ALESSANDRO MINELLI

BIOLOGY AND ITS DISCIPLINARY PARTITIONS – INTELLECTUAL AND ACADEMIC CONSTRAINTS

ABSTRACT: ***BIOLOGY AND ITS DISCIPLINARY PARTITIONS – INTELLECTUAL AND ACADEMIC CONSTRAINTS***
A productive confrontation between biology and philosophy should be based on a serious effort to recover a comprehensive vision of the living world as the subject of a unitary science. Key steps in the emergence of biology as the science of all living beings in the first half of the XIX century are outlined. Academic constraints and personal agendas shaping emergence and fate of individual biological disciplines are examined, with examples from developmental and evolutionary biology. Disciplinary divisions within the life sciences can be seriously limiting for the philosopher of science, much less so for the scientist, although many concepts of foundational importance for different biological disciplines are nomadic concepts that take on the most diverse meanings according to the contexts in which they are used. It is suggested to try a reversal between disciplines and key concepts, turning the latter into anchors for a potentially nomadic set of disciplines.
KEYWORDS: *history of biology; disciplinary structure of science; nomadic concepts; anchor concepts.*

1. *Introduction*

In a well-documented and incisive article entitled *Inclusion and exclusion in the history of developmental biology*, Nick Hopwood[1] demonstrates how the articulation of a science in specialties impinges on decisions on what are the important problems and how these must be addressed. This conditioning has a social dimension, as the division of a science into specialized disciplines affects

[1] N. Hopwood, *Inclusion and exclusion in the history of developmental biology*, in «Development» 146, 2019, dev175448.

very strongly the identity of a scientific community and, consequently, the strategies of academic affirmation, the criteria for the allocation of funds, and the organization of undergraduate degree programs; see also Pauly and Maienschein[2].

As soon as we become aware of the issue, however, action becomes possible. To use Hopwood's words, «Disciplines are made, not found»[3]. Quite a few disciplines, indeed, are simply defined on the basis of inclusion or exclusion criteria. This is more frequent in the case of ancient disciplines and those of applied nature, e.g. in the domains of medicine and agriculture. Nothing to blame, from an operational point of view, if individual researchers or institutions (including scientific societies and their journals) address sets of biological phenomena that have in common only the fact of dealing with the diseases of humans or domestic animals (human or veterinary pathology), or with crop plants, or aquatic animals relevant to fisheries. A very different thing, however, is to consider these disciplines as areas suitable for the development of general concepts, or theories, with regard to the living.

In the course of time, new disciplines emerge, generally characterized by a distinct set of problems or by a common technique, but often energetically pursuing less scientific targets such as the personal affirmation of a scholar or the creation of a new lobby aiming at success in the competition for funding and academic positions[4]. This must be seriously addressed, if we want to identify an organization of the biological disciplines able to stimulate and support a conceptual refreshment of biology and, still more, of philosophy of biology.

[2] P.J. Pauly, *The appearance of academic biology in late nineteenth-century America*, in «J. Hist. Biol.», 17, 1984, pp. 369–397; J. Maienschein, *Shifting assumptions in American biology: Embryology, 1890–1910*, in «J. Hist. Biol.», 14, 1988, pp. 89–113.

[3] N. Hopwood, *op. cit.*, p. 1.

[4] Sapp J. *The struggle for authority in the field of heredity, 1900-1932: New perspectives on the rise of genetics*, in «J. Hist. Biol.» 16, 1983, pp. 311–342; P.J. Pauly, *op. cit.*; N. Hopwood, *op. cit.*

Too little attention has been brought so far to the new perspectives that show up every time the boundaries between two or more disciplines are questioned or newly determined, often facilitating in this way the emergence of new questions, new research directions, and in any case helping refreshing notions and terms, including general and fundamental ones, which interest the philosopher no less than the biologist, such as individual, generation, development, reproduction, evolution.

Admittedly, for the individual researcher it is difficult to avoid privileging the biological discipline on which he or she has spent a life. Even a scholar of the stature of Ernst Mayr, one of the most prestigious figures in evolutionary biology of the last century, insisted that there could not be a biology as unitary science before the acceptance of an evolutionary vision of the living[5] – a questionable statement that downplays at least the importance of the cellular theory, so formulated by Schwann (1839) ca. 20 years before the *Origin* (1859)[6]:

> it may be asserted, *that there is one universal principle of development for the elementary parts of organisms, however different, and that this principle is the formation of cells*. […] The development of the proposition, that there exists one general principle for the formation of all organic productions, and that this principle is the formation of cells, as well as the conclusions which may be drawn from this proposition, may be comprised under the term cell-theory[7].

