Evolutionism: Present Approaches

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Edited by WENCESLAO J. GONZALEZ

General Editor

Wenceslao J. Gonzalez

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Context

EVOLUTIONISM FROM A CONTEMPORARY VIEWPOINT: THE PHILOSOPHICAL-METHODOLOGICAL APPROACH¹

WENCESLAO J. GONZALEZ

From a contemporary viewpoint, evolutionism appears as a multifaceted realm. On the one hand, a historical analysis reveals a clear diversity of evolutionisms to be considered, where Darwinism is a key conception that was preceded and followed by other evolutionary views. On the other hand, a philosophical-methodological study of those evolutionisms —among them, the influential conception developed by Charles Darwin— has a richness that exceeds the contents of any standard book. In effect, evolutionism has a strong influence on science —above all biology— with philosophical consequences that are relevant for general philosophy and methodology of science as well as for special domains (philosophy of biology, philosophy of economics, etc.). In addition, evolutionism has an undeniable repercussion on central parts of philosophy, such as theory of knowledge, metaphysics, and ethics.

In the face of this multifaceted realm of evolutionism, this chapter seeks to offer the context of the philosophical-methodological approach to evolutionism. It takes into account the main lines of the historical background and, thus, within the space available, there are two axes in this contextualization: 1) *Diversity of evolutionisms: Towards a philosophical-methodological framework*, which focuses on the historical analysis of evolutionism, emphasizing the existence of a diversity of evolutionary positions; and 2) *From a philosophical view of nature to naturalism in philosophy*, where philosophy appears also in different ways: a) the philosophical-methodological influences on Darwin's approach; b) the early stages in Darwin's philosophical influence; and c) contemporary philosophical significance of Darwinism. Later on, there is an explanation of the structure and genesis of the book as well as a bibliography on the topics discussed.

1. DIVERSITY OF EVOLUTIONISMS: TOWARDS A PHILOSOPHICAL-METHODOLOGICAL FRAMEWORK

“Evolutionism” is a polysemic term: its sense and reference varies according to the historical period and the school of thought (and sometimes in the same author from one stage of his life to another).² Besides the linguistic diversity, evolutionism also involves different realms because it embraces a wide variety of approaches both in science and in philosophy. Thus, evolutionism can be found in natural sciences —mainly in biology— as well as in social sciences, not only at the level of basic science (e.g., in palaeontology) but also in the stance of applied science (e.g., in evolutionary economics). In philosophy it appears in the discussion of theoretical issues (e.g., in metaphysics) and in the debates on practical matters (e.g., in ethics).

¹ I am grateful to Jean Gayon for his comments on this paper.

² This variety can be found in the list of publications offered in the bibliography of this chapter, where there is a distinction between Darwinism and other kinds of evolutionism.

Initially “evolutionism” is a biological doctrine that started before Charles Robert Darwin (1809-1882), an author whose anniversaries —two centuries since his birthday and 150 years since his key book— should be kept in mind. According to Jean Gayon, “clustered around ‘evolution’ were, among others, the old theory of embryogenesis as the expansion of a preformed organism (this being the primary meaning of ‘evolution’ in the seventeenth and eighteenth centuries); the associated theory of the pre-existence of germs, in connection with which the Swiss naturalist Charles Bonnet first applied ‘evolution’ not only to individual generation, but to the history of the successive appearance of species; the transcendental morphology of the nineteenth century, with its emphasis on parallelisms between embryogenesis and the graduated complexity of species (...).”³

Generally, evolutionism was seen in the broad context of interest in some kind of progress. It received an impulse with Darwin’s views, principally those stated in *The Origins of Species*⁴ and in *The Descent of Man*.⁵ But evolutionism has numerous subsequent outlooks, some of them clearly different from his perspectives, even though he remains a key figure in the development of this conception. In addition, evolutionism became a philosophy in the relevant sense of rational reflection on reality as a whole⁶ (natural, social and artificial). In this regard, it has influenced the main areas of philosophical research: theory of knowledge, metaphysics, ethics, etc. Among them, evolutionism has had a crucial role in general philosophy of science as well as in special domains of this realm (philosophy of biology, philosophy of economics, etc.).

Besides biology, evolutionism has impinged on many scientific fields, which include a wide range of subjects within the social sciences: psychology, sociology, anthropology, economics, etc. Moreover, it can be affirmed that evolutionism—in general, and Darwinism, in particular—is also seen as an intellectual worldview that goes beyond the status of a scientific theory to attract the attention of many people.⁷ From this point of view, it is rather obvious that evolutionism is embedded in cultural approaches (in literature, journalism, etc.) and has a prominent relevance in social discussions in some countries (especially, the United States) with repercussions on ordinary life (education, legislation, etc.).⁸

³ GAYON, J., “From Darwin to Today in Evolutionary Biology,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, Cambridge University Press, Cambridge, 2003, p. 242. “In his *Palingénésie philosophique* (1769), Bonnet argued that God had prearranged the occurrence of new species in the germs of the first organisms he had created. For this reason, Bonnet extended the use of the word ‘evolution’ (literally ‘unfolding’) to the genesis of species,” GAYON, J., “From Darwin to Today in Evolutionary Biology,” pp. 261-262.

⁴ DARWIN, CH., *The Origin of Species by Means of Natural Selection: or the Preservation of Favoured Races in the Struggle for Life*, John Murray, London, 1859; reprinted in facsimile edition by Harvard University Press, Cambridge, MA, 1964.

⁵ DARWIN, CH., *The Descent of Man and Selection in Relation to Sex*, John Murray, London, 1871, 2 vols.

⁶ On the one hand, there is a metaphysical view within the evolutionist approach; and, on the other hand, evolutionism—at least, in the Darwinian brand—has built up a metaphysical conception. Cf. HULL, D. L., *The Metaphysics of Evolution*, SUNY Press, Albany, NY, 1990.

⁷ Cf. RUSE, M., *The Evolution-Creation Struggle*, Harvard University Press, Cambridge, MA, 2005; and BOWLER, P. J., *Monkey Trials and Gorilla Sermons: Evolution and Christianity from Darwin to Intelligent Design*, Harvard University Press, Cambridge, MA, 2007.

⁸ These disputes lie beyond the scope of this philosophical-methodological paper. In addition, these “cultural wars” are only partially philosophical in their origins and have led to a huge number of publications, many of them frequently laden with ideological claims.

Historical aspects of evolutionism should be taken into account due to the diversity of evolutionary conceptions involved. In this regard, the analysis here follows several steps which pay particular attention to biology: 1) initial stages of evolutionism; 2) Darwin's biological approach to evolution, which is also seen in philosophical terms (i.e., the possibility of being a naturalist); 3) the consideration of an intellectual revolution introduced by Darwinism; and 4) other evolutionisms related to biology, which are tackled from different angles (such as "tree of life", process of evolution, microevolution and macroevolution).

1.1. Initial Stages

As regard the first evolutionists, Michael Ruse suggests to "go back nearly three hundred years."⁹ Then he connects the idea of "evolution" with a broad notion of "progress," an enhancement for a better life. He also links Jean-Antoine-Nicolas Caritat, Marquis of Condorcet (1743-1794), with the movement from the recognition of progress in the social world (due mainly to the new discoveries of science) to progress—an escalation—in the biological world.

Thus, *evolution* has in this context a positive character, insofar as it is assumed that the concept of "progress" includes an improvement related to the results or outcomes.¹⁰ In addition, it can be assumed that this initial evolutionism involves the idea of transition at the level of *complexity*, because in social life as well as in nature the organisms can be organized from the simplest to the most complex.

George Louis Leclerc, Comte de Buffon (1707-1788) developed a pre-Darwinian account of organic change, even though he has different foundations in his comprehensive survey of natural history:¹¹ his view entails that the character of each biological family is fixed by its internal mold. "In arguing that a single ancestral form might diverge into a number of 'species,' Buffon came close to the modern concept of evolution. His recognition that migration to different parts of the world might cause the divergence also marks a pioneering effort in the study of geographic distribution as a clue to the history of life. But his idea that the environment acts directly on the organism through organic particles is a long way from the theory of natural selection."¹²

The progressiveness in evolution is an assumption in Erasmus Darwin (1731-1802), mainly in his work *Zoonomia* (1794-1796),¹³ in which he is interested in the "laws of

⁹ RUSE, M., *Darwinism and Its Discontents*, Cambridge University Press, N. York, 2006, p. 9.

¹⁰ On "scientific progress," cf. GONZALEZ, W. J., "Progreso científico, Autonomía de la Ciencia y Realismo," *Arbor*, v. 135, n. 532, (1990), pp. 91-109; and NIINILUOTO, I., *Is Science Progressive?*, Reidel, Dordrecht, 1984. On "biological progress," cf. AYALA, F. J., "The Concept of Biological Progress," in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology, Reduction and Related Problems*, Macmillan, London, 1974, pp. 339-355.

¹¹ Cf. BUFFON [GEORGE LOUIS LECLERC], COMTE DE, *Histoire Naturelle, générale et particulière*, 36 vols., Imprimerie Royale puis Plassan, Paris, 1749-1788.

¹² BOWLER, P. J., *Evolution: The History of an Idea*, University of California Press, Berkeley, 1983; revised edition, University of California Press, Berkeley, 1989, pp. 74-75.

¹³ DARWIN, E., *Zoonomia; or, The Laws of Organic Life*, J. Johnson, London, 1794-1796. This publication by his grandfather was carefully read by Charles Darwin, cf. HODGE, J., "London Notebook Programmes and Projects of Darwin's London Years," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 45.

organic life.” In the case of natural change, he considered an adaptation of plants and animals to their environment. Moreover, Charles’s grandfather has been associated to another key figure: Jean-Baptiste-Pierre-Antoine de Monet, chevalier of Lamarck (1744-1829), because Erasmus “also had upheld a natural, prolonged production of the highest from the lowest life and an ape ancestry for man.”¹⁴

Lamarck was one of the authors whose zoological works were in the *Beagle*’s library during Darwin’s voyage (1831-1836).¹⁵ Jean Baptiste de Monet accepts a “spontaneous generation” in the case of lower life forms and an upward progression of organisms until the human form. Even though he thought that there are sometimes divisions and vagaries (generally brought on by the heritable effects of use and disuse, like the giraffe’s neck), the overall picture of nature is *progress* as it happens in the best human societies as well.¹⁶

Again, besides the acceptance of *variability* in natural world (in this case the specific feature of inheritance of acquired characteristics is included), in this version of evolutionist approach there is an assumption of complexity in biology: “according to Lamarck, the plants and animals presently existing had arisen through a natural process of transformation, owing to the complexifying properties of the fluids running through their tissues, and the adaptive changes brought about when habits changed in response to altered environments.”¹⁷

Undoubtedly this idea of complexity can lead to the existence of some kind of *hierarchy* in the natural world. In fact, Stephen Gould, who has studied Lamarck in this context, pointed out that “his theory (...) rests upon the concept of hierarchy, with distinct causes at two primary levels.”¹⁸ At the beginning —until 1797—, Jean Baptiste de Monet accepted the idea of species as fixed entities. But he then became a supporter of evolutionism: this new perspective is in his inaugural lecture for the *Muséum d’Histoire Naturelle* course of 1800, and later on it appears in his three major works: *Recherches sur l’organisation des corps vivans* (1802),¹⁹ *Philosophie zoologique* (1809),²⁰ and *Histoire naturelle des animaux sans vertèbres* (1815-1822).²¹

But Darwin said little about Lamarck,²² even though his famous “functionalist” approach —the counterintuitive statement that *form* follows *function* as the order of life’s

¹⁴ HODGE, J., “London Notebook Programmes and Projects of Darwin’s London Years,” p. 45.

¹⁵ SLOAN, PH. R., “The Making of a Philosophical Naturalist,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 30.

¹⁶ Cf. RUSE, M., *Darwinism and Its Discontents*, pp. 9-10.

¹⁷ SLOAN, PH. R., “The Making of a Philosophical Naturalist,” p. 21.

¹⁸ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, Belknap Press, Cambridge, MA, 2002, chapter 3: “Seeds of Hierarchy,” p. 175.

¹⁹ LAMARCK, J. B. [DE MONET, CHEVALIER] DE, *Recherches sur l’organisation des corps vivans*, Maillard, Paris, 1802.

²⁰ LAMARCK, J. B. [DE MONET, CHEVALIER] DE, *Philosophie zoologique, ou, Exposition des considérations relative à l’Histoire naturelle des animaux*, Chez Dentu [et] L’Auteur, Paris, 1809.

²¹ LAMARCK, J. B. [DE MONET, CHEVALIER] DE, *Histoire naturelle des animaux sans vertèbres*, 7 vols. Paris, 1815-1822. Reprinted by Culture et Civilisation, Brussels, 1969.

²² Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, pp. 170 and 192-197. There are explicit criticisms regarding “Lamarck nonsense of a ‘tendency to progression,’” DARWIN, CH., *Letter to Hooker*, January 11, 1844 (quoted in *The Structure of Evolutionary Theory*, p. 175).

history—was embraced by Darwin as well.²³ Following Lamarck's biological approach, variety in natural world—or biodiversity—is a by-product of the evolutionary ascent. Thus, his view emphasizes the “vertical dimension” of evolution, whereas Darwin's conception highlights the “horizontal aspect” of evolution or at least the possibility of a plurality of simultaneous branches of the “tree of life.” For him, within the evolutionary process in natural world, there is an increase of complexity due to the broadening of biological diversity.²⁴

Figure 1

Figure 2

Nonetheless, Lamarck became increasingly aware of the importance of differentiation. This means that he progressively introduced complications in his series, which made them resemble more and more to a tree. He uses the expression “*série rameuse*” in his *Philosophie zoologique* to reflect this preoccupation.²⁵ In his approach, as is exemplified in figure 3 by Peter Bowler, “each point on the scale of being we observe today has been derived by progression from a separate act of spontaneous generation. The lower down the scale the organism is today, the more recently its first ancestor was produced. Thus, evolution is not a system of common descent but consists of separate lines progressing in parallel along the same hierarchy.”²⁶

²³ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, p. 177. “We may view Lamarck and Darwin as occupying the common ground of functionalism, with their differing mechanisms of natural selection and soft inheritance as versions of the same deeper commitment. (...) But Lamarckism also includes a second set of concepts, which, when combined with the first set into Lamarck's full system, builds an evolutionary theory truly opposed to Darwin's chief theoretical concept and operational principle as well,” *The Structure of Evolutionary Theory*, p. 179.

²⁴ The difference between both perspectives depicted in the graphics is based on RUSE, M., *The Darwinian Revolution*, The University of Chicago Press, Chicago, 1979, ch. 1.

²⁵ Cf. LAMARCK, J. B. [DE MONET, CHEVALIER] DE, *Philosophie zoologique*, tome second, p. 463, “Tableau servant à montrer l'origine des différens animaux.”

²⁶ BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 85. The figure 3 appears in the same page.

Figure 3

Robert Chambers (1802-1871), who has acknowledged Lamarck as his major source of inspiration,²⁷ was another author to be read by Charles Darwin (and by Alfred Russel Wallace). Chambers was a Scottish publisher who anonymously published in 1844 the book *Vestiges of the Natural History of Creation*.²⁸ This text has been considered as “the paradigmatic early Victorian book on evolution.”²⁹ The important thing is that Darwin was not an isolated man regarding the *support* for some kind of evolutionism before he published his main works: “There was no lack of evolutionists or fellow-travellers in the late 1830s: Baden Powell, William Carpenter, Robert Chambers and Francis Newman would be examples.”³⁰

Meanwhile Augustin Pyrame De Candolle (1778-1841) had defended that “all the plants of a given country are at war with one another,” which was used by Charles Lyell in his main book —*Principles of Geology*, 1830-1833— in comments about the *competitive struggle* as the true cause of species extinction.³¹ This idea sounds similar to Thomas

²⁷ Cf. *The Structure of Evolutionary Theory*, p. 174.

²⁸ CHAMBERS, R., *Vestiges of the Natural History of Creation*, Churchill, London, 1844. Reprinted in facsimile with an introduction by James A. Secord: The University of Chicago Press, Chicago, 1994.

²⁹ WATERS, C. K., “The Arguments in the Origin of Species,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 116.

³⁰ BROOKE, J. H., “Darwin and Victorian Christianity,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 203. Even though Chambers’s view was a precedent of Darwinian conception, the book *Vestiges* was one of the reasons to delay the publication of Darwin’s evolutionary viewpoint, because he did not want to be associated to some of the claims of the “anonymous” book.

³¹ Cf. LYELL, CH., *Principles of Geology*, John Murray, London, 1830-1833, 3 vols. Reprinted in facsimile with an introduction by M. J. S. Rudwick, The University of Chicago Press, Chicago, 1990, II, p. 131; and RADICK, G., “Is the Theory of Natural Selection Independent of its History?,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 160.

Malthus's claims that have had an influence on Darwin. But here is Candolle, who was a Genevan botanist who emphasized both physiological and classificatory botany. His work was the content of a Henslow's botany course at the University of Cambridge around 1828, which Darwin attended.³²

Etienne Geoffroy Saint-Hilaire (1772-1844) was another scientist in favor of evolution whose work was known by Darwin before the *HMS Beagle's* voyage. This acquaintance occurred at Edinburgh University (medical school) around 1826 and through the comparative anatomist Robert Grant.³³ Geoffroy was one of the main architects of the "idealist" (or transcendental) morphology, who "had claimed to find structural affinities, or 'unity of type', between kinds of animals previously classified as belonging to wholly separate taxonomic groups."³⁴

Alfred Russel Wallace (1823-1913) was a biogeographer and specimen collector who was closely related to the publication of *The Origin*, insofar as Darwin received in 1858 an unpublished article from him which —according to C. Kenneth Waters— "anticipated many of Darwin's own ideas about evolution, including the idea of natural selection."³⁵ But this requires more analysis, because most of Darwin's ideas were already formulated in his unpublished book of 1844.³⁶ The following decade, Wallace published an article which supported a vein of organic evolution as a succession of branching events (where he advocated that classification would be presented in a genealogical way, and using a "tree" representing the "divergence" between species).³⁷

Wallace was interested in the distribution and transmutation of species. Moreover, in 1855 he thought that every species that comes into existence *coincident* in space and time has a preexisting closely allied species.³⁸ Three years later he sent Darwin an unpublished article with similar views on evolution. This prompted Charles Darwin to set aside a long book in progress and to write "an abstract," which he completed in nine months. Thus, in November 1859 he published the abstract with the title *On the Origin of Species by Means of Natural Selection*.

Although the list of evolutionists before the publication of Darwin's *Origin* can be enlarged, the important aspect is the existence of several scientists who, either working on animals or studying plants, were in favor of some kind of evolution. The interest in the *transmutation* of species in that time was not the dominant tendency in those days, but was in no way unknown even before Darwin's trip in the warfare ship *HMS Beagle*.

³² Cf. SLOAN, Ph. R., "The Making of a Philosophical Naturalist," p. 23.

³³ Cf. "The Making of a Philosophical Naturalist," p. 20.

³⁴ SLOAN, Ph. R., "The Making of a Philosophical Naturalist," pp. 20-21.

³⁵ WATERS, C. K., "The Arguments in the Origin of Species," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 117. On this evolutionist view, cf. WALLACE, A. R., *Contributions to the Theory of Natural Selection*, Macmillan, London, 1870 (reprinted by AMS Press, N. York, 1973).

³⁶ In 1844 Charles Darwin wrote on *Geological Observations on the Volcanic Islands visited during the Voyage of H. M. S. Beagle*, which was later published in the volume DARWIN, Ch. and WALLACE, A. R., *The Evolution by Natural Selection*, with a Foreword by Sir Gavin de Beer, Cambridge University Press, Cambridge, 1958. See also in this regard Darwin's letter to his friend Joseph Hooker, dated 11 January 1844.

³⁷ Cf. WALLACE, A. R., "On the Law Which Has Regulated the Introduction of New Species," *Annals and Magazine of Natural History*, v. 16, 2nd s., (1855), pp. 184-196.

³⁸ Cf. BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 185.

This is relevant for understanding his approach on evolution as well as for evaluating his intellectual revolution. In this regard, a comparative methodology (e.g., in embryology, anatomy or palaeontology) was already in place, used by those akin to evolutionism.

1.2. Darwin's Approach on Evolution: A "Philosophical Naturalist"?

"Philosophical naturalist" is the label that Darwin uses to describe his own approach in 1837, few months after his *Beagle* voyage.³⁹ This position is different from "natural history" and "natural philosophy." In this context, *natural history* has a wider scope than a merely biological one: it includes geology, geography, human customs, etc. (as can be seen in works such as Buffon's *Histoire Naturelle*). Even though it embraces different fields, such as the geological study of the "theory of the earth" or the "history of the earth", some people tried to emphasize natural history in the Linnaeus tradition (the views of the botanist Carl von Linné). Then the sense of the expression "natural history" is related to the systematic ordering of plants (as well as animals) and the discovery of new species.

Meanwhile, *natural philosophy* —at least in the British tradition of Isaac Newton, the author of *Philosophiae Naturalis Principia Mathematica*— was devoted to the search of general laws in nature (mainly, physical laws). Darwin wanted to follow a different path, working commonly outside these traditions. Initially his search for new patterns was related to comparative anatomists and theoretical geologists, and steadily he moved towards the causal explanation of biological change.⁴⁰

Unexpectedly, in order to characterize his own view, Charles Darwin did not often use the word "evolution."⁴¹ In effect, "although the last sentence of the *Origin of Species* says (in all editions) that 'endless forms most beautiful and wonderful have been, and are being, evolved,' Darwin did not like his theory about transmutation of species to be called a 'theory of evolution.' (...) For Darwin, and many other English naturalists of his era, 'evolution' was an ambiguous word. It evoked various theories that closely associated the history of species with both individual development and an overall progressionist interpretation of the history of nature."⁴² Instead of the expression "evolution," his preference was "descent with modification."⁴³

Historically, the key point is how was the *natural selection* approach formed. This question, requires very careful analysis of the intellectual itinerary that Darwin followed

³⁹ "The law of the succession of types, although subject to some remarkable exceptions, must possess the highest interest to every philosophical naturalist," DARWIN, CH., *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H. M. S. Beagle*, Colburn, London, 1839. Reprinted in BARRETT, P. H. and FREEMAN, R. B. (eds.), *The Works of Charles Darwin*, Pickering, London, 1986, vol. 2, p. 164. Cf. SLOAN, PH. R., "The Making of a Philosophical Naturalist," p. 17.

⁴⁰ Cf. SLOAN, PH. R., "The Making of a Philosophical Naturalist," pp. 17-18.

⁴¹ The analysis of Charles Darwin's approach and his intellectual revolution follows the lines drawn in GONZALEZ, W. J., "Towards a New Framework for Revolutions in Science," *Studies in History and Philosophy of Science*, v. 27, n. 4, (1996), pp. 607-625; especially, pp. 618-624. It includes remarks on the controversy between William Paley's creationism and Darwinian evolutionism.

⁴² GAYON, J., "From Darwin to Today in Evolutionary Biology," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 242.

⁴³ RUSE, M., *Darwinism and Its Discontents*, p. 15.

before he published *The Origin of Species*.⁴⁴ During this period, which begins with the famous voyage of the *Beagle* (1831-1836) and ends with the publication of the *Origin* (1859), he changed his conception regarding this topic several times. In fact, although he introduces an important conceptual change as the result of his individual research, he does it in connection with the scientists of his times and under the influence of the views of some predecessors and contemporaries.

At the start, even during the voyage of the *Beagle*,⁴⁵ Darwin was fixist and creationist in a sense very close to Charles Lyell. This is Darwin's position in January 1836, when the ship is near New South Wales (Australia).⁴⁶ The transformism appears in the *Red Notebook*, which he wrote during the last part of the trip and he continued in March 1837, when he was back in Great Britain. In his notes from the spring 1837 to the autumn of 1838 he adopts two successive kinds of transformist hypotheses: the isolationist version and the transmutation quasi-Lamarckian (*Notebook C*). Later, in the last months of 1838, he reaches the principle of "natural selection," after one year and a half thinking of the transmutation of species. Therefore, after being fixist, Darwin moves on to the natural selection in his third transformist conception.

Consequently, he does not arrive at his theory of evolution devoted to natural selection in an instant, after reading Thomas Malthus (1766-1834) in September 1838.⁴⁷ Nevertheless, the

⁴⁴ This case has been studied by a wide number of specialists, among them HIMMELFARB, G., *Darwin and the Darwinian revolution*, Morton, N. York, 1968; MOOREHEAD, A., *Darwin and the Beagle*, Crescent Books, N. York, 1969; GILSON, E., *D'Aristote à Darwin et retour*, Vrin, Paris, 1971; HULL, D. L., *Darwin and His Critics: The Reception of Darwin's Theory of Evolution by the Scientific Community*, Harvard University Press, Cambridge, 1973; GRINNELL, G., "The Rise and Fall of Darwin's First Theory of Transmutation," *Journal of the History of Biology*, v. 7, (1974), pp. 259-273; GILLESPIE, N. C., *Charles Darwin and the Problem of Creation*, The University of Chicago Press, Chicago, 1979; RUSE, M., *The Darwinian Revolution*, The University of Chicago Press, Chicago, 1979; OSPOVAT, D., *The Development of Darwin's Theory (Natural History, Natural Theology and Natural Selection, 1838-1859)*, Cambridge University Press, Cambridge, 1981; SULLOWAY, F. J., "Darwin's Conversion: The Beagle Voyage and its Aftermath," *Journal of the History of Biology*, v. 15, (1982), pp. 325-396; TEMPLADO, J., *Historia de las teorías evolucionistas*, Alhambra, Madrid, 1982; BOWLER, P. J., *Evolution: The History of an Idea*, University of California Press, Berkeley, 1983; GRINNELL, G., "The Rise and Fall of Darwin's Second Theory of Transmutation," *Journal of the History of Biology*, v. 18, (1985), pp. 51-70; KOHN, D. (ed.), *The Darwinian Heritage*, Princeton University Press, Princeton, 1985; and HODGE, J., "London Notebook Programmes and Projects of Darwin's London Years," pp. 40-68.

On this topic, a balanced and very informative book is CASTRODEZA, C., *Teoría histórica de la selección natural*, Alhambra, Madrid, 1988. A wide bibliography on the topic is compiled in BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, pp. 365-422. Additional bibliographical information can be found in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, pp. 424-460.

⁴⁵ In addition to what Darwin saw during his long trip, he was also influenced by scientific voyages made by naturalists, cf. DROUIN, J.-M., "De Linné à Darwin: Les voyageurs naturalists," in SERRES, M. (ed.), *Éléments d'histoire des sciences*, Bordas, Paris, 1989, pp. 321-335.

⁴⁶ Cf. GRUBER, H. E., *Darwin on Man (A Psychological Study of Scientific Creativity)*, Wildwood House, London, 1974, p. 438. In his letter to his friend Joseph Hooker, dated 11 January 1844, Darwin recognizes that he has changed his mind and he has abandoned his original opinion about the species as immutable: "At last gleams of light have come, and I am almost convinced (quite contrary to the opinion I started with) that species have not (it is like confessing a murder) immutable."

⁴⁷ Cf. HODGE, J. and RADICK, G., "Introduction," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 8; and WATERS, C. K., "The Arguments in the Origin of Species," pp. 118-119. Darwin read the sixth edition of Malthus's book, published in 1826.

latter's book *Essay on the Principle of Population* (1798)⁴⁸ was very influential for the notion of "the struggle for existence."⁴⁹ But Darwin's conceptual change was not straightforward: his approach to the idea of natural selection is not completely mature until 1844, when he finishes an essay of 200 pages on the topic, which he enlarges in the years 1856-1857. And the principle of "evolution" is not in the first edition of *The Origin of Species*:⁵⁰ it appears in the sixth edition of the book, which was published ten years later (1869).⁵¹

Moreover, Darwin does not include the word "evolution" in any of the titles of the fifteen chapters of *The Origin of Species*, and later, in his famous book *The Descent of Man* (1871), the term "evolution" is not in the title of a single chapter. Furthermore, in the brief synopses that he prepared for each one of these chapters (thirty-six including both books), as a summary after the titles of the chapters, there is no mention of "evolution." The reason is clear: his intellectual conceptual change lies on the theory of modification of species through *natural selection*, and it is only after many years that he calls it "evolution."⁵² These facts help us to understand that Darwin's conceptual change was made slowly: from his fixism of 1836 to his evolutionism of 1869 there is a period of 33 years.

Organic or biological *evolution* in Darwin's approach possesses some central components after his conceptual change. a) All the species that ever lived on earth—including present ones— may form a single tree of life. Thus, there are common ancestral species. b) Natural selection is the key mechanism—the main cause or agency— responsible for all divergence on earth, which involves an adaptive and progressive change from ancestral to descendant species.⁵³ c) Sexual selection is the secondary mechanism. "This was an idea that Darwin had had from the first—organisms compete within the species for mates, and thus adaptations like the peacock's tail are produced."⁵⁴

⁴⁸ MALTHUS, TH. R., *An Essay on the Principle of Population as it affects the Future Improvement of Society, with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers*, J. Johnson, London, 1798. Reprinted by the University of Michigan Press, Ann Arbor, 1959.

⁴⁹ Cf. BOWLER, P. J., "Malthus, Darwin, and the Concept of Struggle," *Journal of the History of Ideas*, v. 37, (1976), pp. 631-650. From the point of view of the internal configuration of evolutionary theory, Darwin is seen commonly as supporting three main elements: a) variability in terms of differences among individuals of the same population; b) a scarcity of resources for the level of development of population (a Malthusian influence); and c) heritability of the differential features. Following these elements is the natural selection of the fittest and descent with modification that involves adaptation.

⁵⁰ "Nowhere in the first edition of the *Origin* can the phrases 'theory of evolution' or 'principle of evolution' be found, nor even the word 'evolution,'" GAYON, J., "From Darwin to Today in Evolutionary Biology," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 242.

⁵¹ "Now things are wholly changed, and almost every naturalist admits the great principle of evolution," DARWIN, CH., *The Origin of Species*, The University of Chicago Press, Chicago, 1952, ch. xv, p. 241.

⁵² In fact, the word "evolution" changes its sense and reference. Before the evolutionism, it was understood as the opposite to "involution," related to both an organism and its characteristics (which can e-volve or in-volve); whereas with Darwin and others the term "evolution" moves on to mean the modification of the reality itself to form a different thing (a new species), which includes some kind of selection.

It was a change of meaning from "unfolding" to "epigenesis." Early in the 19th century, several embryologist began to use "evolution" in the sense of "epigenesis." This epigenetic sense was then extended to the history of species. Spencer was the philosopher who gave this epigenetic sense of evolution its full meaning in all areas of knowledge (around 1850s).

⁵³ Cf. HODGE, J. and RADICK, G., "Introduction," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 3.

⁵⁴ RUSE, M., *Darwinism and Its Discontents*, p. 17.

Within Darwin's evolutionism, some previous ideas on "evolution" seem to be somehow assumed: i) the feature of *complexity* in nature, because he recognizes "the infinite complexity of the relations of all organic beings"; ii) the assumption of *variability* in nature due to internal mechanisms (in his case, biological and focused on natural selection); iii) the characteristic of a modality of *progressiveness*, insofar as the struggle for life can produce the survival of the fittest (within a tree of life, which is not linear in any relevant sense); and iv) the trait of a sort of *hierarchy* in the natural world, which can come about from the survival of the sophisticated forms (which involves that less improved forms will go to extinction).⁵⁵

Where Darwin seems to succeed is in presenting evolution *as a fact* rather than in arguing on natural selection as the key mechanism of this process.⁵⁶ He "does not separate out the argument for the fact of evolution from his argument for his mechanism of evolution, but focusing on the fact, we can see that there are three strategies. First, Darwin turns to the world of the animal and plant breeder to convince us that significant change can in fact occur, and that we ought to accept the analogy that significant change can and does occur in nature. Second, Darwin presents his mechanism of natural selection, with the implication that if a mechanism as strong and powerful as this is always operating, there has to be some effect, and this effect will be full-blown evolution. Third, Darwin goes through the whole gamut of biological areas of inquiry, showing that they are explained by evolution and, conversely, that they support evolution."⁵⁷

However, compared with other biologists of his times, there is little change in Darwin's approach on matters of methodology related to *experimentation*. In this regard, it is sometimes seen as amateur. Moreover, Ruse considered that Darwin had "crude ways of experimentation —after all, back then biology was often pretty primitive in these respects, with little more than a scalpel and a rule—."⁵⁸ In addition, it is the case that, "especially in the *Origin*, he writes for a general audience rather than just for specialists."⁵⁹ But he was able to see the big problem for evolution: the final cause, and he offered conceptual novelties in order to characterize naturalistically the final cause of evolution.⁶⁰ In this regard, he was a "philosophical naturalist."

1.3. An Intellectual Revolution

Has Darwin introduced a "scientific revolution" with his evolutionist approach? This question depends directly on the issue of how a "scientific revolution" is characterized. *Prima*

⁵⁵ Some of these ideas are developed in CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, University of Rochester Press, Rochester, NY, 1996, pp. 8-12. Cf. DARWIN, CH., *The Origin of Species*, facsimile edition, Harvard University Press, Cambridge, MA, 1964, pp. 61, 80-81 and 470-471.

⁵⁶ "Natural selection has been the main but not exclusive means of modification," DARWIN, CH., *The Origin of Species*, facsimile edition, p. 6.

⁵⁷ RUSE, M., *Darwinism and Its Discontents*, p. 27.

⁵⁸ *Darwinism and Its Discontents*, p. 22.

⁵⁹ RUSE, M., *Darwinism and Its Discontents*, p. 22.

⁶⁰ Some authors think that Darwin's conception can be seen as a teleological view, cf. RICHARDS, R. J., *The Meaning of Evolution: The Morphological Construction and Ideological Reconstruction of Darwin's Theory*, The University of Chicago Press, Chicago, 1992. But this is seen commonly in a different way.

facie the revolution in science, understood as a human activity, might be conceptual, empirical or heuristical. In this deep scientific change, there may be internal elements (language, structure, knowledge, method, etc.) as well as external factors (social, cultural, etc.).

Certainly this problem has been discussed at length in the case of Thomas Kuhn, who proposed an initial characterization of scientific revolutions and later on offered a more elaborated version (at least, it is less radical in matters of “incommensurability”).⁶¹ But his well-known views on scientific revolutions have been criticized in different ways, for philosophical and methodological reasons —connected with his original embracement of relativist positions— as well as because of considerations of history of science.⁶² In this regard, the alternative to scientific revolutions suggested by Thagard is especially relevant.

1.3.1. *Conceptual Revolution in a Historical Context*

Paul Thagard offers a different view of revolutions in science from the Kuhnian approach. He presents a theory of *conceptual revolutions* to illuminate some historical cases: the development of Copernicus’ theory of the solar system, Newtonian mechanics, Lavoisier’s oxygen theory, Darwin’s theory of evolution, Einstein’s theory of relativity, quantum mechanics, and the geological theory of plate tectonics.⁶³ It seems to me a more sophisticated analysis than the Kuhnian approach, insofar as the focus is now on “conceptual revolutions” and there is a more detailed account of conceptual changes in science. Nevertheless, this perspective also shows several deficiencies. Thus, some new elements should be aggregated in order to compare the real science, as it was, with this new framework for scientific revolutions.⁶⁴

Here the focus is on the analysis of Darwinian revolution,⁶⁵ which appears many times in the book.⁶⁶ In my judgment, it requires a reformulation to be completely in line with the historical facts that made it a conceptual revolution. In other words, the additional information is used to show the need for a wider historical support to sustain his position, because the study of history of science reveals that the conceptual revolutions are more complicated than are described in the book. (In fact, Thagard himself recognizes this

⁶¹ Cf. KUHN, TH. S., *The Structure of Scientific Revolutions*, The University of Chicago Press, Chicago, 1962 (2nd ed., 1970); and KUHN, TH. S., *The Road Since Structure. Philosophical Essays, 1970-1993, with an Autobiographical Interview*, edited by James Conant and John Haugeland, The University of Chicago Press, Chicago, 2000.

⁶² Cf. GONZALEZ, W. J., “Las revoluciones científicas y la evolución de Thomas S. Kuhn,” in GONZALEZ, W. J. (ed.), *Análisis de Thomas Kuhn: Las revoluciones científicas*, Trotta, Madrid, 2004, pp. 15-103; and MACHAMER, P. K., “Las revoluciones de Kuhn y la Historia ‘real’ de la Ciencia: El caso de la revolución galileana,” in GONZALEZ, W. J. (ed.), *Análisis de Thomas Kuhn: Las revoluciones científicas*, pp. 253-273.

⁶³ Cf. THAGARD, P., *Conceptual Revolutions*, Princeton University Press, Princeton, 1992.

⁶⁴ Cf. GONZALEZ, W. J., “Towards a New Framework for Revolutions in Science,” pp. 607-625.

⁶⁵ There are also criticisms on the existence of a “Darwinian revolution.” For Peter J. Bowler, we have an evolutionary revolution rather than a Darwinian revolution, insofar as the idea of “evolution” was accepted soon whereas “natural selection” was acknowledged later on (within the 20th century). Cf. BOWLER, P. J., *The Non-Darwinian Revolution. Reinterpreting a Historical Myth*, Johns Hopkins University Press, Baltimore, MD, 1988. Nevertheless, this is not the most frequent analysis.

⁶⁶ After A. Lavoisier, Ch. Darwin is the author most often quoted in Thagard’s book: he appears in forty-five pages. On the historical context of Lavoisier, cf. BENSUADE-VINCENT, B., *Lavoisier. Mémoires d’une révolution*, Flammarion, Paris, 1993.

complexity and the need of a better model.)⁶⁷ Thus, some philosophical comments are added to clarify the conceptual revolutions and to link them with scientific progress. So the first step here is to offer some key points to the historical reconstruction of the appearance of the theory of evolution, which will be followed by a philosophical evaluation of the conceptual changes introduced by Darwin.

To be sure, this case has similarities with Antoine Lavoisier's conceptual revolution, because —according to Thagard's analysis—⁶⁸ the mature theory of the 1780s was preceded by three previous attempts (1772, 1774 and 1777), and it is clear that no scientist is an island: the development of the scientific ideas is made in a social context.⁶⁹ In the case of the chemical revolution, as well as in the biological revolution, the conceptual change was the result of theoretical and empirical work of years, and the revolution was not something sudden (a kind of Kuhnian psychological conversion).

Lavoisier and Darwin did not offer a satisfactory explanation of their discoveries in their first moments: they reinterpreted their empirical observations as they got new concepts. Both authors have a direct dependence on their times, because they belong to an intellectual atmosphere where some scientists have —to some extent— similar ideas (or, at least, they coincide in rejecting some important scientific views) and, at the same time, both work taking into account the theoretical and empirical contributions of their contemporaries. They produce a *conceptual innovation*, adding something relevant that their contemporaries have not realized and, therefore, their contributions became *revolutionary*.

According to Thagard, "Darwin's theory of evolution must be seen as a direct challenge to the creationist views of his contemporaries."⁷⁰ This background should be analyzed in the context of the intellectual climate of nineteenth century that Charles receives. Although the book highlights the influence upon Darwin of several authors in favor of transmutation of species (such as Erasmus Darwin; Jean Baptiste de Monet, chevalier of Lamarck; or Robert Chambers) and Thagard stresses the striking influence of Thomas Malthus upon Charles Darwin, to complete the image of this period requires emphasis on other influences which make the slow Darwinian conceptual change understandable.

In effect, it is a historical fact that when Darwin is thinking of "natural selection" there was an intellectual tradition which is different from fixism and in favor of *transmutation* of species (although it was not dominant during this period and Darwin contributed to making it more respectable). This tradition has a repercussion: it changes the way of thinking about the problem under discussion, not only in the line of Darwin's natural selection —in *The Origin*—, which includes "struggle for existence" as a component within it, but also in the perspective of Alfred Russel Wallace's struggle for life. Thus, Darwin's ideas were

⁶⁷ "I expect someday we will have computational models of reasoning and learning that are rich enough to provide a much more detailed account of the conceptual generation displayed in Darwin's notebooks," THAGARD, P., *Conceptual Revolutions*, p. 135.

⁶⁸ Cf. THAGARD, P., *Conceptual Revolutions*, pp. 39-46.

⁶⁹ Thagard himself points out this aspect in a recent paper, applying it to the chemical revolution: "Lavoisier had numerous teachers, friends, and associates who contributed to the development of his ideas," THAGARD, P., "Mind, Society and the Growth of Knowledge," *Philosophy of Science*, v. 61, (1994), p. 636.

⁷⁰ THAGARD, P., *Conceptual Revolutions*, p. 132.

not unthinkable for other scientists of his times and the conceptual panorama regarding the biological species has more ingredients than the pure contrast between a creationist fixist of theological character (William Paley) and an evolutionist critic with creationism (Charles Darwin).

De facto, Darwin has more similarities with his contemporaries than is suggested by Thagard, and important scientists who had direct relationships with Darwin are not mentioned in *Conceptual Revolutions*. This is the case of Charles Lyell (1797-1875), whose book *The Principles of Geology* (1830) has a strong influence on Darwin during the *Beagle* voyage.⁷¹ Both dislike the interference of the orthodoxy of the Anglican Church on scientific matters, and they share a common interest for geology, which has a repercussion on Darwin, who thought that the problem of the origin of species was of a geological character. Lyell's geology formed an essential framework for Darwin's conception: he got from Lyell the idea of continuous change in nature, although Lyell himself linked this with a steady-state viewpoint, which is clearly different from progressive evolution.⁷²

There are also certain affinities between Darwin—at least in a period of his intellectual heritage—and some authors of the nineteenth century, most of whom do not appear in Thagard's book: they are naturalists in favor of some kind of transformism, such as Giovanni B. Brocchi (1772-1826),⁷³ Etienne Geoffroy Saint-Hilaire (1772-1844), Christian L. von Buch (1774-1853), Augustin P. De Candolle (1778-1841), Lorentz Oken (1779-1851), or William Yarrell (1784-1856).⁷⁴

Furthermore, Darwin is influenced by several scientists, initially fixists and later transformists, such as Edward Blyth (1810-1873)⁷⁵ and William B. Carpenter (1813-1885).⁷⁶

⁷¹ In the autumn of 1831, Darwin encountered the first volume of Lyell's *Principles of Geology* when the *Beagle* was preparing for the voyage. Lyell gave in it reasons to explain the failure of the schools of geology to deal with the geological history of earth. The second volume of *Principles of Geology* (1832), related to Lamarckism and the birth and death of species, arrived in Montevideo (Uruguay) in late 1832. The third volume of the book, where there are reflections on the causes of geological change, was received in the Falklands Islands in spring 1834. Cf. SLOAN, PH. R., "The Making of a Philosophical Naturalist," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, Cambridge University Press, Cambridge, 2003, pp. 25-27. Lyell's book, insofar as it is related to living beings as agents of geological configuration, was important in making Darwin think how new species arise.

⁷² Cf. BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 21.

⁷³ The Italian historical geologist Giovanni B. Brocchi "explained the extinction of species as [being] due to the exhaustion of a finite quantity of life force. On the Brocchian view, species extinction was thus dependent on internal causes, on analogy with the eventual extinction of a vegetative lineage propagated from an apple tree." SLOAN, PH. R., "The Making of a Philosophical Naturalist," p. 31.

⁷⁴ Cf. HODGE, J., "London Notebook Programmes and Projects of Darwin's London Years," pp. 51, 54 and 61.

⁷⁵ "Several naturalists have been credited with anticipating the discovery of natural selection, principally, William Charles Wells, Patrick Matthew, and Edward Blyth (...). The notebooks confirm the fact that there was no crucial input from these sources, and it is doubtful if any of these so-called precursors of selectionism anticipated the true spirit of Darwin's theory," BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 165.

⁷⁶ "St. George Jackson Mivart claimed (...) that resemblances among various branches of evolution defy natural explanation (1871;...). Mivart insisted that such parallel developments must result from predispositions to evolve in certain directions imposed on life by its Creator. The physiologist William Benjamin Carpenter tried to substantiate this belief on a smaller scale by demonstrating what appeared to be regular patterns of evolution in shells of minute sea creatures, the Foraminifera (1888)," BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 225.

There are others in favor of evolutionism in some way close to Darwin, such as Thomas H. Huxley (1825-1895) or Herbert Spencer (1820-1903). These historical factors are relevant to this scientific revolution: the whole story of the Darwinian revolution is more multifaceted and intricate than the mere controversy with one specific kind of creationism (the fixist sort developed by Paley).⁷⁷

Looking at Darwin's historical context there is a motley intellectual atmosphere rather than a uniform panorama: on the one hand, the presence of a fixist tendency can be found in relevant scientists (G. Cuvier, R. Owen,⁷⁸ W. Whewell, J. L. R. Agassiz, ...), with important differences in their positions; and, on the other hand, there is also a group of authors favorable towards some kind of transformism (either creationist or not), such as J. B. de Lamarck, G. B. Brocchi, E. Geoffroy, R. Chambers, A. de Candolle, Ch. L. von Buch,⁷⁹ St. George Jackson Mivart,⁸⁰ H. Spencer, or A. R. Wallace.

Clearly, the Darwinian revolution belongs to this second group: it is a conceptual revolution from the point of view of rejection of fixism; and his main innovation lies in the discovery of a particular mechanism: the *natural selection*, which later on will be the touchstone of his characterization of "evolution." Thagard however focuses the issue from the point of view of the controversy with the "creationist hypothesis," instead of emphasizing the conceptual revolution made by Darwin in rejecting fixism in biology—and, therefore, in introducing the transmutation of species according to natural selection—. Thus, his historical sketch should be completed more precisely.⁸¹

Obviously, there is no doubt that *The Origin of Species* and, in general, the Darwinian view on evolution is *de facto* incompatible with two forms of *creationism*: the strictly fixist, in which the species separately created cannot give rise to a new one—there is only a change for new varieties—, because the biological design would be completely prefigured; and the moderately fixist, in which the Creator could have a more or less frequent intervention in generating new species. Neither case matches with a biological evolution by natural selection.⁸²

However, evolutionism is compatible with biological theories which, inspired in the idea of "creation," accept the presence of biological laws and tendencies initially

⁷⁷ This historical context does not affect the originality of his conceptual innovation, because Darwin did not borrow the idea of natural selection from an earlier writer.

⁷⁸ "Owen did not accept natural selection and wrote such a bitterly critical review of the *Origin of Species* that many historians have dismissed him as an outright opponent of evolution. There is still some debate over the true state of Owen's opinions on this score," BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, p. 133.

⁷⁹ L. von Buch wrote on the flora of the Canaries (*Physikalische Beschreibung der Canarische Inseln*, 1825), and he is quoted in the correspondence between A. R. Wallace and Ch. Darwin in 1860.

⁸⁰ St. George Jackson Mivart was "a Catholic zoologist who admitted the evolution of organic forms and the existence of natural selection, but opposed Darwin in two points: first, Mivart believed that evolution occurred by sudden changes; second, he thought that the major evolutionary factor was an internal tendency to vary in a given direction, rather than natural selection alone," GAYON, J., "From Darwin to Today in Evolutionary Biology," p. 243.

