V

HOW TO STUDY LIFE: BICHAT'S METHOD

Although Bichat's only formal training was in surgery, his mature work, based upon a deliberate decision he made after Desault's death, was in anatomy and physiology. One of his most influential works, the *Recherches physiologiques sur la vie et la mort*, addressed the fundamental and timeless questions of the nature of life, the nature of death, and the ways in which these conditions of existence manifest themselves in an organism. The arguments developed in the book and the observations that reinforced them, were rooted in the assumptions of vitalism. Often, the experiments recounted appear haphazard and unfocused, a kind of "what if" approach rather than a deliberate attempt to address a question. It is unlikely that any of them could have jeopardized any of his a priori assumptions. The four-volume *Anatomie générale* was more satisfactory in this respect. It seems to have relied less upon a priori notions and more upon careful observations designed to analyse the tissues which compose the organs and other bodily structures. It is also the book whose reputation has best survived the years since its publication.

Some of Bichat's detractors have charged that his work is merely synthetic, and contains nothing original at all. What justification there is for the claim stems from the fact that Bichat dealt extensively with themes common to the eighteenth century. In the following chapters, Bichat's work will be analysed in relation to the theoretical and epistemological views already considered. Nevertheless, Bichat was much more than a mere borrower. His fellow-physicians, his students, and his successors at the Hôtel-Dieu invariably described him as a tireless worker who performed a great many post-mortem dissections as well as innumerable experiments on living animals. In this chapter, I wish to examine the method by which Bichat approached his work as well as some of its underlying assumptions.

The premiss basic to much of Bichat's work, as we have already seen, was that the life sciences are utterly separate from those that treat non-living matter. He developed the arguments in support of that thesis in the first part of *La vie et la mort*, his most complete statement of physiology. He presented evidence there in support of a natural division of living phenomena into animal and organic categories and described five vital properties that derive from sensibility and contractility. By so doing, he took these phenomena from the domain of mere sensation and locomotion and elevated them to be the physiological causes of formation, growth, and nutrition. We are in a position to recognize here an amalgam of notions gleaned from the vitalists, the monists, and the sensationalists. Naturally, he was never without evidence to support his contentions. Looking at Bichat's arguments in support of the animal-organic division of life, we see him writing as the heir to a tradition of interpretation that had its distant roots in the work of Aristotle and its more recent ones in that of Barthez and Grimaud.

The Montpellier tradition from the mid-eighteenth century maintained that observation is the sole reliable source of data about living creatures. This viewpoint was disseminated by its various spokesmen in the *Encyclopédie* and it was taken as belonging to vitalism, which emphasized the spontaneity of life. Claude Bernard cast Bichat into the mould also. In his eulogy of François Magendie, for example, he contrasted the experimental approach of his mentor with that of Bichat, claiming that in his work, "the broad philosophical views of Bordeu subdued and killed the experimental method of Haller". Yet Bichat's own work demonstrates that he himself did not consider vitalism to be a conceptual barrier to experimentation. Indeed, he tried consciously to reconcile the Montpellier approach with that of experiment, asserting that his goal was to ally "the experimental view of Haller and Spallanzani with the broad philosophical views of Bordeu".[1] He made little distinction between experiment and observation. In any case, the variability of the life forces precluded only the mathematization of physiology, not experimentation. So it is that the first part of *La vie et la mort* is largely constructed of arguments having to do with observations of living phenomena. In the second part, however, the phenomena of death are tested by experiment.

Indeed, Bichat approached this second part quite differently from the first. Having dealt earlier with the gradual death of the body due to ageing, Bichat then undertook to examine what happens in violent, accidental, and sudden death. He concentrated on the role of the brain, the heart, and the lungs, for he believed that all sudden death commences with the interruption of either the circulation, the action of the brain, or the respiration. His rationale for such an undertaking was rooted in the notion of the two lives. The primary bodily functions, he believed, proceed from the heart, which is the major organ of the organic life; the brain, which is the centre of the animal life; and the lungs, which participate in both lives and mediate between them. The action of each of these organs, the three "centres" of life, is necessary for the other two.[2] The experiments and observations recorded here supplemented the speculations of the first part of *La vie et la mort*.

Bichat's basic procedure was simply to provoke injuries in specific organs of various animals and to observe the consequences of such actions for the rest of the body. He used animals in abundance. He also frequently attended executions by guillotine so as to be able to make observations on the severed heads and trunks of its victims. After examining the effects of heart injury, Bichat concluded that red blood influences the brain directly by its motion rather than by means of any principles it carries. His initial arguments in support of this notion were somewhat tortuous inferences from anatomical design. He wrote, for example, that animals with long necks and hence with brains rather distant from their hearts appear to be less intelligent than those with short necks. It also appeared to him that the great arterial trunks located at the base of the brain were designed precisely to facilitate the brain's receipt of vascular motion. Finally, the brain's bony home, unlike that of most other organs that are embedded in soft cellular tissue, appeared to him to be specifically designed to reflect heartbeats.

