SECOND PART

CHAPTER V

THE EXPERIMENTAL METHOD ACCORDING TO CLAUDE BERNARD

In the first part of this dissertation we have shown that there is some relation between what is now being taught on the nature of the experimental sciences and that branch of rational philosophy called dialectic. We shall now turn to a classic in the field of experimental biology, written by Claude Bernard (1813-1878). (2)

Bergson in his Discours du Centenaire, commemorating the birth of Bernard, declared that the INTRODUCTION A L'ETUDE DE LA MEDICINE EXPERIMENTALE was for the XIX Century, what Descartes' DISCOURS DE LA METHODE was for the XVII and XVIII Centuries. (1)

The background of this work is worth remarking. Claude Bernard was most familiar with the traditions of the laboratory. It was in contact with facts and their manipulation that his ideas on the experimental method developed. As a professor at the Collège de France, and later at the Sorbonne, he introduced his course to physiology by a number of lectures on the theory of the experimental method. Constrained by sickness to leave Paris, he found time to put his previous ideas in a distinct work. Introduction à l'Etude de la Medicine Expérimentale, which he

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(1) Cf. Moniteur Universel, Nov. 1866.

(2) Cf. Appendix I, for the history of the scientific method.

published in 1865. (1) His exposition of the experimental method is all the more weighty because Bernard ranks among the greatest physiologists of all time. He not only made many important discoveries on the functioning of the liver, the pancreas, and the vaso-motor nerves, but also checked these discoveries so carefully that they seem to be as acceptible today, as the day they were made.

The Introduction is divided into three parts. The first part is an analysis of the general characteristics of the experimental method. It exposes the relation between fact and idea, between experimentation and the mental attitude of the experimentalist. This first part may be termed 'the logic of the experimental method'. "His work (Bernard's) says Lalande, has become known as the classical exposition of the experimental method not only in the natural sciences, but also in physical chemistry. This is due to the clearness with which he has put in relief the a priori idea, and the spirit of invention, along with confidence in biological determinism, fidelity to facts, openness of mind even in respect to the new formulations for which one is enthusiastic; finally, the regard for the technique of verification, the importance of the counter-proof (for example the use of control animals)." (2)

In the second and third parts of the Introduction, Bernard considers the actual employment of the experimental method in

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(1) C. Bernard, Introducti n à l'Etude de la Medicine Expérimentale, Ballière et Fils, Paris, 1865; also Librairie Delagrave, Paris, 1937.

(2) Lalande, Les Théories de l'Induction et de l'Expérimentation, (Boivin et Cie), Paris, 1929, p.204.

physiology and medicine. The experimental method is fundamentally the same in studying living or non-living subjects. However, the study of living organisms is more difficult due to the interiority of life-phenomena, the complexity of the phenomena, and the easy destruction of the subject. Bernard therefore considers the various problems involved in experimentation. From Parts II and III his philosophy of nature can be gathered. In Part III Bernard describes some of his experiments, and points out the difficulties of experimental medicine.

He does not treat directly the relation of biology to philosophy strictly understood, but remains in the field of method. It is a method, however, which is presented in such a way as to challenge philosophy proper. He defines such concepts as he thinks necessary to explain the nature of the experimental method. His exposition of life phenomena, of the kinds of reasoning, of determinism, bring him necessarily into philosophical controversy. Bernard at times speaks harshly of metaphysics and of religion. Consequently his Introduction is thought to condemn all science not fundamentally positivistic. Dorolle says: "He would have one think metaphysically in order to initiate movement, but live and act physically; and to fashion science is to live and to act". (1) Bernard disclaims that experimental medicine, meaning also its methodology, belongs to any philosophical system. He warns the experimentalist to cultivate the philosophical spirit, but to avoid philosophical systems. (2)

(1) C.Bernard, L'Introduction etc., (Première Partie), ed. Delagrave, Paris, 1937, p.15.

(2) C.Bernard, L'Introduction etc., Baillière et Fils, Paris, [illegible]

In the Introduction, Bernard makes a clear, concise, and brilliant analysis of the experimental method the more interesting in that he claims for it freedom from all philosophical systems and controversy. He contends that "experimental medicine, as well as all the experimental sciences, does not feel the need of attaching itself to any philosophical system. The role of the physiologist, as that of every scientist, is to seek the truth for itself, without wishing to use it for the verification of such or such system of philosophy. When the scientist pursuing scientific investigation takes as a basis any philosophical system, he wanders into regions far from reality, or the system gives to his mind a kind of false assurance and an inflexibility which is not in accord with the liberty and flexibility which the experimenter must always retain in his researches. It is necessary therefore to avoid with care any semblance of a system, and the reason (I give) is that systems are not in nature, but only in the minds of men. Positivism, which in the name of science rejects all philosophical systems, has as they, the falsity of being a system. For, to find the truth, it suffices that a scientist put himself before nature, and that he search it by following the experimental method aided by investigatory talents more or less perfect. I think that, in this case, the best philosophical system is to have no system." (1)

We may call attention to two reasons justifying this attitude. The scientist must be free to formulate those hypotheses

(1) Bernard, Introduction etc., Paris, 1865, pp.386-387.

which will best explain the phenomena he deals with. No experimental method can be good unless it assures this freedom. As we shall see later, Bernard claims for hypothesis that which St. Thomas has claimed for the astronomical hypothesis of his time.

> "Dicendum quod ad aliquam rem dupliciter inducitur ratio. Uno modo ad probandum sufficienter aliquam radicem: sicut in scientia naturali inducitur ratio sufficiens ad probandum quod motus coeli semper sit uniformis velocitatis. Alio modo inducitur ratio, quae non sufficienter probet radicem, sed quae radici jam positae ostendat congruere consequentes effectus: sicut in astrologi ponitur ratio excentricorum et epicyclorum ex hoc quod, hac positione fact possunt salvari apparentia sensibilia circa motus coelestes: non tamen ratio haec est sufficienter probans, quia etiam forte alia positione facta salvari possent." (1)

If we considered these hypotheses true, we would indeed be bound, and the progress of experimental science would be hampered. In this field, experience alone should be our first and last guide, and whatever we conceive must save the phenomena as we know them. To give definite value to some hypothesis, however plausible it may seem due to present evidence, is to deny experience. Claim to freedom in this field is therefore well-founded and indispensible.

Secondly we can well understand Bernard's suspicion of philosophical systems. If a philosophy hampers the freedom of experimental science, if it would impose definite principles of such a nature that they deny the freedom of hypothesis, then surely it is a bad philosophy as far as the scientist is concerned. And if such is the nature of philosophical systems as such, then we

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(1) St. Thomas, Summa Theologica, I, q.32, a.1, ad 2.

should have nothing to do with them.

The INTRODUCTION is largely a study of the problem of experimentation in physiology, pathology, and therapeutics; and it also describes certain experiments made by Bernard. Nevertheless, he gives in the first part the pure theory of the experimental method. The method as such is applicable, he says, to the physical sciences, and to the various biological sciences "The naturalist who observes animals to learn their mode of life and habits, the physiologist and the doctor who wish to study the inner functioning of living bodies, the physician and the chemist who determine the phenomena of lifeless matter; all are in the same class - they have before them manifestations which they are able to interpret only by the aid of an experimental criterion, the sole study of which occupies us here." (Introduction p.57) In many places Bernard uses the term 'physiology' and 'biological sciences' interchangebly. (Cf. pp.27, 30, 55, 102, 115, 118, 127, etc.) Naturally as a physiologist he speaks usually of the method in relation to physiology. But he does not consider physiology as belonging to any but the biological sciences. Hence there is no mistake in choosing the INTRODUCTION to give us the exposition of the experimental method in biology.

In fact, Bernard says that the method is the same in the physical sciences as well as in the biological sciences. Unfortunately, this might well be contrary to the freedom which he claims for the experimental sciences. Why must the method be the same? Should the method of mathematical physics be the same as that of experimental psychology? We can see no reason for accepting this *a priori* restriction. But more of this later.

Passing to a detailed consideration of the experimental method according to Claude Bernard, we shall first present his doctrine on observation and experimentation.

1. Observation and Experimentation.

Bernard disagrees with a common explanation that observation is the witnessing of phenomena which nature ordinarily offers, whereas experimentation is the witnessing of phenomena created or determined by the experimenter. In the words of Cuvier: "The observer listens to nature; the experimenter questions it and forces nature to reveal itself." But does this mean that the observer is always passive, and that the experimenter is alone active?

Bernard cleverly distinguishes between the art of investigation and the art of reasoning. In the first place, that observation is characterized by nature being active and the mind being passive is not exactly true. For example, if an epidemic occurs then a doctor has the opportunity to observe the causes and the progress of it. But suppose that another epidemic arises in a different locality, and the same doctor takes to observation. Again nature is revealing herself, but is the doctor simply passive? No, because the observation is of a different kind.

