GASTON BACHELARD'S SCIENTIFIC PHILOSOPHY:

AN APPROACH TO

SCIENCE AND TECHNOLOGY STUDIES

by

Maria Teresa Castelão Pereira

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Science and Technology Studies

APPROVED:

Joseph C. Pitt, Chairman

Richard M. Burian

Mordechai Feingold

Robert Paterson

April, 1990

Blacksburg, Virginia

Abstract

GASTON BACHELARD'S SCIENTIFIC PHILOSOPHY:

AN APPROACH TO SCIENCE AND TECHNOLOGY STUDIES

Chairman: Joseph C. Pitt

The contributions of Gaston Bachelard to the history and philosophy of science are not very well known in the United States. This thesis traces the particular characteristics of Bachelard's epistemology within the context of early twentieth century French culture and science. Bachelard began his career in philosophy comparatively late in life and although his background in mathematics and physics was reflected in his philosophical approach to science, he belonged more to the French intellectual avant-garde than to the traditional philosophies of positivism and pragmatism defended by the Third Republic. Bachelard's writings represent an important contribution to a new vocabulary in epistemology, and they influenced scholars such as Georges Canguilhem, Alexandre Koyré, Louis Althusser and Michel Foucault. His works definitely deserve wider exposure, as they easily connect with problems that American scholars pursue today in Science
Studies.

ACKNOWLEDGMENTS

I would like to leave here a word of appreciation to all people who helped me in so many different ways to succeed in the Science and Technology Studies program and in my adaptation to American culture.

I thank my Committee -- Professors Robert Paterson, Joseph C. Pitt, Richard M. Burian and Mordechai Feingold -- for intellectual motivation, and for their encouragement, affection, faith and respect for my work. To all the people in the Philosophy Department, particularly Professors Joseph Pitt, James Klagge, John Christman and Julia Driver, with whom it was a pleasure and a privilege to work as a teaching assistant. I extend my thanks to Professor Harlan Miller, who helped me coping with my computerphobia and tried to introduce me to the fascinations of logical thinking.

I want to acknowledge the contributions of Professors Jane Morley (who made possible my first contact with the English bibliography on Bachelard, including the first draft of her "Giving the history of science the philosophy it deserves: Gaston Bachelard: 1884-1962)"), Joy Harvey (for the possibility she gave me of corresponding with French scholars concerning my thesis topic), Ann LaBerge (for her bibliographic help concerning the history of France), David Lux, Peter Barker, Ellsworth Fuhrman, Roger Ariew, Nicholas

Smith, Marjorie Grene, Peter Barker, Steve Fuller, Gary Downey and Peggy Stewart.

I also want to acknowledge the efficiency and support of secretaries Kathy MacLeod, Amy Harrell and Carolyn Furrow, without whom I would have had a much harder time dealing with computers, bureaucracy and daily stress. I extend my gratitude to the patient people working in the Interlibrary Loan section of Newman Library. I am also thankful for the support given by the graduate students of the Science and Technology Studies, History and Sociology Departments, especially Nancy Mannikko (for her professional competence, unshakeable sense of humour and Kantian friendship), Govindan Parayil and Garrit Curfs (for just listening), and also to my friends Ronald Grimm and Kathryn Bradee.

Finally, but no less important, I cannot tell how much I will ever owe my Family: my Mother (my only faithful correspondent and grown-up best friend), my Father (for allowing me to still be his little girl), Isabel (my sister, confident and private doctor), João Pedro (my nephew and youngest admirer), and my grandparents. I thank them for all the encouragement, altruism, moral (and economic) support, and for believing in me more than I believe in myself.

TABLE OF CONTENTS

GASTON BACHELARD'S SCIENTIFIC PHILOSOPHY:

AN APPROACH TO SCIENCE AND TECHNOLOGY STUDIES

INTRODUCTION

Gaston Bachelard's works on space, imagination and 'rêverie' seem to be quite well known in art, architecture and geography studies throughout the United States. Their English translations constitute proof of the interest of a particular circle of American and Anglo-Saxon intellectuals in Bachelard's contribution to aesthetics and art critique. Unfortunately, we cannot say the same about his voluminous writings on philosophy and history of science, published between 1927 and 1953. Except for The Philosophy of No: The Philosophy of the New Scientific Mind (The Orion Press, 1968) and The New Scientific Spirit (Beacon Press, 1984), all his other epistemological books are available only in French. As for articles, only Bachelard's "The Philosophic dialectic of the concepts of relativity" (in Schilpp (1949) Albert Einstein: Philosopher-Scientist) is presented in English. This obviously constitutes an enormous limitation on the scope of Bachelard's influence -- and thus the influence of an important part of continental philosophy -- among American scholars.

One of the reasons for such neglect of Bachelard's epistemological writings is probably the extreme reserve American intellectuals had regarding French epistemology during the 20's and 30's, precisely when Bachelard began to elaborate a theory of 'ruptures' and discontinuities within the process of contemporary scientific production. On the other hand, Ernst Mach, Pierre Duhem and Émile Meyerson, for instance, became widely known, since they corresponded to a particular trend of positivism realism that American philosophers seemed to be interested in developing.

Strangely enough, in the 60's and even at present, discontinuity assumptions and Foucault's pseudostructuralism seem to be of interest to historiographers and philosophers of science, but Bachelard continues to be ignored. Koyré and Canguilhem's theories are understood, Cassirer, Wittgenstein, Popper and Feyerabend admired. To a certain extent, all of them were influenced by Bachelardian epistemology. However, we still miss English translations of Bachelard's epistemological writings. We miss an understanding of the 'milieu' in which Bachelard's epistemology appeared and a reason why his works should be considered at the frontier of science studies.

Literature

There are a few good studies of Gaston Bachelard's philosophy of science, particularly in French. His student

Canguilhem is one of the serious philosophers and historians of science who tried to apply Bachelard's categories to biology, and to present a synoptic, highly critical account of Bachelard's epistemological method. Louis Althusser contributed to the introduction of Bachelard's category of 'epistemological break' in studies of Marx's science of history, and Popper tried to do in England what Bachelard was accomplishing in France. Most important is Dominique LeCourt's interpretation and understanding of Bachelard. His Marxism and Epistemology: Bachelard, Canguilhem and Foucault (1975), although focused on a Marxist interpretation of these three authors, is a serious attempt to introduce them not only to scholars but to laymen as well. Bachelard ou le Jour et la Nuit (un essai du matérialisme dialectique) and Epistémologie Historique de Gaston Bachelard, both published in 1974, can be considered a fairly objective analysis of the French epistemologist. The Colloque du Centenaire de Gaston Bachelard (Dijon 1984) published an interesting selection of articles, Bachelard: L'Homme du Poème et du Théorème. But again, except for LeCourt's Marxism and Epistemology, all of these works are in French.

The material written by English or American authors on Bachelard is disappointingly sparse. Among these Roch Smith's Gaston Bachelard (1982) and Mary Tiles's Bachelard: Science and Objectivity (1984) may be considered as valid introductory surveys, but they lack contact with primary sources. David W. Theobald's articles "Gaston Bachelard: Eclecticism in the philosophy of science" (1969) and "Gaston Bachelard and the philosophy of chemistry" (1982), but especially Gaukroger's "Bachelard and the problem of epistemological analysis" (1970) are much more systematic attempts to explicate Bachelard's importance to the American reader of philosophy of science. Mary McAllester's "Bachelard Twenty Years On: an Assessment" (1984),Gary Gutting's "Gaston Bachelard's philosophy of science" (1987) and Alfons Grieder's "Gaston Bachelard: 'Phenomenologue' of modern science" (1986) are the most recent English language articles on Bachelardian epistemology that should be considered worthy of attention. As for books, Gary Gutting's Michel Foucault's Archeology of Scientific Reason (1989) only includes Gutting's article of 1987 on Bachelard. Mary McAllester (ed)(1989) The Philosophy and the Poetics of Gaston Bachelard includes Grieder's article of 1986, as well as a selection of other interesting articles on Bachelard's poetics and scientific writings.

As far as I am aware, there is no literature available to approach the third part of this project. No one has tried to connect Bachelard with Science and Technology Studies. Rorty and Giere virtually ignore him. Capek's The Philosophical Impact of Contemporary Physics (1961) mentions Bachelard several times, but never manages to give a precise account of his epistemology, as the book is concerned with something quite different. Latour and Woolgar's Laboratory Life: the Construction of Scientific Facts (1986) and Steve Fuller's Social Epistemology (1988) mention Bachelard 'en passant' as they seemed to be able to extract from his arguments evidence for the coherence of their own accounts on sociology of science studies. The presupposition that the reader knows in advance who and why they are talking about only proves that Bachelard may become an important author in the realm of Science and Technology Studies, but does not necessarily mean that a critical contact with Bachelard's works has already begun.

The present thesis has three main purposes. One, developed in Chapter I, is to undertake a general overview of French political, intellectual and scientific life during the first half of the twentieth century, in order to understand the specific context in which Bachelard formulates his epistemological categories. The purpose, and the content of Chapter II, is to justify in general terms the importance of Bachelard's epistemology through an analysis of the articulation of his categories, as presented in Bachelard's books in history and philosophy of science. Bachelard's attempt to understand the psychological structure as well as the scientific philosophy embedded in twentieth century theoretical physics and chemistry should be acknowledged as an original contribution to a new attitude in science studies. This leads directly to the third purpose of the thesis, which is to try to explain why Bachelard's work should be accepted as a significant contribution to the foundations of Science and Technology Studies. This will constitute the content of a concluding Chapter III.

In broader terms, the objective of this thesis is to provide American students of Science and Technology Studies with a tool that will enable them to establish a first assessment of Bachelardian epistemology and its possible relevance to science studies.

CHAPTER I - THE FRENCH CULTURAL AND SCIENTIFIC MILIEU IN THE FIRST HALF OF THE TWENTIETH CENTURY

INTRODUCTION

We cannot fully understand the scope and structural implications of Gaston Bachelard's epistemology unless we try to see to what extent his preoccupation with science studies coincided with or were shaped by the French institutional scientific and philosophical 'milieu' in the first half of the twentieth century. This first chapter has a dual purpose: (1) it seeks to provide a general overview of that context, and (2) it sets the stage for a subsequent analysis and articulation of Bachelard's epistemological categories. This survey does not aim at relativizing Bachelard's philosophical assumptions, but instead is meant to help us see to what extent his answers may be considered as completely original, as part of a natural sequence of answers to questions that were only made possible by ongoing scientific controversies and by the social-cultural context, or as both.

The difficulties of this kind of research have to do with the complexity of the period that concerns us here. Too many things were happening in France: the implementation of a specific educational program connected with the political philosophy of the Third Republic (and its difficult relations with Germany), the increasingly pragmatic orientation of scientific institutions (connected with the 'revanche' obsession that beset the French after 1870 when France was defeated by Prussia in the Franco-Prussian war), the new 'imago mundi' provided by relativity and quantum physics (products of the Germanic 'geometric mind' as opposed to the French 'esprit de finesse'), and the intellectual horizons opened by irrationalism, surrealism and psychoanalysis (consequences of a return to subjectivism and idealism).

The methodology I adopted here to cover these aspects was to divide the information concerning this period into three sets of intertwined levels: (1) Institutional-political (the place and orientation of science in French society; (2) Internal-scientific (focused on physics); (3) Comparative-philosophical (the epistemological scenario involving Bachelard's epistemology). The extent to which these levels really influenced Bachelard can only be properly assessed after an analysis in terms of Bachelard's categories in the second chapter.

THE THIRD REPUBLIC, FRENCH SCIENCE AND FRENCH SCIENTISTS

The educational and scientific program established by the Third Republic (1870-1940) may be considered a reaction against the state of French science after the Franco- Prussian war, namely the loss of a prestige that had lasted for a period of at least ninety years (1750 to 1840). This reaction was only one aspect of a wider and all encompassing political project. As S. Hoffmann has emphasized, "the founders of the Third Republic held to a doctrine: they wanted to build a Republican political regime and a complex social system around the idea of the nation."(1)

Although the Republican regime had its moments of acute crises, political as well as economic, it managed to be one of the most stable regimes in France. Social changes, too, occurred as part of a political project that included the establishment of moral values coherent with the ideal of an 'entente sociale' and the possibility of an "active emergence into roles of political and social importance of the lesser bourgeoisie - 'petite' and even 'très petite'."(2)(3) Both ideals of social consolidation and the promotion of culture "based on history and the abstract sciences"(4) helped shape what was to be known as the 'École Républicaine'.

Charles Péguy saw 1880 as the beginning of the 'modern world' in France. It was also the year of radical changes in the French legislation concerning the educational system. These changes were performed by 'hommes politiques' such as Jules Simon, Waddington, Paul Bert and Jules Ferry. The motives for the 'reformes scolaires' were not just those embodied in Ferry's laws (1881 and 1882) concerning free compulsory education. They also included, at a higher level, adaptation to the modern technological and scientific world with its obvious demand for a more scientifically oriented education. Even more important, the new legislation also meant, especially at a university level, the search for an institutional organization similar to the foreign example -- particularly Germany -- able to make French science regain its prestige and maintain its leading role in scientific teaching and research.(5)

At the university level, the Institut Pasteur (1888), the École Supérieure de physique et chimie industrielles (1883) at Nancy, and the École Supérieure d'électricité (1894) at Grenoble were some of the institutions created at the end of the nineteenth century that corresponded to this 'educational' policy. They were added to already preexisting and highly prestigious institutions such as the Sorbonne, the Collège de France, the École Polytechnique or the École Normale Supérieure. The stress given to positive science prevailed in the hierarchical educational system, and was parallel to what Eric Cahn called "the notion of centralized State control of education," already present in the centralized administration of Napoleon I.(6)

The emphasis that was traditionally given to philosophy, literary criticism and mathematics at the Lycées also had a specific purpose: it helped to guarantee the survival of a 'culture classique' and it prepared the student for the Grandes Écoles (the École Normale Supérieure and the École

Polytechnique). As J. Mayer says:

> The Grandes Écoles and their mode of selection based on mathematics play an immense role in the social life of the nation and because their alumni occupy the central positions in scientific, technical, military, industrial and administrative organizations, the dual organization of the Écoles Supérieures (university level) was bound from the start to orient the secondary schools toward scientific concentration on mathematics.(7)

The importance attributed to mathematics helps explaining why French physics is largely mathematical. It may also explain why Bachelard considered it the only mode of thinking proper to physics. This did not prevent physics from being applied in addition to being theoretical. However, despite the changes in the educational system, the modes of explanation at the level of the physical sciences remained traditional.

The Grandes Écoles were undoubtedly the place of the French scientific elites, although Universities too -- trough medicine and pharmacy, for instance -- 'produced' scientists.(8)

From 1877 to 1896, science in France underwent a considerable expansion.(9) The comparison with foreign examples, however, had started earlier in the 1830s. It not only reflected the idea that German laboratories and the German structure of science seemed to work better than the French system, but also the view that other countries like Italy and England had constituted since 1840 an additional threat to French scientific leadership in Europe. By this time it had become commonplace for French scientists to present reports on foreign laboratories facilities to the goverment in order to justify government grants. So, at a political level, the 'revanche' obsession and the solution to the 'German question'(10) seemed to be at the basis of a substantial increase in the importance given by politicians to French scientists and to their ability to accomplish social ideals. This also meant that the early training of scientists should have a particular structure, capable of perpetuating the French 'status quo' as a European scientific leader, and stressing the national characteristics of French science. Public institutions, laboratories and Écoles seemed to be particularly concerned with this problem.

The State's attitude toward applied research, physics included, was a result of the idea that the French defeat in 1870 was a direct consequence of German scientific and technological superiority. This trauma provoked the establishment of the 'Commission des Inventions Intéressant les Armées de Terre et de Mer' (1887), the first organization connected with applied research for military purposes (11) and industry. The creation of the 'Office National des Recherches Scientifiques et des Inventions' (1922), the 'Service National de la Recherche Scientifique' (1930), the 'Caisse National des Sciences' (1930), the 'Centre National de Recherche Scientifique Appliquée' (1938), and finally the all encompassing 'Centre National de Recherche Scientifique' (CNRS, 1939) are all institutional examples of what Harry Paul called "the scientific function of the State."(12) They may also be interpreted as the embodiment of the gradually more important interaction between French scientists and French politicians, aimed at reinforcing republicanism and combating organized Catholicism inside the French scientific community. (13)

By 1900, French universities and French science were considered among the best in the world. (14) At this time French science was also decentralized and, consequently, flourished in the provinces as well. According to Mary Joe Nye:

> The strength of French science lay in the diversity rooted in the provinces. Provincial scientists were often leaders and innovators, not followers of Parisian scientific culture and values. Provincial university science frequently was more open and innovative than Parisian science.(15)

Many scientists worked in the Provinces as university teachers (Duhem at Bordeaux, Poincaré and Cuénot at Nancy, for instance). But as in the case of Nancy, Toulouse or Lyon, institutes in the provinces tended to focus on industrial, agricultural and commercial problems.(16) In the long run, especially in connection with regional interests, this focus was probably more important to the stabilization of the French economy and the construction of modern technology for an efficient 'Defense Nationale' than an emphasis on theoretical sciences would have been.

The success of scientific institutions in the French provinces is a consequence of their research in the applied sciences (chemistry and agronomy, for instance), rather than from teachings in general or theoretical physics.(17) However, this interest did not restrict itself to provincial institutions. Particularly by the end of the 1920s, there was also a shift in the teaching structures of Parisian institutions such as the Sorbonne, which from then on were much more concerned with technical aspects of physics. The strong emphasis given to applied physics became the core of the academic training of French physicists.(18) It was reflected, for instance, in the predominance of traditional modes of exposition of physics subject-matters, as well as in the structure of physics textbooks, where the new theories originated between 1905 and 1930 -- special and general relativity, and quantum physics --, were referred to only in passing or even ignored.(19) Relativity and quantum theory were precisely the theoretical aspects of physics that could be seen as representing a radical break with classical theories of physics.

Philosophically, the new sciences entailed a new approach to the notions of determinism, realism and causality. It is possible that the reform of the 'classe de philosophie' in

1925, implemented by men like Bergson, Le Roy and Parodi, helped to expose future scientists to the advancements of German theoretical physics. The new programme included, within logic, topics such as 'Science and the scientific spirit', 'Mathematics: its subject-matter and method. Its present role in the body of the sciences', 'Examples of the great theories of modern physics, chemistry or biology', etc.(20) Thus, very early in their education students were exposed to philosophy. But it is possible to say that, despite this exposure (and also despite the fact that in France we never find a separation between science and philosophy), it was only from the mid 20s on that future French scientists were trained to be aware of the epistemological implications entailed by the new theoretical aspects of physics. Till then, these counterintuitive theories had not been given proper treatment ouside Germany. French institutions , in turn, were apparently much more concerned with safeguarding formalized theories established by classical modes of thinking. The new theories, whose origin had nothing to do with practical necessity, nevertheless "questioned fundamental schemes of classical physics"(21) and did not seem to depend upon data provided by the traditional experimental research methods. Previously, students had not been taught that theoretical physics was constantly subject to transformations.

The above mentioned attitude was completely different from what could be found in Germany during the same period. As Stephen Mason tells us:

> At the turn of the nineteenth century theories involving particles and discontinuous change appeared in a number of fields which had been dominated previously by the reception of the continuity of matter and of change. Such theories were developed notably, but by no means entirely, by the Germans, who had had a 'penchant' for particle theories throughout the nineteenth century.(22)

In the next chapter we will see how Bachelard's epistemology tries to encompass these new theories with a corresponding philosophy, and how he thought it was important to make French scientists and philosophers aware of their significance for the restructuring of the scientific mind, now opened to completely original modes of research. But we should also keep in mind that the resistance to atomic theory, of which Berthelot is representative (23), is not just a reaction against the development of a specific branch of physics. It was also the idea that, coming from Germany, the new theories would not easily fit the specific characteristics of French science and culture. On the other hand, the desire to adopt the pedagogic models of the German universities seem to contradict this scientific resistance to change, at the same time as it emphasized the national character of the 'École Républicaine', bound to fight Germany through the imitation of its best cultural qualities and strengths.