The insistence on the role of evolutionary theory as a unifying principle of biology also overshadows another great merit of Charles Darwin, who developed his works, including the *Origin*, on a documentary basis without taxonomic restrictions. Two hundred

[5] E. Mayr, *The Growth of Biological Thought. Diversity, Evolution and Inheritance*, Belknap Press of Harvard University Press, Cambridge, MA. 1982; Id., *This is Biology. The Science of the Living World*, Belknap Press of Harvard University Press, Cambridge, MA 1997.
[6] Ch. Darwin, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life*, John Murray, London 1859.
[7] Th. Schwann, *Mikroskopische Untersuchungen über die Uebereinstimmung in der Struktur und dem Wachsthum der Thiere und Pflanzen*, Sander'sche Buchhandlung (G.E. Reimer), Berlin 1839; Id., *Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants*, Engl. transl. by H. Smith, Seydenham Society, London 1847; the quote is from the English edition, pp. 165-166, italics as in the original.

years after the sciences of life were fist unified under the name of biology, such a taxonomically universal perspective is one of the targets we must strive to revive. This will be the subject of Section 3.

Before that, let's briefly examine the burden the social architecture of science exerts on the biological disciplines, in determining, fixing or changing their boundaries without respect for the challenges this imposes on the freedom to articulate questions and to organize knowledge.

2. *Biological Disciplines in Academia*

An innovative or catchy book title may help fixing attention on an emerging science. To some extent, this happened with Treviranus' *Biologie*: up to 1830 at least, most mentions of this word in the academic literature (not only in the German-speaking countries, but also in France) pointed to this book as its source – irrespective of the citing author's actual interpretation of the term, or his willingness to recognize a science of the living in the modern sense of the term. Much more recently, the titles of two successful books[8] helped popularize the idea of a science of biodiversity; in more focused way, the title of Hall's book[9] was immediately adopted as the name of the emerging field of evolutionary developmental biology.

Changes in the titles of academic journals often reflect a new disciplinary focus privileged by the scientific community. This happened e.g. with the Austrian journal established in 1851 as *Oesterreichisches botanisches Wochenblatt*, soon renamed in 1854, with a marginal change, *Österreichische botanische Zeitschrift*, which is published since 1974 as *Plant Systematics and Evolution*:

[8] E. O. Wilson (ed.), *Biodiversity*. National Academy Press, Washington, D.C. 1988; M.L. Reaka-Kudla, D.E. Wilson and E.O. Wilson (eds.), *Biodiversity II: Understanding and Protecting Our Biological Resources*, Joseph Henry Press, Washington, D.C. 1997.

[9] B.K. Hall, *Evolutionary Developmental Biology*, Chapman & Hall, London 1992.

in addition to its obvious internationalization (it is not "Austrian" anymore), the journal specializes now in one broad disciplinary sector within the plant sciences and "botany", the old name of the science covering all aspects of the study of plants, has been dropped. The names of two old disciplines were similarly dropped off when the *Journal of Embryology and Experimental Morphology*, whose first issue was published in 1953, was renamed *Development* in 1987.

Of different nature is the replacement in 1966 by *Journal of Cell Science* for the title of the *Quarterly Journal of Microscopical Science*, published since 1853. In this case, the old title pointed to a circumscription based on a powerful technique (before long, anyway, itself a diversified set of techniques) while the new title points to one level (the cell) of the traditional hierarchy of biological entities. Parallel change affected a German magazine published between 1865 and 1923 as *Archiv für mikroskopische Anatomie*, a name abandoned in 1924 in favor of a new title *Zeitschrift für Zellen- und Gewebelehre*, mentioning objects (cells and tissues) rather than a technique as defining the journal's scope. This title, however, was replaced soon (1925) by *Zeitschrift für Zellforschung und mikroskopische Anatomie*, thus mentioning again microscopy, but in adjectival form, coupled to the name of one of the old biological (better, biomedical) disciplines, i.e. anatomy. Since 1974 the journal resumed, in the English language and in modernized style, exclusive reference to the study of cells and tissues (*Cell & Tissue Research*).

Even more complex, and more informative about the evolution of the involved disciplines, including personal academic agendas, social habits as much as about radical changes in research focus and tools, is the history of the journal first published in 1894/5 as *Archiv für Entwickelungsmechanik der Organismen* (subtitle: *Organ für die gesamte kausale Morphologie*). The two technical terms (*Entwickelungsmechanik*, or mechanics of development, and *kausale*

Morphologie, i.e. causal morphology) characterized the personal approach to the study of development introduced by Wilhelm Roux, the journal's founder. Between 1923 and 1925 this journal was replaced by the hybrid *Archiv für mikroskopische Anatomie und Entwicklungsmechanik* issued by its fusion with the *Archiv für mikroskopische Anatomie*. This did not last long: in 1925, Roux's journal resumed independent publication under its old name to which, however, was added the name of the founder, deceased in September 1924. In 1975, the journal, while moving to a title in English that stressed its international character with the definitive adoption of the current language of science, was renamed *Wilhelm Roux's Archives of Developmental Biology*. This way, it adopted the new name of the discipline, developmental biology, which was already the full title of another journal, *Developmental Biology*, established in 1960. For several years, *Wilhelm Roux's Archives* were subtitled *The official organ of the EDBO*, this being the acronym of the European Developmental Biology Organization. Between 1985 and 1996 the journal was published under the somehow streamlined title *Roux's Archives of Developmental Biology*, eventually changed in 1996 to *Development Genes and Evolution*. The latter change was not a simple cosmetic adjustment to the language of the new times, but expressed two important conceptual innovations: while acknowledging the centrality of genetics in the science of development, the journal was the first to register in its name the emergence of a new disciplinary interface.