"This second observation, made in view of a preconceived idea on the nature and the cause of the disease, is one which must be called a provoked or active observation." Hence the over-simplification of holding that in observation nature is active and the experimenter is passive. In the second place, experimentation is not simply the provocation and manipulation of phenomena. A physiologist who is performing experiments on the facial nerve to learn its distribution could meet with an accidental case of gun-wound in which he need only observe to continue his experiment. He would not, then, be actively working on nature to produce or to control phenomena. Yet he would be experimenting. So neither is the above definition of experimentation satisfactory.

In the true explanation of observation and experience following distinctions are made. "Speaking in the concrete, one says that he makes an observation or experiences when he gives himself to the investigation and research of facts from which the mind can draw instruction. Speaking in the abstract, one says that he depends upon observation or learns from experience when he means that observation is the basis, 'le point d'appui' for the mind which reasons, and experience is the basis of the mind which concludes, or better, that it is the fruit of correct reasoning applied to the interpretation of facts. From this it follows that one is able to learn from experience without making experiments, by the sole fact that one reasons according to well established facts, just as one is able to experiment and to observe without acquiring experience if one limits himself to the mere witnessing of facts.

"Observation therefore is that which shows the facts; and experience is that which instructs on the facts and gives the experience a relation to a thing. But as this instruction is impossible except by comparison and judgement, that is to say, by following a reasoning process, it results that man alone is capable of having an experience and of perfecting himself by experience." (Introduction p.22)

Bernard is careful to distinguish two kinds of instruction which are derived from experience; one that is empirical, the other that is experimental. That of the empirical kind is obtained in a practical way from each thing, and it is accompanied by a vague, experimental reasoning. It is this vague but spontaneous mental activity which the experimental method perfects by making it clear, off-hand, and consciously directed toward an end. The experience in a science is thus always acquired by virtue of a precise reasoning established on an idea which the observation has engendered, and which the experience controls. (Introduction p.23)

Bernard expresses many times, in simple language, the formula of the experimental method. The experimental method does no other thing than pass a judgement on the surrounding facts, by the aid of a criterion which is another fact used to control the judgement, and to give the experience. Experience according to Bernard is of the greatest importance; it is the unique source of human knowledge. For the mind itself has only a feeling (sentiment) of a necessary relation between things. It can not know the exact form of this relation without experience. (Intro. p.24)

Keeping in mind the very important distinction between the art of investigation and the art of experimental reasoning we should note:

1) The art of investigation is the corner-stone of the experimental sciences, because it supplies the facts upon which the experimental reasoning rests.

2) Investigation may be considered as a work of observation or of experimentation. In observation, the observer studies phenomena which he can not manipulate, but simply take from nature. In experimentation the experimenter is able to prepare and modify the subject being studied. This difference in the non-control and control of phenomena in investigation is the foundation for distinguishing a science of observation from a science of experimentation; for example,

astronomy from physiology.* (1)

3) Pure observation of itself never suffices for

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(1) We should take note, however, of a very important bit of doctrine coming from Eddington: "In a recent book, SCIENCE AND HUMAN EXPERIENCE, Professor Dingle draws what I think is a quite unwarranted distinction between the macroscopic and the microscopic entities in the physical world. According to him the latter are unverifiable hypotheses, existences, or events whose unobservability is part of their essential nature (p. 47). He is contrasting them with ordinary 'observable' bodies and events, and he wishes to convey that electrons and protons have an essentially different status in our knowledge from the more ancient denizens of the physical world, such as sticks and stones and stars. I feel sure that this distinction is untenable.

And electron is no more (and no less) hypothetical than a star. Nowadays we can count the electrons one by in a Geiger counter, as we count the stars one by one on a photographic plate. In what sense can an electron be called more unobservable than a star? I am not sure whether I ought to say that I have seen an electron, but I have the same doubt as to wether I have seen a disc of light surrounded by diffraction rings, which has not the least resemblance to what a star is supposed to be; but I give the name star to the object which some hundred years ago started the chain of causation which has resulted in this curious light-pattern. Similarly, I have seen a wavy trail not in the least resembling what an electron is supposed to be; but I give the name electron to the object which has caused this trail to appear. How can it possibly be maintained that I am making a hypothesis in one case and not in the other?

I do not think that either the star of the electron should be called a hypothetical entity. We make no hypothesis by merely giving a name to that which is the origin of certain impressions which reach our senses. But it is difficult to separate the name from the hypothetical images that are commonly associated with it. No doubt hypothetical properties and characteristics have often been attributed to electrons, and some of these have turned out to be erroneous. But I rather think that the same thing has sometimes happened to the stars." (A. Eddington, PHYSICS AND PHILOSOPHY, Philosophy, Macmillan and Co., London, Vol. VIII, No. 29, Jan. 1933. pp. 37-38.)

constructing a science, since it is simple testification of facts. For scientific knowledge there is always requirdd experimental reasoning. (Introd. p.[illegible])

4) In investigation the observer and the experimenter have a common end; namely, to get the facts. Thus an experiment is nothing but a provoked observation. The facts in both cases are the principal interest. But in the experimental method the facts are accompanied by experimental observation and reasoning. Ordinarily the experimenter will be investigating in order to control and verify the experimental idea. The experiment is another observation provoked for the purpose of a control. (Introd. p.36.)

5) The technique of investigation, including observation and experimentation, is specialized in each science. Bernard in the second and third parts of the INTRODUCTION discusses thoroughly the problems of the investigator in the biological sciences, and especially in physiology.

Passing to the consideration of the experimental reasoning in science, we must note its key position in the experimental method. We have already noted the precise meaning of observation and of experience in this method. In observation, the facts are the basis of an a priori idea, or hypothesis; in experience (which is usually founded in an experiment), the facts are the basis for a judgement as to the value of the idea. It is the process of reasoning (of experimental and not of empirical reasoning) which carries the mind from the idea to the judgement, and scientific knowledge. (In the next section experimental reasoning will be analyzed.)

Hence at bottom all sciences, (we exclude the mathematical sciences), reason the same way, that is, they have the same philosophic method. In the sciences of observation, man observes (experimentally) and reasons (experimentally), but he does not experiment. In the sciences of experimentation, again man observes and reasons; but more, he acts upon the materials before him. In experimenting he becomes an inventor of phenomena which give the facts. In a sense then, the experimental sciences are active rather than passive. But in every science, the mind must be active through reasoning experimentally.[1]

Turning to experimentation, we should remark the two important operations. The first consists in premeditating and realizing the conditions of the experiment; the second consists in witnessing the results of the experiment. It is impossible to carry out an experiment without a preconceived idea; to institute an experiment, we have said, is to pose a question; one never conceives a question without the idea which solicits the response.

I consider it, therefore, as an absolute principle, that the experiment must always be instituted in view of a preconceived idea, it being of little import whether this idea is more or less vague, more or less well defined. As for the witnessing of the results of the experiment, which is itself only a provoked observation, I equally hold the principle, that it must be made then as in every other observation, that is to say, without a preconceived idea." (Introd. p.42) By demanding that the experimenter always observe carefully the actual facts, and that he take the facts as they turn out to be, Bernard answers the charge that to start an experiment with an a priori idea is to discredit the results at the very start. As he carefully notes, one must distinguish between the invention of an experiment with the witnessing of the actual results.

"The perfect scientist is the one who embraces at the same time experimental theory and practise. 1) He witnesses a fact. 2) The fact gives rise to an idea in the mind. 3) In view of this idea, he reasons, institutes an experiment, imagines and realizes the material conditions of it. 4) From this experiment there arise new phenomena which he must observe, and so on. The mind of the scientist is in a way always placed between two observations: one which serves for the point of departure for reasoning, and the other which serves him as the conclusion... The observer and the experimenter correspond therefore to different phases of the experimental research. The observer does not reason, he witness the experimenter on the contrary reasons and relies on the acquired facts to imagine and to provoke through his reasoning some other facts. But, if one in theory and abstractly can distinguish the observer from the experimenter, it seems impossible to do so in practise, since we see that the same investigator is alternately observer and experimenter." (Introd., pp. 43-45.)

<u>ART OF INVESTIGATION</u>	<u>ART OF EXPERIMENTAL REASONING</u>
Aim: To get a supply of facts.	Aim: To judge the <u>a priori</u> idea, coming from fact, by another fact.
1) <u>Concrete observation</u>: To witness accurately and without prejudice the facts found in nature. In the sense that the investigator must take the facts as <u>given by nature</u>, he is passive. The <u>sciences of observation</u> are the result.	1) <u>Observation</u>: To form an idea from a fact in or out of an experiment. An <u>a priori</u> idea is necessary to initiate and to control the experiment.
2) <u>Experimentation</u>: To manipulate nature and to find the facts by experiment. The investigator is active and provokes nature to reveal itself. The result is the <u>sciences of experimentation</u>.	2) <u>Experience</u>: The concious and careful observation of a fact which confirms the truth of the preconceived idea. This experience may come with or without experimentation.