In effect, because of this highly rationalistic approach to teaching science, science becomes again a source of ideology. We must not forget, however, that the above mentioned resistance is not against applied science. Duhem, for instance, although critical of the incoherent duality of German science (24) -- evident in electrical theory and in the conflict he saw between the new physics and both common sense and other physical theories (25) -- seemed to regard French and German science in terms of a highly beneficial exchange of attitudes and information. These attitudes were products of two different mental structures and two different national styles of scientific thinking: 'l'esprit de finesse' (French) and 'l'esprit géométrique' (German). Duhem refused to accept the theory of relativity, an obvious product of a geometric mind, as a longlasting theory, and even less as the seminal example of a break with the old Newtonian and Kantian categories of absolute time and space. The educational system was filled with categories capable of perpetuating a certain dogmatism within the French scientific mind. French establishment preferences went to the "validity of the first approach (...) and the refusal of theoretical multiplicity" (31), among the characteristics of orthodox scientific mentality that Bachelard was most critical of.

Bachelard's criticisms of the French traditional scientific mentality probably had more to do with his negative attitude towards positivism as the only viable philosophy of science than with a political move against the republican class and its obvious commitment to positivism. The fact that his academic career had been rather unusual -- in the sense that he had not been exposed to French contemporary science teaching -- may also explain Bachelard's insistence on the need to reform traditional scientific philosophies. By the end of the 20s, precisely when Bachelard was building his concept of 'epistemological break', French politicians agreed to place greater emphasis "on certain branches of physics, increasingly seen as a science of great economic and military potential."(27) It was also the time of a substantial increase in the everpresent interaction of scientists and politicians in France.

The social role and status of French scientists increased proportionally with their involvement in applied research for strictly utilitarian purposes (commercial, military, etc.). This obviously implied negotiations with the political power, in its turn heavily committed to nationalism and 'revanche'. As Jean Mayer said:

> The influence of universities, and scientists in particular, on public life in France has been considerable between the two World Wars and since the end of World War II. This influence is partially due to what has been both one of the glories of French scientists and almost a cause of undoing of French science, the massacre of French scientists during the two wars.(28)

As already stressed, the character of the negotiations between French scientists and French politicians was reciprocal. Not only did those negotiations include the republican interest in science as the embodiment of a particular State ideology, but they also exposed the motivations of the scientific community. The case of physics is particularly interesting in this respect, as its development directly relates to the preoccupation of politicians with defense.

Around 1934, Paris and New York were "the only places where physicists saw the immediate possibility of nuclear energy, had the means to produce that possibility, and did so with ingenuity and urgency".(29) Marie Curie's Radium Institute, for instance, was able to compete with the Cavendish Laboratory in England for leadership in nuclear physics. Physics was becoming one of the most exciting areas of science. The development in physics was probably a consequence of "French scientists' arrangements with government and industry":

> These arrangements were made possible only by the hard work that scientists and statesman of the twenties and the thirties who had set out deliberately to create close contacts between science, industry and the State. Exploiting their contacts with enthusiasm, the College de France team had won something that no other group of scientists then possessed: tons of uranium, and all the help needed to make of this uranium whatever they could.(30)

The strategy was to guarantee the uses of pure science in strengthening the power of France and, again, the expression of a symbiosis of science and patriotism, always cherished by the Republic. The inseparability between applied research and social action seemed to be more obvious than ever. It also helped increase the need for a coordinated activity between laboratories.

1938 and the years that followed may be regarded as the time when the process of nationalization of French research became more obvious than ever (31), even if we take into consideration possible changes that occurred in French scientific research under Vichy. The overthrow of the Third Republic in 1940 entailed, after a period of indecision, a shift in the political purposes of the French government. As P. Farmer says:

> The first six months of the Vichy regime comprised its most critical period, for the reason that this was the time when the new government had to make the decisions which determined its character.... The circumstances of its origin were not such as to give the new regime a precise orientation. Gradually, in the course of the summer and fall of 1940, this ambivalence lessened, and the new regime began to take on a distinctive character. In its initial period, Vichy came to signify, so far as concerns the reform of institutions, an authoritarian government resting on a basis of corporativism and a moral regeneration emphasizing a larger public recognition of the importance of the family and religion.(32)

Institutional reform entailed changes in science policy. As far as the 'Centre National de Recherche Scientifique' was concerned, the instauration of the Vichy regime suppressed research of military character, and emphasized works concerning national economy (33) and a rapprochement between science and production (34), in order to "find the substitutes for the products that France can no longer import." (35) It also ordered the "dismissal of all Jews from influential positions, including teaching jobs." (36) Léon Brunschvicg, Bachelard's professor and advisor, was one of those who suffered the regime's oppressive procedures. Frédéric Joliot, director of the CNRS since 1944 and one of the physicists of the College de France team, was arrested for political reasons. In 1941 the same had happened to Jewish scientist Fernand Holweck, Langevin's student and collaborator of Marie Curie.

"In 1944 and 1945 the CNRS organized groups to do with military research"(37) since "the war had made the importance of science for national strength plainer than ever."(38) The return to military research could almost be considered an extension of the institutional structures and purposes of the Third Republic, were it not for three things: (1) the substitution of scientists' use of political connections to raise support for disinterested science by putting pressure on governments to change their general policies regarding scientific research (39), (2) Resistance activities, and (3) the emphasis given to nuclear physics research. This was just a part of what was happening to science and its relations to politics. It does not include French intellectuals' reactions to the ideologies of both the Republic and Vichy, or even the political and diplomatic problems between France and Germany. Also, it does not include the fascination that German culture exerted upon French scientific, literary and philosophical circles. The enthusiasm intellectuals experienced for German culture could not be considered as proof of collaborationism with the German occupation, as this position would completely disregard what Wright called the complex mosaic of French intellectual history.

France's idolatry towards Germany and its cultural heritage started around 1870 and prevailed during the Third Republic. As Claude Digeon said:

> If we abstract the political problem, it is certain that Germany presents to the young people that were born around 1870 treasures of philosophy and poetry that few countries can offer. And the importance of the German messages is particularly increased by the fact that young Frenchmen were prepared to receive them. The new orientation in the philosophy teaching at the Lycées is part of it; Kant's idealism is not just a moral and civic doctrine, it disposes the mind to see an ideal world beyond the real and phenomenal world.(40)

It is possible that Bachelard, born in 1884, was influenced by the character of this 'German idealism'. Also, we must not forget that 1880 was the time when the philosophies of the unconscious and irrationalism arrived in France. Clearly, Bachelard's caim for a 'psychoanalysis of scientific knowledge' was shaped by contemporary psychologic trends.

SCIENTISTS OR PHILOSOPHERS DILEMMA?

Scientifically as well as intellectually, the beginning of the period we are considering was an extremely dynamic one. The impact of Darwinism in biology, Freud's The Interpretation of Dreams (1900), Rutherford's discovery of alpha and beta rays in radioactive atoms, Max Planck's Laws of Radiation (1901), Marie Curie's research on radioactive substances (1904), Einstein's formulation of the special theory of relativity (1905), were some of the events which stimulated European intellectuals to consider new approaches to the construction and validation of scientific knowledge. These and other events 'produced' Henri Poincaré's La Science et l'hypothése (1903), Dilthey's Expérience and Poetry (1905), Santayana's The Life of Reason (1905), Henri Bergson's L'Évolution créatrice (1907), Brunschvicg's "L'Orientation du rationalisme" (1920), Meyerson's La Déduction relativiste (1925), to mention a few examples. Bachelard summarized that dynamism in science in the following terms:

> We will set up the exact era of the new scientific spirit in 1905, at the time when Einsteinian relativity came to deform primordial concepts that were thought to be forever immobile. From then on, reason multiplies objections, it dissociates and relates fundamental notions, it rehearses the most audacious abstractions. Thoughts, of which just one would suffices to illustrate a century, show up in twenty five years, signals of

> an astounding spiritual maturity. This is the case of Louis de Broglie's quantum wave mechanics, Heisenberg's physics, Dirac's mechanics, the abstract mechanics and soon, no doubt, the abstract physics that organizes all the possibilities of experience. (41)

Undoubtedly, the "new indeterminacies that scientific discoveries suggested" (42), particularly in theoretical physics, proved the necessity for anti-realism and new metaphysical attitudes in art, literature and, of course, philosophy. At the level of the physical sciences, relativity and quantum physics seemed to be the dominant factors that caused new epistemological preoccupations concerning the character of scientific knowledge and its relations to reality, at the same time as they became increasingly more alien to the popular schools of positivism and empiricism.

To a certain extent, it is possible to see the theories of relativity and quantum mechanics as natural and applicable consequences of non-Euclidean geometries discovered by Gauss, Riemann, Lobachevsky and Bolyai in the years of 1878-1880. Duhring, Renouvier, Dodson (Lewis Carroll) and Frege saw these geometries as products of a pluralistic philosophy ("la philosophie de la pluralite") (43) and, contrary to Bachelard's analysis, as completely unacceptable. Imre Toth claims:

> The anti-intuitive character of the NEG (non-Euclidean geometries) had shocked nineteenth century minds because of the dominant conception of geometry considered as the science of physical space or as

> emanation of a spatial 'a priori' intuition, pure and necessary.(44)

Surely, the reaction against the new geometries also stemmed from three other factors connected with their anti-intuitive character: the apparent impossibility of accepting two opposed systems of propositions as simultaneously true (which entailed that they should both have the same ontological value), their lack of practical or scientific utility outside the realm of pure mathematics (which made them just a futile exercise in symbolic languages), and their anti-Kantian character (as they may be considered as proof of the 'a posteriori' quality of the Kantian 'a priori' principles of pure reason, i.e. the dependency of those principles upon systems of reference established in accordance to what is considered as 'observable' in a certain context).

The new geometries introduced a relativity factor into all mathematical operations more systematically than the anti-Euclidean geometries of Saccheri, Lambert, Taurinus, Watcher and Reid. They enabled scientists and philosophers to reaffirm the dependency of knowledge upon conventional axiomatics (Poincaré, Le Roy)(45) that ultimately might help define reality. Time, space and velocity, not to mention causality and determinism, as defined by Kant and ever present in both Euclidean geometry and Newtonian mechanics, had to be redefined, especially when Einstein and other theoretical physicists emphasized the non-Euclidean character of space-time.(46) The new discoveries provided by contemporary physics gave ontological status to these non-Euclidean geometries, at the same time as they seemed to entail a rejection of strict positivism as the only possible approach to scientific thought. Moreover, instead of traditional realism, a new form of idealism was now much closer to the epistemological needs of the new sciences.

The necessity of a conceptual reconstruction in science and epistemology had its roots at the turn of the nineteenth century, when "theories involving particles and discontinuous change appeared in a number of fields which had been dominated previously by the conception of the continuity of matter and of change."(47) This is one of the reasons why Bachelard stresses the importance of the concept of discontinuity as part of a renewed epistemological glossary for the new sciences like quantum physics, again directly connected with their anti-intuitive and paradoxical character. It is precisely these traits that made them unacceptable to such scientists as Duhem. Despite its "contradictions in the attempt to interpret consistently certain subtle experiments, especially the famous experiment of Michelson",(48) Duhem still saw advantages in exploiting the potential possibilities offered by classical physics.

These considerations do not entail that classical physics suddenly became obsolete. As Heisenberg put it, "modern physics has changed nothing in the great classical disciplines of, for instance, mechanics, optics and heat."(49) But both Bachelard and Le Roy are much closer to the philosophical problems raised by relativity and microphysics than, for instance, Duhem or even Meyerson and Einstein, for they at least suggested different epistemological categories to express these new modes of thought. To Bachelard, the new sciences represent an all- encompassing structure of knowledge to which classical physics belongs as a particular case among equally pertinent possible cases, and not just a particular development from classical physics. Although representing a rupture with classical theories, Heisenberg says:

> Modern theories did not arise from revolutionary ideas which have been (...) introduced into the exact sciences from without. On the contrary they have forced their way into research which was attempting consistently to carry out the programme of classical physics - they arrive out of its very nature.(50)

Einstein emphasizes that "the whole of science is nothing more than a refining of everyday thinking."(51). Bachelard argued instead in favor of the idea of a rupture between empirical and scientific knowledge, and also that the new sciences -- including relativity -- have absolutely nothing in common with classical descriptions of reality.

The several possible meanings that can be given to relativity are extremely significant, whether we see relativity as strictly a part of theoretical physics or, on the contrary, as necessarily subjected to differentiated philosophical approaches. It is this last aspect that interests us most. The qualitatively differentiated philosophical implications that both scientists and philosophers are able to extract from relativity and quantum physics enable us to understand three things: (1) the difficulties of pragmatically oriented French science in accepting their implications, (2) the impact of the new sciences on the history and philosophy of science, and (3) the flaws in the long established dichotomy between scientists' and philosophers' speculations.(52)(53) Bachelard thinks that the new ontological, methodological and epistemological aspects provided by contemporary science entail a shift from the knowledge framework of classical physics and Kantian structures of thought.

In 1933, Louis de Broglie said that "the development of contemporary physics had particularly to do with the blooming of two theories: relativity and quantum theory."(54) Although Dirac attempted to reconcile the theory of relativity with quantum mechanics through his theory of the magnetic electron, the relation between these two theories was not easy. Despite the fact that Einstein's attitude towards Mach's positivism changed when he recognized the heuristic value of abstract mathematical thinking, he never accepted the possible discontinuity between relativity and classical physics, on the one hand, and the scientific implications of Bohr's concept of 'complementarity', on the other. As Rosenfeld puts it:

> The most striking difference between Einstein's attitude and Bohr's was that Einstein emphasizes the permanence and definitive character of scientific thought, whereas Bohr insists upon its ceaseless development (...) There is a huge difference between a theory considered in its final stage and the imperfect stages through which it has passed in the course of its development.(55)

Paradoxically, it was precisely the philosophical problems raised by the absence of absolute determinism and absolute causality in Bohr's theory that Einstein would criticize, despite his own contribution to the development of quantum theory.(56) Einstein, among others, claimed that relativity is not completely alien to traditional scientific thought, as it does not challenge determinism.(57) With quantum theory, things are very different. The observer can never make exact predictions or discover the exact causal chains between atomic phenomena, as the theory implies the "impossibility of any sharp separation between the behaviour of atomic objects and the interaction with the measuring instruments which serve to define the conditions under which the phenomena appear."(58) At the level of strict theoretical physics, this attitude is very close to Heisenberg's concept of 'indeterminacy'. As for epistemology, Bachelard's concept of 'phenomenotechnics' is an attempt to explain the implications, for the metaphysics of scientific knowledge, of the interdependency between what is observed and the way it is observed.

The philosophical implications of the new sciences, i.e., the decline of absolute determinism and absolute causality were not easily accepted by French academia. The cultural background provided by the 'École Républicaine' had much more to do with applied science and traditional modes of thought than with the new philosophical and scientific trends coming from Germany. One of the problems with the acceptance of relativity in France was precisely the question of Einstein's nationality and the polemics concerning the compatibility of Einstein's theory with the French spirit. Paul Langevin, for instance, was one of the scientists who tried to stand up for relativity, arguing how "it found its support in Henri Poincaré's ideas" (59), and how Einstein's works coincided with his own. It was probably this attitude towards German science that led Duhem to refuse relativity. Emile Meyerson accepted it, but only with the condition that it had to be in continuity with classical physics, as this would safeguard causality and determinism. On the other hand, some of the avant-garde French intellectuals, scientists and philosophers included, enthusiastically greeted German irrationalism and the new advancements of German theoretical physics. The epistemological works of Bachelard belong to this line of thought, definitely at the margins of French institutional philosophy.

RATIONALISM, IRRATIONALISM AND FRENCH EPISTEMOLOGY

France has always been considered an intellectual center for the creation of philosophies of science, particularly from the seventeenth century on. Traditionally, and up to the 1930's, it is possible to identify in these philosophies of science a double influence: the Cartesian spirit (a reflection of what Gillespie called "the perpetual Cartesianism in French science in its critical provincialism"), and the pervasive influence of eighteenth century French philosophers. In 1931, Abel Rey's article "Philosophy in France, 1929"(60) emphasized that, despite the novelty of Bergson's 'intuitive' phenomenology, the general trend in French philosophical thought was nothing but a return to Aristotelism, Cartesianism and Kantianism. In a way, this was in fact happening. The ideological consequences of a 'classicism revisited' attitude are not surprising. One of them, particularly interesting to what was then considered the only official French epistemology, was the philosophical reduction of diversity in scientific practices and achievements to an illusory and mythical unity. The other, directly connected with the first, was the idea that an analysis of scientific thought through its history undeniably showed a continuous process of knowledge accumulation within unchanging mental structures 'à la Kant'. This is not, however, all that can be said about French epistemology during the 20's.

French intellectual life has always been divided into sharply distinct trends of thought. Bergson's influence in French culture, for instance, was not as minor as the republican Abel Rey appears to be saying. Rey refused to accept the idea that German culture was invading France 'via' Bergson and that the French intelligensia was not as adverse to Germany as republican institutions or 'legal' French epistemology seemed to convey. The fact is that Bergson and German philosophy, art, literature and science, always remained a more or less hidden presence throughout the whole period of time we are dealing with. An analysis of articles on French philosophy in The Philosophical Review between 1900 and 1940, the year Henri Bergson died, show how enormously influential he had been for almost a half century of French culture, particularly his attacks on positivist thought and the scientific dogmatism of the age. We should probably neglect Wright's explanations when he claims:

> The prewar years (...) brought a widening gulf

> between an intellectual avant-garde on the one hand and the world of scholarship, business and politics on the other. Not until after the Great war did the avant-garde revolt against rationalism and science spread out through other social and intellectual strata.(61)

As the analysis of the Philosophical Review shows, in 1900 Bergson's philosophy was "debatable, although it had attracted great deal of notice" (Fr. Paul Lan), in 1905 his doctrines had been welcomed and "regarded with lively sympathy" (Lalande). In the subsequent years up to 1914 his publications or his influence are always referred to. Even Lalande, considered the very image of the philosopher during the Third Republic (62), could not deny its importance. Referring to the state of French philosophy in 1926 and 1927, and later in 1929, Abel Rey was much more precise in the acknowledgement of Bergson's influence:

> French philosophy has changed its orientation appreciably in the last twenty years. Twenty years ago the searching and illuminating criticism of M. Bergson had completely shaken the reigning doctrines -- the positivism of Comte, Littré, Taine, Renan and Ribot; the neo-criticism of Renouvier, Pillon, Brochard, Hamelin and the 'critique philosophique', and the Kantianism or eclectic rationalism of the greater part of the French university.(63)

The renaissance of positivism at the end of the nineteenth century, with its prominent adherents -- Comte, Cournot, Renouvier, Meyerson and Duhem in France, but also Ernst Mach in Vienna and Ostwald in Germany -- also influenced French intellectual styles. One of its effects was that positivism progressively recognized the importance of history -- including history of science -- as a useful explanatory tool. The importance given to history of science in the eighteenth century scientific academies, and its introduction in French institutions of culture in the nineteenth century, were due to the 'école positiviste'. This school saw, as Hegel and Schelling did too, history reflecting what Canguilhem has called the law of the human mind in its historical development.

