Florkin, Marcel

Personality and Scientific Research

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Marcel Florkin (Belgium)

PERSONALITY AND SCIENTIFIC RESEARCH *

No one has extolled the grandeur of the scientist's vocation with more enthusiasm than the geologist, Pierre Termier.[1] "It has well-known characteristics, this vocation", he writes, "which an attentive teacher cannot mistake: first and foremost, its enthusiasm, which displays an exclusiveness that does not tolerate secondary tasks, or only tolerates them with difficulty; its continuity of thought; its indifference to any other considerations than that ever-present thought held constantly in the mind". And, he remarks later, "almost of necessity the scientist will be poor, for disinterested scientific research rarely leads to wealth; but his poverty—provided that he does not sink into misery—does not weigh heavily upon him. Like that great pauper, Paul Verlaine, or yet another apostle of poverty, Léon Bloy, he will have a veritable love of being poor, because poverty magnifies the powers of thought and relieves man from the fascination of triviality".

Was there ever a scientist who corresponded more closely to Termier's portrait, in his enthusiasm, than Joseph Priestley? Yet with his attention vacillating between religion, education, politics, and, it is true, for a short period pneumatic chemistry, he can hardly be taken as a model of continuity of thought. Nor does Sir Humphrey Davy offer greater proof of a continuous vocation than Priestley. Child of a modest family who was delighted to become the idol of London society, Davy was also a poet, novelist, essayist, traveller and man of the world. At twenty, while he was still in Bristol pursuing his research on laughing gas, this man who was to become the very type of the vainglorious scientist wrote a novel entitled *Inula, the Man of Simplicity,*

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* Translation of the lecture delivered in French at the First plenary meeting of the 12th International Congress of the History of Science, Paris, August 26, 1968. Quotations, when not in English, have also been translated.

[1] P. Termier, *La vocation de savant*, Desclée de Brouwer, Paris, undated.

for which he imagined himself the model! Davy's scientific contributions have been described by Berzelius as "brilliant fragments", particularly brilliant when he was writing as the pioneer of electrochemistry and the author, as well, of the discovery of alkaline and alkaline-earth metals.

Fine traits of disinterestedness exist, it is true, in the lives of certain scientists. An unassuming man of great simplicity, hostile to the honours which he always refused, Michael Faraday is an example. First an apprentice bookbinder, then a newspaper vendor, Faraday was prompted by an imperious inclination for the sciences to get hold of tickets for four lectures given by Davy at the Royal Institution and to write to him to ask for employment. Davy was able to hire him as his assistant and take him with him on his journey to Europe, where Faraday was appreciated for his modesty, his amiability and his intelligence by all the savants who met him. "We admired Davy", J. B. Dumas wrote of this sentiment, "but we loved Faraday". Yet Faraday was regarded somewhat as a domestic servant by Davy, and especially by Lady Davy, who made him polish her boots.

Later, following the practice of certain "bosses" of the period, Davy was to show no hesitation in claiming on his own account the credit for the liquefaction of gas accomplished by his assistant, who in turn was shortly afterwards obliged to acknowledge—perhaps with a certain malice towards his master's vanity—that the liquefaction of chlorine had already been realized by Northmore in 1805. It is generally expected, despite numerous daily examples to the contrary, that a scientist follows this practice of rendering to his predecessors that which is their due. It has been possible to make a case for the argument that Lavoisier did not always do justice, in his great discovery of the role played in combustion by the oxygen isolated by Scheele and Priestley, to certain of his contemporaries, such as Guyton de Morveau or Mitouard. But as Henry Guerlac has shown, [2] it is probable that Lavoisier had already conceived of the idea of combustion and the role of oxygen in connection with other researches; and his contribution was in any case developed in a completely new context, extraordinary in its consequences as a result of his rejection of the phlogiston theory.

An extreme case of non-acknowledgement of another scientist's priority is found in Charles Bell's biography. In 1811, Charles Bell, in a book printed for private circulation, had, without proving it, associated the motor function with the anterior roots of spinal nerves. In another text, published in the *Philosophical Transactions of the Royal Society,* and concerned with observations on the cerebellum, he attributes, without demonstration, the sensitive functions to the posterior

[2] H. Guerlac, *Lavoisier: the Crucial Year,* Cornell University Press, Ithaca, New York, 1961.

roots. In 1821 and 1822, Magendie brings in the experimental proof of the motor functions of the anterior roots, and of the sensitive function of the posterior. If this had been the whole story, the expression of Bell-Magendie law would have paid a tribute to the imagination of Bell as well as to the experimental skill of Magendie.

Unfortunately, in 1830, Charles Bell published, under the title *The Nervous System of the Human Body,* a collection of memoirs presented by him to the Royal Society. Though keeping the original date of each paper, Bell introduced in the text, as his own, the demonstrations provided later on by Magendie, as well as by Herbert Mayo, and he deleted the statements in contradiction with these demonstrations.

