuum to be created in experimental settings. On the weakest view, both a small or large vacuum could be created although Nature seized the first opportunity to fill the empty space. These various forms of the received view were tested during the pilot studies to determine which hypotheses were plausible, and therefore open to further, more elaborate testing, and which hypotheses were not plausible, and therefore to be rejected. The testing was achieved by a series of experiments.

In the first experiment, a syringe containing an exact piston

was sealed and placed into a container of water. The piston was pulled upwards in order to create a vacuum within the walls of the syringe. The aperture of the syringe was then unsealed. As the aperture was unsealed, the water arose to fill the syringe in its entirety. In the second experiment, the apertures of a bellows were sealed, the handles were pressed firmly together and the bellows submerged in a container of water. The handles were then separated in order to create a vacuum within the main body of the sealed bellows. The apertures were then unsealed whereupon the water filled the main body of the bellows.

In the third experiment, a forty-six foot glass tube was filled with red wine and its aperture sealed. The tube was inverted into a container of water. The aperture of the tube was then unsealed. The level of the wine within the tube fell to the height of approximately thirty-two feet, leaving a vacuum at the upper end of the inverted tube. In the fourth experiment, a scalene siphon (a U-shaped tube with two apertures) was filled with water and the apertures sealed. The legs of the tube were inverted into separate containers of water. The aperture of each leg was then unsealed. As a result of the displacement of water from each leg, a vacuum was created at the centre of the inverted tube.

In the fifth experiment, a fifteen foot glass tube was filled with water and a cord was suspended within its length. The aperture was sealed so that only a string attached to the cord protruded from the aperture of the tube. The tube was inverted into a container of mercury and the cord was partially removed from the

tube. A vacuum was then created within the upper, inverted end of the tube as a result of the displacement of the cord. Furthermore, the mercury arose to fill the tube to the height of two feet and three inches. The cord was then removed in its entirety creating an even larger vacuum, although the height of the mercury remained stable at two feet and three inches. In the sixth experiment, a syringe containing an exact piston was placed in a container of mercury. The piston handle was pulled upwards and, as a result, the mercury arose to the height of two feet and three inches within the tube. As the piston handle was pulled farther upwards, a large vacuum was created while the mercury remained suspended at two feet and three inches within the tube.

In the seventh experiment, a scalene siphon was filled with mercury and the apertures of the tube were sealed. The legs of the tube were inverted into separate containers of mercury. The apertures of the tube were unsealed. As a result, a portion of the mercury fell from within the tube creating a vacuum at the centre of the tube, although the level of mercury in each leg was suspended to a height of two feet and three inches. In the eighth experiment, a scalene siphon was filled with mercury and a cord was suspended throughout the length of the tube. The apertures of the tube were sealed save for a rope that protruded from the apertures of the tube. The tube was then inverted into separate containers of mercury. The apertures were unsealed and the cord was partially removed from the tube. As a result of the displacement of the cord, a vacuum was created at the centre of the tube. The cord was then

removed from the tube so that a larger vacuum was created, while the height of the mercury in each leg remained suspended at two feet and three inches.

During the pilot studies, Pascal conducted many more experiments in similar fashion to the above mentioned experiments, although he used both a variety of fluids and apparatuses to better test the alternative hypotheses arising from the received view. The first and second experiments had been designed by Pascal only to test the plausibility of the strongest form of the received view. The manipulation of both the syringe and the bellows enabled Pascal to determine if any posited special matter, that would allegedly fill the empty space, could have entered into the experimental apparatuses on creation of a vacuum.

In both experiments, prior to creating a vacuum, the apparatuses were manipulated under conditions that enabled the detection of the passage of special matter entering into the apparatuses. In doing so, Pascal had shown that if any posited special matter possessed detectable qualities then the special matter were not contained in the vacuum. On the other hand, in the case when proponents of the received view asserted that the special matter did not possess any detectable qualities, Pascal would have been in agreement with this view, since he asserted only that matter detectable by the senses or detectable under rigorous experimental conditions were not contained in the vacuum. Thus, the failure to locate, uncover or find any detectable, special matter led Pascal to reject the strongest form of the received

view.

The third and fourth experiments had been designed to test all forms of the received view, although the emphasis was on the weaker and weakest views. In these two experiments Pascal had shown that the size of the vacuum could be altered by intervening on the fluids held in suspension within the various apparatuses. By manipulating the various apparatuses, the fluids were only partially discharged from the tubes so that a portion of the fluids remained in suspension within the tubes. With the fluids held in suspension and by manipulating the tubes in order to vary the height of the fluids, the size of the vacuum could be altered. Furthermore, he had also shown that it was implausible to assert that Nature actively sought the first opportunity to fill a vacuum. Upon creating a vacuum, the empty space could only be filled by manipulating the apparatuses in order to vary the height of the fluids held in suspension.

It was during the third and fourth experiments that Pascal was able to develop alternative research hypotheses to the received view. In the third experiment, he observed initially that the height of the fluids in suspension, the water-wine mixture, would not rise beyond thirty-two feet as measured from the bottom of the tube. Furthermore, on manipulating the height of the tube he observed that the height of the fluids in suspension remained stable at thirty-two feet, although as a result of slanting the tube, the vacuum was filled by the fluids. The fourth experiment further indicated the plausibility of alternative hypotheses to the

received view. Pascal had shown initially that the fluid in suspension remained in equilibrium at approximately thirty-one feet, as measured from the bottom of the tubes in their respective basins. As in the third experiment, it was only with the manipulation of the apparatuses that the height of the fluids fluctuated. Thus, in both cases, the observational consequences indicated that Nature did not actively seek to resist the creation of a vacuum. Furthermore, on Pascal's view, it was plausible to argue that some limited force was related both to the equilibrium of fluids in suspension and the creation of a vacuum.

The fifth through to the final experiment had been designed by Pascal with the express intention of investigating the behaviour of the fluids held in equilibrium within various experimental apparatuses. In the fifth experiment, Pascal had shown that the height of the mercury remained stable at two feet and three inches despite the fact that the height of the water fluctuated as a result of the displacement of the cord from the tube. In the sixth experiment, he had shown that the height of the mercury remained stable at two feet and three inches despite altering the size of the vacuum created within the syringe. In the seventh experiment, he had shown that the height of the mercury remained stable at two feet and three inches even on creation of both a small and large vacuum. In the eighth experiment, he had shown that the height of the mercury remained stable at two feet and three inches while the height of the water fluctuated with the displacement of the cord. In each experiment, Pascal had shown that both the height of the

fluids held in equilibrium and the size of a vacuum could only be altered by manipulating the height of the apparatuses.