Although we may consider positivism as being the official philosophy in France, and to a great extent the legal philosophy of Republicanism, reactions against positivistic thought were quite common. They came from two sets of philosophies: idealism (which incorporated 'Schopenhauerian' German irrationalism) and neo-Thomism. They also came from more literary circles. As Weber puts it in his seminal work France: fin de siecle:

> By 1886, when Le Figaro published the Manifesto of Jean Moreas, explaining decadence as the perception that reality was best aprehended by intuition and best expressed by illusion, poets like Baudelaire, Verlaine and Rimbaud, painters like Puvis de Chavannes, Gustave Moreau, and Odilon Redon, had produced all, or much of their work. To the would be objective and scientific theories of Naturalism, these men opposed a subjective and poetic point of view in which the artist played the part of a magician, delving into and exalting the importance of the unconscious that French and German scientists like Hartmann and Charcot were exploring at about the same time.(64)

Bergson was then important in the reaction against positivism. His thought was more than just an 'accident de parcours'. From the Essai sur les données immédiates de la conscience (1880) to L'Évolution créatrice (1907), and Les Deux sources de la morale et de la religion (1932), Bergson is the defender of intuition 'contra' the excesses of rationalism. His theory of the 'élan vital', furthermore, is regarded as one of the best illustrations of the 'fin de siècle' (or 'la belle époque') in France. Epistemologically speaking, Bergson's ideas on 'time' and 'space' were seen by scientists like Louis de Broglie as extraordinarily well adjusted to the conceptions created forty years later by quantum physics.(65) He may be seen as restoring metaphysics against the positivism and mechanism dominant around 1880, and as liberating philosophical speculations from subservience to scientific methods.(66) The return to subjectivism is clearly pointed out by Émile Bréhier in La Transformation de la philosophie francaise:

> With Bergson's meditation, it is the way we face questions that has changed: general suspicion of conceptual construction, of discussions concerned only with the meaning of words, the temporary and practical character of all classifications; but especially, the philosopher is not seen just as a pure spirit living in a purely intellectual atmosphere; Kantian criticism had [gotten us used] to a certain subject-object relation [that made possible the idea of] an exact description of human knowledge.(67)

Bergson's lectures at the Collège de France were extremely popular but, on the other hand, Bergson was not highly regarded by neo-Thomists. His work was put on the Catholic index in June 1914 (68), after his philosophy had been attacked in 1913 by people like Jacques Maritain.(69)

From the end of the nineteenth century, French positivism had to compete, even at the educational level, with Thomism, considered the "official philosophy of Catholicism."(70) As a result of trying to accommodate itself to science, French Catholicism underwent a considerable expansion. The recent scientific advancements clearly involved a new conjugation of 'fides' and 'ratio' (71) or, in other words, they implied a particular relationship -- if any at all -- between metaphysics and the significance or non-significance of scientific developments.(72) Also, the adaptability of neo-Thomism (73) to modern science did not seem to be easy, as in many respects it could almost be considered a 'neo-Kantianism.'(74) Although Thomist thought in general was seriously opposed to irrationalism, it included different currents, like 'modernism' and 'fideism'. While 'modernists' emphasized the possible reconciliation between church doctrines and positivist science (75), 'fideists' would argue that "an attempt to integrate the conclusions of science into Thomism endangered the claim of metaphysics to be independent of changing scientific hypothesis" (76). Clearly, it was biology, with its new evolutionary hypothesis and the fight over Darwinism (77), that seemed to entail more discussions. The details concerning the arguments involving either an apologetics or a refutation of the integration of science and religion, however, do not belong here. The only thing we should stress is that Bergson's attitude was against Thomism in general and in favor of an adaptation of metaphysics to the new sciences. To him, this also meant a refusal of mathematical models -- used in what he called 'science rigide'-- in favor of biological, psychological and sociological ones.(78) On the other hand, the Catholic Pierre Duhem apparently maintained that scientific theories should be autonomous with respect to religion and metaphysics, although Abel Rey considered Duhem's philosophy as "la philosophie d'un croyant."(79)

Bachelard's attitude regarding the relations between philosophy and science were similar to Spencer's and Bergson's, but only in the sense that, to him, philosophy should stand up to the new demands of scientific thought. However, instead of a Bergsonian 'métaphysique positive', Bachelard followed Brunschvicg's steps when giving importance to mathematics as the language 'par excellence' of the new scientific mind.

All that has been said entails a particular orientation in French philosophy between 1900 and 1947, that which is reported in The Philosophical Review.(80) If we want general trends, Fr. Paulham would comment:

> The present state of French philosophy appears at first sight a little confused. One cannot point out a dominant school and dissenting schools, each having an undisputed leader and fairly submissive disciplines (...) [but] the total results are sufficiently interesting. (81)

By 1912 the situation had changed, since divergent doctrines (all against materialism) coexisted: positivists, idealists, partisans of intuition, mystics, traditionalists (82) and, of course, the omnipresence of Kant, the best known, most learned and, with Schopenhauer, the most worshiped German philosopher.

When we look for constants in terms of subject matter in French philosophy in the first quarter of the twentieth century, they seem to include what is rather normal to find in any chair of general philosophy: ethics, history of philosophy, logic, philosophy of language, mathematical philosophy, 'droit', psychology, sociology, philosophy of religion and, of course, philosophy of science. Some of these subdisciplines have a particular reason for standing out as important preoccupations of the time. Ethics is one of them, as "most of the republican intellectuals (...) were interested in ethics and in developing a nonreligious morality for the republican educational system." (83). Hamelin, Abel Rey, Bergson, Parodi, Brunschvicg are some of the names connected wiht this particular issue. In 1910, Lalande would say:

> Various tendencies (...) have appeared among French writers on ethics during the past fifteen years: biological type of ethics (Metchnikoff), sociological ethics (Durkheim), psychological ideo-motor ethics (Fouillée).(84)

History of philosophy, too, is always present with intellectuals like Émile Bréhier, Étienne Gilson and Léon Robin, but it was particularly during World War I and up to the 1920s that it expanded considerably. Sociology is mainly represented by Durkheim after 1900, but his importance and influence grew after the publication of Les Formes élémentaires de la vie religieuse in 1912, considered by Lalande as "the leading philosophical work of the year."(85) Relations between science and religion interested authors like Parodi, Émile Boutroux, Bergson, Blondel, Goblot, etc. On the other hand, the interest in psychology (Binet, Pierre Janet) produced works as Le Mécanisme cérebral et la pensée (Kostyleff), Matière et mémoire (Bergson), Les origines humaines et l'évolution de l'intelligence (Le Roy), just to name a few.

The presence of philosophies of science is constant. Interestingly enough, it is in 1906, six years after Planck's quantum of action and a year after Einstein's theory of special relativity, that Lalande reports:

> [There is] an increasing number of philosophical works by professional scientists, and the disturbance which the new publications have brought to habits of thought which date back more than a century. (86)

Poincaré, Hadamard, Duhem, Langevin, Brunschvicg and Meyerson are the obvious "professional" scientists. Outside science, we should mention Bergson's L'Évolution créatrice (1907), "an attempt to establish a philosophy of what we call the natural sciences. (87)

By 1924, the union of science and philosophy was already very strong. By then, Meyerson's Identité et réalité (1909) and De l'Explication dans les sciences (1921) were classics in philosophy of science literature. In 1921 and from then on, both Meyerson and Brunschvicg -- not to mention Bergson -- appeared in all 'scenarios' concerning the philosophy of science. The same happened to Duhem, Le Roy and, after 1927, Gaston Bachelard, as is especially evident if we concentrate on philosophy of physics and chemistry. Brunschvicg's L'Expérience humaine et la causalité physique appears in 1922 and coincides with Einstein's visit to Paris. The work constitutes a sort of demarcation , within philosophy of science, between the positivist and neopragmatist philosophies taught at the Sorbonne, with their idea of quasi-absolute 'rational principles', and Brunschvicg's defense of idealism. Brunschvicg's philosophy of science will be criticized later on by Julien Benda as "the doctrine of permanently mobile scientific thought."(88) Brunchvicg's work was permeated with the idea of the plasticity of reason, a conclusion "so clearly disclosed, thanks to theories of relativity."(89)

Restricting ourselves to the orientation of French epistemology -- and not philosophy in general -- during the second quarter of the twentieth century, it is not possible to ignore once again the influence of relativity and quantum physics in the creation, or even better, reinforcement, of an epistemological trichotomy. On one side, we find the traditional positivists like Duhem and Meyerson, on another, the new idealists, represented by Brunschvicg and Bachelard, and finally, the conventionalists Poincaré and Le Roy. Narrowing down this division to what is essential here, two opposite attitudes become increasingly more differentiated in French epistemology, particularly after Einstein's special theory of relativity (1905): (A) the traditional continuity approach to the process of scientific knowledge production, with Meyerson and Duhem, and (B) the new discontinuity thesis. Discontinuism, seen as standing "against the scholastic (latu sensu) tendency towards crystallizing the forms of thought" (90), is represented by Brunschvicg and Bachelard.(91)

In The General Principles of Relativity, published in 1915, Einstein made [the postulate] that "the geometry of space-time was non-Euclidean."(92) To the apologists for the discontinuity assumption, this was further evidence that no scientific absolutes were possible. Also, it meant that philosophy of science had to use new categories to express the structure of scientific development and its history.

Relativity theory, however, had a different impact among apologists for continuity. Duhem, for instance, rejected the theory 'in toto'. As Harry Paul says, "Duhem thought that the geometric mind of the German physicists took great delight in sweeping away the old doctrines based on the principle of relativity."(93) Furthermore Duhem was shocked by the Einsteinian idea that "there is (...) no logical way leading to the establishment of a theory but only groping constructive attempts controlled by careful consideration of factual knowledge."(94)

Meyerson, on the contrary, greeted relativity with enthusiasm, because he saw in it justification for the continuity thesis. Meyerson's influence was considerable as, in 1924, for instance, he was still classified by D. Parodi "among the most knowledgeable (savants), most original, most profound representatives of scientific philosophy in France."(95) Both Meyerson and Einstein saw in relativity a natural and deducible consequence of classical Newtonian physics. Meyerson is an almost constant presence in Bachelard's epistemological writings, the personification of an orthodox and biased attitude towards the new sciences and the changes they necessarily entailed within philosophy of science.

Brunschvicg and Gaston Bachelard opposed the continuity thesis. They argue instead that the new physics has no ancestors, as it represents a completely different attitude towards nature -- in fact, an epistemological rupture with common sense and classical science --, and that contemporary science requires a redefinition of philosophical categories capable of translating the new scientific modes of thinking. Bachelard, with a background in physics, chemistry and mathematics, enters the continuity vs. discontinuity debate in 1928. By this time, and since the turn of the century, the dominant actors in French epistemology were Duhem, Bergson, Meyerson and Brunschvicg.

From 1928 to 1947, Bachelard's books on epistemology are always given proper attention in the articles of The Philosophical Review on French philosophy, whether they are written by Abel Rey or Lalande. His philosophical production during the period is extremely profuse. The Essai sur la connaissance approchée (1928), La Valeur inductive de la relativité (1929), Le Pluralisme cohérent de la chimie moderne (1932), Le Nouvel esprit scientifique (1934), La Formation de l'esprit scientifique (1938), La Philosophie du non (1940), are just a few among the thirteen books Bachelard devoted to epistemology. We do not include here his books on poetry, 'rêverie', literary criticism, or even his articles ranging from metaphysics to art and science. Although the scope of the present work will give particular emphasis to Bachelard's epistemology, it is useful to keep in mind that this only covers a relatively small portion of Bachelard's preoccupations. He is in every way part of the new trend of French intellectuals concerned with French culture and its relations with science. We must not forget that Bachelard is not just a contemporary of the new physics, but also of psychoanalysis and surrealism, from which he will get much of the new vocabulary to translate the work of science (surrationalism, psychoanalysis of scientific thought, etc.).

When Raymond Ruyer says that "between 1930 and 1940, French philosophers stopped being interested in the sciences"(96) it is just to emphasize how this is not the case for Bachelard's work. Bachelard's interest in science -- or, at least, his interest in publishing books concerning philosophy of science --, was only interrupted between 1942 and 1948, precisely when he started to develop the issues contained in his La Psychanalyse du feu (1938). On the other hand, it is not wrong to say that the interest in science came more from scientists writing about the philosophical implications of contemporary science than from philosophers speculating on what they could not grasp for lack of scientific background. One of Bachelard's aims is to offer "science the philosophy it deserves". Philosophers "should go to school with the scientists" because traditional philosophy is not adequate to translate the recent advances of science. The work of the modern scientific mind is a dialectic between rationalism and empiricism. As Abel Rey puts it:

> The agreement, for whoever reasons consistently, between a veritable idealism and a complete realism has such great significance that the capital import of M. Bachelard's work for contemporary philosophy is easily grasped.(97)

This nonradical alternative to both positivism and idealism offered to scientists is a conciliatory position always present in Bachelard's epistemology. It involves the value and limitations of scientific production, the role of metaphysics, and the idea of a constant rectification of concepts in science.

NOTES

The Third Republic, French Science and French Scientists

(1) Decline or Renewal: France Since 1930, p.404.

(2) Wrigth, Gordon. France and Modern Times: From the Enlightenment to the Present, p. 287.

(3) It was the institutional program established by the Third Republic that allowed the 'classes populaires' to progress from illiteracy to literacy in less than fifty years.

(4) Hoffmann, S. Decline or Renewal: France Since the 1930s, p.406.

(5) "The chief function of the French faculties of science in the mid-nineteenth century were lecturing (to laymen rather than to student audiences), and examining lycee students. In the cities, the heaviest burden was imposed by the examining candidates presented by the lycées of the baccalaureat. This situation lasted until the early years of the Third Republic when, as is now well documented, the nature and function of the faculties changed. The changes resulted largely from the appearance of genuine students and from the unprecedented emphasis on research. But perhaps the most striking new departure was the deliberate attempt of the faculties to serve industry by expanding industry-related teaching and research." Paul, Harry. "Apollo courts the Vulcans: the applied science institutes in the nineteenth-century French science faculties" in Fox and Weisz (eds)(1980) The Organization of Science and Technology in France 1808-1914, p. 155.

(6) Politics and Society in Contemporary France (1789-1971), p.519.

(7) Mayer, Jean. "Science" in The Culture of France in Our Time, p.271.

(8) It is necessary to realize that the mission of the university in France was also to preserve classical standards of intellectual culture, even if with "modern" pedagogical methods, and to teach the future high school teachers.

(9) Paul, Harry. The Sorcerer's Apprentice, p.4.

(10) Digeon. La Crise allemande de la pensée francaise, p.1.

(11) in Cahiers pour l'histoire du CNRS 1939-1989, p. 13.

(12) From Knowledge to Power, p.353.

(13) "A problem that plagued secular, rationalist republicans: how to explain away the embarrassing fact that a large segment of the French scientific community held philosophical and religious beliefs subversive of the rationalist-secularist republican Weltanschauung." Paul, Harry. The Edge of Contingency, p. 140.

(14) Paul, Harry. From Knowledge to Power, p.6.

(15) in Science in the Provinces, p.8.

(16) "By the time of the first World War, most French faculties of science were actively engaged in technologically related teaching and research. In contrast with the isolated developments during the Second Empire, the industrial emphasis in university education had spread throughout the system, although the areas of real strength corresponded to the main centers of industry. Whereas in the Second Empire scientists occasionally pursued industrial interests that were peripheral to their teaching duties, in the Third Republic specialized technical institutes emerged which dominated the faculties. This was an important change of direction. The leading technical institutes developed, in the two decades before the first World War, at Grenoble, Nancy and Toulouse, with Lille and Lyon following close behind." Paul, Harry. "Apollo courts the Vulcans: the applied science institutes in the nineteenth-century French science faculties" in Fox and Weisz (eds)(1980), The Organization of Science and Technology in France 1808-1914, p.158.

(17) Pestre, D. Physique et physiciens en France: 1918-1940.p. 13.

(18) "Virtually all the historians who have worked in this field are agreed that there was a clear pattern of growing French marginality beginning about 1840 and lasting until well into the twentieth century. As they show, in a period of unprecedented innovation in theoretical physics, French physicists made striking little contribution to the early, creative phases in the development of thermodynamics, the kinetic theory of gases, electromagnetism, relativity (with

the notable but only partial exception of Louis de Broglie)." Fox, R. and Weisz, G. "The institutional basis of French Science" in Fox and Weisz The Organisation of Science and Technology in France 1808-1914, p.23.

(19) Ibid., p.49.

(21) Lalande. "Philosophy in France, 1925" in The Philosophical Review, XXXV, 6 (1926), p.504.

(22) Pestre,d. Physique et physiciens en France, p.2.

(22) Mason. A History of the Sciences, p.549.

(23) Paul, Harry. From Knowledge to Power, p.260.

(24) Paul, Harry. The Sourcerers Apprentice, p.69.

(25) Ibid., p.72.

(26) Pestre, D. Physique et physiciens en France 1918-1940, p.58.

(27) Paul, Harry. From Knowledge to Power, p.346.

(28) Mayer, J. "Science" in The Culture of France in Our Time, p. 286.

(29) Weart, S. Scientists in Power, p.82.

(30) Ibid., p.103.

(31) Picard,J.-F.; Pradoura, E. "La longue marche vers le CNRS (1901-1945)", Cahiers pour l'histoire du CNRS, p.31.

(32) Farmer, P. Vichy: Political Dilemma, p.177.

(33) Cahiers pour l'histoire du CNRS, p. 35.

(34) Ibid., p.36.

(35) Ibid., p.37.

(36) Weart, S. Scientists in Power, p.162.

(37) Ibid., p.215.

(38) Ibid., p.217.

(39) Ibid., p.258.

(40) Digeon, C. La Crise allemande de la pensée francaise, p.391.

Scientists' or Philosophers' Dilemma?

(41) in La Formation de l'esprit scientifique, p.7.

(42) Weber. A Modern History of Europe, p.1006.

(43) Toth, Imre. "La revolution non euclidienne" in La Recherche en histoire des sciences, p.263.

(44) Ibid., p.262.

(45) "A scientific fact is just a fact translated into a comfortable language". Poincaré in La Science et l'hypothèse, p.8.

(46) "Kant's Critique of Pure Reason has been studied and analysed over and over again in relation to its profound affinity with Newtonian Science. But for the very reason that the putative validity of the transcendental arguments seems to depend upon this particular form of science as its ultimate model, the claim has been made repeatedly that Kant's philosophical stance can have no literal relevance to the actual problems thought germane to twentieth century physical science. Thus, the advent of the theory of general relativity during the period from 1905 to 1916 has been seen almost unanimously as a sufficient cogent refutation of some of the essential claims made by Kant regarding the nature of space and time." Kerszberg, Pierre. "The Critical Philosophy of Relativity" in The Review of Metaphysics, XLI, 1, 161 (Sept. 1987), p.23.

(47) Mason, S. A History of the Sciences, p.549.

(48) Heisenberg, W. Philosophical Problems of Quantum Physics, p.12.

(49) Ibid., p.18.

(50) Ibid., p.13.

(51) Einstein, A. "Physics and Reality" in Arons, A.B.; Bork, A.M. (eds)(1964). Science and Ideas: Selected Readings. New Jersey: Englewood Cliffs, p.49.

(52) Reichenbach, Hans. "The Philosophical Significance of the Theory of Relativity" in Schilpp (ed.). Albert Einstein: Philosopher-Scientist, p.289.

(53) "If they would neglect certain laboratory works or certain mathematical calculus (...) philosophers would lose contact with several of their traditional problems (...) On the other hand (...) physicists, by the development of their own discoveries, are inescapably led to face real metaphysical problems." in E. Le Roy."Ce que la microphysique apporte ou suggere a la philosophie", Revue de Métaphysique et de Morale, XLII, 2 (1935), pp.152-3.

(54) de Broglie, Louis. "Relativité et Quanta" in Revue de Métaphysique et de Morale, XL, 3 (1933), p.279.

(55) Rosenfeld. "Le conflit épistémologique entre Einstein et Bohr", in Revue de Métaphysique et de Morale, 67 (1972), p.150.

(56) "Important progress in the development of quantum theory was made by Einstein himself in his famous article on radioactive equilibrium in 1917, when he showed that Planck's law for thermal radiation could be simply deduced from assumptions conforming with the basic ideas of the quantum theory of atomic constitution." Bohr, N. "Discussion with Einstein" in Schilpp(ed) Einstein: Philosopher-Scientist, p.204.

