VII

THE LIVING ELEMENTS

In his *Anatomie générale*, Bichat compared his twenty-one organic elements to the thirty-three elements of chemistry Lavoisier had described in his *Traité élémentaire de chimie* of 1789. The simple bodies of chemistry, he wrote, are caloric, light, hydrogen, oxygen, carbon, nitrogen, phosphorus, and so on. The simple bodies or tissues of anatomy are (1) the cellular membrane, (2) the nerves of the animal life, (3) the nerves of the organic life, (4) arteries, (5) veins, (6) exhalants, (7) absorbents with their glands, (8) bones, (9) medullary tissue, (10) cartilage, (11) fibrous tissue, (12) fibrocartilaginous tissue, (13) muscles of the animal life, (14) muscles of the organic life, (15) mucous membrane, (16) serous membrane, (17) synovial membrane, (18) glands, (19) dermis, (20) epidermis, and (21) hair (pilous tissue).

Since the nineteenth century, physicians and other commentators have tried to distinguish between Bichat's anatomical and his physiological theories. They did so because they were often troubled by what they saw as the incorrect assumptions that underlay the vitalist physiology. In spite of the limitations of tissue anatomy, which was superseded by cellular theory, these same commentators interpreted it as being basically sound and hence progressive and deserving of their attention. In effect, they would have effectively stripped the anatomical theory of its vitalist substructure, which they felt marred it. Even historians of science have not been exempt from that same tendency. Lain Entralgo, for example, was disturbed by the links of the tissue theory with a vitalism that he would have ignored completely had it been possible to do so. As it was, he merely dismissed it as a "stupidly conservative doctrine which seriously detracted from the beauty of the picture."[1] Such a distinction between allegedly good and bad theories, however, prevented Lain Entralgo from putting Bichat's work into its eighteenth-century context, which is clearer to us because of recent important secondary literature on the subject of monist philosophy.[2] Bichat saw himself as heir to the organicist and monist ideas of physiological function which had been vastly developed in the preceding century. He believed his new anatomical theory to be important, above all, because he considered that he had found the site of the vital forces in the tissues themselves. Vitalism and tissue anatomy were inextricably bound together for Bichat, no more to be separated than the sides of a coin. One cannot truly understand the historical importance of the tissue theory unless one is first aware of its vitalist foundation.

As with many philosophical and scientific ideas, the notion that there exist smallest units of living matter, a kind of biological version of the corpuscular theory, can be

[1] Pedro Lain Entralgo, 'Sensualism and vitalism in Bichat's "Anatomie générale" ', *J. Hist. Med.*, 1948, 3: 47–64.

[2] In connexion with the monist philosophy of the life sciences, for example, it is worth consulting Walter Pagel, 'The religious and philosophical aspects of Van Helmont's science and medicine', *Bull. Hist. Med.*, 1944, Supplement no. 2. Jacques Roger also deals with aspects of it in his *Les sciences de la vie dans la pensée française du XVIII^e siècle*, Paris, Colin, 1963, pp. 98–103, 585–682.

traced back at least to Aristotle, who made a number of references to simple and to composite parts of animals. In *De partibus animalium*, he went so far as to distinguish "three degrees of composition" in nature. The first was based upon the four elementary material particles of the Greeks. "The second degree of composition is that by which the homogeneous parts of animals, such as bone, flesh and the like, are constituted out of these primary substances. The third and last stage is the composition which forms the heterogeneous parts such as the face, the hand and the rest."[3] Galen wrote a short treatise on the subject of the similar or simple parts in which he commented that primary elements which compose the organic parts are such things as skin, cartilage, bone, various fibres, fat, and so on. Such structures as muscles, arteries, veins, and nerves, because they incorporate various membranes into their structures, are no longer simple.[4] This notion of similar parts continued to have an important place in the scholastic and neoscholastic views of the body, serving as a basis for teaching and exposition in anatomy.

The resemblance between those classical concepts of the simple or homogeneous bodily parts and Bichat's notion of the tissues is merely superficial, of course. It fell to Haller to frame the idea in a form that undoubtedly influenced Bichat, who paid him a considerable and unusual compliment when he advised his readers to pay "homage to his memory by following the route which he traced for us".[5] We have already seen that Bichat imitated certain of Haller's experimental techniques. In his investigation of sensibility and irritability, Haller had examined not only organs but also parts of organs. He differentiated between "simple" parts and "composite" ones. In the former category he included the nerves, arteries, veins, smaller vessels, membranes, muscular fibres, tendinous fibres, ligaments, bone, cartilage, and cellular tissue; the latter are the muscles, tendons, ligaments, viscera, glands, great reservoirs, excretory ducts, and larger blood vessels. Haller did not achieve anything approaching the tissue notion, for he did not conceive of the parts as being specific, distinct physiological and anatomical components. Nevertheless, he distinguished between the sensibility of bone marrow and that of bone; between that of dura mater and that of pia mater; and so on. He also assumed that structures whose composition is basically similar must possess similar qualities and properties. For example, because such membranes as the stomach, womb, intestines, bladder, ureters, and vagina are of the same basic nature as skin, they must be sensible like it.[6]

As we have seen, when Bichat assumed that the forces he attributed to the organic life must exist even though one cannot observe them directly, he was essentially imitating Glisson and the Montpellier vitalists. When he considered the animal life, he tested for its forces just as Haller had looked for sensibility and irritability, albeit keeping in mind the objections of Whytt, who showed that even apparently insensible

[3] Aristotle, *De partibus animalium*, bk. II, ch. 647[b], 10–29. Quoted from *The works of Aristotle*, 12 vols., ed. by Sir David Ross, New York, Oxford University Press, 1967.