<u>Science</u>: An experience acquired by virtue of a precise reasoning established on an idea, which the observation has engendered, and which the experiment controls.

2. Experimental Reasoning

a. The A Priori Idea

We have said that the fact gives rise to an idea in the mind, which idea is the same as a question demanding a response. That response must be found in the facts which some well planned and executed experiment will reveal. In the end the experiment will control the idea. It is important to make precise this preconceived, or a priori idea.

1) Origin of the Idea. This idea is not something innate, as for example the A priori forms of Kant. The idea must come from the fact. The mind may at the time be making a simple observation, or a provoked observation. Sometimes the idea is formed from a theory, which in turn is taken from fact. (p.57.)
The mind forms the idea from feeling ('sentiment') or intuition; that is, when the mind is faced with facts it naturally tends to form an idea that things are so and so, or that this effect is due to that cause. (pp.57, 61.) But as coming from an individual mind, the preconceived idea has its peculiarities; it is a quid proprium. Minds differ as to their power to find ideas in facts that are obscure. (p. 61.)

2) Nature of the Idea. Considered negatively:
a) As coming from fact it is not a mere figment of the imagination. b) As in the experimental method, it

is not something totally improbable. The scientist usually starts with the most likely explanation of phenomena. c) Finally, the idea is not of such a form that it is unverifiable in experimentation. An _a priori_ idea as unverifiable is of no scientific value. (p. 58.)

Considered _positively_, the idea is not what the scholastics call a concept, but rather a proposition. This seems to be evident from the words of Bernard: "The experimenter poses his idea as a question, as an interpretation anticipated from nature, and more or less probable. From it the experimenter deduces logically certain consequences which he checks each instant with reality by means of the experiment... The experimental idea is therefore also an _a priori_ idea, but it is an idea which presents itself under the form of an hypothesis whose consequences must be submitted to the criterion of experimentation in order to judge its value." (p. 49.) It is clear then that Bernard means by the _a priori_ idea a dialectical proposition or a 'problem' which may be formed into a 'position' or thesis. This thesis is used in a deduction which with its consequences forms an hypothesis, the latter in turn being a dialectical proposition or interrogation to be tested. This is why he uses idea and hypothesis interchangeably: "Feeling ('sentiment') engenders the idea, or the experimental hypothesis, that is to say, the anticipated interpretation of the phenomena of nature." (p. 37.)

3) <u>Necessity of the A Priori Idea.</u> We have already remarked that the idea is necessary in the experimental method. No experiment, if it is to be worth anything, can be instituted without the idea. The experiment recieves its whole direction from the idea. (Cf. p. 55.) Hence the experimenter must get an idea somehow if he lacks one. Let him even observe or experiment until he gets the first idea how so ever imperfect it may be. (p. 37.)

4) <u>Testing the Idea.</u> While the idea, or hypothesis, initiates the experiment, it in turn must be submitted to what the experiment reveals. As the facts are observed, simply or in a provoked observation, the hypothesis is verified, changed, or entirely rejected. (pp. 41, 49.) <u>The hypothesis is said to be between the facts.</u> Later we shall see that the attitude of the mind toward the idea, even as verified, remains one of doubt. (p. 70.) Hence it is never more than an instrument.

b. Reasoning.

This preconceived idea, as we noted, is used by reason, or in the process of reasoning. According to Bernard: "The forms of reasoning are two: 1) The investigative, or interrogative, which is used by a person who does not know, but wishes to learn. 2) The demonstrative, or affirmative, which is used by the person who knows or thinks he knows, and who wishes to instruct others." (p. 77.) Bernard then notes that according to some philosophers the investigative is called inductive reasoning; and the demonstrative, deductive. He notes that others hold for two scientific methods: the inductive, which is proper to the experimental sciences; and the deductive which is proper to the mathematical sciences.

With this latter conception of scientific methods Bernard disagrees. All sciences, both mathematical and physical, equally use induction and deduction. Therefore they can not be strictly divided as sciences of deduction as opposed to sciences of induction. "The mathematician and the naturalist do not differ in their search for principles. The one, as the other, inducts, makes hypotheses and experiments; that is to say, strives to verify the exactitude of his ideas. But when the mathematician and the naturalist have secured their principles they are then completely different. In fact, as I have said already in another place, the principle of the mathematician becomes absolute, because he does not apply it to objective reality such as it is, but to the relations of things considered in extremely simple conditions, which the mathematician choses and creates in some sort in his mind. But, thus having the certitude that no other conditions than those determined can enter into the reasoning, the principle is absolute, conscious, adequate for the mind, and the logical deduction is equally absolute and certain; there is no longer need for experimental verification, because the logic suffices.

"The situation of the naturalist is different; the general proposition at which he arrives, or the principle on which he supports his reasoning, remains relative and provisional because it represents complex relations about which he can never be certain that he is able to know all. Hence his principle is uncertain, since it is unconscious, and inadequate to the mind; hence the deduction, howsoever logical, remains doubtful always, and it is necessary then to invoke experimentation in order to control the conclusion of the deductive reasoning. This difference between the mathematician and the naturalist is capital in view of the certitude of their principle and of the conclusions that they draw; but the mechanism of the deductive reasoning is exactly the same for both of them. Both start from a proposition; only the mathematician says: This point of departure given, such a particular case necessarily results. The naturalist says: If this point of departure were correct, such a particular case would result from it as a consequence." (pp. 81-82.)

Bernard here seems to oppose demonstrative reasoning to a hypothetical proposition. Most modern logicians commit the error. The reason presumably is that all conditional propositions virtually include a consequence, as in the statement: "If this point of departure were correct, such a particular case would result from it as a consequence." But for hypothetical <u>reasoning</u> we must then add: "But such is the consequence. Therefore the point of departure is correct." However, that such a particular case is the fact, is precisely what we must be established before we have hypothetical reasoning.

Again, the statement "If this point of departure were correct, such a particular case would result from it as a consequence" might be true or probable. It would therefore be wrong to oppose certain reasoning to hypothetical reasoning, for the latter as a form of reasoning prescinds from the matter. The division of reasoning into certain and probable or dialectical is taken from the matter.

Neither is dialectical reasoning interrogative except in the sense that its propositions are interrogative. Dialectic is interrogative not only of the conclusions but of the principles as well.

Notwithstanding these errors concerning logic, we do grasp what Bernard means to say. We may state fairly that he intends to oppose what we call scientific reasoning to dialectical reasoning.

According to Bernard, then, the following important of doctrine may be stated relative to scientific knowledge in general.

1) Sciences are not strictly distinguishable as inductive or deductive; because all sciences use both inductive and deductive reasoning. Yet if a person wishes to use inductive and deductive to

signify the differencein the principles used by mathematics and the experimental sciences, and that the a priori idea (principle) in the experimental sciences must be considered uncertain and requiring verification, then this distinction between inductive and deductive science is admissible. The forms of reasoning are divided as follows:

I Division:

i) Investigative Reasoning: Used by oneself in order to learn.

ii) Demonstrative Reasoning: Used by one to instruct others.

II Division:

i) Reasoning in the Experimental Sciences:

a) Investigative (inductive) used to find principles.

b) Demonstrative (deductive) used to draw conclusions from the given principles.

N.B. In the experimental sciences the principles and conclusions remain uncertain.

ii) Reasoning in Mathematics:

a) Investigative (inductive) used to find principles, which are certain.

b) Demonstrative (deductive) used to draw certain and necessary truths.

2) All principles come ultimately from induction, that is, from the investigation of something inside or outside ourselves. (p. 80.)

3) Given principles, the mind always deduces or reasons in the same way. It is only the subject treated that constitutes 'varieties' of reasoning. (pp. 78-79.)

4) As we shall see later, in all reasoning, purely mathematical or experimental, true knowledge would be impossible without the principle of determinism. (p. 79.)

In regard to reasoning in the experimental sciences, for example in experimental biology, the doctrine may be restated succinctly:

1) The a priori ideas (principles) are taken from facts directly or indirectly by the mind. This entails inductive reasoning.

2) Deductive reasoning consists in drawing consequences from the a priori idea, and thereby constituting a hypothesis.

3) Because the reasoning is uncertain, (as based on uncertain, unconscious principles,) it must be submitted to experimental verification. Thus the experiment controls the idea. In the measure that the scientist assembles the facts, his principles become more and more general and more certain; thus he acquires the certitude which he deduces. In the experimental sciences, the certitude is always provisional because the scientific mind is limited to

certain facts and conditions. (pp. 84-85.)

Finally, there is need of the counter-proof in the experimental method. The hypothesis even as verified is so uncertain and provisional, that the verification must be rechecked. This counter-proof is not a simple comparison of phenomena. It is the application of the principle: 'Sublata causa, tollitur effectus.' The experimenter must prove that in the absence of the cause, which he thinks he has discovered, the effect (phenomenon) does not occur. In the experimental sciences deception is so easy, that this counter-proof is essential to the method. To doubt the verified consequence of a hypothesis is to carry philosophical doubt to the proper extreme. (pp. 97-100.)