In his summary of the pilot studies, Pascal proposed two sets of maxims; one based on the received view, the other on his own research hypotheses. The first set of maxims was based on the received view. This first set merely asserted that only an apparent and not a genuine vacuum had been observed during experimentation. Furthermore, this first set of maxims asserted that Nature provided an active resistance to the creation of a large vacuum in keeping with the weaker view. These maxims also asserted that Nature actively sought the first opportunity to fill the vacuum in keeping with the weakest view. Against such maxims, Pascal proposed a second set of maxims based on the effects observed during experimentation in the pilot studies. Pascal believed that the observational consequences indicated that a genuine vacuum had been created under a variety of experimental conditions. As such, Pascal asserted that the strongest form of the received view was implausible and must, therefore, be rejected. He wrote, "After having demonstrated that none of the materials which are perceived by our senses, and of which we have any knowledge, fills the apparently empty space, my view will be, until someone has shown the existence of some material which might fill it, that it is truly empty and devoid of all matter."<sup>7</sup> Based on the observational consequences, Pascal believed that it was not plausible that the vacuum was filled with any posited special matter that was detectable through elaborate experimentation. Thus, it is clear

from the pilot studies that Pascal rejected the strongest form of the received view.

Despite the rejection of the strongest view, Pascal was not satisfied that he had provided sufficient proof to establish the implausibility of the weaker and weakest views. It was still plausible, although questionable, to argue that Nature provided active, although limited resistance to the creation of a vacuum in order to show her abhorrence to an empty space in the world. However, on retaining the weaker and weakest forms of the received view, Pascal could not assert the plausibility of his own hypotheses, i.e., that an external phenomenon was related both to the equilibrium of fluids and the creation of a genuine vacuum, since it would have been inconsistent with the plausibility of the received view. Thus, although rejecting the strongest view, Pascal cautiously accepted the plausibility of alternative forms of the received view pending further experimentation.

I've dwelt in some length on these various experiments for a number of reasons. (1) It was during these experiments that Pascal first developed his research hypotheses on the vacuum. (2) It was during these experiments that Pascal first became concerned with experimental design for the physical sciences. (3) It is perhaps on the basis of the pilot studies that he is called an empiricist by Longino and others. (4) It was on conclusion of these experiments that Pascal rejected the views of Descartes both on subtle matter and the vacuum. I now turn to other issues.

### 8. Longino's Critique Of The Scientific Approach Of Pascal

We may now assess Longino's critique of the approach of Pascal to scientific inquiry. Longino may have arrived at her critique when Pascal rejected the strongest form of the received view on conclusion of the pilot studies. The strongest view posited the existence of a variety of special matter, ie., *purified air, subtle air* and *spirits* left from fluids, to fill the vacuum. It was perhaps Pascal's rejection of the existence of such postulated entities that led Longino to assert that he was too rigorous an empiricist in the positivist tradition. His rejection of the strongest view, however, does not make Pascal a positivist in any sense of the term.

Pascal had only rejected the special matter posited by the proponents of the received view on appeal to Aristotelian and Cartesian authority. I have shown that elaborate experiments had been designed by Pascal to detect the presence or passage of the posited special matter into the vacuum. The observational consequences indicated that the special matter had not been detected, nor was there any indication even initially of the plausibility of the strongest view. Pascal's rejection of subtle matter was not for empiricist reasons. He did not reject the existence of special matter because these were unobservable. Rather, he rejected these hypotheses because they were implausible, as there was no evidence indicating the existence of any subtle matter within the vacuum. I will now show that Pascal accepted the existence of unobservable processes or forces as natural phenomena

in the world, contrary to the positivist tradition.

Let me recall Longino's critique. She claims that Pascal limited the relation between evidence and hypotheses to observables only. Furthermore, we are told that it was such methodology that prevented Pascal from distinguishing atmospheric weight from atmospheric pressure as an unobservable force. As I have mentioned in the historical context and within his scientific treatises, Pascal, prior to undertaking the Great Experiment had already considered an atmospheric phenomenon, the pressure of air, as the force responsible for the suspension of fluids held in equilibrium within the various apparatuses.

Indeed, Pascal had already asserted that the weight and mass of the air would be much greater at the base of a mountain than at its summit. He also realized, however, that the weight of air alone would not account for the consequences observed during experimentation in the pilot studies. Rather, he realized that the existence of a sustained force in the atmosphere was required to account for the fact that the weight of air was greater at lower altitudes than at higher altitudes. In order to account for such a sustained force Pascal posited the pressure of air as an unobservable force in nature.

Pascal arrived at proof for his hypothesis of the existence of atmospheric pressure as an unobservable force, as a result of the concomitant variation established between the varying levels of mercury within the barometer and the different altitudes above sea level. As I will illustrate in the next section, at the base

of the Puy-de-Dome, the level of mercury was recorded at twenty six inches and three and a half lines. It is estimated that the base of the Puy-de-Dome stands at approximately one thousand three hundred and thirty feet above sea level. Another reading was obtained almost midway to the summit and was recorded at twenty-five inches with an altitude of approximately two thousand five hundred feet above sea level. At the summit, the reading was recorded at twenty three inches and two lines with a corresponding altitude of approximately four thousand eight hundred feet above sea level.

With these readings, as well as others, Pascal formulated the barometric height of altitudes measured in feet and corresponding pressure of air measured in inches based on varying levels of mercury. It was from such variations, based indirectly on the method of statistical analysis, which Pascal distinguished atmospheric weight from atmospheric pressure. That is, we see that the concomitant variation tracked for atmospheric pressure as an unobservable force. From such statistical analyses, Pascal was able to show that higher levels of air provided constant pressure upon lower levels of air, thereby explaining the greater weight of the mass of the air at lower levels than at higher levels of the atmosphere.

It is important to note, however, that Pascal would not have arrived at proof for his hypothesis of the existence of atmospheric pressure had the concomitant variations not been exact. That is, had the variations fluctuated randomly from one altitude to

another, so that the column of mercury did not rise and fall in proportion to specified altitudes, then Pascal would not have been able to claim the readings as proof for his own hypothesis. Failing to provide such proof, Pascal would not have been able to assert that the pressure of air acted on the fluids held in suspension within various experimental apparatuses which, in turn, was related to the creation of a vacuum. Furthermore, this would have seriously impeded Pascal's more general formulation of the weight of the mass of the air being greater in the lowlands than in the highlands. However, the sample data did provide accurate variations from which to predict favourable observational consequences for Pascal's research hypothesis.

It should now be clear that Longino's critique is unwarranted and arises from ignorance of the approach of Pascal to scientific inquiry. Pascal did not adhere to too rigorous an empiricist approach in the positivist tradition but rather provided for experimental methodology that would track atmospheric pressure as an unobservable force. Pascal, therefore, did distinguish between atmospheric weight and pressure. Thus, while Longino is correct in her assertion that Pascal is not on the short list of seventeenth century founders of modern science, she is incorrect in the details leading to this conclusion.

