Biological generality:

General anatomy from Xavier Bichat to Louis Ranvier

Jean-Gaël Barbara
CNRS UMR7102, Université Curie
CNRS UMR7596, Université Diderot

Abstract

Recent epistemological reflection on natural laws and biological theories raises the question of the status of generality in biological sciences. Local historical studies are proposed to understand why and how generality came to be of prime importance and how generality was built and expressed? Such questions are relevant to the works of French anatomists, Xavier Bichat and Louis Ranvier. Our approach sheds light on the ways generality was valued. In both cases, the concept was at the heart of a new disciplinary approach and represented a means of expressing general observations and object categories. Bichat and Ranvier did not consider a single discipline, but anatomy and physiology. Bichat founded the study of tissues, merging together their anatomical descriptions and physiological properties, while Ranvier's microscopic anatomical elements were studied with experimental physiology. In both of these authors, a multiple generality was put forward to build new and supposedly real biological objects.

"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].

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 generalizations[3] exist in biology. Consequently, Richard Burian et al. have argued that the philosophy of science should study how biological knowledge developed locally. They advocate a descriptive epistemological approach[4] within precisely defined historical and geographical contexts. Even so, we may ask why and how generality was occasionally seen to possess great importance. In accords with this view, such studies are more likely to bring answers, if they focus on specific historical milieus. 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 eighteenth-century, a middle way in the art of dealing with details and general facts in accords with the spirit of analysis (Bourbon, 1741). All translations by the author.
[2] I. Hacking. April 25th 2006 Lecture at the *Collège de France*.
[3] (Burian, Richardson and Van der Steen, 1996).
[4] (ibid., 25).

The French discipline, *anatomie générale*, was founded in 1800 by Xavier Bichat (1771-1802). It was taken as a model over Europe, shortly after his death, for the study of medicine, human anatomy and pathology. Bichat's anatomy was later developed in the 1870s, in the French context of microscopy, by Louis Ranvier (1835-1922) at the *Collège de France*. In the context of contemporary debates in science studies stressing local epistemic cultures and denying general biological laws, studying Bichat's and Ranvier's interests in generality as a scientific category renews discussions on the role of generality in the Life sciences.

The concern of Bichat for generality was not a simple consequence of his vitalism, since he 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 was based on the observation of more or less strict experimental regularities in biological phenomena and observations of structures, an attitude we will try to explain. Bichat's work is of interest to understand why the concept of generality gained favor in the Life Sciences at the start of the nineteenth-century, and its present status in experimental biology.

The later career of Louis Ranvier, who held the first chair of *Anatomie générale* in France, will inform us on the ways generality was searched for at the microscopic level and its value in the discovery of real and minute biological objects. With Ranvier, we will get closer in 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 to discover new microscopic objects, and we will concentrate in particular on the role of cellular theory and Claude Bernard's experimental physiology.

I will analyze 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 required collecting general facts - common traits encountered in multiple observations, thought as being part of a same ensemble, defined by a criterion -, and using them to define objects. The studies 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 works aimed to correlate anatomical and physiological common facts and to search for criteria which did not rely alone on either one of them. Consequently, their method could define biological objects and categories by spatially overlapping anatomical and physiological traits.

Bichat's *anatomie générale*

Xavier Bichat is usually considered the founder of General Anatomy. This young surgeon had a private course of anatomy and edited, after the death of his master Pierre Joseph Desault (1744-1795), his master's course in surgery. Bichat died prematurely at age 31, after publishing two anatomical books, *Traité des membranes*[5] and the *Anatomie Générale*[6], which had a profound impact 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 tissues, namely histology, now relies on subtle microscopic observations and selective staining procedures, not available in Bichat's time. Rather, Bichat made use of physiology and pathology to make distinctions between tissues anatomically similar.

Bichat's method can be most easily understood with the example of the first type of tissue of 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 is 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, where membranes were in continuity. Accordingly, a first ensemble lies 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 membrane is apparent when, during a cold, inflammation of the mucous membrane spreads from nose to throat, or *vice-versa*, possibly to sinus or bronchi. In case of stomach acid reflux, inflammation can invade the esophagus to

[5] (Bichat, 1799).
[6] (Bichat, 1801).
[7] (Bichat, 1799, art. II).

larynx and ears. This example shows how *a priori* criteria are used to define tissues, and how tissue categories are defined *a posteriori* referring not only to anatomical, but 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 unique mucous tissue[8]. The novelty of this approach relied in 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, to define single 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 point was the expression of the general and the particular in a new physiological perspective, following the work of Haller, in correlation with anatomy and pathology. This required a diversity of practical procedures, experimental physiology performed on animals, human dissections of healthy and diseased bodies, inspection of sick persons, which Bichat used with talent in a unique perspective. In all these studies, Bichat was to focus on general facts in order to compare each of them to others obtained with different procedures from other disciplines. This explains why the concept of generality was central to his approach.

I will now analyze Bichat's work in a historical perspective to draw the contexts in which he came to study anatomy, surgery and medicine in this new way. Before coming to Bichat's time, some preliminary remarks can be made on generality as a category to compare knowledge from different disciplines before him. In the history of biology, generality is often associated with explanation and causality. The central goal of Bichat was not only a new description the human anatomy. He wished to understand the function of each type of tissues, and the causes of pathological lesions for medical practice. However, such relations between generality and causation are part of rationality as it appeared in Ancient Greek physics and medicine. In his *Physics*, Aristotle claimed to look for general causes within general facts, and particular causes in the particular[10]. The study of general facts was considered a path to discover the general causes at stake.