(57) Cline, B. Men Who Made the New Physics, p.235.

(58) Bohr, N. "Discussion with Einstein" in Schilpp (ed) Einstein: Philosopher-Scientist, p.209.

(59) Le Matin, 23 Mars 1922).

Rationalism, Irrationalism and French Epistemology

(60) in The Philosophical Review.

(61) Wright in France in Modern Times: From the Enlightenment to the Present, p.303.

(62) Belaval. Histoire de Philosophie, vol.III, p.473.

(63) The Philosophical Review, XXXVII, 6 (Nov. 1928), p.527.

(64) p.146.

(65) de Broglie, Louis."Les conceptions de la physique contemporaine et les idées de Bergson sur le temps et sur le mouvement" in Revue de Métaphysique et de Morale, LIII, 4 (1941): 241-257.

(66) Raymond, A. in Lalande,A. "La Philosophie en France, 1940-41" in The Philosophical Review, LI, 1 (Jan. 1942), p.2.

(67) p. 109.

(68) Tint, H. The Decline of French Patriotism 1870-1940, p.140.

(69) Ibid. p.141.

(70) Lalande in Revue de Métaphysique et de Morale, XLVII, 1 (Jan 1838), p.1.

(71) Paul, Harry. The Edge of Contingency, 192.

(72) Ibid., p.12.

(73) Belaval considered it possible to locate the renaissance of Thomism in 1879, the date of Leo XIII's encyclical Aeterni Patris.

(74) Belaval. Histoire de la Philosophie, vol.III, p.498.

(75) Wright. France in Modern Times: From the Enlightenment to the Present, p.304.

(76) Paul, Harry. The Edge of Contingency, p.192.

(77) Ibid., p.24.

(78) Séance de la Société Francaise de Philosophie, le 2 mai 1901.

(79) "La Philosophie Scientifique de M. Duhem" in Revue de Métaphysique et de Morale, 12 (july 1904), p.744.

(80) The philosophical account of French philosophy will follow the one presented in the articles of The Philosophical

Review.

(81) The Philosophical Review, IX, 1 (1900): 42-69.

(82) Lalande. The Philosophical Review, XXII, 4 (July 1913): 357-374.

(83) Paul, Harry. The Edge of Contingency, p.137-38, footnote 1.

(84) The Philosophical Review, XX, 5 (1911): 515-534.

(85) The Philosophical Review, XXII, 4 (July 1913): 357-374.

(86) The Philosophical Review, XVI, 4 (July 1907): 357-386.

(87) Le Roy. The Philosophical Review, XVIII, 3 (1908): 291-315.

(88) Revue de Métaphysique et de Morale, 50 (1945): 161-202.

(89) Lalande. "Philosophie en France, 1922-23", in The Philosophical Review, XXXIII, 6 (Nov. 1924), p.546.

(90) Abel Rey. The Philosophical Review, XXXVII, 6 (1928),p.535.

(91) Also Koyré, mentioned for the first time in The Philosophical Review in 1931.

(92) Mason. A History of the Sciences, p.546.

(93) Paul, Harry. The Sorcerer's Apprentice, p.72.

(94) "De l'explication dans les sciences par Émile Meyerson" in Revue de Métaphysique et de Morale, XXXI, 4, p.4.

(95) Revue de Métaphysique et de Morale, 57 (1952), p.83.

(96) "Philosophy in France, 1929" in The Philosophical Review, XL, 1 (Jan. 1931), p.24.

CHAPTER II - BACHELARD'S SCIENTIFIC PHILOSOPHY

INTRODUCTION

Bachelard's books on history and philosophy of science (physics and chemistry) have a clear purpose. His writings try to make traditional philosophers and scientists aware of the

specific structure of scientific explanation and the dynamics of the scientific mind, through an analysis of science in its historical development. What Bachelard suggests is the adaptation of a new attitude towards science studies -- the use of new categories that illustrate as accurately as possible the radical methodological and conceptual changes produced by contemporary science, as well as its metaphysical, ontological, phenomenological and social implications.

The basic fundamental assumptions of Bachelard's epistemology may be stated as follows:

1. Applied Rationalism. The discontinuities and non-cumulative features of science lead to a complete reformulation of traditional philosophies of science, 'static systems' by definition. Contemporary science -- relativity, quantum physics, wave mechanics, modern chemistry --, requires a new metaphysics capable of reflecting the permanent mobility of scientific thought and the conciliatory dialectic between reason and reality.

2. Psychoanalysis and Scientific Thought. There are radical conceptual and psychological differences at the several stages of scientific knowledge production that a psychoanalysis of scientific objects enables the epistemologist to identify.

3. The Use of History and Philosophy of Science. An alliance between history and philosophy of science is the best methodology to illustrate the crises and progressiveness of scientific reasoning, as well as its conceptual, psychological and technical discontinuities.

4. The Relativity of Scientific Concepts. Mathematical physics is not just a tool for science, but a way of thinking that constructs possibility conditions for the interpretation of a scientifically constructed reality. Differentiated frames of reference prove scientific concepts are not absolute concepts, and reduce Euclidean geometry and classical physics to pure theoretical possibilities.

5. The Role of Social Consensus in Science. The progress of scientific thought involves the methodological organization of research programs objectified by social consensus.

The study of Bachelard's works on epistemology is a complex task. Even if we do not include one of his posthumous publications -- L'Engagement Rationaliste (1972) --, we still have to deal with twelve books of sometimes rather opaque epistemological considerations. The fact that these books are scattered throughout a period of more than twenty five years

-- from 1927 to 1953 -- does not make the analysis of Bachelard's works easier. Also, it is obvious that the development of Bachelard's epistemology and his stress on particular aspects of science construction entail that an analysis of his works should be both chronologic and comparative. The structure of the present chapter tries to obey this double requirement.

In Section I, I analyse Bachelard's epistemological categories as presented in his works between 1927 and 1940. Although Bachelard's epistemological writings always overlapped with his works on art criticism, imagination and poetics, there also was a eight year period -- from 1941 to 1948 -- when Bachelard did not publish any books on history and philosophy of science. When he finally returned to the issue in 1949 (Le Rationalisme Appliqué), 1951 (L'Activité Rationaliste de la Physique Contemporaine) and 1953 (Le Matérialisme Rationnel), some of the previous categories -- like 'scientific city' or 'phenomenotechnics' -- were more strongly emphasized and clearly defined than others. An analysis of both the development and implications of these redefined categories will be the subject-matter of Section II.

The temporal division suggested may be considered problematic. For instance, I cannot say that there was a radical change of purpose in Bachelard's works. The development I find at the surface level of his epistemology may be just the result of a change in emphasis, as each one of Bachelard's books is mainly concerned with particular sets of categories, in relation to which all others are somewhat subsumed. By itself, this fact justifies the correlations I plan to establish among these categories. On the other hand, it is also true that an increased emphasis on categories that did not previously appear to be as important, may lead to a different conclusion regarding the possible evolutionary stages in Bachelard's epistemology. The works between 1949 and 1953 are definitely a return to the history and philosophy of physics and chemistry and to most of the previous categories. However, the sometimes overspecialized language, the stress on the importance of the human mind as twofold -- rational and imaginative -- and the stronger phenomenological assumptions are new. They are probably the result of Bachelard's writings on 'rêverie' and imagination, and also the new advances in theoretical physics. The attempt to explicate the different foci and articulation of Bachelard's categories has to take all these variables into account, and it justifies the division of Section I and Section II into categorical Subsections.

SECTION I - (1927-1940)

Subsection 1. 'Approximation', 'rectification' and 'error' in science; 'epistemological profile' as a philosophical model of scientific change; scientific concepts and the 'arbitrariness' of concept construction.

The Étude sur l'Évolution d'un Problème de Physique: la propagation thermique dans les solides (1927) and the Essai sur la Connaissance Approchée (1928) represent Gaston Bachelard's first attempts at reflecting upon the epistemological problems suggested by both mathematical physics and physical sciences in general, classical as well as contemporary. A comparison between these two books and The Philosophy of No: a Philosophy of the New Scientific Mind (1940) shows that there was a change in the methodology of Bachelard's arguments concerning the role of epistemology and its connections with history of science. The first two show that the evolution of physical concepts entails that knowledge is just an approximation to reality and not something that can be crystallized at some point in time. But the method Bachelard used is too hermetic. Both books try to justify philosophical assumptions out of a systematic approach to case studies in the history of physics and are obviously meant for a learned audience. In The Philosophy of No, however, the objective is to explain the complexities of a new epistemological approach to science to a wider audience of philosophers and scientists. Although constantly present, examples from the physical sciences are clearly secondary to philosophical purposes. As for content, we find a purification of the categories, as well as a development of reflections concerning what we would call today psychology of science. It is not wise, however, to refer to these changes in evolutionary terms alone, as Bachelard's works between 1929 and 1938 are not just propedeutics to The Philosophy of No. Some of them could even be considered as rather atypical. Le Pluralisme Cohérent de la Chimie Moderne (1932), for instance, is one of two full blown studies on philosophy of chemistry (the other being Le Matérialisme Rationnel, 1951). La Formation de l'Esprit Scientifique: contribution à une psychanalyse de la connaissance objective (1938) can also be considered as isolated case, where all previous objective categories intertwine with psychoanalytical meta-interpretations of Alchemy and of what is bound to be chosen as object of scientific knowledge. On the other hand, La Valeur Inductive de la Relativité (1929), Les Intuitions Atomistiques: essai de classification (1933), Le Nouvel Esprit Scientifique (1934) and L'Expérience de l'Espace dans la Physique Contemporaine (1937) should not be classified as either popular or specialized. They are, rather, explanatory justifications for an epistemological path that sometimes was meant to be a reaction to ongoing philosophical controversies concerning the structure of scientific knowledge progress, i.e., the continuity versus discontinuity debate. La Valeur

Inductive de la Relativité, for instance, was supposed to be an answer to Emile Meyerson's La Déduction Relativiste (1925). While Meyerson basically defends the thesis that relativity is logically deduced and potentially contained in Newtonian physics, Bachelard argues instead that there is a complete rupture between classical and modern physics, proved, among other things, by relativity's use of inductive reasoning. Also, the highly metaphysical content of Les Intuitions Atomistiques is further proof that Bachelard aimed at building a pluralistic and multi-sided philosophy, as opposed to the unitary concerns involved in traditional philosophies of science. Bachelard wants to give science the philosophy it deserves. His sharp criticism regarding the inadequacies of traditional philosophies to illustrate the new scientific mind at work is what ultimately leads him to suggest a completely new scientific philosophy. Thus, the basic problem to be solved here is definitely philosophical in nature.

As it is presented in L'Évolution d'un Problème de Physique and the Essai sur la Connaissance Approchée, Bachelard's epistemology is justified through his interest in focusing on the problems concerning the relations between empirical and scientific knowledge on the one hand, and different scientific theories, on the other. The postulates concerning the inexhaustible character of reality and the fundamental open-endedness of knowledge in general (1) necessarily entail the idea that, in order to understand science, we must build an epistemology in accordance with both reality's openendedness and the permanent mobility of thought. To Bachelard, traditional philosophies are unable to express this mobility and the subtleties of contemporary science. The metaphysics of realism, idealism, rationalism and empiricism, cannot 'per se' illustrate the dynamics of scientific reasoning and the history of the continual formation and reshaping of scientific concepts. Each of these philosophies is supposed to be a static system, precisely the opposite of what the scientific process is all about:

> You are confronted with the necessity of applying philosophy, which is perforce finalist and closed, to scientific thinking, which is openended. You are likely to end up dissatisfying everyone: scientists, philosophers, and historians.(2)

The reshaping of scientific knowledge implies a constant process of rectification that can only be expressed philosophically through a dialectic between rationalism and empiricism,(3) something with which previous philosophies of science were not concerned:

> Too often, the philosophy of science remains correlated with the two extremes of knowledge: in the study by philosophers of principles which are too general and in the study by scientists of results which are too particular. It exhausts itself against these two epistemological obstacles which restrict all thought: the general and the immediate. It stresses first the 'a priori' then the 'a posteriori', and fails to recognize the transmutation of epistemological values which contemporary scientific thought constantly executes

> between 'a priori'and 'a posteriori', between experimental values and rational values.(4)

Scientific knowledge does not evolve uniformly. The physical sciences have already reached a degree of maturity that other sciences are still far from achieving. Furthermore, each specialty within a single science evolves in a particular way. The 'epistemological profile' that scientific concepts exhibit over time implies that each stage in the development of science has to be approached with a corresponding philosophy. Only a pliable ('differencée') philosophy is able to account for what is happening in both science and the scientific mind. On the other hand, only an historical analysis of science can give us an idea of how we must approach scientific progress. The 'philosophie de l'inexact', an illustration of 'approximate knowledge' is not, however, a framework that we apply to science to see if the model fits the structure. It is instead the consequence of an analysis of scientific thought throughout its history. The recognition of a new metaphysics for science comes out of science and its epistemological progress. Science and the way the scientific mind works force philosophers to adapt and look for new epistemological categories. These categories will provide historians of science with useful normative tools, and scientists with a constantly rectified epistemology as well as a model of scientific change.

Although created to explain the philosophy of the new sciences -- relativity and quantum physics -- the epistemological categories suggested by Bachelard are not intended to apply to contemporary science alone. Instead, they allow epistemologists to study the formation of scientific concepts within the historical evolution of a specific science. Bachelard's epistemological categories thus serve as a measure of the maturity of a given science and provide `epistemological profiles' of its concepts as they change over time. In The Philosophy of No the notion of 'epistemological profile' -- "which must always be relative to a designated concept" (5) -- emphasizes both the "pluralism of philosophic culture" and the "effective psychological action of the various philosophies in the task of knowing."(6) Bachelard illustrates this double aspect embedded in the construction of every epistemological profile with a study in the notion of mass :

> In the majority of cases the notion of mass presents itself to me with a classical rationalist orientation. For me, to the extent that it is a clear notion, the notion of mass is above all a rational notion.
>
> Yet I can, if need be, approach the notion in the sense of relativist mechanics or of the mechanics of Dirac. But these two orientations, especially the Dirac orientation, are laborious for me. I have to make an effort to prevent my simple rationalist tendency from retaining its hold on me. My simple rationalism blocks my complete rationalism and above all my dialectical rationalism. This is a proof that the healthiest philosophies, like

> Newtonian and Kantian rationalism can, under certain circumstances, become an obstacle to the progress of culture.(7)

'Personal notions' of scientific concepts also mean something else: scientific concepts evolve over time, and only a pliable philosophy can express both the way those concepts have changed and also the way they transform themselves from epistemological acts to epistemological obstacles. Again, the idea is to study, through the identification of their inner metaphysics, scientific notions and the way they evolve within both science and the scientific mind. Usually, the evolution of scientific notions reflect a philosophical hierarchy (animism --> (realism, positivism, rationalism) --> surrationalism). This evolution also suggests a classification of philosophies that, in their turn, allow us to study the progress of reason.(8) The analysis of the way scientific concepts are built and their meaning as heuristic tools within specific theoretical frames of reference is particularly important. In the Essai sur la Connaissance Approchée and The Philosophy of No Bachelard defines scientific concepts as elements of construction (9) or instead as obstacles that "block knowledge instead of summarizing it"(10) and thus as sources of both scientific error and knowledge rectification. Concepts will always be a source of error if the scientist forgets two important factors. One is that, although they are "centers around which knowledge of reality condenses"(11), concepts only have their full significance as part of the construction of knowledge and never as isolated elements. The scientist also errs if he does not consider concepts as arbitrary and constantly capable of reshaping and adaptation according to their conditions of application:

> Even if we confine a concept to pure logic, we can find a trace of essential arbitrariness in the limitation of its understanding. A concept is (...) a real rule through which we get the characteristics we consider sufficient for recognizing an object .... Conceptualization is undoubtedly an effort towards objectivity, but (...) this objectivity will develop in unexpected ways [as it is] the mind that projects multiplied schemes, a geometry, a method of construction and even a method of rectification.(12)

The epistemologist can assess scientific progress by examining the grouping of intuitions and perceptions under concepts and the use of those concepts as interpretative schemes to build networks of significance. He has to use the category of 'approximation' to account for the functional validity of scientific theories and the way they reconcile the possibility conditions suggested by a particular axiomatic with what science postulates as being 'real'.

'Error', 'approximation' and 'rectification' are thus important interconnected categories that are meant to emphasize the unfinished character of scientific knowledge, on the one hand, and the arbitrariness of concept construction, on the other. In the <u>Essai sur la Connaissance</u>

Approchée, but also in "L'Idéalisme discursif" (1934-35) and in fact almost everywhere, Bachelard refers to the category of error as something that epistemologists have to study, not only because it constitutes something that scientists are always trying to rectify, but also because -- and this is one of the innovations of Bachelard's epistemology -- it constitutes an inescapable but positive aspect of the dialectic between reason and experience:

> Before error, a happy intuition is not a clear intuition.... Error is one aspect of a dialectic we necessarily have to traverse. It motivates more precise enquiries, it is the mobilizing element of knowledge. (13)

> The measure of the difference between the criterion of distinctness and the criterion of clarity is precisely a function of the number and importance of antecedent errors.... Every objectification comes out of an elimination of subjective errors and, psychologically, it corresponds to being aware of this elimination.... There is no first truth. Just first errors.(14)

Subsection 2. Historical analysis of the 'rectification' of scientific concepts; 'epistemological obstacles' (intuitions, scientific and intellectual habits, metaphors and traditional metaphysics); 'psychoanalysis of scientific reason'and of scientific objects; the psychological profile of science and the role of history of science.

Interestingly enough, it is the historical analysis of the rectification of concepts that gauges the maturity of a particular science, or some of its parts. Bachelard's Les Intuitions Atomistiques: essai de classification (1933) exemplifies this kind of analysis. The book approaches the concept of an atom in its scientific and philosophical implications.(15) The division Bachelard suggests between realistic atomism and idealistic atomism (positivist, criticist and axiomatic) corresponds to two epistemological directions in the study of the physical world. These different ways of reconciling reason and experience are seen by Bachelard as proof of the different ways each of them transforms particular intuitions into scientific arguments.(16) On the other hand, these directions allow the epistemologist to understand better the postulates used by contemporary science:

> It is by knowing traditional metaphysical intuitions in a discursive and detailed way that we are aware of the exaggerated action of those intuitions in domains where they cannot be anything else but metaphors.... Contemporary microphysics is the science of a new world. In the basis of new experiences, meta- microphysics has to be built with new categories.(17)

Les Intuitions Atomistiques is not the only place where Bachelard criticizes the inadequacies of everyday intuitions for the formation of scientific konwledge. To a greater or lesser extent, all of Bachelard's books refer to these non-intellectualized intuitions -- like all "stereotypes of affective origin" (18) -- as something that needs to be destroyed. The history and role of intuitions and metaphors show how the intervention of ordinary cognition in the formulation of scientific concepts leads to error and constitutes part of what Bachelard calls 'epistemological obstacles' to scientific development:

> It is in terms of obstacles that we should pose the problem of scientific knowledge. And we are not talking about external obstacles, like the complexity and fleeting quality of a phenomenon, or even incriminating our senses or the human mind: it is in the very act of knowing, intimately, that, by a sort of functional necessity, delays and disturbances occur. It is precisely there that we will show the causes of stagnation and even regression (...) the causes of inertia that we call epistemological obstacles. We know against a prior knowledge, by destroying badly constructed knowledge.... When presented to scientific culture, the mind is never young. The mind is even very old, as it has the age of its prejudices.(19)

Again, examples of epistemological obstacles are intuitions and intellectual habits, particularly those connected with 'first experiences'. Because they permeate culture, scientific knowledge and the way science is constructed, epistemological obstacles are difficult to detect.(20) Scientific habits are obstacles to the acceptance of the category of 'approximation' in contemporary science (21), and are sources of the reshaping of knowledge.(22) As an example, following Ferdinand Gonseth's Les Fondements des Mathématiques (1926), Bachelard claims that the idea of human intelligence as characterized by a geometric or a Euclidean structure, is one of those rational habits (23) mistakenly taken for absolute postulates. The theoretical constitution of contemporary physics makes philosophers of science realize the inadequacy of allowing a Euclidean infrastructure to dominate the contemporary scientific mind. Among other reasons for this, "the elementary object of microphysics is not a solid"(24), and scientific theories are just explanatory relational possibilities between natural phenomena. In the interpretation experiments in microphysics, for instance, Riemannian geometry is much clearer and economical (25), constituting further evidence to support the epistemological notion of a functional axiomatic diversity not present in scientific theories prior to the end of the nineteenth century.