#### **9. Popkin's View On The Scientific Approach Of Pascal**

In the last section, I have tried to show that Longino has completely misconceived the approach of Pascal to scientific inquiry. In this section, I will try to show that Richard Popkin

has misconceived the approach of Pascal to a broad issue in the philosophy of science, which is the appraisal or validation of scientific knowledge. This issue concerns the appraisal of observational consequences arising from experimentation in order to determine the acceptance and/or rejection of the corresponding hard core of hypotheses tested. As mentioned in an earlier section, Popkin implies that the approach of Pascal to this issue resembles the contemporary approach of Karl Popper. According to Imre Lakatos however, the approach of Popper has been marked by three distinct stages of development. In order to determine which stage of development essentially characterizes the approach of Pascal, if any, I will first outline in some detail the relevant stages of falsification as identified by Lakatos in the text entitled *Criticism And The Growth Of Knowledge*.

The first stage, that may be termed as Popper<sub>0</sub>, apparently asserted an observational consequence alone, or hard empirical findings, could prove decisively that a theory was false. It is still debated whether Popper ever defended this view since his published works do not support it. The second stage, that may be termed as Popper<sub>1</sub>, is attributable to the text *The Logic Of Scientific Discovery*. This stage of development resulted in an what can be termed as an unsophisticated approach to falsification. On this view, falsification was based on the one-to-one relation between hypotheses and observational consequences arising from experimentation. Broadly construed, Popper<sub>1</sub> asserted that scientists should make serious attempts to falsify hypotheses

arising from theory. In order to do so however, scientists must refrain from recourse to ad hoc reasoning whereby the initial conditions, auxiliary hypotheses or other relevant experimental factors are reformulated to save the theory in question from refutation. Thus, according to Popper<sub>1</sub>, a refuting instance arising from experimentation served to show that the hard core of a theory was to be rejected.

Lakatos provided an extensive critique of Popper<sub>1</sub>. He asserted that it was neither logically inconsistent nor implausible to reformulate initial conditions, auxiliary hypotheses or other experimental factors to save a theory from refutation. The critique of Lakatos, oversimplified for our purposes here, served to reject the unsophisticated falsification approach to of Popper<sub>1</sub>. The third stage, that may be termed as Popper<sub>2</sub>, was a move to what can be termed as sophisticated falsification, although again, it is still debated whether Popper ever arrived at this stage of development.

In place of Popper<sub>1</sub>, Lakatos formulated "*the methodology of scientific research programmes*" of which Popper<sub>2</sub> is said to resemble. On the approach of Lakatos, positive and negative heuristics could be formulated in order to initially protect the hard core of a theory or research programme from refutation. The positive heuristics allowed the formulation of auxiliary hypotheses that would serve as a protective belt around the hard core or theory in question. The negative heuristics prevented the falsification of a theory or research programme in question by redirecting the modus tollens to these auxiliary hypotheses when

an experiment was unsuccessful. On this method of appraisal, a given theoretical framework could plausibly be reformulated whereby only its hard core remained fixed and stable.

On this method of validation, scientific knowledge was appraised over an arbitrarily determined period of time, rather than on a refuting instance arising from experimentation. A theory that ceased to produce novel facts and instead resulted in continuous refuting instances of alternative, auxiliary hypotheses would result in scientific degeneration for the hard core of the theory or research programme. If this occurred, the theory or research programme in question was then refuted in favour of another theory or research programme, whose positive and negative heuristics resulted in scientific progress rather than degeneration. Falsification, then, was only warranted where one theory or research programme was replaced by another, and where the adopted theory or research programme explained what the refuted theory or research programme explained and more, in terms of arriving at novel facts over its predecessor.

What is relevant here, is that Popkin implies that the approach of Pascal resembles Popper, or an unsophisticated brand of falsification. In defence of this view, we may recall the pilot studies on the vacuum. The proponents of the received view posited the existence of a variety of special matter that purportedly filled the vacuum. The results of the pilot studies however, showed that no detectable matter filled the vacuum. On the basis of the observational consequences, and adhering to the principle of

falsification, Pascal rejected the strongest form of the received view. On rejecting the strongest view, it is somewhat plausible to assert that Pascal adhered to Popper's brand of unsophisticated falsification. Following the pilot studies however, I will show that Pascal's method of appraisal was essentially disassociated with an unsophisticated brand of falsification.

Following the pilot studies Pascal designed and conducted the experiment of the vacuum-within-a-vacuum which in turn was followed by the Great Experiment. I will now summarize in some detail both of these experiments in order to identify what I believe to be the more sophisticated elements of the approach of Pascal to the appraisal of scientific knowledge.

Prior to the Great Experiment, Pascal designed an ingenious experiment involving two Torricellian baroscopes. He filled a three foot glass tube with mercury and sealed both ends of the tubes with membrane. He set one end of the sealed tube in a small basin of mercury. He then fastened this baroscope to the upper end of a larger six foot glass tube. This larger tube was partially filled with mercury to the height of the suspended baroscope, with both ends of the tube again sealed with membrane, to which the lower end was placed within a basin of mercury as well. In this way, Pascal had suspended a baroscope within the confines of a larger baroscope. Pascal pierced the lower end of the larger baroscope and observed that a portion of the mercury fell from the tube and into its respective basin. In doing so, he observed that a vacuum was created between the level of mercury left within the tube and the

upper end of the tube where the smaller baroscope was suspended. He then pierced the lower membrane of the suspended, smaller tube and observed that all the mercury fell out of the tube and into its respective basin, without creating the expected vacuum within the tube. This experiment demonstrated two important findings.

First, this experiment showed that it was implausible to argue that Nature actively resisted to the creation of a vacuum only within the larger, outer baroscope and not within the smaller, inner baroscope. The manipulation of the larger, outer baroscope resulted in the expected and partial suspension of the mercury within its respective tube. On this finding, it was somewhat plausible to assert that Nature did actively resist the creation of a vacuum. However, this process was not observed on manipulating the smaller, inner baroscope as the mercury was displaced entirely from its respective tube. The diverging observational consequences was contrary to the received view, since the weaker and weakest views required that the mercury be held in suspension within the smaller tube as well as in the larger tube.

Second, the experiment established the plausibility of Pascal's hypothesis that the pressure of air was related to the mercury held in suspension within the larger, outer tube. On his research hypothesis, the surrounding air exerted pressure on the mercury within the basin of the larger baroscope, which in turn exerted limited pressure on the mercury held in suspension within the larger baroscope. This hypothesis, of the limited pressure of air, served to explain why liquids, of different weight and

density, were suspended at varying heights within a baroscope. More importantly, his research hypothesis was shown to be plausible given the observational consequences resulting from manipulation the smaller, inner baroscope. In this case, there was no pressure of air to hold the mercury in suspension since the smaller baroscope was confined within the vacuum of the larger baroscope. Thus, this experiment provided almost conclusive proof against all forms of the received view, while providing further proof for the plausibility of his research hypotheses.