[1] The question of experiment in relation to physiological theory is discussed by William Randall Albury, 'Experiment and explanation in the physiology of Bichat and Magendie', *Stud. Hist. Biol.*, 1977, **1**: 47–131. The quote from Claude Bernard's *Éloge de Magendie* is taken from this article.

[2] Xavier Bichat, *Recherches physiologiques sur la vie et la mort*, Paris, Brosson, Gabon, 1800, pp. 191–196.

Some readers in 1800 would certainly have found such arguments to be as shallow and unpersuasive as we do. They were, however, merely offered as a preliminary to experimental evidence, which Bichat believed pointed toward the same conclusions. He found, for example, that water injected slowly into an animal's carotid artery had little or no effect, whereas that injected more quickly produced a troubled cerebral activity or even death. An arterial haemorrhage produced a gradual loss of brain-induced activity. Air injected into the veins or arteries in any quantity frequently produced brain injury or death, suggesting to Bichat that it cushions the heartbeat, damping the transmission of motion to the brain.

His conclusion about the blood pounding the brain led Bichat into a long chain of inferences concerning the effect of heart injury upon general bodily processes. Although the influence of the left heart on the brain is through the blood vessels, Bichat believed that that of the brain on the heart and other organs must be through the nerves. It had long been known that an interruption of brain activity paralyses certain nerves and through them, the intercostal muscles and the diaphragm. Because it is centred on the brain, Bichat reasoned that the animal life ceases the moment excitation from that organ is interrupted. Being strangers to the brain's direct influence, however, the organs of the organic life fail largely as a result of the preliminary failure of the circulation, which no longer transports to them the materials they need in order to function. The end of nutrition, exhalation, secretion, and digestion, therefore, follows only gradually. In general, then, Bichat's conclusions about the death of the heart owed less to experiment than to deductions based on certain assumptions concerning the function of the heart and the brain.[3]

Bichat's second investigation, having to do with the consequence of injury or death to the lungs, is, in many ways, the most interesting part of this investigation. The physiological role of respiration was a timely question. Much light had been shed upon it in the preceding century or so by extensive chemical studies of gases. By Bichat's time, oxygen had been identified as the crucial respiratory element, while fixed air or carbonic acid gas, which we call carbon dioxide, was known to be the waste gas discarded in expiration. United with oxygen, blood acquires a crimson hue; united with fixed air, it is dark or black. Red blood carries life and vitality to the parts through which it flows, while black blood transports weakness and ultimately death in the form of asphyxia. By the 1790s, any physiologist had these facts to draw upon.

Bichat distinguished between mechanical and chemical interruption of the activity of the lungs, even though the one condition inevitably produces the other. He could cause mechanical failure by, for example, opening the chests of animals, thereby immobilizing the lungs by the force of external air pressure. Chemical failure was produced by obstructing the trachea, creating a vacuum around an animal, or plung-

[3] Ibid., pp. 197–238. A very recent and interesting paper on this subject is Geoffrey Sutton, 'The physical and chemical path to vitalism: Xavier Bichat's *Physiological researches on life and death*', *Bull. Hist. Med.*, 1984, **58**: 53–71. Sutton points out that in these experiments, Bichat set out to show that the heart has the primary function of sustaining the tissues of the brain by agitating them. The heart's fundamental role in the body is not only to distribute nourishment but by its motion to sustain all the tissues. At bottom, Sutton claims, the discussion offered a disquisition on the importance of mechanical agitation of the sensible organic system, in the form of pulsations, oscillations, and shocks.

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ing it into any number of gases. His subjects included a somewhat arbitrary mixture of hanged criminals, animals that he had strangled, or that he had drowned slowly in stages, and so on. Although it is impossible to be precise, his victims were easily numbered in dozens for this section of his work alone.

The various procedures permitted him a great deal of control over the type and quantity of air available to the body. One of his preoccupations came to be to observe the way in which blood and the various organs are affected by a lung injury, or as the result of altering the availability of air or its condition. He examined pregnant dogs and guinea pigs and found that the umbilical vessels and the foetus are affected as rapidly as the mother's own circulation. Asphyxia, he discovered, is more rapid with nitrous or hydrogen sulphide gas than with carbon dioxide, nitrogen, hydrogen, water, or a vacuum. He even tried to note, with no particular success, the differences in response caused by such factors as age and temperament. Finally, Bichat observed that the close connexion visible between the functions of the lungs and those of the heart in warm-blooded animals does not exist in cold-blooded ones.