The fact that scientific research programs are always dependent on previous discoveries(26) and entrenched theories, also emphasizes the necessity of what Bachelard calls a psychoanalysis of scientific thought and of scientific objects that give an epistemological and psychological profile to science. In <u>Le Nouvel Esprit Scientifique</u> (1934) and <u>The Philosophy of No</u>, for instance, he refers to the category of epistemological obstacle. It is in <u>La Formation de l'Esprit Scientifique</u> (1938), however, that the category is fully developed in connection with Bachelard's psychoanalysis of reason.(27) There it is articulated with other categories such as 'error' and 'epistemological rupture', and is intended to illustrate the change in objective thought. This book also emphasizes the alliance between philosophy and history of science. Although the notion of epistemological obstacle had not been fully articulated with the study of the historical development of science, the presentation of case studies in the history of physics and chemistry in previous books established the importance of this alliance. The necessity of studying the history of science is made clear by the way that Bachelard always justifies philosophical assumptions by means of a descriptive analysis of the subject-matters of science taken from different time periods. But, despite the fact that Bachelard always integrates philosophical interpretations into the description of case studies, the above mentioned alliance is much more obvious from 1938 on. Interestingly enough, this aspect of Bachelard's epistemology coincides precisely with the time when he developed a second analytical tool -- psychoanalysis -- for the study of science and particularly the scientific mind. We can say that history analyses science in the same way psychoanalysis analyzes the scientific mind.

From La Formation de l'Esprit Scientifique (1938) to Le Matérialisme Rationnel (1953), Bachelard assigns to the historian of science the role of providing the epistemologist with research elements for a psychoanalysis of scientific thought.(28) Usually history is not normative, and the traditional historian of science is not philosophically sensitive enough to account for the subtleties of conceptual change:

> It is particularly the development of the notion of epistemological obstacle that will give us the entire spiritual value of the history of scientific thought. Too often the objectivity that leads the historian of science to make a selection from the texts does not enable him to measure psychological variations in the interpretation of the same text.... The epistemologist must try to capture scientific concepts in effective, progressive psychological syntheses, and to establish a conceptual scale within each notion, showing how a concept produced another concept and how concepts connect with each other.(29)

For example, the concept of 'temperature' varies with the scientific context in which it appears. Talking about the 'temperature of the atom' has completely different connotations than when we refer to 'temperature' on a scale thermometer. "Designation does not imply explanation"(30), and "the richness of a scientific concept is measured through its power to deform itself."(31) As epistemologist, the philosopher must perform a 'triage' from the historian's selection of texts (32), and judge them according to the "efforts of rationality and construction" that constitute the errors of the spiritual past of science.(33) At the same time, the normative role given by Bachelard to the epistemologist implies that he must have a previous understanding of the way certain ideas -- always taken as facts by the historian -- fit within a particular thought system.(34) The historian seems to fail by not giving a reason why, despite the facts, there is resistance to the acceptance of certain ideas in science (35). He is thus not fully aware of the psychological evolution of science. Supposedly, the optimal situation is that in which the epistemologist qua epistemologist actually makes history of science (which equals the history of concept evolution) illustrate and justify a new scientific philosophy.(36)

Bachelard's use of case studies in the history of science can be very intricate. He does not seem to be interested in historical generalities, but instead in pointing out, unfortunately at the cost of complexity, some detailed characteristics of scientific knowledge and its evolution within the physical sciences. These studies involve examples of mechanical, electric, spectral, physical, chemical, nuclear phenomena, to mention just a few. Most of his scientific descriptions are so detailed that the reader easily forgets that their point is to provide evidence for the existence of an epistemological rupture between common knowledge and scientific knowledge, and the need for a new metaphysics for science. However, this methodology does not imply that Bachelard is seeking for continuity. On the contrary, continuity only exists within a specific 'system of thought'. Scientific progress entails constant mobility and rupture. The work of philosophers -- and, to Bachelard, 'philosophers' always means 'philosophers of science'-- is precisely to make scientists aware of changes in the meaning of scientific concepts and thus of potential obstacles to the development of scientific reasoning.

<u>Subsection 3</u>. 'Epistemological rupture' or 'break'; stages in the historical development of science; 'systems of thought and the possibility conditions produced by a dialectic between reason and reality; the 'philosophy of no', 'applied rationalism' and 'surrationalism'.

In <u>La Formation de l'Esprit Scientifique</u> Bachelard synthesizes the above mentioned case studies in the history of science into a general classification whose object is to show the progressiveness of scientific thought through what he called 'very rough historical labels' ('grossières étiquettes historiques'):

> The first period represents the pre-scientific state, which includes at the same time classical antiquity and the renaissance as well as the new efforts of the sixteenth, seventeenth and eighteenth centuries.
>
> The second period represents the scientific state, already in preparation by the end of the eighteenth century. It also includes the nineteenth and specially the beginning of the twentieth century.
>
> In the third place, we will locate the era of the new scientific mind in 1905, at the moment when Einsteinian relativity deformed primordial concepts which were thought to be forever immobile. From this date, reason multiplies its objections, it dissociates and remarries fundamental notions, it tries the most audacious abstractions.(37)(38)

Bachelard also tries to classify the scientific mind outside of history, in order to account for the normal psychological path of scientific thought:

> 1. Concrete state, where the mind amuses itself with first images of phenomena and finds support in philosophical literature glorifying Nature and enhancing the world's unity as well as its rich diversity.
> 2. Concrete-abstract state, where the mind adds geometrical schemes to experience and finds support in a philosophy of simplicity. The mind is still in a paradoxical situation: it is so sure of its abstraction that this is more clearly represented through sensible intuitions.
> 3. Abstract state, where the mind undertakes information voluntarily removed from real spacial intuition, voluntarily separated from immediate experience and even in open polemics against an always impure and shapeless first reality.(39)

At first, these divisions do not seem to prove that any kind of discontinuity exists in the development of science and scientific thought. The period in which Bachelard includes all antiquity and eighteen centuries of history of science is vague and innaccurate. The division of the scientific mind into states seems more like a proof that there has been a continuous evolution -- where even an intermediate zone is present -- rather than an illustration of a series of epistemological ruptures between levels.

However, a deeper analysis of Bachelard's methodology yields a different conclusion. When Bachelard talks of 'states' of scientific thought, he implies that there is some form of radicalism in each one of them that cannot be considered as a propaedeutic to the next step. Instead, they involve completely different systems of thought in which the same concepts have different meanings. The need to present an ahistorical division means four things: (1) historical scientific change does not necessarily entail a parallel psychological state. The scientific mind always goes beyond established scientific theories, thus allowing 'commensurability' and scientific value judgements. (2) The division also allows for both continuity and discontinuity within science, which in no way contradicts Bachelard's claims regarding scientific dynamics. (3) Although there is a 'normal psychological path of scientific thought', different sciences progress at different rates, and each science 'per se'-- as well as its several branches -- encounters specific epistemological problems.(40) (4) The ahistorical analysis enables Bachelard to argue that the best philosophy of science is a set of differential (regional) philosophies able to represent, judge and illustrate the constant movement of science 'against' -- or even better, 'beyond' -- nature.(41)

It is a psychoanalysis of scientific thought that identifies errors, resistances and obstacles to the development of the 'esprit' of science. At the same time, only the notion of an epistemological obstacle can really give us the entire value of a history of scientific thought(42), and clarifyes the topological nature of the constant ruptures between common knowledge and scientific knowledge, on the one hand, and within scientific knowledge itself, on the other.

These epistemological ruptures or discontinuities provide support for the claim that "problems change" and that science progresses through a series of epistemological revolutions.(43)(44)

As stressed before, the need for science to break with previous knowledge provided by first experiences implies, to Bachelard, that intellectual obstacles constantly interfere with the knowledge process and with what we could call scientific cognition.(45) It is thus impossible to start building science with the help of simple principles like those provided by Cartesian rationality or by assuming with Locke that before knowledge there is a mental 'tabula rasa' from which experience ends up being cumulatively structured. The notion of an epistemological break clearly implies a victory over the idea of common knowledge. On the other hand, if nineteenth century realist science depended upon first impressions, the category of rupture has to be expanded to include a victory over previous formulations in scientific knowledge itself:

> We will see that the topology of a phenomenon is a far more complex experience than realist science thought it to be....The realist wanted us to assert the presence of an object, which could be a constant measure of the conservation of reality. We will find out that it is only correct to talk of a probability of presence.(46)

The dynamics of scientific activity involves a particular phenomenology and thus a certain notion of what should be considered as 'real'. To Bachelard, science, and particularly contemporary science, should only use 'reality' in two ways: (1) as an 'excuse' for scientific thought to occur(47); (2) as something that science builds itself 'against'. The notion of epistemological rupture becomes clearer if we realize that science is not descriptive, but instead a rational construction of the conditions that make a dialectic between reason and reality possible. And this, of course, brings consequences for both science and philosophy:

> So now, if science brings us the consideration of an object which violates the principles of Euclidean localization -- even by one simple characteristic -- or an object which violates the principles of substantial permanence, we shall immediately be driven to recognize that the any-object-whatever of the older epistemology was relative to a particular class. So then we have to conclude that the conditions retained by Kant as conditions sine qua non of the possibility of experience were adequate conditions but that they are not all revealed as necessary conditions in the new thought. In other words, the organization of classical critical philosophy is perfect within the class any-object-whatever of common knowledge and of classical scientific knowledge. But inasmuch as the classical sciences have just been disturbed in their initial concepts as affirmed with respect to a micro-object which does not follow the principles of the object, critical philosophy needs to be fundamentally recast.(48)

Two criticisms may be inferred from this important excerpt from Bachelard's The Philosophy of No: (1) an attack on the role of Kantian postulates regarding the way the scientific mind operates; (2) a rejection of the role of Euclidean geometry in science. Bachelard often refers to these aspects, and both should be considered philosophical consequences of contemporary physical science.

The first criticism widens the Kantian sphere of objective experience. The 'new thought' proves that mathematical constructs are not solely based upon 'a priori' absolute intuitions of space and time, but rather constitute just one possible instantiation of experience. In this context, philosophy of science denounces any form of dogmatism embedded in the notion that the scientific mode of thinking ('le nouvel esprit scientifique') remains unchanged, independent of the amount of information accumulated. This would correspond to a crystallized structure of thought ('raison architéctonique') as opposed to what should be a real scientific commitment: the admission that the structure of the scientific mind has to reflect the non-cumulative structure of scientific knowledge and, if necessary, change accordingly ('raison polémique').

Bachelard's classification of objects of thought as a sort of Kantian 'noumenon' (mathematical-theoretical constructs such as 'spin', 'positron', 'spectral term', etc.) could, however, lead us to speculate that what he did was to substitute one form of intellectual intuition (time, space) for another (axiomatics). The notion that science produces objects -- 'scientific' as opposed to 'natural' objects -- is clearly ontological, and as we will see, easily connects with

Bachelard's category of 'phenomenotechnics'. On the other hand, the acceptance of the idea that each axiomatic system re-forms and precedes a particular scientific methodology, enforces the notion that scientific thought processes are adaptable and mobile, a notion that was not recognized before 1870.

The new axiomatics embedded in twentieth century science leads us directly to the second criticism, involving the redefinition of Euclidean geometry as a particular case within a larger 'pangeometry':

> Non-Euclidean geometry was not made to contradict Euclidean geometry. It is instead a sort of attached factor that allows the totalization (...) of geometric thought, an absorption into a pangeometry....It draws from the outside, with incredible precision, the limits of ancient thought. The same happens with all other forms of scientific thought that come to project a recurrent light at the obscurities of incomplete knowledge.(49)

Bachelard sees microphysics as the practical consequence of the non-Euclidean and also anti-intuitive geometries discovered by Riemann, Lobatchevski and Bolyai in the years 1870-1880. These new geometries, introduced 'against' ordinary cognition, enabled scientists and philosophers to affirm the dependency of knowledge on 'a priori' axiomatics. Absolute space and absolute time, for instance, ever present in Newtonian mechanics or in Euclidean geometry, had to be redefined. This time, Bachelard proposes to use the category of 'no' to express the epistemological ruptures illustrated by the history of the different levels of the scientific modes of thinking. His historical epistemology enables analysts to reflect on what we could call 'non-sciences', and see to what point they complete the picture of science as an open-ended process:

> The negation must remain in contact with the first formation. It must permit a dialectic generalization. The generalization by negation must include what it denies. In fact, the whole impetus of scientific thought for a century now springs from such dialectic generalizations which envelop what they deny. Thus, non-Euclidean geometry envelops Euclidean geometry; non-Newtonian Mechanics envelops Newtonian mechanics; wave mechanics envelops relativistic mechanics.(50)

At this point, Bachelard's category of 'no' raises several problems regarding issues like 'commensurability' and 'progress' in science.(51) For one thing, it is clear that Bachelard's notion of discontinuity or rupture does not imply the destruction of previous theories by new ones. Within a particular axiomatic and reality level, a theory such as Newtonian mechanics still holds as correct. However, the status of an earlier theory (T1) changes with the appearance of another theory (T2), as long as (T2) is a generalization of (T1). The negation of (T1) by (T2) is not just its negation as an absolute system of explanation, but also the inclusion of (T1) in a system of reference to which it belongs as an interpretative possibility.(52) Usually modern theories

-- built from mathematical models -- include possibilities that have not been taken into consideration by previous explanatory hypotheses. In this sense, progress in science means rectification, generalization and approximation, not to 'reality', but to 'rationality'.

Historically, and even scientifically, all new systems involve and embrace the old ones, establish their contours and limitations. They constitute a lesson in how reality is just a particular case of what is possible. In this sense, the history of crises in science is not merely due to the sudden impossibility of making new phenomena fit old systems of explanation, but rather due to the 'polemic reason' that opens new subsets in the rational construction of scientific reality. The direction of the vector is necessarily from reason to reality and not the other way around. All science ultimately means the adaptation of facts to thoughts. The only scientific philosophy able to translate this process is the philosophy of 'surrationalism', an expression Bachelard often uses to identify the new metaphysics of science.

Despite the fact that new systems of thought envelop old ones, they correspond to two differentiated levels of knowledge. Bachelard does not accept any possible transition or hidden continuity between, for instance, Newton's system and Einstein's system -- contrary to what Mach, Meyerson and Einstein himself suggested. For Bachelard, the relativistic subtleties ('les finesses relativistes') do not correspond in any way to a more accurate application of Newtonian principles. Instead, Euclidean and non-Euclidean geometries correspond to two spatial realities, two plans of abstract thinking and to two different, although not contradictory, systems of rationality (53):

> We do not see in Newton's system anything that would enable us to predict Einstein's and thus undermine the truly transcendental novelty of the modern system. There is no possible inference from the first to the second....It is not possible to talk of approximation between both systems.... Even in their search for precision, these two methods are irreconcilable, as they follow two completely heterogeneous modes of thinking....The Newtonian system does not neglect a part of something, it neglects something else....Relocated (...) at the center of the Einsteinian synthesis, Newton's construction represents nothing but a state of numerical evaluation. If we take it separately, that construction loses its realistic value. It has only a pragmatic value.(54)

To Bachelard, Einsteinian relativity is the example 'par excellence' of an epistemological rupture between contemporary scientific knowledge and both common knowledge and classical science. He develops this point particularly in the books written between 1927 and 1940. La Valeur Inductive de la Relativité (1929), Le Nouvel Esprit Scientifique (1939) and l'Expérience de l'Espace dans la Physique Contemporaine (1937), for instance, offer full accounts of relativity in its conceptual history and its epistemological implications. Both aspects stem from: (1) the identification of contemporary science as a science of relations rather than of isolated objects; (2) the articulation of the fundamental principle of rectification through approximation to a probabilistic phenomenology ('phénoménologie probabilitaire')(55); (3) the methodological importance of 'induction' and 'synthesis' as contrasted with the use of 'deduction' and 'analysis' in modern scientific reasoning.

In the Étude sur l'Évolution d'un Problème de Physique (1927) Bachelard stresses that scientific thought works by methodologically incorporating phenomena into relational systems, formed by "general elements mathematically coordinated."(56) We have seen previously how in Bachelardian epistemology concepts themselves need to be incorporated into 'systems of thought' in order to get their full meaning. In a sense, it is possible to talk of scientific concepts as logical consequences of particular axiomatics, outside of which they would lose all their heuristic value. Relational systems are directly linked to relativity, because relativity, too, assumes certain absolute points of reference around which explanations are produced, and relies upon probability and "relational rather than substantial qualities."(57) Obviously, the notion of relation in science not only includes relations between concepts, or relations between phenomena, but also the particularly unstable relations between concepts and reality:

> After having established the relation [between objects], which may almost be done from a strict logical point of view, it is necessary to study the extremely mobile conditions of its applicability. This study is not completely empirical. As irrational as the perturbation that overlaps with the logical aspect of reality may be, we will have some means to apprehend ('epouser') the movement of that irrationality.... Approximation is an attempt of this sort.(58)

In a sense, the constancy of approximations and rectifications in science (59) has to do with the degree of uncertainty, irrationality and guess work that comes from the concept of 'relation' itself. At the same time, the probabilistic nature of scientific objects and explanations, formalized for instance in Heisenberg's revolution, does not reduce the importance of objectivity in science, but instead reshapes it into what Bachelard calls 'objective indetermination'.(60) In other words, contemporary science deals more with probabilities than with certainties, and the search for a hidden causality is nothing but "the causality of what is probable."(61)

In La Valeur Inductive de la Relativité (1929) Bachelard is particularly interested in developing the category of approximation and its connection with the category of rupture or break, in the context of Einsteinian relativity. Both induction and synthesis, as representatives of the unity between mathematics and experience,(62) reflect the essential ambiguities in physical verification ('vérification physique') and its formal rather than material validity:

> As it is not a metrical organization, relativity cannot have value except as a theoretical hypothesis of coordination. This hypothesis (...) even escapes the rules of common verifiability. It cannot have any value except for its extension or clarity of spiritual synthesis.(63)

Once again, Bachelard is interested in contrasting the purposes of classical science and its concern with precision to the extreme generality offered by contemporary science. The idea is to emphasize the essentially different nature of these two systems of thought and thus their 'discontinuity'. The claim that each of these systems represents a particular approximation to reality makes it clear that 'approximation' cannot be defined as a gradual path towards an ever more perfect knowledge. Instead, approximation entails a sort of 'intentionality' that generates its own objects and methodological approaches to nature. Euclidean geometry is considered as a first approximation; the shift to non-Euclidean geometry implies a shift to a second approximation.(64) Consequently, both approximations are discontinuous with each other.(65)

To highlight the heterogeneity between these two approximations, we notice that the analytical and deductive character of classical and modern science is replaced by the inductive and synthetic characteristics found in contemporary science. This is illustrated by the importance given to the latter in the development of mathematical physics. Mathematical physics, born with Newton,(66) incorporates an ideal of simplicity for science and "intuitively constitutes the 'a priori' framework of a mathematization of reality."(67) It was meant to be an absolute and closed system through which all empirical observations would be analysed and laws deduced. With contemporary science, the role of mathematical physics has radically changed from a simple tool to a way of thinking:

> If we extend relativity to what we think to be its metaphysical consequences, we have the impression that the mathematical conditions from which it departs multiply and prolong themselves into an essentially mathematical ontology. In other words, mathematical conditions (...) are a part of being (...); being is made out of their richness and coordination.(68)

As we have previously seen, the new mode of thinking initiated by the works of contemporary science and illustrated by its history also includes (1) new modes of conceptualization, (2) the importance given to the relationships between concepts and phenomena ('au commencement est la relation') and (3) the constructive quality of the new scientific mind. The essence of relativity lies in its being a rational construction that aims at organizing reality rather than something that can be deduced from primitive intuitions or cognitions of reality.