Following the experiment of the vacuum-within-a-vacuum and on Pascal's request, the various apparatuses to be used during the Great Experiment were individually tested. The glass tubes to be set up as Torricellian baroscopes were tested to ensure that they were of the highest quality. The mercury was distilled and purified to ensure that no impurities would affect the readings to be recorded during the experiment. Two distinct units of measurements were prepared, to be fitted onto the baroscopes, to ensure accurate, independent readings. The one unit of measurement was the common standard of central France or that of *Macon* feet which, by our standards, measured thirteen point two inches per foot. The other unit of measurement was the proposed scientific standard that, by our standards, measured twelve point eight inches per foot. Furthermore, such units of measurement were themselves broken down to twenty-fourths of an inch, called half-lines by Pascal and followers, so that there were twelve lines per inch and twelve inches per foot as measured by the older standards. In this way,

the recording of independent sample data would be simple yet precise. Finally, several locations leading to the summit of the Puy-de-Dome were selected by Pascal as sites for recording sample data during experimentation.

On Saturday, September 19, 1648 at eight a.m., Pascal's brother-in-law Perier and his chosen companions, which included a doctor of medicine, local magistrates and several learned clergymen, carrying the various pieces of apparatuses, set off from Clermont to the garden of the Peres Minimes located near the base of the Puy-de-Dome. Upon arrival, both baroscopes, which were virtually identical, were set up and the level of the mercury within the tubes were measured and recorded. The level of mercury in both baroscopes were recorded at twenty-six inches and three and a half lines. One baroscope was then dismantled and the other was left in the charge of clergymen who were to observe and measure the level of mercury throughout the day. Perier and the remaining observers, along with the dismantled baroscope, set off for the summit of the Puy-de-Dome. At the summit, the baroscope was again assembled and the level of mercury was recorded at twenty-three inches and two lines. At different heights and in different locations, in varying weather conditions, seventeen separate readings were recorded throughout the day.

On return to the garden of the Peres Minimes, the baroscope was once again assembled and the level of mercury in both baroscopes were again measured and recorded at twenty-six inches and three and a half lines. On conclusion of the experiment it was

shown that the level of mercury arose in proportion to the loss of altitude. Indeed, shortly after obtaining the results, with the use of a regression equation, Pascal calculated and developed a formula based on the relation between increasing or decreasing altitude and the varying height of the column of mercury in a baroscope. That is, on analysis of the sample data, Pascal asserted that a change in altitude of one thousand feet was roughly equal to a change in the level of mercury of one inch, given the above experimental conditions. Thus, the Great Experiment of the Equilibrium of Fluids made scientific history.

I will now draw out from the above experiments, the relevant elements that are indicative of the approach of Pascal to the appraisal of scientific knowledge. As shown in an earlier section, the pilot studies had not showed to Pascal's satisfaction, that the weaker and weakest views were implausible as was the strongest view. What is relevant here, however, is that the experiment of the vacuum-within-a-vacuum *should* have provided Pascal with conclusive proof of the implausibility of the weaker and the weakest views. The manipulation of both baroscopes, in similar and immediate experimental conditions, resulted in diverging observational consequences for both the weaker and weakest views. On appeal to the method of appraisal of Popper<sub>1</sub>, it is highly plausible to argue that hypotheses arising from the weaker and weakest views had been shown to be conclusively false.

Despite these findings, Pascal had still not rejected the plausibility of the weaker and weakest forms of the received view.

It was both Pascal's refusal to reject the weaker and weakest views on conclusion of the experiment of the vacuum-within-a-vacuum and the undertaking of the Great Experiment that provided further, more elaborate testing of the weaker and weakest views that is alien to an unsophisticated brand of falsification. The refuting instance had been obtained although the weaker and weakest views were still not rejected. Thus, in this section I have shown that a reading of the scientific works of Pascal indicates that Popkin's assertions about the method of appraisal adopted by Pascal is questionable. The approach of Pascal appears to be fundamentally different from an unsophisticated brand of falsification or Popper<sub>1</sub>.

In the final section, I will try to develop the approach of Pascal to the appraisal or validation of scientific knowledge. Before doing so, in the next section I will first summarize in some detail the experimental methodology invented by Pascal as a result of his internal approach to scientific inquiry. This in turn will provide the basis on which to present his approach to broad issues in the philosophy of science in the final section.

#### **10. Modern Experimental Design**

Prior to the Great Experiment Pascal realized the importance of establishing evidential reasoning in relation to experimentation. He realized that the different levels of mercury in various apparatuses, in and of themselves, did not provide evidence about the nature of the vacuum. That is, the various levels of mercury alone could neither serve as evidence for the received view on the vacuum, nor for Pascal's own hypotheses on the

vacuum. To establish evidential reasoning Pascal realized the need first to formulate alternative, scientifically testable hypotheses concerned with the various state of affairs that could be observed on the vacuum as determined on reflection of the pilot studies.

One of the two scientifically testable hypotheses was to be characteristic of the strong, weaker and weakest forms of the received view so that all forms would be inclusive to experimentation. Properly stated in contemporary terms, and correctly drawn by Pascal, was the following statement which was to serve as the null hypothesis for the Great Experiment: *There would be no difference in the level of mercury within the experimental baroscope at various altitudes or, more specifically, there would be no difference in the levels of mercury of the two identical baroscopes set up at different altitudes.* Both variations of the null hypothesis serve to characterize the received view that Pascal intended to reject conclusively. As Pascal had indicated to Perier, the received view would be consistent and plausible if and only if the observed and/or detectable effects and processes of the suspension of fluids were identical or at least similar at varying altitudes. Thus, on this view, it was neither consistent nor plausible to argue that Nature would show her abhorrence to a vacuum only at lower altitudes and not at higher altitudes.

As a logical alternative to the null hypothesis was Pascal's own hypothesis, which served as the research hypothesis for the Great Experiment. Pascal had formulated several hypotheses based on previous experimentation each of which was complementary to the

another. First, Pascal asserted that the weight and pressure of air decreased proportionately with the rise in altitude. Second, it followed that the weight and pressure of air would press down or exert force on the fluid suspended within the column of the baroscope as Pascal had indicated during the pilot studies. Third, it followed that the level of mercury suspended in the column of the baroscope would co-vary with the increase or decrease in the weight and pressure of air. Fourth, it thereby followed that the size of the vacuum would vary with the increase or decrease in the weight and pressure of air.

Given the above, Pascal was prepared to formulate a scientifically testable hypothesis that would be deduced from such general hypotheses. Properly stated in contemporary terms, and correctly drawn by Pascal, was the following statement that would serve as the research hypothesis: *There would be an observable and/or detectable difference in the level of mercury of the experimental baroscope at various altitudes or, more specifically, there would be an observable and/or detectable difference between the levels of mercury of the identical baroscopes set up at different altitudes.* In this way, Pascal had provided for exhaustive and yet mutually exclusive, alternative hypothesis to be tested during experimentation.

The formulation of the alternative hypotheses gave rise to what we now recognize as the independent and dependent variables for experimentation. Pascal realized that the varying altitudes represented the variable that could be manipulated during

experimentation. Rather, manipulating the independent variable would provide testing for the alternative hypotheses. Furthermore, in order to determine if the independent variable would provide the relation between evidence and hypothesis, Pascal realized that the level of mercury represented the dependent variable. Rather, if the level of mercury did not rise or fall with the varying altitudes then the null hypothesis could not be rejected. If, on the other hand, the level of mercury co-varied with the change in altitude then the research hypothesis would not be rejected. Thus, the independent and dependent variables served as the observable, detectable and measurable factors during experimentation.

