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► **To cite this version:**

Jean-Gaël Barbara. Biological generality: general anatomy from Xavier Bichat to Louis Ranvier. K. Chemla, R. Chorlay, D. Rabouin, (éds.), The Oxford Handbook of Generality in Mathematics and the Sciences, Oxford UP, 2016. hal-03110418

HAL Id: hal-03110418

<https://hal.science/hal-03110418>

Submitted on 14 Jan 2021

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Biological generality: general anatomy from Xavier Bichat to Louis Ranvier

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Version auteur : J.G. Barbara, 2016. « Biological generality and general anatomy from Xavier Bichat to Louis Antoine Ranvier », in K. Chemla, R. Chorlay, D. Rabouin, (éds.), *The Oxford Handbook of Generality in Mathematics and the Sciences*, Oxford UP, 2016, p. 359-384, ISBN-10: 0198777264, ISBN-13: 978-0198777267.

Avis au lecteur, Cet ouvrage est très différent de ceux qui ont paru sur le même sujet. Les uns remplis de préceptes communs, rebutent par leur longueur : les autres bornés à de simples catalogues ...

*Le Cuisinier Gascon, Amsterdam, 1741.*¹

13.1 Introduction

Epistemological studies on generality in the life sciences have primarily focused on the concept of natural law and the generality of theories. Contemporary philosophers often conclude that no such laws or theories, nor natural kinds,² or even generalizations³ exist in biology. Similarly, Richard Burian and coworkers have suggested that generalizing had its dangers in the philosophy of science. Consequently, these authors have argued that the philosophy of science should study how biological knowledge developed locally. They advocate a descriptive epistemological approach⁴ within precisely defined historical and geographical contexts. Even so, we may ask why and how generality was occasionally seen to possess great importance. In keeping with these views, studies focusing on the latter questions are more likely to bring answers if they focus on specific historical milieus. This is precisely the way, in this chapter, that we suggest addressing the following issues: How was generality built and expressed locally? What did it mean?

¹ “Note to readers, this work is far different from those published on the same subject. Some full of common precepts discourage by their length: others are limited to simple tables ...” Louis- Auguste de Bourbon (1700– 1755), Prince de Dombes, expresses a common idea in the eighteenth century, a middle way between the art of dealing with details (“simple catalogues”) and the aim of highlighting general principles (“préceptes communs”), in agreement with the spirit of analysis (Bourbon, 1741). All translations by the author.

² I. Hacking, 25 April 2006 Lecture at the Collège de France. See the paper by Y. Cambefort in this volume.

³ Burian et al. (1996).

⁴ Burian et al. (1996: 25).

The discipline of *anatomie générale* was founded in France in 1800 by Xavier Bichat (1771– 1802). Shortly after his death, it was taken as a model throughout Europe for the study of medicine, human anatomy, and pathology. Bichat's anatomy was later developed in the 1870s in France by Louis Ranvier (1835– 1922) at the Collège de France, by means of microscopy. Contemporary debates in science studies suggest paying attention to local epistemic cultures and usually deny general biological laws. This chapter echoes the first suggestion while rejecting the second; it is intended to study Bichat's and Ranvier's interests in generality as an actor's category. We hope that such an approach can renew discussions on the role of generality in the life sciences.

Bichat's concern regarding generality was not a simple consequence of his vitalism. In fact, Bichat claimed not to rely on a unique and mysterious vital principle, but rather to study particular and complex properties of living matter. Nevertheless, his approach focused on the observation of more or less strict experimental regularities in biological phenomena and observations of structures, an attitude which we will try to account for. Bichat's work is of interest for understanding which kind of concept of generality gained favor in the life sciences at the start of the nineteenth century, and why that happened. Moreover, it sheds light on its present-day status in experimental biology.

The later career of Louis Ranvier, who held the first chair in *Anatomie générale* in France, will inform us about the ways that generality was searched for at the microscopic level and its significance in the discovery of real and minute biological objects. With Ranvier, we will get closer to our understanding of the value of generality in biology today. We will study the context in which Ranvier came to value generality as a heuristic category and how this led him to discover new microscopic objects. We will concentrate in particular on the role of cellular theory and Claude Bernard's experimental physiology.

These case studies will allow us to analyze the changes in meanings and expressions of generality in Bichat and Ranvier. In both cases, generality was at the heart of a new disciplinary approach. The search for generality promoted the search for general facts—common traits encountered in multiple observations, thought of as being part of one ensemble, defined by a criterion— and their use to define the objects of study. The works of both Bichat and Ranvier involved the two disciplines of anatomy and physiology. The sense of generality in biological sciences changed in this cross fertilization. Their studies aimed to correlate facts common to anatomy and physiology and to search for criteria which did not rely solely on either one of them. Consequently, their method could define biological objects and categories by spatially overlapping anatomical and physiological traits.

13.2 Bichat's *anatomie générale*

Xavier Bichat is usually considered the founder of general anatomy. This young surgeon had a private course in anatomy and edited, after the death of his master Pierre Joseph Desault (1744– 1795), his courses in surgery. Bichat died prematurely at age 31, after publishing two anatomical books, *Traité des membranes* 5 and the *Anatomie générale*, 6 which had profound impacts on the teaching and future directions of research in human anatomy and medicine. His work was based on a new concept borrowed from the English school of surgery, the concept of “tissue.” The study of such tissues, namely “histology,” now relies

on subtle microscopic observations and selective staining procedures that were not available in Bichat's time. Rather, Bichat made use of physiology and pathology to make distinctions between anatomically similar tissues.

Bichat's method can be most easily understood by using the example of the first type of tissue in his first category of membranous tissues, mucous membranes.⁷ A first approach was to search for general traits defining an ensemble of anatomical parts as a specific tissue. This search was guided by a priori criteria which could be changed after study. Bichat's criterion for mucous membranes defined them as those inside cavities in continuity with the skin (mouth and nose, for example). Using another criterion of spatial continuity, Bichat divided mucous membranes into two ensembles, whose membranes were in continuity. Accordingly, a first ensemble lay in the interior of nose, mouth, pharynx, larynx, esophagus, stomach, intestine, and anus, while a second is in the urethra, ureter, kidneys, and prostate or vagina. At a physiological and pathological level, a common pathological property of the first kind of membrane seemed apparent when, during a cold, inflammation of the mucous membrane spread from nose to throat, or vice versa, possibly to sinus or bronchi. In case of stomach acid reflux, inflammation can invade the esophagus to larynx and ears. This example shows how a priori criteria were used to define kinds of tissues, and how tissue categories were defined a posteriori, by reference not only to anatomical, but also to physiological and pathological properties. This approach enabled Bichat to build a single category for membranes of nose, mouth, pharynx, larynx, esophagus, stomach, intestine, and anus, which is referred to as a single mucous tissue.⁸ The novelty of this approach relied on defining anatomical parts of the body using non anatomical properties, and the discovery of converging criteria from different disciplines, in the partition of the human body, for defining single types of tissues.

Consequently, the discipline that Bichat established is usually described as a "physiological anatomy."⁹ Defining general anatomical categories as types of tissues (general anatomy), Bichat attempted to describe their organization within organs in a new manner (descriptive anatomy), as well as to understand their functional properties and functions (physiology). His systematic use of the concept of tissue revolutionized anatomy, descriptive anatomy, physiology, pathology, and medicine. After his death, Bichat's method was recognized as the future direction to follow in all of these fields. Its main feature was the expression of the general and the particular in a new physiological perspective, following

5 Bichat (1799).

6 Bichat (1801).

7 Bichat (1799: art. II).

8 Bichat will later make other, finer, distinctions in his tissue categories and his system of tissues will be later criticized for its overwhelming complexity.

9 See, for example, Flourens (1858: 244–7).

the work of Haller (1708– 1777), in correlating anatomy and pathology. This required a diversity of practical procedures, that is, experimental physiology performed on animals, human dissections of healthy and diseased bodies, and the inspection of sick persons, which Bichat skillfully used within a single perspective. In all these studies, Bichat was focused on general facts in order to compare each of them to others obtained with different procedures from other disciplines. This explains how and why generality as he practiced it was central to his approach.

13.2.1 Bringing anatomy and physiology closer together

We shall now analyze Bichat's work within a historical perspective, in order to highlight the contexts in which he came to study anatomy, surgery, and medicine conjointly in this new way. However, before addressing this issue, let us make some preliminary remarks on the way generality had been used as a category for comparing knowledge coming from different disciplines. In the history of biology, generality has often been associated with explanation and causality. The central goal of Bichat was not only a new description of the human anatomy. For medical practice, he also wished to understand the function of each type of tissue and the causes of pathological lesions. Such relations between generality and causation appear in ancient Greek physics and medicine. In his *Physics*, Aristotle claimed to look for general causes within general facts, and particular causes within the particular. ¹⁰ The study of general facts was considered a path to discover the general causes involved.