⁸¹ Cf. THAGARD, P., *Conceptual Revolutions*, pp. 131-135.

⁸² In addition to this incompatibility, there is another difference in the scope: Darwin's views are related to *existing* species rather than to the question of what the *origin* as such was; an issue which those positions thought of as basic.

put in nature by the Creator, according to which new species can appear following the mechanisms of natural selection (as well as other mechanisms of biological change that may be discovered). This possibility, which Thagard admits does not contradict Darwin's position,⁸³ should lead us to discuss the problem in more cautious terms than in the book *Conceptual Revolutions*.⁸⁴

Thagard avoids duplicating the excellent narratives that historians of science have provided. The emphasis is on furnishing a new *cognitive perspective* of scientific revolutions. But, regarding the characterization of the theory that is abandoned after the revolution, there is a noticeable difference between the presentations of Lavoisier's and Darwin's revolutions. In the case of chemistry, the theory appears as a fully developed one and so Georg Stahl's phlogiston theory could be seen as a serious competitor for Lavoisier's oxygen theory; whereas, in the case of biology, the situation looks quite different: besides Darwin the book includes another theory but it does not seem to be a real competitor. Table 6.1. shows this phenomenon in a very expressive way: in Darwin there are 15 pieces of evidence, 3 main hypotheses, 3 auxiliary hypotheses and 7 facts;⁸⁵ meanwhile the other position—which Thagard calls “creationist hypothesis”—has only a single proposition. If we go back to the input propositions for Lavoisier example (table 4.1.),⁸⁶ there are 6 oxygen hypotheses and also 6 phlogiston hypotheses.

To understand the striking difference between Thagard's presentation of the chemical revolution and the *biological revolution*, there are several possibilities, two of which are principal: 1) that the creationism pointed to (William Paley) was effectively a poor scientific theory; and 2) that the debate should be reformulated in a different way. Thus, instead of comparing the evolutionist position with a theological conception (such as Paley's Natural Theology), Darwin's evolutionism should be compared with another scientific view, such as Georges Cuvier's *fixism* (which maintains that the organisms based on similarity include fixed species)⁸⁷.

It is well known that Darwin criticized the “creationism” of his times. In addition, evolutionism and creationism (updated nowadays as “intelligent design” view)⁸⁸ are usually delivered as antithetic positions. Thagard relies on this for his alternative. But he also recognizes it as a historical fact that Darwin was not against the idea of creation, insofar as “the sixth edition of the *Origin* contains, in its eloquent final paragraph, a reference to the Creator that was not in the first edition.”⁸⁹ And the sixth edition is especially important because there he uses the term “evolution” which does not appear in the first edition.

About the second possibility—to reformulate the positions of the debate in a different way—, several theoretical arguments can be offered. To some extent, they are based on

⁸³ Cf. THAGARD, P., *Conceptual Revolutions*, p. 136.

⁸⁴ In this regard, cf. BOWLER, P. J., *Evolution: The History of an Idea*, revised edition, pp. 169-170.

⁸⁵ Cf. THAGARD, P., *Conceptual Revolutions*, p. 143.

⁸⁶ Cf. *Conceptual Revolutions*, p. 83.

⁸⁷ Among Cuvier's books, *Le Règne animal distribué d'après son organization*, published in 1817, had a very important repercussion in his time.

⁸⁸ Cf. BEHE, M., *Darwin's Black Box: The Biochemical Challenge to Evolution*, Free Press, N. York, 1996.

⁸⁹ THAGARD, P., *Conceptual Revolutions*, p. 136.

ideas of Thagard himself. He accepts implicitly that creationism and evolutionism are compatible when he asserts that today “creationists who deny biological evolution are on the fringes of science.”⁹⁰ Creationism is then a theological or a philosophical conception rather than a scientific position; for this reason, it is possible to be creationist and evolutionist at the same time, because they belong to two different levels of analysis.⁹¹

From this point of view, the dichotomy of “natural selection”-“divine creation” is not correct, because natural selection could be the result of a divine creation. Again, this is pointed out by Thagard: “one can always maintain that it was God who created the universe with laws that eventually resulted in natural selection and biological evolution.”⁹² Thus, what he really rules out is *a* historical conception of creationism embedded of fixism (Paley’s theory of 1802) rather than *the* compatibility between creationism and evolutionism, insofar as the former is a philosophical (or theological) option and the latter is a scientific position.

1.3.2. Philosophical Remarks

Philosophically, the alternative built up by Darwin against the biological fixism as well as the time that he spent in order to set up his own position could be presented as a very illustrative case of *conceptual revolution*. In my judgment, the reconstruction of his intellectual itinerary —mainly for getting “natural selection” as a biological mechanism— and the interrelation with other contributions of his time, can teach us several things for a general perspective on “conceptual revolutions” in science.

1) In principle, the new scientific concepts, although they introduce novelty, are not, as such, completely and radically new, insofar as there are some previous or contemporary ideas compatible with the new concepts which can help us to accept them (or, at least, to make them more acceptable when another scientific tradition —or “research program”— is still in vigor). 2) The conceptual change requires a time of maturation (it is not something “instantaneous”), because it needs solid support —theoretical and empirical— before the substitution of the old theory by the new one is made.

3) The justification of the new concepts should not be made only in comparison with the antagonist concepts (in this case, the fixism based on Paley’s Natural Theology) but also taking into account views close to the revolutionary author, even though these views may not be dominant in that period. Thus, some scientific revolutions could be less “revolutionary” than they appear *prima facie*.⁹³ The scientific revolution requires *conceptual novelty*, but this may arise from a modification of other concepts that are in use by other authors. (And it is also possible to discover very close concepts by scientists working on their own, such as —to some extent— Wallace and Darwin, or even to get completely compatible and convergent concepts, such as Newton and Leibniz).

⁹⁰ *Conceptual Revolutions*, p. 132.

⁹¹ Many biologists assume this compatibility between these two levels of analysis in their everyday lives.

⁹² THAGARD, P., *Conceptual Revolutions*, p. 136. Periodically there are scientists who accept views along those lines, such as Francis S. Collins: “there is nothing inherently in conflict between the idea of a creator God and what science has revealed,” COLLINS, F., *The Language of God*, Free Press, N. York, 2006, p. 81.

⁹³ This is one of the reasons why the issue itself of a “revolution” introduced by Darwin has been discussed, cf. RUSE, M., *Darwinism and Its Discontents*, pp. 5-6 and 23-24.

4) A key point of the new conceptual system is its link with the *reality* and its attempt to grasp an *adequacy* with reality (and this requires it to be closer to the information available about the world than its competitors), because the conceptual systems have reality as the last bedrock. Thus, the concepts are not pure “constructions” or mere “mental representations,” rather they are intellectual elements leading to grasping the reality with a higher level of reliability than the possible alternatives.

Interestingly enough, Thagard insists on Darwin as *realist*.⁹⁴ His successive attempts to innovate a conceptual system to grasp the biological transformism could be understood in realist terms: the *concepts* have a cognitive character and seek to know better reality as it is. Thus, the concepts grasp real aspects of the biological world, and the change for new concepts is made by thinking of how to correct our knowledge of that reality (to know more elements or to know them in a better way). Therefore, the concepts are under revision but they have an objective dimension based on the reality itself that is intellectually possessed. The conceptual change has a *progressive* component: to increase our knowledge of the world, not only from a quantitative point of view but also from a qualitative one.

Through the conceptual change there is an *innovation* that contributes to progress in science. This improvement is not a *purely* conceptual advancement, because the revolutions are made in science by looking at the intellectual domain of the reality, which opens the door to new practices: the reality —the world as it is— has the last word in accepting or rejecting new concepts. Within this framework, progress in science is neither a pure continuity, as the neopositivists thought, nor the succession of incommensurable paradigms, as Kuhn suggested in the first version of his methodological position.⁹⁵

Even though Thagard avoids the excesses of neopositivists and Kuhn, because he is closer to history of science and describes conceptual changes in science more carefully, his new cognitive perspective is still defective due to the notion of “concept.” As I have been emphasizing, there is an *objective* element in the concepts which makes scientific progress understandable and puts aside the reductive scheme of logical neopositivism (which confuses the level of sense and meaning with what should be the realm of truth, making the historical revision of concepts in the cognitive process to increase our knowledge of reality very difficult) as well as the relativistic structure of the Kuhnian scientific revolutions (which transforms the advancement of scientific concepts in a psycho-sociological task where rationality in science gives way to a historicist position that does not guarantee the commensurability of theories).

Whereas Thagard’s new cognitive perspective is right in stressing the role of concepts in scientific revolutions, his understanding of conceptual revolutions comes up against the problem of what “concept” is, because he reduces it to “mental representation” instead

⁹⁴ Cf. THAGARD, P., *Conceptual Revolutions*, p. 149.

⁹⁵ On the notion of “progress” in science, cf. GONZALEZ, W. J., “Progreso científico, Autonomía de la Ciencia y Realismo,” pp. 91-109. Scientific progress requires at least the interrelation of the semantical, epistemological and methodological levels in science. See also GONZALEZ, W. J., “The Philosophical Approach to Science, Technology and Society,” in GONZALEZ, W. J. (ed.), *Science, Technology and Society: A Philosophical Perspective*, Netbiblo, A Coruña, 2005, pp. 3-49.

of accepting an objective dimension of cognitive character.⁹⁶ This limitation affects his description of conceptual changes and weakens his alternative to Kuhnian scientific revolutions. (Moreover, Kuhn's view on concepts has attracted the attention of authors within the cognitive approach.)⁹⁷

Undoubtedly, the concepts are more than mental representations of the reality: they seek to grasp objectively the reality itself, even though from a perspective which does not allow an exhaustive knowledge.⁹⁸ Thus, scientific progress is also due to the intelligibility of the reality and concepts look for the variability of the real processes. Reality has then a strong role, which in the case of the theory of evolution has been suggested by John Maynard Smith: "it was in fact the similarities between different kinds, or species, of animals and plants, similarities which make a natural classification possible, which led Darwin, Lamarck, and others to seek an evolutionary explanation of the origin of species, just as it was the fact of adaptation which suggested to them theories as to how evolution might take place."⁹⁹

Following this analysis of conceptual revolutions, which combines historical and philosophical arguments, it is clear that Thagard's views require some revisions. A key issue is that the conceptual change in science is more complicated than *Conceptual Revolutions* maintains; and, therefore, there is an intrinsic difficulty in obtaining an algorithm that could be capable of grasping the diversity of nuances of a conceptual change. In fact, the book offers a *scheme* of a revolutionary conceptual change rather than a complete description of a real conceptual revolution. Thus, the computational model of theory evaluation—the connectionist computer program called ECHO—can only handle some aspects of a revolutionary conceptual change: it is a schematic presentation of a complex interrelation of factors which intervene in a conceptual revolution. The historical reconstruction of cases such as Darwinian revolution gives rise to problems for a theory of explanatory coherence implemented by a computational model of theory evaluation.

1.4. Other Evolutionisms

Besides Darwin's approach, there are several versions of evolutionism. Some of them are focused on the "tree of life," whereas others insist on the kind of process for evolution. Since the publication of *The Origin of Species*, a large number of biologists have become convinced of evolution as a fact. But a different issue was how to understand the structure of life and the acceptance of natural selection as the main mechanism of evolution. "Mayr lists

⁹⁶ After publishing *Conceptual Revolutions*, Thagard has continued insisting on the concepts as mental representations when he explains the acquisition of the new scientific schemes. For him, the new mental representations enable us to understand the scientific revolution and to appreciate the greater explanatory coherence of the new theory (such as in the case of the Lavoisier's oxygen theory). Cf. THAGARD, P., "Mind, Society and the Growth of Knowledge," pp. 637-638.

⁹⁷ Cf. BARKER, P., CHEN, X. and ANDERSEN, H., "Kuhn on Concepts and Categorization", in NICKLES, TH. (ed.), *Thomas Kuhn*, Cambridge University Press, Cambridge, 2003, pp. 212-245; and NERSESSIAN, N. J., "Kuhn, Conceptual Change, and Cognitive Science", in NICKLES, TH. (ed.), *Thomas Kuhn*, pp. 178-211.

⁹⁸ On the characteristics of "concepts," cf. GONZALEZ, W. J., "El empirismo moderado en Filosofía Analítica: Una réplica a P. F. Strawson," in FALGUERA, J. L., ZILHÃO, A. J. T., MARTÍNEZ, C. and SAGÜILLO, J. M. (eds.), *Palabras y pensamientos: Una mirada analítica*, Publicaciones Universidad de Santiago, Santiago de Compostela, 2003, pp. 207-237; especially, pp. 230-233.

⁹⁹ MAYNARD SMITH, J., *The Theory of Evolution*, Cambridge University Press, Cambridge, 1993, p. 38.

five types of evolution theories that were functioning between 1860-1940 —Geoffroyism, orthogenesis (including original Lamarckism), saltationism (including Mutation theory), Darwinism, and neo-Darwinism. He says ‘most authors between 1860 and 1940 adopted a mixture of these theories’. Peter Bowler adds one more, theistic evolution, where the process is directed by God.”¹⁰⁰

1.4.1. From the “Tree of Life” to the Process of Evolution

There were two main ideas in *The Origin of Species*: the tree of life and natural selection (understood as evolutionary process). In relation to the first idea, “species change over time, with some species going extinct while others continue or split into multiple descendent species. Darwin illustrated the resulting pattern as diverging branches of a tree. The second idea, natural selection, offered an account of how species could change. According to this idea, species change through a process of selection akin to the method of artificial selection that breeders used to modify domesticated varieties of plants and animals.”¹⁰¹

Both ideas —the tree of life and natural selection— were in some way or another challenged by a large number of scientists. Historically, “many if not most nineteenth —and early twentieth— century evolutionists remained highly sceptical of natural selection.”¹⁰² This means that criticism of Darwinism did not come only from outside the evolutionist trend, because it was the case that variation and the role of natural selection were among the topics discussed by supporters of versions of evolutionism.¹⁰³

An initial point of criticism to this evolutionist conception was recognized by Darwin himself: his theory of evolution does not provide an account of the *origin of variations*. His view was in favor of random, small and continuous changes. For the position of “orthogenesis,” there were two options on how the changes occurred, but both with variations directed instead of being part of a random process: a) variations as a product of a sort of *élan vital* —an internal drive within the organism itself— that directed species-formation; and b) variations as an outcome of environmental influences, such as climate and food supply. These options, which include the posterior work of Theilhard de Chardin, gradually faded as a significant competing theory due to the absence of convincing scientific evidence.

As second sphere of controversy on Darwinism is the precise nexus between *variations* and the *process of species formation*.¹⁰⁴ According to Darwin, natural selection moves for keeping favorable variations and eliminating unfavorable ones. This conception can be objected to in terms of the need of something else in order to explain biological

¹⁰⁰ CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, p. 26. Cf. MAYR, E., “Prologue: Some Thoughts on the History of the Evolutionary Synthesis,” in MAYR, E. and PROVINE, W. B. (eds.), *The Evolutionary Synthesis: Perspectives on the Unification of Biology*, Harvard University Press, Cambridge, 1980, pp. 5-6; and BOWLER, P. J., *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900*, Johns Hopkins University Press, Baltimore, 1983, p. 7.

¹⁰¹ WATERS, C. K., “The Arguments in the Origin of Species,” pp. 117-118.

¹⁰² “The Arguments in the *Origin of Species*,” p. 123.

¹⁰³ The analysis follows here CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, pp. 27-30.

¹⁰⁴ Regarding the process of species formation, it is particularly influential E. Mayr’s view that commonly asks for a period of geographical isolation between the populations involved.

complexity. Thomas Henry Huxley and Francis Galton —Darwin's cousin— criticized the Darwinian option, and they endorse larger variations of discontinuous kind to explain the formation of new species. "Huxley always thought new species arose by 'saltations' (large sudden changes)." ¹⁰⁵ Besides him and Galton, biologists who have advocated a non-gradual, saltationist, representation of the origin of species include the majority of early Mendelians: William Bateson, Hugo De Vries, Lucien Cuénot, Wilhelm Johannsen and, somewhat later, Richard Goldschmidt. ¹⁰⁶

Far from being forgotten, in recent decades this view has gained new supporters. This "major alternative view of descendant with modification is represented by Niles Eldredge and Stephen Jay Gould's 'theory of punctuated equilibrium,' postulating that the preponderant amount of evolutionary change is concentrated during the event of speciation or 'cladogenesis.'" ¹⁰⁷ Eldredge and Gould do not claim that change leading to a new species is so sudden that it occurs in a single generation (as some geneticists believed at the beginning of the twentieth century)." ¹⁰⁸ Taking into account palaeontological data, they think that species evolve more rapidly when they emerge from splitting than they do later on. This view alters the general Darwinian pattern of the genealogical tree.

Adaptive hypotheses assert that natural selection played a specified causal role in biological evolution. This leads towards the debate about "adaptationism," because Stephen Jay Gould and Richard Lewontin "criticised biologists for uncritically espousing 'just-so' stories about natural selection." ¹⁰⁹ They even went so far as to claim that adaptationism is unfalsifiable; since the defeat of one adaptive hypothesis allows you to invent another, there is no way to refute adaptationism as a claim about nature. Gould and Lewontin also defended a 'pluralistic' view of the evolutionary process, according to which natural selection is one, but not the only, important influence on trait evolution." ¹¹⁰

Another source of criticism is the *level of biological change*. ¹¹¹ This third sphere of controversy is "that evolution is something that does happen only at the level of the species,

¹⁰⁵ BROOKE, J. H., "Darwin and Victorian Christianity," p. 205.

¹⁰⁶ Cf. GAYON, J., "From Darwin to Today in Evolutionary Biology," p. 247.

¹⁰⁷ Cf. ELDRIDGE, N. and GOULD, S. J., "Punctuated Equilibria: An Alternative to Phyletic Gradualism," in SCHOPF, T. J. M. (ed.), *Models in Paleobiology*, Freeman, San Francisco, CA, 1972, pp. 82-115.

¹⁰⁸ GAYON, J., "From Darwin to Today in Evolutionary Biology," p. 247.

¹⁰⁹ Cf. GOULD, S. J. and LEWONTIN, R. C., "The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme," *Proceedings of the Royal Society of London*, B 205, (1979), pp. 581-598. Reprinted in SOBER, E. (ed.), *Conceptual Issues in Evolutionary Biology*, 3rd ed., The MIT Press, Cambridge, 2006, pp. 79-97.

¹¹⁰ SOBER, E., "Metaphysical and Epistemological Issues in Modern Darwinian Theory," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, pp. 282-283.

¹¹¹ There are some authors that endorse evolution without selection or consider that natural selection is a secondary cause: they see evolution as a result of a kind of regularities related to an increase of entropy. Cf. BROOKS, D. and WILEY, E. *Evolution as Entropy*, The University of Chicago Press, Chicago, 1986; WICKEN, J., *Evolution, Thermodynamics and Information*, Oxford University Press, New York, 1987; and WILEY, E. O., "Entropy and Evolution," in WEBER, B. H., DEPEW, D. J. and SMITH, J. D. (eds.), *Entropy, Information and Evolution*, The MIT Press, Cambridge, MA, 1988, pp. 173-188.

In this regard, cf. MARCOS, A., "Información y Entropía", *Arbor*, v. 140, n. 549, (1991), pp. 111-135; MARCOS, A., "Información y evolución", *Contextos*, v. 9, n. 17-18, (1991), pp. 197-221; and MARCOS, A., "Neodarwinismo, Termodinámica y Teoría de la Información: Estado de la cuestión", *Estudios Filosóficos*, v. 41, n. 117, (1992), pp. 215-252.

but also at other levels.”¹¹² It is based on a common observation in palaeontology (e.g., the various orders of mammals). In addition to the distinction between species or genera and higher level, we can consider organisms at various levels of existence, mainly as individual and group. It could be a difference in the pattern of life that involves “a potential clash between two levels, the individual and the group. (...) No one wants to deny that ‘group selection’ (to use the common name for selection making for group adaptations) can and probably does exist. (...) Generally, practicing evolutionists do not want to give group selection a very significant role.”¹¹³

More recently another relevant problem has been pointed out —the fourth— for Darwinian evolutionism. It is related to the configuration of the “tree of life.” The issue deals with the *result of the biological change*, insofar as evolution involves several processes that make the “notion of independent species lineages problematic.”¹¹⁴ The debate is on the phylogeny of the entire living world. This challenge, posed by Carl Woese,¹¹⁵ affects the classical Darwinian view of the genealogy of species, of living beings.

1.4.2. Evolutionism around “Natural Selection”

Certainly, many sympathizers of Darwinian evolutionism “accepted Darwin’s ideas of transmutation and common descent without committing themselves to natural selection. This remained a common attitude well into the twentieth century.”¹¹⁶ Thus, historically most attacks on Darwinism between the main book (1859) and the 1930s focused on the very existence of *natural selection* as a fact. This episode is known as the “eclipse of Darwinism:” the criticism of the idea that natural selection is a *cause* —in the ontological sense— of adaptive evolutionary change.¹¹⁷

Undeniably, a number of relevant difficulties for the acceptance of natural selection as the main evolutionary process were raised.¹¹⁸ 1) The absence in Darwin’s *Origin* of a theory of hereditary transmission of characters. 2) A quantitative approach (variation, rate of survival, rate of reproduction, the role of change, etc.) show a range of complexities beyond Darwin’s expectations, which lead biometricians (Karl Pearson, W. F. R. Weldon, etc.) to reformulate natural selection in statistical terms. 3) The rediscovery of Gregor Mendel’s paper on “Experiments in Plant Hybridization,”¹¹⁹ a genetic view that seemed to support saltationist mutationism rather than gradual selectionism. But the research on the *Drosophila* fly around the 1920s by Thomas H. Morgan and William Castle contributed

¹¹² GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 246.

¹¹³ RUSE, M., *Darwinism and Its Discontents*, pp. 145-146.

¹¹⁴ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 248.

¹¹⁵ Cf. WOESE, C. R., KANDLER, O. and WHEELIS, M. L., “Towards a Natural System of Organisms: Proposal for the Domains Archaea, Bacteria, and Eucarya,” *Proceedings of the National Academy of Science*, v. 87, (1990), pp. 4576-4579; and WOESE, C. R., “Default Taxonomy: Ernst Mayr’s View of the Microbial World,” *Proceedings of the National Academy of Science*, v. 95, (1998), pp. 11043-11046.

¹¹⁶ WATERS, C. K., “The Arguments in the Origin of Species,” p. 137.

¹¹⁷ Cf. BOWLER, P. J., *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900*, Johns Hopkins University Press, Baltimore, 1983.

¹¹⁸ The analysis is developed in GAYON, J., “From Darwin to Today in Evolutionary Biology,” pp. 250-254.

¹¹⁹ MENDEL, G., “Versuche über Pflanzenghybriden,” *Verhandlungen des naturforschenden Vereines in Brünn*, Bd. IV für das Jahr 1865, Abhandlungen, pp. 3-47.

to give a solution to this problem. Thus, it was a vindication of natural selection as a necessary and sufficient cause of an adaptive evolution.

Around the late 1920s and early 1930s there was a crucial impulse to evolutionism: the mathematical population genetics of Ronald A. Fisher,¹²⁰ J. B. S. Haldane,¹²¹ and Sewall G. Wright.¹²² They maintained several ideas: i) natural selection does not automatically change a population in theoretical population genetics; ii) population genetics leads to evidence of natural selection as cause for evolutionary change: H. B. D. Kettlewell's study of industrial melanism in the peppered moth;¹²³ and iii) a relevant conceptual modification was introduced: the existence of natural selection does not depend on a Malthusian principle. "For natural selection to happen, only three conditions are required: heritable variations, differential fitness and correlation between these two phenomena."¹²⁴

Regarding the support of theoretical population genetics, "modern synthesis" was the name of several disciplines at work in the 1930s and 1940s on an evolutionist path. Among them are three kinds of genetics developed by Theodosius Dobzhansky:¹²⁵ a) the new mathematical population genetics (connected with S. G. Wright); b) the cytological genetics (based on Th. H. Morgan School); and c) the experimental genetics of wild populations (built up on a Russian work on *Drosophila* flies). Dobzhansky in 1937 was clear in his support of Darwin's heritage.

A few years later—in 1947—there was another step in this direction: Julian Huxley's book *Evolution: The Modern Synthesis*.¹²⁶ His view was a revival of Darwinian lines insofar as he connected methods and available evidence of several disciplines: comparative anatomy, ecology, embryology, genetics, geographical distribution, palaeontology, etc. The idea was to emphasize natural selection as explanatory power (rather than predictive power) related to different kinds of facts. Thus, besides speciation based on morphological adaptations, Darwinism should be able to deal with geographical variation, phylogenetic trends, etc.

Initially, the "modern synthesis" was headed by Th. Dobzhansky¹²⁷ (genetics), J. Huxley and Ernst Mayr¹²⁸ (zoology), George G. Simpson¹²⁹ (palaeontology) and G. Ledyard

¹²⁰ Cf. FISHER, R. A., *The Genetical Theory of Natural Selection*, Clarendon Press, Oxford, 1930.

¹²¹ Cf. HALDANE, J. B. S., *Possible World, and Other Papers*, Chatto and Windus, London, 1927.

¹²² Several of his main papers are reprinted in WRIGHT, S., *Evolution: Selected Papers*, edited by W. Provine, The University of Chicago Press, Chicago, 1986.

¹²³ Cf. KETTLEWELL, H. B. D., "Selection Experiments on Industrial Melanism in the Lepidoptera," *Heredity*, v. 9, (1955), pp. 323-342.

¹²⁴ GAYON, J., "From Darwin to Today in Evolutionary Biology," p. 252.

¹²⁵ Cf. DOBZHANSKY, TH., *Genetics and the Origin of Species*, Columbia University Press, N. York, 1937.

¹²⁶ HUXLEY, J., *Evolution: The Modern Synthesis*, Allen and Unwin, London, 1942. Reprinted with a new introduction: J. Wiley, N. York, 1964.

¹²⁷ Later on, he published DOBZHANSKY, TH., "Chance and Creativity in Evolution," in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology, Reduction and Related Problems*, pp. 307-338.

¹²⁸ Cf. MAYR, E., *Animal Species and Evolution*, Harvard University Press, Cambridge, MA, 1963; and MAYR, E. and PROVINE, W. B. (eds.), *The Evolutionary Synthesis: Perspectives on the Unification of Biology*, Harvard University Press, Cambridge, 1980.

¹²⁹ Cf. SIMPSON, G. G., *Tempo and Mode in Evolution*, Columbia University Press, N. York, 1944; and SIMPSON, G. G., *The Meaning of Evolution: A Study of the History of Its Significance for Man*, Yale University Press, New Haven, CT, 1949.

Stebbins¹³⁰ (plant biology). Later on, after 1950, there was an expansion: Konrad Lorenz¹³¹ and Nikolas Tinbergen¹³² (ethology), David Lack, Robert MacArthur and Edward O. Wilson¹³³ (ecology), Conrad H. Waddington¹³⁴ (evolutionary biology), etc. These authors contributed to a high recognition of natural selection during the mid-twentieth century,¹³⁵ especially around 1959, a hundred years after Darwin's main book.

Overall interpretations of the modern synthesis approach are the dynamical (or "traditional") view of the theory of evolution and the statistical interpretation of this scientific theory. They share the idea that the modern synthesis approach explains evolutionary change insofar as it contributes to differentiating some phenomena of population (such as selection, drift, mutation, and migration). But the dynamic interpretation is focused on the *causes of evolution*. Thus, modern synthesis sees selection and drift as causes of population change. Meanwhile the statistical interpretation of the theory of evolution maintains that explanations of the modern synthesis only deal with *statistical structure of population*.¹³⁶

1.4.3. After 1959: Micro and Macro

Evolutionary biologists held the momentum around 1959, the centenary of the publication of *The Origin*. Since this overwhelming acceptance to the present moment, several things have happened that invited us to be more circumspect. The events of the last five decades deal with microevolution (those evolutionary changes at the level of biological species) and macroevolution (those evolutionary changes above the level of species and therefore on a larger scale). Both of them have raised questions on evolutionism, especially in the Darwinian brand.¹³⁷

As regards microevolution,¹³⁸ the problems were located in three sectors: a) the diversity of a large amount of polymorphism at the level of proteins and DNA; b) the theory of group selection and the discussion on evolutionary altruism; and c) the problem of competitive highness and the issue of complexity. Related to macroevolution, the main spheres of concern are two: 1) the difficulties in palaeobiology, and 2) the alternative proposed by "punctuated equilibria" (i.e., the proposals on the theory of evolution by Stephen Jay Gould).

¹³⁰ Cf. STEBBINS, G. L., *The Basis of Progressive Evolution*, University of North Carolina Press, Chapel Hill, 1969, and STEBBINS, G. L., "Botany and the Synthetic Theory of Evolution," in MAYR, E. and PROVINE, W. B. (eds.), *The Evolutionary Synthesis: Perspectives on the Unification of Biology*, pp. 139-152.

¹³¹ Cf. LORENZ, K., *Evolution and Modification of Behavior*, Harvard University Press, Cambridge, 1961 (published by Methuen, London, 1965).

¹³² Cf. TINBERGEN, N., *The Study of Instinct*, Oxford University Press, N. York, 1951 (reprinted in 1961).

¹³³ Cf. WILSON, E. O., *Sociobiology: The New Synthesis*, Harvard University Press, Cambridge, MA, 1975.

¹³⁴ Cf. WADDINGTON, C. H., *The Strategy of the Genes*, Allen and Unwin, London, 1957.

¹³⁵ Cf. GAYON, J., "From Darwin to Today in Evolutionary Biology," pp. 253-254, and DEPEW, D. J. and WEBER, B. H., *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection*, The MIT Press, Bradford, 1995, ch. 10-12.

¹³⁶ Cf. WALSH, D. M., "The Pomp of Superfluous Causes: The Interpretation of Evolutionary Theory," *Philosophy of Science*, v. 74, (2007), pp. 281-303.

¹³⁷ The analysis follows here GAYON, J., "From Darwin to Today in Evolutionary Biology," pp. 254-260.

¹³⁸ On microevolution, cf. AYALA, F. J., *Molecular Evolution*, Sinauer, Sunderland, MA, 1976.

Natural selection was thought of as oriented towards the increase of the fitness of the species in their relation with the environment. This advancement was understood as an adaptation. But the existence of a large amount of *polymorphism* at the level of proteins and DNA was considered as a challenge to adaptation due to natural selection. In 1968, Motoo Kimura reported that the rate at which amino acids are replaced in proteins—as they evolve—is more or less constant and, therefore, probably not under the control of natural selection¹³⁹ (understood in Darwinian terms).

What M. Kimura called “the neutral theory of protein evolution” was provocatively renamed as “non-Darwinian evolution” a year later by two molecular biologists, Thomas Jukes and Jack King.¹⁴⁰ “The constant non-adaptive ticking of amino acid substitution was then dubbed by Zuckerkandl a ‘molecular lock’ that would give biology the prestige of physics and chemistry, with atomic and other natural clocks.”¹⁴¹ At first, Darwinians were dismayed by this finding; many presumed that it must be possible, at least in principle, to assign to a unique fitness value to each amino acid. It did not take long, however, for Darwinians to recognize that neutralism is non-Darwinian only if one assumes that evolution must occur at one level alone, presumably its lowest one, and that the only force driving it is natural selection.”¹⁴²

Group selection was another debate on microevolution, which is also connected to the concerns on evolutionary altruism. The issue is directly related to the discussion on the “units of selection.”¹⁴³ The problem came from the apparent impossibility of natural selection, understood in the traditional sense, to account for some adaptive natural changes. Darwin “almost completely rejected the notion of group selection. He had a famous private controversy on the subject with Wallace.”¹⁴⁴ There is only one case where Darwin plainly admitted the existence of ‘tribal selection’, when he tried to explain the origin of moral sense in the human species.”¹⁴⁵

V. C. Wynne Edwards was an ecologist who wrote in favor of group selection. He maintained that it is possible to find some animals that expand or contract the number of their young (for example, in the case of birds) in response to the availability or scarcity of

¹³⁹ Cf. KIMURA, M., “Evolutionary Rate at the Molecular Level,” *Nature*, v. 217, (1968), pp. 624-626.

¹⁴⁰ Cf. KING, J. L. and JUKES, T. H., “Non-Darwinian Evolution: Random Fixation of Selectively Neutral Mutations,” *Science*, v. 164, (1969), pp. 788-798.

¹⁴¹ Cf. ZUCKERLAND, E., “On the Molecular Evolutionary Lock,” *Journal of Molecular Evolution*, v. 26, (1987), pp. 34-46. Genetic code has redundancy that impedes that some parts of the genome can be exposed to natural selection, insofar as—in some cases—a nucleic acid can be changed by another one without any modification in its functionality. This is also due to some parts of the proteins having almost no functional relevance. In this regard, at the molecular level there are some features that are not an outcome of natural selection.

¹⁴² GRENE, M. and DEPEW, D., *The Philosophy of Biology. An Episodic History*, Cambridge University Press, Cambridge, 2004, pp. 271-272, note.

¹⁴³ Cf. ERESHEFSKY, M. (ed.), *The Units of Evolution: Essays on the Nature of Species*, The MIT Press, Cambridge, MA, 1992; and SOBER, E. and WILSON, D. S., “A Critical Review of Philosophical Work on the Units of Selection Problem,” *Philosophy of Science*, v. 61, (1994), pp. 534-555. Reprinted in HULL, D. and RUSE, M. (eds.), *The Philosophy of Biology*, Oxford University Press, Oxford, 1998, pp. 198-220.

¹⁴⁴ On Wallace’s views, cf. WALLACE, A. R., *Studies: Scientific and Social*, Macmillan, London, 1900.

¹⁴⁵ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 255. Cf. GAYON, J., *Darwin et l’après-Darwin*, Kimé, Paris, 1992; translated into English by Matthew Cobb: *Darwinism’s Struggle for Survival: Heredity and the Hypothesis of Natural Selection*, Cambridge University Press, Cambridge, 1998, pp. 70-73.

food “for the good of the species.”¹⁴⁶ But, on the one hand, the idea of “group selection” is no news within evolutionism, insofar as it appears in the discussions between A. R. Wallace and Ch. Darwin; and, on the other hand, the possibility of a group selection seems to be an enlargement of the concept of “natural selection” rather than something incompatible with it.

If the previous objections to Darwinism were focused mainly towards the processes, the third controversy in the microevolutionary sector —the problem of *competitive highness* and the issue of *complexity*— deals directly with the biological outcomes. According to Darwinian natural selection, it works as a causal process to increase fitness. For the theoretical biologist Stuart Kauffman, the “self organization” which involves limitations for the adaptive power of natural selection should be considered. In other words, “the tapestry of life is richer than we have imagined (...). But the tapestry has an overall design, architecture, a woven cadence and rhythm that reflect underlying law —principles of self organization.”¹⁴⁷

On the one hand, the problem posed by Stuart Kauffman is a limitation to adaptive capacity of natural selection, looking at this process from *the inside*: “beyond a certain degree of complexity, there are serious limits to the ability of organic systems to evolve towards higher fitness or even to maintain themselves at given level of fitness.”¹⁴⁸ But, on the other hand, complexity is an issue to be considered in the *transition* from microevolution to macroevolution, which involves a predictive question: are there reasonable bases —theoretical and empirical— to expect that in the future the evolutionary lines will increase the level of complexity?¹⁴⁹

Explicitly, macroevolution has generated more concern for Darwinism than microevolution, insofar as the evidence available on changes at the level of biological species is greater than the data on those evolutionary changes in a larger scale. *Palaeobiology* is a realm where the interaction between micro and macro should be considered. The point of criticism is both epistemological and methodological: natural selection can be used to explain adaptations at a “local” level (microevolution) whereas it is an insufficient process to produce mass extinction events or their consequences (such as explosive diversifications). In other words, macroevolution requires some additional procedure besides natural selection.¹⁵⁰

Punctuated equilibria is an option in the criticism of Darwinism on the topic of biological divergence. For this conception, macroevolution —at least, the morphological divergence— is a consequence of speciation rather than the result of a continued selection. Indeed, natural selection has a role, but it is the pace of speciation and extinction of events

¹⁴⁶ Cf. WYNNE-EDWARDS, V. C., *Animal Dispersion in Relation to Social Behaviour*, Oliver and Boyd, Edinburgh, 1962; and GRENE, M. and DEPEW, D., *The Philosophy of Biology. An Episodic History*, p. 267.

¹⁴⁷ KAUFFMAN, S. A., *At Home in the Universe: The Search of Laws of Self-Organization and Complexity*, Oxford University Press, N. York, 1995, p. 185. On this view, cf. RUSE, M., *Darwinism and Its Discontents*, p. 161.

¹⁴⁸ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 257.

¹⁴⁹ This topic concerns to SZATHMARY, E. and MAYNARD SMITH, J., “The Major Evolutionary Transitions”, *Nature*, v. 374, (1995), pp. 227-232

¹⁵⁰ Cf. RAUP, D., *Extinction. Bad Genes or Bad Luck?*, Norton, N. York, 1991.

that determines the macroevolutionary patterns (at least, genealogical and macroecological) that are observed on a large geological scale.¹⁵¹

Stephen Jay Gould and Richard Lewontin argued that Darwinians assume too quickly that living nature is adaptive and functional. They do not deny the existence of biological adaptations, but they reject a sort of “pan-adaptationism”: every organic feature should be functional insofar as it is a product of natural selection. Then, “referring to the Leibnizian philosopher in Voltaire’s *Candide*, they accused evolutionists of Panglossianism, of thinking that these must be the best of all possible features in the best of all possible worlds. And to make the case complete, supposedly, evolutionists invent ‘just so’ stories—thus named from Rudyard Kipling’s fantasy stories—with natural selection scenarios leading to adaptation.”¹⁵²

Nowadays the overall picture of evolutionism, in general, and Darwinism, in particular, from a *scientific point of view* is twofold. On the one hand, there is a strong influence of Darwinian ideas on biology (as well as on other scientific disciplines, mainly in the social sciences). And, on the other hand, it is not serious to claim that natural selection is a trivial cause of evolutionary change. It appears as a powerful mechanism, even though “it is not all-powerful. Natural selection has its limits—limits that have been recognized since the time of Darwin (he himself noted many of them)—.”¹⁵³ Nevertheless, taken as a whole, it is one of the keys to understanding changes in the organic world. In this regard, there is no call for another “conceptual revolution” yet, although periodically some limitations and restrictions are pointed out.

Microevolution and macroevolution have posed some problems to Darwinism in the last five decades. They have dealt mainly with natural selection as a process (characteristics and limits) and its causal power. In the case of microevolution, the criticisms still connect natural selection and adaptation.¹⁵⁴ Meanwhile, in the sphere of macroevolution, the search for a single causal theory appears to be problematic. There is now more interest in (phylogenetic) patterns than in some process, but “evolutionary biology remains today a largely descriptive and historical science.”¹⁵⁵ Moreover, the main philosophical question on evolutionist change still remains in place: how to explain the transition from the irrational to the rational?

2. FROM A PHILOSOPHICAL VIEW OF NATURE TO NATURALISM IN PHILOSOPHY

It seems clear that “evolutionism” became a philosophy after the scientific contributions made by Charles Darwin and other authors of the second half of nineteenth century. This transition from scientific positions to philosophical views is the result of several factors,

¹⁵¹ Cf. ELDREDGE, N., *Macro-Evolutionary Dynamics. Species, Niches and Adaptive Peaks*, McGraw-Hill, N. York, 1989.

¹⁵² RUSE, M., *Darwinism and Its Discontents*, p. 135.

¹⁵³ *Darwinism and Its Discontents*, p. 165.

¹⁵⁴ Kimura’s “neutral mutations are not adaptations; altruistic traits can be explained by an enlarged concept of selection; and self-organization, while it can generate order or oppose natural selection, does not produce adaptation,” GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 258.

¹⁵⁵ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 260.

among them are the configuration of evolutionism as a worldview —a vision of the reality as a whole—, which can have the general character that accompanies philosophy, and the feature of “radical approach” —in the literal sense: that goes to the roots— of evolutionism, because it can offer a perspective with “deep causes” of natural and social phenomena.

But there are here several levels of analysis: 1) Darwin himself received the influence of philosophical conceptions that have noticeable consequences for his methodological stance. In this regard, his main sources of influence were John Herschel and William Whewell (mainly in the “consilience of inductions” as a methodological tool). 2) Darwinian ideas soon had repercussion on two kinds of philosophical approaches, those related to natural phenomena —biological world— and those connected with the conception of man and society. 3) His views were later on expanded to configure a fully-fledged naturalistic philosophy (e.g., metaphysics, ethics, philosophy of mind, ...). 4) Evolutionism, either Darwinian or an alternative version, has been used to understand philosophy of science, in general, and several special branches (philosophy of biology, philosophy of economics, etc.), due to the assumption of evolutionist positions in scientific theories and in scientific practices.

2.1. Philosophical-Methodological Influences on Darwin's Approach

Unquestionably there is a “Darwin's debt” to the philosophers, especially John Herschel and William Whewell.¹⁵⁶ This means that, besides the influence of previous and contemporary scientific ideas —mainly from biology and geology—, a philosophical influence can be found in the development of his theory of evolution. In effect, “Darwin may well not have read much philosophy; but the model of scientific theorising that he found in Herschel in the early 1830s was certainly of the utmost importance for his own creativity in the field of philosophical natural history.”¹⁵⁷

John Herschel was son of William, and author of the book *Preliminary Discourse on the Study of Natural Philosophy* (1830).¹⁵⁸ This volume offers a reflection on aims, structure, achievements and procedures of science. It gave Darwin “for the first time (...) a systematic account of scientific methodology.”¹⁵⁹ a) The aim of science is to ascribe certain phenomena to “true causes” (*verae causae*), i.e., causes with a real existence in nature instead of being a mere hypotheses of the mind. This search for “true causes” was a goal of Darwin. b) The structure of science implies that facts are classified under empirical laws, and higher theories result from a consideration of these laws. They are used to organize a new set of phenomena. c) The process for secure natural knowledge is through induction. It is an “active” induction rather than a “passive” induction (according to Francis Bacon's distinction).¹⁶⁰

¹⁵⁶ Cf. RUSE, M., “Darwin's Debt to Philosophy: An Examination of the Influence of the Philosophical Ideas of John F. W. Herschel and William Whewell on the Development of Charles Darwin's Theory of Evolution,” *Studies in History and Philosophy of Science*, v. 6, (1975), pp. 159-181. On his views on methodology of science, cf. LENNOX, J., “Darwin's Methodological Evolution,” *Journal of the History of Biology*, v. 38, (2005), pp. 85-99.

¹⁵⁷ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 261.

¹⁵⁸ SLOAN, PH. R., “The Making of a Philosophical Naturalist,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 23.

¹⁵⁹ SLOAN, PH. R., “The Making of a Philosophical Naturalist,” p. 24.

¹⁶⁰ Cf. “The Making of a Philosophical Naturalist,” p. 24.

Taking into account these kind of philosophical-methodological considerations, “Darwin’s framing ideas are almost always in a zone intermediate between ‘general facts’ of nature and theoretical ‘hypotheses’ justifiable through their consequences. His special talent was to understand that this methodological approximation was crucial to the success of causal theories in natural history. Descent with modification, while more a ‘general fact’ than a ‘hypothesis’, is nevertheless both. Natural selection, while more of a ‘hypothesis’ than a ‘general fact’, is nevertheless both.”¹⁶¹

William Whewell is another source of philosophical-methodological influence on Darwin, due to his acceptance of the procedure of the “consilience of inductions.”¹⁶² It takes place when an induction that has been obtained from one class of facts coincides with an induction attained from another class. Thus, this consilience is understood as a test of the theory in which it occurs.¹⁶³ “In the second half of the *Origin*, following the prescriptions of Whewell, whom he knew personally, Darwin tried to explain [evolution scientifically] in a range of areas —instinct, palaeontology, biographical distribution, systematics, anatomy, embryology, and more. Given his success at using an evolutionary hypothesis to explain so many disparate factors, he felt that he had succeeded in showing evolution to be true —to be a fact and not a theory.”¹⁶⁴

Currently, “consilience of inductions” is presented as a version of the “inference to the best explanation,” when the stress is on unification. It is assumed that, if a scientific hypothesis is true —a content of the real world—, then various facts can follow from it. Darwin “set out deliberately to construct a consilience, and felt with some reason that he had succeeded.”¹⁶⁵ He compared organisms from islands (Galapagos and Cape Verde Archipelagoes) and mainland (America and Africa). He thought that the largest range of biological diversity was explained by evolution understood as a fact, and this convergence can be used in favor of the existence of evolution itself as fact. Thus, in the case of the fossil record, if it involves some kind of progressiveness —which is required by evolution in Darwinian sense—, then it can be thought that evolution is a fact, and in addition the sequences expected of evolution can be shown.¹⁶⁶

Both philosophers —Herschel and Whewell— thought of science looking at Newtonian physics as an ideal. They considered the importance of searching for a cause of phenomena. “Herschel claimed that the best examples of science establish a true cause, or *vera causa*. Establishing a *vera causa* (...) entails demonstrating three things: (1) the *existence* of the cause; (2) the *adequacy* or competence of the cause to produce the effects to be explained; and (3) the *responsibility* of the cause for the effects.”¹⁶⁷ In this regard, Darwin offered an

¹⁶¹ GAYON, J., “From Darwin to Today in Evolutionary Biology,” p. 261.

¹⁶² On matters of evolution, Whewell was against it. One objection was that “Darwin could not adduce a single example of one species evolving in nature into another. Nor had plant and animal breeders, through all their efforts, succeeded in producing a single new species,” HULL, D. L., “Darwin’s Science and Victorian Philosophy of Science,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 184.

¹⁶³ Cf. WHEWELL, W., *The Philosophy of the Inductive Sciences*, Parker, London, 1840.

¹⁶⁴ RUSE, M., *Darwinism and Its Discontents*, p. 38.

¹⁶⁵ *Darwinism and Its Discontents*, p. 38.

¹⁶⁶ Cf. BOWLER, P. J., *Fossils and Progress*, Science History Publications, N. York, 1976.

¹⁶⁷ WATERS, C. K., “The Arguments in the Origin of Species,” p. 120. See also RUSE, M., “Darwin’s Debt to Philosophy: An Examination of the Influence of the Philosophical Ideas of John F. W. Herschel and William Whewell on the Development of Charles Darwin’s Theory of Evolution,” pp. 159-181.

analogy between artificial selection and natural selection according to Herschel's ideal of giving a true cause (*vera causa*).

Whewell had a methodological conception where a cause "could be established solely on the basis of *consilience*, the feat of showing that a wide variety of apparently separate phenomena can be explained as a result of the same cause. Darwin's claim, that phenomena ranging from embryology to biogeographical distribution can be explained in terms of transmutation by means of natural selection, adheres to Whewell's ideal of consilience."¹⁶⁸ This methodology seems compatible with an ontological notion of "cause" (such as Herschel's *vera causa*), and both appear to receive Darwin's support.