In every case, Bichat found that it is the black blood that enfeebles the tissues of the body, accounting for its gradual weakening. Does the black blood act upon the fibres themselves or upon the nerves? Although Bichat inclined toward the latter opinion and thought it likely that oxygen is the principle of irritability that activates the tissues, he reminded himself somewhat pompously here of the limits of scientific observation. "Let us stop", he wrote, "when we arrive at the limits of rigorous observation; let us not strive to penetrate there where experience cannot clear the way for us." This attitude had to do, of course, with the frequently stated reluctance of the eighteenth-century scientist to shape hypotheses going beyond the capacity of his data to test. It was a tribute to the Newtonian notion of limited explanation and was born of a disdain for an intellectual exercise that quested for the elusive "first causes" of science. It was also a basic tenet for sensationalists, whose notions of epistemology and explanation Bichat accepted. By quibbling over the evidence supporting the respiratory role of oxygen, however, Bichat revealed, above all, that his knowledge of chemistry was extremely limited. We shall shortly come across a manifestation of this same basic attitude in connexion with Bichat's tissue work, where his sensationalist principles were interpreted as proscribing the use of microscopic observations in anatomy.

Bichat's surgical skill was to stand him in good stead in some rather complicated experiments that he devised to examine the effects of asphyxia on brain functions. He had often observed, he wrote, that the arterial blood of one animal transfused into the carotid artery of another had no effect upon brain function. The venous blood of one animal, on the other hand, though it produces varying results, always causes eventual death when it is diverted to bathe the brain of another animal. That death, he concluded, must be the consequence of asphyxia produced by black blood. As long as the organic life has not yet been extinguished, the asphyxia can be reversed by reintroducing red blood. Again, when he looked for the same phenomena in such cold-blooded animals as frogs and fish, the results were much less clear.[4]

The violence and apparently crude indifference of medical investigators in the

[4] Bichat, op. cit., note 2 above, pp. 239–369.

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eighteenth century toward animals must impress even the most insensitive contemporary reader of their texts. Even if one admits that the infliction of some pain was unavoidable if they were to do their work, the lack of compassion is really quite remarkable. I know of no investigator besides the unhappy and opium-addicted Haller who ever expressed any revulsion at the enormous price exacted from animals. The kindliest researchers and teachers, affectionately remembered by their students, colleagues, and families, seem never to have flinched at the prospect of performing the most hideous experiment, no matter how trivial the anticipated result might be. The mild-mannered Bichat was no exception. For example, he blithely tossed beasts into fire, water, and so on to try to determine in some vague way, and for some ill-defined reason, the different effects that follow from the various types of asphyxiation. The results seem to have been of minimal significance, if any. The best he could have hoped for was a kind of inductive accumulation of data that might possibly at some time be incorporated into a larger theory of organic function. For example, for some obscure reason, Bichat killed a considerable number of animals by injecting such fluids as ink, oil, wine, coloured water, urine, bile, and mucous fluids into their arteries. His only conclusion was the dubious one that these various substances acted on the brain rather than on the arterial surface, because they were more frequently fatal when they were injected into the carotid rather than into, say, the crural artery. Even in his most optimistic and euphoric moments, he could not have anticipated any but minimally important results. At worst, there was virtually no coherent point at all to such experiments.

The final series of experiments in *La vie et la mort* were concerned with the question of the consequences of brain injury. Bichat observed many times that section of the part of the vagus nerve connecting the brain and the lungs will not arrest respiration. On the other hand, section of the spinal marrow between the last cervical and the first dorsal vertebra does so by paralysing the diaphragm and the intercostal muscles, which he claimed belong to the animal life. This confirmed Bichat in his belief that respiration is a mixed animal-organic function. That is to say, he claimed that it belongs to the animal life because it involves voluntary muscular motion and to the organic life because its chemical functions are linked to the heart.