On Pascal's view, the manipulation of one baroscope only during experimentation would possibly give rise to the charge of experimental bias on the part of the proponents of the received view. It could somewhat plausibly be asserted that the baroscope was defective and that the co-variation between the independent and dependent variable was the result of such a defect and, thus, the charge of experimental bias could hold. As a careful experimental scientist, Pascal provided for both a control and experimental baroscope which, as stated earlier, were virtually identical. The control baroscope would not be subjected to the varying altitudes, instead remaining fixed and stable at a given lower altitude. The experimental baroscope, on the other hand, would be subjected to the various altitudes, in order to best test the alternative hypotheses in question. It is important to note that Pascal assured that the control baroscope would be observed and measured for any

changes in the level of mercury, which would indicate a co-variation between the independent and dependent variables. Had this occurred, the experiment would surely have been indecisive. As history shows, however, this was not the case.

Although a co-variance between the independent and dependent variables would serve to reject the null hypothesis it would not, on the above account alone, serve to provide proof in favour of the research hypothesis. During the pilot studies, Pascal had already shown initially that the suspension of fluids was related to the external weight and pressure of air. However, it was not convincing proof in and of itself, since the observed effect had not been exactly determined in varying instances during experimentation. It was for this reason that Pascal had not asserted the plausibility of his own hypotheses in his summary of the pilot studies. For the same reason, the Great Experiment would not have been so great had Pascal not provided for an exact determination of the concomitant variation between the independent and dependent variables.

Pascal, as I have shown, had provided for independent means of observing, detecting and measuring the exact variation between the independent and dependent variables. Such concomitant variation would allow at once for the prediction of further concomitant variation and, in turn, for the first exact statistical table in scientific history. Following the Great Experiment and the formulation of a statistical table, the baroscope became a barometer. That is, it was by then widely accepted as a measuring instrument with practical applications used to predict and detect

various atmospheric phenomena.

On the above account, Pascal had by then provided fundamental contributions to the history of science. It was to the philosophy of science, however, that Pascal's contribution is even more significant. To sum up, the following experimental design features are now standard to modern experimental methodology, if only in a more precise fashion.

Pascal had identified the conceptual elements essential to experimentation with the formulation of exhaustive and yet mutually exclusive alternative, empirically testable hypotheses. With the formulation of the independent and dependent variables, together with the method of concomitant variation, Pascal had provided for the reliable relation between evidence and hypotheses. With the formulation and provision of the control and experimental groups, together with the assurance of quality apparatus, Pascal had provided for well-controlled experimentation for the elimination of experimental bias. With documentation and the provision for statistical tables, Pascal had provided for the repeatability of experimentation. Thus, on the basis of his internal approach, Pascal had invented modern, reliable experimental methodology for scientific inquiry.

## CHAPTER FOUR

### 11. Pascal's Approach To Issues In Philosophy Of Science

In this final section, I will try develop the approach of Pascal to three philosophical issues, among many, that were of primary concern to Pascal, as a result of his internal approach to scientific inquiry. It is interesting to note however, that there is no available text that addresses the approach of Pascal to the following issues. The first issue addresses the epistemic certainty of knowledge derived from scientific practice. To address this first issue we need to look at what Pascal says about his view of induction in the physical sciences. The second issue addresses the method of appraising observational consequences arising from experimentation. This second issue essentially concerns the validation of scientific knowledge. As noted in an earlier section, it still remains to be determined whether he approached this issue from a sophisticated or unsophisticated perspective of falsification. The third issue surrounds the interpretation of the results of the appraisal of observational consequences arising from experimentation. In more familiar terms, this third issue addresses the historical pattern of development of scientific knowledge over time. We now recognize these as broad issues within the philosophy of science. The approach of Pascal to these issues can be identified within his aforementioned treatises. These treatises, among others, are respectively entitled *Lettre A Pere Noel*, *Preface Sur Le Traite Du Vide* and *Recit De La Grande Experience De L'Equilibre Des Liqueurs*. As noted earlier however, these treatises

were left in fragmentary form, to be completed in a larger treatise that never materialized. As a result of the incompleteness of his works, his approach to these philosophical issues remains unsystematic. Although unsystematic, I will try to show nonetheless that he anticipated, if only in a general way, contemporary philosophical discussion concerned with the aforementioned issues.

### *12. Inductive Inference In The Physical Sciences*

Of the first aforementioned issue, I will try to show that Pascal believed that knowledge arising from scientific practice amounted to certainty although only in a specific, limited sense of the term. If we recall in an earlier section what I believe to be his critique of the methodology of Descartes for scientific inquiry, we see that he rejected the view that absolute or certain knowledge, understood in the strict sense, could be achieved on appeal to scientific practice. As I have tried to show, Pascal believed that the two infinities of science, ie., the minuteness and grandness of the universe respectively, were beyond human comprehension. These infinities were beyond human comprehension if only for the fact that any amount of observational consequences obtained during experimentation represented only a small proportion of an infinite set of observable consequences that could be examined. From this view of the infinities of science, I will turn now to Pascal's view of induction in the physical sciences and relate this to his scientific works on the vacuum.

At the conclusion of the *Preface Sur Le Traite Du Vide*, Pascal

identified the epistemic difficulty associated with inductive inference arising from observational consequences within scientific practice. He wrote,

"For in all matters whose proof consists in experiments and not in demonstrations, no universal assertion can be made except by general enumeration of all the different parts or all of the different cases. Thus, it is that when we say that a diamond is the hardest of all bodies, we mean that all the bodies that we know of, and we neither can nor ought to include therein those that we do not know of;..."<sup>8</sup>

On this statement, I take it that Pascal believed that observational consequences in favour of hypotheses did not logically entail the positing of a universal statement about the state of affairs under study.

This formulation of Pascal's view of inductive inference for the physical sciences admits to an essential tension, although I will argue that this tension is misconstrued. That is, if positive observational consequences merely warrant an assertion that an hypothesis is only possibly true in that it cannot amount to certainty in the strictest sense, why then on conclusion of the *Traite De La Pesanteur De La Masse De L'Air*, did Pascal assert that he had proved the existence of the vacuum? Furthermore, on this view of induction, why did Pascal assert that atmospheric pressure was the true cause of both the creation of a vacuum and of the equilibrium of fluids? Indeed, on such assertions it would appear that Pascal had either abandoned his view of induction, or that his

view of induction for the physical sciences is essentially dissimilar to the one I have presented above. However, while Pascal's assertions on the vacuum does admittedly produce an essential tension, I will nonetheless try to show both that Pascal adhered to his view of induction and that this essential tension can be accommodated within his approach to scientific inquiry.