[4] Owsei Temkin, *Galenism*, Ithaca, N.Y., Cornell University Press, 1973, pp. 12–13; G. Strohmaier, *Galen über die Verschiedenheit der homoiomeren Körperteile*, Berlin DDR, Akademie-Verlag, 1970.

[5] Xavier Bichat, *Traité d'anatomie descriptive*, 5 vols., Paris, Brosson Gabon, 1801–03, vol. 3, p. vii.

[6] Albrecht von Haller, 'A dissertation on the sensible and irritable parts of animals', (London, J. Nourse, 1755), a contemporary translation with an introduction by Owsei Temkin, *Bull. Hist. Med.*, 1936, **4**: 652–699.

bodily parts may become painful. Many of Bichat's conclusions coincided with those of Haller. He reported, for example, that nerves are the organs of animal sensibility, so that all those organs possessing that vital property do so because they have a nerve supply. Animal contractility belongs primarily to the muscles of the animal life. Nerves and muscles lack animal contractility and animal sensibility, respectively. In all these cases, he was merely echoing Haller's notions. In very many respects then, although it was conceptually more complex, the *Anatomie générale* was a kind of extrapolation of Haller's work on the subjects of sensibility and irritability. While the original idea for the *Traité des membranes* came from the work of Pinel, it is still probably true that the mature tissue theory would have been impossible had he not had Haller's example.

Methodologically, of course, the tissue theory was indebted also to sensationalist notions of analysis, which held that the proper way to learn something about an object is to study its component parts.[7] According to Bichat, it is thus that one arrives at a Newtonian "simplicity of causes allied to a multiplicity of effects". Indeed, the *Anatomie générale* was a triumph for ideology. Accordingly, Bichat treated the tissues as living elements, the smallest units into which one can subdivide the organism. Like Aristotle, he would have allowed that these elements can be broken down in turn into those of chemistry. But that is the process of putrefaction, which commences only when life has left the body and the living structures are breaking down. "As in chemistry," he wrote, "the simple [living] substances do not vary though the compounds they unite to form may do so." Nervous tissue, for example, is a membrane in the retina but arranged as cords in the nerves; fibrous tissue is arranged as fasciculi in ligaments, but it is a membrane in the fasciae. Whatever a tissue's form, however, its response to the action of chemical and physical agents is constant. On that assumption, Bichat subjected the bodily parts to various procedures and reagents as well as to dissection. "I have examined every tissue under the influence of caloric, air, water, acids, alkalis, neutral salts, etc. Desiccation, putrefaction, maceration, concretion, etc." Any two parts, wherever they occur in the body, that appeared to behave the same way in response to these various treatments were classified together in one category.

Bichat observed thereby that the muscles of the organic life are more resistant than those of the animal life to maceration, boiling, and putrefaction. Veins are observed to putrefy more readily than arteries. The nervous system of the animal life exposed to acid first undergoes a hardening of its coat, and then a softening. The nervous system

[7] The derivation of the tissue theory from "undeniably sensualist stock" is the thesis of Lain Entralgo, op. cit., note 1 above. The debt of Bichat to Pinel for the tissue theory has been forcefully disputed by Othmar Keel in a number of articles including: 'La pathologie tissulaire de John Hunter', *Gesnerus*, 1980, **37**: 47–61; 'John Hunter et Xavier Bichat: les rapports de leurs travaux en pathologie tissulaire', *Congresso Internacional de Historia de la Medicina. 31 agosto – 6 septembre 1980. Actas*. Barcelona, Académia de Ciéncies Médiques de Catalunya i de Balears, 1981, pp. 535–549; 'Les conditions de la décomposition "Analytique" de l'organisme: Haller, Hunter, Bichat', *Études Philosophiques*, 1982, no. 1, 37–62. Keel argues in various contexts that the idea of tissues is implicit in the work of John Hunter and in the work of other persons with whose ideas Bichat must have been familiar even if he did not acknowledge them. He names other persons whose works, predating Pinel's, implied the concept of fundamental tissues. It was apparently the proverbial idea whose time had come. Bichat remains, however, the man who explicitly stated the concept.

of the organic life responds similarly but more slowly. And so on. These are examples *par excellence* of Cabanis' analysis by decomposition.