In animals and in guillotined human bodies, Bichat frequently observed that the heart may be made to contract by direct stimulation for a considerable time after death. Stimulation of the cardiac nerves, vagi, or medulla spinalis, however, has no effect. He took this to be additional evidence for the independence of the heart from the brain and for the separation of the organic life from the animal. The heart stops after injury to the brain, he claimed, only because of the cessation of the activity of those intermediate lungs. Virtually all his observations and experiments, therefore, were somehow related to the animal-organic division, and all of them apparently confirmed it as genuine and natural. Having once satisfied himself that it existed, it never seems to have occurred to Bichat that his division was untested or merely a classificatory convenience. He did not, therefore, analyse it.[5]

Bichat's other great work was his *Anatomie générale*. It, and the *Traité des*

[5] Ibid., pp. 370–434.

membranes, which preceded it, were based deliberately upon techniques of analysis that were much emphasized at the time. In the *Anatomie générale*, Bichat argued that living matter is compounded from twenty-one basic elements, which he called the tissues. That is, Bichat undertook to break such complex structures as organs into their simpler component parts and to study these parts separately. At least in theory, Bichat decomposed some bodily part until it was no longer amenable to further breakdown by any of a number of techniques. He then declared that smallest unit to be a tissue and proceeded to determine its particular distribution of physical and vital properties. He believed that sensibility and contractility, the vital forces, belong to the elemental tissues and through them govern the integrated activity of the body.

The tissue theory was an extension of Bichat's membrane work. His 1798 paper, 'Mémoire sur la membrane synoviale des articulations', was his first offering on the theme. Although Bordeu's name is not even mentioned in it, it was clearly modelled on his study of the glands, and reads as though that work were at Bichat's elbow as he wrote. Using words unmistakably like those of Bordeu, Bichat opened the paper with the assertion that no part of physiology is richer in hypotheses but poorer in facts. His main purpose in doing the work, he continued, was to demonstrate the inadequacy of the mechanist theories that had been adopted thus far to explain how synovial fluid is carried to an articular surface. The synovial system of the body extrudes a viscous fluid which lubricates the joints and tendon sheaths. This fluid cannot be a glandular product, simply because painstaking examination showed that no glands exist in the regions in question. Nor does the marrow extrude the fluid, as he found that its destruction is without effect. The only remaining possibility was that synovial fluid is produced by an active, that is to say, vital, process of exhalation. Bordeu had concluded that each gland in the body secretes its own particular humour because it possesses a unique sensibility. Like him, Bichat remarked that each class of organs had "its proper life independent of that of the other classes of organs".[6]

That paper was meant to be read along with an accompanying 'Dissertation sur les membranes', which itself was an important innovation in the manner of viewing the bodily parts. Bichat wrote that membranes tended merely to be associated with the organs over which they are spread. The pericardium and the heart, or the pleura and the lungs, for example, were always considered together. Although Haller had treated membranes as unique structures, he had not differentiated between them, for he believed them to be merely structural modifications of the organs. The first entirely new insight had been that of Pinel in his *Nosographie philosophique*. Pinel had established "a judicious connexion between the different structures and the different affections of membranes; . . . ."[7] As we have seen, Pinel observed that inflammations, for example, may variously affect the cutaneous surface, cellular tissue, glands, serous membranes, muscles and articulations, and mucous membranes. He classified the dysfunction accordingly. From reading Pinel's work, Bichat formed the idea that membranes of the body can be analysed into the mucous, fibrous, and serous varieties

[6] Xavier Bichat, 'Mémoire sur la membrane synoviale des articulations', *Mémoires de la Société Médicale d'Emulation*, 1798, **2**: 351–370.

[7] Xavier Bichat, *Traité des membranes*, Paris, Richard, Caille et Ravier, 1800, pp. 3–5.

and into compounds of these basic tissues.[8]

At this stage, in 1798, Bichat's method was largely one of painstaking dissection and observation. With it, he established that mucous membranes, so named because of the fluid secreted by glands just beneath their surface, line all the hollow organs that communicate with the exterior of the body, forming the gastrointestinal tract, bladder, womb, nasal fossae, and all excretory ducts. The moist, highly polished serous membranes, he observed further, are generally found in the form of envelopes around those organs whose interiors are lined by mucous membranes. They occur around such contractile organs as the heart, lungs, stomach, intestines, and womb, in which organs they form the pericardium, pleura, peritoneum, and vaginal tunic. Fibrous membranes, not moistened by any fluid, are especially numerous, forming the periosteum, which covers bones; the dura mater of the central nervous system, the sclerotica of the eye; the envelope of the kidney; the internal tunic of the spleen; and the albuginea of the testicles. They form the aponeuroses, which encircle the thigh, leg, arm, and forearm, and the fibrous capsules that cover the synovial membranes of the articulations in the femur and the humerus. Tendons and ligaments are composed of the same strong, elastic, and insensible matter. Finally, Bichat's elaborate dissections showed him that these membranes send numerous extensions into organs, thereby producing a kind of fibrous skeleton that sustains the tissues of testicles, kidneys, and spleen.