2.2. Early Stages in Darwin's Philosophical Influence

Soon after Darwin's main publications some philosophical response to his views was noticeable. Basically, this echo followed three main different lines: i) those thinkers who supported his conception but tried to "adjust" it in order to fit the position within a tradition or a perspective; ii) those philosophers who shared central claims of the Darwinian approach but wanted to "modify" some ideas for dealing with new problems or different issues; and iii) those who opposed the philosophical tenets involved in Darwin's scientific claims, either on nature or about the human being.¹⁶⁹ To some extent, these initial stages of influence are in place until the end of the first quarter of the twentieth century.

Obviously, there are also thinkers whose position is more complex than these three options. This is the case of a philosopher of Darwin's times: John Stuart Mill (1806-1873), who does not fit clearly into the groups of supporters or opponents. Initially he praises *The Origin of Species* insofar as it offers us a remarkable speculation with legitimate hypotheses and according to the rules of induction; but thereafter he considers that "Darwin and his followers had not provided any proof at all for evolutionary theory."¹⁷⁰ Thus, besides the new path of inquiry open by evolutionism, which is full of promise and results that no one can foresee, J. S. Mill saw something different from Darwin: that the "adaptations in Nature afford a large balance of probability in favour of creation by intelligence."¹⁷¹

During those years —the post-*Origin* period— Herbert Spencer (1820-1903) was philosophically influential, with particular repercussion on the evolutionist camp. On the one hand, he is seen to some extent as an "adjuster" of Darwinism, insofar as he tried to fit Darwin's ideas into the intellectual tradition, using evolution as a new solution to old problems (such as the meaning and purpose of existence). Thus, "some have claimed that he used evolution as a replacement for religion."¹⁷² But, on the other hand, Spencer's perspective appears as clearly Lamarckian rather than Darwinian, both on biotic evolution

¹⁶⁸ "The Arguments in the *Origin of Species*," p. 122.

¹⁶⁹ Cf. CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, pp. 18-25. In addition, it can be seen chapters 2 and 3 as well.

¹⁷⁰ HULL, D. L., "Darwin's Science and Victorian Philosophy of Science," p. 187.

¹⁷¹ J. S. Mill wrote this in his book *Three Essays on Religion*, published in 1874. The text is quoted in HULL, D. L., "Darwin's Science and Victorian Philosophy of Science," p. 187.

¹⁷² *Philosophy and the Darwinian Legacy*, p. 19. His main contributions are in SPENCER, H., *The Principles of Biology*, William and Norgate, London, 1864-1867, 2 vols.

and on social evolution. He was a supporter of “organic evolution as part and parcel of the overall upward progress that characterizes literally everything: as a move from the undifferentiated to the differentiated, or as what he called a move from the homogeneous to the heterogeneous.”¹⁷³

Leading American pragmatists, such as Charles S. Peirce (1839-1914), William James (1842-1910) and John Dewey (1859-1952), are seen as “modifiers,” because they thought of Darwin’s approach as a way to recast many of the fundamental questions of philosophy.¹⁷⁴ And so, Darwinism contributes to a philosophical shift from “fixed categories” to an emphasis on the processes as well as an “open-ended inquiry.”¹⁷⁵ Furthermore, Peirce “was initially impressed by Darwin’s theory, finding it a legitimate application of statistical methods to biology, at a time when statistics was rapidly coming into its own.”¹⁷⁶

Opposition to Darwinism took different forms in philosophy, which have repercussions on different areas, such as metaphysics, theory of knowledge and ethics. Along with other thinkers, there are a relevant group of early British idealists, such as Thomas Hill Green (1836-1882) and James Hutchison Stirling (1820-1909), who “were among the staunchest opponents of the naturalism of the Darwinian view. [George Edward] Moore and [Bertrand Arthur] Russell, educated in the Idealist tradition, may well have inherited some of the antipathy to Naturalism that so marked Idealist thought.”¹⁷⁷

Henri Bergson (1859-1941) represents an opposition to Darwinism within an evolutionism framework. He dislikes immutable categories in philosophy, but he does not want to endorse a naturalism incompatible with the idea of creation. He “took much of his evolutionism from Herbert Spencer,”¹⁷⁸ even though Bergson wrote his main book against central claims of Spencer’s approach.¹⁷⁹ Bergson subscribes a *Creative Evolution*¹⁸⁰, where he tries to avoid a mechanical view of evolution in favor of a vital impetus (*élan vital*) that gives the creative impulse. “He insisted on the flowing character of reality and believed that our most reliable access to it was by way of what he called ‘intuition’. His preference for intuition over the fixed nature of intellectual classifications irritated Russell.”¹⁸¹

¹⁷³ RUSE, M., *Darwinism and Its Discontents*, p. 19. Cf. SPENCER, H., “Progress: Its Law and Cause,” *Westminster Review*, v. 67, (1857), pp. 244-267.

¹⁷⁴ In addition to the philosophers already pointed out, Friedrich Nietzsche was also influenced by Darwin, although not directly but rather through the reading of German Darwinians. Cf. SMITH, C. U. M., “‘Clever Beasts who Invented Knowing,’ Nietzsche’s Evolutionary Biology of Knowledge,” *Biology and Philosophy*, v. 2, (1987), pp. 1-27.

¹⁷⁵ Cf. CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, p. 19.

¹⁷⁶ HULL, D. L., “Darwin’s Science and Victorian Philosophy of Science,” p. 188.

¹⁷⁷ CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, p. 19.

¹⁷⁸ RUSE, M., “Belief in God in a Darwinian Age,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 339.

¹⁷⁹ I owe this idea to Jean Gayon. *Personal communication*, June 2008.

¹⁸⁰ Cf. BERGSON, H., *L’Evolution créatrice*, Alcan, Paris, 1907 (repr. PUP, Paris, 1959); translated into English by Arthur Mitchell: *Creative Evolution*, Henry Holt and Company, N. York, 1911 (rep. Dover, New York, 1998). Cf. GILSON, E., *D’Aristote à Darwin et retour*, Vrin, Paris, 1971.

¹⁸¹ CUNNINGHAM, S., *Philosophy and the Darwinian Legacy*, p. 21.

2.3. Contemporary Philosophical Significance of Darwinism: Preference for Naturalisms in Philosophy

About the philosophical significance of Darwinism, Kitcher considers that there are a pair of polar perspectives that have dominated the scene so far. At one extreme are those that emphasize the autonomy of philosophy and conclude with Wittgenstein's *Tractatus* that "Darwin's theory has no more to do with philosophy than any other hypothesis in natural science."¹⁸² And at the other extreme "are naturalists who maintain that 'now that we know' this or that other fact about the cosmos, the human brain, or (most pertinently for present purposes) the role of natural selection in hominid evolution, traditional problems are easily solved."¹⁸³

Although Wittgenstein himself—especially in his first period—is not the best example of the first extreme, certainly it is the case that there are philosophers that commonly assume the claim of a "full purity": that most concepts and methods in philosophy are unaffected by the deliverances of any science. Meanwhile there are authors in favor of "hyper-naturalism," who deny the genuine philosophical insights out of the language of science. Usually the Darwinians are closer to the second extreme than the first.

Basically, in addition to philosophy of science—both general and special—, there are three areas of philosophy that have had a direct influence of evolutionism, particularly of Darwinian brand: metaphysics, theory of knowledge, and ethics. Besides them, there are also other areas of philosophy, such as philosophy of mind and philosophical anthropology, which also have the direct repercussion of Darwinian evolutionism. Usually, the ideas received are those related to some central claims: a) the assumption of anti-essentialism in metaphysics; b) the acceptance of variability and revocability of human knowledge (in general and consequently, scientific knowledge as well); and c) the consideration of ethical values as naturally rooted and "evolutively" changeable.

2.3.1. Positions with a Darwinian Source for Philosophy of Science: Tenets of Metaphysics, Theory of Knowledge and Ethics

Philosophy, as a whole, and philosophy of science, in particular, has received Darwinian influence for many years. The repercussion is more noticeable in some realms—metaphysics, theory of knowledge and ethics—that have connections with specific areas of philosophy of science, such as those who think of the configuration of reality in scientific terms, the characterization of a reliable knowledge of the world (natural, social or artificial), and the kind of ethical values to be used by scientists (both endogenous and exogenous to their activity). In all of them—ontology of science, epistemology and ethics of science—there are philosophers who have a Darwinian source.

Metaphysics is one of the philosophical fields where some Darwinian issues—mainly related with the "tree of life"—have had consequences for philosophy of science. These central views can be integrated in several levels of analysis: i) the general perspective on

¹⁸² WITTGENSTEIN, L., *Tractatus Logico-Philosophicus*, bilingual edition German-English with English translation by C. K. Ogden and F. P. Ramsey, Routledge and Kegan Paul, London, 1922 (reprinted in 1971). New English translation by D. F. Pears and B. F. McGuinness, in Routledge and Kegan Paul, London, 1961 (reprinted in 1981), n. 4.1122.

¹⁸³ KITCHER, PH., "Giving Darwin his Due," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 399.

reality, where Darwin's evolutionism has been used in favor of ontological naturalism, even though the author of *The Origin of Species* was not a supporter of that view;¹⁸⁴ ii) the characterization of natural objects from an anti-essentialist approach, insofar as the species are considered as evolving realities without an internal structure (i.e., properties as basis for an identifying reference);¹⁸⁵ and iii) the vision of change in natural world open to novelty, which gives a especial role to chance.¹⁸⁶ These metaphysical tenets have a clear repercussion on some ontologies of science (conceptions of the fabric of reality from a scientific standpoint).

Theory of knowledge is another philosophical field where a set of positions rooted in Darwinian influence can be founded. They are linked to the "tree of life" and, especially, to the process of "natural selection." The consequences of those tenets for epistemology—the study of scientific knowledge—are direct. Those philosophers that have been inspired by evolutionism in their analysis of human knowledge, in general, or of scientific knowledge, in particular, have basically followed one of these two main paths:¹⁸⁷

1) Evolution of *cognitive contents*, understood in a broad sense, is a sort of historical event: human knowledge evolves through different processes and leads to diverse products that change from one period to another. Those changes can be considered as a perspective compatible with claims of the "historical turn" (Thomas Kuhn, Imre Lakatos, etc.),¹⁸⁸ even though "evolution" and "historicity" have differences from a conceptual point of view.¹⁸⁹
 2) Evolution as a *process* or characteristic of human knowledge itself, either individual or social, where there are some features pointed out by Darwin. In this second case, there are many authors that in one way or another consider themselves as "evolutionist" about human knowledge or human rationality. Moreover, quite different thinkers, such as Nicholas Rescher—a "pragmatic idealist"—¹⁹⁰ or Herbert A. Simon—an empiricist—¹⁹¹, assume "evolutionist" elements in their views of human rationality.

¹⁸⁴ See the papers written by Peter McLaughlin and Michael Ruse in HÖSLE, V. and ILLIES, CH. (eds.), *Darwinism and Philosophy*, Notre Dame University Press, Notre Dame, 2005.

¹⁸⁵ This is the opinion held by Elliott Sober: "There are strong reasons to think that Darwinian theory undermines this essentialist picture [i.e., intrinsic properties] of biological species," SOBER, E., "Metaphysical and Epistemological Issues in Modern Darwinian Theory," p. 275. Nevertheless, the controversy on the notion of "species" is still in place nowadays.

¹⁸⁶ Cf. "Metaphysical and Epistemological Issues in Modern Darwinian Theory," p. 267.

¹⁸⁷ Cf. RESCHER, N. (ed.), *Evolution, Cognition, and Realism: Studies in Evolutionary Epistemology*, University Press of America, Lanham, 1990.

¹⁸⁸ Cf. KITCHER, PH., "Giving Darwin his Due," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, pp. 407 and 420.

¹⁸⁹ Understood in Darwinian terms, "evolution" is originally a biological development with mutations like a tree with many branches, whereas "historicity" is a concept with a wider spectrum of connections both backwards and forward. *Senso stricto*, historicity belongs to humans: it includes decisions open to revisions and, then, it has a direct link with freedom and praxis, cf. GONZALEZ, W. J., "Caracterización del objeto de la Ciencia de la Historia y bases de su configuración metodológica," in GONZALEZ, W. J. (ed.), *Acción e Historia. El objeto de la Historia y la Teoría de la Acción*, Publicaciones Universidad de A Coruña, A Coruña, 1996, pp. 25-111.

¹⁹⁰ Cf. RESCHER, N., *A Useful Inheritance: Evolutionary Epistemology in Philosophical Perspective*, Rowman and Littlefield, Savage, MD, 1989; and RESCHER, N., *Razón y valores en la Era científico-tecnológica*, Paidós, Barcelona, 1999.

¹⁹¹ Cf. SIMON, H. A., *Reason in Human Affairs*, Stanford University Press, Stanford, CA, 1983.

Along with other views on evolution of cognitive contents is the personal conception held by Richard Dawkins. He has suggested an analogy between “genes” —biological evolution— and “memes” —cultural evolution—, which involves a social growth of knowledge as a result of spreading memes.¹⁹² And among those who have proposed an “evolutionary epistemology” is Donald T. Campbell, because he considers human knowledge as a sort of Darwinian procedure. He has argued that “evolution —even in its biological aspects— is a knowledge process, and that the natural-selection paradigm for such knowledge increments can be generalized to other activities, such as learning, thought, and science.”¹⁹³

Ethics is a realm that has had a clear Darwinian influence, especially among those thinkers in favor of naturalizing ethical values. For Philip Kitcher, “there are many different projects relating evolutionary biology and ethics, some of which are perfectly sensible, others flawed.”¹⁹⁴ A key problem in choosing evolutionary roots for ethics is in distinguishing descriptive ethical values (the recognition of changes in society about some ethical principles) and the normative ethical values (certain ideal prescriptions to be implemented). Consequently, there is the possibility of a “naturalistic fallacy” in the transit from ‘is’ to ‘ought to be’.¹⁹⁵

Four main groups can be pointed out to summarize the ethical options rooted in this evolutionary perspective. a) Strong metaethical Darwinism, where the history of life itself is a source of morality and offer us new basic ethical principles (i.e., central moral principles lie outside human world). b) Strong ethical Darwinism: the evolutive character of moral principles leads to a kind of relativism where moral judgments cannot have objectivity and, therefore, moral knowledge is without truth-values. c) Weak ethical Darwinism, where human beings are related to other animals in the “chain of life” and this continuity lead us to treat other beings in particular ways (i.e., an enlargement of our ethical values according to a recognition of the kinship of life). d) Weak methaetical Darwinism, where our species is seen from an evolutionary standpoint that contributes to understanding changes in human history (including variations in ethical values and the social recognition of moral principles).

2.3.2. Repercussions of Evolutionism on Philosophy of Science

Evolutionism, in general, and the Darwinian approach, in particular, has played a key role in many conceptions of philosophy of science, both in the general realm —thought of any science— and in the special sphere (devoted to specific disciplines). The influence is more visible in the naturalist perspectives on science, as a whole, and in several special philosophies of science: those related to biology, economics, sociology, etc. The repercussions can be found in philosophical-methodological analysis of each one of the constitutive elements of science (language, structure, knowledge, method, activity,

¹⁹² Cf. DAWKINS, R., *The Selfish Gene*, Oxford University Press, Oxford, 1976.

¹⁹³ CAMPBELL, D. T., “Evolutionary Epistemology,” in SCHILPP, P. A. (ed.), *The Philosophy of Karl Popper*, Open Court, La Salle, IL, 1974, vol. 1, p. 413.

¹⁹⁴ KITCHER, PH., “Giving Darwin his Due,” p. 411.

¹⁹⁵ “You cannot go from the course or fact of evolution to moral prescriptions,” RUSE, M., *Darwinism and Its Discontents*, p. 255.

values, etc.).¹⁹⁶ Commonly, these philosophical approaches on science involve a version of naturalism. Some of these aspects have been pointed out already: those positions with a Darwinian source (in metaphysics, theory of knowledge, or ethics).

Basically, philosophy of science deals with evolutionism in two main directions: i) it can analyze the *evolutionist thesis* (among them, the Darwinian positions) as they appear in science itself—in the constitutive elements of science—or in any of the sciences (biology, economics, etc.); and ii) it can assume the *evolutionist approach* (e.g., in Darwinian brand) in order to characterize the philosophy of science as such, either in the general scope or in the special context (philosophy of biology, philosophy of economics, etc.). To the first group belong those philosophical analyses where evolutionism is a topic *inter alia*, whereas in the second group evolutionism is a feature of the philosophy of science done (e.g., in Philip Kitcher, Elliott Sober, etc.). The acceptance of some naturalist conceptions is very frequent in both cases.

Naturalism involves a set of views that, in one way or another, assume that “contemporary scientific theory is the source of solutions to philosophical problems. Naturalists look to the theory of natural selection as a primary resource in coming to solve philosophical problems raised by human affairs in particular.”¹⁹⁷ But, on the one hand, there are recent issues of naturalist tendency that were not of Darwin’s concern, because “his philosophical natural history was distinct from the new philosophical naturalism.”¹⁹⁸ And, on the other hand, there are also philosophers of science that received a clear influence of evolutionism, such as Karl Popper (in his evolutionary epistemology), who are not naturalists in any relevant sense.

Nevertheless, these aspects—the differences between Darwin’s naturalism and some contemporary naturalist views as well as the existence of philosophers with evolutionist influence that are not naturalists—are compatible with the propensity to see Darwin as an icon of naturalism in science and, consequently, as a key figure of philosophy of science of a naturalist style. In addition, this intellectual trend is in tune with the idea of “progressivity” as a central feature of naturalism in the philosophical reflection on science.¹⁹⁹ Even so, we can find several kinds of naturalism in science and, therefore, in the philosophical approach based on it.

Contemporary perspectives of *naturalism* in science are basically these: 1) semantic naturalism, where there is an acceptance of meaning as linguistic use, because meaning is based on a practice that can be described rather than prescribed; 2) epistemological naturalism, which accepts that human knowledge is well oriented and assumes a continuity between science and philosophy (and, therefore, that a metaphysical foundation of any

¹⁹⁶ On the constitutive elements of “science,” cf. GONZALEZ, W. J., “The Philosophical Approach to Science, Technology and Society,” pp. 10-11.

¹⁹⁷ ROSENBERG, A., “Darwinism in Moral Philosophy and Social Theory,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 310.

¹⁹⁸ HODGE, J. and RADICK, G., “Introduction,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, p. 12. “The new philosophical naturalists have other aims that do not map at all straightforwardly on to Darwin’s aims,” HODGE, J. and RADICK, G., “Introduction,” p. 11.

¹⁹⁹ Cf. ROSENBERG, A., “A Field Guide to Recent Species of Naturalism,” *The British Journal for the Philosophy of Science*, v. 47, (1996), p. 4.

of them is not needed); 3) methodological naturalism, where the progress of science (including the case of the social sciences) can be made through processes empirically tested according to criteria used in natural sciences; 4) ontological naturalism, which only accepts entities that in one way or another could be observable (i.e., it denies the legitimacy of unobservable entities such as “mind,” “consciousness,” and the like); and 5) axiological naturalism, where the scientific values are those that come from scientific practice.

However, according to the kind of support for these versions of naturalism (historical, psychological, biological, sociological, economic, etc.), there are additional varieties of naturalistic approaches. This is especially clear in the cases of epistemological naturalism and methodological naturalism, because within them there can be a science (history, psychology, biology, sociology, etc.) that holds the naturalist building up of scientific knowledge or scientific method. Thus, in the last two decades, we have seen naturalisms based on historical grounds (such as “normative naturalism”), psychological bases (such as several “cognitive approaches”), biological tenets (such as evolutionary characterizations of “adaptive rationality”), etc. Some of them overlap with the “social turn” in philosophy and methodology of science, whereas others are open to some dimensions of scientific realism.²⁰⁰

Prima facie two main directions appear when evolutionism of the Darwinian brand has repercussions on empirical sciences (natural, social or artificial) and, consequently, on the philosophy made on them: a) Darwin’s perspective is a *conception incorporated* in the scientific view as such, as can be seen in clear cases (sociobiology, evolutionary psychology, developmental evolution,²⁰¹ evolutionary economics, etc.); and b) Darwin’s ideas can be used to characterize or *make intelligible* some scientific positions (e.g., Adam Smith’s “invisible hand,” some sociological trends, certain “market failures” in economics, etc.)²⁰²

Consequently, on the one hand, a number of authors recognize the evolutionary influence —either large or small— on their views (in the case of economics: F. von Hayek, J. Schumpeter, H. A. Simon, R. Selten, etc.), where the repercussion is commonly in favor of a kind of naturalism (semantic, epistemological, methodological, ...); and, on the other hand, evolutionism is the way to grasp some implicit or explicit tenets of certain scientists, a perspective that enlarges the philosophical reflection in particular cases.

Besides the naturalist approaches in philosophy of science, there are non-naturalist views (rationalist, empiricist, Kantian, etc.) under the influence of evolutionism as well. A clear example is Karl Popper, whose critical rationalism endorses an “evolutionary epistemology,” a position that is pre-eminent in the second period of his thought (during the sixties).²⁰³ His book *Conjectures and Refutations* offers an epistemological view of an

²⁰⁰ Cf. GONZALEZ, W. J., “Novelty and Continuity in Philosophy and Methodology of Science,” in GONZALEZ, W. J. and ALCOLEA, J. (eds.), *Contemporary Perspectives in Philosophy and Methodology of Science*, Netbiblo, A Coruña, 2006, pp. 1-28; especially, pp. 5-6.

²⁰¹ Cf. LAUBICHLER, M. and MAIENSCHIN, J. (eds.), *From Embryology to Evo-Devo: A History of Embryology in the 20th Century*, The MIT Press, Cambridge, MA, 2007.

²⁰² On these examples, cf. ROSENBERG, A., “Darwinism in Moral Philosophy and Social Theory,” pp. 328-330.

²⁰³ Cf. GONZALEZ, W. J., “La evolución del Pensamiento de Popper,” in GONZALEZ, W. J. (ed.), *Karl Popper: Revisión de su legado*, Unión Editorial, Madrid, 2004, pp. 23-194; especially, pp. 52-56; and GONZALEZ, W. J., “The Many Faces of Popper’s Methodological Approach to Prediction,” in CATTON, PH. and MACDONALD, G. (eds.), *Karl Popper: Critical Appraisals*, Routledge, London, 2004, pp. 78-98; especially, pp. 80-85.

evolutionary kind (an adaptive procedure of human knowledge) linked to methodology of falsificationism;²⁰⁴ and, later on, the volume *Objective Knowledge* shows a clear ontological perspective of science,²⁰⁵ which includes evolutionary claims as well.

Conjectures and Refutations combines an evolutionary epistemology and a falsificationist methodology. Thus, if the progress of science is to continue, we need positive successes in addition to successful refutations: “we must ... produce theories that entail new predictions, especially predictions of new effects, new testable consequences, suggested by the new theory and never thought of before. Such a new prediction was that planets would under certain circumstances deviate from Kepler’s laws; or that light, in spite of its zero mass, would prove to be subject to gravitational attraction (that is, Einstein’s eclipse-effect). Another example is Dirac’s prediction that there will be anti-particle for every elementary particle. New predictions of these kinds must not only be produced, but they must also be reasonably often corroborated by experimental evidence, I contend, if scientific progress is to continue.”²⁰⁶

Objective Knowledge deals also with an evolutionary approach and stresses the indeterministic status of both natural and social reality, which directly affects the problem of scientific prediction: “*evolutionary processes or major evolutionary changes are as unpredictable as historical processes or major historical changes*. I hold this view because I am strongly inclined towards an indeterministic view of the world, somewhat more radical than Heisenberg’s: my indeterminism includes the thesis that even classical physics is indeterministic, and is thus more like that of Charles Sanders Peirce, or that of Alfred Landé. And I think that *evolution proceeds largely probabilistically, under constantly changing conditions or problem situations*, and that every tentative solution, whether more successful or less successful or even completely unsuccessful, creates a new problem situation.”²⁰⁷

Looking at this view of general philosophy of science (a combination of an evolutionary epistemology —within critical rationalism— and a methodological falsificationism), Michael Ruse maintains that Popper saw Darwinism as philosophy insofar as it was a “metaphysical research programme” (i.e., a possible framework for testable scientific theories) and he tried to take Darwinism seriously as a science. “Somehow, Darwinism did not measure up as a proper science —one that was genuinely falsifiable (the Popperian

²⁰⁴ “Criticism of our conjectures is of decisive importance: by bringing out our mistakes it makes us understand the difficulties of the problem which we are trying to solve. This is how we become better acquainted with our problem, and able to propose more mature solutions: the very refutation of a theory —that is, of any serious tentative solution to our problem— is always a step forward that takes us nearer to the truth. And this is how we can learn from our mistakes.

As we learn from our mistakes our knowledge grows, even though we may never know —that is, know for certain. Since our knowledge grows, there can be no reason here for despair of reason,” POPPER, K. R., *Conjectures and Refutations. The Growth of Scientific Knowledge*, Routledge and Kegan Paul, London, 1963; 5th ed., revised, 1989, p. vii.

²⁰⁵ His three worlds theory includes causal relations between them, and the world 3, which is the realm of science, has objective objects or entities, cf. POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, Clarendon Press, Oxford, 1972 (5th rev. ed., 1979; rep. in 1989), pp. 153-190, especially, pp. 155-158.

²⁰⁶ POPPER, K. R., “Truth, Rationality, and the Growth of Knowledge,” in POPPER, K. R., *Conjectures and Refutations*, p. 243.

²⁰⁷ POPPER, K. R., *Objective Knowledge*, p. 296 (emphasis added).

criterion of demarcation)— at least, not by the standards of physics and chemistry, the standards by which all else must be judged. The result was happy neither for science nor for philosophy.”²⁰⁸

2.3.3. *Evolutionist Impact on Special Philosophy of Science*

Until now, it has been emphasized that special philosophy of science—the philosophical analysis of the diverse sciences— has received a strong evolutionist influence. In addition to biology, this impact has been more noticeable in some social realms: economics, psychology, sociology, etc. On the one hand, the criteria of evolutionism have been assumed by leading scientists in those fields; and, on the other hand, the philosophers working on those disciplines (philosophy of biology, philosophy of economics, etc.) consider the evolutionist repercussion on those scientists and, at the same time, their philosophical analyses are in certain cases embedded in some sort of evolutionism (Darwinian, Lamarckian, ...). Here we draw attention to some points of this wide and complex intellectual panorama.

Most of the scientists working on social realms (economics, psychology, sociology, etc.) accept some sort of evolutionism of a Darwinian brand in order to explain biotic phenomena, but there are a relevant number of them who think of social evolution (economic, cultural, political, etc.) in *Lamarckian* terms, either in a literal sense or in a metaphorical one. Thus, “leading economists such as Jack Hirshleifer (1977), Herbert Simon (1981), Richard Nelson and Sidney Winter (1982), Friedrich Hayek (1988), Christopher Freeman (1992) and J. Stanley Metcalfe (1993) have claimed that it is [‘Lamarckian’] (Hayek and Simon are both Nobel Laureates). Other prominent social theorists such as Karl Popper (1972), William McKelvey (1982), John Gray (1984), and Robert Boyd and Peter Richerson (1985) have likewise accepted that social evolution takes a ‘Lamarckian’ form.”²⁰⁹

Lamarckism means in this context the “proposition that acquired characters can be inherited. Accordingly, variations of type occur largely through adaptations to the environment rather than random mutations.”²¹⁰ Thus, according to Geoffrey M. Hodgson, the distinction between Darwinian and Lamarckian approaches on social or cultural evolution can offer us a list of prominent proponents: Darwinians (David Hull and Daniel Dennett), Lamarckians (Richard Boyd, Friedrich Hayek, Jack Hirshleifer, Richard Nelson, Karl Popper, Sidney Winter, ...), and neither Darwinian nor Lamarckian (Stephen Jay Gould, Alexander Rosenberg, Joseph Schumpeter, ...).²¹¹

Some of these authors have developed a special philosophy of science, because they have been working on specific sciences, such as biology (D. Hull and A. Rosenberg), cognitive science (D. Dennett), etc. There are other thinkers that *de facto* have a special philosophy of science, even though the primary interest was in general philosophy of science (K. Popper)

²⁰⁸ RUSE, M., *Darwinism and Its Discontents*, p. 237.

²⁰⁹ HODGSON, G. M., “Is Social Evolution Lamarckian or Darwinian?,” in LAURENT, J. and NIGHTINGALE, J. (eds.), *Darwinian and Evolutionary Economics*, E. Elgar, Cheltenham, 2001, p. 87.

²¹⁰ HODGSON, G. M., “Is Social Evolution Lamarckian or Darwinian?,” p. 87.

²¹¹ Cf. “Is Social Evolution Lamarckian or Darwinian?,” p. 88.

or it was focused on a concrete science, such as economics (F. von Hayek). Commonly, their evolutionist views are complex enough to make a *reduction* of their positions to a simple dualism —such as Darwinism-Lamarckism— difficult. Nevertheless, in some cases there are also explicit defenses of reductionist conceptions.²¹²

Usually, the Darwinism of those philosophers of science in the special sphere (biology, economics, etc.) shares a kind of naturalism (semantic, epistemological, methodological, ontological, axiological) of the general context. At the same time, they develop in their fields —in the topics of their subject matter— the contents of metaphysics, theory of knowledge and ethics already pointed out. This phenomenon is more noticeable in those philosophers with clear-cut Darwinian tenets (such as D. Dennett, D. Hull, etc.). The limits of their views depend on the validity of Darwin's conception, which was thought of as a scientific theory rather than as a philosophical enterprise *tout-court*.

To sum up, there are several evolutionist approaches before Darwin's book *The Origin of Species*, some of them were already available before his famous voyage on *HMS Beagle*. After his views (the tree of life, natural selection, and sexual selection), there is a large number of evolutionist approaches in science (mainly, in biology). Although he received philosophical influences for his methodology of science (primarily, John Herschel and William Whewell), it seems clear that he has had a strong influence on philosophical conception since the publication of his works. Evolutionism as philosophy with Darwinian flavor has been available from the second half of nineteenth century up to the present.

From time to time there are very hot discussions on evolutionism of Darwinian brand, both in science and in philosophy. But above all the debates are in the cultural setting, due to a variety of reasons (philosophical, theological, political, etc.). Commonly, the controversy is not on Darwinian evolutionism as a naturalist methodology, insofar as it is broadly assumed that science is generally built up through some kind of naturalism in methodology of science (especially in natural sciences). The main disputes arise when there is a jump from methodological naturalism towards an ontological naturalism (which it seems was not explicitly endorsed by Darwin himself, at least as overall view).²¹³ But then the question is an ontological option (a philosophical perspective) rather than a biological position (a scientific approach).

Regarding the revolution introduced by this evolutionist approach, Ruse gives a general view: he thinks that Darwin “wanted a professionally based area of biological science, using natural selection as its main investigative tool. What he ended up getting was a kind of religion substitute, with progress at its heart, and with little interest in mechanisms. But later, in the twentieth century, his ideas were picked up and used for what they are worth, as a means to peer into the mysteries of nature. And this —subject to later discussion— is where we are today.”²¹⁴

²¹² Cf. ROSENBERG, A., *Darwinian Reductionism. Or How to Stop Worrying and Love Molecular Biology*, The University of Chicago Press, Chicago, 2006.

²¹³ Cf. RUSE, M., *Darwinism and Its Discontents*, p. 13. On his intellectual trajectory there are interesting remarks in BROOKE, J. H., “Darwin and Victorian Christianity,” pp. 199-202.

²¹⁴ RUSE, M., *Darwinism and Its Discontents*, p. 24.

3. STRUCTURE AND GENESIS OF THE BOOK

As the main goal of this book is to offer an updated analysis of evolutionism from a philosophical perspective, the structure of the volume follows five steps, which are focused on different domains. Firstly, there is a context of evolutionism from a contemporary viewpoint, taking into account the diversity of evolutionisms available and the relevance of Darwinism. This gives place to a consideration of the historical as well as philosophical aspects. Secondly, there is an analysis of Darwin in the setting of evolutionism. Thirdly, the focus shifts to evolutionism in the present science, seeking new approaches in evolutionary biology. Fourthly, attention goes to evolutionism in the realm of economics, because it receives evolutionary influence in different ways. Fifthly, the nexus between general philosophy of science —epistemology— and evolutionism is studied, considering the views maintained by Karl Popper and Herbert A. Simon.

Each one of these domains has a section in the book. 1) *Context*: “Evolutionism from a Contemporary Viewpoint: The Philosophic-Methodological Approach,” Wenceslao J. González (University of A Coruña). 2) *Darwin and Evolutionism*: “The Evolution of Darwinian Thought Experiments,” James G. Lennox (University of Pittsburgh), and ““Is a New and General Theory of Evolution Emerging?” A Philosophical Appraisal of Stephen Jay Gould’s Evaluation of Contemporary Evolutionary Theory,” Jean Gayon (*Université Paris I-Panthéon Sorbonne*). 3) *Evolutionism and Present Biology*: “Thought Experiments in Evolutionary Biology Today,” James G. Lennox (University of Pittsburgh), and “The Species Concept in Evolutionary Biology: Current Polemics,” Alfredo Marcos (University of Valladolid). 4) *Evolutionism and Economics*: “Three Evolutionary Ideas in Economics: Population, Idle Curiosity and Technological Change,” Santiago López García (University of Salamanca), and “The Concept of Evolution in Hayek: Institutions, Social Order and Economic Process,” José Luis Ramos Gorostiza (Complutense University, Madrid). 5) *Epistemology and Evolutionism*: “Biocosmological Evolutionism and Evolutionist Epistemology in Popper,” Juan Arana (University of Seville) and “Rationality as Evolutionary Adaptation in Herbert A. Simon. A Comparison with Karl Popper and Reinhard Selten,” Francisco J. Castro (University of A Coruña).

Originally, these papers were delivered at the *Jornadas sobre Evolucionismo: Enfoques actuales* (Conference on Evolutionism: Present Approaches), organized by the University of A Coruña with the support of the Society of Logic, Methodology and Philosophy of Science in Spain. The meeting was held at the Campus of Ferrol on 10th and 11th of March 2005. The discussions were oriented towards the main goal: the contemporary philosophical-methodological stance on evolutionism, in general, and Darwinism, in particular. As in the case of the previous *Jornadas sobre Filosofía y Metodología actual de la Ciencia* (Conferences on present philosophy and methodology of science), the tenth edition of these meetings has its central interest in the reflections developed nowadays.

Ultimately, every paper was focused in this direction. The conference had a central speaker: James G. Lennox. He is Professor of History and Philosophy of Science at the University of Pittsburgh. He was the Director of the *Center for Philosophy of Science* from 1997 to 2005 and responsible of the *Annual Lecture Series*. Before that he was the Director of the *Department of History and Philosophy of Science* (1993-1996). In

Pittsburgh he has organized conference such as “Functional Explanation in Biology and Anthropology” (1983), “Three Lectures on the History, Philosophy and Current Status of Neo-Darwinism” (1991), and “Pittsburgh/Konstanz Conference on the Philosophy of Biology” (1993).

James Lennox got his Degree at York University (Toronto) in 1971. Two years later, he did a Master in Philosophy at the University of Toronto, followed by a Ph.D. in Philosophy at the same University (1978). Thereafter, he has been Visiting Professor in the Universities of Cambridge (1987) and Oxford (1994). As a member of the editorial board, he has worked for *History of Philosophy Quarterly*, *Philosophy of Science* and *International Studies in the Philosophy of Science*. In addition, he has prepared reports for *Oxford University Press*, *Cambridge University Press*, *Princeton University Press*, *Edinburgh University Press* and *University of Pittsburgh Press*.

Lennox includes among his books as editor *Philosophical Issues in Aristotle's Biology* (1987), *Self-Motion from Aristotle to Newton* (1994), *Concepts, Theories, and Rationality in the Biological Sciences* (1995), and *Aristotle: On the Parts of Animals I-IV, translation and commentary* (2001). Furthermore, he is the author of *Aristotle's Philosophy of Biology: Studies in the Origins of Life Science* (2001). His papers on evolutionism include “Darwinian Thought Experiments: A Function for Just So Stories” (1991), “Darwin was a Teleologist” (1993), “Natural Selection and the Struggle for Existence” (1994), “Darwinism: Its Descent and Modifications” (1995), and “Darwinism” (2004).

Jean Gayon was another relevant speaker of the conference. He is Professor of History and Philosophy of Science at the *Université Paris I-Panthéon Sorbonne*, where he is the Director of the School of Doctorate in Philosophy. He is a member of the national committee of France on History and Philosophy of Sciences as well as a member of the scientific council of the Max Planck Institute of History of Science in Berlin. He is the author of the monograph *Darwinism's Struggle for Survival: Heredity and the Hypothesis of Natural Selection* (1998). He is the editor of books such as *Philosophie de la biologie: De la biologie à l'éthique* (1999). Among his papers are “La théorie de l'évolution: que signifie ‘darwinisme’ aujourd'hui?” (2000), “The Genetics of Experimental Populations: L'Héritier and Teissier's Populations Cages” (2001), “From Darwin to Today in Evolutionary Biology” (2003), “Épistémologie de la médecine” (2004), and “Évolution et philosophie” (2004).

Before their contribution to the tenth edition of conferences on present philosophy and methodology of science, a relevant number of important philosophers contributed to these meetings. Larry Laudan analyzed in 1996 the relation between history of science and philosophy of science; Ilkka Niiniluoto in 1997 developed his ideas on scientific progress and technological innovation; Evandro Agazzi emphasized in 1998 the relation between science and ethical values; Daniel Hausman contributed in 1999 to the reflection on philosophy and methodology of economics; John Worrall offered in 2000 new important insights on Lakatos's philosophy after 25 years; Wesley Salmon intervened in 2001 with new thoughts on scientific explanation; in 2002 Peter Machamer shed light on Kuhn's scientific revolutions; Donald Gillies in 2003 presented new aspects on Karl Popper's views; and Kristin Shrader-Frechette in 2004 developed the relations between science,

technology and society. All these topics have a volume in the collection *Gallaecia*.²¹⁵ Besides the papers of these authors, other relevant philosophers (Merrilee Salmon, James E. McGuire, Jarrett Leplin, ...) also have chapters in the books.

When a new edition of these conferences is published, it is time to give thanks to the sponsors. My gratitude goes to the *Center for Philosophy of Science* which has contributed to this activity as an expression of the Covenant of cooperation between the University of A Coruña and the University of Pittsburgh on topics of logic and philosophy of science. Acknowledgement to the City Council of Ferrol: the mayor, the City councilor responsible for Campus, and the councilor of Culture, who have appreciated the relevance of this conference as a link between university and society. Thanks also to the Santander Central Hispano bank, which contributes to the activities promoted by the vice-chancellor of cultural extension of the University of A Coruña. And, within the closest circle, my recognition goes to the Faculty of Humanities in the person of its dean. In addition, regarding these *IX Jornadas*, my thanks go to all those —mainly students— who have aided the conference both in the material and organizative domain as well as in its administrative management. Furthermore, I would like to emphasize the role of the mass media of our area (press, radio and television channels), which has highlighted the interest of these conferences for the city.

Finally, I wish to express my gratitude to James G. Lennox (University of Pittsburgh), for accepting this invitation to the conference and his support to this activity. In addition, I am grateful for the presence of Jean Gayon (*Université Paris I-Panthéon Sorbonne*) in this project. I would like also to thank my colleagues Juan Arana (University of Seville), Santiago López García (University of Salamanca), and Alfredo Marcos (University of Valladolid), for their contribution to the conference and this volume (especially to the latter for his suggestions related to this paper). I also thank the authors of the contributed papers: José Luis Ramos Gorostiza (University Complutense, Madrid) and Francisco J. Castro (University of A Coruña). Last but not least, I am grateful to José Fco. Martínez Solano for his assistance in editing this volume.

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Since the beginning of evolutionist approaches, there has been an intense interest on evolutionism, both scientific and philosophical. This twofold phenomenon has produced a huge number of publications. Moreover, the existence of controversies on the main topics discussed and the variety of contents considered —in the books as well as in

²¹⁵ The collection *Gallaecia*. Studies in present philosophy and methodology of science includes the following volumes: GONZALEZ, W. J. (ed.), *Progreso científico e innovación tecnológica*, monographic issue of *Arbor*, v. 157, n. 620, (1997); GONZALEZ, W. J. (ed.), *El Pensamiento de L. Laudan. Relaciones entre Historia de la Ciencia y Filosofía de la Ciencia*, Publicaciones Universidad de A Coruña, A Coruña, 1998; GONZALEZ, W. J. (ed.), *Ciencia y valores éticos*, monographic issue of *Arbor*, v. 162, n. 638, (1999); GONZALEZ, W. J. (ed.), *Problemas filosóficos y metodológicos de la Economía en la Sociedad tecnológica actual*, monographic issue of *Argumentos de Razón técnica*, v. 3, (2000); GONZALEZ, W. J. (ed.), *La Filosofía de Imre Lakatos: Evaluación de sus propuestas*, UNED, Madrid, 2001; GONZALEZ, W. J. (ed.), *Diversidad de la explicación científica*, Ariel, Barcelona, 2002; GONZALEZ, W. J. (ed.), *Análisis de Thomas Kuhn: Las revoluciones científicas*, Trotta, Madrid, 2004; GONZALEZ, W. J. (ed.), *Karl Popper: Revisión de su legado*, Unión Editorial, Madrid, 2004; and GONZALEZ, W. J. (ed.), *Science, Technology and Society: A Philosophical Perspective*, Netbiblo, A Coruña, 2005.

articles— have led to what is considered as an “industry.”²¹⁶ Thus, because the number of publications is beyond the space available here, there are in these pages a selection of books and articles on evolutionism. In addition, this section includes other references with the publications used to prepare this paper, which is focused on a philosophical-methodological viewpoint.

Fortunately, there is at hand *The Complete Work of Charles Darwin Online* (<http://darwin-online.org.uk>, access 28.1.2008). Furthermore, there are some books that have a substantial record of representative publications on evolution, in general, and on Darwinism, in particular. Among the monographs, I would like to mention the books written by Peter Bowler—mainly, *Evolution: The History of an Idea* (1983, 1989, and 2003)—and Michael Ruse (principally, *Darwinism and Its Discontents*, 2006), which can be complemented with M. Grene and D. Depew (*The Philosophy of Biology. An Episodic History*, 2004). The books edited with a considerable amount of references are relatively common. Let me point out some of them: those prepared by Francisco J. Ayala and Theodosious Dobzhansky (*Studies in the Philosophy of Biology, Reduction and Related Problems*, 1974), J. Hodge and G. Radick (*The Cambridge Companion to Darwin*, 2003).

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²¹⁶ Cf. RUSE, M., “The Darwin Industry: A Guide,” *Victorian Studies*, v. 39, n. 2, (1996), pp. 217-235. This phenomenon can also be seen in the document of 223 pages entitled “The Bibliography of Evolution: The Alphabetical List,” prepared in November 2006 by the Editorial Staff of the Darwin Digital Library of Evolution (<http://darwinlibrary.amnh.org/bibliographyfiles/printbibs/EvolutionBibAuthor.pdf>, access, 12.5.2008).

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I

Darwin and Evolutionism

2. The Evolution of Darwinian Thought Experiments

3. 'Is a New and General Theory of Evolution Emerging?' A Philosophical Appraisal
of Stephen Jay Gould's Evaluation of Contemporary Evolutionary Theory

THE EVOLUTION OF DARWINIAN THOUGHT EXPERIMENTS

JAMES G. LENNOX

1. INTRODUCTION

In an earlier paper I argued that Charles Darwin wields a particular argumentative strategy in *On the Origin of Species*,¹ which I referred to as “Darwinian Thought Experiment” (DTE). I provided evidence that he used DTEs both as a way of testing his theory’s explanatory potential and as a method for disarming a particularly worrisome class of criticisms. Here I intend to supplement that earlier discussion in two respects. First, I will place the idea of Darwinian thought experiment in a wider philosophical context, which will help to explain an otherwise puzzling feature of the structure of the *Origin* and a common methodological objection to it. Second, I will trace the origins of this method of reasoning back to Darwin’s *Species Notebooks B-E*, and compare Darwin’s self-conscious development of this pattern of reasoning to a similar though unreflective pattern of reasoning in the second volume of Charles Lyell’s *Principles of Geology*, a work that had been Darwin’s constant companion while on the voyage of HMS Beagle.

2. INDUCTION AND HISTORY

Darwin scholars and biographers are fond of reminding us that in his autobiography, penned late in life for the private entertainment of his family, Charles Darwin singled out Alexander von Humboldt’s *Personal Narrative of Travels to the Equinoctial Regions of the New Continent during the Years 1799-1804* and Sir John Herschel’s *Preliminary Discourse on the Study of Natural Philosophy* as the most significant influences on his decision to pursue the life of a naturalist. But Darwin’s comment about the influence of these books is devoid of specifics. He simply does not say, for example, what particular aspects of Herschel’s fine introduction to scientific method influenced him. I begin, then, by trying to determine some specific Herschelian influences on Darwin’s methods of inquiry and search—on the ‘inductive’ aspects of Darwin’s thought, as this was understood in the early 19th century.

Chapter VI of Sir John Herschel’s *Preliminary Discourse*, entitled “Of the First Stage of Induction,” claims that the advance of science provides us with “a continually increasing stock of such antecedent phenomena, or causes ... competent, under different modifications, to the production of a great multitude of effects, besides those which originally led to a knowledge of them.”² The ability of some process to produce a range of effects far wider than those initially investigated is, on Herschel’s construal, what Newton had in mind by a *vera causa* —“causes recognized as having a real existence in nature, and not being mere hypotheses or figments of the mind.”³ Interestingly, Herschel illustrates this step in the

¹ Cf. LENNOX, J. G., “Darwinian Thought Experiments: A Function for Just-so Stories,” in HOROWITZ, T. and MASSEY, G. (eds.), *Thought Experiments in Science and Philosophy*, Rowman and Littlefield, Savage, MD, 1991, pp. 223-246.

² HERSCHEL, J. F. W., *A Preliminary Discourse on the Study of Natural Philosophy*, Longman, London, 1830; reprinted by The University of Chicago Press, Chicago, 1987, p. 144.

³ HERSCHEL, J. F. W., *A Preliminary Discourse on the Study of Natural Philosophy*, p. 144.

advance of science with geological examples, that is, examples drawn from a *historical* science. These illustrations demonstrate that, for Herschel, having a real existence in nature is only a weak necessary condition for some agent or process being a *vera causa*. For part of the point of these examples is to illustrate that a number of processes postulated to explain the broad classes of facts he mentions are, though demonstrably real, *inadequate* to the explanatory task.

Suppose, for example, we wish to explain the fact that all over the world, in all sorts of different settings, the shells of sea creatures, or their fossilized by-products, are found at high elevations, far from the sea. One might hypothesize, notes Herschel, that pilgrims transported food from the sea to higher elevations and discarded the shells; or one might suppose that fermentation in the soil produced these fossils. Both processes, says Herschel, actually occur in nature: pilgrims do carry mollusks into mountains far from the sea and discard their shells; and there is a known process of fermentation that can produce by-products in the soil. But the 'pilgrim transport' hypothesis cannot account for the vast extent of the phenomena, or for fossils; and there is no evidence at all that fermentation, though a real cause of *some* things, can produce objects that resemble mollusk shells or their fossils. Thus, though both agents are real causes, neither is adequate to the particular explanatory task at hand.⁴

These examples illustrate that for Herschel a *vera causa* must [a] be able to account for the *full range* of phenomena to be explained and [b] be *confirmed as productive of all those phenomena*. Establishing such causes is the first and most fundamental step of scientific induction; and crucial to the process is establishing that the cause is *adequate to the full generality* of the phenomenon in question.