This alleged unity of physical and physiological properties had important implications for the study of disease. Mindful of Pinel's work, Bichat wrote that if each tissue is unique in health, it must be so in disease also. Diseases normally affect only tissues, spreading to entire organs only if unchecked. Nothing is more rare, he wrote, than affections of the mass of the brain, though it is common to find an affection of its arachnoid tunic; often one eye membrane is affected while others remain normal; in convulsions or paralysis of larynx muscles, mucous surfaces are not affected; in catarrhs, the mucous surface is specifically involved. These are but a few of the examples he offered. It is necessary for the physician, therefore, to study alterations of cellular, arterial, venous, nervous, and other systems rather than diseases of organs and regions. Anatomical observation becomes more important than ever. Twenty years at the sickbed observing diseases of the heart, lungs, and gastric viscera will produce only a confusion of symptoms, which will quickly be dispelled if but a few bodies are opened.[8]

Bichat died shortly after he finished teaching a course in pathological anatomy. We know something of its' content, because the lecture notes of one of his students have been preserved and published as *Anatomie pathologique: dernier cours de Xavier Bichat*. The course was divided into sections treating, consecutively, the afflictions of the serous system, mucous system, cellular system, lungs, glands, skin, muscles of the organic life, arteries, veins, nerves, absorbent system, fibrous system, synovial system, cartilage, medullary system, bones, hair, and epidermis. Certain tissues, including those of the muscles of the animal life, appear not to have been considered in a separate category, but it may simply be that the student's notes are incomplete. According to the notes, for example, Bichat taught that serous membranes are subject to acute and chronic inflammations, rashes, whitish spots, occasional membrane ossification, and various sympathetic effects. In subsections, he treated the affections of the pleura, the pericardium, the peritoneum, the vaginal tunic, and the arachnoid membrane.[9] In *La vie et la mort,* Bichat defined disease as an alteration of certain vital properties, not so much a state "contrary to nature" as a modification of a normal condition.[10] In the *Anatomie pathologique*, we read that "the most active organs are most subject to illness."[11] Consistent with that principle, Bichat found that whereas the mucous membrane is frequently painful or inflamed, the hair is subject only to one rare hereditary malady, the "plique polonaise", which presumably dissolves the largely passive pilous tissue. The epidermis, which enjoys the least

[8] Xavier Bichat, *Anatomie générale appliquée à la physiologie et à la médecine*, 4 vols., Paris, Brosson, Gabon, 1801, vol. 1, pp. lxxxv–xcix. Hereinafter cited as *Anatomie générale*. Michel Foucault, *The birth of the clinic*, trans. by A. M. Sheridan, London, Tavistock, 1973, has much to say on the contribution of Bichat's theories to medical practice and teaching in post-revolutionary France, including Bichat's perception of disease and its relationship to the bodily parts.

[9] Xavier Bichat, *Anatomie pathologique: dernier cours de Xavier Bichat*, based on notes taken by P. A. Béclard, Paris, Baillière, 1852, pp. 38–74. Hereinafter cited as *Anatomie pathologique*.

[10] P. Huard observed that, for Bichat, there were no limits between normal and pathological. The notion of the tissue appeared to him to be probably more important in the ill person than in the healthy one. P. Huard, 'Bichat anatomiste', *Hist. Sci. méd.*, 1972, **6**: 98–106.

[11] Bichat, *Anatomie pathologique*, p. 105.

vitality of all, is subject only to corns, which, in themselves, are entirely painless.

In the *Anatomie pathologique*, Bichat's ambiguity about the role of the blood and other fluids showed up again. He told his students that his words about the nature of illness pertain only to solids, even though fluids are unquestionably altered in certain circumstances. Indeed, fluids such as those of cysts and hydatids are produced only in illness. Insofar as he considered them at all, it seems that Bichat interpreted such effects as merely secondary in nature, perhaps having to do with the fluids' partial animalization.[12]

It follows from his views on illness that Bichat believed that remedies act to restore vital forces from an altered state to their proper form and level. Each of the five vital properties ought to have its own class of appropriate remedies.[13] This was not further developed, however. Buisson informs us that at the time of his death, Bichat had begun work on a *materia medica.* What we know of it is contained in a notebook belonging to L. N. Jusserandot and preserved in the Zurich Medical History Institute. It suggests that Bichat was strongly urging a new classification of medicines based upon their activity. Accordingly, he is said to have distinguished those drugs which act on fluids from those which act on solids, all the while making a multitude of observations on the wards of the Hôtel-Dieu.[14]

There are no fluids, only solids, among Bichat's twenty-one tissues. Some vitalists, among them Barthez, believed that the vital principle exists in both the fluid and solid parts of the body. It is that force, he claimed, which causes the blood to circulate.[15] Bichat did not agree with Barthez in that instance. It is possible that his solidist viewpoint was a kind of byproduct of his basic medical education. A surgeon, after all, necessarily treats only the solid parts of the body, and those only locally. Never having considered fluids to be a locus of treatable lesions, Bichat was not inclined to allow them the same status as the solid parts when it came to anatomical classification. Whether or not this accounts for the special status of fluids, he believed that blood is a kind of reservoir whose composition changes constantly. In general, fluids act as excitants in the parts through which they pass. The blood, for example, stimulates the contraction of the heart. But the same fluids lack the capacity to move on their own or to experience sensation. That is to say, they lack vital properties.