In eighteenth- and nineteenth- century anatomy and physiology, general anatomical facts were extracted from observations and considered as possible causes of the function of organs in an Aristotelian perspective. ¹¹ As late as the nineteenth century, Rudolf Virchow expressed a similar opinion, when he asserted that new general anatomical observations had to be developed prior to making any physiological discovery. ¹² General anatomical categories were thus frequently sought in order to explain function. ¹³ This is what, for instance, Georges Canguilhem (1904– 1995) stressed, in his comment on Galen's approach in *De usu partium*:

Anatomy describes organs, physiology explains their functions. How can one claim to deduce physiological rules from anatomical techniques? In fact, any form of physiology understood in this way amounted more or less to a discourse on the utility and use of parts of organisms. ¹⁴

¹⁰ Aristotle (*Physics*, Book II, part 3).

¹¹ Debru (1996: 28).

¹² Virchow (1861).

¹³ Hall (1968).

¹⁴ The discourse on the use of parts of animals refers to Galen's project to deduce the function of organs from the knowledge of their structures. "L'anatomie est la description des organes, la physiologie est l'explication de leurs fonctions. Comment prétendre déduire des techniques de la première les règles de la seconde ? En fait, toute physiologie ainsi entendue revenait plus ou moins ... à un discours sur l'utilité et l'usage des parties de l'organisme" (Canguilhem, 1968a: 227).

By contrast, Claude Bernard's experimental physiology was built against such a principle.¹⁵ However, even if, before Claude Bernard, physiology was already empirical and often experimental, on a theoretical level it provided merely a discussion of general anatomical facts to explain the functions of organs. Haller referred to it as *Anatomia animata*. Although generality was central in discussions linking anatomy and physiology, the relations between these fields were teleological and polarized from anatomy to physiology, never relying systematically on experimental physiology or pathology.

In the eighteenth century, physiologists did not only seek to explain function in terms of general structures, but they also began to propose physiological principles—vitalist or mechanist—to account for life. The vitalist approach defined functional properties, for which no causal explanation was sought. For example, irritability was defined as the property of muscles to contract, without inquiring into its origin. Haller avoided any discussion of the causes of physiological properties, referring to Newton's lack of discussion of the origin of gravitational force. Sensibility, the power of a stimulated tissue to alert an animal, and irritability, the power of inducing contraction in a stimulated tissue, were considered two general physiological properties to be studied. Experimental physiology established these concepts as properties mapped onto organs throughout the body. These researches invented a generality of physiological facts and subsumed them in broad categories of vital properties, which Bichat adopted.

Such physiological studies did not try to account for vital properties in terms of underlying anatomical structures and mechanisms, but rather aimed to understand how they contributed to specific functions. However, such studies were not made without reference to anatomy. Why, then, were general anatomical facts of interest in such an approach? Bichat answered this question in a specific way. He was among the leading anatomists adopting Haller's style of physiological research. His personal interest was in establishing correlations between the general physiological properties described by Haller and general anatomical descriptions in order to define tissues as overlapping categories between those of anatomy and physiology. As we have sketched above, since, for instance, inflammation of the mucous membranes of the urethra never occurred after a cold, for him it belonged to a different tissue category than that of the membrane of the respiratory and digestive tracks. Therefore, he correlated anatomical, physiological, and pathological properties to define categories of tissues. All such observations converged on precisely determined surfaces of the body to define a tissue as a single and general object. Bichat considered tissues as anatomical entities "carrying"¹⁶ specific properties. His goal was, on the one hand, to describe functional differences in apparently similar anatomical objects which could account for specific physiological properties and pathologies, and on the other hand, to search for functional similarities between anatomical objects with different textures, colors, or tastes. Bichat conducted all possible confrontations between classical anatomy and medicine, by relying on the senses and new experimental physiology. He wished to arbitrate between structure and function, to discover a middle way of defining tissues.

15 Bernard advocated that functions should be discovered by experimental physiology alone, without prior reference to structures. Accordingly, physiology should, in his view, be independent from anatomy.

16 Bichat's term.

Locating physiological and pathological properties on anatomical maps allowed him to localize them onto particular territories, defined as tissues. Although Bichat adopted Hallerian physiology, he no longer associated anatomy and physiology in a unidirectional and causal relationship. Their connections relied on overlapping generalities in the organization of life, described only in terms of visible entities, where anatomy and physiology could compare, correlate, and combine their spatial partitions of the body.

13.2.2 The choice to focus on tissues within a historical perspective

Let us now examine the historical contexts in which Bichat decided to found his research on tissues. Bichat's approach is both original and representative of anatomy in the second half of the eighteenth century. As we have already suggested, his quest for generality is apparent in the identification of general anatomical entities and their spatial correlations with physiological properties, which led to the creation of new objects. The history of this approach has been studied by Othmar Keel,¹⁷ who discovered that the concept of tissue was first described by students from John Hunter's school of surgery (1728–93), followed by Philippe Pinel (1745–1826), and later Bichat. Tissues were initially identified by their distinct sensitivity to inflammation, and thus spatially localized by the extension of physiopathological properties.¹⁸ The attention paid to such properties is representative of Bichat's method, which he used systematically. However, Bichat distinguished himself as the only author to make use of general anatomy in this context. Most authors, including British scientists, agree on this fact. We may account for this feature of his approach by referring to his personal method of searching for generality. This search is characteristic of his dominant style of research, as he was the only one who required that a collection of specific practices define the topography of physiological and pathological properties, and demanded their spatial correlations with anatomical observations. Moreover, Bichat gave a theoretical content to the use of the tissue as a concept, and made it the centerpiece of his new method of anatomy. Practices from different disciplines, systematically developed conjointly, were for him a means of avoiding the limitations of anatomy alone and of defining real biological objects.

Bichat's starting point was anatomy studied by the senses. He inspected hundreds of cadavers and believed that the repetition of dissections led to clear and general ideas, since “in this matter, observation is all, as in most physical sciences.... Images last only when they are repeated: the first image is fleeting, the second confused and the third is often indistinct. Senses can teach us better than books.”¹⁹ For Bichat, general facts emerged from repeated observations and were those which most struck the mind and represented the common denominator of all the observations.

¹⁷ Keel (1979, 1982).

¹⁸ According to Flourens, the term tissue was taken by Bichat from Bordeu (Flourens, 1858: 235).

¹⁹ “Ici, l'inspection est tout, comme dans la plupart des sciences physiques ... Les images ne sont durables qu'autant qu'elles sont répétées : la première fuit ; la seconde est confuse ; souvent la troisième n'est pas distincte. Les sens, mieux que les livres, peuvent nous instruire” (Bichat, 1829: xxv).

Bichat emphasized the primary importance of the senses in observation, advising that one should “point out phenomena, and even often refrain from looking for the connection between them;” [Bichat added], “this is most often what we ought to.”²⁰ But Bichat's own practice seemed to some of his contemporaries to contradict this claim. François Magendie (1783– 1855) emphasized this point in a note to the 1827 edition of the *Traité des membranes*: “Principles given here by Bichat are wise and truly philosophical; we regret his active imagination led him away from them too often.”²¹ While Magendie's specific approach advocated against extracting general facts from observations, Bichat used “connections” and “analogies”²² freely for grasping generality. Thus in Bichat's practice, constructing and deriving general facts relied on a psychological procedure, which actively drew on connections and analogies to reach a higher level of generality in a rational manner.

Thus, we come across two modes of creating generality in Bichat's method:

(1) One is based on spatial correlations between anatomical boundaries and the extension of pathophysiological properties, which leads to the definition of general tissues. Such tissues are general in the sense that they represent general entities within three sets of orders: anatomical, physiological, and pathological. They are also general since they can be found in different organs of the body. However, this latter form of generality derives from the former since the properties under consideration and their associations are general and consequently occur in different areas of the body.

(2) A second mode of achieving generality is present in each of these disciplines— anatomy, for example— when similar observations are abstracted by mental processing to build a single and general representation. In this case, this representation is what remains in memory or is actively built. Moreover, it has an educational virtue for teaching.