In the domains of eighteenth and nineteenth-centuries 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]. In nineteenth-century, Rudolf Virchow expressed a similar opinion when asserting new general anatomical observations developed prior to any physiological discovery[12]. General anatomical categories were thus frequently organized in order to explain function[13], except Claude Bernard's experimental physiology built against such principle[14]. Georges Canguilhem (1904-1995) commented on the approach of Galen in *De usu partium*: "Anatomy describes organs, physiology explains their functions. How can physiological rules be deduced from anatomical relations? In fact, any form of physiology relied more or less on a discourse on the utility and use of parts of animals."[15] Therefore, before Claude Bernard, physiology was empirical and often experimental. On a theoretical level, it only provided a mere discussion of general anatomical facts to explain the functions of organs. Haller referred to *Anatomia animata*. However, although generality was central in discussions

[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, 244-247).
[10] Aristote. Phys. Livre II, part. 3.
[11] (Debru, 1996, 28).
[12] (Virchow, 1861).
[13] (Hall, 1968).
[14] Bernard advocated functions should be discovered by experimental physiology alone, without prior reference to structures. Accordingly, physiology was independent from anatomy.
[15] 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).

between anatomy and physiology, the relations between these fields were teleological, polarized from anatomy to physiology, and never relying systematically on experimental physiology or pathology.

In the eighteenth-century, physiologists not only sought to explain function in terms of general structures anymore, but began to propose physiological principles - vitalist or mechanist – to account for life. The vitalist approach defined functional and unexplained properties. For example, irritability was defined as the property of muscle to contract, without questioning it. Haller avoided any specification 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 under study. Experimental physiology established these concepts as unquestioned properties mapped onto organs throughout the body. These researches invented generality of physiological facts and subsumed them in broad categories of vital properties, which Bichat adopted.

Such physiological studies did not try to explain vital properties in terms of underlying anatomical structures and mechanisms, but, rather, aimed to understand how they contributed to specific functions. However, they were not made without any reference to anatomy. What then was the interest of general anatomical facts in such approach?

Bichat answered this question in a specific way. He was among the leader anatomists adopting Haller's style of physiological research. His personal interest was to make correlations between general physiological properties Haller described, with general anatomical descriptions, in order to define tissues as overlapping categories between those of anatomy and physiology. Since inflammation of the mucous membranes of urethra never occurred after a cold, it belonged to another tissue category than that of the membrane of respiratory and digestive tracks. Therefore, correlating anatomical, physiological and pathological properties was used to define categories of tissues. All such observations converged on precise surfaces of the body to define a tissue by a single and general object. Bichat considered tissues as anatomical entities "carrying"[16] specific properties. His goal was on 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 object with different textures, colors or taste. Bichat directed all possible confrontations between classical anatomy and medicine relying on the senses and new experimental physiology. He wished to arbitrate between structure and function, to find out a middle way to define tissues. Locating physiological and pathological properties on anatomical maps let them be localized onto particular territories, defined as tissues. With the adoption of Hallerian physiology, Bichat 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.

I shall now examine the historical contexts in which Bichat founded his research on tissues. Bichat's approach is both original and representative of anatomy in the second half of eighteenth-century. His quest for generality is apparent in the identification of general anatomical entities and their spatial correlations with physiological properties in creating new objects. The history of this approach has been studied by Othmar Keele[17], who discovered the concept of tissue was first described by students from John Hunter's school of surgery (1728-1793), 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]. This represents Bichat's method which he used systematically.

However, general anatomy came to be associated with Bichat alone by most authors, including British scientists, since his personal search for generality was his dominant style of research requiring an ensemble of specific practices to define the topography of physiological and pathological properties, and their spatial correlations with anatomical observations. 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 in concert, were a means to avoid the limitations of anatomy alone, in defining real biological objects.

[16] Bichat's term.
[17] (Keel. 1979, 1982)
[18] According to Flourens, the term *tissue* was taken by Bichat from Bordeu (Flourens, 1858, 235).

Bichat's starting point was anatomy studied by the senses. He inspected hundreds of cadavers and believed 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 glance is fleeting, the second confused and the third is often indistinct. Senses can teach us better than books."[19] For Bichat, general facts emerge from repeated observations which most strike the mind and represent their common denominator.

Bichat emphasized the primary importance of the senses in observation, advising to "present phenomena, without connecting them together"; "[Bichat added] this is most often what we ought to."[20] But Bichat seemed to contradict this claim. François Magendie (1783-1855) replied to 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 the specific approach of Magendie is opposed to extract general facts from observations, Bichat used "connections" and "analogies"[22] freely to express generality. Thus building and deriving general facts relied on a psychological procedure, whereas another level of generality was actively reached, in a rational manner, by connections and analogies.

Thus, we came across two modes of creating generality in Bichat's method, (1) one based on spatial correlations between anatomical boundaries and the extension of pathophysiological properties leading 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 first since the properties under consideration and their associations are general and consequently occur in different areas of the body; (2) a second mode of creating generality is present in each of these orders – 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; it has an educational virtue for teaching.

All these processes of building generality require comparisons of abstractions derived by focusing on similarities and differences. Bichat's way of observing is in accords with the later practices of nineteenth-century anatomists, as described by Ranvier or Mathias Duval (1844-1907). The search for similarities belongs to the domain of the senses, a domain of unconscious perception, upon which generality emerges. It also belongs to the domain of the rational construction of analogies. While the first mode is closely linked with observation and scientific practices, the latter is more concerned with specific rationalities.

Were these methods specific to Bichat, or were there such antecedent principles in other scientific circles? Bichat's principles seem to oppose the traditional anatomical teaching he received from his father physician, 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, and criticized. He therefore developed a pragmatic aspiration, common to many surgeons of his time, to rationalize anatomical knowledge compiled over past centuries[23]. Desault's biographer, noted how "[he] wished to collect in a regular and methodical framework all discoveries he added to surgery; he wanted to transform his journal, remove isolated facts, keeping only those which allowed general inductions; in a word, he wished to establish a code of surgical doctrines."[24]. Desault advocated an analytical surgical

[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).

[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." ibid., pp. 116-117.

[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." (ibid., 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 his work is defective because of the necessity he [Bichat] claimed for connections between similar facts, 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).

[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

anatomy, with each chapters beginning with general facts. Thus, generality was already praised in the circles of surgeons to simplify anatomical knowledge devoted to the art of surgery.