Faraday had been struck by Oersted's observation of 1820, that marks the beginning of our knowledge of electromagnetism, and he developed new experiments on this subject with Davy. With a particularly touching discretion towards the latter, however, he directed his researches towards other areas, which brought him to the isolation of benzene and to his work on steel and the chemistry of glass. The pursuit of these researches would certainly have earned him high position and fortune. But after the death of Sir Humphrey Davy in May 1829, Faraday determined to abandon his applied researches—and the profits they offered—in order to devote himself entirely to the subject he preferred, that of electromagnetism. "I would like, under present circumstances, to lay the glass aside for a while", he wrote on 4 July 1831, "that I may enjoy the pleasure of working on my own thoughts on other subjects." [3] The magnificent discoveries which grew from these thoughts are well known.

We find a contrary motivation in the career of Vesalius, one of whose motives was certainly personal ambition. Vesalius is being seen in a new light, and the originality of his work is appearing more clearly, as his personality emerges progressively from his legend. [4] Born in Brussels in 1514 to a family traditionally devoted to the medical professions, which it exercised in the service of the powerful, Vesalius commenced the study of medicine in Paris in 1533. His ambition was to make a brilliant and lucrative career in the service of someone well placed in the hierarchy of power, and, if possible, of the most powerful of all, the Emperor. The desire to fulfill this ambition, the zeal for work which was its condition, the resolute determination to attain his goal: all of these marked Vesalius' personality. In Paris he learned to dissect not only human corpses but especially those of animals. Neither docile nor a conformist (in his biography [5] Georges Leboucq

[3] J. Kendall, *Michael Faraday, Man of Simplicity,* Faber, London, undated.

[4] M. Florkin, "La renaissance des études vésaliennes au XX[e] siècle," *Commémoration solennelle du quatrième centenaire de la mort d'André Vésale,* Acad. Roy. de Médecine de Belgique, Bruxelles 1964, pp. 161—169.

[5] G. Leboucq, *André Vésale,* Office de Publicité, Bruxelles 1941.

found no better way of describing him than as a doubter) Vesalius did not hestitate to express his derision and doubt. When he attended anatomy lectures as they were given at the time—with the master reading the accepted authority from the rostrum, the barbers dissecting the corpse without knowledge or method, and no one thinking to verify the agreement between the book and the dissection—he could not restrain the ironic outbursts to which such a spectacle inspired him.

He even developed a systematic method of presenting a dissection, during which he himself held the scalpel and discussed the visible evidence which the spectators could verify. When the war between Charles V and Francis I broke out in 1536, Vesalius returned to his native Brabant and spent a year at Louvain, where the influence of Arab medicine was still dominant. In accordance with the prevailing temper, he here prepared a paraphrase of the work of the Arab physician Rhazes; and although there is no direct evidence on this point, it was probably this text that he presented in fulfilment of the requirements for the bachelor's degree. He then left for Padua where he received the degree of Doctor of Medicine on 5 December 1537 and was soon charged with responsibility for demonstrations in surgery. Since anatomy formed the basis of surgery, he devoted himself completely to the study of this science.

Until then an adept of the school of Galen, Vesalius stated the principles of his own method on 15 January 1540 during a dissection which he gave at the University of Bologna at the invitation of the students, who directed the university. With constant supplies of human thence to Basle where he devoted the year 1542 and the first half of 1542, Vesalius was able to convince himself that the Galenic anatomy taught everywhere was not based on the dissection of the human body, but was in effect an extrapolation to the human form of notions derived from the dissection of animals: dogs, monkeys or pigs. It was this that he had the audacity to publish. In order to do so, he resigned his position at Padua to make his way to Venice, in the beginning of 1542, and thence to Basle where he devoted the year 1542 and the first half of 1543 to the preparation of his fundamental work, *De corporis humani fabrica libri septem*. In this magisterial work all the humanistic and aesthetic gifts of Vesalius were deployed. The work was not only a much more extensive and accurate description than that of his predecessors, but it gave anatomy a new language and displayed in the beauty of its numerous plates, as well as in its printing and presentation, a perfection and mastery hitherto unknown.

Vesalius left Basle early in 1543 to present his book to Charles V, to whom it is dedicated. Te emperor took him on immediately as *Medicus familiaris ordinarius*. Thus was accomplished the goal in pursuit of which Vesalius had invested untiring activity, the rarest talents and the courage to speak out against prevailing ideas.

While we would certainly not dream of claiming that personal ambition is necessary to accomplish great anatomical discoveries, we must nevertheless take note that Vesalius—whose talents are revealed in his book without any doubt—can scarcely be taken for a disinterested scientist. Nor can be taken as such, two of the greatest scientists of the 19th century, Schwann and Darwin, who both increased their fortunes through astute financial speculations.

J. D. Watson, one of the authors of the most fruitful discovery of modern biology, that of the double helix structure of DNA, has recently related the history of this discovery.[6] His book constitutes a sincere and touching picture of the human frailties of some of the greatest scientists of our times.

Like other communities, the community of science possesses its modest figures and its vain ones, disinterested men and those greedy for fame or wealth, those who are scrupulous and others less honest. Disinterestedness, the scrupulous love of truth, love for one's fellowmen, honesty towards others, the spirit of poverty, are no more widespread among men of science than financiers or politicians. The ones, like others, are men: with all the weaknesses that human nature implies.