All these processes for achieving generality require comparing abstractions derived by focusing on similarities and differences. Bichat's way of observing evokes later practices of nineteenth-century anatomists, as described by Ranvier or Mathias Duval (1844– 1907). In these practices, the search for similarities belongs to the domain of the senses, a domain of unconscious perception, from which generality emerges. It also belongs to the domain of the rational construction of analogies.

20 “Indiquer les phénomènes, s'abstenir même souvent de rechercher la connexion qu'ils ont entre eux, c'est presque toujours ici ce que nous avons à faire” (Bichat, 1829: 116– 17).

21 “Les principes qu'émet ici Bichat sont très sages et vraiment philosophiques ; il est à regretter que son imagination active l'ait trop souvent conduit à s'en écarter” (Bichat, 1829: 117). These words show the weight that Magendie placed on facts, an emphasis later criticized by Claude Bernard and Louis Ranvier.

22 “Connexions,” “rapprochements,” and “analogies.” In the introduction of a new edition of Bichat's *Traité des membranes*, F. Magendie wrote “anyone will understand the shortcomings of his book if one observes the necessity he [Bichat] felt to connect similar facts, in ways that were often more unexpected and newer than true;” “son besoin de rapprochements, souvent plus nouveaux et inattendus que vrais, expliqueront à chacun les défauts de l'ouvrage ...” (Bichat, 1827: viii).

Were these methods specific to Bichat, or can one find such principles at play in other circles? Bichat's principles seem to have been shaped in opposition to the traditional anatomical teaching he received from his physician father and his master, Parisian surgeon of the Hôtel-Dieu, Pierre Joseph Desault. This education was based on memorizing large collections of particular facts. Desault was aware of this fact and criticized it. He therefore developed a pragmatic aspiration, common to many surgeons of his time, to rationalize the anatomical knowledge compiled over past centuries. ²³ Bichat's biographer, Husson, noted how:

[Desault] had long wished to collect in a regular and methodical framework all the discoveries he added to surgery; he wanted to transform his journal, removing all isolated facts, keeping only those which allowed general inductions; in a word, he wished to establish a code of surgical doctrine. ²⁴

Desault advocated an analytical surgical anatomy, in which each chapter would begin with general facts. Thus, generality was already praised in some circles of surgeons in order to organize and simplify the anatomical knowledge used in the art of surgery.

This search for generality reveals a trend in all areas of knowledge typical of the eighteenth century. While the progress of surgical knowledge, on the smallest parts of the body, attracted students to this discipline, this material could seem "full of scholarly minutiae, so dry that it discouraged young people who were to study the art of healing." ²⁵ After Desault's premature death during the French Terror, Bichat continued his lectures on surgery, and published them, ²⁶ with a synopsis for each chapter on the organization of general facts. Bichat was conscious of the necessity of assembling both general knowledge and relevant particular observations. This same approach is found in his studies on membranes, where Bichat noted that "this science lacks ... some of these general thoughts which begin the treatise of each organic system in our anatomical textbooks ..." ²⁷ Bichat's teaching perspective was clear. He stressed that "method in the sciences is the

²³ Barbara (2008a).

²⁴ "Depuis longtemps Desault formait le projet de rassembler dans un cadre régulier et méthodique toutes les découvertes dont il avait enrichi la chirurgie ; il voulait refondre son journal, en retrancher tous les faits isolés, conserver ceux dont l'ensemble pût fournir des inductions générales ; en un mot, il voulait créer un code de doctrine chirurgicale" (Bichat, 1827: xviii).

²⁵ L'anatomie est "hérissée des minuties scolastiques, [elle rebute] trop souvent par sa sécheresse les jeunes gens destinés à l'étude de l'art de guérir" (Bichat, 1827: xxv). In the preface of the *Œuvres chirurgicales* of Desault, Bichat commented on the state of the teaching of anatomy: "The teaching of anatomy was isolated at the time within boundaries that contingency had drawn and that were maintained by usage. It was on the one hand characterized an actual lack of details in descriptions, and, on the other, by a mass of superfluous and almost isolated facts. The former needed to be enlarged and the latter diminished. Anatomy ought to present, in a more methodical table, a better way to conceive all organs, and a more reliable guide to surgeons through a description of their relations, in less inaccurate terms."; "L'enseignement anatomique, alors enfermé dans des limites que le hasard avait posées & que l'habitude entretenait, offrait d'un côté une insuffisance réelle dans les détails de la description ; de l'autre, un amas superflu de faits presque isolés. Il fallait, en ajoutant aux uns, retrancher à l'autre ; présenter dans un tableau plus méthodique, un ensemble mieux conçu de nos organes, & donner sur-tout dans une histoire moins inexacte de leurs rapports, un guide plus fidèle aux chirurgiens" (Desault, 1798).

²⁶ Bichat (1827).

²⁷ Bichat (1827: 2).

link joining those who learn and those who demonstrate.... [Teaching methods] become the sharing of judgment which classifies, arranges, and coordinates this scattered and confused material.” 28 In my view, Bichat’s interest in generality may have initially been dictated by the need to teach and thereby rationalize anatomical knowledge so that it was correctly used in surgery and medicine. This trend occurred within a wider cultural context in the eighteenth century, whereby various fields of knowledge underwent similar reorganization. However, Bichat later imported this practice into research, taking other disciplines as a guide, such as philosophy, mathematics, and botany, where the question of the value of generality was under discussion.

Bichat intended to simplify anatomical knowledge with a concept of generality that would enable the building of a large framework that embraced a selection of interdependent facts. 29 This was achieved in line with a new philosophical and analytical method. He recommended relying on philosophy, the humanities, 30 physics, chemistry, and mathematics in particular, since in his view “mathematics ... educates our spirit of method and analysis.” 31 In this context, Bichat praised the geometrical spirit of Blaise Pascal (1623– 1662), which “defines all terms and proves all statements.” 32 Bichat makes use of specific criteria and principles to precisely define his categories. He also followed the anatomist Félix Vicq d’Azyr (1748– 1794), who adopted anatomical nomenclature and the use of language as an analytical method, 33 in agreement with Fontenelle’s ideas 34 on the spirit of analysis and the thoughts of Étienne Bonnot de Condillac (1714– 1780) on language. 35 Bichat appreciated these ideas, asserting:

Language influences the sciences to a certain point. Condillac says, ‘there is a true method of analysis which guides us all the more safely that it is exact.’ In the descriptive sciences, the perfection of language lies in attaching images to each term, tying memory to nomenclature, and describing many objects by means of a few words. Language ought to be ... an abridgment of science itself. 36

28 “La méthode, dans les sciences est le lien qui attache celui qui apprend à celui qui démontre.... [Les méthodes d’enseignement] deviennent le partage du jugement, qui classe, arrange, coordonne ces matériaux confusément épars” (Bichat, 1829: vii).

29 On studies devoted to membranes: “a science, subject of so numerous discourses, where what is to be removed exceeds plausibly what is to be added.”; “une science où l’on a déjà tant écrit, et où ce qui est à retrancher surpasse sans doute ce qui reste à ajouter” (Ibid., xiv).

30 “les sciences humaines” including “les belles- lettres,” “la morale,” and “la philosophie universelle.”

31 “Nous aimons les sciences mathématiques, parce qu’elles forment l’esprit de méthode et d’analyse” (Bichat, 1798: ix).

32 “définir tous les termes et à prouver toutes les propositions” (Pascal, 1985).

33 Vicq d’Azyr commented: “Since the whole of language is an analysis, how important it is, in the study of the sciences, to improve the methods thanks to which diverse parts of a whole are dissociated, examined, known, named, compared, and united! For long, only geometers know how to use these procedures: physicists, naturalists have at last learnt to use them.”; “Puisque tout le langage est une analyse, combien n’importe- t- il pas, dans l’étude des sciences, de perfectionner des méthodes à l’aide desquelles les diverses parties d’un tout sont séparées, examinées, connues, nommées, comparées et réunies ! Longtemps les seuls géomètres surent employer ces procédés utiles : les Physiciens et les naturalistes ont enfin appris à s’en servir” (Vicq d’Azyr, 1805, vol. 4: 210).

34 Fontenelle (1708, vol. I: 17– 18).

35 Condillac (1780).

36 “Le langage, dit- il, influe jusqu’à un certain point sur l’étude des sciences. ‘Il est, dit Condillac, une véritable méthode analytique, qui nous dirige d’autant plus sûrement qu’elle est plus exacte.’ Dans les sciences

Thus, the manner Bichat envisaged to express generality was closely associated with new ways of using language and analysis in many areas of science.