When Bernard uses the term 'cause', obviously it is not to be understood formally, but rather as the term of a relation, which term is itself but a sign.

c. Induction.

Bernard speaks of the induction of principles both for the experimental sciences and for mathematics. Before examening the nature of this induction used, we should note the three uses of the word 'induction'. Taken in the first sense, induction signifies the abstraction of an universal concept from a singular object. All our human intellectual knowledge depends upon this type of induction for its concepts, since man begins life in pure potency to knowledge. The second type of induction signifies the knowledge of a per se nota proposition; it is knowledge of a principle which presupposes sensible experience, but which in itself is immediately intelligible. Induction in the third sense signifies an argument, and it is as such that induction is "A progression from singulars sufficiently enumerated, to an universal". For example, to experience several times that fire is hot, and then to conclude that all fire is hot, is to make an induction. And induction is said to be ascending when it is ordained to the discovery of universal truths or generalisations. These truths are universal only to the extent that singulars have been examined and found to prove that the predicate belongs to the singulars which the universal designated. The conclusion of such an induction is only probable. (1) Descending induction proceeds from the universal to the singulars; it is used to demonstrate the falsity of the universal, as an universal, in some particular instance. But supposing the truth of the universal found by ascending induction, the descending induction can serve to show the correspondence of the universal to the singulars contained under it. In both ascending and descending induction, the argument lacks a perfect mean. (2)

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(1) Et inductio, quantum ad ascensum, ordinatur ad inveniendas et probandas veritates universales, ut universales sunt, id est, in quantum constant ex singularibus sub eis contentis. Nec enim potest probari, quod aliquid universaliter sit tale, nisi quia eius singularia sunt talia." (John of St. Thomas, Logic, I, Lib. III, cap. 2, p. 60, Reiser edition.)

(2) "Inductio autem non assumit medium uniens extrema ad probandum extrema uniri inter se, sed probat extremum seu praedicatum aliquod convenire alicui subiecto communi, quia convenit singularibus, aut singularibus convenire, quia convenit communi." (John of St. Thomas, op. et loco cit.)

What is the kind of induction used in the experimental method? The method uses ascending and descending inductive reasoning. Bernard, however, confuses the various kinds of induction, and descending induction with deduction.

1) The experimental method uses induction also in the first sense, that is, the abstractive process whereby the mind has concepts (universals) which represent objects. And Bernard is correct when he says that all sciences use induction, if he means induction in this sense.

2) Does the experimental method use induction to find per se nota principles? We say that it never does, but Bernard says that the mind in knowing the exterior world has an intuition of the principle of determinism. If this were true, and if the basis of the experimental method is the principle of determinism, then we could say that the method uses induction in this second sense. But aside from this one principle, all others in experimental science, according to Bernard, are only provisional, relative true, etc. Hence we may say that Bernard would induct one per se nota principle, and only one. Not even the principles of mathematics are absolutely true, or self-evident because of any induction. "The principle of the mathematician becomes absolute, because he does not apply it to objective reality, such as it is, but

to the relations of things considered in extremely simple conditions, which the mathematician choses and creates in some sort in his mind." (Cf. p.61.) We would hardly agree with Bernard that such principles are absolutely true.

3) Induction in the third sense, as a progression from particulars to the general, and vice versa, is the induction which gives only probability, and characterizes the experimental sciences. As ascending, this induction is the basis of generalization. It is a distinct type of reasoning, which has only probability. Bernard certainly claims it for the experimental method, although he does not seem to distinguish it from induction of the first kind.

> "The situation of the naturalist is different; <u>the general proposition</u> at which he arrives, or the principle on which he supports his reasoning, remains relative and provisional, because it represents complex relations about which he can never be certain that he is able to know all." (Cf. p.62.)

Ascending induction is not used by all sciences. There are such sciences, as philosophy and mathematics, which have no need of ascending induction, since they are dealing with pure intelligibles. The per se nota principles of philosophy come through induction in the second sense.

But it is <u>descending induction</u> that Bernard especially confuses, by failing to distinguish it from deduction.

"given principles, the mind always deduces or reasons in the same way. It is only the subject treated that constitues 'varieties' of reasoning." (Cf. p. 63.) This statement, of course, is far from true. This is evident from an analysis of the examples which Bernard gives of deductive reasoning, – examples which happen to be descending inductions.

We can now turn to an analysis of these examples, having clarified the nature of the induction of which Bernard speaks.

a) "The urine of carnivores is acid;
But the rabbits before me have acid urine;
Therefore they are carnivores, that is, fasting."

(Note: Bernard calls this an <u>inductive</u> reasoning, only in the sense that the principle (major) is probable, and not absolutely certain. He does not use inductive as opposed to deductive. (Cf. p. 64, No.1.)

b) "White chyle is due to the emulsion of fat;
But in the rabbit the chyle forms in the region where the pancreatic sugar enters the intestine;
Therefore pancreatic sugar emulsifies fat, and forms white chyle." (Introd. p. 270.)

In the analysis of the first example of experimental reasoning, we can easily find the ascending and descending inductions. The major is a generalization which has been made by experimentation on a number of animals given flesh as food. By testing the urine of these separate animals, the scientist has discovered that all of them have a urine that is acid. He has proceeded to make the generalization: all carnivores have acid urine. Bernard has accepted this scientific generalization, which is clearly the result of an ascending induction. The minor of the reasoning is an instance put under this generalization. Then follows the conclusion which is only probable. It says no more than: this rabbit with acid urine is probably a carnivore. The acidity of urine is not an infallible sign that an animal is a carnivore, because all carnivores were identified with this phenomenon, simply by making a generalization from several particulars. And so the generalization holds certainly for only those particular animals already examined. There remains the experimental work to prove that the rabbits studied are carnivores. Bernard was able to prove by experiment that these rabbits when fasting from the herbs they ordinarily have for food, begin to digest themselves; that is, become carnivores. Hence Bernard has made a descending induction, and has mistaken it for a true syllogism. This mistake can be quite easily made.(1)

These notions on induction in no way contradict what we have said about Bernard's use of hypothesis. The conclusion of his descending induction remains a hypothesis which must be verified. The scientific generalization made by ascending induction serves as a position or thesis; but it is still a dialectical proposition whose truth is not definitely known.

(1) Note: Inductive reasoning and the syllogism are two distinct species of argumentation and they are not reducible one to the other. The mean of the syllogism is a true universal; whereas the mean of the inductive argument is a collective universal, that is, it stands for a number of singulars investigated. Hence these two should not be confused even though they may appear alike in external form.

Without delaying on the various loo[illegible] of the term hypothesis we wish to point out [illegible] worthy of note. Hypothesis is even identifie[illegible] state of mind. In discussing the various opinions [illegible] of hypothesis Schiller says:

> "This (the problem) will naturall[illegible] with a consideration of hypothesis in [illegible] comprehensive sense, as a mental attitud[illegible] inct activity. For it is here that the [illegible] difference lies between enunciati[illegible] and entertaining a hypothesis. In the [illegible] one is a claim made to propound a truth [illegible] a reflection of reality; in the latter [illegible] direct relation to reality is allege[illegible] hypothesis is a sort of game with rea[illegible] to fancy, make-believe, fiction and p[illegible] Yet on the otherhand this hypothetical [illegible] mediates between thought and action, a[illegible] to break down the superficial distincti[illegible] the theoretic and the practical. It driv[illegible] scientist out of the purely receptive atti[illegible] and makes him a doer." (1)

We have already analyzed carefully the nature of Bernard's hypothesis, but it is also an hypothesis in the broad sense of being that which the scientist uses to penetrate the obscurity that surrounds the most obvious phenomena of nature. When Schiller says that the hypothesis is used to anticipate reality by a guess, to question it, to experiment, to distrust and doubt appearances, to rearrange the world at least in thought, he is expressing almost exactly

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(1) F.C.S. Schiller, "Hypothesis". Studies in the History and Method of Science. Charles Singer, Oxford, 1921, vol. II, p. 418, 428-430.

what Bernard considers to be the purpose of his hypothesis. Bernard, however, puts greater stress on verification than does Schiller. We shall therefore pass on to the consideration of truth and verification in the experimental method.

d. Truth in Experimental Reasoning.

The experimenter proceeds from partial truths to more general ones, but without ever daring to pretend that he holds the absolute truth. (p. 49.) What is the result of this *a priori* and provisional reasoning? It is to know neither the beginning, nor the end, but only the middle, (that is, the phenomena,) of things. But the fact that the scientist is never in a position to know more than the middle is no deep concern to him. If he were ever to have absolute truth on any point, he would know all truth about the external world. There would be no experimental science. (pp. 88, 49.)

Bernard here supposes on the part of nature a determinism so complete that the possession of absolute truth on one single point, would imply knowledge of the whole, each part of the universe being therefore a reflection of the whole. We shall see later on how this follows from his false interpretation of the principle of determinism.