Although he contended that fluids are not the carriers of living forces, Bichat was not prepared to go so far as to claim that they are entirely inert. They must possess, he thought, some intermediate status or quantity of life, if only because they contain within them particles that have been expelled from, or are about to become incorporated into, the animated solids. This problem for animalization or vitalization, however, was largely a mystery for Bichat, as he admitted:

> The alimentary mass is less animalized than the chyle, the chyle less than the blood, etc. It would undoubtedly be a very interesting subject of inquiry to determine how particles hitherto devoid of animal

[12] Ibid., pp. 16–22.

[13] Bichat, *Anatomie générale*, vol. 1, pp. xl–lii.

[14] Mathieu-François Buisson, 'Précis historique sur Marie-François Bichat', in Bichat, op. cit., note 5 above, vol. 3, p. xxv. The existence of the notebook is related in Erwin H. Ackerknecht, *Medicine at the Paris Hospital 1794–1848*, Baltimore, Md., Johns Hopkins University Press, 1967, p. 131.

[15] Paul-Joseph Barthez, *Nouveaux éléments de la science de l'homme*, 2 vols., Montpellier. J. Martel ainé, 1778, vol. 1, pp. 101–117.

properties and enjoying only physical ones should impregnate themselves by degrees with the rudiments of the former .... To say what that vitality of fluids is, is evidently impossible; but its existence is nevertheless real .... Let us observe, in effect, that from the moment the principle of life forsakes the fluids they verge on putrefaction and are decomposed like the solids when deprived of their vital powers.[16]

La Mettrie and especially Diderot had solved that problem, to their satisfaction at least, when they postulated that sensibility is a universal property of matter released under particular forms of organization. But Bichat's assumptions would not permit that solution. His own notions concerning natural forces in general and vital forces in particular had been shaped very strongly by what Barthez had written on the same subject. Vital forces, they both said, are somehow superimposed on inert matter and supersede its own inherent physical forces. The big question, never tackled in an even remotely satisfactory way, was just how such an imposition could take place. The question of vitality came up, therefore, in connexion with the status of the fluids among the tissues. As the quotation above shows, Bichat's speculation was entirely vague, raising more questions that he was inclined to try to answer.

In his *Anatomie générale*, Bichat divided the twenty-one tissues into two major groups according to the way in which they are distributed in the body. The cellular, nervous, vascular, exhalant, and absorbent tissues are dispersed throughout every bodily structure in such a way that if all other material were to be dissolved, they would form an outline of every organ. Their function is necessary for the continued existence of every part of the body. The second group of tissues includes bone, cartilage, tendons, muscles, and the mucous and serous systems. These exist only in certain limited parts of the body, where they perform a more restricted or specialized function than the tissues of the first group.[17]

The *Anatomie générale* is divided into sections labelled "cellular systems", "vascular system of red blood", and so on, and not, as we might perhaps expect, "cellular tissue", and "arterial tissue". Bichat treated systems rather than tissues, because he was interested not only in the form and properties of a particular tissue, but also in its distribution, organization, development, and interrelationships with other tissues and systems. Each of the systems associated with the two muscular systems, for example, is made up not only of muscle tissue but also of the blood vessels, absorbents, secretory vessels, nerves, and other tissues that support, nourish, and generally integrate it into the body as a whole. This implies a basic reluctance on Bichat's part to create a rigid separation between the study of anatomy and that of physiology. An anatomical unit makes sense only in the larger context of the complete organism. It is a logical approach, especially for a vitalist, but it also created certain problems, as I shall try to show.

We have already had occasion to observe how Bichat dealt with the cellular tissue, which is the most abundant of all the parts of the body. This tissue had already undergone considerable discussion before he turned his attention to it. Mention of a "cellular membrane" had been made by both Ruysch and Boerhaave. Haller devoted an entire chapter to it in his *First lines of physiology*, describing it as a supportive structure containing fatty deposits, forming membranes, and acting as a base for

[16] Bichat, *Anatomie générale*, vol. 1, pp. lxi–lxxii.
[17] Ibid., pp. 1–10.