Considering scientists in their proper activity, it must be recognized as obvious that the role of imagination has frequently been a factor in scientific discovery. Among the authors of great discoveries, the source of creative imagination is often found in aesthetic tendencies. This form of imagination is frequent among organic chemists. Ideas take form in the mind in the same way as the themes of a musical composition. As with composers, the idea is seen on all sides and studied again and again until embellished with all its facets. This is one of the inventive caracteristic of Faraday and Liebig, for example, or more recently of Hans Fischer and of Ruzicka.

J. H. van't Hoff has emphasized—notably in an essay recently translated into English[7]—the role of the imagination in the scientist's study of the relation of cause and effect. According to van't Hoff, imagination comes into play in the course of several successive operations: the choice of the moment at which the phenomenon is to be observed and of the conditions which make it most effectively observable; the eliciting of a negative or positive correspondence with other phenomena; the appeal to hypothesis. These steps would remain unproductive without another of the fruits of the imagination, the existence in the researcher's mind of intellectual intentions which are also imaginatively

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[6] J. D. Watson, *The Double Helix. A personal account of the discovery of the structure of DNA*, Atheneum, New York 1968.

[7] J. H. van't Hoff, *Imagination in Science*, Springer, Berlin 1967.

coloured. The particular nature of these intellectual intentions will be considered more fully later. Returning to the factor of imagination, we can discover (with van't Hoff) in the great scientists of the past the expression of a lively imagination, manifested by artistic tendencies such as those found in the form of poetic gifts in Lalande, or a musical one in Lacépède. Different as Davy and Faraday were in their personality, both were endowed with a lively imagination. "Do not suppose that I was a deep thinker, or was marked as a precocious person", Faraday wrote in a letter to De la Rive (cited in Tyndall's biography). "I was a very lively, imaginative person and could believe in the *Arabian Nights* as easily as in the *Encyclopaedia*". We have already recalled the diversity of talents united in Davy's brilliant personality. Cuvier described his poetic gifts as follows: "... from infancy, he was an orator and poet. His impressions were vividly painted in his words; each time he returned to school, his young fellows thronged around him, forgetting everything to hear him describe what he had just seen. His reading did not stimulate him less than his observations: scarcely had a translation of Homer fallen into his hands, than he set himself also to compose an epic on the subject of Diomedes ..." [8]

A form of imagination akin to that of Faraday but in the pure isolated state can be recognized as the predominant factor in the personality of Zénobe Gramme, at the origin of his discovery of the principle of the dynamo and of the electric engine, an achievement of the utmost importance in the history of modern technology. Half illiterate, Gramme died at a ripe old age without having acquired the knowledge common to schoolboys and without having pushed his mathematical training beyond the four operations of elementary school arithmetic. The motivation which led him to his great discoveries is not to be found in any intellectual attitude, but in a simple characterial trait: he was fastidious about clothes and body cleanliness. A simple joiner, spezialized in banister making, he became employed by a Parisian firm of galvanoplasty for making wooden molts. He was shocked by the dirt surrounding the batters used for producing constant current and he started trying to produce it by the use of a revolving machine. He succeeded in 1869, by building the first dynamo [9].

In the history of science, intellectual intentions have played a capital role in the genesis of discoveries and have permitted the neutralization of numerous epistemological obstacles. The idea of the influence of the celestial bodies on human lives has played a fundamental role, in the development of astronomy, as has the quest for the philosopher's stone

[8] G. Cuvier, *Recueil des éloges historiques lus dans les séances publiques de l'Institut de France*, nouvelle édition, tome III, Didot, Paris 1861, p. 118.

[9] J. Pelseneer, *Zénobe Gramme*, Office de Publicité, Bruxelles 1941; L. Chauvois, *Histoire merveilleuse de Zénobe Gramme, inventeur de la dynamo*, Librairie Blanchard, Paris 1963.

in chemistry. The three dreams with which Descartes was visited on the night of the 10th or 11th of November 1619, and from which was to date the *Mirabilis scientia* were probably nourished by the unitary aspirations of Rosicrucian doctrines.

Temkin [10] has found the origins of Magendie's intellectual attitude in the sensualist philosophy of Locke and Condillac, pushed to its extreme form by the idéologues at the time of the French Revolution. Faraday, haunted by the idea of a connection between light and electricity, finished by finding a demonstration of this connection at the level of the influence of magnetism on polarized light. A few weeks before his death, Goethe described the intellectual attitudes of four French scientists—Buffon, Daubenton, Cuvier and Etienne Geoffroy Saint-Hilaire—in the course of the development of the "anatomical philosophy". Buffon takes the external world as it is, as an infinitely diversified whole, the diverse parts of which mutually complement and influence one another. Daubenton, as an anatomist, is constantly separating and isolating, but he takes care not to compare the isolated facts that he has discovered; on the contrary, he arranges each object one beside the other, to measure it and describe it in itself. Cuvier works in the same way with more intelligence and less attention to minute details: he knows how to put things in their place, classifying them and combining the innumerable individual objects that he has observed; but he nourishes against a larger method the secret apprehension which, occasionally, has not prevented him from making use of it without his very knowledge. Geoffroy Saint-Hilaire recalls Buffon in many ways. The latter recognizes the great synthesis of the empirical world, but he utilises and makes known all the differences which distinguish beings one from another. The former draws closer to the great unity, an abstraction of which Buffon had only caught a glimpse: far from recoiling before it, he lays hold of it, dominates it and wrests from it the consequences that it conceals" [11]. Szent-Gyorgyi was for a long time led in his researches by the idea of a relation between antiscorbutic properties and the reducing properties of a constituant of the adrenal glands, at a time when this idea was accepted by no one. Watson was haunted by the idea of the helix structure of DNA before any demonstration existed.