> "When we fashion a general theory in our sciences, the sole thing of which we are certain, is that all these theories are, absolutely speaking, false. They are merely partial and provisional truths which are necessary as steps upon which we rest in our advancing investigation; they represent

only the actual state of our knowledge, and consequently they must be modified with the growth of science, and so much the more often as the sciences are less advanced in their evolution." (p. 63.)

"The theories that represent the ensemble of our scientific ideas are without doubt indispensable in order to represent science. They must serve as the origin of new ideas of investigation. But these theories and these ideas not being unchangeably true, one must be ready always to abandon, to modify, to change them when they no longer represent reality. In a word, it is necessary to modify a theory in order to adapt it to nature, and not modify nature to adapt it to a theory." (p. 70.)

That all general theories are absolutely speaking false is not to be taken strictly. They would be false if they were held to be true. But when hypothesis or suppositions are held for the sake of saving appearances, when we know them to be neither true nor false, but provisionally plausible and sufficient, then our attitude is true. As St. Thomas says:

"Dicendum quod ad aliquam rem dupliciter inducitur ratio. Uno modo ad probandum sufficienter aliquam radicem: sicut in scientia naturali inducitur ratio sufficiens ad probandum quod motus coeli semper sit uniformis velocitatis. Alio modo inducitur ratio quae non sufficienter probet radicem, sed quae radici jam positae ostendat congruere consequentes effectus: sicut in astrologia ponitur ratio excentricorum et epicyclorum ex hoc quod, hac positione facta, possunt salvari apparentia sensibilia circa motus coelestes; non tamen ratio haec est sufficienter probans, quia etiam forte alia positione facta salvari possent." (St. Thom., Summa, I, q.32, a.1, ad.2)

Furthermore we must restrict Bernard's statement that all theories are false, because of the nature of the experience which verifies hypotheses. What is the meaning of experimental verification? Let us note that in rigid demonstration there is no need of experimental verification. The conclusion is true necessarily by reason of the premisses. In the experimental reasoning the conclusion is only probable, as coming from inducted generalization, or pure supposition. Hence it is not surprising to find the experimenter looking for a way to check again his reasoning. It is in need of rectification, which rectification he must find in experimentation.

What is the significance of a conclusion being supported by new experimental facts? Evidently, the new facts can not make the hypothetical reasoning necessarily true. Bernard is confusing when he says that the scientist acquires the certitude he deduces. (See page 64.) He is not speaking strictly of certitude, because he considers his certitudes as provisional. At most, the experimental facts can support the probability, and may reveal new helpful facts. On the new facts discovered, the experimenter may form another hypothesis. Schiller very clearly explains the meaning of verification.

> "For verification neither is, nor can it ever become, proof absolute. It is committed by its method to the formal flaw of Affirming the Consequent: when it argues that a hypothesis is true because the facts that follow from it are observed, this lacks cogency because these same facts, together with others still unknown, might follow still better from another hypothesis not yet formulated. And we cannot lay it down that a hypothesis shall only be accounted true when it alone can account for the facts... All that can be said therefore for a hypothesis which successfully holds the field is that, though it is not absolutely proved and cannot claim absolute truth, it can be accepted as true provisionally and donec corrigatur. And is not this after all, the most sensible thing to do? It is to hold it as good as true, and to give it all the practical

> privileges of truth, and this is all the assurance we practically need, without encouraging a groundless scepticism which appeals to an abstract possibility there is nothing to support. Only we reserve our right to exchange our hypothesis for a better, should one become available, and are perhaps a shade more likely to look out for it. But what harm is there in that?" (1)

Yet there is, in a very restricted sense, truth in the experimental method. The work of verifying the hypothesis may lead to the discovery of new facts. The discovered facts can certainly be called true. But the truth of these facts is not the same as the truth of a rigid syllogism, or the probability of a dialectical reasoning. And it is only by extrinsic denomination that the truth of the facts can be said of the hypothesis. This is the meaning of the statement, that the hypothesis is verified.

3. Principles of Science

There is more implied in the experimental method than intuition of an *a priori* idea which is used by reason and submitted to experiment. Bernard, in spite of his claim that he avoids all philosophical systems, states the broad principles of science upon which the experimental method rests.

"The human mind has passed successively through three stages; namely those of sentiment, reason, experience. First, sentiment imposing itself on the mind created the truths of faith, that is to say, theology. Reason, or philosophy, coming next as the

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(1) Schiller, loc. cit., p. 424.

teacher, produced the scholastic. Thirdly, experience, that is to say the study of natural phenomena, taught man that the truths of the exterior world are not formulated from the start by feeling, or by reason. These two are only our indispensable guides; because to find truths, it is necessary to descend into the objective reality of things; in which these truths hide with their phenomenal form." (p. 50.) It is the excellence of the experimental method to embrace and to perfect the previous two stages of knowledge. Experience and experiment as in the experimental method constitute a new science for the human mind. In so describing the advance of knowledge Bernard subscribes to the 'law of three stages' taught by the positivist, August Comte. (1) It is the third stage that Bernard analyzes and exposes according to his peculiar theory.

Sedondly, Bernard explains ultimately how the experimental method attains relative truths about real external objects. In doing so he borrows an important principle from Descartes. "Just as in the human body there are two orders of functions, those that are conscious and the others that are not conscious, so in the mind there are two orders of truth or of notions, those that are conscious, interior or subjective, and the others that are unconscious, exterior or objective. The subjective truth are those that flow from principles of which the mind has consciousness, and which bring with themselves the sentiment of an absolute and necessary evidence. In fact, the great truths are in

(1) Cf. Turner, History of Philosophy, Boston, 1903, pp.608-609, for brief description of the 'law of three stages'.

reality only a sentiment of the mind; that is what Descartes understood by his famous aphorism.

"We have said, on the otherhand, that man could never know the first causes or the essence of things. Consequently truth never appears to the mind under the form of an absolute and necessary relation or connection. Moreover, this connection can not be absolute except in so far as the conditions of it are simple and subjective, that is to say that the mind has the realization of knowing all. Mathematics represents the connection of things in conditions of ideal simplicity. The result is that these principles or connections, once found, are accepted by the mind as absolute truth, that is to say, independent of reality. One understands consequently that all the logical deductions of mathematical reasoning are as certain as their principles, and they have no need of being verified by experience. Otherwise, one would be putting the senses above the reason. It would be absurd to try to prove what is absolutely true for the mind, or what is not able to be conceived otherwise.

"But when, in place of studying subjective connections of which the mind creates the conditions, man wishes to know the objective relations of nature which he has not created, the interior and conscious criterion fails him. He is always conscious, without doubt, that in the objective or exterior world, truth is also constituted by necessary connections, but that the knowledge of the conditions of these connections escape him. It would, in fact, be necessary for him to create these conditions in order to possess an absolute knowledge and conception of them." (pp.51-52.)

Descartes in his DISCOURS DE LA METHODE took a position of universal doubt, with the intention of systematically reconstructing all human knowledge after the ideal rigor of mathematics. It is the three fundamental rules of the cartesian method which Bernard especially borrows and modifies for explaining the basis of the experimental method. Descartes' point of departure was a clear idea defined as: "Quae cum clara sit, ab omnibus aliis ita sejuncta est et praecisa, ut nihil plane aliud, quam qued clarum est, in se contineat." He insisted upon rigorous deduction from these first intuitive and consequently certain ideas. He considered deduction a successive intuition. Thirdly, the universal criterion of true knowledge was the intuitive evidence of the clear and distinct ideas. Descartes in LA METHODE proposed to put in evidence the veritable richness of the soul; he would open to each one the means of finding in oneself, and without borrowing from another, all the science that is necessary for him in the conduct of his life. It is not hard to detect the influence of cartesian philosophy on Bernard's doctrine. He emphasizes the importance of the mind, of its richness in the experimental method. He speaks of feeling and intuition of ideas (a priori and otherwise); of mathematical principles which are absolute, conscious adequate, and therefore intuitively certain; of other ideas that lack interiority and consciousness, that is really to say, clearness; of rigorous deduction in mathematics; and even of, (as we shall now see,) philosophic doubt. However Bernard does not ever turn from his primary consideration; to expose experimental reasoning and the experimental method, which give science.

Finally there are two observations to make. First, the reality of the external world is not questioned by Bernard. It is clear to the mind. Nor is the necessary principle of determinism, which is fundamental in Bernard's science, ever defended. In his simplicity he states: "Man is always conscious, without doubt, that in the objective or exterior world truth is equally constituted by necessary connections, but the knowledge of the conditions of these connections escape him." (p. 52.) Secondly, the mathematical sciences as interior and perfectly conscious are absolutely true and certain. Bernard is moreover careful to note that as soon as mathematical principles are applied to nature, then experimental verification is required. (pp. 52-54.) It is because the criterion of reasoning is no longer purely interior and conscious. Hence the truth of the deductions is no longer certain and absolute.