In 1961, Walter Cannon published a paper in which he reproduced and discussed a letter sent by Herschel from Cape Town, South Africa to Charles Lyell in February of 1836. This letter clearly establishes that Lyell's *Principles of Geology* was widely understood to be sympathetic to explaining the origins of new species by means of natural causes. Rarely, however, is Herschel's letter discussed against the background of the theory of science Herschel had defended only 5 years earlier in his *Preliminary Discourse*. When this background is acknowledged, the letter takes on added significance. When, for example, Herschel asserts that "... we are led by all analogy to suppose that he [the Creator] operates through a series of intermediate causes" and that "the origination of fresh species" must be a natural rather than a miraculous process—and then adds that "we perceive *no indications of any process actually in progress* which is likely to issue in such a result"—he is noting that even the weak necessary condition for a *vera causa* has not so far been met in this case.⁵

⁴ *A Preliminary Discourse on the Study of Natural Philosophy*, p. 144. Later he stresses that "... we cannot only show [these causes] to exist and to act, but the laws of whose action we can derive independently, by direct induction, from experiments purposely instituted ...," HERSCHEL, J. F. W., *A Preliminary Discourse on the Study of Natural Philosophy*, p. 197.

⁵ Cf. CANNON, W., "The Impact of Uniformitarianism: Two Letters from John Herschel to Charles Lyell, 1836-1837," *Proceedings of the American Philosophical Society*, v. 105, (1961), pp. 301-314; especially, p. 305.

Charles Babbage printed a number of excerpts from this letter as 'Note I' of BABBAGE, CH., *The Ninth Bridgewater Treatise: A Fragment*, John Murray, London, 1837. Darwin comments approvingly late in his species notebooks. "Babbage 2nd Edit, p. 226.—Herschel calls the appearance of new species, the mystery of mysteries & has grand passage upon problem! Hurrah.—'intermediate causes'," BARRETT, P. ET AL. (eds.), *Charles Darwin's Notebooks, 1836-1844*, Cornell University Press, Ithaca, NY, 1987, *Notebook E*, p. 59.

This letter was written only four months before Charles Darwin and Sir John Herschel met for the first time in Cape Town, when the *Beagle* stopped there on its return voyage to Great Britain. Read as I have suggested we read it, in light of Herschel's account of scientific inquiry in his *Preliminary Discourse*, it goes beyond a mere endorsement of search for a natural mechanism for species origins. It specifies a much more precise problem, which (I will argue) is the key problem of Darwin's *Species Notebooks* —to establish as *probable* a *vera causa* for the origination of fresh species. That is, not only must it be shown to be a process that actually operates in nature; it must also be shown to be adequate to the full range of effects, which in this case is daunting —all the known facts about all organisms, past and present!

In his *Beagle Diary*, Darwin refers to a dinner at Herschel's home at the Cape as “the most memorable event which, for a long period, I have had the good fortune to enjoy.”⁶ This is not surprising. Not only do we know of Darwin's unbounded admiration for Herschel's *Preliminary Discourse*; we also know that both Darwin and Herschel had been studying Lyell's *Principles of Geology* closely for the previous three years. Herschel claims in his letter to Lyell to have just read it for the third time, and his letter consists mostly of pages of detailed critical notes. Darwin, as we know from his correspondence, especially with his Cambridge mentor John Henslow, and from his *Beagle* notebooks, was constantly referring to it, and had come to see himself as a disciple of Lyell's. Did he and Herschel, then, discuss its lengthy presentation and critique of Lamarck's views on the indefinite modification of species in the first four chapters of Volume II, or its speculations on ‘the appearance of new species’ in chapter 11, over dinner?

There is no “smoking gun;” nevertheless the indirect evidence for such a conversation is intriguing. Shortly after his departure from South Africa, Darwin writes, in his *Ornithological notes*, that evidence from his field studies might present a challenge to a key conclusion of the second volume of Lyell's *Principles*, the permanence of species.⁷ This is our first evidence that Darwin has been thinking about the question. Moreover, there are some early geological entries in the *Red Notebook* referring to ideas that appear in Herschel's letter to Lyell —and Darwin opened this notebook immediately after the *Beagle* set sail from Cape Town.⁸ At the very least, these entries establish that Darwin and Herschel discussed some problems in Lyell's *Principles* that are presented in Herschel's letter—and therefore that they may well have discussed species origination as well.⁹ That would make the timing of the famous passage in the *Ornithological Notes*, immediately

⁶ DARWIN, CH., *Charles Darwin's Diary of the Voyage of H.M.S. Beagle*, edited from the original manuscript by Nora Barlow, Cambridge University Press, Cambridge, 1933; reprinted by Kraus Reprint Co., New York, 1969, p. 409.

⁷ Cf. DARWIN, CH., “Darwin's Ornithological Notes,” edited by Nora Barlow, *Bulletin of the British Museum (Natural History), Historical Series*, v. 2, n. 7, (1963), p. 262.

⁸ See HODGE, J., “Darwin Studies at Work: A Re-examination of Three Decisive Years (1835-37),” in LEVERE, T. H. and SHEA, W. R. (eds.), *Nature, Experiment, and the Sciences*, Kluwer, Dordrecht, 1990, pp. 249-274; and HERBERT, S. (ed.), *The Red Notebook of Charles Darwin*, British Museum (Natural History), London, 1980; the ideas in Herschel's letter are discussed on p. 30; cf. Herbert's note 40 on p. 86.

⁹ Of a similar entry on *The Red Notebook of Charles Darwin*, p. 115, Herbert says: “Presumably Lyell showed Darwin Herschel's letter, or discussed its contents with him, sometime in late 1836 or early 1837,” *The Red Notebook of Charles Darwin*, note 133, p. 104. I think it equally plausible that Darwin's information is from the same source as the earlier entry.

after leaving Cape Town and Herschel, natural. That passage reflects on a number of examples of closely related species within island chains. It concludes:

“If there is the slightest foundation for these remarks the zoology of Archipelagoes —will be well worth examining; for such facts would undermine the stability of Species.”¹⁰

Why would they, one might well ask? In such cases, the boundaries between variety and species seem blurred and it becomes very easy to imagine that what are now closely allied species may once have been varieties of the same species. And the moment one contemplates *that* thought one is dangerously close to the idea that species may be “capable of indefinite modification,” Lyell’s description of Lamarck’s view. But to entertain that view is, as Charles Lyell puts it on the first page of *Principles*, Vol. II, to entertain the view that species are not “real and permanent.”¹¹ It is, as Darwin says in the above note, to undermine their stability.

The issue raised on the first page of Herschel’s letter is the critical one for someone, like Darwin in 1836, who is worried about “the stability of species” and committed to Lyell’s actualist methodology of invoking as causes of past events only such processes as are currently in operation, and thus observable. A disciple of Lyell’s is limited to explaining events of the geological past—including the introduction of new species—by reference to causes of a kind and intensity that are observable in the present, and thus open to inductive inquiry. To put Lyell’s problem in Herschel’s terms: the only inductively responsible way to develop causal hypotheses about the pre-historic past is by reference to real causes, observed repeatedly, that are “competent, under different modifications, to the production of a great multitude of effects” at least analogous to those effects evidenced in the data of paleontology and natural history.

The opening sentence of Lyell’s *Principles* states: “Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature” and “... the causes of these changes ...”¹² The second volume aims to “turn our attention to those [changes] now in progress in the animate creation,” chief among these “the vicissitudes to which species are subject” and in particular “whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place.”¹³ In chapter 11 Lyell takes up this question, rejecting Humboldt’s assertion that “these are among the mysteries which natural science cannot reach.”¹⁴ Lyell insists that the investigation of the present state of the animate creation *can* shed light on its past.¹⁵ He asks us to consider what sort of evidence we would need to assure ourselves that the “successive creation of species” is “a regular part of the economy

¹⁰ DARWIN, CH., “Darwin’s Ornithological Notes,” edited by Nora Barlow, p. 262.

¹¹ Cf. LYELL, CH., *Principles of Geology*, John Murray, London, 1830-1833, 3 vols. Reprinted in facsimile edition, The University of Chicago Press, Chicago, 1990, pp. 1-2.

¹² LYELL, CH., *Principles of Geology*, Volume I, p. 1.

¹³ *Principles of Geology*, Volume II, pp. 1-2.

¹⁴ LYELL, CH., *Principles of Geology*, Volume II, p. 179.

¹⁵ *Principles of Geology*, Volume II, p. 179.

of nature.” This is the discussion praised for its boldness and courage in the opening page of Herschel’s letter.

And yet Lyell concludes the discussion without even *raising* the question of what “causes now in operation” might lead to the “successive creation of species,” let alone proposing an answer. To attack this issue within the framework of Herschel’s inductive methodology, one must search for observable agents, competent to produce the full range of effects in need of explanation—in this case, the historical appearance and current distribution of species.

Lyell, then, sets the problem of establishing a natural mechanism to explain the origination of species, and Herschel provides the methodological framework within which a solution to the problem is to be sought. It is the problem that Darwin devotes himself to in the years 1837-1839, and as I will argue momentarily, he aims to do so within the parameters laid down by Herschel. Darwin succeeds in establishing a causal process the elements of which are, at least in principle, observable. That is to say, the conditions that he claims will lead to natural selection—the appearance of undirected variation within species, the regular inheritance of variation, the struggle for existence among members of species, a tendency for natural populations to increase at a geometric rate—can all be inductively confirmed. That is not, however, the same as showing that these various features of natural populations work together in just the manner required to produce first new varieties, then new insipient species, and finally new species. In an experimental science, of course, this is precisely the point at which one introduces experiment. And in the twentieth century evolutionary biology becomes an experimental science. But it was not for Darwin. Darwin’s central problem is that he not only needs to establish that each of the components of the selection process has “real existence in nature”—he needs to convince people that it is competent to produce the regular appearance of new species, well adapted to their environments.

How, then, does one argue, in the absence of evidence that in observed cases a cause *has* produced the desired effect, that it *could* produce the desired effect in unobserved cases? In my earlier discussion of Darwinian Thought Experiments I argued that Darwin deployed thought experiments for precisely this purpose.¹⁶ I also pointed out that Fleeming Jenkin’s review of the *Origin* revealed the limitations of this technique and suggested some constraints on its effective use. Jenkin pointed out that the only *actual* evidence of selection bringing about its effects in the *Origin*, the domestic production of varieties, was *inadequate* to the task of the production of species in nature (or under domestication, for that matter). He accepted Darwin’s causal model and inserted plausible quantitative values into Darwin’s imaginary causal narratives, values that would not, however long they were multiplied, lead to the production of a new species.¹⁷

In the next section, I briefly review the results of that discussion and argue that this aspect of Darwin’s methodology accounts for a feature of the structure of the *Origin* that is rarely discussed.

¹⁶ Cf. LENNOX, J. G., “Darwinian Thought Experiments: A Function for Just-so Stories,” in HOROWITZ, T. and MASSEY, G. (eds.), *Thought Experiments in Science and Philosophy*, pp. 223-246.

¹⁷ In his 1831 copy of Herschel’s *Preliminary Discourse* Darwin marks a number of passages that stress that qualitative and vague inductions are easily overturned by quantitatively precise tests. Darwin was rereading Herschel in 1838.

3. THOUGHT EXPERIMENT IN THE *ORIGIN*

For many years Jonathan Hodge has been making the case that Darwin aims to conform, in the *Origin*, to the Herschelian ideal of establishing a *vera causa*. To do so, says Hodge, one needs to establish the *existence* of the causal agency invoked, its *adequacy* to the explanatory task at hand, and its *responsibility* for the effects in need of explanation.¹⁸ Hodge sees the first two tasks as being jointly accomplished in the first eight chapters. In my paper published in 1991 (“Darwinian Thought Experiments: A Function for Just-so Stories”), I focused on the use of thought experiments as a method Darwin deployed to meet the adequacy (or in Herschel’s more typical language, ‘competency’) condition. But Darwinian thought experiments are *imaginative* narratives that serve as tests of natural selection’s explanatory *potential*. An important question arises, then, about what role they can play in Darwin’s argumentative strategy.

In the *Origin*’s first four chapters a variety of processes—inheritation via sexual reproduction, the generation of character variation, the Malthusian tendency for population expansion and various Malthusian checks on such expansion, organism/environment interactions, slow and gradual changes in environmental conditions—are described at a very general level. Darwin’s theory postulates that the interactive operation of these processes is *competent*, given sufficient time, to transform an ancestral species into one or more descendent species.

The notion of *competence* is ambiguous, however. To make the case that something is competent to produce a certain result, one might suppose it is enough to show it is *able* to do so, even if it has never been observed to do so. Alternatively, one might insist that a cause is shown to be competent to the full range of its effects only once properly controlled observation and experiment has shown that it is *actually productive* of those effects. Darwin aimed to achieve the former result—the reactions of the likes of Herschel, Whewell, and Lyell indicate they would only be satisfied with the latter.

Darwin’s use of thought experiment in chapters 4-9 of the *Origin* provides the reader with a variety of concrete, but imaginary, instantiations of the elements of Darwin’s causal model in operation, and asks the reader to imagine gradual changes in these imaginary populations over time. We are asked whether it seems possible that if such changes continue over a long enough period of time one or more new species would result. Darwinian thought experiments share with all thought experiments the function of *testing the explanatory potential* of theories—it is this that distinguishes them, functionally, from “real world” experiments.

Darwinian thought experiments play two distinct roles in the *Origin*: [a] as imaginary, concrete narratives, they aim to show that natural selection is *able* to produce new varieties and species; and [b] as “how possibly” narratives, they are used to turn supposed counter-examples into possible consequences of the operations of the causes proposed by his theory. Task [a] is prominent in the section of chapter four entitled “Illustrations of the action of Natural Selection,” in which Darwin begs permission “to give *one or two*

¹⁸ A brief review of his case, with references to his original defense of the view and comparison to other readings, can be found in HODGE, M. J. S., “Discussion: Darwin’s Argument in the *Origin*,” *Philosophy of Science*, v. 59, n. 3, (1992), pp. 461-464.

imaginary illustrations."¹⁹ Task [b] is the primary work of chapters 6-9, in which Darwin deals with "Difficulties on theory." In chapters 6 and 7, for example, Darwin routinely notes that if his opponents argue that a complex adaptation or instinctive behavior could not possibly have been produced by selection slowly accumulating slight variations, then his task is to establish natural selection *could* do so, a task to be accomplished by Darwinian thought experiments.

But do such flights of imagination count as evidence of how complex adaptations were *actually* produced? Immediately after an extended thought experiment imagining how the vertebrate eye could have evolved by selection, we find one of the most methodologically important passages in the *Origin*:

"He who will go thus far, if he find on finishing this treatise that large bodies of facts, otherwise inexplicable, can be explained by the theory of descent, ought not to hesitate to go further, and to admit that a structure even as perfect as the eye of an eagle *might be formed by natural selection*, although in this case he does not know any of the transitional grades. His reason ought to conquer his imagination..."²⁰

That is, it is on the *combination* of Darwinian thought experiment *and* the evidence of chapters 10-13 that he will rest his case. They are not independent but mutually reinforcing lines of evidence.

Darwin is not consistent about the need for both sorts of support. Often he speaks as if a theory's "ability to group and explain phenomena," the argumentative force of chapters 10-13, is sufficient, as in the following note to Hooker comparing his theory to the wave theory of light:

"... the descent of species with their modifications through natural selection groups together and fairly well explains many phenomena (as classification, morphology, rudimentary organs, embryology, partially Geograph. Distrib. and partially Geolog. Succession) and *therefore* I believe in its truth."²¹

In a letter to Asa Gray the same year, however, Darwin again stresses the need for both. He explains that he could believe a structure was designed "... until I saw a way of its being formed without design, & *at the same time* saw in its whole structure (as in homologies, embryology, rudimentary organs, distribution, &c) evidence, of its having been produced in a quite distinct manner..."²² Darwinian thought experiments are Darwin's primary tool for convincing readers that adaptations *could* be formed by natural selection. All the rest is indirect evidence that they have been.

Darwin stresses the same point in a familiar passage in the *Origin's* introduction. Even if all our evidence from geology and natural history supported species origination by descent, such a conclusion, he insists, would be unsatisfactory if the mechanism driving descent were not also able to explain the beautiful adaptations that result.²³ The

¹⁹ DARWIN, CH., *On the Origin of Species: A Facsimile of the First Edition*, Harvard University Press, Cambridge, MA, 1964, p. 90; italics added.

²⁰ DARWIN, CH., *On the Origin of Species: A Facsimile of the First Edition*, p. 188.

²¹ BURKHARDT, F. ET AL. (eds.), *The Correspondence of Charles Darwin*, vol. 9, Cambridge University Press, Cambridge, 1994, p. 50; compare p. 135, to Herschel.

²² BURKHARDT, F. ET AL. (eds.), *The Correspondence of Charles Darwin*, vol. 9, p. 302.

²³ DARWIN, CH., *On the Origin of Species: A Facsimile of the First Edition*, p. 3.

best Darwin managed on this front, however, was to show how it was *possible* for the causal processes he describes in chapters 2-4 to interact in such a way as to produce such perfection. And therein lies the problem so many members of Darwin's ideal audience had with the *Origin*. These thought experiments, as vivid as they appear to be, are, in fact, figments of Darwin's fertile imagination. They may establish the *possibility* of species arising by slow modification under selection—but they do no more than that.

The second task of Darwinian thought experiment, countering impossibility arguments, highlights an innovative feature of the *Origin's* structure that typically goes unnoticed. This feature is mirrored in its concluding chapter, which opens by commenting that the *Origin* is “one long argument.” This chapter, which is primarily intended as a summary of that argument, begins with seven pages of *difficulties* for his theory—that is, it begins with a summary of chapters 6-9! By considering why Darwin would discuss the theory's difficulties *before* providing positive evidence in its favor, the importance of Darwinian thought experiment to the *Origin's* argument becomes clear.²⁴ The point is stated vividly in a passage in the “Essay Draft” of the *Origin* written by Darwin in 1844:

“... we may here consider whether the instincts of animals offer such a *prima facie* case of impossibility of gradual acquirement, as to justify the rejection of any such theory, however strongly it may be supported by other facts. I beg to repeat that I wish here to consider not the probability but the possibility of complicated instincts having been acquired by the slow and long-continued selection of very slight ... modifications of foregoing simpler instincts...”²⁵

Darwin here acknowledges that if the evidence drawn from instincts shows the theory to be impossible, no amount of “grouping and explaining” will save it. But he also insists that all that is required in order to counter such a claim is a demonstration that it is *possible* for the theory to handle such cases. These passages provide insight into Darwin's decision, when writing the *Origin*, to present such evidence in separate chapters, *prior* to the inductive support for the theory—something he did *not* do in the 1844 draft.

Darwin's use of this form of reasoning to demonstrate what we might designate “weak competency” is innovative. Its origins, however, are not hard to find once one knows what one is looking for. In the next section of this essay we will see the emergence of this innovative cognitive strategy, and the gradual emergence of Darwin's awareness of its value, in his *Species Notebooks*.

4. THE EVOLUTION OF A COGNITIVE STRATEGY

Darwin's post-Beagle notebooks on the species question, written during the years 1837-38 and beautifully edited and annotated by David Kohn²⁶ constitute a private discourse

²⁴ In a recent paper, for example, Ken Waters carefully notes the distinction between chapters 6-9 and 10-13, but doesn't comment on the oddity of placing the discussion of problems before the compelling positive evidence. Cf. WATERS, C. K., “The Arguments in the *Origin of Species*,” in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, Cambridge University Press, Cambridge, 2003, pp. 116-139.

²⁵ BARRETT, P. H. and FREEMAN, R. B. (eds.), *The Works of Charles Darwin, vol. 10: The Foundations of the Origin of Species: Two Essays Written in 1842 and 1844*, New York University Press, New York, 1987, p. 92; cf. pp. 96-97; emphasis in original.

²⁶ Cf. BARRETT, P. ET AL. (eds.), *Charles Darwin's Notebooks, 1836-1844*, pp. 167-456.

of discovery, his gradual development of something that, by the end of Notebook C, he is referring to as “my theory.”

In these notebooks Darwin is *also* developing those cognitive strategies discussed in the previous section of this essay. In fact, Darwin was using a “thought experimental” form of reasoning almost from the beginning of these notebooks, not as a method of defense for his theory, but as a means of exploring the ability of his developing ideas to explain facts that typically pose problems for transformist views of species origins.

From the time he left Cape Town Darwin favored transformism, the view that later species are “transformed” descendants of earlier species. He was confident that a wide range of facts regarding geographic distribution of organisms and their geological succession fit neatly with this view of life’s history. He was also well aware of familiar problems for all such theories. Occasionally, while reflecting on reading related to “the species question” in light of the rich tapestry of experiences provided by his Beagle years, he stops to test the theoretical ideas he is struggling to articulate against such problems. In order to do so, he plays out imaginative scenarios, assuming the operation of those causal processes he is currently considering. Which is to say, he conducts thought experiments.

For example, the 19th century European excavations of the tombs of Lower Egypt had revealed mummified remains of a number of animals, as well as realistic portraits of them. These showed that there had been virtually no change in these creatures over many thousands of years, suggesting the stability or “fixity” of species. Darwin knew of this objection from Lamarck and Lyell,²⁷ and used it to test his developing views about isolation and struggle.

“Aegyptian cats and dogs ibis same as formerly but separate a pair and place them on fresh isld. it is very doubtful whether they would remain constant; is it not said that marrying in *deteriorates* a race, that is alters it from some end which is good for Man.—

Let a pair be introduced and increase slowly, from many enemies so as often to intermarry who will dare say what result.”²⁸

Darwin imagines the consequences of transporting a mating pair of one of these species to an island with predators that cause the population to increase only slowly.²⁹ One consequence will be that close relatives will be mating regularly, which ordinarily would lead to “deterioration,” but all this means is that the offspring don’t turn out as the breeder wishes. On this new island, some of these newly arising variations might be useful.

The “mummy objection” could be met, as Lamarck met it, simply by assuming a constant environment —on Lamarck’s view, if the environment didn’t change, why would the organism? Darwin is asking a follow-up question —under what circumstances *would* they have transformed? What if a pair of Egyptian cats were subject to the sort of process that transformed the first visitors to the Galapagos islands? ‘Who will dare say what result?’ Darwin asks.

²⁷ LAMARCK, J-B., *Zoological Philosophy*, University of Chicago Press, Chicago, 1984, pp. 41-42; LYELL, CH., *Principles of Geology, Volume II*, p. 28.

²⁸ BARRETT, P. ET AL. (eds.), *Charles Darwin’s Notebooks, 1836-1844*, Notebook B, pp. 6-7. As in the Barrett et al. edition, I have retained Darwin’s spelling and punctuation.

²⁹ An alternative reading is that “from many enemies” means “isolated from many enemies” —I am reading ‘from’ as ‘due to’, and thus take this phrase to explain the slowness of the increase.

A few pages later Darwin is worrying about the problem of how to account for cases where an island species is *generically* like a species that is found both on the mainland and on the island, though specifically different. Darwin imagines how this might have happened consistent with the mainland form being the ancestor of some of the island forms.

“Then (remembering Lyell’s arguments of transportal) ... island near continents might have some species same as nearest land, which were late arrivals other old ones, (of which none of the same kind had in interval arrived) might have grown altered. Hence the type would be of the continent though species all different.”³⁰

Much of volume II of Lyell’s *Principles* is devoted to testing the hypothesis that a single “center of creation” for each species is sufficient to explain their current and past geographic distribution.³¹ However, convinced that species are incapable of indefinite modification, Lyell never considers the question that haunted Darwin —why is there a correlation between the *geographic proximity* and *taxonomic similarity* of related, but different, species? In the above passage, Darwin imagines a scenario whereby one island species can be a descendant of a species found on the same island as well as on a nearby continent. Suppose members of a mainland species migrate to a nearby island and are transformed into a new species. Then there is a second migration of the original species; unable now to interbreed with its descendents, it remains distinct.

Driving both of these thought experiments are concerns that free intercrossing of a population is a problem for evolutionary change; the production of a new species, then, requires isolation from its ancestral population. Production of a new species is thus intimately tied to the Lyellian ebb and flow of geological change, especially the production of barriers by elevation and subsidence. The possibility of this mechanism promoting speciation is the focus of yet another thought experiment:

“Species formed by subsidence, Java & Sumatra. Rhinoceros. Elevate & join deep distinct. two species made elevation & subsidence continually forming species.”³²

The pattern of imaginative illustration in chapter 4 of the *Origin* is here seen in embryonic form —not as an illustration of the action of natural selection, however, but as a means of working through problems for his developing transmutational theory. The trick in reading these notes is in determining where the transitions are and where to mark breaks and transitions not clearly indicated by the punctuation. One plausible interpretation of this note, for example, would expand it as follows: *Species [are] formed by subsidence, [e.g.] Java & Sumatra [their distinct species of] Rhinoceros. Elevate [the land] & [these islands] join [whereas when the channel between them is] deep [they are] distinct. [T]wo species [are thus] made. Elevation & subsidence [are] continually forming species.*

The use of thought experiments to counter impossibility objections also emerges in the notebooks. In a passage in Notebook C, for example, Darwin recognizes the problem posed for his views by complex adaptations.

³⁰ BARRETT, P. ET AL. (eds.), *Charles Darwin’s Notebooks, 1836-1844*, Notebook B, pp. 10-11.

³¹ Cf. LYELL, CH., *Principles of Geology, Volume II*, pp. 124-184.

³² BARRETT, P. ET AL. (eds.), *Charles Darwin’s Notebooks, 1836-1844*, Notebook B, p. 82; cf. Notebook C, p. 191.

“We never may be able to trace the steps by which the organization of the eye, passed from simpler stage to more perfect. preserving its relations.—the wonderful power of adaptations given to organization. —This really perhaps greatest difficulty to whole theory.”³³

We hear clear echoes of this note in the introduction to the *Origin* when Darwin remarks on the importance of accounting for complex adaptations, and in his use of thought experimentation to deal with this very objection (and many similar ones) in chapter 6 of the *Origin*. As he writes these notebook entries, he is unaware that this mode of reasoning can be an effective strategy for arguing against the “organs of extreme perfection” objection. By the close of Notebook D, however, that has changed. “In my theory,” he tells himself there, “I must allude to separation of sexes as very great difficulty, then give speculation to show that it is not overwhelming.”³⁴ Darwin here recognizes that thought experiment can be used to fend off an entire class of objections, a major methodological breakthrough.

Clearly, however, this memo needs to be supplemented. Not just *any* speculation will do. It must be concrete enough to engage the reader’s imagination, and it must mention processes, objects and interactions that are familiar and can easily be imagined to have the full range of desired consequences—like those in the *Origin*.

Darwin begins the *Species Notebooks* with a firm conviction that, for a set of paradigmatic facts, the obvious explanation is that new species are the transformed descendants of ancestral species. But he also considers facts from geography and natural history that pose real problems for such a theory. In dealing with these he instinctively imagines concrete historical processes that *could* produce these problematic results by transmutational means. Gradually it dawns on him that a sufficient response to certain “impossibility” objections is to show that the theory is “competent” to explain them. Ready to hand is a form of ‘factually constrained narrative’ he has been using all along to help him imagine how his theory explains. We begin to find memos in these private notebooks to use this pattern in his public defense of “his Malthusian ideas.”

I conclude this section with a passage from “The Torn Apart Notebook” that reveals Darwin planning a strategy for engaging the imagination of his readers and disarming troubling objections—and recognizing that the ability to “group and explain many facts” is not enough. After mentioning a number of difficult cases, he writes that “the whole mind is constituted that a difficulty makes greater impression, than the grouping of ‘many’ facts with laws & their explanation will probably reject this theory;” and he then admonishes himself to face this difficulty “by rooting out curious cases of intermediate structure, & supposing much extinction, give a parallel case.”³⁵ Darwin could now provide a clearly justification for placing his “difficulty” chapters where he does in the *Origin*. He needs to answers those impossibility objections first, before going on to show how well his theory is able to group and explain the facts.

³³ Charles Darwin’s *Notebooks*, 1836-1844, Notebook C, p. 175.

³⁴ BARRETT, P. ET AL. (eds.), *Charles Darwin’s Notebooks*, 1836-1844, Notebook D, p. 159e.

³⁵ BARRETT, P. ET AL. (eds.), *Charles Darwin’s Notebooks*, 1836-1844, Torn Apart Notebook, p. 463.

5. CONCLUSION: A LYELLIAN POSTSCRIPT

In one of the *Species Notebooks*' many reflective and self-conscious moments, Darwin comments on "[t]he difficulty of multiplying effects & to 'ponder' conceive the result with that clearness of conviction" and yet insist that therein lies "the ... foundation stone of further inductive reasoning" —and credits geology with "giving proper ideas of these subjects."³⁶

By "geology," Darwin surely means Charles Lyell. Darwin here records his debt, *not* to the actualism and gradualism he absorbed from Lyell's *Principles*, but to Lyell's use of imaginative illustration. The echoes of this passage reverberate in the conclusion of that section of the *Origin* with which I began.

"I am well aware that this doctrine of natural selection, exemplified in the above imaginary instances, is open to the same objections which were at first urged against Sir Charles Lyell's noble views on 'the modern changes of the earth, as illustrative of geology'."³⁷

In both passages, Darwin praises Lyell for paving the way for his use of "imaginary illustrations" to exemplify the operation of causes postulated by theory. The praise (or blame, depending on one's evaluation of this strategy) is warranted. In *Principles* volume II, we find Lyell over and over again using vividly evocative thought experiments to illustrate how available means of dispersal could account for the geographic range of different species of plants and animals. One example from dozens in these chapters will have to do:

"A deer has strayed from the herd, when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly plunges through many a thicket, and swims through many a river and lake. The seeds of the herbs and shrubs adhere to his smoking flanks, and are washed off again by the streams. The thorny spray is torn off and fixes itself in his hairy coat, until brushed off again in other thickets and copses. Even on the spot where the victim is devoured, many of the seeds which he had swallowed immediately before the pursuit may be left on the ground uninjured."³⁸

This passage has all the earmarks of Darwinian thought experiment —a concrete, imaginary narrative exemplifying the causal process that will lead to seed dispersal, which over the long term will account for the geographic range of the plants in question.

Darwin rightly recognizes the Lyellian origins of the use of thought experiments for these purposes. Lyell was as much a master of the technique as was Darwin. But it was Darwin who reflected philosophically on its value and limitations, and who developed it self-consciously. As with many Darwinian innovations, we can trace this one's roots to Charles Lyell, but it is Darwin who developed a philosophical justification for it. As with many of Darwin's methodological innovations, it met with a skeptical reception.

³⁶ Charles Darwin's *Notebooks, 1836-1844*, Notebook E, p. 6e.

³⁷ DARWIN, CH., *On the Origin of Species: A Facsimile of the First Edition*, p. 95.

³⁸ LYELL, CH., *Principles of Geology, Volume II*, p. 79.

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**‘IS A NEW AND GENERAL THEORY OF EVOLUTION EMERGING?’
A PHILOSOPHICAL APPRAISAL OF STEPHEN JAY GOULD’S EVALUATION
OF CONTEMPORARY EVOLUTIONARY THEORY**

JEAN GAYON

1. INTRODUCTION

In 1980, Stephen Jay Gould (1941-2002) published a provocative paper entitled “Is a New and General Theory of Evolution Emerging?”¹ This paper declared that the synthetic theory, as a general proposition, was dead: “I well remember how the synthetic theory beguiled me with its unifying power when I was a graduate student in the mid-1960’s. Since then I have been watching it slowly unravel as a universal description of evolution. The molecular assault came first, followed quickly by renewed attention to unorthodox theories of speciation and by challenges at the level of macroevolution itself. I have been reluctant to admit it —since beguiling is forever— but if Mayr’s characterization is accurate,² then that theory, as a general proposition, is effectively dead, despite its persistence as text-book orthodoxy.”³

Gould’s huge scientific testament, *The Structure of Evolutionary Theory*,⁴ provides a sensibly different picture of his relation to the Darwinian tradition. This book of 1.433 pages, which appeared shortly before Gould’s death in 2002, is a very personal book, where almost every subject relates to some aspect of Gould’s prolific output. The most general thesis is that the *central core* of the Darwinian theory of evolution persists, although the *structure* of contemporary evolutionary biology has been enlarged and modified in a way that makes it a truly new entity.⁵

This is a significant change of attitude. In 1980, Gould maintained that the synthetic theory had been destroyed and replaced; in 2002, he stated neither that the Darwinian view of evolution had remained unchanged, nor that it had been replaced, but rather that it had “substantially changed.”⁶ In Gould’s terms, there exists a strong conceptual continuity between the classical Darwinian theory and the new theory, a continuity that is not merely genealogical, and involves a genuine conceptual similarity. The older conceptual framework had not been “substituted” by a new one, it had “developed” into a new one.⁷

¹ GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” *Paleobiology*, v. 6, n. 1, (1980), pp. 119-130.

² Gould alludes to the following statement by Mayr: “The proponents of the synthetic theory maintain that all evolution is due to the accumulation of small genetic changes, guided by natural selection, and that transspecific evolution is nothing but an extrapolation of the events that take place within populations and species,” MAYR, E., *Animal Species and Evolution*, The Belknap Press of Harvard University Press, Cambridge, MA, 1963, p. 586. It is quoted in GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” p. 120.

³ “Is a New and General Theory of Evolution Emerging?,” p. 120.

⁴ GOULD, S. J., *The Structure of Evolutionary Theory*, The Belknap Press, Cambridge, MA, 2002.

⁵ GOULD, S. J., *The Structure of Evolutionary Theory*, p. 6.

⁶ Cf. *The Structure of Evolutionary Theory*, pp. 3-6.

⁷ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, p. 9.

One might object that Gould's 1980 revolt was directed against the Modern Synthesis, not against Darwinism in general. This is true. However the 1980 paper has a number of allusions to the "Darwinian orthodoxy" and to Darwin himself.⁸ Although Gould was a little more charitable towards Darwin than towards strict "Darwinism" (i.e. Wallace's version of Darwinism), his criticism of the Modern Synthesis was also a criticism of Darwinism as a whole, seen as a theory of evolution where natural selection within species is the most important evolutionary factor.⁹

Gould was perfectly aware of the philosophical dimension of his claims about the subtle continuity between Darwinism and his final conception of evolution. In the introduction to his 2002 book, he rejects David Hull's proposal of defining conceptual lineages (such as "Darwinism") "purely by genealogy and not at all by content."¹⁰ For Gould, the historian of science should not feel compelled to choose between abstract history of ideas and contextual history of intellectual communities: conceptual lineages should be described in terms of both genealogical continuity and morphological similarity.¹¹

This paper examines the question of the "continuity" of Darwinism over time at a large historical scale. First, I treat the question in its own right, with no particular emphasis on Gould (though he is sometimes part of the story as a scientific actor). Secondly, I analyze Gould's own position on the same issue.

2. IS CONTEMPORARY EVOLUTIONARY BIOLOGY 'DARWINIAN', AND IN WHAT SENSE?

For nearly one-and-a-half centuries, evolutionary biologists have been haunted by the question of whether their conceptions are or are not "Darwinian." This persistent positioning of new scientific developments in reference to a single, pioneering figure is something quite exceptional in the history of modern science. Physicists working in the domain of relativity or quantum theory may refer to Einstein or Bohr (or other individuals). But their debates have not been massively structured through reference to these individual's names in the way that evolutionary theory has been and continues to be today.¹² I know of nothing like "Einsteinianism" or "Bohrism" in physics, whereas "Darwinism" has been a keyword among evolutionary biologists since it was first coined.

What can account for such a fact? One explanation might be that Darwinism, just as Marxism, is not only the name of an ordinary scientific tradition, but also of a massive historical phenomenon, ranging across many areas of modern culture and politics. In such cases it is common to identify a tradition of thinking with a person's name. But although this is perfectly true, we cannot be satisfied with that explanation, or, more precisely, with that explanation alone. The fact is that biologists working on evolution have never stopped returning to Darwin and reading his masterpieces. It is still the case today. And, again, we do not observe anything like this in other areas of the natural sciences. My conviction is

⁸ Cf. "Is a New and General Theory of Evolution Emerging?," pp. 119-130.

⁹ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, pp. 120 and 122.

¹⁰ *The Structure of Evolutionary Theory*, p. 9.

¹¹ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, p. 8.

¹² GAYON, J., "Critics and Criticisms Modern Synthesis: the Viewpoint of a Philosopher," *Evolutionary Biology*, v. 24, (1990), pp. 1-49. See also other references in note 13. Similar views have been recently developed in very original way in LEWENS, T., *Darwin*, Routledge, London, 2007.

that evolutionary biologists' uninterrupted interest in Darwin since 1859 indicates a strong form of connection, such as that between a model (Darwin) and its successive copies (the successive versions of "Darwinism").

I maintain that there exists some kind of isomorphism between Darwin's Darwinism and historical Darwinism. By this I do not mean that everything present in Darwin's evolutionary views has been passed onto the 'Darwinian' tradition. I want to say merely that something crucial in Darwin's own contribution has durably constrained the development of evolutionary theory. This something is not so much a list of particular hypotheses or doctrines (such as a particular interpretation of natural selection, or heredity, or variation, or even descent), but rather a general view related to the structure of evolutionary theory.¹³ Or, to be more precise: a general view of the general framework within which evolutionary research makes sense. What matters is the overall structure, not the truth of Darwin's personal hypotheses about this or that element of this structure (at least up to a certain point: if Darwin had been wrong about each element, the overall structure would not have remained for so long).

Let us first recall that Darwin referred to his theory in *The Origin of Species* as "Descent with modification through natural selection."¹⁴ This formula suggests that Darwin's theory was made of two components or even sub-theories: the first component is "descent with modification," that is a theory about we would call today the general "pattern" of evolution; the second part ("through natural selection") refers to the conjecture that natural selection is the main explanation for the modification of species.

Darwin did not organize his book in line with this distinction. Indeed, he organized the whole book in such a way that the two parts are always tightly connected to each other. Nevertheless there are two good reasons for taking this distinction seriously. First, Darwin was perfectly aware of its importance. In a letter to the American botanist Asa Gray, who reacted quite favourably to the *Origin*, he wrote this revealing sentence in 1863: "Personally, of course, I care much about natural selection, but that seems to be utterly unimportant compared to the *Creation or Modification*."¹⁵

¹³ I have been trying for some time to develop this structural view of the history of Darwinism. The present paper relies on several (more or less successful) efforts in that direction: GAYON, J., "Critics and Criticisms Modern Synthesis: the Viewpoint of a Philosopher," pp. 1-49; GAYON, J., "Neo-Darwinism," in WOLTERS, G. LENNOX J. G. and MCLAUGHLIN, P. (eds.), *Concepts, Theories, and Rationality in the Biological Sciences*, The Second Pittsburgh-Konstanz Colloquium in the Philosophy of Science, Universitätsverlag Konstanz and University of Pittsburgh Press, Konstanz-Pittsburgh, 1995, pp. 1-25; GAYON, J., "The Paramount Power of Selection: From Darwin to Kauffman," in DALLA CHIARA, M. L., DOETS, K. D., MUNDICI, D. and VAN BENTHEM, J. (eds.), *Structures and Norms in Science, Volume Two of the Tenth International Congress of Logic, Methodology and Philosophy of Science*, Kluwer, Dordrecht, 1997, pp. 265-282; GAYON, J., "Sélection," in LECOURT, D. (ed.), *Dictionnaire d'histoire et de philosophie des sciences*, Presses Universitaires de France, Paris, 1999, pp. 854-861; GAYON, J., "From Darwin to Today in Evolutionary Biology," in HODGE, J. and RADICK, G. (eds.), *The Cambridge Companion to Darwin*, Cambridge University Press, Cambridge, 2003, pp. 240-264; and GAYON, J. and RICQLÈS, A. DE, "Évolutionnisme," in: *Dictionnaire des idées*, Encyclopaedia Universalis, Paris, 2005, pp. 271-275. See also note 30.

¹⁴ DARWIN, CH., *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, John Murray, London, 1859, p. 459. This formula remained the same till the sixth and last edition, where Darwin added one word: "... Descent with modification through *variation* and natural selection."

¹⁵ DARWIN, CH., *Letter to A. Gray*, 11 May 1863; reprinted in BURKHARDT, F. ET AL., *The Correspondence of Charles Darwin*, Cambridge University Press, Cambridge, 1985-2007, v. XI, p. 403. (Italics and bold characters are in text.)

The second reason is that the scientific community did not react to the two parts of Darwin's theory in the same way. "Descent with modification" was quickly renamed "evolution" by Darwin's readers and by Darwin himself, who accepted this term and introduced it in the last edition of *The Origin* (1972), where it appears seven times, as an abbreviation for the "descent with modification" of the previous editions. This part of the theory was so successful and so rapidly adopted in the last third of the 19th century that it became common to call it "the general fact of evolution," whereas the explanation of this "general fact" through natural selection has been subject to unending controversies since 1859. For these two reasons, the issue of the continuity *versus* non-continuity of Darwinism over time deserves being examined from these two different perspectives, and not only from the viewpoint of the theory of natural selection.

2.1. Descent with Modification or "the General Fact of Evolution"

Darwin did not provide an explicit definition of what he meant by "descent with modification" in *The Origin of Species*. He probably thought that this expression, which was made of two common terms among naturalists, was self-evident: species "descend" from one another and they are "modified." Nevertheless Darwin had a rather restrictive interpretation of this common idea—we might well say a model of it. This model is clearly expressed, not in a definition, but in the unique illustration given in *The Origin*, the famous branching diagram given in chapter 4. This diagram (see figure 1) was so important for Darwin that he felt the need to comment on it at length twice in his book, using no less than eleven full pages in chapter 4 (devoted to natural selection) and three full pages in chapter 13 (devoted to classification and embryology)¹⁶.

This diagram expresses a series of conjectures, none of which is trivial:

[1] Species are subject to modification.

[2] This modification is slow and gradual.

[3] Many species go extinct.

[4] The species that do not go extinct usually split into other species.

[5] Once two or more species have split, they diverge indefinitely.

[6] The diagram applies to all taxonomical levels from the lowest local varieties to the most encompassing groups (e.g., "A" may be a variety that leads to a species with eight varieties, or a species that leads to a genre with eight species, or a genre that leads to a family containing eight genres, etc.).

[7] Postulate [6] means that classification is entirely determined by genealogy. Therefore there are as many "ranks" as there are branching events of ramification, and all taxonomic categories used in systematics (species, genres, families, etc.) are arbitrary.

[8] Postulate [6] also implied for Darwin that the entire process of diversification reduces to diversification at the lowest level (varieties and species); supra-specific taxa have no particular role in evolution, they are just an outcome.

¹⁶ Cf. DARWIN, CH., *On the Origin of Species*, pp. 116-126 and 420-422 (pages wholly devoted to comment the diagram).

To be fair, I should add that there is an asymmetry between the two passages devoted to the explication of the diagram. In chapter IV, Darwin often refers to the process of natural selection; in chapter XIII, he does not, and comments only on the classificatory "arrangement" (or pattern in modern terms).

Darwin's tree-like diagram had an almost immediate effect upon the entirety of the biological community. Within a short period of time, it became the paradigmatic representation of organic evolution as an established fact, the "general fact of evolution." The sudden and dramatic effect of this diagram constitutes one of the most spectacular examples of a paradigm-shift in the history of science, to use Thomas Kuhn's famous terminology. One could not say the same for Darwin's theory of natural selection, which opened a long series of controversies.

However, from a methodological point of view, the characterization of Darwin's tree-of-life as a "general fact" of nature is misleading. This diagram, with the non-trivial postulates that it illustrates, is a theoretical construction. The kind of theory involved is not a causal theory, although it may be used for explanatory purposes in certain contexts. It is a theory that postulates the general existence in nature of several classes of phenomena. Such a theory looks like a descriptive generalization, but it is not. It is a heuristic device, a plausible bet about the general form and pace of the phenomena that constitute evolution, and that call for explanation. Of course, the more scientists accumulate data within such a framework, the more they tend to consider this framework as a literal description. But this is not the case: Darwin's theory of "descent with modification," as summarized in his diagram, is a low level theory, but nevertheless a theory. As Doolittle and Bapteste recently wrote in a fascinating article, "descent with modification is only one of [the evolutionary] mechanisms, and a single tree-like pattern is not the necessary (or expected) result of their collective operation."¹⁷

Now the question is: has the scientific consensus about the so-called "fact of evolution," as represented by Darwin's diagram, been significantly threatened since Darwin's time? There have been at least three serious challenges to Darwin's tree-of-life picture. Each of these challenges, or classes of criticisms, relates to the shape of the tree. The first two have been recurrent since the time of Darwin. The third is recent.

The first kind of criticism can be found among those biologists or paleontologists who have advocated a non-gradual or saltationist representation of the origin of species. Since Thomas Henry Huxley, Francis Galton and the early Mendelians, saltationist theories of the emergence of species have been numerous and varied.¹⁸ Scientists belonging to very different biological sub-disciplines have defended them: morphologists, paleontologists, biometricians, geneticists, and developmental biologists. Today, the most famous and most convincing example is represented by Eldredge's and Gould's theory of "punctuated equilibria." This theory, first formulated in 1972,¹⁹ postulates that evolutionary change

¹⁷ DOOLITTLE, W. F. and BAPTESTE, E., "Pattern Pluralism and the Tree of Life Hypothesis," *Proceedings of the National Academy of Sciences of the United States of America*, v. 104, n. 7, (2007), p. 2043, abstract.

¹⁸ For an overview of the early forms of saltationist theories, see BOWLER, P. J., *The Eclipse of Darwinism. Anti-Darwinian Evolution Theories in the Decades around 1900*, Johns Hopkins University Press, Baltimore, 1983, especially, chapter 8.

¹⁹ ELDRIDGE, N. and GOULD, S. J., "Punctuated Equilibria. An Alternative to Phyletic Gradualism," in SCHOPF, T. J. M. (ed.), *Models in Paleobiology*, Freeman, Cooper and Co., San Francisco, 1972, CA, pp. 82-115.

occurs primarily during events of speciation or cladogenesis (i.e. the splitting of a given species into two or more species). Although it may take many generations, this change is rapid at a geological scale.

Whatever the particular form they take, saltationist theories of evolution entail a significant alteration of Darwin's tree. Instead of branches that progressively diverge, the tree will have the shape of successive candelabras. The most famous example is Gould's and Eldredge's "tree" in their 1972 paper [figure 2]. This kind of criticism, which focuses on the level of species (or at least on low taxonomic levels) challenges the second and the sixth Darwinian postulates listed above: gradualness of change, and indefinite divergence after splitting.