This search for the appropriate level of generality reveals a typical problem in all areas of knowledge in 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 and discouraging to young people attracted to 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 to each chapter on the organization of general facts. Bichat was conscious of the necessity to assemble both general knowledge and relevant particular observations. This same approach is found in his studies on membranes, where Bichat noted "this science lacks ... some of these general thoughts which begin the treatise of each organic system in our anatomical textbooks ..."[27] The teaching perspective of Bichat was clear. He mentioned "method in the sciences is the link joining those who learn and those who demonstrate .... [Teaching methods] become the act of judgment which classifies, arranges and coordinates this scattered and confused material."[28] I may propose that Bichat's interest for generality initially lied in the art of teaching and rationalizing anatomical knowledge for its proper use in surgery and medicine, in a wide cultural context where various fields of eighteenth-century knowledge were under similar reorganization. However, Bichat extended this view to research taking other disciplines as a guide, philosophy, mathematics and botany, where the question of the right level of generality was under discussion.

Bichat wished to simplify anatomical knowledge with a concept of generality enabling to build a large framework embracing a selection of dependent facts[29]. This was achieved in the line of a new philosophical and practical analytical method in the context of Enlightenment. He recommended relying on philosophy, humanities, and mathematics in particular, since he said "mathematics ... educates our spirit of method and analysis ."[30] Bichat praised the geometrical spirit of Blaise Pascal (1623-1662), which "defines all terms and proves all statements"[31]. Bichat's metaphoric expressions point to his use of criteria and principles in building new 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[32], in agreement with Fontenelle's ideas[33] on the spirit of analysis outside mathematics and the thoughts of Étienne Bonnot de Condillac (1714-1780) on language[34]. Bichat appreciated these ideas, writing "language influences the

---

ceux dont l'ensemble put fournir des inductions générales ; en un mot, il voulait créer un code de doctrines chirurgicales." (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.", (ibid., 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 by contingent lines maintained by usage. It was on the one hand characterized by insufficient details in descriptions, and, on the other, by a bundle of superfluous and almost isolated facts. First ones were to be added and latter ones removed. Anatomy ought to present a more methodical table, a better way to conceive all organs, and a more reliable guide to surgeons devoted to the investigation of their relations, described 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 presqu'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] (ibid.)

[27] (ibid., 2).

[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] (Bichat, 1798, ix).

[31] "définir tous les termes et à prouver toutes les propositions" (Pascal, 1985).

[32] Vicq d'Azyr commented: "Since all language is analysis, how important it is to improve the methods in the study of the sciences thanks to which diverse parts of a whole are dissociated, examined, known, named, compared and united! For long, these procedures were only limited to geometry: physicists, naturalists have finally 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).

[33] (Fontenelle, 1708, vol. I., 17-18).

[34] (Condillac, 1780).

sciences to a certain point. Condillac says "there is a true method of analysis which conducts more safely when it is exact. .... In the descriptive sciences, the perfection of language lies in attaching images to each term, linking memory to nomenclature, and describing many objects in few words. Language ought to be ... a short guide to science itself."[35] Thus, the manner Bichat envisaged to express generality was closely associated with the new ways of using language and analysis in many areas of science.

However, the eighteenth-century "spirit of analysis" also concerned scientific practices, which Condillac described with the metaphor of the dressmaker able to take apart and reassemble a dress[36]. Bichat considered this spirit crucial in studies of general anatomy akin to "that practiced by an architect wondering what materials he should use before building a house."[37] Thus, Bichat's rationality is not only expressed with language, but involves decomposing and reassembling body parts with practical procedures of dissections, with a superimposed and operating associated descriptive terminology. In this respect, analysis allows practical anatomy and fictive anatomy, as often practiced in teaching, to be closely associated, while remaining dis tinct[38].

Following this spirit of analysis required a search for a middle way between two extremes, as described by Pascal and Bichat. For Pascal, geometrical order implies "not to define or demonstrate everything, neither define nor demonstrate nothing, but to be in the middle ....[39] Asking whether anatomy must name all details, Bichat similarly warned "anatomy has two pitfalls that must be equally feared: superfluous details ... exaggerate precision on the one hand ..., a narrow framework not fully describing its correlative knowledge ..."[40] Naming all details concerns descriptive anatomy where generality is absent, whereas using only gross categories misses essential points. This perception of generality as a middle way seemed common in the eighteenth-century[41]. In Bichat's work, a middle way was to be found at two levels, between things and words, but also between anatomy, physiology and pathology, in the lines of the evolution of eighteenth-century Life sciences.

Concerning the second level, where a middle-way was needed, the method of Bichat required an analytical approach of both physiology and anatomy. Marie-Jean-Pierre Flourens (1794-1867) distinguished the *analyse physiologique* of Haller, and Bichat's *analyse anatomique*. Bichat's method relied on a new analytical anatomy developed in concert with physiology. Consequently, Bichat's *analyse anatomique* did not only 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."[42] This principle was also justified by the over-generality of observations emerging from analyses of form alone in Bichat's critique of Haller on membranes[43]. Bichat found the scope of Haller's generalizations on membranes too large[44], since Bichat described three types, whereas Haller had only considered one, as judged by their similar appearance. Bichat's middle

[35] "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 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).

[36] "[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 sçavent donc l'analyse aussi-bien que les philosophes" (Condillac, 1780, 23).

[37] "[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).

[38] (Foucault, 1966).

[39] "non pas à tout définir ou à tout démontrer, ni aussi à ne rien définir ou à ne rien démontrer, mais à se tenir dans ce milieu" (Pascal, 1657).

[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] See note 1.

[42] "les différences de formes peuvent n'être qu'accessoires, et le même tissu se montre quelquefois sous plusieurs états différens. .... C'est donc de l'organisation des propriétés, que les principales différences doivent se tirer." (Bichat, 1799, lxxx-lxxxi). The *analyse antomique* 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 consider relations between them and this is an essential void"; "les anatomistes, frappés de la différence de structure des organes, ont oublié que leurs 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).