For EDBO, a kind of federation of societies focusing on developmental biology established in 1978[10], it was convenient to associate itself with a long existing journal and to provide support to the latter's change of name. In other cases, scientific societies were intentionally founded with the aim to publish a

[10] N. Skreb and J. McKenzie, *The early days of European Developmental Biology Organisation (E.D.B.O.)*, in «Anat. Anz.», 150, 1981, pp. 443-448.

leading journal in a new or emerging field. In the field of evolutionary biology, this happened first in America with the Society for the Study of Evolution (1946) and its journal *Evolution* (1947)[11], later in Europe, with the European Society for Evolutionary Biology (1987) and its *Journal of Evolutionary Biology* (1988)[12].

In the case of a more recently recognized discipline, evolutionary developmental biology, international societies (the European Society for Evolutionary Developmental Biology, founded in 2006, and the Pan-American Society for Evolutionary Developmental Biology, founded in 2015) were only established when the first specialized journals focusing on the same discipline were already being published for some years: *Development Genes and Evolution*; and *Evolution & Development* and the section on *Molecular and Developmental Evolution* of the *Journal of Experimental Zoology*, both published since 1999.

The Society for the Study of Development and Growth, born about 1940, was renamed the Society for Developmental Biology in 1965[13]. In the meantime, its journal, originally published as *Growth*, had been re-launched in 1960 as *Developmental Biology*.

The general trend in the names of societies and journals established or renamed in the last decades is one of increasing specialization, thus of increasing distance from a biological approach in the most comprehensive sense of term. There are interesting exceptions, however. The Society of Systematic Zoology, founded in 1947, was renamed Society of Systematic Biologists in 1991; correspondingly, its journal, published

[11] B. Smocovitis, *Organizing evolution: Founding the Society for the Study of Evolution (1939-1950)*, in «J. Hist. Biol.», 27, 1994, pp. 241-309.

[12] S.C. Stearns, *How the European Society for Evolutionary Biology and the Journal of Evolutionary Biology were founded* in «J. Evol. Biol.», 21, 2008, pp. 1449–1451.

[13] J.M. Oppenheimer, *The growth and development of developmental biology*, in M. Locke (ed.), *Major Problems in Developmental Biology* (*Symposia of the Society for Developmental Biology*, vol. 25), Academic Press, New York 1966, pp. 1-27.

between 1952 and 1991 as *Systematic Zoology*, was renamed *Systematic Biology* in 1992. Similarly, the American Society of Zoologists, established in 1902, changed its name to Society for Integrative and Comparative Biology in 1996. Its journal was published between 1961 and 2001 as *American Zoologist*; the named was changed to *Integrative and Comparative Biology* in 2002. In both instances, the primacy was given the approach (systematics; integrative and comparative biology) while the taxonomic specialization was deleted, thus inviting broader intellectual exchange. It is fair to add, however, that more than twenty years after the change to the society's name, «SICB has remained principally a society that supports integrative zoological research»[14].

The survival of a number of the traditional disciplinary partitions of the life sciences can be seen at a glance in the examples presented in Table 1.

Worth noting among the categories recognized by the Web of Science is the presence of Biology without further qualification, together with some categories corresponding to disciplines defined based on taxonomic circumscription (*Entomology*, *Ornithology*, *Zoology*): none of these disciplinary categories is present in the articulation of the life sciences in PNAS. Furthermore, botany is not present in any of the two lists, even if its scope is largely overlapping with the disciplines listed as *Plant Sciences* (Web of Science) or *Plant Biology* (PNAS). The more conservative nature of the Web of Science partitions is also seen in the presence of *Anatomy & Morphology* and especially *Microscopy*, a term – defined by a technique rather than by the study object or by the problems addressed – that showed up in the titles of scientific journals around mid-nineteenth century. The list of biological disciplines

[14] R.M. Ogburn and E.J. Edwards, *Celebrating a new Division of Botany at SICB: An introduction to the Integrative Plant Biology Symposium*, in «Integr. Comp. Biol.», 59, 2019, pp. 489-492.

in the Natural Sciences Tripos (4 years) at the University of Cambridge, UK, is similar to the PNAS sections, except for the presence of *Zoology* (while botany is present under *Plant Sciences*).

The presence of one of the life sciences in the list of disciplines taught at universities or in the other contexts exemplified in Table 1 reveals only a part of the history. Botany, for example, which does not appear in this table, still gives its name to important scientific societies, prestigious academic journals and highly participated international conferences. More subtly, the persistent divide between animal and plant biology continues to have heavy negative effects on taxonomically transversal disciplines such as developmental biology or reproductive biology. In developmental biology, the results of studies carried out only on some model species, often limited to representatives of the animal kingdom, are sometimes assumed to apply to multicellular organisms generally even in a number of instances where this is unwarranted. In reproductive biology, the use of a very different terminology in the description of phenomena affecting plants and animals continues to hinder comparisons and attempts at generalization[15]. Overcoming these academic barriers is also very difficult in the context of didactics. For example, the proposal to introduce a course in reproductive biology spanning over all large groups of living beings clashes with the almost universal lack of teachers willing to leave the narrow field of their specialization, so the course is likely to be broken in two or three modules, respectively entrusted to biologists with zoological, botanical and microbiological training. In this way, we do not achieve the cultural target of a comprehensive biology.