A second class of criticism emphasizes the view that evolution is something that does not happen only at the level of varieties and species, but also takes place at higher taxonomic levels. This kind of criticism has also been extremely popular since Darwin, especially among morphologists and paleontologists. In its commonest expression, it states that higher taxa tend to appear and diversify rather suddenly, giving rise to morphological types that remain stable ever after. In such a view, modification and multiplication of species are superficial phenomena, not the core of the evolutionary process. Biologists and paleontologists who adopt this view do not accept Darwin's "tree;" they refer to the image of a "bush" with parallel twigs arising from a given level. In 1929, the French morphologist Louis Vialleton gave a vivid summary of the shift from traditional Darwinian trees to "bushes" in systematics at the end of the 19th century and at the beginning of the 20th century:

"Genealogical trees, by illustrating in a simple way a number of infinitely complex relations in the real world, were very useful to the transformist theory; they provided the concrete examples of transformation that Lyell demanded from Darwin. ... The first diagrams were quite satisfying. They strikingly represented the evolutionary unfolding of beings and seemed to be able to provide their natural relationships that had been sought for such a long time. But disillusion came fast... Taking into account the time of appearance of various forms [and not only this or that morphological criterion], it soon appeared that genealogical trees looked quite different from how they looked before. Instead of showing a more or less elongated trunk during the period when only the supposed initial form existed, they had the shape of bushes whose twigs stemmed from approximately the same height above the ground, and moved away in a parallel way from each other, each of them being more or less ramified."²⁰

²⁰ VIALLETON, L., *L'Origine des êtres vivants. L'illusion transformiste*, Librairie Plon, Paris, 1929, pp. 179-180. French original: "Les arbres généalogiques, matérialisant d'une manière simple des rapports infiniment complexes dans la réalité, ont beaucoup servi le transformisme, en lui fournissant les exemples concrets de transformation que Lyell réclamait à Darwin... Ces premiers schémas donnèrent d'abord pleine satisfaction. Ils représentaient d'une manière saisissante, facile à retenir, le déploiement évolutif des êtres et ils paraissaient donner la solution si longtemps recherchée de leurs rapports naturels. Mais on déçanta bientôt. On s'aperçut bien vite que les arbres étaient très différents suivant les auteurs, en raison même du critérium choisi pour les construire. La plupart d'entre eux en effet n'étaient point fondés sur l'ensemble des caractères et sur une juste appréciation de la constitution ou de la vraie nature des êtres... En tenant compte de l'époque de l'apparition des diverses formes, on ne tarda pas à voir que les arbres généalogiques prenaient un aspect tout différent de celui adopté jusqu'alors. Au lieu de présenter un tronc plus ou moins allongé répondant à la durée pendant laquelle existait seule la forme initiale supposée, ils avaient la forme de buissons dont les tiges, partant à peu près du même niveau au-dessus du sol, s'écartaient parallèlement les unes des autres en se ramifiant plus ou moins."

To illustrate these doubts about Darwinian “trees,” Vialleton gave two different representations of the genealogical tree of Mammals: one was borrowed from the American paleontologist Henry Fairfield Osborn (figure 3), the other was Vialleton’s representation of exactly the same data and geneological interpretation (figure 4). Vialleton’s representation emphasizes the idea that something decisive occurs at high taxonomic ranks. To be fair, Vialleton was as anti-Darwinian as one can imagine: he thought that “transformism” (his name for Darwinian evolution —i.e., gradual modification and splitting of species) was only a superficial phenomenon, whereas genuine “evolution” was the generation of major morphological novelties in groups that suddenly appeared and remained approximately stable thereafter.

More recently, Eldredge’s and Gould’s punctuated equilibria have provided a totally new version of the old idea that evolution is not confined to the level of species. The famous diagram reproduced in figure 2 illustrates the hypothesis that a given evolutionary trend in a taxonomic group (either stasis or directional evolution) might well result from changes above the level of species. For instance, in lineage “B,” the evolutionary trend results from differential success of (static) species exhibiting morphological change in a particular direction. Although this way of thinking is far from Vialleton’s typological approach (and, in that sense, much closer to Darwin), it exemplifies another manner of advocating evolution above the species level, and consequently of challenging the Darwinian postulates [6] and [8] listed above (and, also, [5]: the entities that dynamically “diverge” are not necessarily species). Most of the literature in paleobiology since the mid 1970’s illustrates a similar search for specifically macroevolutionary patterns.²¹

The third class of criticism of Darwin’s diagram is more recent and, in a sense, more radical. The suspicion is that this diagram represents only a fraction of the real pattern of the history of life. Darwin’s tree involves the conviction that a tree of irreversible divergence of *species* adequately and sufficiently represents the history of biological diversity. Although Darwin did not explicitly say this, his diagram has been understood as meaning that there actually exists *one* single “tree of life,” the branches of which (namely, species) become, at some time or another, totally isolated from any other in terms of reproduction and hereditary transmission. An increasing number of phenomena challenge this view of species as (material) monads “without any doors or windows,” to freely pastiche Leibniz’s famous formula.²² These two phenomena are lateral gene transfer and symbiosis.

Since the end of the 1990s, lateral gene transfer has been known to be a major phenomenon among prokaryotes (Eubacteria and Archaea). Prokaryotes are single-celled organisms without a membrane-bound nucleus. Since Carl Woese’s pioneering work in the 1970s and 1980s, they are divided into two “domains:” Bacteria and Archaea. Eukaryotes constitute the third “domain:” they include all single-cell and multicellular organisms with a membrane-bound nucleus. At the beginning, the application of molecular techniques to prokaryotes generated the hope of reconstructing the unique and universal tree of life.²³

²¹ For a comprehensive review, see STANLEY, S. M., *Macroevolution. Pattern and Process*, The Johns Hopkins Press, Baltimore, 1998.

²² Leibniz’s monads, of course, were not material, but spiritual entities...

²³ Cf. WOESE, C. R., “Bacterial Evolution,” *Microbiology and Molecular Biology Reviews*, v. 51, (1987), pp. 221-271.

But an increasing number of anomalies led to the discovery that gene transmission among prokaryotes is not only vertical, it is also horizontal. The magnitude of this phenomenon has been fiercely debated for almost twenty years now. It is now clear that it is important enough to cast serious doubts on the very existence of a unique tree representing the natural relationships among all cellular organisms, or, at least, on the possibility of reconstituting this tree if it exists.²⁴ This is due to the facts that almost all (if not all) prokaryotic genes have been subject to lateral gene transfer, and that the turnover of genes in different species is incredibly high at all scales in evolution. It is presently uncertain whether the “tree of life hypothesis” will be able to successfully combat the “network of life hypothesis.” In reality, it is likely that both the “tree” and the “network” will have to coexist in a pluralistic view of evolutionary patterns, where *several* histories are told by several methodologies.²⁵

What is certain is that modern evolutionary theory must admit that Darwin’s diagram, which focuses exclusively at the level of species, encapsulates only one fraction of the history of life. In the case of Prokaryotes at least, lateral gene transfer has been important enough to obliterate, and, perhaps, overcome “vertical transmission” at a large historical scale. Today, a number of specialists in the evolution of Prokaryotes claim that lateral gene transfer between organisms belonging to different species is analogous to panmixia within sexual species: “Indeed, if the HGT [horizontal gene transfer] rates observed in *E. coli* were found to apply to all prokaryotes, their evolutionary history would be essentially horizontal. That is, prokaryotes would effectively share a common gene pool and, from an evolutionary point of view, they would behave in a way that is not unlike that the populations of a single species.”²⁶

Another process that jeopardizes Darwin’s representation of genealogy is symbiosis. Symbiosis has probably been a major evolutionary process, especially at the level of cell evolution²⁷. Symbiosis is much more rare than lateral gene transfer; but when it occurs, it may have dramatic effects because it implies the coexistence of two full genomes. Symbiosis seems to have been a key process in the emergence of a number of major groups of unicellular eukaryotic organisms, and of Eukaryotes themselves. Symbiosis does not challenge the notion of irreversible divergence of *species*, because separate organisms that fuse initiate new species that diverge from others. But fusion events between organisms introduce complications that cannot be assimilated by an exclusively tree-like pattern of phylogeny. Figure 5, taken from a recent review, provides a fairly balanced representation of the complications that horizontal gene transfer and symbiosis add to the traditional “tree of life.”

I now conclude on the first aspect of Darwin’s theory (descent with modification of species). Darwin’s diagram has proved immensely fertile. It remains the basic intuition

²⁴ For a recent and excellent review, see MCINERNEY, J. O., COTTON, J. A. and PISANI, D., “The Prokaryotic Tree of Life: Past, Present... and Future?,” *Trends in Ecology and Evolution*, v. 3, n. 5, (2008), pp. 276-281.

²⁵ See DOOLITTLE, W. F. and BAPTESTE, E., “Pattern Pluralism and the Tree of Life Hypothesis,” pp. 2043-2049.

²⁶ MCINERNEY, J. O., COTTON, J. A. and PISANI, D., “The Prokaryotic Tree of Life: Past, Present... and Future?,” p. 277.

²⁷ For a synthesis, see the stimulating and provocative book Lynn Margulis and Dorion Sagan: MARGULIS, L. and SAGAN, D., *Acquiring Genomes. A Theory of the Origins of Species*, Basic Books, New York, 2002.

behind most of the work on phylogenies. But it is not true that the diagram has remained unchanged. Several of the postulates embodied in Darwin’s representation appear not to be false, but rather a simplified view. At least four of the seven postulates that I have listed have been seriously challenged: [2] (gradualness of modification), [5] (irreversible divergence of species), [6] (uniform validity of the tree-like diagram at all levels), and [8] (evolution above the species level). Modern evolutionary biologists are not in agreement regarding the assertion that modification of species is *always* slow and gradual (against [2]). Indefinite divergence of species after splitting is not strictly false, but it is only one part of the story of life: important horizontal relations (at the levels of genes, species and other entities) must be taken into account (against [5] and [6]). Finally, many contemporary biologists (especially paleobiologists) deny that evolution is nothing more than modification of species (against [8]).

Although I have not elaborated this retrospective analysis of the fate of Darwin’s diagram by reference to the specific case of Stephen Jay Gould, it is pretty clear that he has been involved in all these challenges, both in his theoretical and his popular writings.

2.2. Natural Selection as an Explanatory Principle

I now turn to the second half of “Darwin’s theory,” the theory of modification through natural selection. Whereas “descent with modification” was a first-level theory about the general pace of evolution, natural selection was for Darwin an explanatory hypothesis that aimed at unifying the entirety of evolutionary phenomena under a common set of law-like statements. Just as in the case of “descent with modification,” I will first remind the reader of Darwin’s views about the theoretical status of natural selection. Then I will compare the post-Darwinian history of evolutionary biology with Darwin’s conception of his explanatory theory.

To be frank, I should add that I do not believe that, either in Darwin’s work or later work, there exists a perfectly well defined frontier between the two aspects of Darwin’s theory, the descriptive and the explanatory level, or, in more modern terms, “patterns” and “processes.” Nevertheless this distinction helps in clarifying the issue of whether contemporary evolutionary theory is Darwinian or not. But I will ignore this complication for the moment, and return to it later in this paper.

In *The Origin of Species*, Darwin used a double strategy for justifying the principle of natural selection. The first strategy consisted in providing inductive arguments in favour of the existence of natural selection as a process. The second strategy was hypothetico-deductive: it consisted in showing that natural selection explains and unifies various classes of independent facts.

Strangely, Darwin did not make this double strategy explicit in the text of the *Origin*, although the overall structure of the book corresponds more or less to it: on the whole, chapters 1 through 6 of the first edition establish the plausibility of the existence of natural selection on the basis of a mixture of empirical generalizations and deductions; chapters 7 through 13 are devoted to establishing its explanatory power. It is a little more complicated than that, because the first part of the book already involves an aspect of explanation; but this is a useful approximation. In fact, it is only in the introduction of *The Variation of Animals and Plants Under Domestication*, published nine years after the first edition of

The Origin of Species, that Darwin made perfectly explicit his argumentative strategy. In this introduction, most of which is devoted to a retrospective explanation of the project of *The Origin*, Darwin wrote a page, probably in response to those who had reproached him for not using a well defined scientific method. Here is the text:

“In scientific investigations it is permitted to invent any hypothesis, and if it explains various large and independent classes of facts it rises to the rank of a well-grounded theory. The undulations of the ether and even its existence are hypothetical, yet every one now admits the undulatory theory of light. The principle of natural selection may be looked at as a mere hypothesis, but rendered in some degree probable by what we positively know of the variability of organic beings in a state of nature, —by what we positively know of the struggle for existence, and the consequent almost inevitable preservation of favourable variations, —and from the analogical formation of domestic races. Now this hypothesis may be tested, —and this seems to me the only fair and legitimate manner of considering the whole question, —by trying whether it explains several large and independent classes of facts; such as the geological succession of organic beings, their distribution in past and present times, and their mutual affinities and homologies. If the principle of natural selection does explain these and other large bodies of facts, it ought to be received.”²⁸

This text deserves careful reading. In an extremely dense formulation, Darwin distinguishes two levels of justification of natural selection as a theoretical principle.

At the first level, natural selection is a “mere hypothesis” that is “rendered probable” by empirical arguments. Two different sorts of arguments are invoked. One is analogical: artificial selection, which shares some preconditions with the hypothetical process of natural selection (variation, heredity, biases in survival or reproductive rates) does modify species. This argument (developed in chapters 1 and 2 of *The Origin*) was crucial to Darwin, since he had no direct evidence for the existence of natural selection in nature.

The second kind of argument invoked at this level is based upon empirical generalizations about the two specific preconditions of natural selection: “struggle for existence” or the “Malthusian principle,” resulting from the rate of reproduction of organisms and the limitation of resources (developed in chapter 3 of *The Origin*), and the notion of more or less “favourable” variations (chapter 4 of *The Origin*). Taken together, these arguments establish the plausibility of natural selection as a very general process existing in nature, in all species, for many characters and at all times.

At the second level, Darwin says, “this hypothesis may be tested” through its capacity to “explain” a large array of “independent classes of facts.” This refers to chapters 7 through 13 of *The Origin*, and Darwin mentions some of the facts explained in the passage quoted. One might disagree about exactly what the list should contain; but, on the whole, Darwin claims that natural selection explains at least: adaptations (morphological and instinctual), the geographic distribution of species, the stratigraphic distribution of fossils, extinction, divergence, homologies, the relation between development and evolution, and taxonomic patterns. This second level of justification of natural selection was crucial to Darwin, since it is at this level that the “mere hypothesis” becomes “a well-grounded theory.”

²⁸ DARWIN, CH., *The Variation of Animals and Plants Under Domestication*, John Murray, London, 1868, pp. 8-9.

The Newtonian style of the entire argument has been underlined by a number of commentators.²⁹ The point that I want to stress here is that the argumentative structure provides a powerful tool for the understanding of the structure of evolutionary research since Darwin. The first level led to the development of population biology, with a careful exploration of the bases and modes of natural selection as a widespread principle in nature. The second level provided a theoretical principal for the reframing of the entire field of natural history. At that second level, natural selection is not only a common and fascinating process in nature, but also a principle that unifies many classes of facts, and, ultimately, biology as a whole. Figure 6 gives a schematic representation of this argumentative structure.

Note that the explanation of adaptations does not fit perfectly with this representation, for the emergence of adaptive traits is the direct outcome of the process of natural selection. Therefore it belongs to both levels of argument. Perhaps a better way of representing the whole argumentative structure would be to have adaptation as a bottleneck just below the "hypothesis," all other *explananda* (the boxes at the bottom of the figure) being subordinated to this primary *explanandum*.

Let us now assess the fate of this grand scheme. The first hundred years of evolutionary theory after Darwin may be summarized in a rather simple way. For a period of approximately seventy years after the publication of *The Origin* (1859), most of discussions and criticisms were targeted at the very existence of natural selection as a process, and of its capacity to account for adaptation. The reason for this was the absence of a convincing theory of variation and heredity. Of course, if this level was problematic, the second was even more so. In the 1920s and 1930s, it became clear that Mendelian genetics was able to reformulate Darwin's hypothesis (or a particular model of it, I would say) in a way that made it testable and predictive. I will not comment further on this complicated story, to which I have devoted an entire book.³⁰

Then came the "modern synthesis," built in the period 1930-1950. As Julian Huxley said when he coined this expression,³¹ this period consisted in a "rebirth of Darwinism." Since population genetics was able to prove the existence and efficacy of natural selection, the time became ripe for developing the second aspect of Darwin's theory. The modern synthesis consisted in an attempt to show, in its modernized genetic version, that natural selection was indeed a major principle for the explanation of such phenomena as geographical variation, long-term modification of species (anagenesis), speciation (cladogenesis), extinction, the tempo of evolution and phylogenetic trends. This enterprise was genuinely collective. A number of different disciplines and scientists all over the

²⁹ Cf. KAVALOSKI, V. C., *The vera causa Principle: A Historico-philosophical Study of a Metatheoretical Concept from Newton through Darwin*, Ph Dissertation, University of Chicago, 1974; RUSE, M., "Darwin's Debt to Philosophy: An Examination of the Influence of the Philosophical Ideas of John F. W. Herschel and William Whewell on the Development of Charles Darwin's Theory of Evolution," *Studies in History and Philosophy of Science*, v. 6, (1975), pp. 159-181; and HODGE, M. J. S., "Natural Selection as a Causal, Empirical, and Probabilistic Theory," in KRÜGER, L., GIGERENZER, G. and MORGAN, M. S. (eds.), *The Probabilistic Revolution*, The MIT Press, Cambridge, Massachusetts, 1987, vol. 2, pp. 233-270.

³⁰ GAYON, J., *Darwin et l'après-Darwin*, Kimé, Paris, 1992. Translated into English as GAYON, J., *Darwinism's Struggle for Survival: Heredity and the Hypothesis of Natural Selection*, Cambridge University Press, Cambridge, 1998.

³¹ HUXLEY, J., *Evolution: The Modern Synthesis*, Allen and Unwin, London, 3rd ed., 1978, p. 26. The text of the third edition is unaltered relative to the first, published in 1942.

world contributed to this “synthesis”: theoretical population geneticists (Fisher, Haldane, Wright), field and experimental population geneticists (e.g., Dobzhansky), cytogeneticists (Darlington, White), animal and plant systematists (Mayr, Stebbins), paleontologists (Simpson, Newell), embryologists (Schmalhausen, Waddington), ecologists (Lack) and specialists in human evolution (Rensch), to mention just a few.³²

In 1959, the year of the centenary of Darwin’s *On the Origin of Species*, the triumph of natural selection as an explanatory principle seemed to have no limit.³³ These years corresponded to the time when evolutionary biology was institutionalized as a discipline. In subsequent years, however, evolutionary biologists became more circumspect. Two kinds of criticisms developed, at the levels of microevolution and macroevolution. Before examining Stephen Jay Gould’s own participation in this rebellion against orthodoxy, I will give here a schematic classification of these challenges to Darwinism.³⁴

– *Criticisms of natural selection at the level of microevolution.* At the level of microevolution, what natural selection explains is first and above all adaptations. One should observe that since the modern synthesis, this ambition has never been seriously challenged. For almost all contemporary biologists, natural selection is the sole explanation for adaptations. This was true sixty years ago, and it is even truer today. Many modern textbooks on evolutionary biology can testify to this.³⁵ However, three main criticisms have been addressed to natural selection at the microevolutionary level over the past fifty years.

First, at the molecular level, the discovery of an unexpected amount of polymorphism in proteins and DNA has led to the recognition that most of this polymorphism is approximately neutral with respect to natural selection. This has been the central tenet of the “neutral mutation-random drift hypothesis of molecular evolution.”³⁶ This theory has generated one of the most intense controversies in population genetics in the second half of the 20th century, precisely because it challenged the idea that natural selection controls the evolution of biological phenomena at all levels.³⁷ The theory is now widely admitted. It states that natural selection does not control everything at the molecular level, especially

³² See the reference books by MAYR, E. and PROVINE, W. B., *The Evolutionary Synthesis*, Harvard University Press, Cambridge, MA, 1980, and SMOCOVITIS, B. V., *Unifying Biology. The Evolutionary Synthesis and Evolutionary Biology*, Princeton University Press, Princeton, NJ, 1996.

³³ See for instance MAYR, E., “Where are We?,” *Cold Spring Harbor Symposia on Quantitative Biology*, v. 24, (1959), pp. 409-440.

³⁴ For a more detailed exposition, see GAYON, J., “Critics and Criticisms of the Modern Synthesis: the Viewpoint of a Philosopher,” pp. 1-49; GAYON, J., “The Paramount Power of Selection: From Darwin to Kauffman,” pp. 265-282; and GAYON, “From Darwin to Today in Evolutionary Biology,” pp. 240-264.

³⁵ See for instance what it is perhaps the most successful of them: RIDLEY, M., *Evolution*, 2nd ed., Blackwell Scientific Publishing, Cambridge, MA, 1996, chapter 13, pp. 338-368. To give an idea, the titles of the first three sections of this chapter are entitled: “13.1. Natural selection is the only known explanation for adaptations”; “13.2. Pluralism is appropriate for the study of evolution, not of adaptation”; and “13.3. Natural selection can, in principle, explain all known adaptation.”

³⁶ This hypothesis was first published in KIMURA, M., “Evolutionary Rate at the Molecular Level,” *Nature*, v. 217, (1968), pp. 624-626. The expression “neutral mutation-random drift hypothesis of molecular evolution” was first used in KIMURA, M., “Mutation and evolution at the molecular level,” *Genetics* (Supplement), v. 73, (1973), pp. 19-35.

³⁷ The best image of this controversy can be found in LEWONTIN, R. C., *The Genetic Basis of Evolutionary Change*, Columbia University Press, New York, 1974.

DNA; it controls only the limited fraction of mutations that affect the phenotype at a given time in evolution.

Secondly, there has been a huge debate about group selection. Darwin and most population geneticists in the middle of the 20th century denied the existence of group selection, or at least its ability to generate adaptations. Here also, things have changed. Group selection, which was first perceived as a threat to Darwinism (because it went against the particular model of natural selection that was favoured by Darwin and by population biologists in the period 1930-1980) is now treated as a legitimate model of natural selection, which appears to be important for the explanation of the origin of major biological phenomena such as sex and a number of phenomena of cooperation.³⁸

Thirdly, theoretical biologists in the name of complexity have formulated strong attacks against Darwinism at the microevolutionary level. The claim, here, is that complexity imposes strong limits to the modifying power of natural selection. Because of the large amount of connectivity existing in genetic systems, natural selection may fail to increase the mean fitness of the population, whatever the intensity of selection.³⁹

These challenges to Darwinism at the level of microevolution are important. All of them have led to the development of new and fertile domains of research in evolutionary biology. The first and the third (neutral theory of molecular evolution and complexity theory) share a similar character: both of them relativize the idea of natural selection as an all-sufficient principle in evolution. Natural selection does not operate on a passive field of variation. Its action is limited by formal constraints such as stochasticity and generic properties of self-organized systems. The second challenge (group selection) is different: by admitting multilevel models of natural selection, it increases the theoretical content and explanatory power of natural selection rather than restricting it. It also makes natural selection much more complicated, much less intuitive, and probably difficult to put at test. Gould would say that this is an "expansion" of Darwinism (see below). But, ultimately, none of these criticisms has challenged natural selection as the only acceptable explanation for adaptations. Therefore, on the whole, all attempts to challenge the explanatory power of natural selection at the microevolutionary level have resulted in enrichment rather than a decline of Darwinism.

– *Macroevolutionary criticisms of natural selection.* Over the past forty years it is mainly at the level of macroevolution that major cracks in the Darwinian edifice have occurred. Remember here that for Darwin, the crucial test for the "acceptability" of natural selection was the ability of this hypothesis to explain "independent classes of facts:" not only adaptations, but also extinction, divergence and other macroevolutionary phenomena (the boxes at the bottom of figure 6). What has become problematic over the past forty years is precisely the claim that natural selection suffices for the explanation of *all* macroevolutionary phenomena. Here, I will just give two examples.

The first example is extinction. In the traditional Darwinian view (i.e. that of Darwin himself and of classical theories of extinction in the mid-20th century), extinction is just

³⁸ For a general approach, see SOBER, E. and WILSON, D. S., *Unto Others: The Evolution and Psychology of Unselfish Behavior*, Harvard University Press, Cambridge, MA, 1998.

³⁹ Cf. KAUFFMAN, S. A., *The Origins of Order: Self-Organisation and Selection*, Oxford University Press, New York, 1993.

a large-scale effect of natural selection within species: as natural selection transforms biological species, some happen to be fitter in the competition with other species. The less favoured species (those which evolve more slowly) decrease in numbers and go extinct. But paleobiologists have shown that such an explanation does not work in the case of mass extinction. In episodes of mass extinction (a phenomenon that has occurred many times in the history of life, at different scales), species go extinct not because of their relative success when competing with other species for places in the ecological theatre, but because they are ill equipped to face a brutal perturbation of their physical environment.

For instance, if diatoms survived better than other planktonic forms during the great cretaceous extinction, it is because they were endowed with a capacity of becoming encysted. This feature had evolved for reasons that had nothing to do with the environmental conditions that generated the mass extinction of the cretaceous. The diatom's dormancy is an adaptation to life in cold water that had been acquired long before. As David Raup said in his magisterial book on extinction, when species go extinct in mass extinction events, this is not due do "bad genes" but to "bad luck."⁴⁰

Another example is divergence. Following Eldredge and Gould's seminal paper on punctuated equilibria, a number of paleobiologists have denied that morphological divergence is necessarily the result of continued selection within species. They have supported alternative explanations, according to which divergence can also be a consequence of repeated events of speciation and extinction of species, either because of species selection, or because of "species drift" (resulting itself from stochastic considerations or from some kind of developmental constraint). This kind of theory is now currently being debated among paleobiologists.⁴¹

Other examples could be used, showing that the predominance of natural selection in the explanation of macroevolutionary phenomena is seriously contested today. This is not to say that contemporary evolutionary biologists deny that natural selection is a major force that should always be taken into account when studying the history of life. But the majority of them think that things are more complicated: other principles are needed, and perhaps there is no hope of deducing everything in the history of life from a list of theoretical principles: history and contingency matter.

3. DEATH OR PERSISTENCE OF DARWINISM? FROM GOULD 1980 TO GOULD 2002

This is not the place to enter in detail into the intellectual biography of Stephen Jay Gould. However I would like to recall three major aspects of his scientific contributions. One is his early work on allometry (i.e., relative growth). In this initial work, Gould was a remarkable biometrician, who tried to bring a major phenomenon within the ambit of the modern synthesis.⁴² This early work made him sensitive to the constraints that change in size imposes on morphological evolution. The second major contribution was to show

⁴⁰ Cf. RAUP, D., *Extinction. Bad Genes or Bad Luck*, Norton and Company, New York, 1991.

⁴¹ See STANLEY, S. M., *Macroevolution. Pattern and Process*, passim.

⁴² The two major papers were: GOULD S. J., "Allometry and Size in Ontogeny and Phylogeny," *Biological Reviews of the Cambridge Philosophical Society*, v. 41, (1966), pp. 587-640; and GOULD S. J., "An Evolutionary Microcosm: Pleistocene and Recent History of the Land Snail *P. (Poecilozonites)* in Bermuda," *Bulletin of the Museum of Comparative Zoology*, v. 138, (1969), pp. 407-532.

For a historical appraisal, see GAYON, J., "History of the Concept of Allometry," *American Zoologist*, v. 40, (2000), pp. 748-758; and GAYON, J., "Gould biométricien," *Comptes Rendus Palevol*, v. 2, (2003), pp. 353-360.

that heterochrony is a significant illustration of the constraints that development imposes upon evolution.⁴³ The last and most important theoretical contribution was the theory of punctuated equilibria.⁴⁴ As already stated, this theory was the starting point of major proposals among paleobiologists regarding evolution above the species level.

The question that I would like to clarify here is that of the relationship between Gould and Darwinism. This was always an explicit concern for Gould. Three periods can be distinguished.

The first period corresponds to the earliest papers on allometry (approximately 1966-1972). At that time, Gould was still a graduate student working under Norman Newell, a paleontologist close to George Gaylord Simpson who worked hard to show that allometry and, more generally morphology, could be thoroughly remoulded in a Darwinian way. Just like Newell, the young Gould was motivated by the prospect of wholly integrating morphology into the theoretical framework of the modern synthesis. In this remarkable work, perhaps the most rigorous of all his career, Gould's inimitable style can already be seen at work: uncommon theoretical ambition, exceptional and thorough interest in the history of science and knowledge of large amounts of relevant literature written in languages other than English. Although this work already showed a major interest in issues of developmental constraints and heterochrony, no clear sign of revolt against the Neo-Darwinian can be seen in it. The idea was rather to open up the classical Darwinian framework.

The second period begins with the joint paper with Eldredge on punctuated equilibria in 1972,⁴⁵ and culminates with the 1980 paper, provocatively titled "Is a New and General Theory of Evolution Emerging?"⁴⁶ This paper was probably the most radical attack against Darwinism, or, more precisely, against the "modern synthesis," that Gould ever published. This paper deserves careful analysis, because it provides an exceptional landmark for anyone who wants to understand what was at stake when a number of evolutionary biologists began to say, around 1980, that the classical "Darwinian" view of evolution was in deep crisis.

Let us first point out the precise target of Gould's attack. Although he often writes of "Darwinism," it is only a particular version of Darwinism that he has in mind —the modern synthesis. In the first section of the paper, entitled "The modern synthesis,"⁴⁷ Gould quotes the following passage from Mayr: "The proponents of the synthetic theory maintain that all evolution is due to the accumulation of small genetic changes, guided by natural selection, and that transspecific evolution is nothing but an extrapolation and magnification of the events that take place within populations and species."⁴⁸

Here is Gould's reaction to this sentence, already quoted in the introduction of this paper: "... if Mayr's characterization of the synthetic theory is accurate, then that

⁴³ GOULD, S. J., *Ontogeny and Phylogeny*, Harvard University Press, Cambridge, MA, 1977.

⁴⁴ Cf. ELDREDGE, N. and GOULD, S. J., "Punctuated Equilibria. An Alternative to Phyletic Gradualism," pp. 82-115.

⁴⁵ "Punctuated Equilibria. An Alternative to Phyletic Gradualism," pp. 82-115.

⁴⁶ Cf. GOULD, S. J., "Is a New and General Theory of Evolution Emerging?," pp. 119-130.

⁴⁷ Cf. "Is a New and General Theory of Evolution Emerging?," pp. 119-121.

⁴⁸ MAYR, E., *Animal Species and Evolution*, p. 586. The quotation by Gould is in his page 120.

theory, as a general proposition, is effectively dead, despite its persistence as text-book orthodoxy.”⁴⁹

What were Gould’s arguments supporting the “death” of the synthetic theory? The 1980 paper advocates a “hierarchical approach” to evolution, with three main levels: variation within populations, speciation, and patterns of macroevolution.⁵⁰ Gould defends the claim that at each of these three levels, the conception of evolution as an accumulation of small genetic changes, guided by natural selection, has been refuted.

At the level of *population genetics*,⁵¹ Gould evokes the neutrality of most genetic changes: “In short, the spectre of stochasticity has intruded upon explanations of evolutionary *change*. This represents a fundamental challenge to Darwinism, which holds, as its very basis, that random factors enter only in the production of raw materials, and that the deterministic process of selection produces change and direction.”⁵²

At the level of *speciation*,⁵³ he refers to various models of speciation (especially White’s parapatric model) showing that reproductive isolation is not a by-product of adaptation, but rather a rapid and stochastic event: “We can, in fact, reverse the conventional view and argue that speciation, by forming new entities stochastically, provides raw material for selection ... A discontinuity in explanation exists between allelic substitutions (sequential, slow and adaptive) and the origin of new species (often discontinuous and non-adaptive). During the heyday of the modern synthesis, Richard Goldschmidt was castigated for his defense of punctuational speciation ... We do not now accept all his arguments about the nature of variation, but his explicit anti-extrapolationist statement is the epitome and foundation of emerging views of speciation discussed in this section. There is a discontinuity in cause and explanation between adaptation in local populations and speciation ...”⁵⁴

Finally, at the level of *macroevolution*,⁵⁵ Gould primarily discusses punctuated equilibria, and proposes that evolutionary trends are not a mere extrapolation of intra-specific evolution, but result from differential rates of speciation and extinction among species: “... if species originate in geological instants and then do not alter in major ways, then evolutionary trends cannot represent a simple extrapolation of allelic substitution within a population. Trends must be the product of differential success among species.”⁵⁶ In other words, species themselves may be inputs, and trends the result of their differential

⁴⁹ GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” p. 121.

⁵⁰ Cf. “Is a New and General Theory of Evolution Emerging?,” section II, “Reduction and Hierarchy,” p. 121.

⁵¹ Cf. “Is a New and General Theory of Evolution Emerging?,” section III, “A note on local populations and neutrality,” pp. 121-122.

⁵² GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” p. 122.

⁵³ Cf. “Is a New and General Theory of Evolution Emerging?,” section entitled “The level of speciation and the Goldschmidt break,” pp. 122-125.

⁵⁴ GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” p. 124.

⁵⁵ “Is a New and General Theory of Evolution Emerging?,” section V, “Macroevolution and the Wright break,” pp. 125-128.

⁵⁶ Cf. ELDREDGE, N. and GOULD, S. J., “Punctuated Equilibria. An Alternative to Phyletic Gradualism,” pp. 82-115; and STANLEY, S. M., “A Theory of Evolution above the Species Level,” *Proceedings of the National Academy of Sciences of the United States of America*, v. 72, n. 2, (1975), pp. 646-650.

origin and survival. Speciation interposes as an irreducible level between change in local populations and trends in geological time. Macroevolution is, as Stanley argues,⁵⁷ decoupled from microevolution.”⁵⁸

Thus Gould's 1980 paper leaves the reader with the conviction that the traditional “Darwinian” or synthetic theory of evolution has broken down, and has been, or will soon be, replaced with another theory, where natural selection of small individual-level inherited variation is just one process among others, and definitely not a unifying principle for the evolutionary process as a whole.

If we now look at Gould's testament, the luxuriant book published in 2002, the very year of his own death, under the title *The Structure of Evolutionary Theory*, we observe a rather different attitude regarding Darwinism. The first chapter is wholly devoted to summarizing the entire argument of the book. Gould, again, explains the structure of the new theoretical framework through a comparison with the former classical, or purely Darwinian, framework. But this time he refers to Darwin himself rather than to the synthetic theory. He maintains that the new theoretical framework of evolutionary biology is neither an “extension” of the older Darwinian theory, nor a “destruction” or “replacement” of it.

This vocabulary, which the author uses very carefully, is both puzzling and stimulating. In Gould's terms, “extension” would mean that the same principles have been applied to a wider spectrum of phenomena. “Replacement” would mean that other principles are now at the heart of evolutionary theory. Instead of these two terms, Gould prefers “expansion.” “Expansion” means that the same principles remain central to the theory, but they have been “reformulated” in a way that gives a truly different aspect to the entire edifice (just as an architect makes a new edifice from an older one, by adding new parts to the existing unchanged ones, which themselves constrain the whole building):

“I do believe that the Darwinian framework, and not just the foundation, persists in the emerging structure of a more adequate theory. But I also hold ... that substantial changes, introduced during the last half of the 20th century, have built a structure so expanded beyond the Darwinian core, and so enlarged by new principles of macroevolutionary explanation, that the full exposition, while remaining within the domain of Darwinian logic, must be construed as basically different from the canonical theory of natural selection, rather than simply extended.”⁵⁹

This notion of expansion is rather unorthodox in terms of current philosophy of science. “Extension” would make philosophers think of a wider explanatory scope. “Replacement” irresistibly evokes Thomas Kuhn's “paradigm shift.” But, obviously, Gould wants to avoid these two classical ways of interpreting scientific change. What, then, does he mean precisely by “expansion.” He defines the “Darwinian framework” (which he also calls “the Darwinian logic”) as a conjunction of three principles: 1. “Agency”: natural selection works almost entirely at the level of organisms. 2. “Efficacy”: natural selection is *the* mechanism responsible for the emergence of evolutionary novelty, the exclusive factor that

⁵⁷ Cf. STANLEY, S. M., “A Theory of Evolution above the Species Level,” p. 648.

⁵⁸ GOULD, S. J., “Is a New and General Theory of Evolution Emerging?,” pp. 125-126.

⁵⁹ GOULD, S. J., *The Structure of Evolutionary Theory*, p. 3.

shapes evolutionary change. 3. “Scope”: the extrapolation of minute, incremental changes, can explain the entirety of the history of life.⁶⁰

Knowing as we do the theses that Gould maintained throughout his career, it is obvious that he could not accept these three general principles. For Gould, natural selection does not work only at the level of organisms: — species selection or even clade selection is essential to him (this is indeed the major commitment of his 2002 book). Neither is selection the only mechanism of evolutionary novelty: morphological constraints, developmental constraints and historical constraints play a huge role in evolution. For Gould, these constraints are not external limits, but positive factors that canalize evolutionary pathways. Finally, Gould does not admit that the entirety of life is explained by extrapolating from small intraspecific changes to macroevolution.

Why, then, does Gould say that Darwin’s principles have been “expanded” rather than “replaced”? “Expansion” seems to be a convenient word for the expression of two ideas:

1. Generalization of Darwinian (or more precisely synthetic) principles: species selection, species drift, clade selection and clade drift are obvious examples of this strategy. Gould’s final judgment is that he and other paleobiologists have applied Darwinian schemes to entities that were not considered by Darwin.⁶¹

2. Addition of new principles, such as morphological, developmental and historical constraints.

To make these ideas more intuitive, Gould makes use of an image (figure 7). He compares the relationship between Darwinism and the new theoretical framework with a coral. At its basis, this coral has a trunk with three successive branches. The central trunk represents the theory of natural selection and cannot be severed. The branches represent the three “Darwinian principles” (agency, efficacy, scope). These principles remain at the basis of the new theoretical framework, but each of them has been “truncated” at a rather low level, so that they all “expand” and “develop” into an “organism” substantially different from the original one.

There is of course a good deal of metaphor in Gould’s rhetoric. I would like to make three observations on this rhetoric.

My first remark is psychological. It is interesting to see that one of the most brilliant critics of Darwinian schemes in the second half of the 20th century concluded his career by saying roughly this: “I have not replaced Darwin’s theory by another one, I have contributed to the expansion of its basic intuitions.”

My second remark is about the developmental metaphors used by Gould for presenting the relation between the present state of evolutionary theory and the classical Darwinian (or neo-Darwinian) framework. In Gould’s terms, a new theory has not replaced the classical theory of evolution; rather, it has *developed* into a new one. There is no need to insist on Gould’s major interest for development as a practicing scientist.

What is worth underlining here is Gould’s massive use of the history of science in his entire work, and more than ever in his last book. Just as in his early work on allometry,

⁶⁰ Cf. *The Structure of Evolutionary Theory*, pp. 14-15.

⁶¹ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, p. 6.

or in his *Ontogeny and Phylogeny*, *The Structure of Evolutionary Theory* pretends to be a genuine scientific treatise, but it has more than 400 pages devoted to history of science (out of 1,343). In the introduction to the book, Gould says that history has played a major role in the processes of both discovery and justification of his own conceptions. This is something quite unusual in contemporary science, evolutionary biology included. There is no doubt that Gould's relation to Darwinism has been deeply affected by this intellectual choice to use history in his scientific writings.

My third and last remark is about this historical relationship. Gould claims that this is not only a question of genealogy. The new theory that has emerged is not only connected with the older Darwinian theory through a chain of contextual influences (these might include the fact that Gould was the pupil of Newell, who was inspired by Simpson, who himself admired Darwin). The claim is that there is a genuine conceptual similarity or "isomorphism" (not identity) between the two theories. In other words, the relation between Darwin, Darwinism and the modern evolutionary theory is not only historical; it is also a formal relation.

This brings me back to the previous part of this paper, where I exposed my own view of the relationship between the original Darwinism (Darwin's own view of evolution) and Darwinism as a historical tradition. Just like Gould, I am convinced that the repeated references made to Darwin by so many evolutionary biologists since 1859 are not only a matter of "genealogy." In a very strong sense, Darwin settled a framework that constrained the very structure of evolutionary theory for a long time, though certainly not the entirety of its empirical and theoretical content.

4. CONCLUSION

To conclude, I would like to add a word on the distinction that I have made in section 2 of this paper between the two aspects of Darwin's theory: descent with modification and natural selection. Today, this distinction is commonly relabeled patterns *versus* processes. This distinction is certainly not an absolute one, especially if understood as meaning "general facts" vs. "theoretical hypotheses." In reality, theories deeply affect the kind of patterns that evolutionary biologists look for. For instance, Darwin's tree, with its particular features, reflects in many ways his conception of the evolutionary process as driven by natural selection acting upon small individual differences within the species.

Similarly, Eldredge's and Gould's "tree" (figure 2) cannot easily be separated from these authors' conviction that there exist important processes that canalize evolutionary change above the level of the species. This is in fact explicit in the legend of this figure, which mentions differential rates of speciation and extinction. Furthermore, in both cases (Darwin and Eldredge-Gould), it is very difficult to dissociate the pattern and the process aspects: it is as though these authors make everything possible to obliterate the distinction. This may be due to a conception of science that privileges theories over facts.

However, I do think that the pattern/process distinction, which has taken such an importance in contemporary evolutionary theory, is a safe guideline for a proper assessment of what has changed and what has not changed in evolutionary theory since Darwin.

Important changes have occurred in both respects, but the continuity of evolutionary theory since Darwin cannot be underestimated. Both for patterns and explanatory hypotheses, Darwin seems to have imposed a general framework that has canalized most of the evolutionary debates, and still canalizes them. In order to properly understand this statement, one has to be clear about “framework.”

Most of theoretical changes that have occurred both in the cases of patterns and processes since Darwin have consisted in proposing alternative models within the same general theoretical framework. In the case of patterns, Darwin’s “tree” was a particular model of the genealogical relations between lineages; others have been proposed, but always as models of genealogical relationships. Eldredge’s and Gould’s tree is another model of these genealogical relationships. Even the “network” approach of contemporary biologists, who emphasize lateral transfer, remains within the genealogical paradigm, albeit at different levels (e.g. genes, membranes, etc.). The same can be said for theories about processes. Contemporary evolutionary biologists admit many more models of natural selection and competition than Darwin did, but, on the whole, they remain within a general paradigm that favours a populational approach to evolutionary phenomena at all levels.

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FIGURES

Figure 1. Charles Darwin, *On the Origin of Species* (1859), double page *contra* p. 117. This is the only figure in the book. There is no legend. The “diagram,” as Darwin’s calls it, is commented on twice in the book: chapter IV, “Natural selection,” pp. 116-125, and chapter XIII, section on “classification,” pp. 420-422. In chapter IV, A, B, C ... L represent “the species of a genus large in its own country.” They produce local varieties which modify and diverge during many generations (Darwin says that the interval between the horizontal lines may represent a thousand or ten thousand that have survived have differentiated into several species (for instance, A has led to eight species). In chapter XIII, A, B, C... L represent “allied genera” which will lead at level XIV to a greater number of genera (for instance, A has differentiated into eight genera forming a family). The same reasoning can be applied to any desired level of taxonomic categories. What is natural is the genealogical “arrangement.” “Ranking” (variety, species, genus, sub-family, etc.) is arbitrary.

Figure 2. Niles Eldredge and Stephen Jay Gould, "Punctuated Equilibria. An Alternative to Phyletic Gradualism" (1972), p. 113. Original legend: "Three-dimensional sketch contrasting a pattern of relative stability (A) with a trend (B), where speciation (dashed lines) is occurring in both major lineages. Morphological change is depicted here along the horizontal axes, while the vertical axis is time. Though a retrospective pattern of directional selection might be fitted as a straight line in (B), the actual pattern is stasis within the species, and differential success of species exhibiting morphological change in a particular direction." Note the mixture of "pattern" and "process" in this legend (see the conclusion of the present paper).

Figure 3. Louis Vialleton, *L'origine des êtres vivants. L'illusion transformiste* (1929), p. 183. Original legend "Arbre généalogique des mammifères (d'après Osborn)" [Genealogical tree of Mammals (from Osborn)]. Vialleton refers to OSBORN, H. F., *L'origine et l'évolution de la vie*, Masson, Paris, 1921.

Figure 4. Louis Vialleton, *L'origine des êtres vivants. L'illusion transformiste* (1929), p. 181. Original legend "Arbre généalogique des mammifères (d'après Vialleton)" [Genealogical tree of Mammals (from Vialleton)].

Figure 5. James O. McInerney, James A. Cotton and Davide Pisani, "The Prokaryotic Tree of Life: Past, Present ... and Future?" (2008), p. 278. Original legend: "A network of life. (a) Eukaryotes are known to be chimeric, with chloroplast and mitochondrial genes having a different origin from nuclear genes, and originating from different groups of Eubacteria. There is more debate over whether lateral gene transfer between Eubacteria, Archaeobacteria and Eukaryota and between major groups of prokaryotes is common or rare. (b) Lateral gene transfer is known to be so common between members of some groups of bacteria that they are effectively panmictic, whereas (c) it can be completely absent from other groups." Thus, the real pattern of the entire genealogy of life is a mixture of tree and network.

Figure 6. From Jean Gayon, “The ‘Paramount Power of Selection’: From Darwin to Kauffman” (1997), p. 270. This diagram is a visual representation of Darwin’s comment on the structure of the argument supporting the hypothesis of natural selection in *The Origin of Species*. The two levels of the diagram (above and below “hypothesis of natural selection”) represent the two levels of justification of the hypothesis according to Darwin (see text). Note that adaptations (morphological and instinctual) are the direct outcome of natural selection; Darwin speaks of “the paramount power of selection” only for adaptations. The other boxes at the bottom of the diagram represent more remote consequences of the process of natural selection.

Figure 7. Stephen Jay Gould, *The Structure of Evolutionary Theory* (2002), p. 18. The plate is drawn from the 17th plate representing a coral. Gould uses it to illustrate the fate of the “Darwinian logic.” The letters “K,” “R” and “S” have been added by Gould. “K” for “killing cuts.” The K-cuts “sever at least one of the three central principles of Darwinian logic and thereby destroy the theory *tout court*.” “R” for “revision cuts”; “S” for “subsidiary cuts.” A revision cut “removes enough of the original form on one of the central branches to ensure that the new (and stronger or more arborescent) branch, in regrowing from the cut, will build a theory with an intact Darwinian foundation, but with a general form sufficiently expanded, revised or reconstructed to present an interestingly different structure of general explanation.” Subsidiary cuts modify more special aspects of the original theory. This image dominates the overall organization of Gould’s book.

II

Evolutionism and Present Biology

4. Thought Experiments in Evolutionary Biology Today

5. The Species Concept in Evolutionary Biology: Current Polemics

THOUGHT EXPERIMENTS IN EVOLUTIONARY BIOLOGY TODAY

JAMES G. LENNOX

1. INTRODUCTION

In my previous essay in this book, in which I discussed the evolution of Darwin's deployment of thought experiments, I used the phrase "Darwinian Thought Experiment" (DTE),¹ as I had in my 1991 essay on the topic, to refer to an imaginative narrative that serve as a test of natural selection's explanatory potential.² It posits hypothetical or imaginary test conditions; specifying particular instantiations of the causal processes identified by the theory; and it displays a concrete state of affairs needing explanation as the end result of repeated iterations of these processes.