[43] It is also reminiscent of Bernard's later attack of anatomical deduction of organic functions.

[44] (Bichat, 1827, 3).

way thus relied on associating disciplines to define the right level of generality. Physiology regulated the creation 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. Putting together general facts from anatomy, physiology and pathology was considered a means to define real objects. In procedural terms, general anatomy of Bichat begins by abstracting physiological and pathological observations, and then relating them to abstractions of structures. For Bichat's biographer, Husson, there is "more merit to anticipate differences in the organization of anatomical parts from the diversity of diseases, than to classify disorders by anatomical knowledge of these same parts."[45] Thus, Bichat did not aim to construct a new classification of disorders, but he wished to order them according to a new anatomy. Rather his method proceeded from knowledge on both healthy and sick anatomical organs and tissues to define general and real anatomical categories, impossible to define either with anatomy, physiology or pathology alone.

Complex relations between normal and pathological anatomy and physiology represented Bichat's own way for a middle ground. This explains why Bichat advocated the unification of anatomy and physiology which will become a major idea developed in Auguste Comte's (1798-1857) philosophy of biology[46]. Physiological properties were already central to Desault's surgical anatomy and Bichat regretted that other scientists, physicians in particular, considered these disciplines separately: "Struck by this difference between the parts of a science, physicians had placed between them a line of demarcation which was established and respected with time. Cadavers belonged to the domain of anatomy; physiologists were concerned with living phenomena: as if the studies of the former were not inextricably linked with the second domain; as if the study of an action could be separated from that of the agent that produced it.... One could ask here whether anatomy or physiology lost more from this long separation."[47]

Accordingly, Bichat's anatomical generality is multiple, taking advantage of structures, illness and experiments which make use of desiccations, putrefactions, macerations, boiling, cooking, treating with acids or alkali, etc.[48] Furthermore, Bichat's generality aims for truth, since "the idea of abstracting the different simple tissues of our parts is not imaginary; its basis is most real and will exert, I think, a most powerful influence on physiology, as on medical practices. Indeed, tissues never appear similar, whatever our point of view is. Nature delineated them, not science."[49] The search for truth using generality relied on assembling homologous observations to provide natural divisions among things and defining tissues as real objects.

Hence, Bichat arrived at generality using a multidisciplinary strategy to define biological objects from complementary analyses. This was another legacy of Desault, since Bichat described 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; another deals with properties; the last is for functions: each is subdivided into sections intertwined without merging together and following each other without overlapping. Their union gives a general formula applicable to organs from all systems ...."[50] Bichat

---

[45] "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." (ibid, xx-xxi).

[46] (Comte, 1830, Leçon 44).

[47] "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 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).

[48] (Bichat, 1801, vi).

[49] "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." (ibid., lxxx.

[50] "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 union naît une formule générale, applicable aux organes de tous les systèmes, offrant à chaque point de leur description 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).

claimed 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 simple categories and partial tissue classifications. Aspects of Bichat's method reflect 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 .... Their grouping into a single class must only rely on the identity of their external configuration, structure, vital properties and functions. Natural methods only can lead us to useful results."[51]

How should we understand "natural" here? Probably the term referred to discussions in botany. The idea of a natural method was refined in the second half of eighteenth-century. Methodological advances in botany were strikingly similar to those of Bichat's anatomy. Both fields conceived of Nature as a continuous ordering of things with relative affinities, defined from similarities and differences between them, and described by a unique classification. Car 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[52]. Antoine Laurent de Jussieu warned more anatomical characteristics should be used, weighted according to their relative importance and contribution to the function of organs[53]. Georges Cuvier (1769-1832) acknowledged this shift towards a more natural method and influenced the botanist Augustin Pyramus de Candolle (1778-1841)[54] who claimed equivalent distinctions should be made whatever main plant function was chosen[55]. In these authors, a natural method required to study various morphological and functional traits, if they were to define real categories of plant species reflecting the order of Nature. Bichat also used as many characteristics as possible, anatomical and physiological to separate tissue classes. His method also relied implicitly on the equivalence of the distinctions made with fundamental divisions derived from anatomy, physiology or pathology. Hence, the routes to generality Bichat developed had affinities with the natural methods of botany. As for botanical systems, Bichat's tissue classes were believed to represent real distinctions of Nature[56], founded on a sum of anatomical and physiological characteristics, in accord with their function. Therefore, Bichat followed progresses in botany when he defined his natural method. This method was thought as natural because it was seen as the unique and correct way to approach and define real categories, botanical taxa or tissues.

Similarly to 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[57]. Even at this stage, his method showed some weaknesses. An astute choice of the characteristics observed was crucial to this comparative approach[58], as it had been in botany. Magendie felt that choices made by Bichat led him into "foolish views and even mistakes"[59]. Nonetheless, Bichat's conception of generality contained an indisputable heuristic in accessing new objects, later ignored when anatomists, including Geoffroy Saint-

---

51 "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).

52 (Larson, 1968, 312-313).

53 (Jussieu, 1789, 5-9).

54 (Lorch, 1961, 284-285).

55 "The author of a natural method does not choose [characteristics] ; he follows rigorous principles in the observation of all organs, and in attributing to each of them a distinctive importance, which does not rely on the facility to see them, but to the rôle they 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 in accord with the major functions of plants, are necessarily identical to those established upon others."; "... 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.", (ibid., 79).

56 (Bichat, 1801)

57 (ibid., 8).

58 "Comparative anatomy, which can be equally named general anatomy, encompasses all organised bodies ; it studies by comparison what they share as common or general, and how they differ from each others."; "L'anatomie comparative, qui serait aussi bien nommée anatomie générale, embrasse dans son domaine tous les corps organisés ; elle a pour objet de rechercher, par la comparaison, ce qu'ils ont de commun ou de général et en quoi ils diffèrent les uns des autres." (Béclard, 1827, 1).