This shows clearly enough that he refutes his contention that the experimental method, as he conceives it, is independent of any philosophical system. By this we do not mean that he is wrong in his effort to state the necessary conditions of experimental science, conditions which lie beyond the reach of the method itself. But what he says here shows that he does adhere to philosophical systems, to a mixture of Descartes, Kant and Compte. This was entirely superfluous.

We agree to what he says on the certainty of mathematics, not on the precise cause of it. It is indeed the science most proportionate to our mind. It needs no verification in experience. But what is important in Bernard's continual recurrence to mathematics, is the necessity of making clear the nature of experimental science by comparing it with some ideal science of which the former falls short. It is in fact true that dialectic presupposes formal logic and demonstrative logic.

4. Determinism and Philosophical Doubt

It is necessary to clarify these apparently contradictory principles; namely, that the scientist is certain of determinism, but that he is also certain that his position is always one of philosophic doubt.

a. Determinism.

We have seen that Bernard claims man is certainly conscious that in the experior world truth is likewise constituted by necessary connections, that is determined. Without this principle there could be no science. "The absolute principle of the experimental sciences is a necessary and conscious determinism in the conditions of the phenomena. It is of such a sort that a natural phenomenon, whatever it is, being given, the experimenter can never admit that there is a variation in the expression of this phenomenon, unless at the same time there be the intervention of new conditions in its manifestation; moreover, he has an a priori certitude that these variations are determined by rigorous and mathematical connections. Experience simply shows us the form of the phenomena; but the connection of the phenomenon to a determined cause is necessary and independent of experience, and it is necessarily mathematical and absolute. We thus see that the principle of the criterion of the experimental sciences is in reality identical with that of the mathematical sciences, since in each of them this principle is expressed by a necessary and absolute relation of things. Only, in the experimental sciences these connections are surrounded by numerous, complex, and infinitely varied phenomena, which hide the connections from our view. By the aid of experience we analyze, we dissociate the phenomena, in order to reduce them to relations and conditions more and more simple. We so wish to seize the form of scientific truth, that is to say, to find the law which should give us the key to all the variations of the phenomena. This experimental analysis is the only means that we have for searching out the truths in the experimental sciences; and the absolute determinism of the phenomena, of which we have an a priori consciousness, is the sole criterion or the sole principle which directs and supports us. In spite of our efforts, we are still very far from this absolute truth; and it is probable, especially in the biological sciences, that we shall never see it in its nudity." (94-95.) Science therefore has for its end, the banishment of indeterminisms, or in other words, to find proximate causes.

It is clear that some kind of determinism is necessary for the scientist working with natural beings. He has to take for granted that the same effects have the same causes, and that once he has determined the conditions of a phenomenon, he may cause it to occur again. If there were absolute indeterminism in nature, then they would be simply prime matter, which by itself is inexistent, as well as unintelligible. In fact, there is no absolute indetermination in nature, for natural beings are determined by their form, and act according to this form. As constituted by matter and form, they act orderly. No one knows this better than the scientist.[1]

However, when Bernard claims that "the experimenter has an *a priori* certitude that the variations of phenomena are determined by rigorous mathematical relationships," and that one should extend this determinism to all observable phenomena, then one can ask from what source does this certitude spring? And if as he says "the doubter is the true scientist" whence comes this evidence for the universal application of absolute determinism to *all* phenomena of nature? The true scientist is said to be conscious of it *a priori*. It must be admitted moreover that if experimental science is an absolute science, it must be equally true that its principles and the material basis of these principles are absolute. But how do we know that experimental science is an absolute science? This is a problem which one should not presume to resolve in an *a priori* manner. The true scientist searches for the absolute where he can find it. He need have no doubt as to the existence of science, but he must ask himself if the matter he is studying conforms itself to the demands of an absolute science.

Supposing that there is not absolute determinism in nature, then determinism can be adopted as a methodological principle. In practice the scientist will hold that the events in his scientific world are knowable only in so far as they are determined. The future will be adequately knowable only in so far as it is already determined in the present. Accordingly he will consider all indetermination as provisional, and will strive to resolve it as much as possible. Determinism will thus be a limit toward which his doctrines will move. But he can never hope to arrive at absolute determinism. Neither will the experimental scientist care to, for then his scientific work would come to an end. Bernard seems to grasp the methodological character of his principle of determinism when he says:

> "Certainly we shall never arrive at the absolute determinism of everything; man would no longer be able to exist. There shall always be, therefore, indeterminism in all sciences, and in medicine more than in the other sciences. But the intellectual conquest of man consists in diminishing and pushing back indeterminism, in proportion that by the help of the experimental method it gains ground on determinism. That alone must satisfy man's ambition, because it is by this method that man can and will extend more and more his power over nature." (p.246)

b. Philosophical Doubt.

Because the scientist has the principle of determinism, he can not be a sceptic; he must believe in science. The sceptic believes in no science whatsoever. On the other hand, the scientist knows that his a priori idea is not absolutely certain, and that his theory is never more than an approximation. In fact, all theories are absolutely speaking false. Consequently, he must retain always a mental attitude of philosophical doubt.

"The great experimental principle, therefore, is doubt, the philosophic doubt which leaves the mind its freedom and initiative, and from which come those qualites the most precious in an investigator in physiology and in medicine. One should nelieve in our observations and our theories, but with the right of verifying them experimentally. If one believes too much, the mind is tied and restricted by the consequences of his own reasoning; he has his liberty of action no longer, and lacks consequently the initiative which one possesses who knows how to free himself from blind faith in theories, which is in reality scientific superstition." (Introd. p.66.)

Certain consequences follow from this mental attitude of philosophic doubt. First the scientist gives to the experimental method an independent character. It is never that he thinks is true, or what another scientist thinks is the correct theory, it is what the experimental method proves. And so, all due credit to great scientists past or present, authority must yield to the method. Secondly, if philosophical doubt leaves the mind free, it also leaves it in a continual state of change, of movement. Science is no longer something fixed, certain, and final. This is what Bernard holds to be true. "In the experimental sciences the truths being only relative, science is able to advance only by revolution and absorption of the older truths under a new scientific form." (Introduction, p.72.)

Understanding the difference between demonstrative science and dialectic, Bernard's doctrine on the place of doubt in the experimental method is easily admitted. Using dialectical reasoning, experimental biology cannot give a certainty which will rest the mind. Hence it is, that the scientist no sooner formulates his theories than he begins to doubt their worth, in view of the new facts continually presenting themselves. This doubt is an important part of the method, because it is a necessary condition for movement on to better theories. While liberty, independence, and initiative of mind are attributed by Bernard to this principle of doubt, they actually derive from the dialectical character of the method itself, abd the doubt is but a declaration of ones right to such dispositions of mind.

CHAPTER VI

ON DIALECTICAL DEFINITIONS IN EXPERIMENTAL BIOLOGY

We have so far shown by a comparison of modern and traditional texts that the method of experimental biology is dialectical. But this comparison bore only on propositions and discourse. It now remains for us to show that the very definitions and the terms used to signify these definitions are dialectical. If we do not continue in this chapter to compare our position with texts from modern writers on the subject, it is because the latter have not treated this subject in explicit enough fashion.

1. On the Nature of Dialectical Definition.

We here take definition as "oratio naturam rei exponens;" and which is divided into the nominal definition and into the real definition. "The real (quid rei) definition is divided into essential, descriptive, and causal.

> 1) The essential or quidditative definition is speech explaining something through its parts or essential predicates, as: 'Man is a rational animal.' Moreover, since the physical parts in each thing are considered as matter and form; and the metaphysical parts as genus and difference, the quidditative definition is twofold; namely,
>
> a) The real physical definition which is composed of matter and form; and
>
> b) The real metaphysical definition which is constituted by the genus and difference.
>
> Although in a physical definition matter holds the place of the genus, and the form

What we need to remember is that in the scientific method there is an interplay of facts and supposition. It is these two factors that we should observe and relate in the course of our history.

A. Ancient Science.

The biological sciences, among the Greeks, were first studied in connection with medicine. Hippocrates (500 B.C.), called the father of medicine, and other ancients have left us records which instruct us on the nature of early medical science. "If we were to examine these early medical works, we should find that whole departments of knowledge, which are now considered necessary for a doctor are entirely absent from them. Thus, for instance, they betray little or no anatomical, physiological, or chemical knowledge. The doctor of those times had no instruments for examining patients, such as listening tubes, thermometers, or magnifying glasses. He had only his own senses to guide him and he had very little record of what those who had gone before had seen of disease. On the other hand, his senses were well trained and he observed carefully and well, and put down what he saw with a wonderful eye for what was essential."(1)

There was, therefore, in early science a great reliance on careful observance of the plain facts. While not without his theory as to the cause of disease, Hippocrates was contending against superstition which attributed sickness to the gods or

(1) C. Singer, op. cit., p.2.

to the demons. There was an effort to teach people that diseases were due to natural causes. Philosophical doctrine was not without its influence. The ancients supposed that all matter was composed of four elements; earth, air, fire, and water. Following this idea, Hippocrates supposed that all human bodies are composed of four humors; blood, yellow bile, black bile, and phlegm. These four humors had a special relationship to the four elements. Health depended on the correct proportion between these humors, and various disproportions of them accounted for various diseases. In spite of the crudeness of this explanation there is an advance over the belief that diseases were caused by the gods.