There are also "composite membranes", Bichat wrote, which adhere to one another in such a way that a single membrane is produced by the union of two other types. By the time he composed the *Traité des membranes*, Bichat found that he was encountering membranes that did not belong to any of those six subdivisions. The middle tunic of arteries is normally classed among the muscular organs, but Bichat thought it demonstrated certain characteristics of fibrous membranes. The inner tunic of blood vessels was different in veins and arteries. There were such unknown membranes as the lining of the medullary canal of bones, the iris, the choroides, the retina, and the pia mater. In certain cases, the body forms unnatural membranes such as cysts, cicatrices, and scars.[9]

In the original paper, Bichat had little to say about the vital forces in various membranes. By the time of the *Traité des membranes*, he had come to consider their distribution to be as characteristic of a membrane as its anatomical properties. He searched for sensibility, just as Haller had done half a century before. Mucous membranes, Bichat found, possess a "lively sensibility" because of structures resembling papillary bodies located beneath the surface of the epidermis. Serous membranes normally possess only an obscure sensibility. Nature has so designed them because ordinarily they are not in contact with foreign bodies. Haller had classified fibrous structures among insensible organs, but Bichat found that they become painful when

[8] Othmar Keel, 'Les conditions de la décomposition "Analytique" de l'organisme: Haller, Hunter, Bichat', *Études Philosophiques*, 1982, no. 1, 37–62, argues that Bichat's claim of indebtedness to Pinel notwithstanding, the method of analysis or decomposition was present long before the time of the ideologues in the work of Haller, Bonn, Hunter, and others.

[9] Xavier Bichat, 'Dissertation sur les membranes, et sur leurs rapports généraux d'organisation', *Mémoires de la Société Médicale d'Émulation*, 1798, **2**: 371–385.

exposed to air for a time. While such fibrous structures as ligaments are not irritated by chemical agents, they are painfully affected by agents that cut, tear, or dislocate them. Like Whytt, Bichat remarked that one should never pronounce upon the insensibility of any organ until one has exhausted all means of irritating it.

With his *Anatomie générale*, Bichat took this work a very significant stage further. By incorporating into it all the material found in the *Traité des membranes*, he made the earlier work redundant. In the fifteen months separating the publication of the two works, he had analysed all the solid parts of the body into elements and observed and recorded their various vital and physical properties and responses. The membranes became but four of twenty-one tissues. The theories of the two lives, the vital properties, and properties of texture were wedded to the notion of physiological elements to produce the tissue theory, which was at least a precursor to histology.

Bichat proceeded in an orderly and thorough fashion, providing as much information as possible about the structure, distribution, properties, and particular functions of every one of the tissues he had identified. A brief glance at his extensive analysis of cellular tissue, the most abundant of all the parts of the body, should illustrate Bichat's general approach to the living elements.[10] He described cellular tissue first as it appears when one is merely tracing its distribution during the course of a dissection. He found it lining one side of the skin and the serous and mucous membranes and external to the arteries, veins, absorbents, and excretories. The quantity of the tissue, its form, and the strength of its adherence to the structures it accompanies were discussed in every case. Sometimes, even when the presence of the tissue was not obvious, it could nevertheless be shown to exist by indirect methods.

> In many of these organs . . . it may be made perfectly distinct by maceration, which insensibly softens and separates their fibres, as in the tendons and fibrous membranes. Boiling deprives some of their nutritious matter, gelatine for instance, and leaves a membranous residue which is evidently cellular. In all, even bones, cartilage and so on, granulation, the production of which, as we shall find, is specifically of a cellular nature, proves the existence of this internal tissue, of which there are so many processes.[11]

His observations convinced Bichat that, as well as covering and thereby insulating the organs from one another, cellular tissue formed one of the principal elements uniting their parts.

Bichat next outlined for his readers the distribution of his system throughout the various parts of the skull, face, neck, chest, abdomen, pelvis, and the extremities. He described the variously shaped "cells" or gaps that gave the system its name and that exist to absorb fat or fluids as necessary. Examining the serum of the cellular tissue, he found that it varies in quantity, depending on where it is in the body. It is most abundant in such parts as the scrotum, eyelids, and prepuce, which are deprived of natural fat. Chemical experiments show it to be albuminous in nature. He described the distribution of cellular fat throughout the various organs, remarking also upon its various states in health, disease, and age. He speculated about how it is separated from the blood during the course of its formation, without, however, arriving at a conclusion.

[10] Xavier Bichat, *Anatomie générale appliquée à la physiologie et à la médecine*, 4 vols., Paris, Brosson, Gabon, 1801, vol. 1, pp. 11–114.

[11] Ibid., p. 32.