Approximation is not so much to reality as to rationality. This does not imply, however, that relativity is committed to philosophical idealism. Instead, 'approximation' is a dialectical effort towards rectification of previous theories. It ascribes to reality a completely new epistemological role, and to science a new philosophy -- applied rationalism:

> In a way, pure possibility is going to penetrate reality, and give it (...) its true figure. By the same token, reality is going to strengthen the framework of pure possibility. Reality and possibility are going to be subsumed under a totality of a particularly homogeneous order. They will become mobile and substitutable pieces of a rational construction.(69)

In the context of this cooperation between mathematics and experience (70) -- and to Bachelard 'experience' is not the same as 'observation'(71) -- mathematical physics is not only important for its inductive value, but also because it enables the theoretical physicist virtually to construct scientific objects. These scientifically constructed objects will help the scientist to understand better natural phenomena at their first level of approximation. This is why, in the case of chemistry, for instance, "the artificial side of experimentation shows up immediately."(72)(73) So, rather than yielding an empirically based phenomenology, mathematical physics establishes the grounds for what Bachelard calls 'phenomenotechnics', the true scientific phenomenology.

<u>Subsection 4</u>. 'Phenomenotechnics' and the 'technical organization' of scientific reality; the

'scientific and technical cities' as loci of 'social objectification.'

Phenomenotechnics is one of the most curious of Bachelard's categories, as it often appears connected with other notions like 'scientific city' and 'social control'. The category of phenomenotechnics is explained for the first time in the article "Noumène et microphysique" (1931-32), but it is only from Le Nouvel Esprit Scientifique (1934) on that it becomes a fundamental category. Both 'phenomenotechnics' and 'scientific city', however, are referred to implicitly, prior to 1934, e.g., when Bachelard refers to the importance of instruments and technology in the construction of science (74), and to the social consensus required in the notion of 'objectification'(75). Throughout most of his writings, Bachelard insists that scientific objects -- as opposed to natural objects -- are products of instruments and theories. Scientific instruments, on the other hand, are 'reified' or 'materialized' theories (76). Instruments do not simply mediate between scientists and reality; they provide the locus where scientific objects are virtually constructed according to (1) rational coherence and (2) social objectification.

References to technology, techniques and their importance in making science precise are very common in works like the Essai sur la Connaissance Approchée (1928), Les Intuitions

Atomistiques (1933), Le Nouvel Esprit Scientifique (1934) and L'Expérience de l'Espace dans la Physique Contemporaine (1937). The connections established between microphysics and instruments, for instance, are of such importance that they introduce a philosophy of scientific technology into Bachelard's epistemology. The result is an 'instrumental epistemology'(77), embodied in the quasi-sociological category of phenomenotechnics.

In the Essai sur la Connaissance Approchée Bachelard already refers to the "primordial role of instruments in the approximate knowledge of physics" ('les connaissances approchées en physique')(78)(79), and the obvious dependence of scientific knowledge upon the instrument's degree of sensitivity and precision. The fact that "precision in measurement (...) characterizes the scientific methods of a certain time"(80) enables us to say that "the history of approximate knowledge is the history of scientific systems"(81) and makes science subordinate to a certain form of instrumental determinism.(82) On the other hand, to the degree that we admit that the study of reality is technically organized(83), we have to acknowledge that the content of scientific knowledge is at least as artificial as the techniques imposed on reality and used to temporarily validate particular theories:

> The scientist faces an artificial nature. He

> does not study a mixed and global phenomenon that offers a general and lazy interpretation [but instead] fragments reality down to the interior of its categories.(84)

As Bachelard claims in Les Intuitions Atomistiques, it is technology and technique that allow this artificial fragmentation to take place:

> With instruments [we do not aim at] reconstructing the phenomena as they offer themselves to us through our senses; on the contrary, we aim at a phenomenon that is precise, schematized, impregnated with theory. This phenomenon is not found, but instead it is produced. Modern science [is] a science of effects.(85)

If instruments are materialized theories, artificial scientific phenomena instrumentally produced necessarily have a theoretical label(86) which they are meant to justify and strengthen. Bachelard thinks that we should consider scientific phenomenology as essentially a phenomenotechnics (87). In this context, it is appropriate to talk of technological axiomatics that organize research as much as scientific theories and mathematical postulates do. Tensor calculus, for instance, is considered by Bachelard as a "mathematical instrument that creates contemporary physics the same way the microscope creates microbiology."(88) This enables us to understand better (1) the primary role that should always be given to theory formation and (2) the creative aspect of scientific thought reified in the technical production of scientific objects.(89)

The production of scientific objects -- phenomena impregnated with theory -- necessarily involves the organization of precise scientific research programs(90) to justify, reify and rectify it. In contemporary science, the responsibility for this organizational aspect, as well as for all techniques of realization (91), whether theoretical or instrumental, comes from the 'scientific city'.(92) La Formation de l'Esprit Scientifique (1938), as we have seen, is basically focused on the psychological aspects of the scientific mind at work. It is the only book written between 1927 and 1940 that connects scientific knowledge production with the normative aspects of the scientific city. Basically, two factors are involved in this connection: (1) the work of the scientist is not performed in isolation -- even great discoveries presuppose some form of verification and acceptance from the scientific community; (2) modern standardization of instruments and techniques -- as opposed to instrumental heterogeneity of the scientific and pre-scientific periods -- allows superior levels of objective precision and sensitivity.

Bachelard's speculations on phenomenotechnics and rational coherence reified in complex scientific societies seem to imply a sociological approach to scientific knowledge. This 'sociology', however, at least in the first epistemological period we have been analyzing, does not produce the rhetorical 'jump' from admitting that scientific objects -- and thus science -- are artificially created through standardization and consensus, to the idea that scientific knowledge is 'in toto' socially constructed. Bachelard's idea of 'social control' (93) and the foundation of scientific objectivity on 'social objectification' emphasizes the aspects of scientific work connected with 'recognition' and 'intersubjectivity', rather than identifying science as one more social product. 'Reasons of group' and the 'instinct of social objectification' in the acceptance of scientific knowledge exist within a scientific city, but are only considered 'social' when finally taught in schools.

Culture infects the scientific mind. The psychoanalysis of scientific thought and the history of science are meant to identify all cultural, intellectual and intuitive factors that constitute obstacles to the normal path of scientific thinking processes. In this respect, the influence of social factors in science is more an influence that has to be discovered and discarded rather than part of science's destiny:

> We suggest (...) a prior doubt that has to do at the same time with facts and their liaisons, experience and logic. If our thesis seems artificial and useless, it is because most people are not aware that modern science works on experimental materials and logical frameworks that have long ago been socialized and consequently controlled. Every precise measure is a prepared measure. The order of increasing precision is an

> order of increasing instrumentalization, thus of increasing socialization.(94)

Nevertheless, the relative ambiguity of some of Bachelard's earlier assumptions on what he considers to be 'social' in science will be clarified in his three last books on epistemology.

SECTION II - (1949-1953)

<u>Subsection 5</u>. Epistemology as a 'philosophy of the hierarchy of scientific thoughts'; new categories ('psychosynthesis', 'rupture of intentionalities'and 'mutual agreement') as old categories revisited; 'phenomenotechnics' as a particular case of phenomenology and of philosophy of technology; 'intersubjectivity' and 'tacit agreement' in science; contemporary science as an illustration of the permanent mobility of reason.

As I have said in the introduction to this chapter, after the publication of <u>The Philosophy of No</u> (1940) there was an eight year period (95) during which Bachelard only wrote books on imagination and literary criticism. From 1949 to 1953, he returned to the publication of books on history and philosophy of science, intermingling them with writings on other topics that had interested him between 1941 and 1949.(96) A comparison between Bachelard's epistemological preoccupations from 1927 to 1940 and, afterwards, in 1951 and 1953, show that they did not undergo any deep structural or conceptual change. The categories discussed above, as well as their articulation, remain practically unchanged. Another sign of epistemic consistency in Bachelard's philosophy of science is provided by the many references to the works of the first period in the later books -- particularly La Formation de l'Esprit Scientifique and The Philosophy of No.(97) The return to psychoanalysis of scientific thought in Le Rationalisme Appliqué (1949) and epistemology of chemistry in Le Matérialisme Rationnel (1953) provide further evidence for this inner coherence. Again, Le Matérialisme Rationnel is considered by Bachelard as providing further support for the theses defended in both Le Rationalisme Appliqué and L'Activité Rationaliste de la Physique Contemporaine (1951).

Some things changed, of course. As before, Bachelard chooses to emphasize certain aspects of his epistemology and relegate others to secondary status, not because they are not important any more, but because they are already explained elsewhere. Although we may consider this as a strategy adopted to encompass new elements provided by nuclear physics, for instance, the fact is they make us aware of a set of problems that should be dealt with in science studies. Any change in Bachelardian epistemology only makes more relevant the importance, given by Bachelard himself, to a 'poliphilosophy' capable of translating the psychological features of the new scientific mind at work.

Structurally speaking, it is possible to find many similarities between the earlier books and the later ones. The list of Bachelard's positions given at the beginning of this chapter applies to both periods. At a more superficial level, the extreme descriptive complexity of case studies in the history of physics and chemistry, which had almost disappeared in 1938 and 1940, reappears in 1949 and 1953. However, the purpose is not to explore the history of a single concept, as it had been in Les Intuitions Atomistiques, or a single problem, as in L'Évolution d'un Problème de Physique. Instead, the purpose is to present new case studies that emphasize the need for a renewed epistemology of science. Bachelard refers to this epistemology as a "philosophy of the hierarchy of cultural thoughts, of active thoughts in a culture."(98)

The criticism of traditional philosophies of science remains the same. This criticism is thoroughly developed in L'Activité Rationaliste de la Physique Contemporaine. In Le Rationalisme Appliqué, traditional philosophies are schematically positioned in correlation with applied rationalism (and technical materialism):

Idealism
↑
Conventionalism
↑
Formalism
↑
Applied Rationalism and Technical Materialism
↓
Positivism
↓
Empiricism
↓
Realism

(99)

As we can see from the above chart, idealism and realism, for instance, represent the philosophical extremes of pure rationalism or pure materialism in science. Although they correspond to stages of science in its connections with common knowledge and past scientific achievements, they are completely outmoded. They do not represent in any way the necessary dialectic between reason and experience defended by applied rationalism. All other philosophies are inadequate approximations to the real scientific philosophy.

The above presentation is useful because it synthesizes what Bachelard had attempted to explicate in earlier books, and it introduces the dialectic purposes of both scientific thought and scientific philosophy. It also enables Bachelard to return to the issues of the artificiality of scientific reality, and of science as being constantly rectified. Science and its historical development helps build the historical development of reason, the history of rationalist culture(100) in its spiritual activity.(101) At the same time, the study of history of science enables us to detect the epistemological paths of sciences and to what point, due to its different stages of evolution, is still bound to be interpreted by different degrees of philosophical analysis.(102)

Le Matérialisme Rationnel and Le Rationalisme Appliqué are interesting in the sense that they present us with the suggestion of even newer categories, like 'psychosynthesis' (103), 'rupture of intentionalities'(104), 'mutual agreement' ('interconstatation').(105) However, these categories do not really introduce epistemological novelties beyond those contained in previous categories like 'psychoanalysis', 'epistemological rupture', and 'social objectification'. If we take a look at the sense of epistemological 'intentionality', for instance, another new category, it is easy to realize that it represents Bachelard's familiar preoccupation with the subject itself as a mixture of culture, consciousness and rationality:

> When it comes to (...) scientific thought, we cannot trust the immediacy of a 'non-me' as opposed to 'me'. The scientific object is positioned in the perspective of its definition after the 'me' was already in a particular kind of thinking and a particular kind of existence. The rationalist cogito that tends to affirm the thinking subject in an apodictic thought activity must function as an emergence above an already more or less empirically affirmed existence.(106)

This aspect of subjectivity is just an extension of

Bachelard's psychoanalytical speculations. His concerns were always directed to psychoanalyzing both scientific objects and scientific minds. In this respect, Le Rationalisme Appliqué (1949) is not an improvement over La Formation de l'Esprit Scientifique (1938), although the vocabulary used in 1949 is perhaps more phenomenologically oriented than before. However, the category of 'mutual agreement' is of more interest here, as it seems to give Bachelard's epistemology certain 'sociological' characteristics:

> [Mutual agreement] forms itself before the agreement between the 'I' and the `You`, because in its first form it appears within the isolated subject, as a certainty of agreement with a rational other (l'autrui rationnel')....It is possible to force awareness: as I acknowledge that what I just thought is a normality to normal thought, I have means the to force you to think what I think....You will think what I thought as soon as I make you aware of the problem that I have solved. We will be united in the proof as long as we have the guarantee of having clearly posed the same problem....There is consecration of method, proof of thought efficiency, socialization of truth.(107)

A study in Husserlian phenomenology might help us to better interpret the above passage, particularly the concept of intersubjectivity implicit in Bachelard's notion of 'mutual agreement'. But for our purposes, I will stress merely Bachelard's emphasis on what he considers to be a 'tacit agreement',i.e., an assumed rule of the scientific community and technical city. This agreement directly connects with two qualitatively different but intertwined factors: (1) the possibility given to the scientific community of rationally assessing the degree of a theory's explanatory adequacy, and (2) the implications for science of the standardization of measuring instruments and scientific methodologies. The technical methodologies surrounding scientific thought and practice were discussed under the category of 'phenomenotechnics'. Now the idea of tacit agreement within the technical and the scientific cities(108) is much more systematized in the works of 1949 to 1953. However, two factors prevent these notions from collapsing into pure sociology: (1) the classification of the new sciences as revolutions of reason (109) and (2) the notion that the scientific city has to establish itself independently of the social city:

> If the spirit formed itself directly inside the scientific city, we could do an economy of psychoanalysis of psychologism and directly establish the principles, not of reason (...) but the principles of the rational organization of scientific culture. But that is not the case. The scientific city is established at the margin of the social city. So the scientific city must fight against a particular psychology in order to create a new psychologism. [The scientific city] will always transcend not only common knowledge, but also the primary knowledge of culture ('connaissance de première culture').(110)

Despite what was said, we cannot neglect the epistemological consequences of Bachelard's orientation towards an analysis of scientists' and technicians' relationships. This point is particularly clear in L'Activité

<u>Rationaliste de la Physique Contemporaine</u>:

> Following contemporary physics, we abandon nature to enter the factory of phenomena. Rational objectivity, technical objectivity, social objectivity, are from now on three strongly connected aspects. If we forget but one of these aspects of modern science, we enter the domain of utopia.(111)

The aspects mentioned in the above quotation also include second level assumptions: (1) the intersubjective quality of scientific thought gives it an undeniable social character(112); (2) the progress of science is proof of its social character(113); (3) scientists depend on codified objectivity values(114). These assumptions are consistent with what Bachelard had stressed in his earlier books about 'social objectification' and 'tacit agreement' in science. As we have said, the social aspects Bachelard seems to find in scientific thought are not meant to trivialize the content of science or equate it with just one more socially determined phenomenon. Science should rely on its own concepts. Bachelard's purpose is to bring out contemporary characteristics of science: collectiveness, communication and specialization as embodied in precise research programs. The acceptance of theories is more a matter of rationality than of negotiation. The determinism of science is rational and technical rather than purely social, if we take 'social' as meaning more than a micro-level agreement upon what is rationally objective.

In <u>L'Activité Rationaliste de la Physique Contemporaine</u>, Bachelard returns to the emphasis in his earlier works on the need for a radical reform in both philosophy and history of science. It is science that teaches philosophy to become the correct scientific philosophy. Philosophers should go to school with scientists because science has created a form of philosophy of which both philosophers and scientists are still unaware. The task of philosophy must be to inflect its language in order to translate contemporary scientific thought in its flexibility and mobility. It is history of science that constitutes evidence of scientific progress, particularly the "historical rupture in the evolution of modern science"(115), and the dialectic of epistemological obstacles and epistemological acts.(116) History of science has a double role which is expressed for the first time in <u>L'Activité Rationaliste de la Physique Contemporaine</u> in the following terms:

> We must understand the importance of a historical dialectic suited to scientific thought. It is necessary to present science to form and reform the dialectics of expired history ('histoire perimee') and sanctioned history ('histoire sanctionne') by the present science. The history of phlogistic theory is expired because it rests upon a fundamental error....An epistemologist should only be interested in it as it provides him with motives to psychoanalyse objective knowledge. A historian of science (...) must know that he is working on the paleontology of an extinct scientific mind....Contrary to the phlogiston hypothesis, other works such as Black's hypothesis on caloric (...) should be considered as elements of sanctioned

> history. There is a constant interest in knowing them theoretically, illuminating them epistemologically, and following their incorporation in a body of rationalized concepts...There are concepts so indispensable in a scientific culture that it is impossible to conceive abandonning them.... Reason (...) distinguishes between motives that engage future thought and notions that are gauges of a future for culture.(117)

Normativity had already been pointed out in Bachelard's earlier writings as a fundamental trait in the new history of science. It allows the detection of epistemological obstacles and it accounts for the dynamics of science as a dialectical process where experience is just a condition within the possibilities offered by mathematical rationalism. As the normal process of science involves a gradual separation between rational life and oneiric life, abstraction and imagination(122), the psychoanalysis of scientific thought is intrinsic to epistemology. However, psychoanalysis can only be performed with the material provided by the selective works of the historian of science. History shows us continuities and ruptures, evolution through error and revolution, concept rectification and reality approximation. These studies also imply an awareness of the technical methodologies of science and the procedures of theory acceptance through rational tacit agreement.

NOTES

(1) ECA, 13.

(2) PN, 4.

(3) For a good study on Bachelard's notion of dialectics, see Canguilhem, G. "Dialectique et philosophie du non chez Gaston Bachelard" in Etudes d'Histoire et de Philosophie des Sciences (1983): 173-207.

(4) PN, 5.

(5) PN, 36.

(6) PN, 35.

(7) PN, 37.

(8) PN, 18.

(9) ECA, 19.

(10) PN, 19.

(11) ECA, 19.

(12) ECA, 23.

(13) ECA, 249.

(14) "L'Idéalisme Discursif"in Études, 89.

(15) Bachelard used Léon Robin's La Pensée Grecque et les Origines de l'Esprit Scientifique to get most of the information pertaining to atomism in ancient philosophy.

(16) IA, 12.

(17) IA, 14-15.

(18) FES, 46.

(19) FES, 13-14.

(20) "We must constantly demonstrate what remnant of common knowledge still resides in scientific knowledge." PN, 35.

(21) ECA, 5.

(22) IA, 23.

(23) NES, 41.

(24) NES, 42.

(25) NES, 43.

(26) ECA, 62.

(27) See also Lecourt, Dominique Bachelard le Jour et La Nuit, Chapter IV.

(28) Bachelard continues to develop the role of psychoanalysis in Le Rationalisme Appliqué, especially in Chapter IV -"La Surveillance intellectuelle de soi".

(29) FES, 17-18.

(30) FES, 17.

(31) FES, 61.

(32) "The epistemologist has to work only upon really salient data. His discipline relates to facts that science has found, to thoughts that have indeed worried scholars ('savants') and schools of thought. To the epistemologists, a valid idea is an idea that turned out to be influential." PCCM, 19.