In addition, the eighteenth- century “spirit of analysis” also related to scientific practices, which Condillac described using the metaphor of the dressmaker able to take apart and reassemble a dress. 37 Bichat considered this spirit crucial in studies of general anatomy. Such an analysis was, in his mind, akin to that “practiced by an architect who, before building a house, attempts to know in detail the distinct materials he will have to use.” 38 Thus, Bichat’s rationality is not only expressed with language, but it also involves decomposing and reassembling parts in the body with the practical procedures of dissections, the latter being carried out with a superimposed and operation- associated descriptive terminology. In this respect, analysis allows practical anatomy and fictive anatomy, as often practiced in teaching, to be closely associated, while remaining distinct. 39

Asking whether anatomy must name all details, Bichat warned: “anatomy has two pitfalls that must be equally feared: superfluous details ... exaggerate precision on the one hand ..., too narrow a framework [which] only allows us to catch a glimpse of the whole picture that it contains ...” 40 Naming all details characterizes descriptive anatomy, in which generality is absent, whereas using only gross categories misses essential points. In Bichat’s work, a middle way was to be found at two levels, between things and words, but also among anatomy, physiology, and pathology, in line with evolutions in eighteenth- century life sciences. Concerning the second level, where a middle way was needed, the method of Bichat consisted of an analytical approach to both physiology and anatomy. Marie- Jean- Pierre Flourens (1794– 1867) distinguished between Haller’s *analyse physiologique* and Bichat’s *analyse anatomique*. Bichat’s method relied on a new analytical anatomy developed conjointly with physiology. Consequently, Bichat’s *analyse anatomique* did not limit itself to favor general forms of objects, since “differences in form may only be accessory, and the same tissue sometimes shows different states.... Main differences must therefore also be derived from the organization of properties.” 41 This principle was also justified by the de description, attacher des images à chaque terme, enchaîner, pour ainsi dire, la mémoire à la nomenclature, exprimer beaucoup d’objets par un petit nombre de termes, voilà la perfection du langage. Il faudrait, si je puis m’exprimer ainsi, que le langage fût un abrégé de la science elle- même” (Bichat, 1829: xx– xxi).

37 “[Dressmakers] will imagine how to take apart and reassemble again the dress you ask naturally. Thus, they know analysis as well as philosophers.”; “[Les couturières] imagineront naturellement de défaire & de refaire la robe que vous demandez. Elles savent donc l’analyse aussi- bien que les philosophes” (Condillac, 1780 : 23).

38 “[L’analyse] à laquelle se livre un architecte, qui, avant de construire une maison, cherche à connaître en détail tous les matériaux isolés qu’il a à employer” (Bichat, 1829: x).

39 Foucault (1966).

40 “prenons- y garde, répond Bichat, l’anatomie a deux écueils également à craindre : d’un côté les détails superflus ... une précision exagérée ... [de l’autre] un cadre trop étroit [qui] ne laisse qu’entrevoir le tableau qu’il renferme ; de même une méthode trop concise ne présente qu’à demi les objets qu’elle embrasse”(Bichat, 1829: xiii).

41 “Les différences de formes peuvent n’être qu’accessoires, et le même tissu se montre quelquefois sous plusieurs états différents.... C’est donc de l’organisation des propriétés, que les principales différences doivent se tirer” (Bichat, 1799: lxxx– lxxxi). The *analyse anatomique* criticized those who put too much emphasis on differences in structures: “anatomists, struck by differences in the structure of organs, have forgotten that their distinctive membranes could be analogous; they neglected to establish relations between them and this is an essential lacuna”; “les anatomistes, frappés de la différence de structure des organes, ont oublié que leurs

over generality of observations emerging from analyses of form alone, as Bichat's critique showed Haller had done on membranes. 42 Bichat found the scope of Haller's generalizations on membranes too large, 43 since he himself described three types of membranes, where Haller, judging on a similar appearance, had only considered one. Bichat's middle way thus relied on associating disciplines to define the right level of generality. Physiology regulated the shaping of generality in anatomy and vice versa, by correlating specific criteria from each of these fields in the definition of tissues.

In doing so, Bichat aimed at founding new objects. He considered that putting together general facts from anatomy, physiology, and pathology was a means to define real objects. In procedural terms, Bichat's general anatomy begins by abstracting from physiological and pathological observations, and then relates the abstractions obtained to abstractions of anatomical structures. For Bichat's biographer, Husson, there is "more merit in anticipating differences in the organization of anatomical parts from the diversity of diseases, than in classifying disorders by anatomical knowledge of these same parts." 44 From this perspective, Bichat did not aim to construct a new classification of disorders, but he wished to order them according to a new anatomy. His method proceeded from knowledge on both healthy and sick anatomical organs and tissues to define general and real anatomical categories, which were impossible to define with anatomy, physiology, or pathology alone.

Establishing a specific web of complex relations between normal and pathological anatomy and physiology represented Bichat's own way of finding a middle ground. This explains why Bichat advocated the unification of anatomy and physiology. This thesis became a major idea which Auguste Comte (1798– 1857) developed in his philosophy of biology. 45 Physiological properties were already central to Desault's surgical anatomy. Bichat regretted that other scientists, physicians in particular, considered these disciplines separately:

Struck by this difference between the parts of a same science, physicians had drawn between them a line of demarcation which was established and respected with time. Cadavers belonged to the domain of anatomy; physiologists were concerned with phenomena attached to life, as if the studies of the former were not inextricably linked with the researches of the latter; as if the knowledge of an effect could be separated from that of the agent that produced it.... One could wonder here which of the two, anatomy or physiology, lost more from this long separation. 46 membranes respectives pouvaient avoir de l'analogie ; ils ont négligé d'établir entre elles des rapprochements, et c'est là un vide essentiel" (Bichat, 1827: 2).

42 It is also reminiscent of Bernard's later attack of anatomical deduction of organic functions.

43 Bichat (1827: 3).

44 "il y a plus de mérite à pressentir, d'après la diversité de nos maladies, la différence dans l'organisation de nos parties, qu'il n'y a de difficulté à classer nos affections d'après la connaissance parfaite de ces mêmes parties" (Bichat, 1827: xx– xxi).

45 Comte (1830: Leçon 44).

46 "Frappés de cette différence entre les parties d'une même science, les médecins avaient tiré entre elles une ligne de démarcation que l'habitude consacra et que le temps a respectée. Les dépouilles des morts furent le domaine de l'anatomiste ; le physiologiste eut en partage les phénomènes de la vie : comme si les travaux de l'un n'étaient pas immédiatement enchaînés aux recherches de l'autre ; comme si la connaissance de l'effet

Accordingly, Bichat's anatomical generality has multiple facets, taking advantage of structures, illness, and experiments which make use of desiccations, putrefactions, macerations, boiling, cooking, treating with acids or alkali, etc. 47 Furthermore, as we have already suggested, Bichat's emphasis on generality is motivated by his conviction that such an approach will bring out real entities. He asserts:

The idea of considering thus abstractively the different simple tissues of our parts is not an imaginary conception; its basis is most real and will exert, I think, a most powerful influence on physiology, as well as on medical practices. Indeed, tissues never appear similar, whatever our point of view is. Nature delineated them, not science. 48

The search for truth by means of generality relied on assembling homologous observations to provide natural divisions among things and on defining tissues as real objects.

13.3 Classifying tissues by combining different frameworks: another eighteenth century legacy

Bichat arrived at a certain generality through the use of a multidisciplinary strategy that aimed to define biological objects from complementary analyses. He himself perceived that this was another legacy of Desault. This point appears clearly in Bichat's own description of his master's work as:

A vast framework split into secondary ones by salient lines. External form belongs to a first framework; structure to a second one; another one deals with properties; the last one is for functions: each is subdivided into several sections linked to each other without merging together and following each other without overlapping. Their union gives a general formula applicable to organs from all systems, every point being described and located, when previously omissions left empty spaces in previous descriptions, leaving to the reader following this sketch the exact knowledge to be remembered on each part. 49

pouvait se séparer de celle de l'agent qui le produit.... On pourrait se demander ici laquelle, de l'anatomie ou de la physiologie, a le plus perdu à ce long isolement" (Bichat, 1829: vi).

47 Bichat (1801: vi).

48 "L'idée de considérer ainsi abstractivement les différens tissus simples de nos parties, n'est point une conception imaginaire ; elle repose sur les fondemens les plus réels, et je crois qu'elle aura sur la physiologie comme sur la pratique médicale, une puissante influence. En effet quel que soit le point de vue sous lequel on considère ces tissus, ils ne se ressemblent nullement. C'est la nature, et non la science, qui a tiré une ligne de démarcation entre eux" (Bichat, 1801: lxxx).