[15] G. Fusco and A. Minelli, *The Biology of Reproduction*, Cambridge University Press, Cambridge 2019.

Table 1. Biological disciplines (applied ones excluded) recognized as categories by the Journal Citation Reports (https://jcr.clarivate.com/JCRHomePageAction.action?) or as subsections of the Biological Sciences in the *Proceedings of the National Academy of Sciences of the United States of America* (https://www.pnas.org/) and a partial list of disciplines in the Natural Sciences Tripos at the University of Cambridge, UK (https://www.undergraduate.study.cam.ac.uk/courses/natural-sciences)

<table>
<tr><th>Journal Citation Reports</th><th>PNAS</th><th>Cambridge</th></tr>
<tr><td>Anatomy & Morphology</td><td></td><td></td></tr>
<tr><td>Anthropology</td><td>Anthropology</td><td></td></tr>
<tr><td>Behavioral Sciences</td><td></td><td>Experimental Psychology</td></tr>
<tr><td>Biochemical Research Methods</td><td rowspan="2">Biochemistry</td><td rowspan="2">Biochemistry & Molecular Biology</td></tr>
<tr><td>Biochemistry & Molecular Biology</td></tr>
<tr><td>Biology</td><td></td><td></td></tr>
<tr><td>Biophysics</td><td rowspan="2">Biophysics and Computational Biology</td><td></td></tr>
<tr><td>Mathematical & Computational Biology</td><td>Mathematical Biology</td></tr>
<tr><td>Cell Biology</td><td>Cell Biology</td><td>Biology of Cells</td></tr>
<tr><td>Developmental Biology</td><td>Developmental Biology</td><td>Cell & Developmental Biology</td></tr>
<tr><td>Ecology</td><td>Ecology</td><td>Ecology</td></tr>
<tr><td>Endocrinology & Metabolism</td><td></td><td></td></tr>
<tr><td>Entomology</td><td></td><td></td></tr>
<tr><td rowspan="3">Evolutionary Biology</td><td>Evolution</td><td>Evolution & Animal Diversity (formerly Animal Biology)</td></tr>
<tr><td rowspan="2">Population Biology</td><td>Evolution & Conservation</td></tr>
<tr><td>Evolution & Behaviour</td></tr>
<tr><td>Genetics & Heredity</td><td>Genetics</td><td>Genetics</td></tr>
<tr><td>Marine & Freshwater Biology</td><td></td><td></td></tr>
<tr><td>Microbiology</td><td>Microbiology</td><td>Plant &</td></tr>
</table>

		Microbial Sciences
Microscopy		
Mycology		
Neurosciences	Neuroscience	Neurobiology
Ornithology		
Paleontology		
Parasitology		
Physiology	Physiology	Physiology
Plant Sciences	Plant Biology	Plant Sciences
	Systems Biology	Systems Biology
Reproductive Biology		
Zoology		Zoology

3. *Biology – A Science or just an Umbrella?*

> Very soon after I began to teach Natural History, or what we now call Biology, at the Royal School of Mines, some twenty years ago, I arrived at the conviction that the study of living bodies is really one discipline, which is divided into Zoology and Botany simply as a matter of convenience; and that the scientific Zoologist should no more be ignorant of the fundamental phenomena of vegetable life, than the scientific Botanist of those of animal existence. Moreover, it was obvious that the road to a sound and thorough knowledge of Zoology and Botany lay through Morphology and Physiology.

This is how Thomas Henry Huxley expressed himself in the preface to the *Course of Practical Instruction in Elementary Biology* written in collaboration with the young physiologist Henry Newell Martin[16].

A few years earlier, Huxley had published a series of articles that linked discussions of the cell, protoplasm and evolution to proposed changes in medical and science education[17]. The design of a biology as the science of all living beings was already in his mind before Huxley adopted an evolutionary vision of the living world. This is demonstrated by the three *Fullerian Lectures on Biology Principles* he held in 1858 at the British Royal Institution. In these unpublished lessons, in addition to stating

[16] T.H. Huxley and H.N. Martin, *A Course of Practical Instruction in Elementary Biology*, Macmillan, London 1875, p. V.
[17] T.H. Huxley, *On the physical basis of life*, in «The Fortnightly Review», N.S. 5, 1869, pp. 129-145.

that biology deals with all living beings, Huxley characterized it as a synthetic and unitary science that makes use of the contribution of all life disciplines[18].

In 1860 Thomas Henry Huxley and Joseph Dalton Hooker succeeded in having biology included as a discipline in the organization of studies at the University of London[19]. In 1866, the British Association for the Advancement of Science created, albeit with difficulty, a biology section, but already in the nineties of the nineteenth century this was dismembered. When Huxley retired, his chair of Biology was replaced by a chair of animal biology and one of plant biology. And in 1898 the Faculty of Science replaced the biology exam with two separate exams (zoology and botany, thus following the traditional taxonomic divide).