Aspects of the scientist's *cogito*, the thematic components of his personality, can nevertheless play an unfavourable role as well as a favourable one in the pursuit of discovery. It is clear that intellectual attitudes are more often at the origin of the persistance of error than

[10] O. Temkin, "The Philosophical Background of Magendie's Physiology," *Bull. Hist. of Med.*, 1946, 20, pp. 10—35.

[11] Quoted by Th. Cahn, *La vie et l'oeuvre d'Etienne Geoffroy Saint-Hilaire*, Presses Universitaires de France, Paris 1962.

at the origin of new discoveries. Louis de Broglie found in the fact of Henri Poincaré's nominalism an explanation for the failure to formulate the theory of relativity, although he came close to it.

Kepler, profoundly mystical, was also a mathematician of genius and a very gifted theoretician in astronomy. Mysticism and mathematics converged in his mind in the synthesis of a profound faith in the supreme harmony of the universe, manifested by the simple and clearly defined relations of its proportions. Mysticism and aesthetic motivation came together to inspire his book on the Harmonices Mundi. For him, the relations between the maximum and minimum speed of planetary motion were dependent on a properly musical harmony, expressed in musical intervals. Thus, he said, the planets play a music that only our spiritual ear can perceive.

Mirko Grmek [12] has recently classed Galileo, with Boscovich, among the antimystical extroverts, contrasting them with the category of theoreticians with leptosomic appearance and schizomythic character who contribute particularly to the advance of the physico-mathematical sciences, among whom he places Newton, Kepler and Pascal.

Galileo, although Kepler's contemporary, was in fact his antithesis in every way. The characteristic traits of his personality were exuberance, optimism, lively imagination. There was nothing of the modest man about him. His jovial, witty and lively temperament often pushed him to sarcasm, which was to cause him numerous difficulties. Although a devout catholic, he was also completely rational and objective; and it is to him that we owe the introduction into science of the method making possible the invention of schemas of experience, which has since received the name "scientific method".

Rational and objective as he was, Galileo was nevertheless profoundly attracted to concepts of an aesthetic origin, as for example the Platonic conception of the perfection of circular motion. It is perhaps this which prevented him from discovering the elliptical motion of the planets, and he was not even to take the trouble of reading the books in which Kepler described this elliptical movement. However, "Sphaera cujus centrum ubique, circumferentia nullibi" was also a saying dear to Kepler; and it was not without regret that he found himself forced to break the circle of classical astronomy. His "new philosophy" was not that of a metaphysican, but it admitted of an aesthetic component in the context of a splendid and harmonious Universe created by the Great Geometer, agent of what Kepler called "the mystical mathematics of the City of Heaven". The planets aspired to circular motion but the limitations of their crude nature made them approach it in an elliptical movement, imitating as much as their nature per-

[12] M. D. Grmek, "La personalité de Galilée," *Galilée. Aspects de sa vie et de son oeuvre*, Presses Universitaires de France, Paris 1968, pp. 48—73.

mitted "the beauty and nobility of the circle". Kepler's mathematics, even if he approached it by way of the "Geometer-God", was no less incontestable for that. It remains the monument assuring his glory, of which he was confident when—not without remorse—he doubted the Platonic circle and consummated its rupture.

This "philosophy of the circles" is found again as one of the factors in the discovery of the circulation of the blood by William Harvey.

The personality of William Harvey is a striking contrast with the background of the poetical and mystical tendencies of his time. Of a grave and serious character, cold and very reserved in his judgments, Harvey was a little man who was always master of himself, always alert, courteous, black of eye, a great lover of painting, a matter-of--fact mind. Everything in his work is exact, precise, objective, devoid of poetry or philosophy and with a minimum of rhetoric. For him, the human body was far from being the marvel of marvels. It followed the same plan as that of the eel, the serpent and the crayfish which he examined on his dissecting table, or of Mrs. Harvey's parrot: a little mechanical world, made up of machines functioning according to the currently accepted principles of mechanics. And yet the circle of perfection—which Kepler had broken—remained in the mental structure of William Harvey; and it is evident even in his work describing the circulation of the blood, *Exercitatio anatomica de motu cordis* [13]. Meditating on the whole of his experiments, "I began", he says, "to think whether there might not be a MOTION, AS IT WERE, IN A CIRCLE. Now this I found afterwards to be true". The capitalization in Harvey's statement indicates the importance of the circle as a clue to blood circulation. It is probable that, had he been more preoccupied with the "new philosophy", this factor would not have intervened at that moment.

As Jung wrote, "even the freest possible activity of the mind, imagination, can never wander at random (although the poet has this impression): it remains bound to previously formed possibilities, prototypes, archetypes or original images. By the resemblance of their themes, the tales of the most distant peoples reveal this subjection to certain primordial images. Even the ideas which serve as the basis of scientific theories remain confined within the same limits: ether, energy, their transformations and their constancy, the theory of atoms, affinities, *etc.*" [14] G. Canguilhem admits "that theories do not originate from the facts which they organize and which are supposed to have given rise to them. Or more exactly, facts give rise to theories, but they engender neither the concepts which unify them internally nor the

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[13] See M. H. Nicolson, *The Breaking of the Circle*, rev. ed., Columbia University Press, New York and London 1962, p. 132.