In a brief, closing section of my original 1991 paper on this subject, I made two points, primarily by means of examples.³ The first point was that the problem of showing how something that seems *prima facie* impossible is in fact possible within the parameters of Darwinism has recurred constantly throughout the history of Darwinism in the 20th century. I noted, for example, that in the 1920s Ronald Fisher and J. B. S. Haldane, both brilliant mathematicians and naturalists, set about to integrate a mathematical generalization of Mendelian genetics for natural populations with the theory of evolution by natural selection. There was a *prima facie* roadblock in the way of this task—given what was known about the underlying genetics, it did not seem possible that a slight selective advantage bestowed on a rare Mendelian mutation at a single genetic locus would allow it to spread through a large, randomly interbreeding population at an acceptable rate to account for evolutionary change. As mathematicians, both men saw it as one of their most important tasks to prove that it was *possible* for a slight variation with a slight selective advantage to become fixed in a population in a surprisingly short time. It was someone else's job to show that it actually happens. I briefly suggested that it was the primary task of the early defenders of "kin selection" and "inclusive fitness" to establish the *plausibility* of these theoretical constructs as explanations of so-called "altruistic" behavior by means of thought experiments, much as Darwin sought to do for selection explanation of the social behavior of ants or bee hive construction. As with Darwin, the goal was to show that phenomena that appear to be impossible to explain by reference to natural selection could be so explained.

¹ Cf. LENNOX, J. G., "The Evolution of Darwinian Thought Experiments," in GONZALEZ, W. J. (ed.), *Evolutionism: Present Approaches*, Netbiblo, A Coruña, 2008, pp. 63-76.

² Cf. LENNOX, J. G., "Darwinian Thought Experiments: A Function for Just-so Stories," in HOROWITZ, T. and MASSEY, G. (eds.), *Thought Experiments in Science and Philosophy*, Rowman and Littlefield, Savage, MD, 1991, pp. 223-246.

³ Cf. LENNOX, J. G., "Darwinian Thought Experiments: A Function for Just-so Stories," pp. 238-241.

2. DARWINIAN THOUGHT EXPERIMENTS IN THE SYNTHESIS

These two examples show the historical importance of Darwinian thought experiments vividly. For what these initial demonstrations of plausibility did —as thought experiments regularly do— is to *open up* a domain for experimental and natural historical inquiry. In effect, when done well, they suggest modes of explanation and testing that had not occurred to researchers in the field.

Likewise, I might add, the “neutralist” *alternative* to neo-Darwinism aimed to do the same —i.e. to demonstrate that it was plausible to suppose that a trait that was strictly neutral from a selective standpoint could become fixed in a population under conditions that were not uncommon in nature. Again, the primary arguments were *thought* experimental —the *actual* experiments to show that what was demonstrably possible actually occurs in anything approaching an interesting number of cases is still a debatable issue. Perhaps in this case it is somewhat Pickwickian to call them *Darwinian* thought experiments —in just the same way that it was for me to refer to Jenkin’s use of “Darwinian” thought experiments against the theory presented in the first edition of Darwin’s *Origin*. But the pattern and the goal of the reasoning in both cases is the same.

Both Fisher and Haldane were self-conscious of the role of thought experiment in their work. Take the following comments from the preface to the first edition of *The Genetical Theory of Natural Selection* —and keep in mind that Fisher’s initial training was in mathematical physics.

“What is profoundly susceptible of training is the imagination, and mathematicians and biologists seem to differ enormously in the manner in which their imaginations are employed. Most biologists will probably feel that this advantage is all on their side. ... Perhaps I can best make clear that the mathematician’s imagination also has been trained to some advantage, by quoting a remark dropped casually by Eddington in a recent book —‘We need scarcely add that the contemplation in natural science of a wider domain than the actual leads to a far better understanding of the actual.’⁴ For a mathematician the statement is almost a truism. From a biologist ... it would suggest an extraordinarily wide outlook. No practical biologist interested in sexual reproduction would be led to work out the detailed consequences experienced by organisms having three or more sexes; yet what else should he do if he wishes to understand why the sexes are, in fact, always two? The ordinary mathematical procedure in dealing with any actual problem is, after abstracting what are believed to be the essential elements of the problem, to consider it as one of a system of possibilities infinitely wider than the actual ...”⁵

The recommendation Fisher makes here of what a biologist ought to do in order to understand why the apparent upper limit on sex number is 2 —work out the detailed consequences of having three or more— is, I needn’t remind anyone at this point, a thought experiment. Postulate in imagination a population of 3, 4 or 5 sexes, and then think through in your imagination what the long run consequences would be for such a fictional population, especially if it were competing with a two-sex population.

⁴ EDDINGTON, A. S., *The Nature of the Physical World*, Cambridge University Press, Cambridge, 1928, p. 267.

⁵ FISHER, R. A., *The Genetical Theory of Natural Selection: A Complete Variorum Edition*, Oxford University Press, Oxford, 1999, preface to the first edition [Clarendon Press, Oxford, 1930], pp. viii-ix.

The second point I touched on in that conclusion had to do with the uses and abuses of what Steven Jay Gould, following Rudyard Kipling and followed by many others, referred to as “Just-so Stories.” I pointed out that whether these were to be maligned or praised very much depended on the aims of the story-teller. Take the example I quoted, from Richard Dawkins:

“Pitt-digging is a complex behaviour pattern. It costs time and energy, and satisfies the most exacting criteria for recognition as an adaptation.⁶ It must, then, have evolved by natural selection. How might this have happened? The details don’t matter for the moral I want to draw. Probably an ancestral antlion existed which did not dig a pit but simply lurked just beneath the sand surface waiting for prey to blunder over it. Indeed some species still do this. Later behaviour leading to the creation of a shallow depression in the sand probably was favoured by selection because the depression marginally impeded escaping prey. By gradual degrees over many generations the behaviour changed so that what was a shallow depression became deeper and wider.”⁷

This is a classic Darwinian Thought Experiment. Dawkins asks how the evolution of the antlion’s pitt digging behavior *might have* evolved. He boldly asserts that the details don’t matter for the moral he wants to draw. That is a good thing, because, frankly, nobody does or ever will know the details! The paleontology of invertebrate behavior is a little short on data. He then tells a narrative about what *probably* happened —*possibly* would have been a better choice of word. Notice that, just as Darwin tended to do, Dawkins inserts a remark about the *actual* behavior of an extant, closely related, species to help convince that his imaginative narrative is a plausible one.

What is the moral he wants to draw, such that the details don’t matter (he doesn’t mean that the details can be left out; he means that *which* details you choose doesn’t matter) —such that a thought experiment is sufficient? The moral is that, as complex and perfectly designed as the behavior appears to be to serve the antlion’s purposes, nothing prevents it from being the product of slow, gradual natural selection. It is *exactly* like Darwin’s thought experimental replies to his intelligent design critics in chapter 6 of the *Origin*. Compare the above passage from Dawkins’ *The Extended Phenotype* with the following passage from the first edition of *On the Origin of Species*, imagining how selection produced the earliest flying mammals.

“Now look at the *Galeopithecus* or flying lemur, which formerly was falsely ranked among the bats. It has an extremely wide flank-membrane, stretching from the corners of its jaw to the tail, and including the limbs and the elongated fingers: the flank-membrane is, also, furnished with an extensor muscle. Although no graduated links of structure, fitted for gliding through the air, now connect the *Galeopithecus* with the other *Lemuridae*, yet *I can see no difficulty in supposing that such links formerly existed*, and that each had been formed by the same steps as in the case of the less perfectly gliding squirrels; and that each grade of structure had been useful to its possessor. *Nor can I see any insuperable difficulty in further believing it possible that*

⁶ Dawkins here cites WILLIAMS, G. C., *Adaptation and Natural Selection: A Critique of some Current Evolutionary Thought*, Princeton University Press, Princeton, 1966, and CURIO, E., “Towards a Methodology of Teleonomy,” *Experientia*, v. 29, (1973), pp. 1045-1058.

⁷ DAWKINS, R., *The Extended Phenotype*, Oxford University Press, Oxford, 1982, p. 20.

the membrane-connected fingers and fore-arm of the *Galeopithicus* might be greatly lengthened by natural selection; and this, as far as the organs of flight are concerned, would convert it into a bat.”⁸

Does Darwin have any actual evidence that this is how the flying lemur or bats evolved? Of course not. But that is not what he is trying to prove. Neither Darwin nor Dawkins is trying to convince fellow evolutionists that there is good evidence in favor of this particular narrative. What they are trying to prove is that the theory of natural selection has the explanatory resources to explain such cases.

Using Dawkins as my modern day exemplar of a Darwinian Thought Experimenter is not a random selection on my part. In the first chapter of *The Extended Phenotype*, from which the above quotation about pitt digging antlions was taken, Dawkins proclaims that he is “not trying to convince anyone of the truth of any factual proposition.” His goal is “to show the reader a way of seeing biological facts.”⁹ He then defends the use of thought experiment in achieving this goal (a defense that opens, by the way, with a discussion of Fisher’s earlier defense of “imagining the possible”).

“Playing with an imaginary world, in order to increase our understanding of the actual world, is the technique of “thought experiment”. It is much used by philosophers. ... In this book I shall make frequent use of the thought-experiment technique. I warn the reader of this in advance, since scientists are sometimes annoyed by the lack of realism in such forms of reasoning. Thought experiments are not supposed to be realistic. They are supposed to clarify our thinking about reality.”¹⁰

There are a number of questions that need to be asked about Dawkins’ use of thought experiments, and I will turn to those questions momentarily. But before doing so allow me to explore what Dawkins says about his purposes in *The Extended Phenotype*. This book was intended as a sort of sequel to *The Selfish Gene*. In these books, Dawkins is not presenting any new biological information. Neither book presents the results of a long-term investigation as, say, Peter and Rosemary Grant did in *Evolutionary Dynamics of a Natural Population*.¹¹ Rather, Dawkins is asking us to see the processes involved in evolution—and especially in the production of adaptation—in a particular way. It is not even a *new* way—as he freely acknowledges, he is defending a point of view articulated vigorously by a number of population geneticists before him such as George G. Williams in *Adaptation and Natural Selection*.¹² In the first chapter he responds to those who read

⁸ DARWIN, CH., *On the Origin of Species: A Facsimile Edition*, Harvard University Press, Cambridge, MA, 1964, p. 181; italics added.

⁹ DAWKINS, R., *The Extended Phenotype*, p. 1.

¹⁰ *The Extended Phenotype*, pp. 4-5. Though the issues I am discussing are not primarily in focus, readers will find much of interest regarding problems and possibilities in *The Extended Phenotype in Biology and Philosophy*, v. 19, (2004). There are three essays revisiting its arguments after twenty years by Eva Jablonka (“From Replicators to Heritably Varying Phenotypic Traits: The Extended Phenotype Revisited,” pp. 353-375), Kevin Laland (“Extending the Extended Phenotype,” pp. 313-325) and J. Scott Turner (“Extended Phenotypes and Extended Organisms,” pp. 327-352), and a 20 page reply by Dawkins (DAWKINS, R., “Extended Phenotype—But Not Too Extended. A Reply to Laland, Turner and Jablonka,” *Biology and Philosophy*, v. 19, (2004), pp. 377-396.)

¹¹ GRANT, B. R. and GRANT, P. R., *Evolutionary Dynamics of a Natural Population*, The University of Chicago Press, Chicago, 1989.

¹² See note 6 of this chapter.

*The Selfish Gene*¹³ as advocating genetic determinism (it does not), and in the second chapter he discusses the various constraints on selection as a mechanism for the production of adaptations.

But the overall aim of the book is clear: he wants us to think of adaptations as good for items he refers to as “replicators,” rather than for “interactors.” The principal, though not only, contrast he has in mind is that adaptations are to be considered as for the good of an organism’s genes, not for the good of the organism. Dawkins is interested in pushing the limits of this way of thinking about adaptation as far as he can. The title of the book stems from the topic of chapter 11, in which he tries to show that even adaptive selection of variations in animal “artifacts” such as beaver huts, bird nests or spider webs are adaptations for the good of the genetic alleles that lead to the behavioral variations that in turn lead to the variations in the artifacts.

3. DARWINIAN THOUGHT EXPERIMENTS AND *THE EXTENDED PHENOTYPE*

To get a concrete sense of the role of Darwinian Thought Experiments in his argument, I shall begin with a series of examples from chapter 11 of *The Extended Phenotype*. Then I shall ask the critical question —why use a thought experiment for this purpose? To borrow a phrase from David Hull, perhaps it is time to enter “a plea for real examples” in evolutionary biology.¹⁴

We may begin with the key theoretical claim Dawkins wants to make: “It is customary to speak as if differences always mean differences between individual bodies or other discrete ‘vehicles’. The purpose of the next three chapters is to show that we can emancipate the concept of the phenotypic difference from that of the discrete vehicle altogether, and this is the meaning of the title ‘extended phenotype’.”¹⁵

As you can see, this is a key move in the “Gestalt shift” he wishes to achieve in his readers. Famously, Dawkins wants us to think of organisms as vehicles “owned and driven” by their genes —just as you think of your car as a vehicle “owned and driven” by you. In the chapter 11, he seeks the “conceptual emancipation” of phenotypic difference from discrete vehicle by focusing on the artifacts built by organisms as phenotypic differences unrelated to bodily discreteness. The chapter is really an extended series of Darwinian Thought Experiments, a fact he freely acknowledges as it draws to a close:

“It is unfortunate that this chapter has had to be rather hypothetical. There have been only a few studies of the genetics of building behaviour in any animal, but there is no reason to think that ‘artefact genetics’ will be any different, in principle, from behaviour genetics generally.”¹⁶

I will return to this passage, as an example of a researcher using thought experiment in the hope of spawning a new area of research.

¹³ DAWKINS, R., *The Selfish Gene*, Oxford University Press, Oxford, 1976.

¹⁴ Cf. HULL, D., *Science and Selection: Essays on Biological Evolution and the Philosophy of Science*, Cambridge University Press, Cambridge, 2001, pp. 151-165 and 196-221.

¹⁵ DAWKINS, R., *The Extended Phenotype*, p. 196.

¹⁶ *The Extended Phenotype*, p. 207.

The series of thought experiments in the chapter has two aims: first, to license a use of the expression “gene for X” where the gene has no direct biochemical link to X; and second, to legitimate the idea that there can be genes for beaver ponds, spider webs and termite mounds, i.e. artifacts that are not aspects of the bodies or behaviors of the organism that carries the genes around. Indeed, in the case of termite mounds some of the crucial genes are not even termite genes, but the genes of symbiotes of the termites living in their digestive tracks that aid in the digestive process that produces the material for such mounds.

Dawkins begins with “a hypothetical species of caddis-fly whose larvae build houses out of stones which they select from those available on the bottom of the stream.”¹⁷ He imagines that there are two different colored houses, and that we do experiments and we discover that caddis-flies breed true for larvae that select dark pebbles versus light pebbles in their building activity. After noting that the example is entirely a product of his imagination, he concludes:

“But my point is that, if the practical difficulties could be overcome, nobody would be very surprised if house colour did turn out to be a simple Mendelian character in accordance with my thought experiment.”¹⁸

You might well ask, then, what is the point of the thought experiment? Dawkins replies:

“All that this chapter adds [to what any ethologist would agree to] is a logical point: once we have accepted that there are genes for building behaviour, the rules of existing terminology imply that the artefact itself should be treated as part of the phenotypic expression of genes in the animal.”¹⁹

Before following out Dawkins extension of this example, allow me to draw your attention to a number of features of his argument to this point which reveal it to be an instance of a Darwinian thought experiment. Most broadly, the issue at stake for Dawkins is to extend the approach to evolution by natural selection that he favors, where the target of selection is the gene and the organism is a mere “vehicle,” to break a conceptual bond between the phenotype and the vehicle. Phenotypic properties are not necessarily properties of vehicles, but they can be under the control of genetic causes nevertheless. So the issue at stake is how to understand selection, even though the focus tends to be on the link between phenotypic expression and genetic variation. Second, he is using the technique of imaginative narrative, but being careful to tell a tale that is similar enough to actual cases, and depends sufficiently on actual facts, that the narrative and its outcome are plausible. That is what sanctions him saying that “no one would be very surprised” if things did in fact turn out the way his imaginary narrative suggests.

This is also the point of using a real organism and discussing a real behavior of its larvae. He is aiming to make it *plausible* for you to think of the variation in rock color as a phenotypic trait under genetic control. He apparently feels it is necessary to do this because he thinks that initially we will resist this idea. Finally, he hopes that the narrative will allow you to see that talking this way is actually in accord with —perhaps even mandated

¹⁷ *The Extended Phenotype*, pp. 197-198.

¹⁸ DAWKINS, R., *The Extended Phenotype*, p. 198.

¹⁹ *The Extended Phenotype*, p. 198.

by— standard rules for using the genotype/phenotype distinction. That is, the requisite rhetorical setting is in place for Darwinian thought experiments—a skeptical audience who is asking “how can that possibly be?”. In this case, Dawkins imagines us so wedded to the idea that genes are connected to their phenotypic expressions by biochemical pathways and that those pathways end at the edge of a vehicle’s body that he needs to do something to make the concept of the extended phenotype seem plausible—and that something is thought experiment.

Perhaps the reader will by now be developing thought experiments about how Richard Dawkins might develop his imaginative narrative to include spiders and beavers—it can be done without too much difficulty. The approach is identical:

“Now consider a spider sitting at the centre of her web. ... In a very real sense her web is a temporary functional extension of her body, a huge extension of the effective catchment area of her predatory organs. ... Once again, I know of no genetic analysis of spider web morphology, but there is nothing difficult in principle about imagining such an analysis. It is known that individual spiders have consistent idiosyncrasies which are repeated in web after web. One female *Agyiella-x-notata*, for instance, was seen to build more than one hundred webs, all lacking a particular concentric ring.²⁰ Nobody ... would be surprised if the observed idiosyncrasies of individual spiders turned out to have a genetic basis.”²¹

Note once again the use of an actual case of apparently hard-wired variation to give plausibility to the narrative, and the refrain that “there is no difficulty in imagining that,” “nor should anyone be surprised if,” these “extended phenotypes” turned out to be genetically based. Again, one hears clear echoes of Darwin’s language in similar contexts.

With the beaver dam Dawkins make the relevance of all this to natural selection more explicit.

“As to the advantage of the pond from the beaver’s point of view, the best guess seems to be that it increases the distance the beaver can travel by water, which is safer than traveling by land, and easier for transporting wood. ... By building a dam across the stream the beaver creates a large shoreline which is available for safe and easy foraging without the beaver having to make long and difficult journeys overland. If this interpretation is right, the lake may be regarded as a huge extended phenotype ... As in the case of the spider web, nobody has done a genetic study of beaver dams, but we really do not need to in order to convince ourselves of the rightness of regarding the dam, and the lake, as part of the phenotypic expression of beaver genes. It is enough that we accept that beaver dams must have evolved by Darwinian natural selection: this can only have come about if dams have varied under the control of genes (Chapter 2).”²²

Here we see the full story, only implicit in the two previous thought experiments. The reason why the idea of the extended phenotype is so important to Dawkins is because it frees us from thinking that the individual organism is central to the theory of natural selection. There is a strong inclination, Dawkins believes, for all of us to think that phenotypic traits

²⁰ WITT, P. N., REED, C. F. and PEAKALL, D. B., *A Spider’s Web*, Springer, Berlin, 1968.

²¹ DAWKINS, R., *The Extended Phenotype*, pp. 198-199.

²² *The Extended Phenotype*, p. 200.

must belong to the bodies of vehicles and must be linked to their genetic base by a direct biochemical pathway. But a beaver dam can be shown to be a phenotypic trait, by just thinking through the implications of this thought experiment—and yet it is the product of the activity of many related beavers often over many generations; and the genes that lead to the behavior that leads to its production are not related to the lake by any biochemical pathway at all. Nevertheless, Dawkins argues, if there are such obvious advantages to beavers of creating lakes by dam-building, we are licensed to say they evolved by natural selection; and such evolution can only take place if there was genetically based variation in the dams that were constructed. But this is to paint a picture in which the individual organism is incidental to the link between genotype and phenotype; and this is the picture that Dawkins wants us eventually to find attractive.

4. CRITICS OF DAWKINS' THOUGHT EXPERIMENTS

Now I want to make it clear that I do not find this picture attractive, nor do I find Dawkins' arguments very compelling. But my dissatisfaction is not due to his use of thought experiment, which I find absolutely appropriate to the theoretical goals he is pursuing here. I think there are logical objections to his claim that the replicator is the target of selection, and that evolution is a replicator-centric process. But rather than focus on these disagreements, which would take us away from the topic of Darwinian Thought Experiments, I want to discuss two criticisms of Dawkins that *do* focus on his use of thought experiment. The two criticisms come from Steven Jay Gould's *The Structure of Evolutionary Theory*²³ and from David Hull's *Science and Selection*.²⁴

4.1. Gould on Dawkins

In chapter 8 of *The Structure of Evolutionary Theory*, Steven Jay Gould is defending a "hierarchical theory of selection" against a variety of alternative points of view, one of these being Dawkins' particular brand of genic selection. He begins by tracing the history of the distinction between replicator and interactor from G. C. Williams through David Hull to Richard Dawkins. A series of logical and conceptual criticisms follow, and with some caveats, I would say Gould wins the day. However, he also takes on Dawkins' methodology in *The Extended Phenotype*. He quotes Dawkins introduction, to the effect that he is not trying to convince us of the truth of a new factual hypothesis or theory but rather trying to convince us to look at the facts in a different way. Indeed, there are passages where Dawkins seems to say that no experiment or observation could help decide between his gene-centered perspective on selection and the "orthodox" view. In Gould's view this is plain conventionalism, and an unqualified rejection of the view Dawkins advocated in *The Selfish Gene*.²⁵ He does not, however, condemn conventionalism completely, but rather argues that it is inappropriate here:

"But conventionalism cannot apply to this case because an empirical resolution exists, and the apparent Necker-cube duality of gene or organism does not denote, as

²³ GOULD, S. J., *The Structure of Evolutionary Theory*, Harvard University Press, Cambridge, MA, 2002.

²⁴ HULL, D., *Science and Selection: Essays on Biological Evolution and the Philosophy of Science*, Cambridge University Press, Cambridge, 2001.

²⁵ Cf. GOULD, S. J., *The Structure of Evolutionary Theory*, p. 640.

Dawkins mistakenly argues, two equally valid perspectives on the same issue, but rather expresses a correct vs. a false view of the nature of causality in Darwinian theory.”²⁶

“The conventionalism of *The Extended Phenotype* negates and denies the explicit defense of genic selectionism as an empirical reality, as presented in *The Selfish Gene*.”²⁷

With all due respect for Gould, I find this unfair. Let us look carefully and what Dawkins says about his aim in *The Extended Phenotype* and why thought experiment will be important to accomplishing that aim. Dawkins does use the analogy of the Necker Cube—indeed, he chose the image for the cover of the book; but what Gould does *not* tell you about is the following passage.

“The analogy of the Necker Cube expresses my *minimum* hope for this book. I am pretty confident that to look at life in terms of genetic replicators preserving themselves by means of their extended phenotypes is at least as satisfactory as to look at them in terms of selfish organisms maximizing their inclusive fitness. ... But I said that was a minimum hope. I shall discuss phenomena, ‘meiotic drive,’ for instance, whose explanation is lucidly written on the second face of the cube, but which makes no sense at all if we keep our mental gaze firmly fixed on the other face, that of the selfish organism. Moving from my minimum hope to my wildest daydream, it is that whole areas of biology, the study of animal communication, animal artifacts, parasitism and symbiosis, community ecology, indeed all interactions between and within organisms, will eventually be illuminated in new ways by the doctrine of the extended phenotype.”²⁸

And it is now time to remind you of a passage from chapter 11 of *The Extended Phenotype* that I quoted earlier, where Dawkins talks about the possibility of a field called “artifact genetics”, so that he wouldn’t need to resort to thought experiments to make his point. Here he goes much further, dreaming of a sort of revolution in a variety of fields initiated by the “vision” of the extended phenotype. In fact, though Dawkins demurs for the most part, the review essays mentioned earlier by Jablonka, Laland and Turner in *Biology and Philosophy* discuss more recent developments in evolution, development and ecology as possible applications of Dawkins’ vision.

Now it is easy to read all this language of “illumination” and “Necker Cubes” as fluff at best, conventionalism or relativism at worst. But the above quote shows that this is not true in this case. As one very simple example of how this would impact the biological sciences, take the still hypothetical field of “artifact genetics”. In Dawkins view, research of this kind does not exist because people have trouble envisaging animal artifacts as tools constructed by replicators to further their perpetuation. And until they can be thought of in this way, no such investigations will take place.

And that is precisely where I want to focus your attention. One extremely important role of thought experiment in science is that it allows researchers to see things in unorthodox and unfamiliar ways, and thereby conceive of research and experiments that would otherwise not be considered. The reader of chapter 11 of *The Extended Phenotype* is given both a plausibility argument for seeing such things as beaver ponds and spider webs as genetic

²⁶ *The Structure of Evolutionary Theory*, p. 640.

²⁷ GOULD, S. J., *The Structure of Evolutionary Theory*, p. 641.

²⁸ DAWKINS, R., *The Extended Phenotype*, p. 7.

traits; but he is also provided with a wealth of ideas about research that could be done to turn this plausible conjecture into confirmed theory. Nothing in Gould's remarks would prepare you for that.

4.2. Hull on Thought Experiments in Biology

Another possible objection to the use of thought experiment in biology can be found in a number of papers by David Hull, two of which are conveniently packaged in the collection published as *Science and Selection: Essays on Biological Evolution and the Philosophy of Science*.²⁹ The argument has two parts. The first is the negative impact of thought experimental method on philosophy. It is not hard to come up with lots of examples of that —XYZ on Twin Earth, Brains in Vats, Grues and Bleens, and so on. Interestingly, Hull tends to think of thought experiment exclusively in terms of imaginary counter-examples, of the sort used by Fleeming Jenkin against Darwin and “I” discussed in my 1991 paper “by Fleeming Jenkin”,³⁰ in which he showed that under certain plausible conditions, you could grant Darwin natural selection and it would never produce a new species. Interestingly, contrary to what Hull would lead you to believe, these thought experiments were extremely valuable —Darwin acknowledged the power of Jenkin's review³¹ a number of times, and systematically rewrote the *Origin* in response to these thought experiments. But what I have been calling Darwinian Thought Experiments are not imaginary counter-examples. Their role is positive —they are intended to help the reader see that it is plausible that a certain phenomenon, perhaps thought to be beyond the scope of natural selection, is the product of a selection process.

Hull finds this quite unnecessary in biology. Regarding debates about how to define species, he considers two hypothetical cases which would challenge one or another definition.

“As it turns out, no such thought experiments are necessary because nature supplies numerous examples of both situations and many more besides. In the absence of such examples, biologists might be forced to invent them, and I am willing to bet that even the most fertile imaginations would not have been able to come up with the bizarre situations that actually occur in nature.”³²

I see two problems here. First, it assumes a highly delimited role for thought experiments, namely to come up with extreme, bizarre counter-examples. Hull doesn't seem to imagine that a rather modest and highly plausible example, full of information about the actual world, such as those we find both in Darwin and in chapter 11 of *The Extended Phenotype*, might nevertheless be a thought experiment. Second, Hull apparently thinks that if real life examples are possible or conceivable, then we should have no need for thought experiments. But as I have been stressing, and as one sees in Dawkins' work, one function

²⁹ HULL, D., *Science and Selection: Essays on Biological Evolution and the Philosophy of Science*, Cambridge University Press, Cambridge, 2001.

³⁰ Cf. LENNOX, J. G., “Darwinian Thought Experiments: A Function for Just-so Stories,” pp. 230-236.

³¹ Cf. JENKIN, F., “The Origin of Species,” *North British Review*, v. 46, (1867), pp. 277-318; reprinted in HULL, D. L., *Darwin and His Critics: The Reception of Darwin's Theory of Evolution by the Scientific Community*, Harvard University Press, Cambridge, 1973, pp. 302-350.

³² HULL, D., *Science and Selection: Essays on Biological Evolution and the Philosophy of Science*, p. 155.

of a Darwinian Thought Experiment is to encourage researchers to think in new directions that may, in fact, generate new information.

And the outcome is not pre-ordained. Dawkins assumes that if we get down to artifact genetics, we are going to turn up genes for beaver ponds. After all, are not such ponds advantageous to beavers, and so are they not adaptations, and so are they not products of selection? Well suppose the answers to all those questions is “yes.” It does not, contrary to Dawkins’ most basic assumption, prove that there is a gene, or a suite of genes, for beaver ponds. But that is not to criticize his use of thought experiments—it is to criticize his basic assumption that evolution by natural selection always operates on replicators.

5. CONCLUSION

I want to close by noting that there are lots of other places to find Darwinian Thought Experiments in contemporary evolutionary biology. There is a burgeoning area of research into what is called “artificial life” which is conducted almost entirely by means of computer simulations run on programmed plausible assumptions. I would call these “thought experiments”, and Darwinian ones if the assumptions being tested include natural selection’s ability to generate a certain sort of outcome. Then there is the realm of “optimality”. Take the following suggestion of Peter Abrams about how to understand this concept in evolutionary biology:

“Optimality models or a dynamic variant of such models, represent the only reasonable way to determine which traits would be adaptive under hypothetical circumstances when verbal reasoning does not suffice...”³³

That, I submit, is to claim that optimality models function as Darwinian Thought Experiments. And they are no less useful for all that!

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³³ ABRAMS, P. “Adaptationism, Optimality Models, and Tests of Adaptive Scenarios,” in ORZACK, S. H. and SOBER, E. (eds.), *Adaptation and Optimality*, Cambridge University Press, Cambridge, 2001, p. 293.

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THE SPECIES CONCEPT IN EVOLUTIONARY BIOLOGY: CURRENT POLEMICS

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1. INTRODUCTION

The philosophy of science today recognizes that many scientific concepts are theory-dependent, that is, their meaning depends to some extent on the theory of which they form part and can change whenever the theory changes. This has happened to the concept of species in biology. The most far-reaching theoretical change to occur in biology was the change from a fixist stance to an evolutionist one. With such a shift, it is hardly surprising that the concept of species should also have undergone changes (section 2). We might even wonder whether, in the wake of the Darwinian revolution,¹ a single concept of species has taken shape or there are several rival ones. The question of species has immediate repercussions in all branches of biology, and each one seems to demand some concept of species (section 3).

Outside the strict field of life sciences themselves, changes in the notion of species also affect the philosophy of biology. Debates on scientific realism, on the nature of laws and theories, as well as the scientificity of biology may be affected by the argument on the ontological status of species (section 4).²

After this overview we shall take stock of the situation (section 5) in order to go on to tackle the yet further repercussions of the debate, in the realm of ethics, where some major questions depend on the notion of species that has taken shape within the setting of evolutionism. We shall give especial attention in section 6 to ethical problems linked with the conservation of biodiversity and the so-called anti-speciesist's dilemma, which affects both environmental ethics and the question of human dignity.

2. THE CONCEPT OF SPECIES AND THE DARWINIAN REVOLUTION

The historical description of the concept of species usually begins with Plato. A species (*eidōs*) would, for him, be a type, an Idea, whose existence is unalterable and eternal. In the world of the senses we find more-or-less degraded copies of the Idea. This concept of "species" is not limited to living beings but can be applied to the whole of reality. Indeed, it does not seem particularly suitable for living beings quite simply because of its static nature.

¹ I use this expression, which has become quite common (cf. RUSE, M., *The Darwinian Revolution: Science Red in Tooth and Claw*, The University of Chicago Press, Chicago, 1979), without the conviction that such an event has actually occurred. As Bowler maintains, evolutionism triumphed quickly, in a way that could be considered revolutionary, but selectionism, which is the most clearly Darwinian component, did not take over until some time after the publication of *The Origin of Species* (1859), and has always been a very controversial point, as it still is. Cf. BOWLER, P., *The Non-Darwinian Revolution: Reinterpreting a Historical Myth*, Johns Hopkins University Press, Baltimore, 1988.

² Cf. MARCOS, A., "Sobre el concepto de especie en Biología," in ABEL, F. and CAÑÓN, C. (eds.), *La mediación de la Filosofía en la construcción de la Bioética*, Publicaciones Universidad Pontificia de Comillas, Madrid, 1993, pp. 41-60.

It was Aristotle who, with the eyes and interests of a biologist, criticised the Platonic notion of species. In Book I of his treatise *On the Parts of Animals* he comes down heavily on the system of classification by dichotomic division followed by the disciples of Plato. He considers the process to be too *logos*-orientated, too dedicated to the satisfaction of human reasoning, not taking sufficiently into account the reality of things, which are often far less orderly than we would like to think. Together with the point of view of the *logos*, Aristotle was an advocate of the *physis*. He renounced the staticness of the Platonic world of Ideas, and largely abandoned the intention of classification,³ but even so sought to find elements of order and rationality in the dynamic and changing world of living things.

This tension is present throughout Aristotle's work. In the words of Jean Gayon, "in the Aristotelian corpus there is tension showing through of two concepts of *eidos*. One of them is of a logical and classificational nature, used in connection with that of genus (*genos*), it is applied to all realms of reality, and constitutes a tool for hierarchizing universals. This concept of *eidos* as a logical class is valid without restriction, and not only for living beings. In biological treatises, nevertheless, a second concept of *eidos* arises, that of *eidos*-form: from this point of view, the *eidos* is the soul of the individual organism, that is an organizing principle transmissible by generation [...] In most contexts, Aristotle avoids using *eidos* in the meaning of a class subordinated to a genus and more frequently uses a word connoting form (*morphè*) or configuration (*schema*)."⁴

The important thing about Aristotelian thought on this point is that it poses the thorny problem of the relations between the species as a logical class and the species as a physical principle intervening in generation. Nevertheless, this qualified wealth of Aristotelian biophilosophy is often overlooked, so, according to Lennox, "Aristotle is often characterized, by both philosophers and evolutionist biologists, as the fountainhead of a typological theory of species that is absolutely inconsistent with evolutionary thinking."⁵ He goes on to say, however, "Aristotle treats variations between one form [*eidos*] of a kind [*genos*] and another as differences of degree. Such a move conflicts with the sort of typological thinking traditionally ascribed to Aristotle by biologists and philosophers [...] It should become clear that Aristotle's essentialism is *not* typological, nor is it in any obvious way 'anti-evolutionist.' Whatever it was that Darwin was up against, it was not Aristotelian essentialism."⁶

This last observation of Lennox's is valuable in this context. The stereotyped telling of history causes the evolutionist concept of species to arise in contrast to a supposed Aristotelian typological concept. This unfair simplification does not only fail to make use of the suggestions that Aristotle's thought may still be able to make, but also makes it difficult to appreciate the very evolutionist concept of species. In order to be able to

³ Cf. PELLEGRIN, P., *La classification des animaux chez Aristote*, Les Belles Lettres, Paris, 1982.

⁴ GAYON, J., "L'Espèce sans la forme," in GAYON, J. and WUNENBURGER, J.-J. (eds.), *Les figures de la forme*, L'Harmattan, Paris, 1992, pp. 51-52.

⁵ LENNOX, J., "Kinds, Forms of Kinds, and the More and Less in Aristotle's Biology," in GOTTHELF, A. and LENNOX, J. (eds.), *Philosophical Issues in Aristotle's Biology*, Cambridge University Press, Cambridge, 1987, p. 339.

⁶ LENNOX, J., "Kinds, Forms of Kinds, and the More and Less in Aristotle's Biology," in GOTTHELF, A. and LENNOX, J. (eds.), *Philosophical Issues in Aristotle's Biology*, pp. 340-341.

argue on the evolutionist concept of species we must know beforehand what other concept or concepts of species it enters into direct conflict with. It seems obvious, as Jean Gayon points out, that "... it is in the naturalist thinking of the 19th century where we must look for the modern use of the term species in the life sciences."⁷

Nevertheless, the confusion that we have been detecting with regard to Aristotle leads to statements like this one of Ernst Mayr's: "The typological species concept going back to the philosophies of Plato and Aristotle (and thus sometimes called the essentialist concept), was the species concept of Linnaeus and his followers."⁸ This is not so: the concept of species that Darwin confronted was that of Linnaeus and the naturalists of the 18th century and first half of the 19th, not Aristotle's, among other reasons because the 18th-century concept of species arose against an "evolutionist" background, which did not happen in Aristotle's. Several vicissitudes divide Aristotle's concept of species from Linnaeus'. We must not overlook the medieval polemic on universals and the extreme positions of realists and nominalists.⁹ Nor can we disregard the chaotic wastefulness of the Renaissance in dealing out transformations here and there throughout nature.

It is not surprising, then, that naturalists before Darwin should have thought that a scientific, rational and realistic biology could only be established on the basis of a consistency in types of organisms through reproduction or, in other words, on the basis of the stability of species. Only thus could biology construct genuinely scientific classifications and laws, like those already existing in the physical sciences.

The persistence of the fixist element appearing in definitions of species from John Ray onwards, shows, if anything, that they have been formulated with the intention of avoiding transformationist temptations that would put biology back into a pre-scientific state. Darwin's position on the concept of species is compromised, as it has to deny fixism, but without abandoning the very concept of species which had actually been defined in its day in fixist terms, and without reneging on biology's status of scientificity that seemed to depend on that definition. Let us examine some of those immediately pre-Darwinian definitions in order to better understand this point.

John Ray (1627-1705) offers a first clear definition of biological species as a constant group of genealogically related organisms.¹⁰ Ray builds the species up from the bottom, from where individuals share similarity, not from the top down, from the Idea. This shift was fundamental for transforming a merely logical concept of species into one that was indeed biological. Nevertheless, the fixist element is explicitly contemplated in Ray's definition. In Buffon (1707-1788), we find another fixist definition: "We should regard two

⁷ GAYON, J., "L'Espèce sans la forme," in GAYON, J. and WUNENBURGER, J.-J. (eds.), *Les figures de la forme*, p. 51.

⁸ MAYR, E., "Species Concepts and Their Application," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, The MIT Press, Cambridge, MA, 1992, p. 16. Mayr's influential text was first published in 1963, since which time the author has modified his positions (cf. MAYR, E., *Towards a New Philosophy of Biology*, Harvard University Press, Cambridge, MA, 1988), but the text is still published with no changes on this point.

⁹ Cf. STAMOS, D., *The Species Concept: Biological Species, Ontology, and the Metaphysics of Biology*, Lexington, Lanham, MD, 2003, pp. 1-9 and ch. 2.

¹⁰ Cf. JAHN, I., "Naturphilosophie und Empire in der Frühaufklärung (17. Jh.)", in JAHN, I. (ed.), *Geschichte der Biologie*, Spektrum Akademischer Verlag, Berlin, 2000, pp. 222-225.

animals as belonging to the same species if, by means of copulation, they can perpetuate themselves and preserve the likeness of the species; and we should regard them as belonging to different species if they are incapable of producing progeny by the same means.”¹¹

Linnaeus (1707-1778) aspired in principle to establish a natural classification, although in the course of his research he realized how difficult the task was and that he would have to settle for a classification that was useful, clear and operative. Even so, he always believed that species and genera were present in nature, although higher categories arose only from human opinion and from our need to simplify complex natural reality. He understood that species were separate units, but also on this point his research led him to qualify his positions, to the point of accepting that several species of one gender could have a common origin, although different genera could not. So, at least at the genus level, fixism was guaranteed, according to Linnaeus.¹²

Charles Bonnet (1720-1793) declares: “There are no changes or alterations, but full identity. Species keep triumphing over the forces of nature.”¹³ For Cuvier (1769-1832), “... a species comprehends all the individuals which descend from each other, or from a common parentage, and those which resemble them as much as they do each other.”¹⁴ Cuvier explicitly defends fixism, in opposition to Lamarck, and his concept of species is obviously incompatible with the Darwinian idea of a common origin for *all* living things. According to Marc Ereshefsky, “Linnaeus, John Ray, Maupertuis, Bonnet, Lamarck, and Lyell all adopted an essentialist (or typological) view toward systematics.”¹⁵

Let us finally quote Charles Lyell, one of the people with most influence on Darwin: “The name of species, observes Lamarck, has been usually applied to ‘every collection of similar individuals produced by other individuals like themselves.’ [...] But this is not all which is usually implied by the term species; for the majority of naturalists agree with Linnaeus in supporting that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species.”¹⁶ As James Lennox states, “Lyell pretty clearly assumes that to allow for evolution is to deny the reality of species [...] To accept evolutionary change, on this view, you must become comfortable with a variety of nominalism about species.”¹⁷

We might ask why there has been so much insistence on the typological notion of species, on fixism and on essentialism. There can only be one answer: because the

¹¹ Quoted in BEATTY, J., “Speaking of Species: Darwin’s Strategy,” in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, The MIT Press, Cambridge, MA, 1992, p. 229. We know, however, that Buffon’s position on the stability of species changed over his activity as a naturalist.

¹² Cf. JAHN, I., “Biologische Fragestellungen in der Epoche der Aufklärung (18. Jh.)”, in JAHN, I. (ed.), *Geschichte der Biologie*, pp. 235-242.

¹³ Quoted in JAHN, I., “Biologische Fragestellungen in der Epoche der Aufklärung (18. Jh.)”, in JAHN, I. (ed.), *Geschichte der Biologie*, p. 246.

¹⁴ CUVIER, G., *Essay on the Theory of the Earth*, Blackwood, Edinburgh, 1813, p. 120.

¹⁵ ERESHEFSKY, M., “Introduction to the Part II: Philosophical Issues,” in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*. The MIT Press, Cambridge, MA, 1992, p. 187.

¹⁶ LYELL, C., *Principles of Geology*, John Murray, London, 1835, 4th ed., vol. 2, p. 407.

¹⁷ LENNOX, J., “Darwinism,” in ZALTA, E. N. (ed.), *The Stanford Encyclopedia of Philosophy* (Fall 2004 Edition), <<http://plato.stanford.edu/archives/fall2004/entries/darwinism/>>.

debate on the possible transformation of species was already in the air, and this, in the opinion of many naturalists of the day, threatened the scientificity of biology, the possibility of establishing laws and explaining deviations as perturbations (as physics has done since Galileo).¹⁸

Now we can justly appreciate Darwin's conflict with the notion of species and the position he adopts. Darwin cannot accept the definition of species current in his day, but he needs to be able to count on species for his theory not to be exposed to anti-evolutionist objections like that put forward by William Hopkins in 1860: "Every natural species must by definition have had a separate and independent origin, so that all theories —like those of Lamarck and Mr. Darwin— which assert the derivation of all classes of animals from one origin, do, in fact, deny the existence of natural species at all."¹⁹ Or, more succinctly, Louis Agassiz asks: "If species do not exist at all, as the supporters of the transmutation theory maintain, how can they vary?"²⁰

In short, Darwin had to convey his new ideas to the community of naturalists that he felt part of, and for that he had to use the language common to the members of that community, especially as far as "species" was concerned. And yet, what he had to tell them denied the defining characteristics of the very *category* of species. How did Darwin tackle this problem? His strategy consisted in accepting the common reference of the term "species" without taking its definition. What Darwin had to tell his fellow naturalists was that *what they called species*, and believed to be stable and independent groups, had in fact evolved from a common origin. "We have to discuss in this work —Darwin said— whether *forms called by all naturalists distinct species* are not lineal descendants of other forms."²¹ He does not question the *taxa* belonging to the category of species as established by contemporary naturalists, what he denies is the unchanging and independent nature that they attribute to them. In *The Origin of Species*, we can read: "Hence, in determining whether a form should be ranked as a species or variety, the opinion of naturalists having sound judgement and wide experience seems the only guide to follow."²² In this way, he ensures that he is speaking about the same genealogical segments that his fellows identify as species. He ensures, apart from the ability to communicate his new thesis, that those genealogical segments evolve through time and have a common origin.

Nevertheless, if Darwin disagrees with the definition then in force of the category of species, we can ask what definition he would replace it with. The answer would be this: "Nor shall I here discuss the various definitions which have been given of the term species. No one definition has as yet satisfied all naturalists; yet every naturalist knows

¹⁸ This certainly has little to do with the motivations of Aristotle, for whom the species was not even a fixed taxonomical category, anchored in a hierarchical system, but a mere correlate of genus.

¹⁹ Quoted in BEATTY, J., "Speaking of Species: Darwin's Strategy," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, p. 232.

²⁰ Quoted in BEATTY, J., "Speaking of Species: Darwin's Strategy," p. 232.

²¹ DARWIN, CH. R., *Charles Darwin's Natural Selection: Being the Second Part of this Big Species Book Written From 1856 To 1858*, edited by Robert C. Stauffer, Cambridge University Press, Cambridge, 1975, p. 97.

²² DARWIN, CH. R., *On the Origin of Species by Means of Natural Selection*, Penguin Classics, London, 1985, p. 104. Therefore, Darwin goes on to say: "In the following pages I mean by species, those collections of individuals, which have commonly been so designated by naturalists," in DARWIN, CH. R., *Charles Darwin's Natural Selection: Being the Second Part of this Big Species Book Written From 1856 To 1858*, p. 98.

vaguely what he means when he speaks of a species.”²³ Regarding the job of finding a suitable definition of the category of species, he says this: “...this has been found hopelessly difficult by naturalists, if we may judge by scarcely two having given the same name.”²⁴ Darwin considered the difficulty to stem from “trying to define the indefinable,”²⁵ and from chasing “the undiscovered and undiscoverable essence of the term species.”²⁶

Let us now look at the necessary distinction between the taxa that we call species, for example *Homo sapiens* and *Panthera leo*, and the taxonomic category of species itself, which is bordered by variety on one side and by genus on the other. Well, Darwin accepts taxa as established by naturalists, and declines from defining the category of species. For him, the problem lies in drawing a clear distinction between what must be considered variety, species or genus. We understand why the boundaries between the three categories are so blurred for Darwin as soon as we adopt, like him, an evolutionary perspective. Between species and varieties, and between species and genera, there is a continuum, with no abrupt frontiers, where varieties are species being formed and genera are species that have split apart reproductively.

Regarding the birds observed in the Galapagos Islands, Darwin reminds us that he was “much struck how entirely vague and arbitrary is the distinction between species and varieties [...] But to discuss whether they are rightly called species or varieties, before any definition of these terms has been generally accepted, is vainly to beat the air.”²⁷ And, on the other hand, “we shall have to treat species in the same manner as those naturalists treat genera, who admit that genera are merely artificial combinations made for convenience.”²⁸

But can biology work without defining something so far-reaching as the concept of species? Is it impossible to draw up a realistic notion of species from an evolutionist standpoint? As Popper states, scientific knowledge is developed from question to question. Obviously Darwin left these new questions as a task for his successors. In the same way that he encountered definitions of species dependent on fixist theories, definitions destroyed by the theoretical change proposed by Darwin himself, later Darwinians would have the job of drawing up new definitions of species adapted to the evolutionist stance. This is what has happened. But the result has not been one definition of species, but many, as we shall see.