Thus ended the century that had seen the introduction of the term biology as the name of the science of the living. This was prepared by an intellectual journey to which both natural sciences, philosophy and medicine had contributed[20].

The first prerequisite for the birth of biology was that the whole of living beings was identified as the legitimate and primary object of study of a scientific discipline, excluding inanimate bodies such as minerals and rocks. This is a position from which Linnaeus, according to whom *Naturalia dividuntur in Regna Naturae tria: Lapideum, Vegetabile, Animale*[21] was still very distant. At that time, wherever there was a grouping between two of the three disciplines (zoology, botany and mineralogy), this was not obtained by bringing together the study of animals and plants, but rather between zoology and mineralogy.

[18] Id., *On the study of biology*, in «The American Naturalist», 11, 1877, pp. 210-221.

[19] J.A. Caron, *“Biology” in the life sciences: A historiographical contribution*, in «Hist. Sci.» 26, 1988, pp. 223-268.

[20] J.H. Zammito, *The Gestation of German Biology. Philosophy and Physiology from Stahl to Schelling*. Chicago University Press, Chicago-London 2018.

[21] C. Linnaeus, *Philosophia botanica, in qua explicantur fundamenta botanica cum definitionibus partium, exemplis terminorum, observationibus rariorum, adjectis figuris aeneis*, G. Kiesewetter, Holmiae 1751, p. 1.

This was obvious, for example, in Jena, where the list of disciplines for the summer semester 1788 in the newly established curriculum in Natural History (*Naturgeschichte*) included general natural history (*allgemeine Naturgeschichte*), natural history of the mineral and animal kingdoms (*Naturgeschichte des Mineral- und Thierreichs*), and two courses on plants, i.e. botany (*Botanik*) and dissection of flowers (*Zergliederung der Blumen*)[22]. In 1787-88 August Batsch published a textbook on animals and minerals as a support to his classes at that university[23].

It may seem strange that zoology was combined with mineralogy rather than botany, but this reflected a consolidated academic tradition[24]. In 1760, the Dutch botanist Johan Frederik Gronovius had published two bibliographic repertoires[25], one of botanical literature, the other of works on zoology and earth sciences. Nearly one hundred years later, a similar repertoire (zoology cum geology) would be published by Louis Agassiz and Hugh Edwin Strickland[26].

In 1847 Agassiz became Professor of Geology and Zoology at Harvard. This academic association did not finish with him. Alpheus Spring Packard Jr., one of the leading exponents of American Neolamarckism and one of the founders of *The American Naturalist* (1867), taught zoology and geology at Brown University

[22] P. Ziche, *Von der Naturgeschichte zur Naturwissenschaft. Die Naturwissenschaften als eigenes Fachgebiet an der Universität Jena*, in «Ber. Wissenschaftsgesch.», 21, 1988, pp. 251–263.

[23] A.J.G.C. Batsch, (1787-88) *Versuch einer Einleitung zur Kenntnis und Geschichte der Thiere und Mineralien*, Gebauer, Halle 1787-1788.

[24] A. Minelli, *Biologia. La scienza di tutti i viventi*, Forum, Udine 2019.

[25] L.Th. Gronovius, *Bibliotheca regni animalis atque lapidei, seu Recensio auctorum et librorum qui de regno animali & lapideo methodice, physice, medice, chymice, philologice, vel theologice tractant, in usum naturalis historiae studiosorum*, Sumptibus auctoris, Lugduni Batavorum 1760; Id., *Bibliotheca botanica, sive, Catalogus auctorum et librorum qui de re botanica, de medicamentis ex vegetabilibus paratis, de re rustica, & de horticultura tractant, a Joanne Francisco Seguierio Nemausense digestus, accessit Bibliotheca botanica Jo. Ant. Bumaldi, seu potius Ovidii Montalbani Bononiensis, nec non auctuarium in Bibliothecam botanicam Cl. Seguierii*, Cornelius Haak, Lugduni Batavorum 1760.

[26] L. Agassiz and H.E. Strickland, *Bibliographia zoologiae et geologiae. A general catalogue of all books, tracts, and memoirs on zoology and geology*, 4 vols., Ray Society, London 1848, 1850, 1852, 1854.

in Providence, Rhode Island, from 1878 until his death in 1905[27]. The academic coupling of geology and zoology extends into our times: Stephen Jay Gould had the distinction to be, at the same time, Alexander Agassiz Professor of Zoology and Professor of Geology at Harvard University.

A philosophical tradition crediting plants with a lower nature in respect to animals may have contributed to delaying the association of animals and plants as subjects of the same discipline. According to Aristotle, plants have only a vegetative soul while animals, in addition, have also a sensitive soul. Plants received even worse treatment by some modern thinkers: still in 1754, the German philosopher Hermann Samuel Reimarus regarded plants as inanimate objects[28].