Under the heading 'Composition of cellular tissue', Bichat described the behaviour of the soft and delicate cellular tissue in response to various substances and reagents. When exposed to air, cellular tissue dries quickly and remains white. It does not putrefy as rapidly as, for example, the glandular or muscular parts. He found it to be considerably resistant to soaking in water and even to boiling. Forcing himself to vomit food he had ingested earlier, he determined that gastric juices affect cellular tissue less than they do the fleshy or muscular parts of the body. This type of analysis illustrates well Bichat's basic assumption concerning the elemental nature of a tissue. An isolated chemical element, by definition, behaves consistently in response to any treatment. And so it is with bodily elements. Because of its unique nature, cellular substance will behave consistently in response to various types of physical or chemical treatment.

Very significantly for his general purposes, Bichat examined the tissue and vital properties. He attributed extensibility to cellular tissue simply because of its striking ability to expand in response to oedema, fat accumulation, tumours, and so on. It must be extensible to permit the motion of the limbs and the flexion and extension of every part. It follows that it must also possess contractility, simply because the tissue contracts whenever extensibility ceases.

Searching for what he described as the "animal properties", Bichat sounded unmistakably like Haller:

> You may divide it as you will with the scalpel, draw it out in every direction and distend it with gases. The animal when submitted to these experiments shows no signs of pain; if any be felt, it is produced from the threads of nervous tissue which supply it, and may perchance have been accidentally injured. In a morbid state, on the contrary, the sensibility of the part is increased to that degree, that it becomes the seat of the most acute pains. We have an obvious instance of this in phlegmonous inflammation.[12]

He had had little to say about the "organic properties" of the membranes earlier. Now, however, he directed his attention to them as much as to the animal properties. He could only infer their presence in the tissues from the functions that they were alleged to perform, because, by definition, organic sensibility and contractility are neither consciously regulated nor perceived. He assumed that organic properties are present in every living tissue, because, according to the physiological system worked out in *La vie et la mort*, he had assigned to them the most fundamental functions without which life could not exist. He assumed, therefore, that cellular structures must have the level of organic sensibility and contractility necessary to maintain their nutrition. In addition, the cellular tissue must have a very specific type and quantity of the organic forces to account for its absorption of fat and serum. "The existence of insensible organic contractility is indisputably proved", he wrote, "in the cellular tissue by the processes of exhalation and absorption taking place there." Because his clinical experience had taught him that suppuration and inflammation occur frequently in cellular tissue, he wrote, "it is obvious that the principle of life is abundantly developed in the cellular system. . . . The phenomena of inflammation for this reason run their career with great celerity in this system."[13]

Bichat remarked upon the fact that, unlike most other organs, cellular tissue

[12] Ibid., p. 81.
[13] Ibid., p. 82.

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possesses the faculty of extending and reproducing itself. The formation of cysts, cicatrices, and tumours all depend on the ability of the cellular tissue, which is their common base, to reproduce itself. He observed the development of each one of these formations and outlined his observations in considerable detail.

Finally, Bichat examined the development of cellular tissue, looking for its presence shortly after conception, in an older foetus, and in the various stages of life. In some cases, he looked specifically for the tissue in animals that he dissected. In others, however, his information simply came from observations made upon the large number of subjects he personally dissected or whose dissection he supervised in the course of his clinical work.

Bichat's approach to cellular tissue has been outlined in rather tedious detail simply because it is typical of his approach to all the tissues. In general, his technique may be summed up as one involving a combination of thorough dissection and exploration of the body as a whole in various conditions of age and health with an examination of the tissues under the influence of various physical and chemical reagents and a search for their vital and tissues properties. His search for the animal forces of life, as we have seen, involved the use of the method Haller had described in his work on sensibility and contractility. His search for the organic forces, on the other hand, was altogether indirect, having to do primarily with an observation of the functions that the tissue performs. If, like the cellular or glandular tissue, it performs extensive secretory and absorptive functions, Bichat inferred that it must be rich in organic properties. Inevitably, he was merely extrapolating from what he assumed he had clearly established in the course of formulating his physiological theory.

Bichat's treatment of the exhalant tissues of the body is particularly interesting, simply because no such structure is visible to the naked eye. Bichat devoted many pages in the *Anatomie générale* to a discussion of the distinction between excretion and exhalation, which he had first raised in his 1798 paper on the synovial membrane. Most authors, he claimed, tended to call everything secretion. But, "On being guided by inspection only and without penetrating to enter into the intimate nature of the organ, it is evident that whenever secretion occurs, a gland exists." Exhalations, on the other hand, which are deposited over the serous, mucous, synovial, cutaneous, and cellular surfaces, are extracted from the circulating fluids directly without the intermediary of a gland. At least stretching, if not breaking with, his own sensationalist rules concerning clear and simple demonstration, he stated that he would proceed by "strict reasoning" in his study of these largely hypothetical "tissues". After a discussion of why the invisible exhalants must be present in the body, he wrote: "All duly considered, 1st. The existence of exhalants, 2ndly. Their origin from the capillary system of the part where they are found and 3rdly. Their termination on diverse surfaces are the only facts correctly ascertained."[14] But he was merely guessing, of course. It is particularly ironic that he should have done so in view of his frequently voiced aversion to anything but clear and simple sensory demonstration. It was Bichat, after all, as an earlier quotation shows, who had quibbled over the reliability of the evidence in support of the theory that oxygen is the essential respiratory gas.