49 "C'est un vaste cadre que des lignes saillantes séparent en plusieurs autres cadres secondaires. Dans l'un se range la conformation externe ; à l'autre appartient la structure ; un autre embrasse les propriétés ; le dernier est réservé aux usages : chacun se subdivise en plusieurs sections qui s'enchaînent sans se confondre et se succèdent sans empiéter sur leurs limites. De leur réunion naît une formule générale, applicable aux organes de tous les systèmes, offrant à chaque point de leur description, une place à occuper, indiquant ce qu'on omet par les vides qu'elle présente, & laissant à celui qui l'a parcouru, le tableau exact de tout ce qu'il faut apprendre sur chaque partie" (Desault, 1798: préface, 11).

Bichat claimed that the reality of tissues was grounded in the combination of such frameworks. It was his work to put Desault's ideas into practice in his definitions and classifications of tissues.

Bichat's studies led to complex classifications. His first study of membranes proposed categories of elementary tissues, which provided a partial classification of tissues. Aspects of Bichat's method also reflected new trends in eighteenth-century taxonomy. As a matter of fact, Bichat described his method as "natural":

It must be precisely determined which membranes belong to the same class.... The grouping of two membranes into a single class must rely only on the simultaneous identity of their external configuration, structure, vital properties, and functions. Only natural methods can lead us to useful results. 50

How should we understand "natural method" here? Probably the term referred to discussions in botany and in natural sciences more generally. The idea of a natural method was the object of much discussion in the second half of the eighteenth century. Methodological advances in botany were strikingly similar to those in Bichat's anatomy. In both fields, there emerged the conception that Nature was a continuous ordering of things with relative affinities, defined from similarities and differences among them, and that it could be described by a single— natural— classification. Carl von Linné (1707– 1778) suggested that elements and groups of elements should be delineated as a function of all fundamental affinities and distinctions between them. 51 Antoine Laurent de Jussieu (1748– 1836) warned that anatomical characteristics should be used and that they should be weighted according to their relative importance and contribution to the function of organs. 52 Georges Cuvier (1769– 1832) acknowledged this shift toward a more natural method and influenced in that respect the botanist Augustin Pyramus de Candolle (1778– 1841). 53 For the latter, equivalent distinctions should be made whatever main plant function was chosen. 54 For these authors, a natural method required studying various morphological and functional traits, if they were to define real categories of plant species which reflected the order of Nature. This approach is similar to that of Bichat, who also used as many characteristics as possible, both anatomical and physiological, to identify

50 "Il faut donc fixer avec précision quelles membranes appartiennent à la même classe.... Ce n'est que sur l'identité simultanée de la conformation extérieure, de la structure, des propriétés vitales et des fonctions, que doit être fondée l'attribution de deux membranes à une même classe.... ce n'est que par les méthodes naturelles que nous pouvons être conduits ici à d'utiles résultats" (Bichat, 1827: 5– 6).

51 Larson (1968: 312– 13).

52 Jussieu (1789: 5– 9).

53 Lorch (1961: 284– 5).

54 "The author of a natural method is not free to choose [characteristics]; he follows rigorous principles in the observation of all organs, and in attributing to each of them a relative importance, which does not rely on the facility to see them, but to the part that the organs play in the life of beings."; "L'auteur d'une méthode naturelle n'a pas la liberté du choix [des caractères] ; il est conduit par des principes rigoureux à observer tous les organes, et à donner à chacun une importance relative, non à la facilité que nous avons de le voir, mais au rôle que cet organe joue dans la vie des êtres" (Candolle, 1819: 52– 53); "... truly natural classes, established according to the one of the major functions of plants, are necessarily identical to those established upon another."; "... les classes vraiment naturelles, établies d'après une des grandes fonctions du végétal, sont nécessairement les mêmes que celles qui sont établies sur l'autre" (Candolle, 1819: 79).

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tissue classes. Bichat's method also relied implicitly on the equivalence of the distinctions that could be derived from anatomy, physiology, or pathology. Hence, the routes to generality that Bichat developed had affinities with the natural methods of botany. Bichat's conviction that his tissue classes represented real distinctions of Nature, 55 since they were founded on a sum of anatomical and physiological characteristics, in agreement with their function, is an echo of contemporary attitudes toward botanical systems. One may thus assume that Bichat was inspired by practices in botany when he defined his natural method. This method was thought of as natural because it was seen as the single and correct way to approach and define real categories, botanical taxa, or tissues. Like botanical and zoological taxa, Bichat's objects remained theoretical. In his *Traité des membranes*, Bichat defined three classes of simple membranes: serous, fibrous, and mucous; and three complex mixed membranes: fibro-serous, sero-mucous, and fibro-mucous. 56 In the eyes of some of his contemporaries, his method showed some weaknesses. An astute choice of the characteristics observed would have been crucial for such a comparative approach, as it had been in botany. Magendie felt that choices made by Bichat led him into "foolish views and even mistakes." 57 Nonetheless, Bichat's conception of generality had an indisputable heuristic potential that enabled him to access new objects, with a combination of physiological and anatomical facts that were later ignored when anatomists, including Geoffroy Saint-Hillaire, 58 developed analogies based on form alone. Bichat's classifications were later much criticized—because of the multiplication of the tissues he defined—but his method remained used. Other scientists followed quite parallel paths. In his *Encefalotomia nuova universale*, 59 Vincenzo Malacarne (1744–1816) had initiated a systematic, universal, and topographical study of the anatomical parts of the brain, using geometrical and geographical abstractions to highlight the stable configurations of elements. Malacarne used form, physiology, and pathology to classify fibers, membranes, and humors. This similarity of Malacarne's and Bichat's approaches can be traced back to the work of the pathologist Giovanni Battista Morgagni (1682–1771). They both finally came to consider tissues as general entities, 60 while both rejecting microscopy. 61 Malacarne's ideas can thus be perceived as another outcome of a reflection on generality, the results of which are convergent with Bichat's.

55 Bichat (1801).

56 Bichat (1801: 8).

57 "... vues hasardées et même [les] erreurs" (Bichat, 1799: viii–x).

58 See paper by S. Schmitt in this volume.

59 Cherici (2005); Malacarne (1780).

60 Cherici (2005).

61 In Bichat's days, microscopy was tricky and often led to great variety in the descriptions of minute anatomical entities. Magendie attacked Bichat's opinion that each observer could see what he himself imagined (Bichat 1799: 35, 35–36n). However, Ranvier recognized the inadequacy of microscopical instruments at that time. According to him, they could have brought only confusion to Bichat's general anatomy: "Bichat was a thousand times right when he refused to use such defective instruments"; "Bichat a eu mille fois raison de ne pas vouloir se servir d'instruments aussi imparfaits [comme les microscopes de son époque]" (Ranvier, 1880: 4). Bichat's rejection of microscopy perhaps reflects his idea that general microscopic observations could not be gathered, if one used the instruments of his time, and that a diversity of particular observations could not help anatomy.

However, Bichat's work is more explicit regarding the ways that generality is searched for, expressed, and separated from mere speculations.

In conclusion, we see that Bichat lies at an epistemological crossroad, where the convergence of several mature disciplines (anatomy, physiology, and pathology) raised a new question regarding how these distinct bodies of knowledge could be combined. Bichat wished to compare and link together general facts that had been defined in each of these disciplines. The search for generality within each of these disciplines was previously felt to be necessary for teaching and for the light it cast on the question of causation. These were ancient questions requiring generality built on the basis of sense perception and actively created with analogies. However, the comparison of several orders of generality, each perceived from within a given discipline, raised the question regarding at which level generality was to be grasped within different disciplines. A balance was to be achieved between concrete and abstract facts to establish connections between general facts from different disciplines. Within disciplines, categories were to be defined at the right level of generality, because broad categories making connections easier would not be of great interest for defining generality across disciplines. The search for such a balance can be seen in the anatomists' interest in terminology as well as in the new method that was shaped in eighteenth-century botany in order to get closer to natural classifications. In all these cases, the key issue was that of discovering reality as such, and not simply what was visible. Whereas different disciplines focus on particular aspects of reality, real objects are not readily accessible to our senses, but require different orders of analyses. Convergences between different disciplines are necessary to create a novel rationality leading to the definition of real objects.

Thus, Bichat embodies an epistemological model in the way in which he brought anatomy, physiology, and pathology closer to each other. His great emphasis on generality provided him with the means to create a new science. However, Bichat remained closer to anatomy. Therefore his work leads to the characterization of anatomy in a novel manner, with using the concept of tissue. Nevertheless, general anatomy allowed new researches in other disciplines and made possible closer connections between them.