This persisting contrast between botany vs. zoology and geology was also rooted in the different material resources on which these disciplines were largely founded. Both minerals and animals (extinct and extant alike) were largely studied on museum specimens. Lamarck described both fossil and living species of mollusks based of the same sets of shell characters and in the collections of the time, a spiny *Murex* collected on the beach and a *Murex* isolated from a block of sandstone from the Miocene period would be found in the same drawer. Plants were largely described on freshly collected specimens, from field notes and the study of specimens in cultivation in the botanical gardens. As to herbaria, their place was rather in the library, on the same shelves as books, rather than in the cabinets reserved for zoological, paleontological and mineralogical specimens.

Things changed when Pallas opened his book on zoophytes – living beings such as corals and sponges, with an organization seemingly intermediate between plants and "typical" animals – with a *Refutation of the Kingdoms of Nature*, denouncing that it is

[27] T.D.A. Cockerell, *Biographical memoir of Alpheus Spring Packard 1839-1905*, in «Biogr. Mem. Natl. Acad. Sci.» 9, 1920, pp. 181–236.
[28] J.H. Zammito, *op. cit*.

> customary to divide all the objects that make up our globe, and those that it contains, in three kingdoms – animal, vegetable, and mineral – but this distinction accepted until now is arbitrary and imaginary; Nature is organized very differently, if we look at the system of Nature with a spirit free from preconceptions, we must instead recognize within it the primary distinction between inert and brute bodies and living and organic ones[29].

For a while, however, Pallas' suggestion failed to elicit changes in the academic system.

This is not the place to contribute to the still open discussion on the identity of the author of the name biology, which is generally but not universally credited to either Lamarck or Gottfried R. Treviranus, or both[30].

Let's instead briefly examine here how they contributed to defining the scope of this science.

In 1800 Lamarck started working on a book that was to be called *Biologie ou Considérations sur la nature, les facultés, les développements et l'origine des corps vivants* (Biology, or Considerations on the Nature, Faculties, Development and Origin of Living Bodies). However, the project ran aground very soon and the few pages of notes remained unpublished. In print, Lamarck used the term biology for the first time in 1802, in a work actually dealing with other aspects of natural history[31]. In the same year, Treviranus published the first volume of a work in which the name of the new discipline appears in the title: *Biologie oder Philosophie der lebenden Natur* (Biology or Philosophy of Living

[29] P.S. Pallas, *Elenchus zoophytorum, sistens generum adumbrationes generaliores et specierum cognitarum succinctas descriptiones, cum selectis auctorum synonymis*, Varrentrapp, Hagae Comitum et Francofurti ad Moenum 1766, p. 3, my transl.

[30] Cfr. J.A. Caron, *op. cit.*; P. McLaughlin, *Naming biology*, in «J. Hist. Biol.» 35, 2002, pp. 1-4; A. Minelli, *Biologia. La scienza di tutti i viventi*, cit.

[31] J.-B. Lamarck, *Hydrogéologie, ou Recherches sur l'influence qu'ont les eaux sur la surface du globe terrestre, sur les causes de l'existence du bassin des mers, de son déplacement et de son transport successif sur les différens points de la surface de ce globe, enfin sur les changemens que les corps vivans exercent sur la nature et l'état de cette surface*, Chez l'Auteur, Paris an X (1802).

Nature)[32]. The crux of the matter is: should the relationship between biology and the disciplines that deal with particular aspects of the living world be based on taxonomic circumscription (e.g., zoology, botany) or on the structural and functional features of organisms (e.g., morphology, inheritance, development)?

According to Lamarck, the living bodies

> offer, in themselves and in the various phenomena they present, the materials for a specific discipline which has not yet been founded, which does not even have a name, of which I have proposed some bases in my *Philosophie zoologique*, and to which I will give the name of Biology. It is understood that everything that is generally common to plants and animals, as well as all the faculties that are peculiar to each of these beings, without exception, must constitute the unique and vast object of biology; since the two kinds of beings I have just mentioned are all essentially living bodies, and they are the only beings of this nature that exist on our globe[33].

More detailed is Treviranus' programme:

> The objects of our investigation will be the various forms and manifestations of life, the circumstances and laws on the basis of which this condition occurs and the causes that determine it. The science that deals with these objects we will call it by the name of biology or doctrine of life. […] What were zoology and botany till now other than dry lists of names, mixed with the results of disconnected experiences [...]? On the contrary, if we consider these sciences as parts of biology, both appear in a completely different light. We then recognize in them the need for a systematic ordering, but we treat the latter as subordinate to a higher goal [...]. The observations on the way of life of animals and plants that until now have found a place in the whole of natural history without connections between them thus receive the place that they deserve and unite in a whole, in which the spirit sees unity and harmony[34].

In principle, this can result either in the inclusion in a comprehensive science of life of all possible specialty approaches, or in some form of coordination between a biology that deals only with general problems, structural and functional aspects common – at least in principle – to all living beings, and the various specialist disciplines, which retain their autonomy.

[32] G.R. Treviranus, *Biologie oder Philosophie der lebenden Natur für Naturforscher und Aertzte*, Erster Band., Röwer, Göttingen 1802.
[33] J.-B. Lamarck, *Histoire naturelle des animaux sans vertèbres*, tome premier, Verdière, Paris 1815, pp. 49-50, my transl.
[34] G.R. Treviranus, *Biologie oder Philosophie der lebenden Natur für Naturforscher und Aertzte*, cit., p. 4, pp. 7-8, my transl.