"The method of the Hippocratic writers is that known today, as inductive. These men remained for the most part patient observers of fact, sceptical of the marvellous and unverifiable, hesitating to theorize beyond the data, yet eager always to generalize from actual experience; calm, faithful effective servants of the sick. There is almost no type of mental activity known to us that was not exhibited by the Greeks and cannot be paralleled from their writings; but careful and constant return to verification from experience, expressed in a record of actual observation, the habitual method adopted in modern scientific departments, is rare among them except in these early medical authors." (1)

During the development of the Coan medical school, centered around Hippocrates and his writings, medicine in the western

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(1) C. Singer, Greek Biology and Greek Medicine, Oxford, 1922, p. 91.

Greek world was being influenced by the philosophy of Empedocles of Agrigentum (430 B.C.). He spoke of the blood as the seat of the 'innate heat', which was identified with the human soul. His teaching led to a belief in the heart as the center of the vascular system and the chief organ of the 'pneuma' which was distributed by the blood vessels. The pneuma was equivalent to both soul and life, but it was sometimes identified with air and breath. Some of these terms were used in medicine for two thousand years.

Medicine, of course, advanced as more attention was given to anatomy, physiology and the kindred sciences. Especially famous is the Alexandrian school (300 B.C.) to which credit is given for organizing medical teaching. Finally there is the great figure of Galen (130-200 A.D.). The works of Galen alone form about half of the mass of surviving Greek medical writings, and occupy, in the standard edition, twenty-two thick, closely printed volumes. These cover every department of medicine, anatomy, physiology, pathology, medical theory, therapeutics, as well as clinical medicine and surgery.

The general standpoint of the Galenic writings is not unlike that of the Hippocratic writings, but the noble vision of the lofty-minded, pure-souled physician has passed away. Galen was an ingenious physiologist, a born experimenter and an expert anatomist. He possessed a good knowledge of the human skeleton and an accurate acquaintance with the internal parts so far as this can be derived from dissecting animals. He was equipped with all the learning of the schools of Pergamon, Smyrna, and Alexandria; he had practised in Rome. It is to his credit that he repeatedly acknowledged his debt to Hippocratic writings. Galen is criticised for putting teleological explanations in many of his writings. Singer says that Galen did not hesitate to intrude his religious beliefs into his scientific works.

Turning to Aristotle (384-322 B.C.), we have under study one who is probably the greatest philosopher and biologist of all times. His biology appears in continuity with his philosophy. This has already been spoken of when we discussed the movement of concretion in the study of living things. (See page 9.) Aristotle's chief biological works are his Parva Naturalia, Historia Animalium, De Partibus Animalium, De Motu et De Incessu Animalium, and De Generatione Animalium. Only those who carefully scrutinize these various works can realize the great work done by him. They contain a prodigious number of first-hand observations. It has always been hard to understand how one investigator could collect all the facts that he did. It is claimed that Alexander the Great had thousands of men inevery part of the then known world assisting him in composing his Historia Animalium. The latter work proves that he was at his best in the department of natural history. He also wrote on the organs and parts of the body, that is anatomy and physiology, but with less accuracy. Aristotle lacking the instruments used today in science is considered more of an observer than an experimenter. However, he was familiar with the scientific method of his day, and certainly experimented according to the fashion of his times.

In the beginning of De Partibus Animalium Aristotle gives what he called the canons to be followed in the intelligent study of biological problems. They fall in line with what has been stated before in his Physics. He advocates that one treat general properties of body and soul first in the study of living things. In this way repetition of common facts can be avoided as one treats each animal or function separately. Afterwards, separate species and their peculiar properties can be studied. (1)

With the nature and the number of animal parts described in the Historia Animalium, Aristotle next inquires what are the causes which have in each case determined the composition of each part. (2) Which are the principal causes for the natural scientist to determine? He teaches that there are two; namely, final cause, and efficient cause. In citing these two causes Aristotle differed from other Ancients who made material cause the principal one of study. For Aristotle matter is disposed in this or that manner in a thing, because of the final cause.

> "The causes concerned in the generation of the works of nature are, as we see, more than one. There is final cause, and there is motor cause... Plainly that cause is first which we call the final one. For this is the reason, and reason forms the starting point alike in the works of art and in the works of nature... For if a house

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(1) Aristotle, De Partibus Animalium, Cambridge, 1937, (Loeb Classical Library), Bk. I, chap.1, 639a, 15.

(2) Aristotle, op. cit., Bk.II, 1, 646a, 5-15.

> heart; why? Because they are bound to have a source for their blood. All blooded creatures, it is true, have a liver too; but no one would care to maintain that the liver is the source either of the blood or of the whole body, because it is nowhere near the place of primacy and governance, and, also, in the most highly finished animals it has something to counter-balance it, as it were, viz. the spleen." (1)

It is not the place here to explain or to justify the close relation which Aristotle established between his philosophy and his biology. Evidently his method was not scientific in the modern sense of that word. It is not a method which would appeal to present day scientists. For, Aristotle in his work asked questions very foreign to the interest of the modern biologist who is seldom interested in the ultimate nature and origin of life. "The business of the modern biologist is mainly with vital phenomena as he encounters them and he is not concerned with the deeper philosophical problems. The man of science considers a part of the Universe where the philosopher makes it his business to regard the whole. With Aristotle this modern scientific process of taking a part of the sensible Universe, such as a particular group of animals or the particular action of a particular organ, and considering it in and by and for itself without reference to other things, had not fully emerged. Philosophy and science are still inextricably linked and there is no clear demarcation between them." (2)

3. Foundation Period of Modern Biology.

After Galen (130-200) there was no period of great biological

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(1) Aristotle, op. cit., Bk.III, 4, 665b, [illegible].

activity until the sixteenth century. The teachings of Hippocrates and Galen were accepted almost blindly until the time of Harvey (1578-1651). The decline of science in this interim is attributed by Singer to the mental attitude of the ruling class in the Roman Empire. The Romans being practical minded did not consider the theoretical investigation of nature important. In the period of Scholasticism, philosophy and theology absorbed the interest of the learned. Yet we must mention the names of Roger Bacon and of Albert the Great. Bacon already had a grasp of the experimental method, but he did not work in the field of biology. Albert the Great is famous for his works on animals and plants. While he is criticised by Singer for following Aristotle too slavishly, he is nevertheless recognized as remarkable for his period, because he personally made careful observations. And too, he at times corrects the statements of Aristotle. It is seldom that Saint Albert receives from historians of science the full credit that is due him.

William Harvey may be considered the precursor of modern biological science. He is famous for his work on the circulation of the blood in the human. The thoroughness of his work is attested by such a fact, that he examined the heart action of over forty other animal species, besides that of man. In the use and study of specimens, and in the employment of dissection, Harvey is not unique. He was but following the method of such famous men as Versalius, Eustachi, Fallopio, Fabricius of Aquapendente, and others. Yet Harvey seems to have grasped the importance of experiment. However simple these experiments were, they confirmed his theories on circulation. They were actively performed for the sake of verification, even though the exact significance of verification may not have been understood. Moreover, in arguing for continuous circulation Harvey employed simple mathematics. Consider, he says, the capacity of the heart Suppose that the ventricle holds but two ounces. If the pulse beats seventy-two times in a minute, then in one hour the left ventricle will force into the aorta no less than 72 x 60 x 2; 8, 640 ounces; or 540 pounds of blood, which is three times the weight of man. Where can all this blood come from? Where can it go? There must be a circulation of blood. In reasoning thus, Harvey is probably one of the first to use mathematics in biology. Its use presages the use of other sciences in studying biological phenomena. For at times, some departments of biology have been practically reduced to mechanics, physics, or chemistry.

To Harvey, then, belongs the credit of giving in physical terms, an adequate explanation of a bodily process. "His work is not only the starting point of modern physiology, but it is also the first milestone on the road to the modern rationalization of biological thought." (1) With this rationalization such concepts as 'innate heat', 'animal spirits', 'pneumatic force' were gradually abandoned. In their place were substituted simpler concepts of the new biology, of physics and of chemistry. As part of this movement Harvey belongs with the moderns. As still remaining conservative, adhering to Aristotle and to Galenic teaching,

(1) C.Singer, The Story of Living Things, p.115.

Harvey belongs to the old order. For this reason, he is something of a precursor of modern experimental biology.

In the foundation period, changes also occurred in regard to scientific facts, which we have said are an important element of the scientific method. If we except Aristotle, who is said to have had thousands of other men helping him to investigate nature, biologists of the early centuries were as much in need of facts, as of theories to explain facts. Now facts became so numerous as to overwhelm the investigators. For example, the scientific work of Thomas Moufet (1590) shows a naturalist unable to handle the wealth of material collected from many countries.