(33) FES, 17.

(34) This idea corresponds probably to what later on Michel Foucault would call 'epistéme'.

(35) FES, 46.

(36) For further information on Bachelard's history of science, see Martin, R. "Dialectique et esprit scientifique chez Gaston Bachelard" in Études Philosophiques, 4 (Oct.-Dec. 1963): 404-419.

(37) FES, 6.

(38) The only things that excuse this historical division are the fact that Bachelard recognizes it at once as a "grossière étiquette" and that, at least for the reader, it represents

an agreeable change on the opaque complexity of the case studies presented evrywhere else in his books.

(39) FES, 8.

(40) PN, 16.

(41) The distinction Bachelard makes in Le Rationalisme Appliqué between 'historical formation' and 'epistemological formation'seems to be adequate in this context.

(41) PN, 16.

(42) For a nice study on Bachelard's model of scientific change, see Gary Gutting's article "Gaston Bachelard's philosophy of science" in International Studies in the Philosophy of Science, 2 (1987):55-75.

(43) FES, 16.

(44) "Lumière et substance", in Études, 47.

(45) Interestingly enough, Bachelard's preoccupations concerning the way the scientific mind works and builds knowledge according to specific systems of thought directly connect to two contemporary trends in science studies: constructivist philosophy and psychology of science.

(46) EEPC, 29.

(47) NES, 10.

(48) PN, 92.

(49) NES, 12.

(50) PN, N139.

(51) On the possibility of some form of 'incommensurability' in Bachelard's epistemology, see David Theobald's "Eclecticism in the philosophy of science", in Technology and Society, 5, 2 (1969): 56-59.

(52) This dialectic relationship between theories is nicely developed in A. Grieder's "Gaston Bachelard - 'Phénoménologue' of modern science", in Journal of the British Society for Phenomenology, 17, 2 (May 1986): 107-122.

(53) PN, 43.

(54) VIR, 43-48.

(55) NES, 121.

(56) EEPP, 158.

(57) NES, 33.

(58) ECA, 152.

(59) To Bachelard, rectification also implies discontinuity: "It is not by a simple historical accident that Relativity was born to deny the ether conception in Michelson's experiment. Relativity does not <u>continue</u> previous theories, it <u>rectifies</u> them." VIR, 148.

(60) NES, 126.

(61) NES, 121.

(62) VIR, 8.

(63) VIR, 19.

(64) VIR, 30.

(65) The normative character that Bachelard ascribes to history of science and the idea that scientific reason develops historically, does not seem to coincide with his apparent acceptance of all systems as atemporally valid -- at least if we see approximation the way it was just described. If, on the other hand, we see approximation as something that can be originated within the same 'system of thought', then we will also have to accept a certain continuity of systems and, thus, the denial of a diversity between systems.

(66) VIR, 28.

(67) <u>Ibid</u>., 28-29.

(68) VIR, 211.

(69) VIR, 81.

(70) "Noumène et microphysique", in <u>Études</u>, 21.

(71) "Contrary to common belief, there is no continuous line between observation and experimentation. Instead, there is

a reversal of perspective." MR, 219. 'Experimentation' implies the existence of prior scientific referential frames that shape and structure scientific problems. This 'objectivity' does not exist in individual, immediate observation.

(72) PCCM, 65.

(73) For more information on Bachelard's philosophy of chemistry, see David Theobald's "Gaston Bachelard et la philosophie de la chimie", in Archives Philosophiques, 45 (1982): 63-83.

(74) ECA and IA.

(75) VIR.

(76) IA, 140 and NES, 16.

(77) ECA, 77.

(78) ECA, 61.

(79) Most of the time, the definition of 'instrument' also makes room for methodologies and mathematics.

(80) ECA, 69.

(81) Ibid., 69.

(82) Ibid., 65.

(83) ECA, 160.

(84) ECA, 165.

(85) IA, 139.

(86) NES, 16.

(87) NES, 17.

(88) NES, 58.

(89) The creative aspect of science is pointed out by Bachelard in many places. We think that the following quote from Berthelot's La Synthèse Chimique (1876), used by Bachelard in Le Pluralisme Cohérent de la Chimie Moderne (1932) is most appropriate: "Berthelot a insisté à plusiers

reprises sur cet effort créateur de la chimie moderne: "La chimie crée son objet. Cette faculté créatrice, semblable à celle de l'art lui-même, la distingue essenciellement des sciences naturelles et historiques. Les dernières ont un objet donné d'avance et indépendant de la volonté et de l'action du savant....Au contraire, les sciences expérimentales ont le pouvoir de réaliser leurs conjectures. Ces conjectures servent elles-mêmes de point de départ pour la recherche de phénomènes propres à les confirmer ou à les détruire: en un mot, les sciences dont il s'agit poursuivent l'étude des lois naturelles, en créant tout un ensemble de phénomènes artificiels qui en sont les conséquences logiques. À cet égard, le procedé des sciences expérimentales n'est pas sans analogie avec celui des sciences mathématiques." PCCM, 71.

(90) FES, 33.

(91) FES, 217.

(92) FES, 241.

(93) Ibid.

(94) Ibid.

(95) Perhaps it is worth mentioning that Bachelard wrote articles in epistemology for the Revue de Métaphysique et de Morale in his 'imagination' period.

(96) The overlapping of subject-matters -- epistemology and imagination -- did not happen in this period alone. In 1938, for instance, Bachelard published both La Formation de l'Esprit Scientifique and La Psychanalyse du Feu, and in 1939 Lautreamont came out before The Philosophy of No appeared in 1940.

(97) In the later epistemological period, Bachelard suggests a return to some of his works of the imagination period. For instance, Le Rationalisme Applique points out the importance of his La Terre et les Reveries du Repos (94) RA, 61. Also, La Psychanalyse du Feu is given as a seminal example of the importance that should be attributed to a psychoanalysis of elements and objects worthy of scientific consideration.

(98) RA, 15.

(99) RA, 5.

(100) RA, 31.

(101) RA, 37.

(102) RA, 10.

(103) MR, 72.

(104) MR, 208.

(105) RA, 58.

(106) RA, 50-51.

(107) RA, 58.

(108) RA, 3-6.

(109) RA, 45.

(110) RA, 22-23.

(111) ARPC, 10.

(112) ARPC, 6.

(113) *Ibid*., 6.

(114) *Ibid*., 7.

(115) ARPC, 24.

(116) *Ibid*. 25.

(117) ARPC, 25-26.

Appendix

Bachelard's books

EEPP. Étude sur l'Évolution d'un Problème de Physique: la propagation thermique des solides (1927)

ECA. Essai sur la Connaissance Approchée (1928)

VIR. La Valeur Inductive de la Relativité (1929)

PCCM. Le Pluralisme Cohérent de la Chimie Moderne (1932)

Études. Études (1931-34)

IA. Les Intuitions Atomistiques: Essai de classification (1933)

NES. Le Nouvel Esprit Scientifique (1934)

EEPC. L'Expérience de l'Espace dans la Physique Contemporaine (1937)

FES. La Formation de l'Esprit Scientifique: Contribution à une psychanalyse de la connaissance objective (1938)

PN. La Philosophie du Non: La Philosophie du nouvel esprit scientifique (1940)

RA. Le Rationalisme Appliqué (1949)

ARPC. L'Activité Rationaliste de la Physique Contemporaine (1951)

MR. Le Matérialisme Rationnel (1953)

CHAPTER III - CONCLUDING REMARKS AND AREAS FOR FURTHER RESEARCH

Although the previous chapters of this thesis did not exhaust what can be said about Bachelard's scientific philosophy and the context in which it appeared in France, we may draw some conclusions about the way Bachelard's epistemology was shaped, and add a few remarks concerning its relevance to science studies. This concluding chapter will focus particularly on the following:

1. The relevance of the analytical levels developed in Chapter I (institutional-political, internal-scientific, comparative-philosophical) to Bachelard's epistemology;
2. A brief criticism of Bachelard's philosophical analysis of scientific change;
3. The historical and current value of Bachelard's epistemology as a tool for science studies.

The overview of political and social events in France during the Third Republic helps illuminate Bachelard's historical epistemology only if we take that epistemology as an intellectual reaction against the status quo in French institutions, heavily committed to scientism and positivism. Both were indeed the official philosophies of this period in France. But Bachelard thought that positivism -- in fact, any single philosophy -- did not correctly characterize what was happening in contemporary science. To him, all traditional philosophies (systematized, closed) are unable to conceptually represent the clear rupture separating common knowledge and science. Those philosophies are not sensitive enough to detect the epistemological breaks within mature theoretical sciences, and are totally inadequate to account for the discontinuous, dialectical and historical development of science. Thus, it is not surprising that the interests of the 'École Républicaine'-- the stabilization of the French economy, the development of industry, the emphasis on research and applied science, the construction of modern technology -- do not appear explicitly in Bachelard's books. However, Bachelard' writings often show his resentment of what he calls the 'strange' educational policy implemented by the French governmental cause. He sees the French cultural system as much more concerned with traditional science and modes of explanation than with exposing young minds -- including future scientists -- to the necessity of a fundamental antidogmatism in science.

Throughout the nineteenth-century Germany had had a fascination for particle theories. In this regard, there is a greater affinity between Bachelard's views and what was happening in Germany than in France, particularly the relevance given by German scientific institutions to theoretical physics. Despite his concerns with the psychological and phenomenological rather than the logical character of scientific knowledge construction, Bachelard is very close to the "École Allemande de logique quantique", which originated between 1925 and 1927, and its preoccupations with "trying to reconcile (...) the logical difficulties of quantum theory with the explanation of their consequences at the level of a theory of knowledge."(1)

Bachelard's reflections on the epistemological novelties brought about by contemporary physical sciences after 1905 -- relativity, quantum theory and modern chemistry -- led him to drastically oppose the philosophies of both Émile Meyerson and André Lalande, and thus the orthodox philosophy institutionalized by the 'système universitaire français'. Émile Meyerson (1859-1933), for instance, was considered one of the most prominent representatives of scientific philosophies in France. Meyerson defended realism and causalism in science, as well as the traditional continuity approach to the processes of scientific change. He accepted relativity, because he saw it in continuity with classical physics. But, to him, quantum theory (particularly its interpretation by the Copenhagen School) was not worthy of scientific or philosophical consideration. Bachelard was highly critical of Meyerson's epistemological position, as it did not take into account the need to construct new philosophical concepts for modes of thinking that are radically different from those embodied in the classical sciences.

Bachelard was not isolated in his opposition to the French system. He definitely sided with Hamelin, Henri Bergson and Brunschvicg. Although very much aware of the values of French culture, Bachelard was also fairly representative of a group of avant-garde French intellectuals who thought that institutions should adapt to constant cultural and scientific change. As we have seen in Chapter I, Bergson, for instance, defended continuity in science. But, like Bachelard, he attacked scientific dogmatism, positivism and rationalism, and argued for radical changes in scientific philosophy.(2) Obviously, the awareness of the need for change in French epistemology had to do with the cultural milieu in the first decade of the twentieth century. The members of the avant garde sought a return to irrationalism and subjectivism, the recognition of the importance of the unconscious and, of course, the absorption of scientific novelties coming from Germany, Austria, and even from France.

Bachelard's epistemology was shaped by these new values; they certainly constituted a motivation for his interest in building a new vocabulary for science studies. His emphasis on subjectivity, on the necessity of building a psychoanalysis of scientific objects (3), on the importance of history as an illustration of the progress of reason (4) and on the city of science as a locus of rational and technical production of scientific objects, illustrate the features of his epistemology that connect with the above mentioned Franco-German dynamic cultural context.

It is much harder to specify the relationships of Bachelard's thought with ongoing scientific controversies. Chapter I emphasized Bachelard's acknowledgment of the role of axiomatics in science, the new scientific methodologies required by relativity and quantum physics and their implications for philosopy of science. Like Duhem, Poincaré, Meyerson and Brunschvicg, Bachelard was trained in the French scientific milieu. But as far as we know, he never really established direct contact with the theoretical physicists of his time. He often mentioned Einstein, Bohr, Dirac, Louis de Broglie or Heisenberg, but unlike Meyerson who at least had one of his books reviewed by Einstein (5)(6), he never had a similar kind of 'rapport' with the scientific establishment. To a certain extent, this lack of contact can be criticized, particularly because Bachelard himself emphasized the inadequacy of the philosophy of the scientists as a portrayal of the character of their science and the need for traditional philosophers to go to school with scientists to learn how the new scientific mind works.

It is difficult to understand how it was possible for Bachelard to locate the new scientific mind in 1905 with relativity, especially since Einstein himself defended determinism, causality and continuity in physics, exactly the opposite of what Bachelard saw in the theory. Strangely, although the philosophical implications of Bohr's theory are much more in line with Bachelard's epistemological assumptions (probability, discontinuity, etc.),(7) that theory does not seem to play as central a role in Bachelard's books as does Einsteinian relativity.

Another criticism of Bachelard is that he does not seem to be fully aware of the fundamental incompatibility between the quantum theory and relativity theory for the purposes of his epistemological categories.(8) Instead, he classifies both as exemplars of a radical discontinuity between common sense and classical scientific knowledge and contemporary science. For instance, he does not take into account the ways in which his concept of phenomenotechnics has more to do with the interference of the observer and measuring instruments at the micro-level (acknowledged by Bohr) than with the absolute character of the laws of nature regardless of the reference frame (defended by Einstein). On the other hand, Bachelard's classification is epistemologically accurate if we take into consideration his claim that each system of thought represents a different intentionality, that each of them is not more of the same, but instead 'something else'. This may imply a fundamental incommensurability, one that highlights the versatility suggested by the scientific mind at work.

The fundamental discontinuity that Bachelard sees between classical and modern science is hard to understand, particularly if we try to connect it with the concept of incommensurability. Like relativity and quantum mechanics, classical and modern science belong to two different systems of thought and two different approximations to reality. Furthermore, Bachelard claims that modern science is a 'rectification' of classical science. The category of 'rectification' involves an attachment between systems, and thus creates a sort of functional unity. Bachelard accepts rational determinism reified in the progress of reason and illustrated by the development of the sciences into stages of increasing maturity. Precisely because of this rational determinism, he would have to admit that there cannot be a total incommensurability between classical and modern science, even if they are relatively independent. A complete independence justifies how the claim that concepts represented by identical terms designate 'something else'(cf. the example of 'temperature'). However, it does not explain how modern scientific concepts are purifications of prior concepts, particularly if, as Bachelard says, they do not contradict one another.

Without passing through Newtonian mechanics it is impossible to reach the creative possibilities opened up by the concepts of relativity. Non-Euclidean geometries do not contradict Euclidean geometry, but instead permit the 'totalization' of geometric thought. By the same token, classical and modern science represent a temporary 'totalization' of the thought of physical science, and thus they should mean more to each other than the category of 'epistemological break' allows. I think Bachelard tries to solve this difficulty by using an ahistorical division to explain the several stages in the development of scientific reason. This division accepts both a dialectic between qualitatively different things -- realism and idealism, reason and experience, for instance -- and the notion that there is no linear progress inside one single science and among the sciences themselves. So, if one seeks to identify Bachelard's category of 'epistemological break' with 'incommensurability', one should take into consideration that the first includes the notions of 'rectification', 'totalization', 'approximation' and 'intentionality'. In this respect, it would be of interest to contrast Bachelard's epistemological category of 'rupture' with alternative routes to incommensurability, e.g., Feyerabend's.(9)

Philosophically, we can classify quantum mechanics as a form of logical positivism, whereas relativity may be seen as the scientific expression of abstract realism.(10) Bachelard did not commit himself to either one -- positivism or realism.

Rather, what he defended was a dialectic between the two -- applied rationalism -- capable of expressing the dynamics of scientific thought in constant struggle against epistemological obstacles represented by intuitions, intellectual habits and past scientific knowledge. Unfortunately, we are never faced in Bachelard's writings with clear definitions of what he calls 'traditional philosophies', as he is not particularly concerned with a hermeneutics of failed epistemologies.

Regardless of such critical considerations, I hope to have shown the importance of Bachelard to science studies. In Chapter II, I surveyed Bachelard's works on epistemology and articulated his epistemological categories. The aim was to show how his epistemology connects with the philosophy and history of science, philosophy of technology, and with many problems we now pursue in science studies. Obviously, the picture I produced of Bachelard's scientific philosophy is not complete. However, it already conveys the idea that a comparison of his views with those of Fleck (on the non-cumulative features of science), Popper (on discontinuity, falsifiability and error), Kuhn (on paradigms and revolutions) and Hacking (on philosophy of technology), for instance, would be of great interest.(11)

Bachelard is an original thinker. Although he owes much to Henri Bergson, Hamelin and Léon Brunschvicg, Bachelard was really the first French philosopher to systematize an epistemology that closely followed the progress of theoretical physics. Recognition of the importance of introducing history into epistemology began with Duhem, Meyerson and the 'école positiviste'.(12) Bachelard, however, was the first to pay attention to history of science as a history of the development of sharply separated systems of concepts. This development led him to believe that each science and each stage in the history of a single science implies logically independent sets of concepts and a fundamental conceptual discontinuity between epistemologically and ontologicaly different systems of thought.

To Bachelard, history of science is the history of the formation and reshaping of concepts. History of science is the history of the progress of scientific knowledge through the creation of multiple discontinuous systems of approximation to reality, all representing just a small portion of what is rationally possible. Bachelard's history of science is neither purely 'internal' nor 'external' history. His category of 'epistemological obstacle' suggests an external approach, because it implies the interference of external factors -- intuitions, metaphors, intellectual habits, institutions, etc. -- that shape the way science is built. On the other hand, Bachelard's claim that science has to liberate itself from those interferences also suggests that science must establish its own rules at the margin of cultural and societal values. This is clearly an internal approach to science, and helps explain how prior scientific discourse becomes non-scientific. It also explains the existence of two parallel histories of science: a history of errors, and a sanctioned history of lasting and potentially creative concepts.

Science creates its own discourse, and scientific technology -- 'humain, trop humain' -- creates its own objects, in clear opposition to 'nature':

> As bizarre as such an expression is, one must recognize that particles are human. They are very 'twentieth century', with the slight exception of the precursor electron. No imaginary history, no philosophical utopia, could detach them from the epoch of the maturity of the electrical techniques where they appeared.(13)
>
> The most typical particles -- the electron, proton, positron and neutron -- all appear in the technics of electrical phenomena.... These electrical techniques are not 'natural'.(14)

The connection of the above quotations from L'Activité Rationaliste de la Physique Contemporaine with the category of 'phenomenotechnics' is obvious. Bachelard's epistemology often emphasizes the role of instruments in the construction of scientific knowledge. In L'Essai sur la Connaissance Approchée (1928) he already refers to the scientific study of reality as being technically organized. Scientific technology creates scientific objects, and instruments are materialized theories. This implies a dialectic that only applied rationalism is capable of explaining. Furthermore, the rules of both the construction of science and technology are established through 'social consensus' within the scientific city. The human aspect of scientific culture is also embodied in the category of 'phenomenotechnics'. The development of these issues in Chapter II shows how Bachelard's writings may be of value to history and sociology of science, and especially philosophy of technology.

Unlike those working in the Anglo-Saxon epistemological tradition, preoccupied with the principles of the sciences, Bachelard is much more concerned with studying the scientific mind, and with what he called the historical and psychological development of scientific knowledge. Although extremely critical -- as Husserl had been -- of any form of psychologism, Bachelard was influenced not only by psychoanalysis, but also by the psychologists Pierre Janet and Jean Piaget. But his use of their work was quite original. In the case of psychoanalysis, for instance, he said:

> In fact, classical psychoanalysis,especially internal psychology, that is to say, individual psychological reactions determined by social and family life, did not direct its attention to objective knowledge. It did not see that there was something special in the human being that abandons men for objects.(15)

In this respect, it would be interesting to connect some of Bachelard's non-epistemological works -- La Psychanalyse du Feu (1938), L'Eau et les Rêves (1942), L'Air et les Songes (1943), La Flamme d'une Chandelle (1960) -- to the epistemological ones. As we have seen above before, La Formation de l'Esprit Scientifique and La Psychanalyse du Feu, both published in 1938, are complementary works, as the latter is a psychoanalytical case study that illustrates the approach to scientific knowledge made in the former. In any case, it is easy to see that Bachelard's studies would be of great interest to the psychology of science.