Pascal's view of induction for the physical sciences was essential different from his view of evidential reasoning in the mathematical sciences. Indeed, in his treatise entitled *The Geometric Mind*, within the mathematical sciences, and particularly within geometry, he believed that some mathematical statements or propositions amounted to demonstrations. Pascal believed that mathematical demonstrations amounted to epistemic certainty and that the denial of any of such demonstrations resulted in contradiction. As an illustration of this view, he asserted that when equal numbers are added to equal numbers the result, in all possible instances, will be an equal number as well. In this way, the denial of the conclusion in the above demonstration would result in a contradiction. On the other hand, within the context of the physical sciences, observational consequences in favour of hypotheses or scientific statements could never amount to a demonstration, if only for the problem of inductive inference. That is, while negative observational consequences amounted to refutation on denial of an hypothesis, positive observational consequences amounted to mere acceptance of an hypothesis until such a time as it might be refuted.

Although positive observational consequences could never produce epistemic certainty, it was still only within the limited context of scientific practice that Pascal asserted that he had found the true cause of both the vacuum and of the equilibrium of fluids. That is, on appeal to both the reason and the senses, Pascal believed that his research hypothesis, of atmospheric pressure, was the cause of the vacuum. Indeed, the evidence arising from experimentation, together with favourable outcomes for predictions about barometric readings, and the lack of refuting instances, was, for Pascal, an indication that his research hypothesis was true if only in a limited sense. This is consistent with his internal approach.

While he would agree that the principle of induction showed that all scientific hypotheses were only possibly true, he nonetheless believed that his hypothesis was true within the limited context of scientific practice. More specifically, although Pascal believed that scientific statements could never be certain in an absolute sense, he nonetheless believed that within the limited context of scientific practice his hypothesis of atmospheric pressure would not be refuted, although it was always open to refutation. While there is tension with this view, it is nonetheless clear that Pascal had not enunciated his view of inductive inference for the physical sciences. Thus, while Pascal believed that his research hypothesis was true, it was nonetheless true only in a limited sense relative to the context of scientific practice. From this first issue, I now turn to the appraisal of

observational consequences arising from experimentation. This second issue concerns the validation of scientific knowledge.

### 13. The Validation Of Scientific Knowledge

This second issue is raised in order to determine the acceptance and/or rejection of the theoretical framework corresponding to hypotheses tested during experimentation. In other words, while hypotheses themselves are tested and appraised on the results of experimentation, the corresponding hard core is not directly tested by experimentation. I will try to show, against Popkin's view, that the approach of Pascal to this second issue resembles the approach of Lakatos or sophisticated falsification and not the approach of Popper<sub>1</sub> or unsophisticated falsification. I will not argue however, that Pascal adhered to, or identified all the elements of the approach of Lakatos, but only those core elements that characterize sophisticated falsification as distinguished from its unsophisticated counterpart.

Lakatos, we may recall, argued against appraising observational consequences on appeal to an unsophisticated brand of falsification. Broadly construed, he asserted that negative observational consequences alone could never show that the corresponding framework of an hypothesis should be rejected. Instead, he asserted that it was neither logically inconsistent, nor implausible to formulate alternative hypotheses to save the hard core of an hypothesis from refutation. Lakatos did assert however, that if these alternative hypotheses resulted in degeneration rather than progress for the hard core or theory or

research programme of the refuted hypotheses, then the theory or research programme should be refuted in favour of adopting the hard core or theory or research programme of the alternative hypotheses that resulted in progress rather than degeneration.

Central to the approach of Lakatos was the view that experimentation be designed to test alternative hypotheses arising from competing views, theories or research programmes. In this sense, the principle of falsification was applicable to a set of competing hypotheses so that, in turn, the method of appraisal was also applicable to a set of competing theories rather than to one single theory as required by the criteria established on unsophisticated falsification. With these details in mind, I will now examine the pattern of development of the scientific works of Pascal on the vacuum in order to determine the approach of Pascal.

On conclusion of the pilot studies, I have shown that Pascal had only rejected the strongest form of the received view. In this sense, as mentioned in an earlier section, it is plausible to argue that Pascal adhered to an unsophisticated brand of falsification, as he rejected the strongest view without positing an alternative hypothesis. However, I have shown this view to be misleading as Pascal had not rejected the alternative hypotheses, ie., the weaker and weakest forms of the received views, on conclusion of the pilot studies. Furthermore, as mentioned in a previous section, it was Pascal's decision not to reject the alternative hypotheses arising from the received view that strongly suggests a method of appraisal of evidential reasoning based on sophisticated falsification.

The observational consequences arising from the experiment of the vacuum-within-a-vacuum showed conclusively that the received view, and its corresponding alternative hypotheses, were implausible and therefore to be rejected, although Pascal had not in fact rejected these alternative hypotheses. Pascal's decision not to reject the received view runs completely counter to the core elements of unsophisticated falsification. Why then did Pascal not reject the alternative hypotheses based on the received view? Why then did he undertake the Great Experiment not only to provide evidence for his own research hypothesis, but also to again test and refute the received view? To offer a plausible explanation of both Pascal's decision not to refute the received view prior to the Great Experiment and of his decision to conduct further testing of the received view as well as for his own research hypothesis, we see that the approach of Lakatos is anticipated here.

It is my view that Pascal chose not to reject the received view on conclusion of the experiment of the vacuum-within-a-vacuum until such a time as he had developed his own research hypothesis as an alternative to the received view. Furthermore, Pascal had opened both alternative hypotheses, i.e., the hypotheses based on the received view and his own research hypothesis to scientific testing, thereby providing for the possibility of refutation of all hypotheses in question. That is, the alternative hypotheses formulated for the Great Experiment served to test for both the possibility of refutation and to determine decisively if the received view was degenerative or progressive. Furthermore, it also

served to determine if Pascal's own research hypothesis was degenerative or progressive in similar fashion. The parameters of the alternative hypotheses tested during the Great Experiment served to determine which of these hypotheses was progressive and degenerative respectively. Thus, the continued testing of the received up to and including the undertaking of the Great Experiment is indicative of sophisticated falsification and not of unsophisticated falsification.

Pascal, furthermore, had anticipated the element of the approach of Lakatos that allowed for appeal to initial conditions to initially save the hard core of a theory from refutation. That is, unlike Popper<sub>1</sub>, Pascal had allowed for the reformulation of initial conditions or other experimental factors before requiring falsification of an hypothesis and its corresponding hard core. In the treatise *Traite De La Pesanteur De La Masse De L'Air*, Pascal, in referring to initial conditions of an experiment, wrote, "Moreover, should the experiment be performed, I should enjoy this advantage: that if no expansion of the balloon were observed even on the highest mountains, my conclusions, nevertheless, would not be invalidated; for I might then claim that the mountains were still not high enough to cause a perceptible difference."<sup>9</sup> On this view, the positing of alternative hypotheses, the reformulation of initial conditions or of other experimental factors adheres to criteria associated with sophisticated falsification and not unsophisticated falsification. Thus, based on the development of the scientific works of Pascal, I contend that he adhered to and

anticipated, if only in a general way, a sophisticated falsification approach such as the one developed by Lakatos. I turn now from this second issue to the third and final issue which is the debate about the development of scientific knowledge over time.