In order to perceive the future of Bichat's epistemological approach, it is possible to draw parallels between Bichat's concept of tissue and the foundation of the neuron as a biological object in the twentieth century.⁶² The construction of the neuron from an ensemble of concepts taken from different disciplines (histology, electrophysiology, pharmacology) required the correlation of both structural and functional data. Thus, different and partial visions, deriving from multiple techniques, encouraged the convergence of incomplete descriptions of the neuron into a single biological object. Twentieth-century neuroscientists were guided by homologies between concepts of the nerve cell, led as they were by the conviction that different structural and functional techniques clarified distinct facets of a general object. Thus, we now accept that the generality of a biological object derives from homologies among general facts from various disciplines. In the eighteenth century, the generality of Bichat's tissue was also achieved by combining disciplines.

62 Barbara (2007a, 2010a).

As demarcations among tissues were shown not to rely on particular techniques, it was possible to accept that they reflected real partitions among the objects themselves. The underlying assumption was that the objects under study were all the more real when general observations made by different approaches converged, the idea being that all means of investigation are appropriate if we are to reach real objects. In this scheme, the pursuit of generality means to abstract general facts from various disciplines, in order to draw parallels and define homologies among them, and then combine them with each other so as to define the single and real objects toward which these various general facts converge. The greater the diversity of the techniques used, the higher the probability that homologies between different observations reflect the true nature of biological objects. Such ideas were original in Bichat's time and, as we shall see, became central in the nineteenth and twentieth centuries. 63

13.4 Ranvier's *anatomie générale* at the Collège de France

Louis Ranvier became the French leader in microscopic anatomy, when he was given a chair of *Anatomie générale* at the Collège de France in 1876. In the 1850s, he was trained as an anatomopathologist in Lyons and Paris, and opened a private course in microscopy when the use of microscopes was under discussion in medical faculties. 64

The anatomies of Bichat and Ranvier differ in the size of their objects of enquiry and the consequent need for microscopy. Ranvier's observations focused on subcellular elements such as the myelin sheath of nerve fibers. As in Claude Bernard's texts, "anatomical elements" were not only cells, but also cell parts— "anatomical details," to use Bernard's term—, the definite and stable structures of which could be explained in terms of local functions. Even with these differences in scale, Ranvier and Bichat conceived of generality in a similar way. However, the examination of Ranvier's studies is essential for understanding one of the meanings of generality in present-day biology, since Ranvier needed to extend generality to the microscopic world. Moreover, Ranvier's research illustrates how Bichat's wish to discover real objects was tenable at lower scales, if one merges together different technological procedures, as well as both anatomical and physiological observations.

In the first phase of the use of microscope in life sciences, the inadequacy of the instruments and the abundance of microscopic observations of living or dead materials favored passive descriptions of an infinite world of microscopic entities. In this context, one cannot perceive an interest in general facts from which theoretical explanations of the functions of organs could be derived.

Speculative approaches developed in this domain. Leibniz' ideas were influential from the perspective of defining life by general components. Their impact can be traced in the

63 See the quotation from Renault (1889) in note 86.

64 Barbara (2007b).

works of Maupertuis, Buffon, and Lamarck in France, or Oken in Germany. 65 The cellular proto- theories defined by François Duchesneau 66 were developed, in a similar context, to deduce function from analytic dissections of organs into micro- systems. A fibrillar theory took shape, in which the contractile property of muscles was explained by the fibrous and geometrical aspects of its fibers. 67 However, none of these theories relied on unquestioned observations and precisely defined general microscopic elements.

The development of cell theory was a major and initial step in defining general microscopic observations. In Germany, Matthias Schleiden (1804– 1881) and Theodore Schwann (1810– 1882) based their explanations of the development of living structures on general mechanisms involving the cell concept, and Rudolph Virchow (1821– 1902) further generalized the concept to pathology.

Microscopic anatomy rested on ideas of generality similar to those of Bichat. As a result, German histologists considered Bichat a prominent reference. Along the lines promoted by Bichat, comparison and observation were systematically used to derive general characteristics. The French histologist of the Strasbourg school, Mathias Duval (1844– 1907), described how these ideas influenced microscopy:

We must remember that, in addition to the education of the eye and the hand that lead to certifying the facts, it is even more important to observe. Any observation, like any experience, requires successive comparisons that highlight the reason of the things certified through mere contemplation. This is especially true for all microscopic observations which imply continual comparisons. 68

This recalls Bichat’s ideas on observation, which were similar to those developed later by Ranvier. 69

However, this approach was much criticized in France, where German cell theory was regarded as highly speculative in Ranvier’s time. For most French scholars, generality could not be extended to the microscopic world. They believed in a diversity of elements. In their views, this diversity paralleled that of molecules in the realm of chemistry. 70 These ideas were developed under the influence of Comte’s philosophy of biology. Such stands derived from an adoption of Bichat’s views in two respects: his rejection of microscopy, and his project to build generality from human senses alone. 71

65 Canguilhem (1952: 187).

66 Duchesneau (1987).

67 Canguilhem (1952: 185– 6).

68 “Rappelons qu’indépendamment de cette éducation de l’œil et de la main qui mène à constater le fait, il faut plus encore observer, toute observation comme toute expérience exigeant une succession de comparaisons qui donnent la raison des choses constatées par la simple contemplation. Cela est surtout vrai pour les observations microscopiques qui toutes impliquent cette comparaison d’une manière incessante” (Duval, 1878).

69 Ranvier (1863, 1865).

70 Robin often referred to the chemist Eugène Chevreul (1786– 1889); see Robin and Verdeil (1853). Charles Robin (1821– 1885) was the first professor of histology at the Faculté de Médecine de Paris. He rejected the generality of the cell, as the single anatomical unit of life, and cell theory.

71 See note 61 for Ranvier’s opinion on Bichat’s rejection of the microscope. Microscopes in Bichat’s time were not reliable instruments.

In France, Ranvier's general anatomy developed thanks to the help of Claude Bernard (1813– 1878) and the extension of experimental physiology, as separate from anatomical and anatomopathological studies. The medical milieu was hostile to Ranvier's personal project. Detractors of microscopy flourished, ⁷² and some of its prominent partisans, including the first professor of histology at the Faculté de Médecine de Paris, Charles Robin (1821– 1885), rejected what he perceived as the German style of research, characterized in his view by a preeminence given to abstraction, the search for generality, and cell theory. Claude Bernard helped Ranvier develop a cell- theory- based histology combining anatomy and physiology to search for general structures, in a small histological laboratory at the Ecole Pratique des Hautes Etudes, which was later transferred to the Collège de France (1867). Thus, generality at the microscopic level, as a natural extension of Bichat's work at a lower scale, was pursued despite the hostility of French scientists.

How did Ranvier manage to define new and real microscopic objects, which allowed him to found Anatomie générale at the Collège de France, along the same lines as Bichat? Ranvier developed a physiological form of anatomy, as Bichat had done. In addition, the relationships between Bernard and Ranvier were closer than usually thought. Ranvier trained as a physiologist and practiced vivisection with Bernard. His biographer, Justin Jolly, insisted that Ranvier should be considered a physiologist, with a special interest in anatomy. I have shown elsewhere that Ranvier's program was based on Bernard's principles as laid out in his *Leçons sur la physiologie et la pathologie du système nerveux*, ⁷³ which Ranvier attended when he was a student. ⁷⁴ Bernard urged that the study of nerve fiber sheaths, ganglion cells, tactile corpuscles, that is, all structures which he considered as "anatomical details" and which constituted "anatomical elements," should be integrated into physiological explanations of tissue functions. Bernard did not doubt that these structures were cells or cell parts. ⁷⁵ The cell concept allowed Bernard to consider the functioning of organisms as a whole built from the coordinated activity of elementary parts. ⁷⁶ With such an integrated interpretation of life, Bernard avoided turning away a narrow physicochemical determinism ⁷⁷ by adopting what he named in one of his notebooks the "true vitalism of B(ichat)." ⁷⁸ Embracing Bernard's perspective, Ranvier created, through the observation of both dead and living tissues, a new field of enquiry devoted to anatomical details, which he studied with microscopy from both an anatomical and a physiological point of view.