[14] C. G. Jung, *Types psychologiques*, trad. Le Gay, Genève 1950, p. 310.

intellectual intentions which develop them. These intentions have remote origins and these concepts are few in number. That is why theoretical themes survive the apparent destruction that a polemical refutation is credited with inflicting upon them." [15]

At times identified with the concept of God, the archetype of the unity of nature—regarded by Bachelard as one of the most baneful of epistemological obstacles—has inspired innumerable intellectual intentions. In his writings on historical chronology as in his investigations of natural philosophy, Newton was guided by the same idea: the quest for the work of a single Creator, ruling master of the universe that was his handiwork, "living intelligent and powerful Being", "eternal and infinite", "omnipotent and omniscient", [16] the watchmaker God whom Leibnitz criticized for having to wind up his creation from time to time. This God is not the philosophical God of Aristotle or of Descartes, the first impersonal Cause at the origin of the conception of scientific materialism and of mechanism. Nor is he any more the God of the personal religion of Joseph Priestley than the organizer God of Plato.

To illustrate the part played by intellectual attitudes in the process of discovery, we shall deal in greater detail with one particular case: that of Theodor Schwann, one of the authors of the cellular theory of organisms. Georges Canguilhem justly identified the significance of the cellular theory as that of an extension of the analytical method to the totality of theoretical problems posed by experience. The cellular theory prolonged, on the biological terrain, the old debate over continuity and discontinuity. The search for a common structural principle of living beings, outside of imaginary entities such as the "molecules" of Buffon, has preoccupied many scientists. In his biography of Virchow, [17] Ackerknecht distinguished several successive forms of this search for a common principle. In the 18th century, the principle was the "fibre". According to this views, which Ackerknecht designates as cellular theory N° 1, the development of fibres had as their point of departure little globules, such as those admitted by Prochaska (1797). After these views were abandoned, a new theory appeared in the school that John R. Baker [18] has termed "globulist", which is Ackerknecht's cellular theory N° 2. It is to this school that Oken belongs, as well as Meckel, Mirbel, Dutrochet, Purkinje, Valentin and Raspail. The notion of "globule" embraced the greatest variety of elementary units:

[15] G. Canguilhem, *La connaissance de la vie*, Hachette, Paris 1952.

[16] *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World* (translated into English by A. Motte), quoted from F. E. Manuel, *Isaac Newton Historian*, Cambridge University Press, 1963.

[17] E. H. Ackerknecht, *Rudolf Virchow*, University of Madison, Madison 1953.

[18] J. R. Baker, "The Cell Theory: a Restatement, History and Critique," Part I, *Quart. J. Micr. Sci.*, 1948, 89, pp. 103—125.

particles and nuclei, as well as optical illusions. The globulists many times included one or another form of cell among their "globules", but none of them can be regarded as having conceived of the organism solely comprised of cells, of modified cells or of products of cells. It was not until 1830 that the perfecting of the microscope permitted the botanist, Robert Brown, to recognize the presence of the nucleus as the essential characteristic of the plant cell.

In 1839, in his *Mikroskopische Untersuchungen,* Theodor Schwann formulated what Ackerknecht has called the cellular theory N° 3, which insists on the common cellular origin of everything which lives. By "cell", Schwann meant "a layer around a nucleus", which could differentiate itself: covered over by a membrane, for example; as the seat of deposit of a more consistent substance; growing hollow as a vacuole; or fusing itself with the "layer" of other cells. He also accepted—a part of his theory which has been reconized as inexact—that cells form themselves by crystallization within the blastema. Ackerknecht's cellular theory N° 4, which remains current, is that of Remak and Virchow, the first part of which follows Schwann in acknowledging the cellular composition of organism, with the cell as the vital element, the bearer of all the characteristics of life. The second part of this theory, expressed in the dictum "omnis cellula a cellula", contradicts the error of Schwann in admitting the formation of cells by crystallization within a "blastema".

Returning to the cellular theory of Schwann, whose role in the intellectual history of biology is not contested, let us analyze the intellectual intentions which led him to conceive of his theory, both in those parts which are still accepted as true today and in his error as to cellular origins. The personality of Schwann [19] is well known to us from numerous unpublished texts, of which several are autobiographical.

An account of Schwann's early life has something of the confined atmosphere of the edifying tales of saintly childhood. It was at Neuss, classical Novaesium (at the gates of which Drusus, the brother of Tiberius, threw a celebrated bridge over the Rhine) that Theodor Schwann was born on 7 December 1810. In the eyes of his teachers and fellow pupils in primary school and at the progymnasium, Schwann was an exceptionally cooperative child, dilligent and modest. Little tempted by the delights of society, lacking self-confidence, excessively shy, he withdrew into study, family life and piety. Equally brilliant in all branches of education, he showed particular inclination for mathematics and physics. Given his lack of inclination for the outside world and his freedom from strong passions, it was accepted that his

[19] M. Florkin, *Naissance et déviation de la théorie cellulaire dans l'oeuvre de Théodore Schwann,* Hermann, Paris 1960.

vocation should be directed towards the Church when he left his native town in 1826 with the intention to enter the College of the Three Crowns in Cologne.