many structures. Perhaps the most extensive work before Bichat's own was the treatment accorded the tissue by Bordeu in his *Recherches sur le tissu muqueux ou l'organe cellulaire*. Bordeu described mucous or cellular tissue as the most extensive part of the body. It nourishes all the organs, forms their base, and connects them one to another. It is the seat of several illnesses and of many phenomena of the animal economy. Under the microscope, Bordeu observed many small translucent bodies or "cells" linked together. Leeuwenhoek had remarked earlier that these cells are the same size in a flea as in a cow. Consequently, Bordeu considered it possible that these cells are somehow the basic material of the animal body.[18] The mucous tissue forms a great sac underneath the epidermis, which is subdivided into one part in the head and neck, one part in the thoracic region, and one in the pelvic area. Throughout the body, it is constricted along the median line of the body to form the *raphé générale*. It is clear enough, therefore, if we compare Bichat's basic treatment of the tissue to that of Bordeu, that Bichat owed something to his predecessor at least with respect to the form, distribution, and function of the tissue. Displaying his usual lack of grace when he referred to Bordeu's work, however, Bichat merely dismissed his *Recherches sur le tissu muqueux* as "some very vague ideas on the subject of the tissue peculiar to the organization of the cellular system which were not even supported by experiment."[19]

When he undertook to examine nervous tissue, Bichat found that it seems to subdivide naturally into two types in accordance with the animal-organic division. The nervous tissue of the animal life has its centre in the brain. It receives external sensations and activates voluntary muscles. That is to say, it controls the muscles of the animal life. The nervous system of the organic life has many centres in the ganglia of the great sympathetic nerve that travels alongside the spinal cord. Its nerves are distributed to the organs of the viscera. Neither system, however, is strictly confined to the organs of its own life, for cerebral nerves send branches to glands and to involuntary muscles, while the ganglia send branches to some voluntary muscles.[20] This admission is interesting, for conceivably it might have suggested to Bichat that the animal-organic division is a less rigid and integral a part of nature than he had once supposed. His addiction to it, however, would not allow him to be deflected.

The most abundant – in fact, virtually the only – property of the nerves of the animal life is animal sensibility, which they transmit from the bodily parts to the brain. Laid bare and excited, they cause the animal much pain. These same nerves, as Haller had long since declared, possess absolutely no animal contractility. Taking no active part in secretion, exhalation, and other internal functions, the cerebral nerves possess few organic properties. Nor are they well endowed with tissue properties, as nerves are rarely stretched.[21]

Bichat described the ganglia or anastomoses, which belong to the nervous system of the organic life, as insulated nerve centres, each one of which functions as a little brain. He saw the great sympathetic nerve as merely a cord which provides a series of

[18] Théophile de Bordeu, 'Recherches sur le tissu muqueux ou l'organe cellulaire', in *Oeuvres complètes*, 2 vols., Paris, Caille et Ravier, 1818, vol. 2, pp. 735–740.
[19] Bichat, *Anatomie générale*, vol. 1, p. 64.
[20] Ibid., pp. 115–118.
[21] Ibid., pp. 125–212.

communications between the numerous nervous systems located one above the other. Any communication between these miniature brains or ganglia is merely accessory. Unlike the regular and symmetrical nerves of the animal life, those of the abdomen, the heart, and other organs of the organic life are irregular as are their ganglia.[22]

The properties and even the functions of organic nerves gave Bichat more difficulty than had those of the animal nerves. He found no animal contractility and only a little animal sensibility in them. Though they affect the sensible organic contractility of the heart and intestines, they do not control it, for cutting them does not annihilate that vital property. In effect, Bichat could find no particular use for these nerves in spite of the abundance in the body. Bordeu had linked the activity of glands and of other viscera to their respective nerve supplies. Had Bichat been prepared to do so, his problem of nervous function would surely have been simpler. He maintained, however, that by their very nature, the organic properties are confined to their respective organs or tissues. Hence, they must exist apart from nerves. This conviction was at the root of his dismissal of Bordeu's evidence concerning the very critical nervous role in glandular activity.[23] The result, however, was confusion for Bichat. Indeed, his treatment of this part of the nervous system was undoubtedly the least satisfactory of all the sections of the *Anatomie générale*.

Bichat's treatment of the parts of the circulatory system again reveals the strength of certain prejudices and presumptions in his work. He distinguished between arterial and venous tissue as thousands had done before him. Nevertheless, he divided his discussion in the *Anatomie générale* into that having to do with the "vascular tissue of the red blood" and the "vascular tissue of the black blood". It was a curious pair of categories, especially for an anatomical work, for it appeared to be a remarkably awkward way of disregarding an obvious anatomical distinction. In its place, Bichat took account primarily of the quality of the fluid that circulates in the various parts of the system. That approach seems to be inconsistent not only with his views about the nature of tissues but also with his belief that the blood is basically an inert mixture of elements. The red blood system, Bichat wrote, originates in the lungs, where blood acquires a colouring principle from the air. It includes the pulmonary veins, the left heart, and the arterial system of the trunk. In the trunk, the blood loses its colouring principle and the resultant vermilion hue. The black blood system includes the venous system of the trunk, the right heart, and the pulmonary arteries. While he admitted the confusion of two types of vessels, he pointed out that his division is logical if one considers the function of the blood in the body. The red blood circulation furnishes the body with the material it needs for secretion, exhalation, and nutrition. The black blood system, on the other hand, is a kind of general reservoir receiving discarded lymph, serous exhalants, and various nutritive wastes. Here above all in this work, Bichat's instincts as an anatomist were deflected by a preoccupation with physiology, which caused him to lose sight of his own precise definition of the word "tissue".[24]