The articulation of anatomy and physiology in Ranvier's work, in the context of cell theory and the development of histology, led to a new disciplinary approach. Ranvier contributed to the establishment of the generality of the cell. Later, he demonstrated general subcellular structures, including regularly spaced constrictions in the nerve myelin

72 La Berge (2004).

73 Bernard (1858).

74 Barbara (2007b).

75 Schiller (1962: 65).

76 Canguilhem noted the complexity of relations between the parts and the whole in the views of Bernard.

77 Canguilhem (1968b).

78 "Le vrai vitalisme de B(ichat)" is the expression used by Bernard in one of his laboratory notebooks and

which he crossed out. Bichat was alluded to by the letter "B" (Canguilhem, 1968b: 157).

sheath of a nerve fiber (the “nodes of Ranvier”). Thus, as Bichat had done, Ranvier managed to define anatomy from a new perspective, in which closer relations to physiology were made at the microscopic scale.

While Bichat usually began his studies by delineating the spatial extent of a physiological property and localizing it in anatomical elements, Ranvier first focused on describing anatomical details that he later studied physiologically in diverse experimental conditions. For example, Ranvier examined the penetration of a dye into a nerve fiber through a node in the myelin sheath, and concluded that this structure was important to the nutrition of the nerve fiber. Physiology thus met general anatomy in the search for the function of cell parts. Anatomical generality was combined with a physiological generality created by experimental histology as envisaged by Bernard and founded by Ranvier. The combination of these approaches was facilitated by Ranvier’s method, which consisted of working on dissociated living elements, rather than on the fixed stained specimens used by most contemporary histologists. Thus, Ranvier’s generality may be considered the counterpart of Bichat’s in the field of microscopy. It contributed to the rise of physiology to the extent that physiology could then rival the status of anatomy. Scholars of the Paris science faculty and the faculty of medicine considered such an achievement impossible. It relied on great technical advances and the construction of histology as a renewed discipline both in France and Germany.

The theoretical context of Ranvier’s work was also of major importance in the foundation of microscopic histology. At the moment when his chair of general anatomy was created, during his opening lecture, Ranvier recalled how Bernard’s principles underpinned his methods of enquiry:

The goal of physiology and general pathology is to study the most intimate and most essential parts of organs, the tissue elements.... Anatomical knowledge of these organic elements is not enough. One needs to study their properties and functions by means of the most delicate experiments; in a word, experimental histology is needed. That is the ultimate goal of our research. That is the basis of future medicine. 79

Ranvier also stressed his debt to Bichat. In parallel with the way that Bichat had proceeded, Ranvier’s anatomy was intimately linked to physiology:

When a part of any one of these systems has been observed, as a histological configuration, it must be compared with the same disposition that can be recognized in other parts of the same system. Then, we must pursue the work still further to establish the generality of observed facts, comparing them with each other in the various systems of the organism. This is general anatomy, since it takes as its object not only the structure or texture of tissues (Bichat), 80 but also, and above all, their relations. When searching for a definition

79 “Le problème de la physiologie et de la pathologie générale a pour objet les parties les plus intimes et les plus essentielles des organes, les éléments des tissus ... Il ne suffit pas de connaître anatomiquement les éléments organiques, il faut étudier leurs propriétés et leurs fonctions à l’aide de l’expérimentation la plus délicate ; il faut faire en un mot, l’histologie expérimentale. Tel est le but suprême de nos recherches, telle est la base de la médecine future.” Ranvier’s quotation of Claude Bernard (Ranvier, 1880: 1). This is the text from Ranvier’s opening lecture to his course at the Collège de France (Ranvier, 1876: 1).

80 Added by the author.

of this science, I already confessed that general anatomy could be viewed as comparative anatomy restricted to a single organism. It represents the science dealing with the plan of organization par excellence. 81

Of prime importance was the role played by cell theory. Other schools of general anatomy, apart from that of Ranvier, flourished at the time. However, most of those in France rejected cell theory. 82 Duval reports Robin’s opinion: “According to him, general anatomy is a part of anatomy. Its name indicates both its object and aim. Its aim is to determine

the intimate and real nature of things, whose activity and movement is called life.” 83 This statement illustrates that general anatomy could be used as a tool to classify most structures, whether or not cell theory was used as a framework for morphological comparisons and analogies. Ranvier accepted cell theory as propagated by the teaching of Bernard and used it to suggest experiments, provide hypotheses, and coordinate results. 84 While Robin’s ideas also certainly played similar roles, cell theory demonstrated greater utility in providing links between anatomy and the physiology of histological elements. This is why we can consider that Ranvier’s work extended to the microscopic scale the methodological generality proposed by Bichat, in which the combination of multiple techniques validated the reality of objects.

The French histologist Joseph Louis Renault (1844– 1917) expressed a similar idea from the perspective of the techniques used:

If a fact were real, all technical methods applied to the same object will concur to prove its existence: each showing one or several details not revealed by others. If, on the contrary, the fact that one believed one had observed is not real, any method other than that which created the illusion will not allow the illusion to persist, and the mistake will no longer occur as would be the case if one contented oneself of a single method of observation for the object to be analyzed. 85

Renault referred to this approach as the “principle of converging methods.” 86

81 “Lorsque nous avons observé un département de quelqu’un de ces systèmes, une disposition histologique, il importe de le comparer avec celle que l’on peut reconnaître dans d’autres départements du même système. Il convient ensuite d’aller plus loin encore et d’établir la généralité des faits observés en les comparant entre eux dans les divers systèmes de l’organisme. C’est en cela que consiste l’anatomie générale, puisqu’elle a pour objet non seulement la structure et la texture des tissus, mais encore et surtout leurs rapports. En cherchant la définition de cette science, je vous ai déjà dit que l’anatomie générale pouvait être considérée comme l’anatomie comparée limitée à un seul organisme. C’est, par excellence, la science qui s’occupe du plan de l’organisation” (Ranvier, 1880 : 10).

82 Robin’s introduction (Cadiat, 1871: 111).

83 “L’anatomie générale est, selon lui, une partie de l’anatomie dont le nom indique à la fois l’objet et le but. Ce dernier est la détermination de la nature intime et réelle des choses dont l’activité, le mouvement, s’appelle la vie” (Duval, 1886).

84 Ranvier (1880: 14).

85 “Si le fait est bien réel, toutes les méthodes techniques appliquées à un objet concourront à mettre son existence hors de conteste : chacune indiquant un ou plusieurs détails laissés dans l’ombre par les autres. Si au contraire le fait qu’on avait cru observer n’est pas réel, toute autre méthode que celle qui avait engendré l’illusion ne laissera plus subsister cette dernière, et l’erreur ne pourra plus être commise comme il arriverait si l’on se contentait, pour l’objet à analyser, d’une seule et unique méthode d’examen” (Renaut, 1889– 99: ix).

86 “L’importance du principe des méthodes convergentes” (Renaut, 1889– 99: ix).

Ranvier's school of general anatomy was clearly a successful multidisciplinary effort. Even so, the histology Ranvier practiced had moved closer to physiology than that of Bichat. Accordingly, Ranvier did not share Bichat's and Bernard's doubts about anatomical deductions of physiological functions and their insistence on its indispensable cooperation with physiology. Bichat and Bernard thought that approaches other than purely structural observations were needed to understand function. Bichat had attacked Haller on an over-reliance on visual analysis of membranes. In a similar line, Bernard argued that cell types in the pancreas with similar morphologies had distinct functions. However, in his dispute with Haller, Bichat in fact deviated from his conception of anatomy and physiology as two facets of an underlying and single reality. 87

This paradox was resolved by Ranvier, leading him to advocate in a new manner for the principle of anatomical deduction. Ranvier claimed that combining morphological and physiological evidence to define an object helped to lead to an understanding of its function. For example, the anatomical demonstration of a few muscular fibers in an organ would always indicate a local contractile function, since the intimate role of muscle fibers is to contract surrounding tissues. Therefore, Ranvier associated observations of muscle fibers with their contractile function. His anatomo-physiological correlations considered anatomy and physiology as equivalent. This was the key condition for deducing local functioning from structures and vice versa. Ranvier's confident correlations between anatomical and physiological properties were an important feature of his general anatomy. Cell types, and not tissues, became the new general categories of anatomy. And generality became possible at this smaller scale, because cell types shared common organizations in different organs. Later, in the 1890s, neurons were defined and found not only in the brain, but in the spinal cord and nervous ganglia. Thus, while Bichat gave a method for building generality and discovering possibly real objects in the realm of the common senses, Ranvier's studies showed how anatomy and physiology could converge to define cell types and their functions in all organs at a microscopic level.