As for sociology of science, Bachelard's later works seem to have some bearing on a number of issues, particularly through the categories of 'social objectification', 'tacit agreement' and 'phenomenotechnics'. Most of the problems they raise regarding intersubjectivity are related to phenomenology and the philosophical aspects included in Husserl's phenomenological psychology. But the fact is that those categories have overtones of what we call today the 'social construction of science'.

There is some ambiguity in Bachelard's explanations concerning the way science is produced inside the scientific city. The vocabulary he uses is clearly sociological. Both 'social consensus' and the category of 'phenomenotechnics', for instance, definitely have social connotations. Bachelard may not have been aware of this fact, particularly at a time when the demarcation between psychology and sociology was not as sharp as today. Although missing important points such as the effect of society as a whole upon scientific events, the above categories should be taken as highly sophisticated analytical tools, even by social studies of science. Nonetheless, there is a limit to social determinism in science. Those categories introduce a rationality factor that prevents science from being the mere product of a negotiation between actors striving for social recognition. Scientific objects are determined by scientific technology, but science has to be independent from society. At the same time, Bachelard's positions regarding the normative role given to the city of science -- 'la surveillance intellectuelle de soi' -- as well as the notion that scientific objectivity is dependent from rational and social consensus adds importance to his scientific philosophy as a locus of interdisciplinary work.

To a certain extent, it is precisely this interdependency of disciplines that enables us to regard Bachelard's works not only as part of the historical foundations of Science and Technology Studies, but also as an important epistemological 'corpus' deserving a proper assessment by American scholars.

Notes

(1) "Leur originalite [de l'École Allemande] la plus evidente est de concilier l'exposé rigoureux des difficultés logiques de la theorie quantique avec l'explication des conséquences de ces doctrines sur le plan de la théorie de la connaissance. Cette manière de procéder ouvre pour la logique quantique la possibilité d'une discussion de ses fondements et de sa signification philosophique." Chevalley, Catherine, "De Bohret von Neumann a Kant: l'école allemande de logique quantique" in Jacob, P. (dir.) L'Âge de la Science: Lectures Philosophiques, p.153.

(2) 93-129. For a good comparison between the philosophies of Bergson and Bachelard see Goyard-Fabre,Simone."Bachelard et Bergson: deux grandes pensées" in Lafrance, G. (ed.)(1987). Gaston Bachelard: Profils Epistémologiques, 93-129.

(3) Curiously enough, Bachelard was, in this respect, much influenced by the Brazilian psychoanalyist Pinheiro dos Santos, particularly his works on Ritmoanálise.

(4) In fact, a position inhereted from the positivist French school.

(5) Meyerson's The Relativist Deduction: Epistemological Implications of the Theory of Relativity. Appendix 1 to this book is a review by A. Einstein, and starts with the following: "It is easy to say what is so unique about this book. It was written by a man who has grasped the pathways of thought of modern physics and who has penetrated deep into the history of philosophy and the exact sciences with a sure eye for psychological motives and interrelationships. Logical acumen, psychological instinct, multi-faceted knowledge, and straightforward expression are happily united here."(p.252)

(6) We do not even know to what extent Bachelard was aware of Einstein's philosophical considerations of relativity, although it is clear that he knows Heisenberg's reflections on quantum mechanics.

(7) Heisenberg and Niels Bohr emphasize, in texts concerning the Copenhagen interpretation of quantum theory, that it

"imposes a rupture with the modes of thinking connected with classical physics, representation habits, categories of understanding, certain rules of logic and the relation between words and things." Chevalley, Catherine "De Bohret von Neumann a Kant: l'école allemande de logique quantique" in Jacob, P. (dir.) L'Age de la Science: Lectures Philosophiques, p. 157.

(8) In this respect, Mendel Sachs's Einstein versus Bohr: The Continuing Controversies in Physics (1988) is most interesting, as it clearly displays the opposing concepts of the quantum and relativity theories (table on pages 237-238, for instance).

(9) For an interesting approach to similar issues see Bhaskar, Roy. "Feyerabend and Bachelard: two philosophies of science", in New Left Review, 94 (Nov.-Dec. 1975): 31-55.

(10) Sachs, Mendel (1988) Einstein versus Bohr: The Continuing Controversies in Physics, p.238.

(11) An attempt of this kind is part of the subject matter of a very good article by Stephen Gaukroger: "Bachelard and the problem of epistemological analysis" in Studies in the History and Philosophy of Science, 7 (1970): 189-244.

(12) Canguilhem, G. Gaston Bachelard's Historical Epistemology, p.50.

(13) ARPC, 87.

(14) Ibid., 91.

(15) NES, 183.

REFERENCES

GASTON BACHELARD'S BOOKS

(1973) Étude sur l'Évolution d'un Problème de Physique: la propagation thermique des solides. Paris: J. Vrin (1st ed. 1927)

(1987) Essai sur la Connaissance Approachée. Paris: J. Vrin (1st ed. 1928).

(1929) La Valeur Inductive de la Relativité. Paris: J. Vrin.

(1973) Le Pluralisme Cohérent de la Chimie Moderne. Paris: J. Vrin (1st ed. 1932).

(1933) Les Intuitions Atomistiques: Essai de classification. Paris: J. Vrin.

(1978) Le Nouvel Esprit Scientifique. Paris: P.U.F. (1st ed. 1934).

(1937) L'Expérience de l'Espace dans la Physique Contemporaine. Paris: Librairie Felix Alcan.

(1986) La Formation de l'Esprit Scientifique: Contribuition à une psychanalyse de la connaissance objective. Paris: J. Vrin (1st ed. 1938).

(1968) The Philosophy of No: a Philosophy of the New Scientific Mind. New York: the Orion Press (1st ed. 1940).

(1975) Le Rationalisme Appliqué. Paris: P.U.F.(1st ed. 1949).

(1951) L'Activité Rationaliste de le Physique Contemporaine.

Paris: P.U.F.

(1953) Le Matérialisme Rationnel. Paris: P.U.F.

(1970) Études. Paris: P.U.F.

ARTICLES ON BACHELARD

Bhaskar, Roy. "Feyerabend and Bachelard: two philosophies of science", New Left Review, 94 (Nov.-Dec. 1963): 31-55. "Monsieur Gaston Bachelard et le 'Nouvel Esprit Scientifique", La Pensée (Jan.- Mar. 1945): 47-55.

Canguilhem, Georges. "Gaston Bachelard", Études d'Histoire et de la Philosophie des Sciences (1983): 173-207.

Catesson, J.. "Autour d'un cogito scientifique: Gaston Bachelard et le matérialisme rationnel", Critique (1969): 352-360.

Gaukroger, Stephen. "Bachelard and the problem of epistemological analysis", Studies in the History and Philosophy of Science, 73 (1976): 189-244.

Goyard-Fabre, Simone. "Bachelard et Bergson: deux grandes pensées", Gaston Bachelard: profils epistémologiques, Canada: Presses Universitaires d'Ottawa.

Grieder, A. "Gaston Bachelard: 'phenomenologue' of Modern Science", Journal of the British Society of Phenomenology, 17, 2 (May 1986): 107-123.

Gutting, G. "Gaston Bachelard's philosophy of science", International Studies of the Philosophy of Science, 2

(1987):55-71.

Martin, Roger. "Dialectique et esprit scientifique chez Gaston Bachelard", Études Philosophiques, 4 (Oct.-Dec. 1963): 409-419.

McAllester, Mary. "Bachelard twenty years on: an assessment", Revue de Littérature Comparée, 58, 2 (1984): 165-76.

Ruyer, Raymond. "Le Matérialisme rationnel selon G. Bachelard", Revue de Métaphysique et de Morale, 58 (1953): 413-422.

Theobald, David. "Gaston Bachelard: Eclecticism in the philosophy of science", Technology and Society, 5, 2 (1969): 56-59. "Gaston Bachelard and the philosophy of chemistry", Archives de Philosophie, 45, 1 (1982): 63-83.

BOOKS ON BACHELARD

Aron, Raymond (1965). Notice sur la Vie et les Travaux de Gaston Bachelard (1884-1962). Paris: Académie des Sciences Morales et Politiques.

Gagey, Jacques (1969). Gaston Bachelard ou la Conversion à l'Imaginaire. Paris: ed. Marcel Rivière et Cie.

LaFrance, Guy (ed.) (1978). Gaston Bachelard: Profils Epistémologiques. Canada: Presses Universitaires d'Ottawa.

LeCourt, Dominique (1969). Marxism and Epistemology:

Bachelard, Canguilhem and Foucault. London: Humanities Press. (1974). Bachelard: Le Jour et la Nuit (un essai du matérialisme dialectique). Paris: ed. Grasset. (1978). L'Epistémologie Historique de Gaston Bachelard. Paris (1st ed. 1969).

MacAllester, Mary (ed.)(1989). The Philosophy and Poetics of Gaston Bachelard. Washington: Center for Advanced Research in Phenomenology & University Press of America.

Margolin, J.-Claude. Bachelard. Paris: ed. du Seuil.

Quillet, Pierre. (1964). Bachelard. Paris: Seghers

Gaston Bachelard: L'Homme du Poème et du Théorème: Colloque du Centenaire de Gaston Bachelard, 1984. Dijon: Presses Universitaires de Dijon.

GENERAL ARTICLES

Revue de Métaphysique et de Morale

Benda, Julien. "De la mobilité de la pensée selon une philosophie contemporaine", 50 (1945): 161-202.

Berthelot, René. "Sur quelques philosophies des sciences dans la France contemporaine", 37 (1930): 181-221.

Brunschvicg, Léon. "L'Orientation du rationalisme. Representation, concept, jugement", T.XXVII, 3 (1920): 261-343.

"Le Temps et la causalité", T.XXIX, 1 (1922): 1-13.

"La Relation entre le mathématique et le physique", XXX, 3 (1923): 353-363.

de Broglie, Louis. "Au Delà des mouvantes limites de la science", 52 (1947): 277-287.

"Les Conceptions de la physique contemporaines et les idées de Bergson sur le temps et sur le mouvement", T.LIII, 4 (1941): 241-257.

Delbos, Victor. "La Préparation de la philosophie moderne", 37 (1930): 289-335.

Gilson, Étienne. "Souvenir de Bergson", 64, 2 (1956): 129-140.

Guillaume, E. "La Théorie de la relativité et sa signification", T.XXVII, 4 (1920): 423-469.

Meyerson, E. "La Science et les systèmes philosophiques", T.XXXIX, 1 (1916): 203-242.

"Le Relativisme, théorie du réel", T. XXI, 1 (1924): 24-48.

Rosenfeld, L. "Le Conflit epistémologique entre Einstein et Bohr", 67 (1972): 147-151.

Le Roy, E. "Ce que la microphysique apporte ou suggére à la philosophie", T. XLII, 2 (1953): 151-184.

<u>The Philosophical Review</u>

Paulhan, Fr. "Contemporary Philosophy in France", IX, 1 (1900): 42-69.

Lalande, André. "Philosophy in France", XIV, 4 (1905): 429-

454.

"Philosophy in France (1905)", XV, 3 (May 1906): 241-266.

"Philosophy in France (1906)", XVI, 4 (July 1907): 357-386.

Le Roy, E. "Philosophy in France (1907)", XVII, 3 (1908): 291-315.

Lalande, André. Philosophy in France (1909)", XIX, 4 (July 1910): 373-394.

"Philosophy in France, 1910", XX, 5 (1911): 515-534.

"Philosophy in France in 1911", XXI, 3 (May 1912): 279-302.

"Philosophy in France in 1912", XXII, 4 (July 1913): 357-74.

"Philosophy in France, 1913-1914", XXIV, 3 (May 1915): 245-269.

"Philosophy in France in 1915", XXV, 4 (July 1916): 523-545.

"Philosophy in France, 1917", XXVII, 5 (Sept. 1918):443-468.

"Philosophy in France, 1918", XXVIII, 5 (Sept. 1919): 443-465.

"Philosophy in France, 1920", XXX, 5 (sept. 1921): 439-464.

"Philosophy in France, 1922-1923", XXXIII, 6 (Nov.1924):

533-559.

"Philosophy in France, 1925", XXXV, 6 (Nov. 1926): 499-521.

Rey, Abel. "Philosophy in France in 1926 and 1927", XXVII, 6 (Nov.1928): 527-556.

Lalande, André. "Philosophy in France in 1928", XXXVIII, 6 (Nov. 1929): 511-538.

Rey, Abel. "Philosophy in France, 1929", XL, 1 (Jan.1931): 1-31.

"Philosophy in France, 1930", XLI, 1 (Jan.1932): 1-36.

Lalande, André. "Philosophy in France, 1931", XLII, 1 (Jan.1933): 1-30.

"Philosophy in France, 1936-1937", XLVII, 1 (Jan. 1938): 1-27.

Parodi, D. "Philosophy in France, 1937-1938", XLVIII, 1 (Jan.1939).: 1-30.

"Philosophy in France, 1938-1939", XLIX, 1 (Jan. 1940): 1-24.

Lalande, André. "La Philosophie en France, 1946-1947", LVIII (1948): 35-52.

GENERAL BIBLIOGRAPHY

Belaval, Yvon (dir.)(1974). Histoire de la Philosophie. Paris: Encyclopédie de la Pléiade, Gallimard.

Bréhier, Émile (1950). Transformation de la Philosophie

Française. Paris: Flammarion.

(1960). The History of Philosophy. Vol. III: Contemporary Philosophy since 1850. Chicago: the University of Chicago Press. (1st ed. 1933).

Cajori, Florian (1962). A History of Physics in its Elementary Branches (through 1925): Including the Evolution of Physical Laboratories. New York: Dover Publ. (1st ed. 1929).

Canguilhem, Georges (1983). Études d'Histoire et de Philosophie des Sciences. Paris: J. Vrin.

Capek Milic (1961). The Philosophical Impact of Contemporary Physics. Princeton, New Jersey: D. Von Nostrand Company, Inc.

Cline, Barbara (1987). Men Who Made the New Physics: Physicists and the Quantum Theory. Chicago: University of Chicago Press.

Crubellier, Maurice (1974). Histoire Culturelle de France: XIX-XXème Siècle. Paris: Armand Collin.

Digeon, Claude (1959). La Crise Allemande de la Pensée Française (1870-1914). Paris: P.U.F.

Farmer, Paul (1977). Vichy: Political Dilemma. New York: Octagon Books.

Fleck, Ludwik (1979). Genesis and Development of a Scientific Fact. Chicago and London: The University of Chicago Press.

Fuller, Steve (1988). Social Epistemology. Bloomington and Indianapolis: Indiana University Press.

Fox, R.; Weisz, G. (eds.)(1980). The Organization of Science and Technology in France 1808-1914. Cambridge: Cambridge University Press.

Giere, Ronald (1988). Explaining Science: a Cognitive Approach. Chicago and London: The University of Chicago Press.

Gutting, Gary (1989). Michel Foucault's Archeology of Scientific Reason. Cambridge: Cambridge University Press.

Hacking, Ian (ed.)(1981). Scientific Revolutions. Oxford: Oxford University Press.

Hoffmann, S., and others (1963). In Search of France. Cambridge, MA: Harvard University Press.

Jacob, Pierre (ed.)(1989). L'Age de la Science: Lectures Philosophiques. Paris: ed. Odile Jacob.

Lantman and others (1988). Cahiers pour l'Histoire du CNRS. Paris: ed. du Centre National de Recherche Scientifique.

Kuhn, Thomas (1962). The Structure of Scientific Revolutions. Chicago: The University of Chicago Press.

Latour, Bruno; Woolgar, Steve (1986). Laboratory Life: The Construction of Scientific Facts. Princeton, New Jersey: Princeton University Press.

Mason, Stephen F. (1962). A History of the Sciences. New

York: Collier Books.

Meyerson, Émile (1921). De l'Explication dans les Sciences. Paris: Payot.

(1925) The Relativistic Deduction: Epistemological Implications ofthe Theory of Relativity. Dordrecht, Boston, Lancaster: D. Reidel Publishing Co.

Nye, Mary Jo (1986). Science in the Provinces: Scientific Communities and Provincial Leadership in France, 1860-1930. Berkeley: University of California Press.

Ory, Pascal; Sirinelli, J.-F.(1986). Les Intellectuels en France de l'Affaire Dreyfus à nos Jours. Paris: Armand Collin.

Park, Julian (ed.)(1954). The Culture of France in Our Time. New York: Cornell University Press.

Paul, Harry W. (1979). The Edge of Contingency: French Catholic Reaction to Scientific Change from Darwin to Duhem. Gainsville, FL: University Presses of Florida.

(1972). The Sorcerer's Apprentice: the French Scientist's Image of German Science, 1840-1919. Gainsville, FL: University Presses of Florida.

(1985). From Knowledge to Power: the Rise of the Science Empire in France, 1860-1939. Cambridge: Cambridge University Press.

Pestre, Dominique (1984). Physique et Physiciens en France: 1918-1940. Genève: ed. des Archives Contemporains.

Rorty, Richard (1979). Philosophy and the Mirror of Nature. New Jersey: Princeton University Press.

Sachs, Mendel (1988). Einstein versus Bohr: the Continuing Controversies in Physics. Illinois: Open Court.

Schilpp, Paul A. (1949). Albert Einstein: Philosopher-Scientist. Evanston, IL: The Library of Living Philosophers, Inc.

Singer, B. (1980). Modern France: Mind, Politics and Society. Seattle: University of Washington Press.

Thuillier and others (1983). La Recherche en Histoire des Sciences. Paris: ed. du Seuil.

Weart, Spencer R. (1979). Scientists in Power. Cambridge, MA: Harvard University Press.

Weber, Eugene (1986). France: Fin de Siècle. Cambridge, MA: Harvard University Press.

Wright, Gordon (1981). France in Modern Times: From the Enlightenment to the Present. New York: Norton and Co.

CURRICULUM VITAE

MARIA TERESA CASTELÃO PEREIRA

Graduate Program, Science & Technology Studies | J112Shawnee Blacksburg Virginia

Center for the Study of Science in Society
Price House
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Education: VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Blacksburg, Virginia
Master of Science in Science and Technology Studies
April 1990

SUPERIOR SCHOOL OF EDUCATION
Lisboa, Portugal
Sciences of Education Graduation 1988

LISBON CLASSIC UNIVERSITY
Lisboa, Portugal
Licenciatura em Filosofia 1980
Bacharelato em Filosofia 1979

Master's Thesis:

"Gaston Bachelard's Scientific Philosophy: an Approach to Science and Technology Studies."
Major Advisor: Joseph C. Pitt

Publications:

Principles of Psychology. Lisboa, Portugal: Plátano. First edition, 1988. Second edition, 1989. Third and forth editions, 1990. (in Portuguese)

"The humanism in Shakespeare." Forthcoming in Revista Portuguesa de Filosofia, edited by the Portuguese Catholic University, Braga. (in Portuguese)

Professional Associations:

International Society for the Philosophy, History and Social Studies of Biology

Portuguese Society of Philosophy

Employment History:

Graduate Assistant (1989-present), Graduate program in Science and Technology Studies, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Assigned to the Philosophy Department.

Research Assistant (1989), Summer Seminar in Philosophy of Biology for College Teachers, Department of Philosophy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Graduate Assistant (1988-89), Graduate Program in Science and Technology Studies, VPI & SU, Blacksburg, Virginia.

Secondary School Teacher (1980-88), Lisboa, Cascais and Vila Franca de Xira, Portugal.