His description of grasshoppers and locusts reveals his confusion:

> "Some are green, some black, some blue. Some fly with one pair of wings, others with more; those that have no wings they leap, those that cannot either fly or leap, they walk; some have longer shanks, some shorter. Some there are that sing, others are silent. And there are many kinds of them in nature, so their names were almost infinite, which through neglect of Naturalists are grown out of use." (1)

Briefly, the causes of the new wealth in facts are as follows. First, there was the humanistic movement which was reviving the learning of antiquity. There were the scientific voyages which brought information from all parts of the world. And took there was the new interest of men in the natural things

(1) C.Singer, op. cit., p.173.

that surrounded them. Secondly, not only were a multitude of facts discovered, but they were also made the common property of biologists. In addition to the new art of printing, there were other very important channels of communication. There were the newly formed academies, the collections, the museums, and the scientific journals. These were powerful organizing forces for biological study and progress. Thirdly, there was the invention of the greatest of biological instruments, namely, the microscope. By itself, it opened up a world of mysteries to the biologist, which will never be completely understood scientifically. While the first microscopists had no effective followers until the nineteenth century, there works were not without influence. "The general tone of the biological writings that followed them is very different from that which precedes them. Variety and complexity now begin to overawe the naturalist. Amidst the multiplicity of phenomena, order must be sought if knowledge is not to lose itself in detail. So it is that in the age that follows, the importance of classification becomes greatly emphasized." (1)

We must not think that facts alone can constitute science. Bacon himself in advocating the search and categorizing of facts seemed to think that facts might be passed through a sort of logical mill. The truth is that the experimenter must meet facts with the activity of the mind; a judicious choice of facts must be made in the scientific method. Very often biology has failed

(1) C. Singer, op. cit., p.171.

to supply this necessary mental activity, and in these periods biology has remained almost purely descriptive. For example, the use of the comparative method demanded little more than a recording of observed characteristics in plants and animals. The method, however, did turn out to be of value chiefly because it prepared the way for the theory of evolution. We must inquire, therefore, what change, if any, occurred in the experimental method by way of a change in the part played by the mind in this method.

We find a distinct change in the part played by the mind. We saw that Hippocrates used the inductive method in his profession; that is, he generalized the discoveries that he made by simple observation. Certain physical signs meant a certain type of sickness, which would end in such and such way.

In later centuries, we have the generalizations of Galen, Versalius, and Harvey. They were often enough confirmed by simple observation or experiment. But now we begin to see the mind, in the presence of such a chaotic mass of material, supplying a provisional principle of order. This is to say that the biologist without realizing it began to use supposition, or hypothesis. For example, one of the greatest problems facing the biologist of the sixteenth century was how to order the many specimens of plant and animal life. A start was made in the solution of this problem, by Obel, Cesalpini, and Bauhin who chose, each for himself, a principle of classification. Obel used the leaf as the basis of grouping; Cesalpini, the flowers and fruit; Bauhin, the twofold distinction of genus and species. Later, Jung, Ray, Tournefort, Linnaeus, and Cuvier perfected a system which has a place for every known animal and plant. Hence we have evidence of a method in which facts are manipulated by the mind working according to provisional principles, or hypotheses. In this method the problem is not solved for all time. For, any system of classification is open to changes, as we well know, from the theories of evolution, embryology, and heredity. But the method does give the feeling that something is being accomplished.

To trace the history of biological method from the rise of classificatory systems to the present day problems can not be undertaken here. Yet there are some other facts of history which bring out the importance of the question of verification. The rise of the comparative method, the growing interest in palaeontology, the study of the distribution of living things in space and time, all prepared the way for the problem of evolution. From certain facts, the biologist has supposed that living things have evolved genetically one from the other. This is the hypothesis of evolution. In this hypothesis the resemblances rather than the differences (as in classification) are considered the more important. Having posed evolution as though it were a fact, the biologist must then find other facts, or formulate other hypotheses to explain the cause of this evolution. Thus the theories of Buffon, of Lamarck, Darwin, and many others entered into biological history. Whatever the one-time greatness of these theories as to the causes of evolution, the theories themselves were never strictly verifiable by experimentation. For evolution is a problem of race development, in the usually accepted meaning of the term. The lack of the verifiability seems to explain why men like Woodger consider the problem of race development "of little importance for scientific biology." (1) On the other hand, if evolution is studied as a living problem, whose solution may be hidden in the problem of heredity, then it is certainly one for modern experimental biology. Then the demand for verification can also be met. Failing to meet this demand, a hypothesis must be rejected as scientifically useless; it must be considered sterile for science. To what extent modern biology verifies is studied in the thesis.

B. Contemporary Biology

In contemporary biology the problem of evolution no longer holds the place of honor. There are a handful of problems, considered key problems, which open the door to the investigation of many associated problems. These key problems are as follows:

1) The Cell and the Organism.

   This problem is the first carry-over from the foundation period of modern biology. It is concerned with the constitution of living matter, the construction of plant and animal organisms, the nature of growth and repair.

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(1) C. Woodger, Biological Principles, London, 1929, p.428.

2) The Problem of Vital Activity.

What are the simple operations of living organisms? Does chemistry, physics, the laws of energetics explain them fully? This is the problem in which biology easily becomes confused with philosophy. Other problems are those of muscular, nervous, etc. activity.

3) The Problem of Biogenesis.

It includes not only the question of the origin of life, but also the questions of infection, disease, and immunity. These are the subject matter of bacteriology.

4) The Problem of Individual Development.

What are the steps by which an individual developes? This is a problem that received the attention of such men as Fabricius and Harvey. Hence it is an old problem. The study of development is now known as embryology.

5) Mechanism of Heredity and Variation.

At present this problem is in the position of favor. It includes the special problems of the germ plasm, sex, the Mendelian laws of inheritance, and mutation. Theories of heredity are being offered to explain evolution.

It would be wrong to think that these problems are lending themselves to quite easy solution, because of the great advance of biology. In the opinion of Alexis Carrel those who are studying life phenomena are as men lost in a jungle, in a forest where innumerable trees change continuously in place and form. Moreover, these students feel themselves buried under a mass of facts which they can describe, but which they are not able to define by algebraic formulas. This is disappointing to some scientists who would like to do in biology what is done in those sciences treating inert matter. These latter sciences, namely, astronomy, mechanics, and physics, have as their bases concepts which are expressed in precise mathematical language. Their discoveries can be summed up in a mathematical formula. But this is not true to the same extent of biology. (1)

Indeed biology has, in studying its subject, turned to other sciences for help. This is especially noticeable in physiology, in which biologists have used concepts of physics, chemistry, and mechanics to carry on their investigations and to express the results. Liebig used chemistry to explore vital activity; Karl Ludwig relied on physics and chemistry; others, such as Maxwell, employed the laws of energetics. But whether the partitioning of biology among other sciences is a good thing is disputed. There are such well-known biolohists as Haldane and Carrel, and writers on the theory and history of biology, such as Woodger and Singer, who demand that biology be autonomous, and free to formulate its own basic concepts.

(1) A.Carrel, L'Homme, Cet Inconnu, Paris, 1935, Librairie Plon, pp.1-2.

According to Carrel the real nature of living man is little known today because the biologist has not been studying man in his entirety, in his living part, and in his own relations with the exterior world.[1]

Such reflections will disillusion us that all is well in theoretical biology, and that we are going to find the analysis of the methodology of biology an easy one. There remains before us the problem of the nature of the scientific method in biology. Only through an analysis of this method can we know the nature of biological knowledge.[1]

Historical Outline of Biological Method

	Ancient Medicine	Greek Biology	Foundation Period	Modern Perio
FACTS:	Keen observation of facts naturally presented to the senses.	Aristotle able to collect and record many facts on plants and animals.	Search for and observation of facts by dissection and experiment. Great abundance of facts due to new channels of information.	Overwhelming number of fhcts Selected in relation to ke problems: the cell, heredit etc.
MENTAL ACTIVITY:	Simple induction fom observed facts Formation of doctrines under influence of philosophy.	Aristotle proposed study of final and efficient cause.	Inductive generalization. Use of new concepts. Introduction of hypothetical reasoning to interpret facts.	Inductive and hypothetical reasoning. (To be studied.)
VERIFICATION:	Exact verification rarely made.	Simple form used. Ver. often deserted for speculation.	Verification by simple experiment. Nature of verification not understood.	Demand for verification of all hypotheses. Its nature much better understood.
REMARKS:	Scientific method essentially present but undeveloped. Hampered by superstition; influenced by philosophical doctrines.	Aristotle made his philosophy of nature and biology continuous. His method unsatisfactory to moderns. He visualised some of the modern problems.	Method strictly scientific and advanced over Greek method in medicine. General rationalisation of all explanations. Use of mathematics and other sciences.	(To be analysed and evaluated.)