#### 14. Historical Growth Of Scientific Knowledge

The debate about the pattern of development of scientific knowledge is essentially one of conservation of scientific knowledge over time versus change in scientific knowledge over time. The conservation of scientific knowledge essentially characterizes a progressive view, while a change in scientific knowledge essentially characterizes a non-progressive view of the historical development of scientific knowledge. While Pascal had not explicitly formulated his approach, he nonetheless asserted that over time, there was a progressive character to scientific knowledge. It is not at all clear however, that he accepted the view that science progressed in a cumulative fashion, as both Descartes, in Pascal's own time, and modern justificationist scholars would argue. I will contend that Pascal believed that scientific knowledge was progressive in one sense, although in another it was not. These two dissimilar senses of the pattern of development of scientific knowledge represent what I believe to be the two complementary parts of the approach of Pascal to this debate.

Of the first part of his approach, scientific knowledge first progressed on the success of results obtained at the level of experimental science. As shown, Pascal believed that his view of

induction was primarily relevant to experimental application in the physical sciences. He believed that reliable experimental methodology was the basic element of scientific inquiry that would lead to the progressive character of science as a whole. In the *Preface Sur Le Traite Du Vide*, Pascal wrote, "The experiments which give us an understanding of them [Nature's secrets] multiply continually; and, as they are the sole principles of physics, the consequences multiply proportionally."<sup>10</sup> Pascal further developed this progressive view of the physical sciences on analogy to the progress of individuals within the human race over the ages.

Referring to the process of education in an individual's life, at least under normal circumstances, he asserted that an individual is essentially ignorant at birth. However, on continual instruction from a variety of sources, and within a variety of chosen disciplines, the process of education for that same individual would result in the acquisition of at least some knowledge over the years. The acquisition of such knowledge, passed on to other individuals, throughout the ages, would then result in the progressive instruction of knowledge in general.

By analogy then, scientific knowledge, passed on throughout the ages, would also result in the progressive character of science as a whole, notwithstanding occasional blunders throughout the course of scientific history. This formulation of the approach of Pascal to the progressive pattern of development of scientific knowledge strongly resembles a justificationist approach that is essentially cumulative in character. On its own, it suggests that

Pascal held the view that the scientific knowledge acquired in his time was an addition to, rather than a replacement of the scientific knowledge of earlier times. Despite this semblance of the first part of the approach of Pascal to the cumulative pattern of development, I will argue that what I take to be the second part of his approach strongly suggests otherwise.

Of the second part of his approach, scientific knowledge proceeded by replacement and not by addition which, as noted, is a feature that is characteristic of a cumulative model of development. In this second sense, science as a whole was not necessarily a progressive enterprise in the strongest sense of the term. Indeed, many of the passages within the treatise *Preface Sur Le Traite Du Vide* are indicative of this view. As an illustration of this view he wrote, "It is in this way that we can today hold other views and new opinions without contempt and without ingratitude, since the basic knowledge that they have given us has served as a stage for our own, and in these advantages we are indebted to them for the ascendancy that we have over them;"<sup>11</sup> On this view, the scientific knowledge of the seventeenth century was not obtained cumulatively by addition from the scientific knowledge obtained in the middle ages nor from antiquity. This passage indicates, at least implicitly, that science as a whole is not necessarily a cumulative enterprise and therefore not entirely progressive in the strongest sense of the term.

The availability of such passages do suggest a pattern of development essentially unlike a cumulative model. The mention of

ascending to scientific knowledge by stages is not necessarily cumulative in the strictest sense. Nonetheless, mere reference to such passages alone does not serve to determine his approach to this final issue. We must therefore look to the approach of Pascal to the previous issues in order to determine his approach to this final issue. That is, in order to determine whether he accepted the view that the pattern of scientific knowledge developed by addition or by replacement, we may look to the approach of Pascal to the aforementioned issues.

I have shown that the approach of Pascal to the formulation of reliable experimental methodology posits two alternative hypotheses open to testing during experimentation. In an important sense, the rejection of one hypothesis in favour of accepting its alternative is a matter of the replacement of hypotheses and not a matter of addition of one alternative hypothesis over another.

I have argued, furthermore, that his method of appraisal for observational consequences arising from experimentation is also one of replacement rather than that of addition. On Pascal's view, the falsification of hypotheses on conclusion of experimentation first required that an alternative hypothesis and its respective corresponding hard core be posited as a replacement of, and not as an addition to the view or theory being refuted. It is plausible then to assert that Pascal would have urged that the same pattern of replacement applied to the development of scientific knowledge as a whole. Thus, it is plausible to argue, at the very least, that

the approach of Pascal to the pattern of development of scientific knowledge is one of change rather than one of conservation.

To contend that the approach of Pascal is characterized by replacement and therefore by change, rather than by conservation of scientific knowledge over time, suggests, on my view, that his approach to this final issue is of an accretional view of the progression of knowledge in the physical sciences.

On this accretional view, the pattern of development of scientific knowledge, while it is one of replacement and change, is nonetheless continuous. That is, it is the methodology of scientific practice itself that allows for the continuous progression of scientific knowledge over time. Thus, on an evolutionary model, the pattern of development, although one of replacement and change, is essentially related to reliable experimental methodology that gives rise to knowledge in a cumulative fashion.

On this accretional approach, however, concerning the validation of scientific knowledge, the replacing theory brings forward those successes relevant to its predecessor, if any, although the new theory must obviously yield more precise results in those same areas of inquiry as well as in others. Indeed, again, in the treatise entitled *Preface Sur Le Traite Du Vide*, Pascal indicates that the successes of a previous framework are to be preserved, although the new framework should explain the same phenomena and processes studied by the old framework, only in a more precise manner. Pascal wrote, "Our view is more extended, and,

although they knew as well as we all that they were able to observe of nature, they nevertheless did not know it as well, and we see more than they did."<sup>12</sup> On my reading this view suggests that an alternative hypothesis and its corresponding theoretical framework merely *corrects* the hypothesis that is refuted within an experimental setting. This correction of the refuted hypothesis and its corresponding framework leads to a replacement of the old framework. Pascal's assertions about the preservation of a predecessors successes occur, nonetheless, only in a context where the predecesing theory has been falsified and therefore replaced.

In this section, I have tried to outline the approach of Pascal to three related although distinct broad philosophical issues. On my view the internal approach of Pascal to scientific inquiry resulted in his approach to these philosophical issues. Furthermore, as suggested, these issues, for Pascal, operate at three distinct although related levels of scientific inquiry. At the first level, his view of induction is at the basis of scientific practice. At the second level, the method of appraisal essentially validates scientific knowledge once the results of experimental findings have been determined. At the third level, the pattern of development of scientific knowledge essentially concerns the results of the appraisal of scientific knowledge. I have tried to show that Pascal was the first to formulate or anticipate a particular approach to these philosophical issues during the seventeenth century.