Even more curious is the fact that Bichat refused to use a microscope in his

[14] Ibid., vol. 2, pp. 549–576.

investigations and that he denied any validity to the evidence it provided. It might conceivably have confirmed the existence of the exhalant tissues, but Bichat would not have considered using it to look for them. This stance has aroused curiosity and, occasionally, acrimony ever since. It seems particularly perverse of the man who has been dubbed the founder of histology to construct his theory all the while disdaining the use of what has since become its most important instrument. On the other hand, Bichat's contemporaries, at least in the Paris clinical school, understood his position very well. The instrument had, of course, made certain contributions to medical observation before 1800, but their importance is a matter for debate even today. In any case, certain observations could have been directly related to aspects of Bichat's work, or so it appears today with hindsight. For example, in 1660, Marcello Malpighi had used a microscope to observe the capillaries, whose existence William Harvey could merely postulate in 1628. By so doing, Malpighi had provided the last element necessary to complete the theory of blood circulation.

Because he would not observe them with a microscope, Bichat was unable to learn anything specific about the structure of these small, thin vessels. He believed in their existence nevertheless, devoting a section of the *Anatomie genèrale* to them. What evidence we have, he claimed, is limited to what is observed during inflammation. He found also that injection of a coloured fluid into the fine artery of a cadaver will reveal that such vessels exist in every part of the body, but "Such is their tenuity that up to this point we have had no facts grounded in experience and observations."[15] Similarly, he dismissed the microscopic studies done by Leeuwenhoek and others on muscle fibres, claiming that such an examination of the intimate structure of organs is merely a futile search for inaccessible first causes "whose knowledge would add nothing to physiological notions on the motion of muscles".[16] Although the microscope in the hands of Malpighi and Ruysch had revealed much about glandular structure, Bichat dismissed it as pointless.[17]

Bichat's reluctance to use the microscope in the analysis of tissues can best be understood in relation to sensationalist notions concerning the proper study of nature. Microscopy implied a search for first causes, and as we have had occasion to observe, no eighteenth-century scientist grounded in sensationalist principles would admit to such an exercise. Bichat admonished his readers as follows:

> Let us neglect all these idle questions where neither inspection nor experience can guide us. Let us begin to study anatomy there where the organs begin to fall into the range of our senses. The rigorous progress of sciences in this century does not accommodate itself at all to these hypotheses which have been nothing but a frivolous fiction of general anatomy and physiology in the previous century.[18]

This statement is actually the crux of the matter, providing the clue to a prejudice that Bichat shared with many other medical men. John Locke and Thomas Sydenham, both judged to be outstanding medical pioneers by Bichat's contemporaries, had rejected the microscope, arguing that a search for the intimate material bases of disease contributes nothing to medical practice. David Wolfe considered this attitude to be a manifestation of Puritan morality. Subsequently, Laënnec, Cabanis, Pinel,

[15] Ibid., pp. 469–548 deal with the capillary system. The quotation is on p. 507.
[16] Ibid., pp. 224–338 deal with the muscular system of the animal life. The quotation is on p. 231.
[17] Ibid., vol. 4, pp. 569–639.
[18] Ibid., p. 576.

and other exponents of the "cult of observation" of the Paris school mistrusted the use of instruments, because they believed that only knowledge garnered from experience is legitimate. To sharpen the human senses artificially was to distort their role in the process of observation and to transgress a fundamental rule of procedure.[19]

The rejection of an instrument that we regard as having enormous potential importance for anatomy seems akin to the attitude of the apparently reactionary Aristotelians who, some two centuries earlier, had refused to look through Galileo's telescope. They could not be persuaded that the images that suddenly become visible when some lenses are interposed between one's eye and an object exist in reality. Neither they nor the sceptical seventeenth- and eighteenth-century physicians were being entirely unreasonable. Many beautiful microscopes by skilled artisans survive, demonstrating that they existed in large numbers. They tended, however, to be largely the playthings of educated amateurs. Genteel folk owned them, much as many people today own microscopes or telescopes simply because of a largely passive interest in the objects of nature. The microscope was more of a tool used to gaze upon such marvels of creation as an intricate butterfly's wing that one intended for purposes of discovery. Indeed, there was relatively little important scientific work done in the eighteenth century that owed much to the microscope. If physicians owned them, it was primarily because they were gentlemen rather than because they were medical men.