Anatomy and physiology have continued an intimate association with the emergence of recent disciplines such as cellular physiology or cellular and molecular biology. The ascension of experimental physiology and belief in determinism have been crucial. Modern biology has added statistics to deal with the essential variability of complex biological systems. 88 Moreover, experimental reductionism has also improved our understanding of the determinism of such systems, 89 and made the search for general facts easier, with experiments tending to give more stable results. Similarly, the search for anatomical generality became dependent on modern histological techniques, which included complex processes of dissociation, slicing, or staining to objectivize properties of the objects under study. The methodological convergence formulated by Renault, at play when two staining procedures reveal a similar object, 90 applies more generally to all recent biotechnologies in the definition of new objects. In Ranvier's time, microscopic biological objects were

87 Béclard (1827).

88 Hacking (1983).

89 Rheinberger (1997).

90 For example, methylene blue was shown to stain neurons similarly to the Golgi method.

not created by means of single theoretical concepts, but they emerged rather from closely compatible scientific practices and the coalescence of different modes of objectivization linked to specific experimental systems. 91

13.5 Conclusion

This chapter has focused on generality through the studies of two French schools of anatomy, at the beginning and at the end of the nineteenth century. Let me now formulate my main conclusions and discuss them in a broader framework, including my current ideas on the concept of scientific object. 92

Bichat's work cannot be solely analyzed as resulting from a simple shift in ways of creating knowledge at the turn of the nineteenth century. Some aspects of his method are representative of the early eighteenth century, while others already belonged to the nineteenth century and formed the basis of many of Auguste Comte's ideas on biology. 93 In particular, the concept of generality in Bichat's work embodies more than an eighteenth-century principle in the ordering of things, depending on their specific aspects and distinguishing levels of generality. It is true, however, that such a principle, rooted in botany, was fundamental to him and in keeping with the spirit of analysis and eighteenth-century paradigms for teaching in anatomy and many other fields. 94 Bichat's method is consistent with such a perspective, as is evidenced by his references to mathematics, philosophy, and humanities. His method rested on the belief in a general order of things on the basis of which real objects could be discovered and defined.

What else characterizes Bichat's method? We agree with Foucault's rejection of the idea that progress in eighteenth-century natural history depended only on a novel use of analysis to provide order and enable discovery. 95 Alternatively, natural history, as well as Bichat's anatomy, can be considered as also depending on new practical procedures, while for them philosophy and mathematics represented simply parallel paradigmatic methods used as metaphors in defining new goals.

There is however one essential difference between natural history and Bichat's anatomy. In natural history, objects are conceived of as natural and concrete, whether they are rocks, animals, or plants. Classification and analysis represent the means for ordering them. In contrast, Bichat created his objects as categories, through an observation of structures and

91 The birth of the neuron in the twentieth century represents one such field of investigation (Barbara, 2007a, 2010a, 2010b).

92 Cf. the concept of scientific object developed in Barbara (2007a, 2010a).

93 Comte (1830: Leçons 40–5). Comte considered as outdated some of Bichat's ideas, such as his opposition between life and death, rooted in eighteenth-century philosophy. However, Comte shared many of Bichat's ideas, such as the need to combine anatomy, physiology and pathology.

94 Cooking, for example. See note 1.

95 “La constitution de l'histoire naturelle, ... il ne faut pas y voir l'expérience forçant ... l'accès d'une

connaissance qui guettait ailleurs la vérité de la nature ; ... l'histoire naturelle, c'est l'espace ouvert dans la représentation par une analyse qui anticipe sur la possibilité de nommer.... L'instauration à l'âge classique d'une science naturelle n'est pas l'effet direct ou indirect du transfert d'une rationalité formée ailleurs (à propos de la géométrie ou de la mécanique). Elle est une formation distincte” (Foucault, 1966: 142).

their variation in different physiological and pathological contexts. These observations were used as partial representations of the objects to be defined. So, unlike natural history, Bichat's anatomical classification was concerned with ordering general properties to define tissue categories as concepts, rather than as concrete objects of nature.

As a matter of fact, Bichat's objects were not visible. For example, where Haller saw one type of membranes, Bichat defined three, which were not readily discernible with the naked eye. In the *Birth of the clinic*,⁹⁶ Foucault described changes in the relations between the visible and the invisible at the end of eighteenth century. He suggested that invisible objects were progressively clarified via the emergence of a novel, clear, and objective language. Foucault interpreted Bichat's work by stressing his advances in deciphering the body, according to a two-dimensional order and based on similarities between surfaces.⁹⁷ He examined how a new and unitary discourse could emerge to represent and classify both organs and their diseases. Foucault insisted that Bichat's work was established at the level of visible things. Consequently, Bichat's quest for invisible aspects of things was only partially clarified by Foucault's analyses. For instance, these analyses did not place emphasis on Bichat's method as an integrated system of practices engaged in the search for invisible objects. Bichat's classifications were not analyzed with the intention of showing how they created invisible objects. These questions are nonetheless at the heart of Bichat's concept of generality, and are crucial for understanding how eighteenth-century scientific analyses of visible things moved toward an acknowledgment of invisible objects by specific practices and the definition of objects as new concepts.

With Ranvier, multiple factors such as cell theory, Bernard's physiology, the rise of experimental histology, and especially exploration at microscopic scales all changed the ways scientific objects were studied. The objects created by Bichat from physiological, anatomical, and pathological observations remained essentially anatomical. In contrast, Ranvier used anatomy to construct objects that could be studied from a physiological perspective. Placing himself at the level of cell parts allowed him to localize unitary properties to subcellular parts. His descriptions at the sub-cellular level permitted correlations between their structure and function. Such microscopic studies were possible, because all living organizational levels possess general structures.

Closer to our time, the constitution of the neuron in the twentieth century can be seen as a later multidisciplinary coalescence of distinctive generalities from physics, chemistry, pharmacology, electrophysiology, histology, histochemistry, biophysics, and immunohistology: a coalescence which constituted a common and general scientific object.⁹⁸ In this case, a form of generality was reached by means of the convergence in the ways objects were described within particular experimental set ups. When different scientific communities realized their objects of inquiry (partially artificially created to make them suitable to experimental work, such as a "synaptic potential" or an isolated synaptic vesicle) were homologous, measures and concepts could merge in a single description.

96 Foucault (1975).

97 Foucault (1975: 130).

98 Barbara (2007a, 2010a, 2010b).

This shift to the present permits us to conclude with two remarks on the article in which Richard Burian and coworkers consider generality in biology. 99 We agree with them that epistemology and philosophy need local studies and must escape from the search for absolute, general views. We hope that our examination of eighteenth- and nineteenth- century anatomies has shown the utility of studies on specific schools to clarify how generality was valued, built, and what it meant. Such interpretations seem likely to lead to novel, if local, conclusions whose generality can then be examined. We suggest that our analyses of generality, in the works of Bichat and Ranvier, provide new and general insights into the relations between general observations and the creation of biological objects. Furthermore, Burian et al. (1996) discussed how the gene was constructed as a scientific concept, from different, and sometimes complex, structural and functional representations, originating in diverse disciplines. This leads to our second remark which expresses our difference with these authors with respect to general biological findings. They argued that a general understanding of the gene was hindered by the multiplicity of its representations. I would suggest instead that the essence of the biological object is a single representation highlighting and taking into account the complexity of partial representations attached to particular concrete objects, to the moment when all the bodies of knowledge, developed in different contexts, can be unified. Perhaps the gene is not yet a single concept, and, in a similar way, categories of biological objects may share the complexity of the gene. However, we are learning how to describe, model, and manipulate different related objects at any required level of generality, according to our specific needs and, in a dialectic process, these objects may appear as a single representation. This is what the history of the neuron shows. In this case, all the representations of the neuron converged when polemics died out. The search for generality is thus characterized by an unremitting attempt to assemble and manipulate what appear to be distinct objects, rather than by a passive process looking for homologies between possibly heterogeneous observations. Convergence of knowledge is the way to the essence of biological objects. The passive and archaic form of generality is almost useless for biology at the present time and it can be easily criticized. As a tool to manipulate objects however, we would argue that the active search for generality has become a route to creation, which is distinct from paths by which real objects were formerly sought for. Such a route is characterized by processes whereby distinct objects are built and then coordinated into single objects. 100 This new path involves a plurality of object phenomenologies which evolve, merge, or sometimes disappear as science progresses.

Acknowledgments

The author wishes to thank Dr. Richard Miles, Chantal Barbara, and the editors for advice and careful reading of the manuscript.

99 Burian et al. (1996).

100 Barbara (2008b).

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