Denying the status of a separate tissue to capillaries, Bichat treated them as the focus of yet two other tissues, the exhalants and the absorbents. He nevertheless

[22] Ibid., pp. 213–218.
[23] Ibid., pp. 220–244.
[24] Ibid., vol. 2, pp. 245–468.

devoted many pages to an enlightening discussion of the place of the capillaries in the animal economy. It is precisely in the capillary vessels of the trunk, he wrote, that red blood is transformed into black blood; in the capillaries of the lungs, black blood takes on a vermilion hue. The system is the focus of such important organic functions as secretion, nutrition, absorption, exhalation, and heat production. The minute canals are the seat of various inflammations. Although the lower classes of animals frequently lack a heart, they all possess the basic and fundamental capillary circulation. It is a kind of link, Bichat speculated, between plants and animals.[25]

Organic sensibility and the organic contractility that inevitably accompanies it are the dominant vital properties in all those tissue systems which act in one way or another through the capillary system.[26] Being the instruments of nutrition, absorption, and so on, capillaries actively become part of every organ of the body. While the capillaries of the muscles, spleen, pituitary, and certain parts of the mucous surface contain only blood, those of the tendons, cartilage, hair, and certain ligaments have no blood at all. Bichat ascribed the separation of the various fluids in this vast and interconnected system to the ubiquitous and highly specific organic sensibility of the various bodily parts:

> It depends entirely on the connection between the organic sensibility of each part of the capillary system and the fluid which it contains .... Why does the trachea admit air and repulse all other fluid? All this has to do with the fact that each part, each portion of the organ, each organic molecule has its own type of sensibility so to speak which has a rapport with only one substance and repulses all others.

This explanation of organic sensibility is unmistakably linked to Bordeu's explanation of the selective secretion of the particles from the blood by glands owing to their unique and specific sensibilities. Bichat admitted as much, commenting that "however slightly the phenomena of the capillary system are examined, the facts which Bordeu first recognized will be easily observed".[27]

When he located heat production in the capillaries, Bichat was tackling a phenomenon that has baffled philosophers and physicians for centuries. He observed that some parts of the body are warmer than others. While this is more striking in the case of a local inflammation, he went on, it occurs even in complete health, so that the general temperature of the animal body arises from the combined individual temperatures of many parts. Believing, like Lavoisier, that heat or caloric is a material element, Bichat wrote that blood absorbs it from food and from respired material in the capillary system. Each system has a unique level of heat simply because its secretion, like that of other circulating particles, depends upon the system's specific *insensible organic sensibility:* "Each system has its peculiar mode of heat production just as each gland has its peculiar mode of secretion; each exhaling surface its peculiar mode of exhalation; each tissue its peculiar mode of nutrition and all this directly proceeds from the modifications of the vital properties in each part."[28]

In view of their functions, it follows that the tissues of exhalation and of absorption are distributed throughout all parts of the body. Bichat wrote that exhalation, like

[25] Ibid., pp. 469–470.
[26] Ibid., pp. 487–504.
[27] Ibid., pp. 591–602. The capillary system is discussed on pp. 470–548.
[28] Ibid., pp. 520–536.

secretion, is a process whereby liquids are separated from the blood and poured over various surfaces. While secretion occurs in glands, however, only the capillary plexus separates arteries from exhalant vessels. Exhaled materials are synovial fluid, fat, serum, mucous, bone marrow, and all nutritive substances. Apparently devoid of all animal properties, the exhalant system is governed exclusively by the *organic sensibility* and the *insensible organic contractility* specific to each system. This specificity ensures that mucous exhalant, for example, is different from the serous one. An exhaled fluid that has served its purpose passes through the lymph glands into the minute capillary vessels and thus into the black blood. What Bichat named the absorbent system was the combination of these glands and their vessels. All the known absorbents unite into two principal trunks, delicate and transparent, which finally empty into the superior vena cava. Like the exhalants, they function simply because they possess appropriate organic properties.[29]

The careful reader may find himself uneasy with these two tissue categories, for, once again, Bichat seems to have confused anatomical divisions with physiological functions. In the introduction to the *Anatomie générale*, he strongly insisted that he intended to treat structures as though they belong to a single tissue system if they responded similarly to chemical and physical manipulation. However, the existence of absorbents and exhalants was inferred rather than demonstrated, for they could not be directed, observed, or experimentally manipulated. Bichat admitted as much. According to his own definition of a tissue, the capillary vessels deserve their own category. They contain certain apparatus which governs absorption, exhalation, and so on. Having lost sight of his original goal when he discussed the parts of the circulatory system, however, Bichat was prevented from according the capillaries their due status in the body. To permit such inconsistencies to remain in his work, Bichat must have been submitted to considerable pressure from an impatient and uncritical publisher.