Here Schwann experiences the influence of an exceptionally religious teacher, Wilhelm Smets. For an extremely shy young man lacking in self-confidence and until then acquainted only with the strict aspects of piety, but also endowed with a brilliant intelligence and a lively sensibility, Smet's teaching of religion was the revelation of an entirely new aspect of God and especially of the singular fact of man's liberty in the face of the whole of nature. It is from him that Schwann learned the lesson of the elevation of many by personal perfection.

More and more enamoured with reason, he renounced theology to take up medical studies. His philosophical position became that of a Christian rationalist whose personal philosophy was in the tradition of Descartes and Leibniz.

Remaining a practising Catholic, Schwann nevertheless abandoned himself, especially after the death of his mother in 1835, to an extreme mechanistic tendency, which guided him in the impressive work that he accomplished in Berlin from 1834-1839, in the laboratory of Johannes Müller. At this time, then, Schwann's conception of God was that of the philosophical and impersonal God of Descartes.

During this period, Müller was working on the *Handbuch der Physiologie,* which introduced into Germany the experimental method of Magendie in medical studies. Until his death, Müller remained a convinced vitalist. Recourse to experimentation was for him (as it had been for Bichat) a means of studying the effects of the vital force peculiar to each organ. Restricted in his chemical and physical background, he was to detach himself progressively from physiology to devote himself entirely to comparative morphology, in which field he acquired fame. From the beginning of his career as a researcher, on the contrary, Schwann took a completely different position, which inaugurates the quantitative period of physiology.

Müller's Handbuch was in no way a work of mere compilation, for he critically examined all the notions that he printed. Repeating the experiments of others, imagining new ones, opening avenues not yet explored, this treatise is a work unique in its conception as in its realization. In the section entrusted to him, Schwann enriched Müller's treatise with the results of extensive work and contributed numerous new notions: the structure of voluntary muscles, the existence of a special capillary wall, the muscular contractibility of arteries, the reproduction of severed nerves, the structure of elastic tissue, *etc.* This treatise also contains an account of a study clearly showing the innovating tendency of Schwann, the first experiments on which can be dated on the basis of his laboratory notebooks at 16 April 1835.

In these texts, pursuing the line of his method, Schwann envisaged various experiments in which it would be possible to subject the physiological properties of an organ or of a tissue to physical measurement. One such method involved measuring the secretion of a gland. But it was the muscle which seemed to him likely to furnish the most rewarding results. He planned to measure for different loads the length of a muscle contracted by the action of the same stimulus; or, further, to compare the intensity of the contraction with that of the stimulus. He accomplished the experiment by means of the "muscular balance" and in a sense established the first tension-length diagram.

It is difficult for us to appreciate the sensation produced in physiological circles by this simple experiment. "It was for the first time" as Du Bois-Reymond has underlined "that someone examined an eminently vital force as a physical phenomenon and that the laws of its action were quantitatively expressed". In a milieu in which the idealistic philosophy and the theories of Fichte and Hegel were still dominant, the *Fundamental Versuch* came as a revelation and constituted the point of departure for a new physiology. Dissociating itself from the teaching of Müller and resolutely abandoning the notion of vital force for the study of molecular mechanismus, the school stemming from Schwann's experiment was to be particularly distinguished by the work of his successors at the Berlin Laboratory, Emil du Bois-Reymond, and Hermann Helmholz.

Paralleling his experiments on the muscle, Schwann pursued the researches which led him to the discovery of pepsin. About 1835, on the other hand, different observations of Gay-Lussac prompted by the experiments of Appert rendered current the notion that oxygen was the agent of fermentation, as of putrification. This stimulated a recrudescence of the theories of spontaneous generation and a tendency to return to the ideas of Needham, for whom the effect of heat was to deprive the air of the oxygen necessary for the birth of "animalcules".

Having observed that neither infusoria nor the smell of putrefaction appeared in the maceration of meat that had been boiled, if previously heated air was introduced into the maceration, Schwann then observed the appearance of both these effects when he used an unboiled maceration or unheated air. Convinced that it was the destruction of germs which prevented the development of infusoria and moulds, and which precluded putrefaction, Schwann wished to make a counter-proof by showing that the heating of air did not prevent the operation of a process of a chemical nature to which it contributed oxygen and not germs. He demonstrated that a frog breathes normally in previously heated air; and he turned towards alcoholic fermentation which also depended, in the current opinion, on the influence of the presence of oxygen. To his great astonishment, he observed that heating the air which he bubbled through a boiled suspension of yeast in a sugary solution prevented fermentation in certain experiments. In January 1836, he noted down in his laboratory notebook the conclusion that alcoholic fermentation is the work of a living being.

The description of the multiplication and the increase of yeast cells appears in his laboratory notebook under the date 16 February 1836. Certainly, the merit of having announced to the public the relationship between alcoholic fermentation and the life cycle of yeast belongs to Cagniard-Latour, who described the multiplication of yeast in the issue of the journal l'*Institut* dated 23 November 1836. Independently, however, Schwann's paper (1837) brought a confirmation of the organic nature of the agent of fermentation and arguments of a new order.