In this thesis I have shown that the contributions of Pascal

to the philosophy of science have been downplayed in modern times and have been downplayed even further in recent times. Despite this orthodoxy of these modern and contemporary views, I contend both that Pascal was one of the important founders of seventeenth century science and that he should rightly be considered, perhaps above and beyond Rene Descartes, as one of the most influential scholars in modern scientific thought, at least within the context of the seventeenth century. Thus, in this thesis I have tried to contribute to the restitution of Pascal as an influential figure in modern science.

## CONCLUSION

In this thesis I have tried to develop and defend the approach of Pascal both to scientific inquiry and to philosophical issues pertaining to science. I have shown that Pascal rejected the methodology for scientific inquiry that arose on appeal to the authority of two influential scholars. Pascal asserted that Aristotle and Descartes, both of whom were almost universally accepted as the sole authorities in the sciences, attributed epistemic priority to reason alone for acquiring knowledge of the world. The appeal to reason alone I have tried to show, gave rise to an external approach which was essentially founded on a broader theory of knowledge that was outside the context of scientific practice.

As an illustration of an external approach, I have shown that the approach of Descartes to scientific inquiry was essentially based on a metaphysical foundation largely independent of empirical investigation. Pascal, I have tried to show, identified the implications arising from appeal to an external approach for scientific inquiry. He asserted that the approach of Descartes gave rise only to hypotheses about the nature of phenomena and processes in the world, although it did not provide proof for the plausibility of such hypotheses. Thus, for Pascal, an external approach to scientific inquiry, at least one that was independent of appeal to scientific practice, was not an appropriate approach from which to obtain knowledge of the world.

I have tried to show, on the other hand, that Pascal appealed

to an internal approach to scientific inquiry. In developing the internal approach of Pascal, I have tried to show that he had invented modern experimental design for scientific inquiry. The invention of modern experimental design led Pascal to undertake further, more elaborate experimentation on the vacuum. It was the undertaking of further, more elaborate experiments that is particularly significant to the philosophy of science, although I have shown that the philosophical contributions of Pascal have traditionally been downplayed.

The failure to account for the philosophical contributions of Pascal is attributable in part to the misconception of his approach to distinct although related issues within the philosophy of science. Based on his invention of modern experimental design, I have tried to show that his view of inductive inference and the epistemic difficulty derived from it was relevant to the physical sciences both in Pascal's time and for ours. Furthermore, I have tried to show that his approach to the appraisal or validation of scientific knowledge resembles the approach developed by Imre Lakatos and not the approach of Karl Popper. Finally, I have tried to show that his approach to the historical pattern of development of scientific knowledge anticipated an evolutionary model of development.

Based on his philosophical contributions both to scientific inquiry and to broad issues in the philosophy of science, I have tried to argue that the significance of his contributions should be acknowledged among contemporary philosophers of science. More

specifically, I have tried to argue that Pascal should be recognized as an important figure in the growth of seventeenth century science and that he is an important contributor to the philosophy of science.

END NOTES

- 1- Blaise Pascal, 'Reply to Father Noel' in Pascal Selections. Edited by Richard R. Popkin, New York: MacMillan Publishing Company, 1989, p.52.
- 2- Blaise Pascal, 'Great Experiment' in Pascal Selections., p.44.
- 3- Blaise Pascal, 'On the Weight of Air' in The Physical Treatises Of Blaise Pascal. Translated by I.H.B. and A.G.H. Spiers, New York: Octagon Books, 1973, p.31.
- 4- Helen Longino, Science As Social Knowledge. New Jersey: Princeton University Press, 1990, P.49.
- 5- Blaise Pascal, 'Lettre a Pere Noel' in Pascal Selections., p.53.
- 6- Blaise Pascal, Pensees. Translated by A.J. Krailsheimer, Markham: Penguin Books Canada Ltd., 1966, p.90.
- 7- Blaise Pascal, 'New Experiments About The Vacuum' in Pascal Selections., p.40.
- 8- Blaise Pascal, 'Preface To The Treatise On The Vacuum' in Pascal Selections, p.66.
- 9- Blaise Pascal, 'On The Weight Of Air' in The Physical Treatises Of Blaise Pascal., p.31.
- 10- Blaise Pascal, 'Preface To The Treatise On The Vacuum' in Pascal Selections, p.64.
- 11- Blaise Pascal, 'Preface To The Treatise On The Vacuum' in Pascal Selections, p.64.
- 12- Blaise Pascal, 'Preface To The Treatise On The Vacuum' in Pascal Selections, p.64.

## BIBLIOGRAPHY

- Arnold, Keith, 'Pascal's Great Experiment' in Dialogue. Volume 28, number 3, 1989.
- Arnold, Keith, 'Pascal's Theory of Scientific Knowledge' in Journal Of The History Of Philosophy. Volume 27, number 4, 1989.
- Birault, H., 'Science Et Metaphysique Chez Descartes Et Pascal' in Archives De Philosophie. Volume 27, Paris: Beauchensne Et Ses Fils, 1964.
- Brunschvicg, L., Boutroux, P., Gazier, F., editors, Oeuvres De Blaise Pascal. volumes 1-5, Paris: Hachette, 1904-1914.
- Cohen, Morris, Drabkin, I.E., editors, A Source Book In Greek Science. Toronto: McGraw-Hill Company, 1948.
- Grant, Edward, editor, A Source Book In Medieval Science. Cambridge: Havard University Press, 1974.
- Hooker, M., ed., Descartes: Critical And Interpretative Essays. Baltimore: John Hopkins University Press, 1978.
- Humbert, Pierre, L'Oeuvre Scientifique De Blaise Pascal. Paris: Editions Albin Michel, 1947.
- Kourany, Janet, editor, Scientific Knowledge: Basic Issues in the Philosophy of Science. Belmont: Wadsworth Publishing Co., 1987.
- Krailsheimer, Alban, Pascal. New York: Hill and Wang, 1980.
- Lakatos, Imre, Musgrave, Alan, eds., Criticism And The Growth Of Knowledge. Cambridge: Cambridge University Press, 1970.
- Longino, Helen, Science As Social Knowledge. New Jersey: Princeton University Press, 1990.

McMullin, Ernan, 'The History and Philosophy of Science; A Taxonomy' in Historical And Philosophical Perspectives On Science. Minnesota Studies in the Philosophy of Science, V, Minneapolis: University of Minnesota Press, 1970.

Middleton, Knowles W.E., The History Of The Barometer. Baltimore: John Hopkins Press, 1968.

Pascal, Blaise, Pensees. Edited by A.J. Krailsheimer, London: Penguin Books, 1966.

Picard, Emile, Pascal Mathématicien Et Physicien. Paris: Hachette, 1923.

Popkin, Richard R., Pascal Selections. New York: MacMillan Publishing Co., 1989.

Spiers, I.H.B. & A.G.H., translators, The Physical Treatises Of Pascal: The Equilibrium of Fluids and the Weight of the Mass of the Air. New York: Columbia University Press, 1937.

Tourneur, Z., Une Vie Avec Blaise Pascal. Paris: Librairie Philosophique J. Vrin, 1943.