3. THE DIFFERENT CRITERIA FOR SPECIES IN EVOLUTIONARY BIOLOGY

The notion of species is at the very heart of the so-called Darwinian revolution, together with the notions of evolution and selection. Darwin carried out much of his work by arguing at length on evolution and selection. Nevertheless, his successors did not tackle the part of the work corresponding to the concept of species until almost a century after

²³ DARWIN, CH. R., *On the Origin of Species by Means of Natural Selection*, p. 101.

²⁴ DARWIN, CH. R., *Charles Darwin's Natural Selection: Being the Second Part of this Big Species Book Written From 1856 To 1858*, p. 95.

²⁵ Quoted in BEATTY, J., “Speaking of Species: Darwin’s Strategy,” p. 237.

²⁶ DARWIN, CH. R., *On the Origin of Species by Means of Natural Selection*, p. 456.

²⁷ *On the Origin of Species by Means of Natural Selection*, pp. 104-105.

²⁸ DARWIN, CH. R., *On the Origin of Species by Means of Natural Selection*, p. 456.

the publication of *The Origin of Species*. And when the job was taken on, the result was a diversity of concepts and a lengthy debate. David Stamos²⁹ brings forward the explanation of the facts. In the first place, reflection on the concept of species was delayed because it had to wait for the drawing up of the Synthetic Theory of Evolution, which did not happen until halfway through the 20th century. Secondly, the coming of age of biology as a science has produced inevitable specialisms, so in fact each discipline has constructed its own concept of species depending on its outlook and needs.

Overall, however, we shall see how tension is kept up between the morphological component, which is based on appearance, and the genealogical one, which depends on ancestry. The criterion that has become most widespread, to the point of being considered classical, is that of the *biological concept of species*. In relation to this concept, either in opposition to it or as developments based on it, we shall go on to see the others.

The canonical formulation of the biological concept of species is to be found in the writings of Ernst Mayr.³⁰ He sets out the idea that species are maximal Mendelian populations, that is, reproducing communities reproductively isolated from others. Mayr considers this criterion to be basic and that it paves the way for a set of suitable predictions about the process of speciation, reproductive barriers and integration of the genotype. Mayr maintains that both populational genetics and ecology are tributaries of this concept of species.³¹ Indeed, the strictly reproductive criterion has been complemented by Mayr himself by the addition of ecological elements,³² whereby a species would be the maximal Mendelian population occupying its own ecological niche. The reason is linked with the theory of speciation also developed by Mayr, whereby every process of speciation begins with a phase of geographical isolation which, over time, becomes a reproductive isolation. Without reproductive isolation, two groups would end up as one, but without its own ecological niche, no group can survive extinction. So a specific entity stable enough to be taken into account must have these two defining elements: reproductive isolation and its own ecological niche.

Mayr's *biospecies*, although they bear in mind the ecological element, must not be confused with the *ecospecies* as defined by Van Valen,³³ according to whom inter-fertility is not a necessary or sufficient condition for defining the category of species, for, in his opinion, species owe their continued existence to ecological factors. And he draws up an *ecological concept of species*, according to which each species is a lineage occupying an area of adaptation, or ecological niche, minimally different from that of any other lineage, and which evolves separately. The set of selective pressures on each ecological niche is what keeps species as distinct taxonomical units. The role of the ecological niche is very

²⁹ Cf. STAMOS, D., *The Species Concept: Biological Species, Ontology, and the Metaphysics of Biology*, pp. 352-353.

³⁰ Cf. MAYR, E., *Animal Species and Evolution*, Harvard University Press, Cambridge, MA, 1963. A similar point of view is put forward by Theodosius Dobzhansky, one of the creators of the synthetic theory of evolution (cf. DOBZHANSKY, T., *Genetics and the Evolutionary Process*, Columbia University Press, New York, 1970, p. 357).

³¹ Cf. MAYR, E., *Towards a New Philosophy of Biology*, p. 318.

³² Cf. MAYR, E., *The Growth of Biological Thought*, Harvard University Press, Cambridge, MA, 1982, pp. 273.

³³ VAN VALEN, L., "Ecological Species, Multispecies and Oaks," *Taxon*, v. 25, (1976), pp. 233-239.

different in Mayr and Van Valen, as for the former it is reproductive isolation that ensures that a species remains adapted to its ecological niche, while for the latter, it is the selective pressures of the ecological niche that maintain the characteristics of a species, and among them, those of its reproduction.

On the other hand, the biological criterion of species is not without its limitations and problems. Firstly, it is obvious that the category of species thus defined is not applicable to organisms lacking sexual reproduction. Furthermore, crossing between members of a given population or between two populations must be understood as potential, for it is obvious that many individuals considered co-specific never actually cross.³⁴ That being so, what kinds of barriers must be considered adequate before we can talk about different species? Geographical ones? Behavioural ones? If that were the case, we should have to consider as populations of different species groups that may be identical from the morphological and genetic points of view. Conversely, there are groups with notable differences that are inter-fertile under certain conditions.

For these and other reasons, other concepts of species have arisen that stress morphological aspects,³⁵ like the *phenetic concept of species*, which is at the root of phenetic taxonomy, also known as numeric taxonomy. Its advocates propose classifying organisms according to their morphological appearances measured or codified numerically. By comparison, it will be possible to calculate the index of similarity between taxa. In this way, taxonomic categories can be delimited by the proximity of indices.³⁶ In the case of polytypic species,³⁷ lists of characteristics have to be drawn up, so that some combinations can be taken as a sufficient condition for belonging to a species, but no single characteristic is a necessary condition.

The problem of phenetic taxonomy is that it can place closely related species that have diverged morphologically through evolution into very different taxa, while species that are physically similar but are less closely related may end up in more proximate taxa.³⁸ In fact, the use of theoretical criteria to assess the relative importance of diverse characteristics becomes unavoidable; otherwise, as Mayr³⁹ points out, the differences within polymorphic species, along with those due to age, sex or individual variations, would give rise to very

³⁴ In fact, Mayr refers explicitly to *potential* crossing in his definition of 1942 (MAYR, E., *Systematics and the Origin of Species*, Harvard University Press, Cambridge, MA, 1942, p. 120) and later he deletes the reference, considering it redundant.

³⁵ Cf. also SOKAL, R. and CROVELLO, T., "The Biological Species Concept: A critical evaluation," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, The MIT Press, Cambridge, Massachusetts, 1992, pp. 27-56.

³⁶ The classical exposition of these techniques may be seen in SNEATH, P. H. and SOKAL, R., *Numerical Taxonomy*, Freeman, San Francisco, 1973. Discussions on them with a philosophical approach are to be found in RUSE, M., *The Philosophy of Biology*, Hutchinson, London, 1973; ROSENBERG, A., *The Structure of Biological Science*, Cambridge University Press, New York, 1985; and MAYR, E., *Towards a New Philosophy of Biology*, Harvard University Press, Cambridge, MA, 1988.

³⁷ Polymorphism is variability *within* each population of a given species, while polytypism is variability *between* populations of a single species. Cf. DOBZHANSKY, T., AYALA, F., STEBBINS, L. and VALENTINE, J., *Evolution*, W. H. Freeman and Company, San Francisco, 1977.

³⁸ Cf. DOBZHANSKY, T., AYALA, F., STEBBINS, L. and VALENTINE, J., *Evolution*, W. H. Freeman and Company, San Francisco, 1977.

³⁹ Cf. MAYR, E., *Towards a New Philosophy of Biology*, p. 316.

strange classifications. On the other hand, the most typological concepts of species, like phenetic taxonomy, have the undeniable advantage of operativeness. In many cases, it is much more feasible to compare morphological characteristics than to establish inter-fertility. Even for the supporters of biospecies, the comparison of characteristics constitutes a valuable symptom for inferring the species status of a given group.

The difficulties in determining biospecies are particularly arduous when we are dealing with populations separated by long periods of time—it is very difficult to deduce from fossil remains whether two populations were inter-fertile. Worse still, we can reasonably suppose that any individual can cross with one of the previous generation,⁴⁰ which threatens to bring down the whole tree of life in a single species. This is what has led palaeontologists and researchers into phylogenesis to stipulate the *evolutionary concept of species*, useful for the determination of species on the basis of fossil remains.

An evolutionary species, according to George G. Simpson,⁴¹ is a lineage evolving separate from others, with its own functions and tendencies in the course of evolution. Edward O. Wiley⁴² expresses it in other terms, insisting that a species retains its identity, its evolutionary tendencies and its destiny throughout evolution. According to Mayr, this criterion can only apply to monotypic species, and, moreover, evolutionary tendencies can only be detected over very long successions of generations. Therefore, in Mayr's opinion,⁴³ the determination of chronospecies, that is, species that replace their forerunners over time in the same phylogenetic line, will be arbitrary.

Much like Simpson, Joel Cracraft also adopts a diachronic point of view, proposing a *phylogenetic concept of species*.⁴⁴ For him a species is a lineage whose members share a single characteristic set of new evolutionary traits. Nor do Paul Ehrlich and Peter Raven recognize inter-fertility as a necessary or sufficient condition to talk about species.⁴⁵ They put forward what according to them are empirical reasons. It is not a necessary condition, as there are groups whose populations are geographically isolated and yet we would consider them as forming a single species.

Something analogous occurs with asexual organisms. Nor is it a sufficient condition, as there are differentiated species that remain differentiated although their members exchange genetic material with some frequency. What is not clear, to my way of thinking, is that these reasons can be purely empirical. Here, the empirical and the theoretical go hand in hand, for if we are going to continue taking as species separate populations that frequently exchange genes, we need a concept of species different from the *biological one*.

⁴⁰ This occurs with the sole exception of the phenomena of abrupt speciation, that is single-generation speciation. In plants, for example, occasionally polyploidy occurs: an organism has x chromosomes and its immediate descendants have the same number doubled or multiplied by n . In such cases, the descendants are of a different species and back-crossing could not occur.

⁴¹ Cf. SIMPSON, G. G., *Principles of Animal Taxonomy*, Columbia University Press, New York, 1963.

⁴² WILEY, E. O., *Phylogenetics: The Theory and Practice of Phylogenetic Systematics*. John Wiley, New York, 1981.

⁴³ MAYR, E., *Towards a New Philosophy of Biology*, pp. 323-324.

⁴⁴ CRACRAFT, J., "Species Concept and Speciation Analysis," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*. pp. 93-120.

⁴⁵ Cf. EHRlich, P. and RAVEN, P., "Differentiation of Populations," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*. pp. 57-68.

In fact, the authors mentioned suggest a *selectionist concept of species*. According to them, what allows geographically isolated species to go on indefinitely belonging to the same species is natural selection.

Also, by linking it to Mayr's classic definition, we can understand Hugh Paterson's,⁴⁶ and this time not through opposition but rather through development. Paterson develops *the recognition species concept*. According to Paterson, this is at work when the individuals of a group do not recognize those of another as potential mates. And conversely, the organisms that may recognize each other as reproductive mates belong to the same species. Therefore, Mayr's definition should, in Paterson's opinion, be modified, in order for us to consider as a species the most inclusive population of individual biparental organisms sharing a *common fertilization system*.

Alan Templeton remarks that the concept of species proposed by Paterson is beset by the same difficulties as we have seen with regard to the classical concept of *biospecies*.⁴⁷ He maintains that the concept of species can be reformulated in *genetic* terms so that it might also include populations that do not actually cross, like those of asexual organisms or geographically isolated ones. Those with sufficient genetic similarity would belong to the same species. The *cohesion* between these populations is maintained by several mechanisms. One is crossing, but it is not the only one. Exposure to the same environmental pressures also favours cohesion between different populations. So, a genetic novelty, like a mutation, may become established in two populations without the need for crossing, simply because it happens in both, and both are subjected to the same environmental pressures. In short, species will be genetic canals with genes flowing through them.

4. THE DEBATE ON THE ONTOLOGICAL STATUS OF SPECIES

The other axis of the current discussion on the concept of species is of a more philosophical nature, although it obviously does not exclude the biological perspective. It is the establishment of the ontological status of species or, in other words, the kind of entities they are. "The Darwinian species," says Jean Gayon, "is not one form: it is a variable group of individuals whose coherence is almost exclusively reproductive, and which constitutes the physical thing that is really modified. This thing does not have the status of a logical class (a universal), given that it is precisely one thing: only one thing is transformed; an abstraction, which is by definition timeless, is not transformed. *A fortiori*, the Darwinian species is neither an essence nor a type."⁴⁸

Evolution does not admit immutable essence, so several authors have opted to consider the species of evolutionist biology as a physical thing, as a concrete entity. Some have even opted for the radical solution of considering species as individual entities. This shift has unquestionable advantages: it endows the notion of species with realism and allows for the channelling of the question of the scientificity of biology. Nevertheless the *species-as-*

⁴⁶ Cf. PATERSON, H., "The Recognition Concept of Species," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, pp. 139-158.

⁴⁷ Cf. TEMPLETON, A., "The Meaning of Species and Speciation: A Genetic perspective," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, pp. 159-183.

⁴⁸ GAYON, J., "L'Espèce sans la forme," in GAYON, J. and WUNENBURGER, J.-J. (eds.), *Les figures de la forme*, p. 58.

individuals thesis (hereafter the s-a-i thesis) is not lacking in problems. In the light of this, intermediate routes have appeared between the conception of species as classes and the conception of species as individuals. We shall see below the proposals made in this regard by Mayr, Ruse and Kitcher. David Stamos has recently proposed a conception of *species as relationships*, in an attempt to break with what he considers a false alternative of classes and individuals. I shall attempt to present what is essential to this debate on the ontological status of species.

The s-a-i thesis begins with the Californian zoologist Michael Ghiselin,⁴⁹ who has received support from the philosopher David Hull.⁵⁰ In principle, the thesis resolves the question of the realism of species. If each one is an individual, then it has an existence which is just as real as any organism's. Furthermore, like organisms, and unlike logical classes, they can *do* things, that is, they can evolve, produce other species through the process of speciation, become extinct, etc. We also had the problem of the scientificity of biology. Its recognition as a science is one of the preoccupations of David Hull, who believes that the s-a-i thesis is an advance in this regard. Ghiselin also insists that his thesis does not only affect technical questions concerned with taxonomy, but is an attempt to unify scientific knowledge and shore up a monist metaphysics. If each species were a class, it would surprise us that biology could not formulate laws for each of them, as physics and chemistry do for the classes that they deal with. For example, there are general laws of a chemical nature for carbon that apply to all samples of carbon.

There are, however, no universal laws for each species. Nor are we able to establish a set of sufficient and necessary conditions of belonging, or define species. But if each species is an individual, then there is nothing untoward here, for individuals are not defined, just described. Individuals are not made up of elements, like sets, or of members, like classes, but of parts that we consider peculiar to the individual because of their origin and physical relation with the other parts. If species are individuals, then organisms will be their parts. And biological laws will have to be looked for a step further up, and they will be regularities adhered to by all species. Thus, in any system endowed with variation, inheritance and selection, there will be certain regularities. We have, then, laws for the class of species as units of evolution, not for *this* species in particular, which is an individual, just as physics and chemistry provide laws for the atom or for carbon, not for *this* atom or for *that* sample of carbon.

Of course, the objection could be made that the concept of scientific law used by Hull is too near to what in the philosophy of science is called "the received view". In this regard, Frederick Suppe states that the existence or otherwise of laws valid for each species depends on what the world is like, not on whether we consider species as individuals or classes. Moreover, from a given individual, it will always be possible to form the class of its parts. Whether this class is natural or not, whether its members comply with laws or

⁴⁹ Cf. GHISELIN, M., "A Radical Solution to the Species Problem," *Systematic Zoology*, v. 23, (1974), pp. 536-544; GHISELIN, M., "Species Concepts, Individuality and Objectivity," *Biology and Philosophy*, v. 2, (1987), pp. 127-145; and GHISELIN, M., *Metaphysics and the Origin of Species*, State University of New York Press, Albany, 1997.

⁵⁰ Cf. HULL, D., "Are Species Really Individuals?," *Systematic Zoology*, v. 25 (1976), pp. 174-191; HULL, D., "A Matter of Individuality," *Philosophy of Science*, v. 45, (1978), pp. 335-360; and HULL, D., "The Role of Theories in Biological Systematics," *Studies in History and Philosophy of Biological and Biomedical Sciences*, v. 32, (2001), pp. 221-238.

not, are empirical questions. So, for Suppe, the s-a-i thesis is irrelevant in connection to the possibility of establishing laws in the sphere of evolutionary biology.⁵¹

From the taxonomic point of view, the s-a-i thesis complements the classification criteria proposed by the cladistic school of taxonomy, as they allow for the establishing of quite precise division lines between different species. Cladists consider that a species coincides with the group of organisms situated between two speciation events, or between one speciation event and an extinction event, which tends to solve the problem of the delimitation of species as individuals. Mark Ridley goes as far as stating that the correct explanation of why species in the evolutionary theory are individuals and not classes may be found in the cladistic concept of species.⁵²

From the point of view of the s-a-i thesis and also of cladistics, the unit of evolution, that is the species, also becomes the unit of classification. It is not organisms that are classified, but species. Below the species, organisms are individual entities, but lack sufficient continuity to evolve. Above the species, the opposite is true: higher taxa evolve, but not as units. Given that no classification is exempt from theory, it is good that biological classification is adapted to evolutionary theory, that is, that units of evolution are at the same time units of classification.

Even the procedure for naming species seems to acquire sense from the point of view of the s-a-i thesis. The procedure can be seen as an act of baptism consisting in taking a specimen, which need not even be especially typical and giving it a name for the species. The name thus applied to a circumstantially representative part is a proper name without intension.

But, as we had pointed out, the s-a-i thesis is not without problems. The most obvious one is that it is not based on any prior definition of individual. Here, Hull's strategy is clear: he asks us to make do with our prior intuitions as to what an individual is and with the paradigmatic case of organisms. But species, in some aspects, do not seem to fit the characteristics of the case that is put forward as a paradigm. For example, species do not have the same space-time unity and continuity that organisms have. It is true that the genetic flow gives species some continuity, but, as Michael Ruse points out, "it was once thought that gene flow, between populations, was a key factor in keeping the organisms of a species alike. Now, it seems more likely that normalizing selection is the key causal factor."⁵³

If what Ruse says is true, then the s-a-i thesis has a serious problem. There is also a problem concerning twin species, which are reproductively isolated, but hardly differ.⁵⁴ The very decision to see species as individuals would oblige us to consider them different species. The same is true for the possibility of recuperating extinct species by means of genetic engineering. Discontinuity over time would oblige us to say that we did not have the *same* species, even though the "new" one is in every way identical to the extinct one. And the same problem arises from cases of reiterated polyploidism.

⁵¹ Cf. SUPPE, F., *The Semantic Conception of Theories and Scientific Realism*, University of Illinois Press, Chicago, 1989, pp. 223-225.

⁵² Cf. RIDLEY, M., "The Cladistic Solution to the Species Problem," *Biology and Philosophy*, v. 4, (1989), pp. 1-17. For the cladistic concept of species, see also MISHLER, B. and DONOGHUE, M., "Species Concept: a Case for Pluralism," in ERESHEFSKY, M. (ed.), *The Units of Evolution. Essays on the Nature of Species*, pp. 121-138.

⁵³ RUSE, M., *The Darwinian Paradigm*. Routledge, London, 1989, p. 108.

⁵⁴ An example is the case of *Drosophila pseudoobscura* and *Drosophila persimilis*.

Given the state of the debate, we could ask if there is no third way, something to bring together the advantages of the condition of class and the condition of individual, but without the drawbacks they show when we try to think of species. "Individualized classes" and "complex particulars" are the hybrid categories proposed respectively by Van Valen and Suppe.⁵⁵ Philip Kitcher and Bradley Wilson have defended that species are *sets*,⁵⁶ while Mayr says they are *populations*,⁵⁷ Ruse *groups*⁵⁸ and recently Stamos has spoken of them as *relationships*.⁵⁹ Allow me now to briefly examine the advantages and problems of these positions. I shall concentrate on the last four, as the most developed proposals.

Kitcher suggests reading the proposition "species evolve" in terms of sets as "there can be organisms, descendants of a given species, which do not belong to that species, but to a different set." Nevertheless, it must be recognized that the set theory adapts very badly to realities over the course of time. We would have to ask what the elements of a given species-set were, for example those of *Canis lupus*. We could include all the wolves alive today plus all those that have ever existed, which seems quite problematic, but the future would pose an even worse problem. If we have not included future wolves, every time one is born, we shall have a new set, by dint of the axiom of extensionality and, therefore, a new species. On the other hand, to include all future wolves would be very odd, as they have no existence in any reasonable meaning of the word. The species would be made up of a mixture of existing and non-existent entities.

At the end of the day, we have to resort to the conceptualizing of each species not as a set but as a long string of sets, each one of them corresponding to the organisms forming part of a species at a given moment. Let us add to this that if we adopt the biological criterion of species as a criterion of membership, then co-membership to the same set is no longer a transitive relation. I shall explain: although organism A can cross with B, and B with C, this does not guarantee that A can cross with C. Such biological phenomena as clines, for example the clines of the salamanders by the American West Coast, or rings, for example gulls around the North Polar Circle, bear witness to this. Contiguous populations can cross, but the ends of a cline cannot. In the case of the rings, the phenomenon is more striking, as the end populations share territory. Again, we run up against the difficulty of capturing biological phenomena in logical concepts such as the set.

For his part, Mayr sympathizes essentially with the s-a-i thesis, but disagrees on the terminology. To call species "individuals" is to go too far. What is true is that we are dealing, in his view, with concrete entities, not with logical abstractions. But biologists would understand better if we called these entities "populations" or, better still, "biopopulations," to indicate that they are not just any populations, but populations whose members can

⁵⁵ Hybrid concepts of this type, between the logical and the physical, are reminiscent of Plato's Ideas, which are concrete entities at the same time as they function as abstract universal concepts. Hegel also speaks of the *concrete universal* as the dialectic synthesis of the general abstract and the particular.

⁵⁶ Cf. KITCHER, PH., "Species," *Philosophy of Science*, v. 51, (1984), pp. 308-333; and WILSON, B., "Are Species Sets?," *Biology and Philosophy*, v. 6, (1991), pp. 413-432.

⁵⁷ Cf. MAYR, E., "The Ontological Status of Species: Scientific Progress and Philosophical Terminology," *Biology and Philosophy*, v. 2, (1987), pp. 145-166.

⁵⁸ Cf. RUSE, M., *The Darwinian Paradigm*, pp. 108-109.

⁵⁹ Cf. STAMOS, D., *The Species Concept: Biological Species, Ontology, and the Metaphysics of Biology*, passim.

cross. However, the philosopher Mario Bunge rightly points out that if we could equate “biospecies” and “biopopulations,”⁶⁰ then one of the terms would be redundant. But it turns out that we need both for the obvious reason that there are unispecific populations and plurispecific ones.

According to Michael Ruse, species are indeed groups. Groups are seen as more concrete things, more physical than classes. But if we take their consideration as things to extremes, we find that we have emptied them of all formal content, just as Jean Gayon warns in the lines quoted above. By emptying the group of all formal content we are also left with no other criterion of belonging than the reproductive one, but we have seen that this criterion is by no means clear or complete, as Darwin himself knew.

We have Stamos’s proposal left to consider. For him, species must be thought of as relations of similarity. Philosophically he uses Bertrand Russell’s notion of relation and the treatment of the relation of similarity as a real object, which Arda Denkel has recently done.⁶¹ When one considers relations, one also considers the *relata*, that is the poles related, but one sees something else, that is, the relation itself. Each species would then be both a complex of relations of similarity and as the corresponding *relata*, that is, the organisms thus related. One might object that every organism is like any other in some way. Stamos replies that that is indeed so, but nature itself, by means of causal relations, affords guidelines for distinguishing those complexes of relations of similarity that we can call species with a real basis. Causal relations delimiting species are of several types: mainly of inter-fertility, gene transfer, ecological, ontogenetic and social.

Stamos maintains: “Nature itself is partly composed of various causal relations that more or less divide the similarity relations between organisms into species.”⁶² In his opinion, the conception of species as relationships of “biosimilarity” has major advantages. It allows us to reject pure nominalism. In fact, Stamos defends a realist conception of species. He also sees as an advantage the fact that species do not necessarily have to be monophyletic. In this way, we avoid having to classify species of multiple origin into different taxa, as is the case of those originating from reiterated polyploidism or genetic engineering. We also avoid having to consider any extinction as definitive, by definition. Furthermore, it is a sufficiently wide concept to include organisms that do not reproduce sexually. On the other hand, the conception of species as *complexes of relationships of biosimilarity* also has its problems.

On the biological plane, those problems arise especially when we look to the so-called vertical dimension of species, that is, their development over time. Biosimilarity is thought of mainly as a horizontal relationship, one of similarity between organisms related causally. In other words, this way of looking at species would not adapt well to palaeontology and would definitely adapt badly to some of the taxonomical schools, above all with those that lay greater stress on the common and sole origin of taxa. On the philosophical plane, it can pose problems regarding the *physical* reality of relations, particularly those of similarity.⁶³

⁶⁰ Cf. BUNGE, M., “Biopopulations, not Biospecies, are Individuals and Evolve,” *The Behavioural and Brain Sciences*, v. 4, (1981), pp. 284-285.

⁶¹ Cf. DENKEL, A., *Object and Property*, Cambridge University Press, Cambridge, 1996.

⁶² STAMOS, D., *The Species Concept: Biological Species, Ontology, and the Metaphysics of Biology*, p. 297.

⁶³ Cf. GOODMAN, N., “Seven Strictures on Similarity,” in DOUGLAS, M. and HULL, D. (eds.), *How Classification Works*, Edinburgh University Press, Edinburgh, 1992, pp. 13-23.

5. OVERVIEW: THE CONCEPT OF SPECIES IN EVOLUTIONARY BIOLOGY

After the review we have made of the situation, we may say that current biology requires a plural concept of species, for it has to be useful in a number of disciplines, each with its own interests and points of view. The notion of species that may be useful in paleontology is not so applicable in zoology or botany, while these do not have to fit the interests of a biologist dealing with asexual organisms. And each of them will give rise to its own organization of the living world. Something similar may be said for the concept of gene, which does not identify exactly a fragment of DNA, but several possible ones depending on the function we have in mind. That is to say, the gene seen as a unit of mutation, recombination or codification of proteins gives rise to different cut-off points in the DNA sequence. Many different functions are also required of the species. It will be a group of similar organisms that are also inter-fertile, with a common near origin, with their own phylogenetic trajectory and a differentiated ecological niche—it is the unit of evolution and also for some the unit of biodiversity. It is not odd that, depending on which function of the notion of species that we are dealing with, somewhat different cut-off points will appear. And, in any event, the tension between the morphological and genealogical aspects will always be there.

In my opinion, the conceptual difference between species and populations must be maintained for the reasons put forward by Mario Bunge and because a species may be constituted by a number of populations. The idea is for the concept of population to take the burden of the physical aspects, while that of species takes those of logic. A population is always a concrete entity, situated in space-time. We can even argue as to whether it is an individual or not. From my point of view, it is an empirical question and admits degrees. A population can have a greater or lesser degree of individuality. It will be more individual insofar as it displays a greater degree of cohesion or functional integration and insofar as it possesses a greater memory of past interactions. Functional integration allows us to speak of an individual and memory allows us to speak of the *same* individual throughout time. Both memory and functional integration admit gradation.

Species should be considered as classes, perhaps diffuse classes, to which different populations can belong—or, if we like, as classes constructed on the basis of relations of similarity. As classes they retain their intensional or formal component. The expression “species evolve” would now have to be understood as “populations evolve, changing through time from one species to another.” In the same way, we do not say “childhood grows,” but “the child grows and passes from childhood to adolescence.” The diffuse aspect of species may not stem from an epistemic fault on our part, but from reality itself. The best way of understanding species may be based on the structure of the theory of fuzzy sets. In this way, we should avoid the paradox on the intransitivity of the relation of co-membership. On the other hand, this option allows for the existence of generalized laws on the domain of each class. If we accept that their borders are fuzzy, the laws will be formulated in probabilistic terms. Obviously, what I am suggesting here is not just a number of indications that may or may not be of some usefulness for thinking about such an old and complex concept as the species, so laden with changing theoretical connotations and affected by new empirical discoveries.

6. ETHICAL REPERCUSSIONS OF THE QUESTION OF SPECIES

Let us now consider to what extent the concept of species, after the theoretical mutation brought about by evolutionist biology, affects debates of an ethical nature. We shall even have to ask whether the concept still has any usefulness in moral contexts or is just a source of problems and confusion. In the latter case, the question would inevitably arise of possible replacements for the concept of species in arguments of an ethical or political type. I shall concentrate on two questions where I believe that the presence of the notion of species is particularly noticeable and important. Firstly, I shall refer to the debate on the conservation of species, which clearly depends to a great extent on the notion of species itself. Secondly, I shall deal with the so-called anti-speciesist dilemma. It is a moral problem in which we find the notion of species involved in an obvious way.

6.1. *Species and Biodiversity*

The biodiversity debate swings between deep-rooted and shared intuitions, favourable to conservation, and a notable inability to establish with any clarity either the reasons for these intuitions or the very concept of biological diversity. The concept of biodiversity is very general and concerns all levels of life, from the cellular to the ecological and even the scenic. But we are especially interested in the number of species to be found on our planet,⁶⁴ and their internal diversity. According to such authors as Stamos⁶⁵ and Cracraft,⁶⁶ it is precisely the risk of extinction that many species are running that is putting most pressure on the reflection on the very concept of species. Both of them consider that the debate on this concept requires a resolution, and not just for intellectual reasons, but also for practical ones, which have much to do with our supposed responsibility for the extinction of species. They thus point to the need for a *realistic* solution to the debate, for nominalism does not seem to be a good driver of policies for the conservation of species. Even if we think of species as an abstraction, the motivations for conservation seem to be weakened. Let us examine this further.

The arguments for conserving diversity are normally divided between anthropocentric and non-anthropocentric ones. The former propose conserving species for their usefulness to man, while the latter advocate their intrinsic value. But neither concept is at all clear. For example, we sometimes speak of the advisability of conserving a species for the aesthetic or intellectual pleasure afforded by its contemplation, and this is offered as a non-anthropocentric argument. In my opinion, it is just as anthropocentric as the argument proposing conservation to maintain man. It would be necessary to consider widening the anthropocentric arguments to contain those referring to aesthetic, emotional or cognitive values. Thus understood, the anthropocentric justification may be perfectly worthy and legitimate.

On the other hand, as we have seen, the species is an entity whose ontological status is far from being clear in current biology, so the concept of intrinsic value of those species

⁶⁴ Cf. GLEICH, M., MAXEINER, D., MIERSCH, M. and NICOLAY, F. (eds.), *Life Counts. Eine globale Bilanz des Lebens*, Berlin Verlag, Berlin, 2000.

⁶⁵ Cf. STAMOS, D., *The Species Concept: Biological Species, Ontology, and the Metaphysics of Biology*, p. 356.

⁶⁶ Cf. CRACRAFT, J., "Species Concept in Systematics and Conservation Biology. An Ornithological Viewpoint," in CLARIDGE, M. F., DAWAH, H. A. and WILSON, M. R. (eds.), *Species: The Units of Biodiversity*, Chapman and Hall, London, 1997, pp. 325-339.

cannot be clear, either. For example, for a strict nominalist, such intrinsic value cannot be. I am not sure that the conservationist discourse is always accompanied by awareness of the ontological suppositions that it requires.

According to the proposal made in section 5, we should establish a distinction between the reasons for respecting the life of populations and organisms, and the reasons for keeping species. In some cases, the two ends could even conflict. Only reasons for respecting the lives of populations and organisms can be non-anthropocentric. But whenever mention is made of reasons for conserving species, it will have to be admitted that they are of an anthropocentric nature. Species, even if they have an objective basis in the characteristics of organisms, are not concrete *things*.

When one considers the conservation of a species, one does not think of concrete populations and individuals, but of the functions that these execute in an approximately equivalent way —functions of two kinds: on the one hand, ecological and, on the other, cognitive, aesthetic and emotional. Each type of living being has an ecological function contributing to the upkeep of the ecosystem to which it belongs. The idea of maintaining a species for its ecological value transfers to the species the value that we grant to the ecosystem.

Ecosystems have always been in a state of change, where some balances fail and others arise. It is possible to eliminate or harm the life of an organism or population without contributing anything to that of another, but, unless all life is destroyed on our planet, it is not possible to unbalance an ecological situation without creating another. The very identity of ecosystems is difficult to establish. If some appear more valuable than others, it is because they are more useful or beautiful to us, so, the final source of the ecological value of a species is in its relation to man.

Species also have a cognitive role, as objects of knowledge. Knowledge of universals demands different *types* of individuals as their “food.” We cannot eliminate species, that is laminate the wealth of the universe as an object of contemplation without putting at stake our possibilities for happiness. This idea, in one way or another, is frequently expressed in conservationist discourse. Species as such cannot be submitted to rights. It is humans who can recognize each other’s right to ask for protection for their lives or for other life forms or for their own interests in connection with biodiversity.

6.2 The Anti-Speciesist Dilemma

Speciesism would be, according to such authors as Peter Singer, a form of discrimination analogous to racism or sexism, and therefore unfair. The anti-speciesist asks that no living being should be discriminated against because of the species that it belongs to. However, if we abandon the criterion of species, we have to look for another one in order to value beings and adapt our behaviour to their value, for we have, of necessity, to discriminate. Now, that criterion will be fixed by some concrete characteristic of living beings, not in their mere belonging to a species. For example, we can establish the value as a function of the capacities of each being, the capacity to suffer or enjoy, presence of mind, linguistic or social capabilities, autonomy, etc. However, if we act thus, we would be putting at risk the basic equality between human beings as far as their dignity is concerned. That is to say,

the anti-speciesist, who is against any discrimination on the grounds of species, either does not discriminate at all between living beings, which is not a viable course, or puts at risk the equality between humans, which is not to be desired.

If we do not wish to use the species as a criterion of discrimination, we shall need a theory of the value of living beings that fulfilled three desiderata: (i) it should recognize the objective value of living beings, an important point, for if we only recognize their instrumental value and do not discriminate on grounds of species, then it would follow that some human beings would simply be means of serving others; (ii) it should bring in some non-species-based gradation of the value of living beings; and (iii) it should not violate the equal dignity of all human beings.

We must accept that such a theory has yet to appear and presents a challenge for the ethics of our times. Singer's ideas, for example, do not fulfill the third desideratum. According to Singer's ethics, it is in fact the weakest humans that are left unprotected. One can only view with trepidation the fact that the same hand writes in favour of animal liberation and infanticide: "The life of a newborn baby is of less value to it than the life of a pig, a dog or a chimpanzee is to the nonhuman animal."⁶⁷ After this statement, one might expect Singer to undertake a defence of all of them, but what follows is not that, but an attempt to justify infanticide: "I do not regard the conflict between the position I have taken and widely accepted views about the sanctity of infant life as a grounds for abandoning my position. These widely accepted views need to be challenged [...] None of it shows, however, that the killing of an infant is as bad as the killing of an (innocent) adult [...] The grounds for not killing persons do not apply to newborn infants."⁶⁸

This, obviously, violates the minimal equality among human beings. Further anxiety may be caused by Singer's lack of clarity on the age of children who, in his view, do not deserve especial protection. He mentions such ages as "a week," "a month," "two year" and even "three years."⁶⁹ Singer does not suggest leaving children of three unprotected, although he suggests that it would be no catastrophe: "Of course, where rights are at risk, we should err on the side of safety [...] a full legal right to life comes into force not at birth, but only a short time after birth —perhaps a month."⁷⁰ Singer even sets out the circumstances in which "killing an infant" would be acceptable. Obviously, "we should certainly put very strict conditions on permissible infanticide". But, in fact, the only condition that Singer sets for infanticide is that "those closest to the child do not want it to live."⁷¹

The question is whether it is possible to support respect for animals and their correct treatment, avoiding their rough consideration as machines or objects, avoiding the behaviourist stance that denies them a mind or emotions, without leading to the antihumanist consequences of Singer. I believe that it is possible to find a different basis, which does not lead to disregard for the lives of the weakest human beings.

⁶⁷ SINGER, P., *Practical Ethics*, 2nd edition, Cambridge University Press, Cambridge, 1993, p. 169.

⁶⁸ SINGER, P., *Practical Ethics*, 2nd edition, pp. 170-171.

⁶⁹ *Practical Ethics*, 2nd edition, pp. 169-171.

⁷⁰ SINGER, P., *Practical Ethics*, p. 172.

⁷¹ *Practical Ethics*, p. 173.

Perhaps one of the problems of anti-speciesism lies in the fact that the very concept of species is not the most suitable for moral or political contexts. It already has its problems in biological contexts, as we have seen. In ethical contexts, it is mainly individuals and populations that count, as they are concrete entities. When we wish to make reference to humanity as a whole, it is preferable to use an expression with obvious moral connotations and a reference to concrete entities, such as “the human family,” as in the preamble of the *Universal Declaration of Human Rights*.

Cospecificity is not a relationship that necessarily entails emotional, social, affective or moral bonds, while belonging to the same family is. Bonds of this type should be gradually extended to other animals and living beings. For this, obviously, it is necessary for them to be respected within the human family itself. If we manage to recognize signs of familiarity in other humans—in all of them—and if we manage to expand, from the closest to the most distant those bonds of respect and affect that unite us—or should unite us—with our family, and that spring from the most elementary self love, then we shall be ready to go on to a new extension, then we shall be able to have our compassion reach other living beings. It is not therefore a question of abstract reasoning on criteria of discrimination of classes or sets, but to extend the bonds that unite us (or which should) to the other members of our human family.

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III

Evolutionism and Economics

6. Three Evolutionary Ideas in Economics: Population,
Idle Curiosity and Technological Change

7. The Concept of Evolution in Hayek: Institutions, Social Order and Economic Process

THREE EVOLUTIONARY IDEAS IN ECONOMICS: POPULATION, IDLE CURIOSITY AND TECHNOLOGICAL CHANGE

SANTIAGO LOPEZ GARCIA

1. INTRODUCTION

In his works *The Expression of the Emotions in Man and Animals* and *The Descent of Man and Selection in Relation to Sex*, Darwin showed interest in the evolution of human behaviour. According to Darwin, the study of behavior should start from a biological basis.¹ Similar propositions have been made by biologists ever since. One of the greatest advocates in this regard is O. Wilson.² He maintains that economists and social scientists will find in biology the premises they need for their predictive models, just as biology found them in chemistry and physics. However, the majority of economists does not accept this view. But without this change in mentality economics will continue to be what it is now: a social science full of ideological positions, good descriptions of the past, and conjectures relatively well adapted to mathematical formulation. Nonetheless, within economics there are trends that base their principles on evolutionary ideas.

Evolutionary economists have various intellectual origins. Some use the Darwinian concept of a human being and try to realize A. Marshall's *dictum* "the Mecca of the economist lies in economic biology rather than in economic dynamics."³ Others consider themselves as followers of J. A. Schumpeter, who became the creator of evolutionary economics from within economics, without having to resort to Darwinian principles. Some apply Th. Veblen's philosophy, he was first to defend evolutionary economics based on technological, and particularly institutional, change. He considered institutions as well as individuals as units of evolutionary selection.⁴

Without going into G. M. Hodgson's extensive and integrating taxonomy,⁵ there are three viewpoints as to evolutionary economics. a) Neo-Schumpeterians, with G. Dosi, R. R. Nelson and S. G. Winter at the forefront, who are joined by a host of economists studying technological change from an angle introduced by N. Rosenberg and C. Freeman. b) Institutionalists and neo-institutionalists, who can be more or less thought of as the followers of Th. Veblen or of R. Coase. c) Economists who apply game theory in the same manner as evolutionary theoretical biologists, headed by J. Maynard Smith.⁶

¹ Cf. MAYNARD SMITH, J., *Evolution and the Theory of Games*, Cambridge University Press, Cambridge, MA, 1982.

² Cf. WILSON, E. O., *Consilience*, Knopf, New York, 1998.

³ Cf. MARSHALL, A., *Principles of Economics*, Macmillan, London, 1890; 8th edition, Macmillan, London, 1948, p. XIV.

⁴ Cf. VEBLEN, TH., *The Theory of the Leisure Class: An Economic Study of Institutions*, Macmillan, N. York, 1899, p. 188.

⁵ Cf. HODGSON, G. M., *Economics and Evolution. Bringing Life Back into Economics*, Blackwell, Oxford, 1993.

⁶ Cf. TIROLE, J., *The Theory of Industrial Organization*, The MIT Press, Cambridge, MA, 1988, pp. 261 and 311-314.

This grouping is not exhaustively complete. To these three circles of scientists we should add at least a series of authors who, from the study of human behavior have tried to uphold it on its biological basis. Since they are experts closer to biology than to economics, their standpoint is not that of economists; so here we have Maynard Smith himself, H. A. Simon, G. Becker (the most obviously economist), I. Eibl-Eibesfeldt and O. Wilson in socio-biology.⁷ On the other hand, there is the evolutionary literature that views the enterprise as if it were a kind of entity undergoing evolution. In this regard Alchian's paper is still a classic.⁸

With such a broad set of interests and views it is appropriate to split up the analysis of evolutionism in economics. In view of the scarcity of resources and variables with which to investigate the biological basis to economics, I would like to concentrate on three ideas, or debates, that have been pursued by evolutionary authors since the end of eighteenth century to this day.

I will begin with the relationship between Malthus and Darwin and the issue of population, that is the fundamental concept in evolutionary economics, as opposed to the individual which is the prevailing one in the rest of economics. In the second part I address the nature of the innovative individual, basing my case on Veblen's idea of "idle curiosity," as opposed to the optimizing individual, based on Bentham's utilitarian concept of pleasure-maximizing rationality, on which economics is usually based. Finally, I will further explore in depth beyond the concepts of population and the individual, and I delve into about those we could define as the quintessence of mutation in mankind, in human-population cultures. I also cover the concept of the technological paradigm, one of the fundamental bases of the evolutionary economic theory as it was formed during the past thirty years.

Hence, I try to analyze three ideas (population, individual, and technological change) with regard to the polemics, controversies and complementary notions between authors, since the time of Malthus, at the end of the eighteenth century, until the 1980s, when the evolutionary-economics school was established thanks to Dosi, Nelson and Winter.⁹

2. MALTHUS AND THE CONCEPT OF POPULATION IN ECONOMICS

Malthus influenced Darwin—as Darwin pointed out himself—to such an extent that we could consider him as a precursor of evolutionism.¹⁰ It is from Malthus that we can derive three matters concerning the understanding of Darwin's evolutionism:

⁷ Cf. GANDOLFI, A. E., GANDOLFI, A. S. and BARASH, D. P., *Economics as an Evolutionary Science: From Utility to Fitness*, Transaction Publishers, New Brunswick, 2002; SIMON, H. A., *Models of Bounded Rationality*, vols. 1 and 2, The MIT Press, Cambridge, MA, 1982; EIBL-EIBESFELDT, I., *Ethology: The Biology of Behavior*, Holt-Rinehart, N. York, 1975; and ALCOCK, J., *The Triumph of Sociobiology*, Oxford University Press, Oxford, 1999.

⁸ Cf. ALCHIAN, A. A., "Uncertainty, Evolution and Economic Theory," *Journal of Political Economy*, v. 58, (1950), pp. 211-221.

⁹ Cf. DOSI, G., "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy*, v. 11, n. 3, (1982) pp. 147-162; and NELSON, R. R. and WINTER, S. G., *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, MA, 1982.

¹⁰ Cf. YOUNG, R. M., "Malthus and the Evolutionists: The Common Context of Biological and Social Theory," *Past and Present*, v. 43, (1969), pp. 109-145; and HODGSON, G. M., *Economics and Evolution. Bringing Life Back into Economics*, pp. 62-67.

1. Malthus perceived the infinite variety of life in nature and the existence of “apparent blemishes,” both notions that clashed with the idea of nature by the Enlightened. In this way Malthus discovered one of the keys to evolutionary theory: the duet of variety and mutation. It is from this viewpoint that he considered diversity together with its imperfections as crucial to the existence of a population as a whole. He maintained that diversity was the beginning of change and that these changes were renewed in a certain process of selection. Just like Darwin, Malthus understood that variation existed, causing changes, and that the influence on the environment (natural selection) came after that. Darwin shared this Malthusian view.

2. He also asserted that natural development takes place not only from life (survival of the fittest), but also from death (success in reproduction and failure in dying without having reproduced).

3. Another crucial notion in understanding the transcendence of Malthus in evolutionary thinking is that for him there is no teleology, i.e. that there is no going towards an ultimate harmony. As opposed to general notions of equilibrium as in the Scottish school, which considers the world like the Enlightened, Malthus puts forward crisis and situations that end up in catastrophes. We shall see that Veblen shares this important view.

Malthus’ work on human behavior is philosophical in nature; it considers humans as a group, and not as just many individuals. This led him to concentrate his interests on the “behavior” of populations. Hence, when he studied human populations he was able to discern the evolutionary process underlying any kind of population of people. However, he did not formulate an explicit theory of evolution like Darwin, because he only saw the struggle for the limited resources by a growing population, and did not consider the possibility of an increase in resources through innovation that would ensure success in reproduction.

On reading Malthus’ *An Essay on the Principle of Population*¹¹ Darwin recognized that the problem in understanding evolution was to comprehend the evolution of populations over and before that of individuals. We can imagine Darwin wondering, not so much about how individuals evolve, but rather how a determined population evolves until it leads him to the concept of species: the pair formed by mutation and individual and their replication in the population. The mechanism would have to be the same; the whole population would suffer from the same process, in the way that the same law would drive all populations of all species. And according to this law, as deduced from Malthus’ work, evolution had to do with the scarcity of resources at the disposal of populations. But where Darwin saw evolution Malthus saw the end of a population, because populations were without mutations, without innovations, which improved the acquisition of goods.

Darwin maintained that a situation of scarce resources led to a struggle for them between species and within a species. Hence, within population A of a species, an individual obtained more resources because it had developed a mutation, and by reproduction was establishing a new, somewhat different from A, population B (its mutation thus proliferated). The rate at which B reproduced within A+B determined how quickly B was replacing A. Thus, to the mutation-proliferation mechanism success in the struggle for resources and/or achieving a higher rate of reproduction is added.

¹¹ MALTHUS, TH. R., *Essay on the Principle of Population*, 6th edition, 2 vols., John Murray, London, 1826.

From this viewpoint, Malthus' mark in evolutionary biology is fundamental, but in economics he didn't develop an alternative idea to that of market struggle. He didn't overcome Adam Smith's classic view based on specialization of work and the market. For economists the problem was and continued to be the one of distribution of the scarce resources between individuals. Malthus was interested in the day by day of how humans could come to a better distribution of their scarce goods. The old Aristotelian notion of equilibrium invaded everything. The solution was obvious: the market offered to each individual, according to their preferences, the opportunity to pay ("struggle") the amount they were prepared to do so.

For Darwin, this was a problem of secondary importance. When Darwin watched a flamingo and saw its beak so well designed to filter food, he did not just see constant competition between that particular flamingo and its identical neighbor, but between all similar birds in a crammed lake. The latter was what his contemporary economist colleagues were interested in seeing and, at the most, comparing with what was happening to humans when they competed for something they valued. Darwin, on the other hand, wondered which was the flamingo whose beak allowed it to filter more and better nutrients. That flamingo, if it reproduced, would bring about a lineage of flamingos that were better at filtering food and, with time, and with a chain of coincidences, could become a new species.