59 "... vues hasardées et même [les] erreurs" (Bichat, 1799, viii-x).

Hillaire [60], regressed to 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.

Other scientists followed quite parallel paths. In his *Encefalotomia nuova universale*[61] Vicenzo Malacarne (1744-1816) had initiated a systematic, universal and topographical study of anatomical parts 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 in the approaches of Malacarne and Bichat can be traced back to the work of the pathologist Giovanni Battista Morgagni (1682-1771). They both finally came to consider tissue as general entities[62], while both rejecting microscopy[63]. Malacarne's ideas thus represent another reflection on generality which converged with Bichat. However, Bichat's work is more explicit on the ways generality is searched for, expressed and separated from mere speculations.

I conclude Bichat lies at an epistemological crossroads where the convergence of several mature disciplines (anatomy, physiology and pathology) raised a new question: how this knowledge may be combined? Bichat wished to define and link together general facts from each of them. The search for generality within disciplines was previously thought as necessary in teaching and in the establishment of disciplinary rationalities, where the principle of causation stands. These were ancient questions where generality was both built by sense perception and actively created with analogies. However, the comparison of several orders of generality raised the question to what extent generality was to be expressed within disciplines. Similarly to mathematics, a balance was to be achieved between concrete and abstract facts to establish connections between general facts. 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 to define a new order of generality. The search for such balance can be seen in the anatomists' interest in terminology and the new path eighteen-century botany created in getting closer to natural classifications.

In all cases lies the question of discovering reality, not simply conceived of as visible. If disciplines define particular visible aspects of reality, real objects are not readily accessible to our senses, but require different orders of analyses. These convergences are necessary to create a novel rationality leading to the definition of real objects.

Thus, Bichat gave us an epistemological model of bringing closer together anatomy, physiology and pathology, putting great emphasis on generality, as a means to create a new science. However, Bichat remained closer to anatomy. Therefore his work leads to characterize anatomy in a novel manner, with the use of the concept of tissue. Nevertheless, general anatomy allowed new researches in other disciplines and made possible closer connections between them.

In order to assess the future of Bichat's 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[64]. 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, derived 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, believing 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 between general facts from various disciplines. In the eighteenth-century, the generality of Bichat's tissue was also achieved by combining disciplines. As demarcations between tissues were shown not to rely on particular techniques, it was possible to accept

[60] See paper by S. Schmitt in this volume.
[61] (Cherici, 2005; Malacarne, 1780).
[62] (Cherici, 2005).
[63] In Bichat's days, microscopy was tricky and often led to a great variety in the descriptions of minute anatomical entities. Magendie attacked Bichat's opinion that each observer could see what he imagined. (Bichat, 1799, 35, 35-36n). However, Ranvier recognized the inadequacy of microscopical insruments of these times which, according to him, could have brought confusion only 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 refusal of microscopy perhaps reflects his idea that general microscopic observations could not be gathered with the instruments of his time, and that a diversity of particular observations could not help anatomy.
[64] (Barbara, 2007a).

that they reflected real partitions between the objects themselves. The underlying assumption was that the reality of objects grew when general observations made by different approaches converged, with the idea that all means of investigation are appropriate to reach real objects. In this scheme, generality is a way to abstract general facts from various disciplines, in order to draw parallels and define homologies, and combine them altogether to define unique and real objects. The greater the diversity of 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 nineteenth and twentieth-century[65].

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 Lyon and Paris, and opened a private course of microscopy, when the use of microscopes was under discussion in medical faculties[66].

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 cell parts, "anatomical details", using Bernard's term, which definite and stable structures 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 to understand the meaning of generality in current biology, since Ranvier needed to extend generality to the microscopic world. Also, Ranvier's studies show how Bichat's wish to discover real objects was tenable at lower scales, merging together different technological procedures, and both anatomical and physiological observations.

The inadequacy of microscopes, the interest of amateurs and the abundance of initial microscopic observations of any living or dead matters, first favored passive descriptions of an infinite world of microscopic entities. It was thus difficult to build general facts from which theoretical explanations of the functions of organs could be derived.

Speculative approaches filled in this gap. Leibniz' ideas were influential in the perspective of defining life by general components. They can be traced in the works of Maupertuis, Buffon and Lamarck in France, or Oken in Germany[67]. The cellular proto-theories defined by François Duchesneau[68] were developed, in a similar context, to deduce function from analytic dissections of organs into micro-systems. A fibrillar theory was developed with the contractile property of muscles explained by the fibrous and geometrical aspects of its fibers[69]. 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. In his lines, comparison and observation were systematically used to derive general characteristics. The French histologist of the Strasbourg school, Mathias Duval, described how such ideas influenced microscopy: "We must remember the primary importance of repeated observation, coupled to the education of the eye and the hand, in the deduction of facts. Any observation, like any experience, requires successive comparisons and reflection to understand the nature of the observation."[70] This recalls Bichat's ideas on observation, similar to those developed later by Ranvier[71].

---

[65] See the quotation by Renaut (note 87).
[66] (Barbara, 2007b).
[67] (Canguilhem, 1952, 187).
[68] (Duchesneau, 1987).
[69] (Canguilhem, 1952, 185-186).
[70] "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

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[72]. These ideas were developed in the context of Comte's philosophy of biology. They relied on Bichat's rejection of microscopy, and his project to build generality from human senses alone[73].

In France, Ranvier's general anatomy could never have developed without the help of Claude Bernard (1813-1878) and the extension of experimental physiology, aside from anatomical and anatomopathological studies. The medical milieu was hostile to Ranvier's personal project. Detractors of microscopy flourished[74], and some of its prominent partisans, including the first professor of histology at the *Faculté de Médecine de Paris*, Charles Robin (1821-1885), rejected the German style of research favoring abstraction, the search for generality and cell theory.

Claude Bernard helped Ranvier to 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*, and later transferred to the *Collège de France* (1867). Thus, the establishment of generality at the microscopic level, as a natural extension of Bichat's work at a lower scale, was not favored by prominent French institutions and represented a prominent epistemological obstacle.