The tissues discussed so far are the most basic ones, without which an animal organism could not exist. Accordingly, they are distributed throughout every part of a body. The remaining ones perform more specialized functions and are, therefore, more localized. The bones, cartilage, fibrous tissue, and animal muscles are destined for locomotion; the organic muscles and the serous and mucous tissues are incorporated into the digestive apparatus; the respiratory, circulatory, and glandular tissues together are responsible for secretion; the cutaneous system of the dermis, epidermis, and pilous tissues constitutes the external sensitive apparatus.

Bony tissue possesses only organic properties, except when its sensibility is raised to an animal level because of caries or other bone disease. Bones are formed, Bichat observed, as calcium phosphate is deposited into the cartilaginous skeleton of the foetus.[30] Not all cartilage turns into bone, however. It is a white, hard, elastic substance organized into tightly interlaced fibres. In an adult, it is found only at the articular ends of movable bones and on the parieties of certain cavities, such as the cartilage of the nasal partition, the ribs, and the larynx.[31]

Inside the bones, one finds medullary tissue. Bichat described it as a fine vascular

[29] Ibid., pp. 549–636.
[30] Ibid., vol. 3, pp. 5–104.
[31] Ibid., pp. 119–144.

interlacing that adheres to the inside of all the bones and serves as the exhalant organ of the medullary juice. It possesses animal sensibility, especially in the long bones, he found, for amputation or the introduction of an instrument into the bone causes severe pain when they touch medullary tissue.[32]

The mucous, serous, and fibrous membranes had been examined by Bichat as early as 1798 and featured in his *Traité des membranes*. We have had occasion to consider these tissue categories briefly earlier. In the *Anatomie générale*, the fibrous category was extended to include ligaments and tendons. In the interim, Bichat found that he could isolate a combined fibrocartilaginous tissue, which he claimed occurs in ears, nostrils, the trachea, eyelids, and at vertebral articulations. Fibrous tissue is the common base of these structures, but more like cartilage, they develop animal sensibility when they become inflamed.[33]

The muscle system, Bichat found, naturally divides into animal and organic tissues. The two categories correspond closely to what we know today as the voluntary and involuntary muscles. The muscle tissue of the animal life is the more extensive of the two. It fills numerous regions and is spread out under the skin. Its muscles are red and disposed in obvious fibre bundles. Although Leeuwenhoek had done microscopic studies of these muscle fibres, Bichat naturally dismissed them as a futile search for "the intimate structure of organs" and hence for inaccessible first causes.[34]

In general, Bichat found that the muscles of the animal life possess a remarkable degree of vitality and function more rapidly than does any other organ or bodily part. They alone possess at least a measure of all the various vital forces. Amputation of such a muscle is painful only when its nerve filaments and not the muscle fibres themselves are being cut. Recall that Haller had claimed that voluntary muscles do not possess sensibility. Bichat claimed, nevertheless, that this particular tissue is endowed with animal sensibility, simply because it is very susceptible to the sensation of weariness. Of all the tissues, only the muscles of the animal life have animal contractility. In this, he was in agreement with Haller. Indeed, it is this vital force that accounts for the unique and important functions this type of muscle performs in the body. The primary cause of voluntary animal muscle activity is the soul. The signal for it is transmitted by the nerves of the animal life from the brain, which is the intermediary between the soul and the nerves just as the nerves are intermediaries between the brain and the muscles.

Laid bare, the muscles of the animal life are observed to demonstrate sensible organic contractility, for they react involuntarily to the direct application of various stimuli or irritants. In cases of mental alienation, delirium, head wounds, or inflammation, muscular contractions become involuntary, for the soul's direction is overpowered by sympathetic signals from other parts of the body. Strong passions such as anger emanating from the organic life can also occasionally triumph over the will. Muscle power varies greatly depending upon whether a particular activity has come about because of the activity of the soul, the sympathies, or merely mechanical agents.[35]

[32] Ibid., pp. 105–118.
[33] Ibid., pp. 145–224.
[34] Ibid., pp. 315–317.
[35] Ibid., pp. 224–339.

The muscle tissue of the organic life participates in the formation of the heart, gastrointestinal tract, bladder, and womb. Except for the heart, its fibres are flat and membranous and often curved, folded, and formed into bags and cylinders. Because the tissue is not subject to the will, it does not weary and is not painful if cut or irritated directly. Under normal conditions, therefore, it possesses no animal properties at all. The predominant muscular property in the organic life is sensible organic contractility, which is excited by blood in the heart, urine in the bladder, food in the gastric organs, and so on. "Each individual muscle is possessed of a degree of organic contractility peculiar to it and upon which certain fluids only in the animal economy can act with regularity."

