Claude BERNARD (1813 – 1878), the father of modern physiology and experimental medicine

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The Lesson, by Léon Augustin L'Hermitte.
Claude Bernard is surrounded by students, colleagues and préparateurs.
To his left and wearing a black cap, his trusty 'caretaker', Père Lesage.

For a man of science, there is no separate science of medicine or physiology, there is only a science of life.

Claude Bernard 1865

Biography

Claude Bernard was born on 12 July 1813 in the village of Saint-Julien, in France's Beaujolais region. He was first educated in the church school of Saint-Julien, then at the Jesuit College in Villefranche-sur-Saone near Lyon. His school performances were not promising, and he moved to the Royal College in Thoissey. He became interested in philosophy, in particular by René Descartes' emphasis on the quest for truth stimulated by doubt. At that time, his main interests were focused to Romantic writers (Victor Hugo) and painters (Eugene Delacroix), and Victor Hugo's tragedy 'Hernani' was one of his favorites. Claude Bernard himself wrote two pieces, a piece of vaudeville comedy ('La Rose du Rhône') and a five-act historical tragedy ('Arthur de Bretagne'). When searching for an editor in Paris in 1834, one of them advises him to abandon his projects for literature, and Claude Bernard began his medical studies at the Faculty of Medicine of Paris. There, he shared a lodging together with Charles Lassègue (the future prominent neurologist). Following lectures by François Magendie, Professor of Experimental Medicine at the Collège de France, he decided to devote his own life to experimental physiology and, because of his skillful aptitudes, he was engaged by Magendie in 1841 as a research assistant (*préparateur*). By deference to the methodological approach and scientific interests of his mentor, his first experimental studies were orientated towards the nervous system and chemical aspects of digestion. During his whole life, Claude Bernard will acknowledge Magendie's positive influence on his own career. In 1843, Claude Bernard became a medical doctor but failed to qualify for teaching medicine, and he had to work in the private laboratory of a close friend of Magendie.

Scientific discoveries

Beginning in 1847, the scientific life of Claude Bernard was a continuous series of studies, publications and honors. During spring 1848, he performs the first of seminal discoveries. After having perfected the procedure of making pancreatic fistulae, he collected pancreatic juice from a dog and he used this liquid to verify his hypothesis according which gastric and pancreatic juices contain the same digestive principle. Contrary to this hypothesis, he found that the pancreatic juice exerted a particular action upon fats, provoking their emulsion. A few

months later, he made another fundamental discovery when investigating the fate of sugar after ingestion. Expecting that, according to the current theory, the process of respiration should burn sugar, he tried to identify the organ wherein sugar was disappearing from blood. During this work, he tried to see whether sugar was present in the blood of dogs that had not eaten and, to his great surprise, he observed that blood from portal vein was containing high amounts of sugar. Following a series of ingenious experiments, he thought to having demonstrated that sugar was penetrating blood through the liver. The discovery by Bernard of the glycogenic function of liver raised a very high interest, as well as the identification of the substance from which blood sugar derived. In 1855, by flushing with water the vessels from an isolated liver and by leaving the organ for one night, he demonstrated that sugar was derived from an unsolvable substance present in the hepatic tissue. He isolated that substance in 1857, called it glycogen, and showed that is was similar to starch. His third great discovery was the demonstration that there are two types of vasomotor nerves, vasoconstrictors and vasodilatators, both of them regulating blood flow in the arteries. He also identified the nerves that control secretion of saliva by submaxillar glands. He also showed that carbon monoxide blocks respiration in erythrocytes. For physiologists at that time and in the world, all of these discoveries have rendered famous the name of Claude Bernard. Even in Germany, the physiologist Du Bois-Reymond had to acknowledge in 1860: “this discoverer, more lucky than anyone, now forces everybody to look toward the vivisection table in the College of France”.

Introduction to the Study of Experimental Medicine

In 1865, forced by sickness to abandon his teaching and research activities, he writes his book ‘Introduction to the Study of Experimental Medicine’, in which he establishes as general principles his thoughts about experimentation in physiology and medicine. In this work, he analyses experimental reasoning, highlights the respective roles of ideas and observations, underlines the importance of doubt and the obligation to abandon working hypotheses when experimental data contradict predictions.

Determinism. For Claude Bernard, the apparent spontaneity of living beings does not constitute an obstacle to experimentation because the principle of determinism applies to both inanimate and organic worlds. “One must admit as an experimental axiom that, both in living organisms and inanimate objects, the conditions for reality of every phenomenon are determined in an absolute way. Which means in other words that, being known the condition

of an event, this event has to be reproduced, always and necessarily, as the researcher wishes. The negation of this proposition would be nothing else than the negation of science itself".

Authority and observation. When a scientist observes a fact which contradicts the prevailing theory, he has to accept the fact and abandon the theory even if this theory is supported by great names and commonly accepted.

Induction and deduction. Science is a permanent exchange between theory and experimental facts. There is an intimate connection between induction, *i.e.* reasoning from the particular to the general, and deduction, *i.e.* reasoning from the general to the particular. A general theory and its theoretical deductions must be tested with new experiments designed to control their reality. And the results from these particular experiments may induce new theories.

Fallibility. A long time before Karl Popper, Claude Bernard was convinced by the fallible character of every scientific theory. The scientist who studies natural phenomena must have a spirit completely free of prejudgments, relying on philosophical doubt. If a scientific theory is elaborated from experimental studies, the only true thing is that such theory is false. A partial, provisional theory exists but it only constitutes a step for going further in scientific investigation.