Schwann came to the idea of alcoholic fermentation as related to the metabolism of yeast in starting from his conception of putrefaction as related to the metabolism of living beings.

As we have seen, the prevailing doctrine in the laboratory of Johannes Müller was the vitalism derived from Paracelsus and his principles, hostile to the Cartesian unity of natural forces. The mechanistic and unitarian antagonism of Schwann towards this intellectual attitude had already been clearly manifested in his studies of muscles, of the mechanism of digestion and of fermentation. This tendency to introduce a more exact mode of explanation than that in terms of the „vital force" then in vogue, was to find its culmination in the formulation of the cellular teory.

Schwann has himself defined his attitude towards the vital force, such as was accepted by his master, Johannes Müller, author of the notion of the proper energy of tissues: "A simple force different from matter, as it is supposed, the vital force would form the organism in the same way as an architect constructs a building according to a plan, but a plan of which he is not conscious. Furthermore, it would give to all our tissues that which is called their proper energy, *i.e.* the properties which distinguish living tissues from dead tissues: muscles would owe it their contractibility, nerves their irritability, glands their secretory function. Here, in a word, is the doctrine of the vitalist school. Never was I able to conceive the existence of a simple force which would itself change its mode of action in order to realize an idea, without however possessing the characteristic attributes of intelligent beings. I have always preferred to seek in the Creator rather than in the created the cause of the finality to which the whole of nature evidently bears witness; and I have also always rejected as illusory the explanation of vital phenomena as conceived by the vitalist school. I laid down as a principle that these phenomena must be explained in the same way as those of inert nature."

Schwann aimed at replacing teleological explanation by physical explanation. For him, the phenomena of life were not produced by a force acting according to an idea, but by forces acting blindly and with necessity, as in physics. Individual finality itself, such as it was observed in each organism, was determined by the same manner as in inert nature: its explanation depending entirely upon the characteristics of matter and the blind forces with which it had been created by an infinitely intelligent being. He found the confirmation of this view, already pre-existing in his mind, in the notion of the uniformity of the texture and the growth of animals and plants, such as he developed in his cellular theory. "The uniformity of this development demonstrated that it is the same force which everywhere unites molecules into cells, and that this force could be nothing but that of molecules or atoms: the fundamental phenomenon of life therefore had to have its *raison d'être* in the properties of atoms". The error suggested to him by Schleiden—the formation of cells within a blastema, which Schwann assimilated to the phenomenon of crystallization—satisfied his mechanistic tendency to such a high degree that one understands a little more easily why he accepted it on the strenght of arguments as weak as those which he presented to demonstrate it, those concerning an alleged preexistence of the nucleus in the cartilages, for example.

Convinced that all the "elementary parts" of tissues should (as he believed he had recognized for the cartillage) derive from cells formed by crystallization around a nucleus, he turned to the most fruitful part of his work, finding with the aid of a microscope that the varied forms of the elementary particles of tissues—whether they be epithelia, hooves, feathers, crystalline lens, cartilages, bones, teeth, muscular tissue, fatty tissue, elastic tissue, muscles, nervous tissue, *etc.*—are products of cellular differentiation. He found, in other words, that all these elementary parts are nothing but transformed cells: a discovery which was to change biological science completely and the fecundity of which is not yet exhausted today. The continuity of the process of development of organisms, whether plant or animal, from the crystallization within a blastema to the differentiation of "elementary parts", was now nothing more than the expression of a union of molecules in cells. A force reigned everywhere in biology, which could no longer be anything but that of molecules or atoms.

The solution to the philosophical problem of finality proposed by Schwann transferred it from biology to the Universe and to its constituent particles, and from the vital force to the creator. As O. Temkin has underlined [20], it continued to be influential in the philosophical domain and Lotze was notably inspired by it in his celebrated study

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[20] O. Temkin, "Materialism in French and German Physiology of the Nineteenth Century," *Bull. Hist. of Med.*, 1946, 20, pp. 322—327.

of the nature of life published in 1842. The cellular theory of Schwann can be regarded as marking the origin, in the domain of biology, of the mechanistic materialism which Brücke, Du Bois-Reymond, Helmholtz and Carl Ludwig were to make famous. As for the discovery itself, the theory which led, according to Schwann, from the molecule (and here we are dealing with the molecule of the chemist) to the organism by way of the universal stage of the cell, was inspired in him by an intellectual, mechanistic tendency in reaction to Müller's vitalism. Chimerical as it might appear to us in certain of its aspects, this theory was to lead him to the discovery of the development of organisms through cellular differentiation, a discovery of inestimable significance.