How Ranvier came to define new and real microscopic objects in the lines of Bichat, which allowed him to found *Anatomie générale* at the *Collège de France*? Ranvier developed a physiological form of anatomy, as had Bichat. Relations 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 Ranvier's program was based on Bernard's laid out in his *Leçons sur la physiologie et la pathologie du système nerveux*[75], which Ranvier attended when he was a student[76]. Bernard urged that the study of nerve fiber sheaths, ganglion cells, tactile corpuscles, all structures he considered as “anatomical details", and constituting “anatomical elements", should be integrated in physiological explanations of tissue functions. Bernard did not doubt that these structures were cells or cell parts[77]. The cell concept let him consider the functioning of organisms as a whole built from the coordinated activity of elementary parts[78]. By distancing life from a strictly physicochemical determinism[79], Bernard avoided opposition to the "true vitalism of B(ichat)"[80]. In Bernard's perspective, Ranvier could create a new field of enquiry devoted to anatomical details, studied with microscopy from both an anatomical and a physiological point of view, by the observation of both dead and living tissues.

The meeting 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 demonstration of the generality of the cell. Later, he demonstrated general subcellular structures, including regularly spaced constrictions in the nerve myelin sheath of a nerve fiber (nodes of Ranvier). Thus, Ranvier managed to define anatomy in a new perspective, as did Bichat, where closer relations to physiology were made at 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

---

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).

71 (Ranvier, 1863, 1865).

72 Robin often referred to the chemist Eugène Chevreul (1786-1889); (Robin &Verdeil, 1853).

73 See note 64 for Ranvier's opinion on Bichat's rejection of the microscope. Microscopes in Bichat's time were not reliable instruments.

74 (La Berge, 2004).

75 (Bernard, 1858).

76 (Barbara, 2007b).

77 (Schiller, 1962, 65).

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

79 (Canguilhem, 1968b).

80 "le vrai vitalisme de B(ichat)" is the expression used by Bernard in his laboratory notebook and which he crossed out. Letter "B" referred to Bichat. (ibid., 157).

search for the function of cell parts. Anatomical generality was combined with physiological generality born from experimental histology described by Bernard and founded by Ranvier. The combination of these approaches was facilitated by the work of Ranvier on dissociated living elements, rather than on 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, and contributed to the rise of physiology to rival the status of the field of anatomy. This achievement was thought as impossible among scholars of the Paris science faculty and the faculty of medicine. 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 creation of his chair of general anatomy, 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 parts is not enough, the study of their properties and functions requires most delicate experiment; in a word, experimental histology is needed. This is the ultimate goal of our research."[81] Ranvier also stressed his debt to Bichat. As with Bichat, his anatomy was intimately linked to physiology: "When a category of systems is observed, as a histological configuration, it must be compared with other categories of the same system. Then, we must pursue the work still further to establish the generality of observed facts, comparing them together in all systems of the organism. This is general anatomy, since it aims not only at the structure or texture of tissues (Bichat)[82], but most of all to their relations. When searching for a definition of this science, I already confessed that it could be viewed as comparative anatomy restricted to a single organism. It represents the science dealing with the plan of organization *par excellence*."[83]

Of prime importance was the role played by cell theory. Other schools of general anatomy, apart from that of Ranvier, flourished at the time, and most in France rejected cell theory[84]. Duval reports Robin's opinion: "general anatomy is a part of anatomy. Its name indicates both its object and aim. The intimate and real nature of parts, which activity and movement is called life, must be established."[85] 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[86]. While Robin's ideas also certainly played these roles, cell theory demonstrated greater utility in providing links between anatomy and the physiology of histological elements. Thus the work of Ranvier extended at microscopic scales the methodological generality proposed by Bichat, in which the combination of multiple techniques validated the reality of objects.

The French histologist Joseph Louis Renaut (1844-1917) expressed a similar idea in a technical perspective: “If a fact were true, all technical methods applied to the same object would prove its existence: each showing one or several details not revealed by others. If, on the contrary, the observed fact is unreal, any method other than that which created the illusion would show a different result, and no

[81] "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).

[82] added by the author.

[83] "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).

[84] Robin's introduction (Cadiat, 1871, 111).

[85] "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).

[86] (Ranvier, 1880, 14).

mistake would be made as when a single means is used to analyse the object."[87] Renaut described this approach as the "principle of converging methods". [88]

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 doubting of anatomical deductions in the face of the rising discipline of 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. In this dispute, Bichat deviated from his conception of anatomy and physiology as two facets of an underlying and single reality[89].

This paradox was resolved by Ranvier, leading him to his advocacy of the principle of anatomical deduction. Ranvier claimed that combining morphological and physiological evidence defining an object aided in understanding its function. For example, the anatomical demonstration of even a few muscular fibers in an organ would always indicate a 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 to deduce local functioning from structures and *vice versa*. Ranvier's confident correlations of 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 share common organizations in different organs. Later, in the 1890s, neurons will be defined and found not only in the brain, but in the spinal chord and nervous ganglia. Thus, while Bichat gave a method to build generality and discover possibly real objects in the realm of common senses, Ranvier's studies showed how anatomy and physiology could converge to define cell types and their functions.

Anatomy and physiology have continued an intimate association with the emergence of such recent disciplines including cellular physiology or cellular and molecular biology. The ascension of experimental physiology and determinism has been crucial. Modern biology has added statistics to deal with the variability inevitable to complex biological systems[90], and experimental reductionism has also improved mastering the determinism of such systems[91], and made the search for general facts easier, with experiments tending to give more stable results. Thus, generality began to concern the properties of living matter in specific experimental contexts. Similarly, anatomical generality became dependent on modern histological techniques including complex processes of dissociation, slicing or staining to objectivize the subjects studied. The methodological convergence of Renaut, seen when two staining procedures reveal a similar object[92], apply more generally to all recent biotechnologies in the definition of new objects. In Ranvier's time, microscopic biological objects were not created from single theoretical concepts, but rather emerged from closely compatible scientific practices and the coalescence of different modes of objectivization linked to specific deterministic experimental systems[93].