Cause and effect. The scientist tries to determine the relationship between the cause and the effect. The ultimate objective of research is to establish the connection between each natural phenomenon and its cause. A working hypothesis is formulated to elucidate the relation of cause and effect of some phenomena. The working hypothesis is submitted to experimentation. If one hypothesis is demonstrated by experimental observations, it becomes a scientific theory. "Before that we have only groping and empirism". Scientific theories have to be only hypotheses controlled by experimental facts. Those controlled by experiments are the best theories but they are never final and do not have to be believed in an absolute way. The true scientist must always try to deconstruct his personal conclusions by counter experiments. The ardent desire of knowledge is the only valuable reason that motivates scientists in their efforts and studies. The discovery of fragments of universal truth, this is the real science. "The complete scientist is one who masters both theory and experimental practice: 1, he observes a fact; 2, he conceives an idea with reference to this fact; 3, on the basis of this idea he pursues a line of reasoning, plans an experiment and imagines and organizes its material conditions; 4, this experiment produces more phenomena that shall be subjected to observation and so on. In a sense, the scientist's mind is always between two observations: one is the starting point of the reasoning, the other its conclusion".

Known and unknown. “The scientists are marked by ideas which light up phenomena hitherto obscure and carry science forward”.

With regard to the spiritual sphere, Claude Bernard explained in his book ‘Lessons about Phenomena of Life’ that the physiological determinism does not tolerate any exception and that each manifestation of living creatures is a phenomenon depending on defined physicochemical conditions. This is the absolute determinism: it implicates that psychological and spiritual spheres are completely determined by physicochemical world. In the same perspective, Claude Bernard will reject any notion of ‘Galenic’ teleology and metaphysical philosophy according which all physiological functions have an ultimate and precise goal. So he closely participates to the move of scientific procedure from the question ‘why’ to the question ‘how’. For Bernard, the nature and intimate essence of each phenomenon, living or inanimate, will remain unanswered forever. “Science has precisely the privilege of making us know what we ignore, substituting reason and experience to feeling, and showing clearly the boundaries of our present knowledge”. If our usual feeling incites us to ask why, our reason show that only the question ‘how’ can be answered.

Milieu intérieur

In the history of biomedical research, one of Bernard’s key discoveries is to have elaborated the concept of *milieu intérieur*. He was well aware that anatomy remained the basis of physiology, but he made it clear that physiological processes cannot be explained on the basis of the sole anatomy. He stated that humoral or physicochemical components, which cannot be dissected and constitute our internal environment, had been neglected for too long. This concept has exerted a profound and long influence on biologists and physicians. He was fully conscious of its importance and supported that, together with the principle of determinism, this concept constitutes the basis of the new experimental medicine. “The constancy of the internal environment is the condition for a free and independent life”. By writing this, he opens one of the most intriguing and fascinating fields in science, the one of regulations, adjustments, and compensations. Claude Bernard mentioned four examples that have been illustrating this concept until today: regulation of water volumes, body temperature, oxygen concentration, and metabolic stores. In 1926, Walter Cannon will reformulate the constancy of the internal environment in a new way as the concept of *homeostasis*.

If Claude Bernard has made physiology progress much more than another scientist before or after him, this is greatly due to his great talent of intuitive generalization. So did he write: “Particular facts are never scientific; only generalization can establish science”, and “When

one calls a new fact a discovery, the fact itself is not a discovery, but rather the new idea derived from it". The genius of Bernard has not been only limited to a great number of seminal discoveries, but also to an immediate understanding of their general meaning and perspective. His experiments on the fate of sugar in the animal organism leads him to the concept of unity of living creatures, to the definition of internal (endocrine) secretions, to new ideas for understanding pathogenesis of diabetes, and to the concept of 'milieu intérieur'. Quite simple experiments about curare quickly led him to general and new ideas about muscles, nerves, and the essence of life itself. Whatever their intrinsic limitations, these generalizations have proven their pragmatic and operational values for dozen years after their formulation. Nobody has defended with more tenacity and intelligence the need for a new medicine based on physiology. As a protagonist of the experimental medicine, he hoped to see scientific medicine quickly replacing empirical medicine, which was essentially based on observation. The physician should continue to carefully observe his patients but, through experimental science, he should be able to analyze each symptom trying to explicit them by vital laws that understand the relation of the pathological state to normal or physiological state. Claude Bernard was convinced that the formation of such physicians could only be performed in specialized laboratories because useful precepts are only those resulting from experimental practice in a precise scientific domain. However, because the parsimonious policy of the French government and because he was not teaching in medical institutions, Bernard did not took benefit from the same advantages than his foreign colleagues to reach his objectives. Even during his period of scientific glory, his personal laboratory always conserved modest dimensions. Only a small group of attentive students could learn experimental physiology under direction of this great master.

Predicting the future, Claude Bernard wrote that "the experimental physician wants to understand what he does (…) He wants to scientifically experiment and to understand the physiological mechanisms underlying the disease process and the curative action of one drug". He will say also that, "if the hospital is the antechamber of scientific medicine, the laboratory is the real sanctuary of medical science". In the laboratory, the scientist explores and discovers the explanations about the nature of life phenomena both in normal and pathological conditions.

Claude Bernard occupied the seat 29 at the Académie française from 1868 and was succeeded by Ernest Renan. When he died in 1878, he was accorded a public funeral, an honor that had never before bestowed in France to a man of science, and his grave resides in Père Lachaise

cemetery in Paris. He has been the father of a scientific revolution, and his heritage is still active nowadays in parallel with the current genetic revolution.

Further information

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