As we observed earlier, Bichat was troubled by the fact that these organic muscles receive nerves from both the brain and the ganglia. The bladder and rectum possess certain limited animal properties. But Bichat could not understand why, for example, any nerves of the animal life should travel to the organic muscles in the abdominal region. He came to no conclusion, merely remarking that he was not sufficiently acquainted with the influence of the brain and nerves on the muscles.[36]

When he came to consider the glandular tissue, Bichat naturally had to refer to Bordeu's work. Much as Bordeu had, Bichat defined a gland as an organ that separates a certain fluid from the blood and expels it through one or more ducts. In this category, he included the salivaries, lachrymal glands, mammae, liver, pancreas, kidneys, prostate, testes, and mucous glands. He did not, however, include the lymphatics, pineal, thyroid, thymus, and suprarenal bodies, because, he said, they do not possess the required excretory duct. Once again, it would appear that Bichat lost sight here of his anatomical definition of "tissue". He himself pointed out the obvious fact that the texture of the glands varies a great deal. That of the liver, for example, is entirely different from that of the kidney, and both differ substantially from the salivary glands. Bichat's instincts as a physiologist gained the upper hand over those of the anatomist. He found evidence, however, that there is such an anatomical element as glandular tissue. He relates that when he subjected various glands to the effects of drying in the air, putrefaction, heating, boiling, acids, and so on, they responded similarly. They reacted in various ways to maceration, however. The liver, for example, resisted the action of the water better than the kidneys, while the salivary glands broke up almost immediately. But that, he suggested, is largely the consequence of the fat contained in each gland and not of its texture.

Dismissing the microscopic studies of Malpighi and Ruysch, Bichat commended Bordeu for having clearly demonstrated that vital and not mechanical activity is the cause of glandular activity. He disagreed sharply, however, with Bordeu's contention that nerves govern this vital action. He pointed out that glands secrete even in cases in which an organ in which they are situated is paralysed and presumably its nerves are inactive, as, for example, the mucous glands in an inactive bladder. Being altogether uncertain of the role of the nervous tissue in the organic life, as we observed, Bichat preferred to believe that glands function simply because they possess the two basic properties of the organic life:

[36] Ibid., pp. 224–414.

> It is by means of its organic sensibility that the gland secretes the materials proper to it from the mass of the blood. It is by means of its insensible contractility or by its tonic powers that this organ contracts and rises . . . to expel those matters heterogeneous to this secretion . . . it is by means of its peculiar mode of organic sensibility that each living part in the economy thus distinguishes what its functions require . . . . In the fluids approaching the small vessels of this gland, this sensibility is the sentry that warns and insensible contractility the agent that opens or shuts the doors of the organ according to the principles which must be admitted or rejected.[37]

Those words could just as easily have been written by Bordeu.

When he came to consider the skin or dermoid tissue, Bichat described it as a sensitive boundary that establishes a relationship between the body and the external world. In effect, it is the outer surface of the animal life. Its internal surface lies against cellular tissue, which is adjacent in turn to muscles. Skin is composed of a passive corion, of reticular bodies that ramify as small vessels on the skin surface, and of the small sensitive papillae on the external surface of the corion. The papillae are the receptors for the sense of touch, providing one with sensations of mass, heat and cold, humidity and dryness, hardness and softness. They are, therefore, the primary organs of the sensory life.[38] The outermost layer of the skin or the epidermal tissue, on the other hand, has so little vitality that it is almost inorganic. It serves as a kind of semi-organized body, which Bichat described as intermediate between the physical and organic realms of nature.[39]

Finally, the hair or pilous tissue, which arises from the cellular tissue, has the least vitality of all. Because man has the most active external life of all the animals, he has the least hair to lessen his contact with external bodies. Curiously, of all the tissues, the almost inert epidermis and the hair alone can replace themselves. Bichat remarked upon this fact without attempting to explain it.[40]

Bichat's final published work, the *Anatomie descriptive*, was intended to complete the analytic process begun in the *Anatomie générale*. Having by now succeeded in decomposing the organs and structures, he proceeded to the next stage of the total process by, theoretically at least, recomposing the organs and the systems from their parts. Whereas the twenty-one tissues were the object of the *Anatomie générale*, Bichat wrote that it was their various recombinations that concerned him in the *Anatomie descriptive*. It was divided into sections dealing with the "apparatus of the animal life" and the "apparatus of the organic life". The former includes the bones and muscles of locomotion, voice, external sensation, and internal sensation, and the organs of feeling and motion in general. The latter apparatus included digestion, respiration, circulation, absorption, and secretion.

The tissue theory seems to have made considerable impact upon the medical world almost as soon as it appeared. The many flaws in the work were merely those of detail and in themselves insufficient to detract from the virtues of the basic theory. By the time he was writing the *Anatomie descriptive* and lecturing in pathology, Bichat seems to have discarded such awkward categories as the red and black blood systems, and have returned to the far more anatomically sound divisions of arterial and venous

[37] Ibid., pp. 569–639.
[38] Ibid., pp. 640–756.
[39] Ibid., pp. 757–791.
[40] Ibid., pp. 792–828.

tissues. For all the compliments it received in its own time and since, the tissue work nevertheless was superseded within a few decades by the cellular theory, which incorporated it. It is, in a very real sense, tissue theory's distant relative. The tissue theory remains, nevertheless, an incisive concept of some importance for the subsequent development of the life sciences.

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