In my understanding, one of the most worrying aspects of the academic and educational literature of the life sciences is that most of what is described as general biology, or simply biology, does not apply to a large part of the tree of life. Even by restricting attention to multicellular eukaryotes (as such, already a strongly burdening restriction), we should not ignore that only a part of these have tissues and embryos, not to mention a digestive tract or a nervous system. But this is not the main problem we must address, which is the problem of disciplinary divides other than based on taxa.

What is General Biology today? Other than specifying that the approach is alternative to any and all of the specialties within the life sciences, a positive reference to a core of characterizing questions or approaches is generally lacking. This is, for example, the description of the program in General Biology offered by the University of California San Diego (https://biology.ucsd.edu/):

> This program allows the most diversified exposure to biology of any of the majors offered by the Division of Biological Sciences. It is designed for students with broad interests who do not wish to be constrained by the specialized requirements of the other majors and who desire maximum freedom to pursue their particular educational goals.

This statement simply says that General Biology is other than any of the biological specialties, but fails to offer even a single hint to a unifying criterion: General Biology thus reduces to a simple collection of specialties.

4. *Concepts and disciplines*

The biological concepts whose definitions have proved most controversial are probably those of species[35], homology[36], gene[37], individual[38], and organism[39].

[35] F.E. Zachos, *Species Concepts in Biology. Historical Development, Theoretical Foundations and Practical Relevance*, Springer, Basel 2016.

[36] A. Minelli and G. Fusco, *Homology*, in K. Kampourakis (ed.), *The Philosophy of Biology: A Companion for Educators*, Springer, Dordrecht 2013, pp. 289-322;

Over time, these have become nomadic concepts[40], with meaning and domain of application changing with the new disciplinary contexts in which they migrate. The disciplines in which they find application, on the other hand, tend to be considered as fixed areas, to which concepts are subsequently anchored. For example, "gene" is a nomadic concept that over time has been anchored to Mendelian genetics, population genetics, molecular genetics, developmental biology, evolutionary biology. In the meantime, homology, progressively moving away from Owen's original definition as «the same organ in different animals under every

G.P. Wagner, *Homology, Genes, and Evolutionary Innovation*, Princeton University Press, Princeton, NJ, and Oxford 2014.

[37] P. Portin and A. Wilkins, *The evolving definition of the term "gene"*, in «Genetics», 205, 2017, pp. 1353-1364; R. Falk, *What is a gene?*, in «Stud. Hist. Philos. Sci.», *A* 17, 1986, pp. 133-173; M. Snyder and M. Gerstein, *Defining genes in the genomics era*, in «Science», 300, 2003, pp. 258-260; P.E. Griffiths and K.Stotz, *Genes in the postgenomic era*, in «Theor. Med. Bioethics», 27, 2006, pp. 499-521; S. Müller-Wille and H.-J. Rheinberger, *Das Gen im Zeitalter der Postgenomik. Eine wissenschaftshistorische Bestandsaufnahme*, Suhrkamp, Frankfurt am Main 2009; E.F. Keller, *The Century of the Gene*, Harvard University Press, Cambridge, MA 2000.

[38] B. Santelices, *How many kinds of individual are there?*, in «Trends Ecol. Evol.», 14, 1999, pp. 152-155; J. Wilson, *Biological Individuality: The Identity and Persistence of Living Entities*, Cambridge University Press, Cambridge 1999; P. Godfrey-Smith, *Darwinian Populations and Natural Selection*, Oxford University Press, New York 2009; F. Bouchard and P. Huneman (eds.), *From Groups to Individuals. Evolution and Emerging Individuality*, MIT Press, Cambridge, MA 2013; T. Pradeu, *Organisms or biological individuals? Combining physiological and evolutionary individuality*, in «Biol. Philos.» 31, 2016, pp. 797-817; C.Fields and M. Levin, *Are planaria individuals? What regenerative biology is telling us about the nature of multicellularity*, in «Evol. Biol.», 45, 2018, pp. 237-247.

[39] P. Bateson, *The return of the whole organism*, in «J. Biosci.», 30, 2005, pp. 31-39; J. Pepper and M. Herron, *Does biology need an organism concept?*, in «Biol. Rev.», 83, 2008, pp. 621-627; P. Huneman, *Assessing the prospects for a return of organisms in evolutionary biology*, in «Hist. Philos. Life Sci.», 32, 2010, pp. 341-372; L. Nuño de la Rosa, *Becoming organisms: The organisation of development and the development of organisation*, in «Hist. Philos. Life Sci.», 32, 2010, pp. 289-316; C.T. Wolfe, *Do organisms have an ontological status?*, in «Hist. Philos. Life Sci.», 32, 2010, pp. 195-232; D. Nicholson, *The return of the organism as a fundamental explanatory concept in biology*, in «Philosophy Compass», 9, 2014, pp. 347-359; Ch. Shields, *What organisms once were and might yet be*, in «Philos. Theor. Pract. Biol.», 9:7, 2017.