Schwann's short and brilliant scientific career extended from 1834 to 1839, after which he abandoned rationalism and became a mystic. The scientist gave way to the professor, the inventor and the theologian. The beginning of this transformation dates from the attacks directed at Schwann by the chemists. Having shown an exceptional insensitivity to epistemological obstacles during his years of fruitful work, he was to succumb to a particularly violent attack dictated by one of these obstacles, almost inconceivable as the work of those illustrious scientists who unleashed it and whose memory it tarnishes. At the beginning of 1839, following a translation of a general paper by Turpin on the mechanism of alcoholic fermentation considered as a result of the activity of yeast, an article entitled "Das enträthselte Geheimnis der geistigen Gährung" appeared in the *Annalen der Chemie und Pharmazie*. The work of Wöhler, embellished by Liebig with some particularly ferocious touches, this satirical text presented a caricature of the views of Cagniard-Latour, Schwann and Kützing on the subject of the role of yeast in alcoholic fermentation. According to this facetious article, yeast in suspension in water assumes the form of animal eggs which hatch with an unbelievable rapidity in a sugary solution. These animals, in the shape of an alembic, have neither teeth nor eyes but they have a stomach, an intestine, an anus (in the form of a pink dot) and urinary organs. Immediately upon leaving the eggs, they throw themselves on the sugar and devour it; and it is presented as penetrating their stomach, to be digested, with the subsequent production of excrements. In a word, they eat sugar, expelling alcohol at the extremity of their digestive tube and carbonic acid through their urinary organs. Moreover, their bladder has the shape of champagne bottle.

Shortly afterwards, a lengthy memoir of Liebig appeared in the same periodical formulatin the theory of alcoholic fermentation as the result of instability produced in sugar by the instability of a substance occurring with the acces of air to the nitrogenous substances of plant juices. This theory was to enjoy a long popularity among chemists and it was necessary to wait for Pasteur for justice to be done to Cagniard-

-Latour, Schwann and Kützing. The cruel treatment dealt out to Schwann by the benighted scientific pontiffs of his time, ridiculed him completely and made it impossible for him to pursue a scientific career in Germany. His sensitive nature was deeply wounded. At the same time, the rationalism which had been so ardent in him grew lukewarm and he became preoccupied with religious meditations, doubtlessly fostered by the influence of his brother, the theologian Peter Schwann, author (under the pseudonym of Dr. J. F. Müller) of an edition of *The Imitation of Christ.* After he failed in his candidature for a chair at the University of Bonn, these disappointments led him into exile where he became professor of anatomy at Louvain. But the mainspring of enthusiams and discovery was broken. As Pascal did before him, he abandoned rationalism to return to the God of his childhood, the "God of the heart, not of reason." A conscientious professor at Louvain and then at Liège, Schwann remained a bachelor until his death in 1882, leading a solitary existence darkened by episodes of depression of an anxious nature. He devoted his meditations to constructing a theology derived from his cellular theory, while his taste for laboratory work was satisfied in the inventor's craft, in which his greatest accomplishment was to construct respiratory apparatus from which the apparatus for measuring the metabolism is derived as well as the apparatus used by divers and astronauts.

The relationship between the personality of the researcher and the genesis of his discovery could be illustrated with many more examples. But there is no doubt that this relation is more important in the prehistory of science, even though the case of the discovery of the double helix of DNA reveals its occasional incidence in the most recent science.

Having emphasized the importance of the factor of "imagination" as revealed in the history of science, van't Hoff remarked that his examples are taken from periods when extraordinary talents and an exceptional enthusiasm for the pursuit of truth permitted particularly gifted men to overcome the obstacles standing in the way of a scientific career. Today this path is largely open and very well-trod. As Jean Rostand underlined not long ago when writing on the subject of the scientists of our time: "All researchers, or almost all, work with the same intellectual resources and with the success of one or another of them depends upon chance factors having nothing to do with what is commonly called inspiration, imagination, genius. Choice of experimental material, operational skill, better-adjusted and more precise apparatus, qualities of character, a little more determination, care or perseverance, this is what is most often decisive." [21]

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[21] *Les Nouvelles Littéraires,* 7 septembre 1967.

The inquiries in all directions which the present structure of research permits, the ease with which hypotheses can be formed as a result of the wealth of new facts contributed each day: these constantly enrich the conceptual system of science with new achievements. The scientists of today start much more frequently from postulates and theories of a scientific order than from intellectual attitudes; they accumulate hypotheses favorably subjected to the control of experiment or to that of their agreement either with a mass of statistically valid relations, or with the general forms of thought from which verifiable consequences are derivable. This conceptualist system, although the majority of our contemporaries do not yet realize it, has taken admirable proportions. The pressure of new data and the acceleration of discovery, which have now become continuous, relegate to a secondary importance the personality of the majority of scientists. Having taken command of scientists, science, establishes a sort of internal control, a process of self-purification, of self-systematization and self-regulation, the ways of which are disentangled by scientists in order to follow them. We are witnessing a new phenomenon in the history of science, which consists in the fact that certain notions, or certain concepts, without anyone having attacked them or refuted them, are disappearing from the system by the simple action of its internal cohesion and of the compatibilities which its structure accepts. It might be suggested that we find here an indication of a new stage of the conceptualist system of science, and of its intellectual fecundity. The glory of the human mind, the supreme value of man, science is becoming more and more independent of its human origins. Superior to man, it develops by itself, cultivated by him according to the special laws of its own growth. As Descartes hoped, "it bears forth spontaneous fruits". It is of this science, and not of scientists, that Jacques Monod says with justice that it is a purifying discipline, or an ascese of objectivity, productive of the ethic of knowledge, the only one which is compatible with the modern world.