Conclusion

[87] "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, 1889-1899, ix).

[88] "L'importance du principe des méthodes convergentes", ibid.

[89] (Béclard, 1827).

[90] (Hacking, 1983).

[91] (Rheinberger, 1997).

[92] For example, methylene blue was shown to stain neurons similarly to the Golgi method.

[93] The birth of the neuron in the twentieth-century represents one such field of investigation (Barbara, 2007a).

I have focused on generality through the studies of two French schools of anatomy, at the beginning and at the end of the nineteenth-century. I now describe my main conclusions and discuss them in a broader framework, including my current ideas on the concept of scientific object[94].

The work of Bichat cannot be solely analyzed in the context of a single shift in ways of creating knowledge at the cusp between two centuries. Some aspects of his method are representative of the early eighteenth-century, while others belonging already to the nineteenth-century form the basis of many of Auguste Comte's ideas on biology[95].

Thus the concept of generality in Bichat's work embodies more than a vague eighteenth-century principle in the ordering of things, depending on their particular aspects and levels of generality. Nevertheless, 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[96]. The method of Bichat is consistent with such perspective, as shown with his references to mathematics, philosophy and humanities. It rested on the belief in a general order of things from which real objects could be discovered and defined.

What else delineates 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 permit discovery[97]. Alternatively, Natural History, as well as Bichat's anatomy, can be considered to rely on new practical procedures, while philosophy and mathematics were simply parallel paradigmatic methods used as metaphors in defining new practical goals.

There is however one essential difference between Natural History and the anatomy of Bichat. In Natural History, objects are conceived of as natural and concrete, as rocks, animals and plants. Classification and analysis represent means to order them. On the contrary, Bichat created his objects as categories, observing structures and 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 rather concerned with ordering general properties to define tissue categories, as concepts, rather than concrete objects of nature.

Certainly, Bichat's objects were not visible. For example, when Haller saw one type of membranes, Bichat defined three, which were not readily discernible with naked eyes. In the *Birth of the clinic*[98], 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 the work of Bichat by stressing his advances in deciphering the body, according to a two-dimensional order and based on similarities between surfaces[99]. 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 which did not consider Bichat's method as an integrated system of practices engaged in the search for invisible objects. In particular, the meaning of Bichat's classifications was unquestioned and could not be linked to the invisible objects Bichat described. These questions are nonetheless at the heart of Bichat's concept of generality, and are crucial to understand how eighteenth-century scientific analyses of visible things moved towards an acknowledgement of invisible objects by specific practices and the definition of objects as new concepts.

With Ranvier, multiple factors - cell theory, Bernard's physiology, the rise of experimental histology, and especially the descent to the microscopic scale - all changed the way 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

94 We refer here to the concept of scientific object developed in Barbara, 2007a.

95 (Comte, 1830, Leçons 40-45). Comte referred to Bichat's old eighteenth-century philosophy in his classical opposition between life and death, but shared many of his ideas, for example, on the need to combine anatomy, physiology and pathology.

96 Cooking for example. See note 1.

97 "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).

98 (Foucault, 1875).

99 (ibid., 130).

studied in a physiological perspective. 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.

In recent times, the constitution of the neuron in twentieth-century can be seen as a later multi-disciplinary coalescence of distinctive generalities from physics, chemistry, pharmacology, electrophysiology, histology, histochemistry, biophysics and immunohistology to constitute a common and general object[100]. In this case, generality was reached by 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) were similar, measures and concepts could merge in a single description.

This shift to the present permits us to conclude with two remarks on the article in which Richard Burian et al. consider generality in biology[101]. We agree that epistemology and philosophy need local studies and must escape from the search for absolute, general views. We feel our examination of eighteenth and nineteenth-centuries 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 insights into relations between general observations and the creation of biological objects in general.

Furthermore, Burian et al. 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 concerning our difference with these authors on 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 objects, considered as a single representation, requires taking this complexity into account so that all knowledge 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 scientific objects at any required level of generality, according to our specific needs, which may eventually merge. Combining these objects together seems possible in the light of the history of the neuron, where all its representations converged, when polemics died out. The search for generality is thus becoming a way to assemble and manipulate objects, rather than a passive process looking for homologies between possibly heterogeneous observations. This latter passive and archaic form of generality is almost useless for biology now and it can be attacked easily. As a tool to manipulate objects however, we would argue that the active use of generality has become a route to creation, distinct from paths by which real objects were formerly searched for, a route where objects are built and coordinated into single objects[102]. This new path involves a plurality of object phenomenologies which evolve, merge or sometimes disappear as science progresses.

Acknowledgement: The author wishes to thank Dr. Richard Miles for advice and careful reading of the manuscript.

Bibliography

Barbara J. G. (2007a) *La Constitution d'un objet biologique au XX^{e} siècle. Enquête épistémologique et historique des modes d'objectivation du neurone*. Ph.D. Dissertation, Paris: Université Diderot.

Barbara J. G. (2007b) 'Louis Ranvier (1835-1922): the contribution of microscopy to physiology, and the renewal of French general anatomy', *Journal of the History of the Neurosciences*, 16: 413-31.

Barbara J. G. (2008a) 'Diversité et évolution des pratiques chirurgicales, anatomiques et physiologiques du cerveau au XVIII^{e} siècle', in *Querelles du cerveau à l'âge classique*, eds. Céline Cherici and Jean-Claude Dupont. Paris: Vuibert, forthcoming.

100 (Barbara, 2007a).
101 (Burian, Richardson and Van der Steen, 1996).
102 (Barbara, 2008b).

Barbara (2008b) 'L'étude du vivant chez Georges Canguilhem : des concepts aux objets biologiques', in *Philosophie et médecine. Hommage à Georges Canguilhem* »», eds. Anne Fagot-Largeault, Claude Debru and Michel Morange, Paris: Vrin, forthcoming.