[40] I. Stengers (ed.), *D'une science a l'autre: des concepts nomads*, Seuil, Paris 1987; J. Surman, K. Stráner and P. Haslinger, *Nomadic concepts–biological concepts and their careers beyond biology*, in «Contr. Hist. Concepts», 9, 2, 2014, pp. 1-17.

variety of form and function»[41], has been evolving into a plethora of notions, most of which can be classified as either historical or proximal-cause concepts of homology[42]. Example of the first is Bock's formulation:

> features (or conditions of a feature) in two or more organisms are homologous if they stem phylogenetically from the same feature (or the same condition of the feature) in the immediate common ancestor of these organisms[43].

An example of the proximal-cause concepts of homology is instead the following:

> Structures from two individuals or from the same individual are homologous if they share a set of developmental constraints, caused by locally acting self-regulatory mechanisms of organ differentiation[44].

The situation could change if we try to reverse the relationship between concepts and disciplines: instead of working with nomadic concepts that are anchored to different disciplines, we may identify a small number of stable *anchor concepts* with respect to which the disciplines concerned could acquire a nomadic behavior, by redefining their borders and their mutual relations whenever advisable.

Recently, in proposing this reversal of perspective[45], as an epistemological exercise that could help overcome the current rigidity of the barriers between biological disciplines, I have suggested three examples of situations in which an appropriate anchor concept could produce a useful redetermination of the boundaries between biological disciplines. I will briefly mention here only one of them.

The boundary between reproduction and development may deserve a reorganization by treating these two chapters of biology as

[41] R. Owen, *Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals, Delivered at the Royal College of Surgeons*, Longman Brown Green and Longmans, London 1843.
[42] A. Minelli and G. Fusco, *Homology*, cit.
[43] W.J. Bock, *Philosophical foundations of classical evolutionary classification*, in «Syst. Zool.», 22, 1974, pp. 386-387.
[44] G.P. Wagner, *Homology, Genes, and Evolutionary Innovation*, cit., p. 62.
[45] A. Minelli, *Disciplinary fields in the life sciences: evolving divides and anchor concepts*, in «Philosophies» 5, 34, 2020.

nomadic disciplines. This can be attempted starting from a redefinition of some key concepts that link the two disciplinary fields, in particular the concept of generation. For example, we can introduce[46] a distinction between demographic generation and genetic generation, which we can define as follows:

Demographic generation: individuals produced by individuals of a parental generation by sexual or asexual reproduction.

Genetic generation: a set of individuals produced by a set of individuals (representing a distinct genetic generation) by a sexual process (sexual reproduction or pure sexuality, i.e. sexuality without reproduction, as occurs in ciliate protozoans).

A periodization of the biological cycle based on the notions of generation defined above opens the way to sound and broad-ranging comparisons between the most diverse groups of living beings and suggests new perspectives. For example, recognizing the unicellular phase of a typical animal life cycle as a distinct demographic and genetic generation legitimizes the description of gametogenesis in terms of developmental biology: that is, a displacement of gametogenesis from reproductive to developmental biology and a recognition of unicellular organisms as legitimate study objects of the latter.

5. *Conclusions*

1. Speaking of life sciences, in the plural, is an objective way to recognizing the great autonomy with which the various scientific disciplines that deal with living beings operate. This autonomy is generally (not always) unproblematic for the scientist, but it can be very limiting for the philosopher of science, not to mention that it is also educationally dangerous, in a training program for specialized biologists. In my opinion, a productive confrontation between biology and philosophy of biology

[46] A. Minelli, *Developmental disparity*, in A. Minelli and T. Pradeu (eds.), *Towards a Theory of Development*, Oxford University Press, Oxford 2014, pp. 227–245.

cannot ignore a serious effort, on both sides, to recover an open and comprehensive vision of the living. In the living world, there are not only man and model animals such as mouse or *Drosophila*. Moreover, there is much in biology beyond DNA, Darwin and neurosciences.

2. At present, some of the most important concepts of biology are nomadic concepts that take on the most diverse meanings according to the contexts in which they are recognized and used. In itself, this situation may represent an interesting research topic for the philosopher of science, but the philosopher in turn could help the scientist overcome the communication difficulties and cognitive limitations that too often arise from ignoring the semantic problems generated by the undisciplined usage of the terms currently adopted for these concepts. The suggested reversal of role (nomadic vs. anchor) between disciplines and key concepts, is one of the strategies that, at the moment, it seems appropriate to explore.

3. Is this a promising strategy towards an improved dialogue between science and philosophy? I firmly think so, at least as far as biology and the philosophy of biology are concerned. In the face of the amazing diversity and complexity of the phenomena of life, we might be tempted to confine our horizon to a narrow selection of organisms (perhaps, just humans, or a few model species), or to a set of topics and problems predefined by traditional disciplinary boundaries, and to disregard the pitfalls of the ever changing circumscription and meaning of the terms used for the core concepts in life sciences. Focusing on these problems and joining efforts to identify the semantic issues and to find a solution to them (a temporary one, at least) will be a rewarding effort.

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ALESSANDRO MINELLI già Professore ordinario di Zoologia presso l'Università di Padova

alessandro.minelli@unipd.it