Leeuwenhoek's and Malpighi's work notwithstanding, Bichat and his equally sceptical fellow-physicians and researchers were probably right to remain suspicious of microscopic evidence. The value of the illustrations they had left behind was dubious to begin with. Leeuwenhoek, for example, had been very secretive about his handheld single-lens microscopes, not permitting even the artist whom he commissioned to do his illustrations to look through them. Apart from that, until about the 1830s, observations made with microscopes were seriously hampered by spherical and chromatic aberration. Even today, an untrained observer such as a student, as often as not, sees only what he has been told he should expect. With the cruder instruments and staining techniques that would have been available to Bichat and to his predecessors, the problem of interpreting a vague and complex image would have been far greater still. If we judge his scepticism as a streak of reaction, it is merely because with hindsight we believe that the microscopists were on the right track and their work would have reinforced Bichat's observations. He, on the other hand, was showing exemplary scientific caution in the face of a dubious instrument that was still little more than a rich man's toy.

It is doubtful whether Bichat's work on general anatomy would have been enriched even by the assiduous use of the microscope. Probably the only way to answer such a question would be to look at the sorts of tissue specimens he described with a microscope of the period. His prohibition against it, interestingly, did not extend to the hand glass, which he used without apology. Nor is this completely inconsistent, if we bear in mind that the hand glass is little more than a kind of spectacle lens, magnifying but slightly, distorting apparently not at all, and requiring no preparation of the specimens. It helps an observer to see rather than bringing new images before him for interpretation. The strictures against the dubious and mysterious effects of elaborate

[19] David Wolfe, 'Sydenham and Locke on the limits of anatomy', *Bull. Hist. Med.*, 1961, **35**: 193–220.

instruments need not, therefore, apply to it.[20]

Since Bichat disdained the use of instruments to extend his senses, it would have been consistent for him to avoid formulating theories that were untestable because they were also beyond the range of those same senses. For example, because microscopic observation of capillaries was prohibited, it should have been equally unacceptable to speculate about the existence and nature of organic sensibility and organic contractility, about the production of heat, and about the nature of inflammation in those same all but invisible capillaries. Whereas the properties he attributed to the animal life are easily observed in the body, the existence of the remaining vital activities was merely conjectured. They are, in a sense, as much microscopic properties as minute fibres are microscopic structures. Bichat's confidence in the existence of those alleged forces arose from the mere fact that every bodily part must be nourished, must exhale, absorb, and secrete. However justifiable such confidence seemed to him to be, it was not based on the evidence of his senses. He therefore transgressed his own sensationalist principles and rules of procedure.

In all of Bichat's work, there is not one single illustration. It must appear to any modern reader to be a major omission in a work of general anatomy. Indeed, it would often have been far easier to read his books if he had resorted to at least the odd diagram to supplement a complex verbal description of the form or the distribution of some structure. It would seem that having written often enough about the sufficiency of sensory evidence for the scientific investigator, he might have obliged his readers by showing them roughly what his own skilfully trained visual senses had focused upon. If he thought about it at all, Bichat might possibly have assumed that the type of person to whom he addressed the book, the physician and the medical student, would not have missed illustrations too sorely. It is also possible, however, that Bichat avoided illustration for more fundamental reasons. The *Anatomie générale*, after all, was about the tissues whose essential structure could no more be visualized than could the essential structure of Lavoisier's chemical elements. A multitude of his anatomist predecessors had extensively and adequately illustrated the objects of gross anatomy. But the anatomical elements with which Bichat was preoccupied were beyond the scientists' ability to picture. If Bichat felt so, he would not draw them for the same reason that he would not use a microscope. But that is merely speculation, for Bichat showed no sign that he felt his omission required explanation.

To have completed so vast a quantity of work in a few years, combining it with his clinical work at the Hôtel-Dieu, is impressive, and accounts for Bichat's reputation as a tireless worker. The remainder of my discussion will focus upon the way in which it fits into eighteenth-century currents of thought concerning the nature of life and of living matter. Though I shall write of borrowing and of synthesis, it should be clear by now that his ideas were equally derived from a large amount of observation and testing. The work of his predecessors was there, he knew it well, and he used it, as should become clear. Nevertheless, he did so always with a view to having it merely to assist him in confronting raw material that he had personally acquired.

[20] I am indebted to David Bryden, former curator of the Whipple Museum of Cambridge University for useful insights and information concerning the nature and technical limitations of early microscopes.