Béclard P. A. (1827) *Elemens d'anatomie générale*. Paris: Béchet.

Bernard C. (1858) *Leçons sur la physiologie et la pathologie du système nerveux*. Paris: Baillière.

Bichat X. (1798) *Mémoire de la société médicale d'émulation*. Paris: Maradan.

Bichat X. (1799) *Traité des membranes en général et de diverses membranes en particulier*. Paris: Richard, Caillé et Ravier.

Bichat X. (1801) *Anatomie générale appliquée à la physiologie et à la médecine*. Paris: Brosson, Gabon et Cie.

Bichat X. ([1799], 1827) *Traité des membranes en général et de diverses membranes en particulier*. Paris: Méquignon-Marvis.

Bichat X. (1829) *Anatomie descriptive*. Paris: Gabon.

Bourbon (de), L.-A. ([1741], 1999) *Le Cuisinier Gascon*. Paris: Loubatières.

Burian R. M., Richardson R.C., Van der Steen W.J. (1996) 'Against generality: meaning in genetics and philosophy', *Stud Hist Phil Sci*, 27: 1-29.

Cadiat L. O. (1871) *Anatomie générale*. Paris: Delahaye et Cie.

Candolle (de) A. P. (1819) *Théorie élémentaire de la botanique*. Paris: Déterville.

Canguilhem G. (1952) 'Note sur les rapports de la théorie cellulaire et de la philosophie de Leibniz' in *La Connaissance de la Vie*. Paris: Vrin.

Canguilhem G. (1968a) 'La constitution de la physiologie comme science', in *Etudes d'histoire et de philosophie des sciences*. Paris: Vrin.

Canguilhem G. (1968b) 'Claude Bernard et Bichat', in *Etudes d'Histoire et de Philosophie des Sciences*, Paris: Vrin.

Cherici C. (2005) *L'anatomophysiologie du cerveau et du cervelet chez Vincenzo Malacarne (1744-1816). L'ébauche d'une médecine de l'intellect*. Ph.D. Dissertation, Paris: Université Diderot.

Comte A. (1830) *Cours de Philosophie Positive*. Paris: Rouen frères.

Condillac, (de) E. B. (1780) *La logique, ou Les premiers développements de l'art de penser*. Paris: L'Esprit et de Bure l'aîné.

Debru A. (1996) *Le corps respirant : la pensée physiologique chez Galien*. Leiden, New York: Brill.

Desault P. J. (1798) *Œuvres chirurgicales de P.J. Desault*. Paris: Desault.

Duchesneau F. (1987) *Genèse de la théorie cellulaire*. Paris: Vrin.

Duval M. (1878) *Précis de technique microscopique et histologique*. Paris: Baillière.

Duval M. (1886) 'L'anatomie générale et son histoire', *Revue scientifique*, 1rst sem., 107-12.

Hall T.S. (1968) 'On biological analogs of Newtonian paradigms', *Philosophy of science*, 35:6-27.

Flourens P. (1858) *De la Vie et de l'Intelligence*. Paris: Garnier frères.

Fontenelle B. (1708) *De l'utilité des mathématiques et de la physique*. Paris: Boudot.

Foucault M. (1966) *Les Mots et les Choses*. Paris: Gallimard.

Foucault M. (1975) *The Birth of the Clinic: An Archaeology of Medical Perception*. Translated by A. M. Sheridan Smith. New York: Vintage Books.

Hacking I. (1983) 'Nineteenth Century Cracks in the Concept of Determinism', *Journal of the History of Ideas*, 44: 455-75.

Jussieu (de) A. L. (1798) *Genera plantarum secundum ordines naturales disposita* ... Paris: Viduam Herissant and Theophilum Barrois.

Keel O. (1979) *La généalogie de l'histhopathologie*. Paris: Vrin.

Keel O. (1982) 'Les conditions de la décomposition "analytique" de l'organisme : Haller, Hunter, Bichat', *Les Etudes philosophiques*, 1: 37-62.

La Berge A. (2004) 'Debate as Scientific Practice in nineteenth-Century Paris: The Controversy over the microscope', *Perspectives on Science: Historical, Philosophical, Social*, 12: 424-53.

Larson J. L. (1968) 'Linnaeus and the natural method', *Isis*, 58,304- 20.

Lorch J. (1961) 'The natural system in biology', *Philosophy of science*, 28: 282-95.

Malacarne V. (1780) *Encefalotomia nuova universale*. Turin: Briolo.

Ranvier L. (1863) 'De quelques modes de préparation du tissus osseux', *Journal de Physiologie de l'Homme et des Animaux*, 6: 549-53.

Ranvier L. (1865) *Considérations sur le développement du tissu osseux et sur les lésions élémentaires des cartilages et des os*. Paris: Inaugural Ph.D. Dissertation.

Ranvier L. (1876) *Leçon d'ouverture du cours d'anatomie générale*. Paris: Duval.

Ranvier L. (1880) *Leçons d'anatomie générale sur le système musculaire*. Paris: Savy.

Renaut J. (1889) *Traité d'histologie pratique*. Paris: Rueff et cie.

Rheinberger H. J. (1997) 'Experimental Complexity in Biology: Some Epistemological and Historical Remarks', *Philosophy of Science*, 64: supplement, S245-4.

Robin C. and Verdeil F. (1853) *Traité de chimie anatomique et physiologique normale et pathologique ou des principes immédiats normaux et morbides qui constituent le corps de l'homme et des mammifères*. Paris: Baillière.

Schiller J. (1962) 'Claude Benard and the cell', *The physiologist*, 4: 62-8.

Pascal B. ([1657], 1985) *De l'esprit géométrique*. Paris: Flammarion.

Vicq d'Azyr F. (1805) *Œuvres complètes*. Paris: Duprat Duverger.

Virchow R. (1861) *La pathologie cellulaire basée sur l'étude physiologique et pathologique des tissus*. Paris: Baillière.