If instead of flamingos we speak about humans we could ask the following question: which would be the human being whose hand allowed him/her to obtain more and better nutrients? An economist's answer would be: the hand that had more and better capital (a good tool). The hands of an individual who would have in his/her head information as to how the world functions (science) as well as how tools are employed (technology) in order to improve it. Once we have answered this question of primary importance, it makes sense to ask one of secondary importance such as: how are the scarce resources distributed amongst members of the species *homo sapiens*?

The answer is: with the market. We could say that also with violence or affection, but what is the market if not a tool at hand? Consequently, the question of primary importance, referring to the particular case of the market, is who were the humans to whom it occurred to use exchange as a method (as a tool) to obtain more and better nutrients? Obviously, we could generalize this question and arrive at the really relevant one, but of primary importance: since when does humankind have the ability to use tools (including institutions in the sense of tools and within these institutions commercial exchange) in order to obtain more and better nutrients?

If we center explanations in economics on the fact that it is a science studying the way in which scarce resources are distributed between humans, then we deduce that the market is a *deus ex machina* without explaining its reason of being, nor its nature. Our explanation is hindered by the fact that humans build science and technology, and that it is because they build science and technology that they developed and we continue developing market forms. Not understanding that before market operations we have to explain the mechanisms by which the human being builds science and technology, having it as the heart of our discipline, leads economists, time and again, independently of their ideology and school of thought, to wrong predictions.

Jevons predicted the end of the economic system by 1914, because the coal reserves would have disappeared.¹² There have always been economists or other organizations that have forewarned in the same manner. Remember the *Rome Report* and its derivations, or the positions defended by Baran and Sweezy, that predicted catastrophes in the system, not to mention the ultimate crisis of capitalism forecasted by Marxists.¹³ Certainly, there will be ultimate crisis, but forecasts fail time and again. Just like the trite topic of arriving at a stable state with a convergence of all the economies.

To focus the study of economics on the market and its crisis or its stable state is to see only one part of the human condition, the one of “Homo optimizer” (struggle for the scarce goods), and not to see “Homo innovator” (generation of ideas). It was Veblen who appreciated the existence of that man pushed by his *idle curiosity*: “the most substantial achievement of the race —its systematized knowledge and quasi-knowledge of things.”¹⁴

3. VEBLEN AND THE IDLE CURIOSITY

Veblen overcame the deficiencies of social Darwinism and the assumptions of Herbert Spencer. In order to prevent any teleology, he rejected Spencer, but also classical and neo-classical economists. Together with Malthus they are the two economists we could consider fully evolutionary, because they did not accept a state of equilibrium or that of rest; the ultimate consummation.¹⁵

To Veblen’s thinking, people are not instant rational calculators of pleasures and pains, but are curious beings that, together and by their own nature, come up with new ways of doing things.¹⁶ Therefore, there is no natural law that maintains individuals on the path of bringing about greater well being to a greater number of people in the society. This could come about or not. Pareto’s concept of the optimum is only a momentary equilibrium as a result of particular circumstances, because people are complex creatures and, above all, creative, whose behaviour is difficult to understand without resorting to what Veblen himself called instincts and habits, and which today we would call anthropological components or human ethology.

When Veblen made an innovator from the human being, naming him “useless curious,” with a tendency to deliberate action and a creator by nature, all the classical edifice was offended, because he introduced imbalance as the crux of behaviour, and not utility. As

¹² Cf. JEVONS, W. S., *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-Mines*, Macmillan, London, 1866.

¹³ Cf. MEADOWS, D. H., MEADOWS, D. L., RANDERS, J. and BEHRENS III, W. W., *The Limits to Growth: A Report for the Club of Rome’s Project on the Predicament of Mankind*, Universe Books, N. York, 1972; and BARAN, P. A. and SWEETZ, P. M., *Monopoly Capital: An Essay on the American Economic and Social Order*, Monthly Review Press, N. York, 1966.

¹⁴ VEBLEN, TH., *The Instinct of Workmanship and the State of the Industrial Arts*, The MacMillan, N. York, 1914, p. 87.

¹⁵ Cf. HODGSON, G. M., *Economics and Evolution. Bringing Life Back into Economics*, pp. 43-46.

¹⁶ Cf. VEBLEN, TH., “Why is Economics not an Evolutionary Science?,” *The Quarterly Journal of Economics*, v. 12, n. 4, (1898), pp. 373-397; VEBLEN, TH., *The Theory of the Leisure Class: An Economic Study of Institutions*, passim; VEBLEN, TH., *The Place of Science in Modern Civilisation and Other Essays*, Augustus Kelly, N. York, 1919; VEBLEN, TH., *The Engineers and the Price System*, The Viking Press, N. York, 1921; and VEBLEN, TH., *Essays on Our Changing Order*, edited by L. Ardzrooni, The Viking Press, N. York, 1934.

opposed to utilitarianism, Veblen put forward the concept of “useless curiosity” innate to humans — today we know that in general to primates — so as to describe the economic process. Curiosity is causal and needs time — the lapse of time that the human being needs between one innovation and another.¹⁷

To give meaning to his new concept of humans, Veblen turned to the material culture of men, i.e., to their technology. By this, he avoided at the same time any danger of falling into the void of the historicist kind, because his foundations, his view of the world and its societies rested on concrete material circumstances under which humans found themselves. In this way he created an anthropologic vision founded on almost invariable characteristics of the human nature (the need to create and innovate), that act by linking technologies (inventions, innovations and production methods and processes) and institutions (ways of doing things, ways of thinking about things, including philosophy and religion, distribution of rewards for doing things and rules governing possession, management and distribution of things).

For Veblen, economic change was the interaction of technologies and institutions, which were started or activated by different people who were disposed to change either the technological aspects, or the institutional ones, within a population. When technologies and institutions work in unison production and productivity increase.

Veblen anticipated some thought provoking, and for today’s economists basic, ideas. He reflected the problem of his epoch: the separation of property and management, and the unity of property and management facing technologists and explains the technology as “the joint stock of knowledge of the community.”¹⁸ Veblen was the first economist to develop the notion that companies base their decisions on routines that were formed over time. This concept was also developed by H. A. Simon and at present is the main idea in the analysis carried out by Nelson and Winter.

On the other hand, Veblen stressed that recessions in capitalism were rooted in technological displacement caused by new and more efficient innovations, that rendered old industries obsolete, which stopped investment and causing them to disappear altogether with the consequent general feeling of recession. This placed him as a predecessor of Schumpeter himself. Moreover, in his concern for formalizing a theory of the rights of property, he came to identify as “sabotage” by businessmen so as to avoid crisis, the action of “seeking” of the regulatory apparatus of the government to exercise, especially through restrictions to external trade and customs duty, what we would call today the rent-seeking policy.

Although it is true that Veblen announced several ways in which economics should go,¹⁹ the fact is that not even in his own school did he have a lasting following. The now so-called “new institutionalist economics” has discounted Veblen preferring to use R. Coase’s transaction-costs theory as a more consistent starting point.²⁰ The best example, in this

¹⁷ Cf. BERGSON, H., *L'évolution créatrice*, Les Presses universitaires de France, Paris, 1907. English edition: *Creative Evolution*, Dover, N. York, 1998.

¹⁸ VEBLEN, TH., *The Engineers and the Price System*, p. 19.

¹⁹ Cf. VEBLEN, TH., “Why is Economics not an Evolutionary Science?,” pp. 373-397.

²⁰ Cf. COASE, R. H., “The Nature of the Firm,” *Economica*, v. 4, n. 4, (1937) pp. 386-405.

regard, is that of D. North.²¹ This is certain, transaction costs are the material of which institutions are made, but to their lesser or greater presence we have to add the inevitable human will to create new institutions.

Therefore, thanks to Malthus and Veblen, economists have their own evolutionary bases without needing to directly evoke Darwin. However, the analysis of the evolutionary in economics didn't focus on its critical point: technological change.

4. TECHNOLOGICAL CHANGE: WOLF AND SCHUMPETER

Julius Wolf was a German economist at the beginning of the twentieth century whose work is little known and is not up to the importance of that of Schumpeter. However, his contribution to the understanding of how technological change affects economic development is major. Introducing Wolf's ideas means we have to ask the following question: what happens to economic growth based on technological change when we apply the concept of diminishing returns to technology? What allows us to understand the processes of technological dissemination, convergence, and decline?

J. Wolf published his major work *Die Volkswirtschaft der Gegenwart und Zukunft* in 1912.²² It was a collection of lectures devoted to the phenomenon of delay, or postponement, of some economies and industrial sectors within the general economic progress. Wolf defended his "Law of the limits of techno-economic development" or "Law of the obstacles to technological progress"—*das Gesetz der technisch-ökonomischen Entwicklungsgrenze*. This law points out that technological progress in the first phases of development of new industries is more rapid than when these are already mature.

Furthermore, it establishes that these phenomena occur under two conditions: 1) that the knowledge needed for the gradual improvement of a determined technology is limited, and 2) that the cost of the consecutive improvements increases according to technology, as it approaches what would be defined as its long-term level of operation or technological maturity.

Wolf's originality was to use diminishing returns and apply it to technology. He knew that technological progress could increase productivity of resources in a crucial manner, exactly as empirical studies have shown time and again. Productivity obtained from using innovations (from product, from process, and from organization) in some economies and industrial sectors in the course of time could show a decreasing rate. There are many examples in this regard, both in countries and in industrial sectors, and especially in companies. This is the practical verification that corresponds with Wolf's theoretical explanation.

Note that if we take time away from Wolf's Law, then we will finally reach a world in perfect equilibrium; the true stable state caused by technologies without innovation.

²¹ Cf. NORTH, D. C., *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge, 1990; and NORTH, D. C. and WALLIS, J. J., "Integrating Institutional Change and Technical Change in Economic History. A Transaction Cost Approach," *Journal of Institutional and Theoretical Economics*, v. 150, n. 4, (1994), pp. 609-624.

²² WOLF, J., *Die Volkswirtschaft der Gegenwart und Zukunft*, A. Deichertsche Verlagsbuchhandlung, Leipzig, 1912.

But what is of interest in Wolf's Law is time — at least the time it takes for Wolf's Law to invade everything — and how companies, organisms, industries, and economies work during periods of technological progress or stagnation.²³

After Wolf other authors thoroughly studied the relationship between economic growth and technological progress.²⁴ The first and most systematic was Kuznets, who in 1930 returned to the interpretation of economic progress in relation to the technological one, even in the view of Wolf's Law. Kuznets' conclusion was that the study of patents showed that improvement in each of the industrial branches tended in their totality to decrease with time, as the initial invention was nearing its perfection.²⁵

A few years later, in 1939, Schumpeter's theory of innovation emerged and, from that moment on, it would guide investigations on the relationship between technological change and economic growth. This meant a change from views close to Wolf's Law; which was left out of the field of investigation by economists until it was revived by J. S. Metcalfe, C. Freeman, C. Perez, and L. Soete in the 1980s.²⁶ To Schumpeter, Wolf's Law was not important, since radical innovations made the technological diminishing returns notion remain behind.

However, the views of Wolf and Schumpeter, although they seem antagonistic, are really complementary. The first acts in the short term, and explains the life cycles of products and processes, and even of concrete technologies. This is micro evolution that is adaptive, partially reversible, gradual, and relatively ultimate. The second works in the medium and long term, and throws light on how an innovation changes products and processes in a series of technologies and methods qualitatively and in a more radical way. This is macro evolution that is irreversible, random and episodic.²⁷

The understanding of an eclectic view in both theories (those of Wolf and Schumpeter) began at the end of the 1940s with the works of B. S. Keirstead, who came to the conclusion that Schumpeter's "major innovations" weren't the key to growth, but that "widely adaptable innovations" were. With this term Keirstead referred to innovations that caused a flow of minor improvements through many economic activities. In this way, widely adaptable innovations are present in different sectors, connecting improvements that are transferred from one sector to another. To him, the characteristics of usefulness and of serving as a connection between these innovations caused economic growth, thanks to the stimulus they induced in investment and employment and, in the long term, in the

²³ Cf. PACEY, A., *Technology in World Civilization*, Basil Backwell, Oxford, 1990, pp. 94-97, and MOKYR, J., *The Lever of Riches: Technological Creativity and Economic Progress*, Oxford University Press, Oxford, 1990.

²⁴ Cf. USHER, A. P., *A History of Mechanical Inventions*, Harvard University Press, Cambridge, revised edition, 1954 (first edition 1929).

²⁵ Cf. KUZNETS, S. S., *Secular Movements in Production and Prices Their Nature and Their Bearing Upon Cyclical Fluctuations*, Houghton Mifflin-The Riverside Press, Cambridge, 1930, pp. 10-11; and BURNS, A. F., *Production Trends in the United States since 1870*, National Bureau of Economic Research, N. York, 1934, p. 141.

²⁶ Cf. METCALFE, J. S., "Impulse and Diffusion in the Study of Technical Change," *Futures. The Journal of Forecasting and Planning*, v. 13, n. 5, (1981), p. 351; FREEMAN, C., CLARK, J. and SOETE, L., *Unemployment and Technical Innovation: A Study of Long Waves in Economic Development*, Pinter, London, 1982; and PEREZ, C. and SOETE, L., "Catching up in Technology: Entry Barriers and Windows of Opportunity," in DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G. and SOETE, L. (eds.), *Technical Change and Economic Theory*, Printer Publisher, London, 1988, pp. 458-479.

²⁷ Cf. METCALFE, J. S., "Impulse and Diffusion in the Study of Technical Change," pp. 351-354.

increase in general welfare.²⁸ Keirstead's contribution meant the first coupling between the Wolfian and Schumpeterian views, and through his concept of "widely adaptable innovations" he introduced an idea that is very close to that of the technological path that appeared in the 1970s.

In the mid-1970s N. Rosenberg again put forward this micro-macro evolutionary dilemma assuming that although technological change covers a number of forms, all of them are found under the common denominator of certain kinds of knowledge, that makes it possible to obtain, either a bigger total-production volume, or qualitatively-superior total production, starting from a determined quantity of resources.²⁹

In the 1980s a general synthesis of the different views was formed, with the concept of a technological paradigm, that major innovations are not the only factor responsible for economic growth. There are small contributions and learning processes happening during manufacture and use that affect growth, and these contributions can't arise without a previous base of knowledge and experimentation. From this starting point, the challenge was to elucidate how major innovations fitted together with the minor and adaptive ones. Authors such as G. Dosi,³⁰ D. Sahal,³¹ C. Freeman, C. Perez, and L. Soete gave a guideline to follow while exposing their concepts as to technological paradigms.³² They affirmed that agents which effect technology in the economic processes, with the objective of innovation, are subject to what they designate as "paradigms."

A technological paradigm can be defined as a pattern of a solution to particular technoeconomic problems which are hinged on very select principles derived from natural sciences, together with specific rules aimed at the acquisition of new knowledge and safeguarding it, if possible, from quickly spreading among the competition.³³ A paradigm provides insights into problem solutions, and allows vistas into previous achievements (products and processes); it also sets up theoretical (scientific principles and laws), political

²⁸ Cf. KEIRSTEAD, B. S., *The Theory of Economic Change*, Macmillan, Toronto, 1984, pp. 135-136.

²⁹ Cf. ROSENBERG, N., *Inside the Black Box: Technology and Economics*, Cambridge University Press, Cambridge, 1990; SCHUMPETER, J. A., *The Theory of Economic Development*, Harvard University Press, Cambridge, MA, 1934; SCHUMPETER, J. A., *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, McGraw-Hill, N. York, 1939; SCHUMPETER, J. A., *Capitalism, Socialism, and Democracy*, Harper, N. York, 1942; and SCHUMPETER, J. A., "The Creative Response in Economic History," *Journal of Economic History*, v. 7, (1947), pp. 149-159.

³⁰ Cf. DOSI, G., "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," pp. 147-162; DOSI, G., *Technical Change and Industrial Transformation the Theory and an Application to the Semiconductor Industry*, Macmillan, London, 1984; DOSI, G., "Sources, Procedures, and Microeconomic Effects of Innovation," *Journal of Economic Literature*, v. 26, (1988), pp. 1120-1171; DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G. and SOETE, L. (eds.), *Technical Change and Economic Theory*, Printer Publisher, London, 1988; DOSI, G., PAVITT, K. and SOETE, L., *The Economics of Technical Change and International Trade*, Harvester Wheatsheaf, London, 1990; and DOSI, G., GIANNETTI, J. and TONINELLI, P. A. (eds.), *Technology and Enterprise in a Historical Perspective*, Oxford University Press, Oxford, 1992.

³¹ Cf. SAHAL, D., "Technology Guide-Post and Innovation Avenues," *Research Policy*, v. 14, n. 2, (1985), pp. 61-82.

³² Cf. FREEMAN, C. and PEREZ, C., "Structural Crises of Adjustment, Business Cycles and Investment Behaviour," in DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G. and SOETE, L. (eds.), *Technical Change and Economic Theory*, pp. 38-66.

³³ Cf. DOSI, G., *Technical Change and Industrial Transformation the Theory and an Application to the Semiconductor Industry*, ch. 2.

(patents and contracts of technological transfer), and economic (obtaining economies of scope and scale) principal bases on which any subsequent model would be based. In short, a paradigm is the radical material innovation and reference (conceptual) model for future projects and innovations.³⁴

Introducing the paradigm concept implies converting radical innovation, in Schumpeterian analysis, into a much wider concept which better fulfils the necessary requirements of the Schumpeterian model itself —here we find the key interpretative suggestion by Dosi. In this view, in which radical or greater innovation is replaced by a technological paradigm, innovation of Schumpeterian characteristics is more of a conceptual (symbolic) than material fact. So, for instance, a Schumpeterian notion would propose that the existence of the internal-combustion engine was a radical innovation at a given moment, as a unique object, unbeatable and constantly reproduced.

However, all internal-combustion engine presents a notion of *paradigm*. The paradigm of the engine consists of some basic principles of physics, chemistry and engineering represented by a host of experiences. The paradigm of “internal-combustion engine” exists and is displayed in the original patent and the enormous variety of artifacts that keep discarding improvements that became antiquated, and incorporating new ones. Yet, the basic design will be the same while it continues to run according to the same theoretical principles of physics, chemistry and engineering (existing in complementary patents and connected to the original one of the internal-combustion engine).

A “paradigm,” in a broad sense, consists of several radical innovations (mutations) and of clusters of minor innovations constituting generations of knowledge, which give the characteristics of continuity to technological change. These minor innovations have been the fruit of the exploration of variations following avenues that passed tests of their utility and functioning before.³⁵ Bearing this in mind is essential, since this is how the mechanism of selection in the evolution of technology works. The said mechanism of selection concedes, both to the innovator and the imitator, that all possible variations of an innovation are not examined (which would lead to a continued and gradual evolution governed by Wolf’s Law). In other words, the apprentice chooses the useful knowledge according to its closeness of the paradigm he/she pursues, excludes the obsolete knowledge of this paradigm, and saves, if it is possible, the obsolete-advanced notions until they might become useful in the future.

5. CONCLUSION

In 1995 R. R. Nelson wondered which were the characteristics of evolutionary theory relating to economics, and showed that if the term evolutionary was to be applied to an economic theory, argument or model then the following criteria should apply:³⁶

1. Their aim has to account for the movement of something in time, or explain why something is what it is at a given moment in relation to how it came to be what it is. The

³⁴ Cf. DOSI, G., “Sources, Procedures, and Microeconomic Effects of Innovation,” p. 1127.

³⁵ Cf. DURAND, T., “Dual Technological Trees: Assessing the Intensity and Strategic Significance of Technological Change,” *Research Policy*, v. 21, (1992), p. 361.

³⁶ Cf. NELSON, R. R., “Recent Evolutionary Theorizing About Economic Change,” *Journal of Economic Literature*, v. 33, (1995), pp. 48-90.

analysis should be expressly dynamic. Attention should be focused on the change of one variable or systems of variables studied and, in the theoretical part, on the reason for this change.

2. Presentation should deal both with random variables, which are modified through variations into new variables, as well as with mechanisms which systematically try to keep a variable stable, i.e. mechanisms which select variations that affect a variable less so as to fix it in a particular specialization.

3. Analyzed processes allows putting forward the premise that inertia exists and this reinforces the continuity of those that have survived in the process of selection. These processes can be studied as if followed guidelines and as if learned from their own experience, but at the same time depend on random selection.

Under this umbrella of general ideas, which explain both variations and guidelines with time, learning processes should be studied as well, both those of adaptation and those of selection.

To a certain degree, what I have done is to present a “prehistory” of evolutionary economics. At present there are two disciplines, relatively unconsolidated, through which the biological reason for the phenomena of adaptation, selection, and learning in a culture and/or the activity of economic agents is sought. These two disciplines are neuroeconomics and memetics.³⁷ Both point out the same problem: where does human decision making reside? Everything points at the brain, at the neurons, at active mental states. And that question entails other issues of an evolutionary nature, since the locus of decision making will also be the locus of all the decisions (instructions) on which behavior is founded. Can instructions and behavior be maintained, replicated, and/or modified? Can they evolve? Can they infect other brains or reproduce in other brains?

In my opinion, in order to make the most of these disciplines it is advisable to have a certain formalizing criterion and apparatus. Evolutionary game theory and formalization of human conduct developed by classic micro economics around the concept of utility are those that give better possibilities.³⁸ From a different point of view, we may also consider the sciences related to behavior (human ethology, psychology, artificial intelligence, and socio-biology). From among these disciplines I would like to emphasize the evolutionary game theory, since it allows us to carry out a systematic and combined examination of the “ingredients” of evolutionary processes (selection, adaptation, and learning), without destroying the concept of utility so cherished in economics.

The “ingredients” of evolutionary games are: the agents (players, companies, and organizations created by humans), the actions (behaviors available to, imitable by, and invented by each agent in the process), the payments (rewards for actions taken, minus the

³⁷ Cf. GLIMCHER, P. W. and RUSTICHINI, A., “Neuroeconomics: the Consilience of Brain and Decision,” *Science*, v. 306, (2004), pp. 447-452; and AUNGER, R., *The Electric Meme*, The Free Press, N. York, 2002.

³⁸ Cf. MAYNARD SMITH, J., *Evolution and the Theory of Games*, passim; FUNDENBERG, D. and TIROLE, J., *Game Theory*, The MIT Press, Cambridge, MA, 1991; VEGA REDONDO, F., “Technological Change and Institutional Inertia: A Game-theoretic Approach,” *Journal of Evolutionary Economics*, n. 3, (1993), pp. 199-224; VEGA REDONDO, F., “Evolución y estrategia: Teoría de Juegos con agentes limitados y un contexto cambiante,” *Hacienda Pública Española*, v. 125, n. 2, (1993), pp. 127-142; VEGA REDONDO, F., *Evolution, Games, and Economic Behavior*, Oxford University Press, Oxford, 1996; and VEGA REDONDO, F., *Economics and the Theory of Games*, Cambridge University Press, Cambridge, 2003.

costs incurred in entering the game or in being active or not in a game) birth and death (in the sense that players die, and their exit is a result of their incapacity to obtain certain minimum payments for their actions) and the gaps between pieces of information (between action and action there is time for transmission and of assimilation).

This first formalization allows us to go very far and detect apparent paradoxes in the expected utilitarian behavior. This is when the crucial question arises: why do individuals make apparently wrong decisions or decisions that are counter to their best interest. The fact is that we are not short of answers. We have the ideas of utility viewed as a vital cycle, typical of Becker's analysis and of the notions of altruism understood as egoism in the very long term. But these answers are intuitions about intuitions. We know by intuition that we are utilitarian, but we know that we are not always utilitarian.

The solutions to these situations from an economics viewpoint are varied. One option is to isolate the case and wait for major advancements in the formalisation of economic models. The other alternative is to directly reject the problem: classify it as "irrational" from utilitarian economics and discard it as irrelevant behavior. Finally, there are those looking towards biology, psychology, and other sciences whose objectives are to understand the brain. In this regard neuroeconomics and memetics are points of contact. Let us see how they operate.

When we formalize a human behavior, by means of game theory, and we arrive at a contradiction it is normal that, using the rudiments of evolutionary game theory, we can explain non-utilitarian behavior thanks to grasping the evolutionary processes. Now then, having arrived at this point, we can only argue that this paradox arises because evolutionists consider that all human action is controlled, both by the struggle for space (to get hold of food for oneself) that could resemble utilitarianism, and by the struggle to reproduce, which has no parallel in non-evolutionary economics. Therefore, if the two sides are not considered, then paradoxes are envisaged where they don't exist.

However, if we replace one decision basis (utilitarianism) with two (adaptation and reproduction) what happens? The key question that arises while trying to fathom neuroeconomics is whether these two behaviors actually exist in the brain. The answer, though weak, is yes, because when necessary experiments that design dilemmas and decision making are posed, neuroeconomists (using scanners) can detect the brain's electric response and locate activated brain areas, even the neuronal circuits that activate these mental states of mind.

Today we can see that, depending of the circumstances, the neuronc circuits related to utility operating in the brain, at the same time as, according to circumstances, others areas warning of risk can be activated or not. Normally these areas are associated with assuring survival as a species, which block or control the former ones (utility areas). Evidently, if there are reaction chains in the brain that identify mental states of mind activated by these dilemmas, then evolutionary questions, such as the following, could be posed: do these mental states reproduce, modify, or evolve? Are these mental states transmitted through cultural activity? In the history of evolution, when were neuronal tissues that maintain these mental states developed? Are these mental states "memes"?

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THE CONCEPT OF EVOLUTION IN HAYEK: INSTITUTIONS, SOCIAL ORDER AND ECONOMIC PROCESS

JOSE LUIS RAMOS GOROSTIZA

1. INTRODUCTION

Since the 1980s, evolutionary economics has become a well established trend in economic thought through international associations, specialized journals and international meetings. However, the use of the evolutionary analogy in economics was scant until its recent application to the theory of the firm by Nelson and Winter.¹ That is to say, the idea of evolution has achieved no relevance in the history of economic thought. Furthermore, when it has occasionally been mentioned, it has been used mainly in the broad sense, with reference to the notion of change, or as a mere declaration of intent, as in the case of Alfred Marshall.

Evolutionism has only been meaningful in the work of those economists with a wider conception of the economic process, who have been particularly interested in the dynamics and institutional aspects. Among these economists—often critics of mainstream economics—are, for example, those quoted by Geoffrey Hodgson in his book *Economics and Evolution*:² Marx, Menger, Veblen, Schumpeter or Hayek, together with others such as Boulding or Hirschleifer. All of them withdraw—to some extent—from the economic approach which has been dominant since the end of the nineteenth century.

This view was based on comparative static analysis and equilibrium, focused on the short term, and increasingly formalized in mathematical terms with no attention paid to institutional factors. To some extent, these economists attempted to go beyond the mechanical analogy which has led economic research since the marginal revolution, when physics was considered the model for the new microeconomic theory.

Among the economists previously cited, Hayek is perhaps the one who has developed the idea of evolution in a more explicit and coherent way, in connection with the study of human institutions. His work is an uncommon example of wide interests, including Political Science, Economics, Law and even Theoretical Psychology. In fact, he was awarded the Nobel Prize in 1974 for his original analysis of the market process integrating social, economic and institutional aspects. Following Menger's intellectual legacy and the Austrian tradition, he tried to go beyond the narrow frontiers of standard economics reflected in handbooks.

Hayek is a central figure in twentieth-century economics and foremost representative of the Austrian tradition. The major Hayekian insights—such as the idea of the price system as a communication network—have been incorporated into the mainstream economics

¹ Cf. NELSON, R. R. and WINTER, S. G., *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, MA, 1982.

² HODGSON, G., *Economics and Evolution*, Polity Press, Cambridge, 1993.

literature. Nowadays, as Peter Boettke has pointed out,³ Hayek's influence can be seen in cognitive direction of research that has been taken by Timur Kuran and Douglass North.⁴ It can also be seen, for example, in the work of Mancur Olson and Andrew Shleifer on institutional quality and the politics of predation,⁵ or in the works on the relevance of institutional environment, encouraging cooperation and minimizing conflict.⁶ Finally, there is a research line on the importance of entrepreneurship to understanding economic growth and the competitive market process.⁷ But Hayek's influence has gone far beyond economics, because of his contributions to the disciplines of philosophy and politics, touching also on the fields of psychology and jurisprudence.

Hayek considered that institutions, with a spontaneous origin and an evolutionary nature, performed an essential role in the social order and in the market process. This article, in particular, will focus on discussing Hayek's evolutionism, which is linked to the idea of institutional change (section 4). Previously, it will briefly review the importance of the concept of evolution in economics, in order to underline the singularity of Hayek's evolutionism in the history of economic thought (section 2). Next, an analysis will be made of Hayek's viewpoint on the contribution of some social scientists—such as Mandeville, Hume or Smith—to the development of an idea of cultural evolution, which could have some influence on Darwin (section 3). Finally, the paper will end with a section on conclusions (section 5).

2. EVOLUTIONISM IN THE HISTORY OF ECONOMIC THOUGHT: HAYEK'S SINGULARITY

In social sciences, the use of the term “evolution” meaning a progressive change—the opposite to a fast and deep transformation associated with the idea of “revolution”—was common during the two centuries previous to the publication of *The Origin of Species* (1859).⁸ But after Darwin's book the characterization of the socio-cultural development as a cumulative process of small continuous changes, instead of drastic and unconnected breaks, was decidedly emphasized by social scientists, such as the economist Walter Bagehot.⁹

³ Cf. BOETTKE, P., “Hayek and Market Socialism: Science, Ideology and Public Policy,” *London School of Economics*, Public Lecture, October 19, 2004, pp. 10–11.

⁴ Cf. KURAN, T., *Private Truths, Public Lies*, Harvard University Press, Cambridge, MA, 1995; and NORTH, D. C., *Understanding the Process of Economic Change*, Princeton University Press, Princeton, 2004.

⁵ Cf. OLSON, M., *Power and Prosperity*, Basic Books, New York, 2000; and SHLEIFER, A. ET AL., “The New Comparative Economics,” *Policy Research Working Paper Series 3054*, The World Bank, New York, 2003.

⁶ See, for example, OSTROM, E. GIBSON, C., SHIVAKUMAR, S. and ANDERSSON, K., *Aid, Incentives and Sustainability*, Swedish International Development Cooperation Agency (SIDA), Stockholm, 2002.

⁷ See, for example, BAUMOL, W., *The Free-Market Innovation Machine*, Princeton University Press, Princeton, 2002.

⁸ Cf. GORDON, S., *The History and Philosophy of Social Science*, Routledge, London, 1991, p. 538.

⁹ Generally, historians have tended to focus their studies on political history, paying special attention to great events (such as wars, dynastic changes and so on) which often involve revolutionary transformations. Walter Bagehot, however, underlined the idea of gradual changes in his work *Physics and Politics: or Thoughts on the Application of the Principles of “Natural Selection” and “Inheritance” to Political Society* (1872).

But Bagehot did not refer to notions such as competition, heredity or survival of the fittest. In fact, his use of the term evolutionism was very poor, and it was limited to the mere idea of gradualism. In other works, such as *English Constitution* (1867) or *Lombard Street* (1873), he also pointed out that the formation of the political and financial institutions of Great Britain had been the result of an evolutionary process, through the accumulation of small changes.

However, apart from this simple idea of gradual change referred to social phenomena in general, the concept of evolution did not have any influence on mainstream economics. It is true that Alfred Marshall, the founder of the neoclassical school and perhaps the most celebrated economist of the period, profoundly admired Spencer's work, but this did not lead him to develop a new economic approach. The sociologist Herbert Spencer was always very interested in biology. Before the publication of Darwin's book, he was already a Lamarckian evolutionist.¹⁰ In fact, he tried to describe the cultural evolution of the social organism as an adaptive process, in which certain social characteristics arising in a specific period can be transferred between generations, becoming an established part of the social structure.¹¹ Moreover, Spencer affirmed that the evolutionary process tended to generate an increasing heterogeneity, which would entail an increasing differentiation of institutions and individuals.

Marshall was very interested in biology, as his *Principles of Economics* shows.¹² For him, "the Mecca of the economist lies in economic biology rather than in economic dynamics."¹³ Nevertheless, this was only a mere declaration of intent thinking about the future, when Economics becomes a more developed science. In practice, in order to create his own economic theory, Marshall opted for the mechanical analogy: "Biological conceptions are more complex than those of mechanics; a volume of Foundations must therefore give a relatively large place to mechanical analogies; and frequent use is made of the term 'equilibrium', which suggests something of static analogy."¹⁴ In this way, Marshall decided to follow the same direction which had already been taken by other authors of the Marginal Revolution at the beginning of the 1870s, such as Jevons or Walras. Later, this would also become the direction followed by mainstream economics.

The purpose of the economists of the Marginal Revolution was to analyze the allocation of resources, so the dynamic perspective disappeared from the economic research agenda. The aim was no longer to "inquire into the nature and causes of the wealth of nations" in the long term, but to get the best possible use of given means with alternative ends. As a consequence, the previous concern for the institutional framework, the demographic increase or the role of natural resources in economic growth became less important.

¹⁰ According to the idea of Lamarckian evolution, it is possible to pass characteristics acquired by adaptation to the environment on to the progeny. However, according to the Darwinian idea of evolution the progeny is not identical: in spite of a common origin, the heredity traits of the different individuals differ; as a result of the demographic pressure, the individuals who survive are those with genetic variations which allow a better adaptation to the environment. In conclusion, Darwin underlined the continuous accumulation of small mutations throughout time in a process of selection which affects the species as a whole, whereas Lamarck defended heredity between discontinuous generations of organisms.

¹¹ Spencer went even further, affirming that evolution was a universal and inevitable phenomenon, which derived from the metaphysical nature of the cosmos. On the other hand, he linked the theory of evolution and the idea of progress, connecting science and ethics. In the field of social policy, Spencer was considered to be an advocate of "social Darwinism": competition in a *laissez faire* framework would act as an instrument of selection for the survival of the fittest.

¹² Cf. MARSHALL, A., *Principles of Economics*, Macmillan, London, 1890, 8th edition, 1920 (reprinted in 1994), chapter 8, book IV.

¹³ MARSHALL, A., *Principles of Economics*, 8th edition, p. xii.

¹⁴ *Principles of Economics*, 8th edition, p. xii.

The abandonment of the dynamic perspective also implied that the idea of evolution could not become a relevant one in economic theory, and economists looked for inspiration in classical physics in order to do research into the allocation problem.¹⁵ So long as the mechanical analogy triumphed in mainstream economics at the end of the nineteenth century, the possibility of using biological analogies or developing an evolutionary approach were limited to critics such as Marx or Veblen, or to ambitious theoretical positions beyond the model of competitive equilibrium, such as those represented by Menger or Schumpeter.

Marx and Darwin were contemporaries. The German philosopher knew Darwin's work and admired it.¹⁶ In fact, he praised Darwinian evolutionism as "a natural-scientific basis for the class struggle in history."¹⁷ However, although Marx and Engels quoted Darwin in different contexts, the Marxian conception of socioeconomic change is not evolutionary at all in a Darwinian sense, but revolutionary, and is marked by discontinuity and suddenness. Moreover, both rejected the natural selection mechanism because it was based on the Malthusian notion of "the struggle for existence."¹⁸

Veblen, the founder of American institutionalism, rejected the mechanical analogy, on which neoclassical economics was based, and sought inspiration in biology. In an article published in 1898 he asked: "Why is Economics Not an Evolutionary Science?"¹⁹ A year later, in his main work, *The Theory of the Leisure Class*,²⁰ there appeared thought-provoking evolutionary analogies. For Veblen, institutions were "settled habits of thought common to the generality of men," which supplied social stability and guaranteed a principle of continuity and heredity throughout time. They were subject to mutation and selection processes in such a way that the best adapted institutions multiplied and were imitated, whereas the badly adapted died out.²¹ In addition, he considered that technical change, which was the engine of economic progress, should be also studied from an evolutionary perspective. However, the imprecision in the terms in which Veblen's evolutionary ideas were expressed, together with the limited development of evolutionary theory in biology at his time, became an impediment to a detailed and coherent theoretical approach in economic terms.

¹⁵ "Any system that involves a conservation principle (given means) and a maximization rule (optimal satisfaction) is a mechanical analogue," GEORGESCU-ROEGEN, N., *The Entropy Law and the Economic Process*, Harvard University Press, Cambridge, MA, 1971, reprinted in 1976, pp. 318-319.

On the one hand, the allocation problems are easily dealt with in mathematical terms, as they are characterized by the ideas of optimization and marginal substitution. On the other hand, the concept of equilibrium of physical forces appears to be a good model to imitate. Therefore, economists such as Jevons, Walras, Edgeworth, Pareto and Fisher explicitly recognized that their main objective was to create "the mechanics of utility and self-interest," JEVONS, W. S., *The Theory of Political Economy*, Macmillan, London, 1871; reprinted by Reprints of Economic Classics, Augustus Kelley, New York, 1965, pp. xvii-xviii.

¹⁶ Cf. UREÑA, E. M., "Marx and Darwin," *History of Political Economy*, v. 9, n. 4, (1977), pp. 548-559.

¹⁷ Quoted by HODGSON, G., *Economics and Evolution*, p. 73.

¹⁸ Engels, who was careful as regards scientific matters, discussed the Darwinian Theory at length in his *Dialectics of Nature*. Cf. ENGELS, F., *The Dialectics of Nature* [written in 1873-1866, published in 1925], Progress Publishers, Moscow, 1954. He accepted Darwin's idea of evolution, but rejected the notion of "the struggle for life," which he associated with Malthus. For Engels, "the struggle for existence" was a weak ideological buttress for capitalist competition.

¹⁹ Cf. SOWELL, T., "The Evolutionary Economics of Thorstein Veblen," *Oxford Economic Papers*, v. 19, n. 2, (1967), pp. 177-198.

²⁰ VEBLEN, TH., *The Theory of the Leisure Class: An Economic Study of Institutions*, Macmillan, N. York, 1899; reprinted by George Allen and Unwin, London, 1949.

²¹ The principle of "idle curiosity" was for Veblen the ongoing source of variety or mutation in the evolutionary process.

J. A. Schumpeter is considered today as the main reference in evolutionary economics owing to his theory of innovation, entrepreneurial function and endogenous economic change. In addition to this theory, included in his *Theory of Economic Development*,²² there is also a clear analogy between his idea of “creative destruction” associated with capitalism and the biological idea of “natural selection.” Nevertheless, the starting point of Schumpeterian dynamics is the Walrasian model of general equilibrium.

Faced with great difficulties, Schumpeter tried to harmonize it with his own theory of economic development, and he never considered biology as a source of theoretical inspiration. On the other hand, his understanding of capitalism as a system subject to constant disturbing innovations is nearer to the notion of “revolutionary” economic transformations than to the idea of “evolutionary” cumulative changes. Therefore, as Hodgson has pointed out, although “Schumpeter remains a worthy inspiration for theorists of dynamics economics systems,” he “provides neither a systematic theory nor an ideal epitome for a new evolutionary economics.”²³

C. Menger fathered the Austrian School of Economics. He tried to apply the evolutionary metaphor to the analysis of the emergence of social institutions. As Menger’s work influenced markedly on Hayek, his contribution will be examined in section 4. Here, by way of example now, suffice it to say that he was able to develop a subjective theory of value and thus is considered one of the pioneers of the Marginal Revolution together with Jevons and Walras. However, his approach to economic problems is very different, because it is not based on static equilibrium and maximizing behavior by perfectly rational agents (see section 4).

After reviewing the idea of evolution in the history of economic thought, it can be concluded that the majority of economists have not taken this into consideration. Evolutionism has only aroused interest among those authors with a wider conception of the economic process, who have moved away to some extent from the economic approach which has been dominant in mainstream economics, focused on comparative static analysis, equilibrium and the short term. Given this state of affairs, Hayek’s work turns out to be particularly important, because he probably has been the economist who has developed a more explicit, comprehensive and coherent evolutionary approach.

Finally, it must be pointed out that evolutionary economics has become an important trend in recent economic thought since the 1980s. Before this decade, in the 1970s, Kenneth Boulding was the main advocate of a close association of economics and biology, especially in his books dedicated to environmental matters. Other economists, such as J. Hirshleifer, also tried to establish interesting parallelisms between the economic system and the biological world in some specific works.²⁴

²² SCHUMPETER, J., *Theory of Economic Development*, Harvard University Press, Cambridge, 1911, 2nd edition 1926, translated from German into English in 1934 (reprinted in 1961).

²³ HODGSON, G., *Economics and Evolution*, p. 151.

²⁴ For example, BOULDING, K., *A Primer on Social Dynamics: History as Dialectics and Development*, The Free Press, New York, 1970; BOULDING, K., *Ecodynamics: A New Theory of Societal Evolution*, Sage, Beverly Hills, 1978; BOULDING, K., *Evolutionary Economics*, Sage, Beverly Hills, 1981; HIRSHLEIFER, J., “Economics from a Biological Viewpoint,” *Journal of Law and Economics*, v. 20, n. 1, (1977), pp. 1-52; HIRSHLEIFER, J., “Competition, Cooperation and Conflict in Economics and Biology,” *American Economic Review*, v. 68, n. 2, (1978), pp. 238-243; and HIRSHLEIFER, J., “Natural Economy versus Political Economy,” *Journal of Social and Biological Structures*, v. 1, (1978), pp. 319-337.

But the real change arrived when Nelson and Winter developed an evolutionary theory of the firm which was highly convincing:²⁵ organizational routines were equivalent to genes and certain acquired characteristics by adaptation to the environment were considered transferable as heredity, in the Lamarckian way. Moreover, for Nelson and Winter competitive market forces acted as a selective mechanism and the analogy of mutation could be applied to economic systems.²⁶ Since then, evolutionary economics has developed in different fields, although perhaps the theory of the firm is still the main one.²⁷

3. THE SOCIOECONOMIC CONCEPTIONS AND THE EMERGENCE OF THE DARWINIAN IDEA OF EVOLUTION: HAYEK'S VIEWPOINT

In order to understand Hayek's interest in evolutionary analogies, it is important to take into account his criticism of social engineering and the "slavish imitation of the method and language of science." In fact, Hayek used the term "scientism" with reference to the improper application of the method of natural sciences to the field of social science, because it is not possible to make controlled experiments, there is no systematic registers of exact data, and there are no quantitative constants or functional relations that allow the utilization of mathematical language.²⁸

As has been stated above, the triumph of the mechanical analogy in mainstream economics is associated with the Marginal Revolution and the subsequent imitation of the method and language of physics. In fact, the chronology and content of the economic works of the Marginal Revolution can be explained by parallel developments in physics around the middle of the nineteenth century. As Mirowski has stated,²⁹ classical physics

²⁵ NELSON, R. R. and WINTER, S. G., *An Evolutionary Theory of Economic Change*, Cambridge, Mass., Harvard University Press, 1982.

²⁶ Before Nelson and Winter there had already been interesting evolutionary approaches in relation to the firm, but there was no sufficiently developed theory. See, for example, PENROSE, E. T., "Biological Analogies in the Theory of the Firm," *American Economic Review*, v. 42, n. 5, (1952), pp. 804-819.

²⁷ For example, see ALDRICH, H., *Organizations Evolving*, Sage, London, 1999; LANGLOIS, R. N. and ROBERTSON, P. L., *Firms, Markets and Economic Change: A Dynamic Theory of Business Institutions*, Routledge, London, 1995; or SUTTON, J., *Technology and Market Structure: Theory and History*, The MIT Press, Cambridge, MA, 1998.

There are also evolutionary approaches in microeconomics and game theory (for example, BOWLES, S., *Microeconomics: Behaviour, Institutions and Evolution*, Princeton University Press, Princeton, NJ, 2003; GINTIS, H., *Game Theory Evolving: A Problem-Centered Introduction to Modeling Strategic Interaction*, Princeton University Press, Princeton, 2000; or SAMUELSON, L., *Evolutionary Games and Equilibrium Selection*, The MIT Press, Cambridge, MA, 1997), and in international economics as well (DE LA MOTHE, J. and PAQUET, G. (eds.), *Evolutionary Economics and the New International Political Economy*, Pinter, London, 1996).

In the field of institutional analysis there are works such as that of YOUNG, H. P., *Individual Strategy and Social Structure: An Evolutionary Theory of Institutions*, Princeton University Press, Princeton, NJ, 1998; or VROMEN, J. J., *Economic Evolution: An Inquiry into the Foundations of the New Institutional Economics*, Routledge, London, 1995. For a global review of the evolutionary economic literature see NELSON, R. R., "Recent Evolutionary Theorizing About Economic Change," *Journal of Economic Literature*, v. 33, (1995), pp. 48-90; and VALDALISO, J. M. and LOPEZ, S., "Economía y evolución. Un enfoque multidisciplinar," *Revista Anthropos*, n. 182, (1999), pp. 21-26.

On the evolutionary paradigm in general, see, for example, HANAPPI, H., *Evolutionary Economics: The Evolutionary Revolution in the Social Sciences*, Avebury Publishers, Aldershot, 1994; or ANDERSEN, E. S., *Evolutionary Economics: Post-Schumpeterian Contributions*, Pinter, London, 1996.

²⁸ Cf. HAYEK, F. A., *The Counter-Revolution of Science: Studies on the Abuse of Reason*, Collier-Macmillan, London, 1964.

²⁹ Cf. MIROWSKI, PH., *Against Mechanism: Protecting Economics from Science*, Rowman and Littlefield, Lanham, MD, 1988, pp. 13 and 17.

was fundamental for the birth of neoclassical theory because it provided unity to the new economic science: an important metaphor (the conservation principle), some mathematical techniques as a means of expression, and new attitudes toward theoretical research. In some cases, the formulation of problems even reached a complete mimicry, substituting the term energy for the term utility in the same equations³⁰. In reality, with the exception of Marshall, the economists of this period did not use the mechanical analogy properly and did not understand the restrictions that it implied for the development of economic theory.

F. A. Hayek was certainly aware that the use and misuse of the mechanical analogy in economics had entailed clear limitations. Probably for this reason, he decided to explore the possibilities that the idea of evolution could offer. Following Menger and assuming the Austrian dynamic conception of the economic process, Hayek not only tried to apply the idea of evolution to explain socioeconomic change, but also studied the influence of the economic ideas of the eighteenth century on the emergence of the Darwinian idea of biological evolution.

Hayek considered Darwin's work as the culmination of a long development which had begun with Mandeville and the Scottish Enlightenment (Hume, Ferguson, Smith and so on)³¹. That is, the idea of evolution, in the broad sense, was older in social sciences than in natural ones, and it was related to the emergence of law, ethics, money, markets and language. In the following paragraph Hayek explained it in detail:

"The tradition which Mandeville started includes also Edmund Burke, and largely through Burke, all those 'historical schools' which, chiefly on the continent, and through men like Herder and Savigny, made the idea of evolution a common place in the social sciences of the nineteenth century long before Darwin. And it was in this atmosphere of evolutionary thought in the study of society, where 'Darwinians before Darwin' had long thought in terms of the prevailing of more effective habits and practices, that Charles Darwin at last applied the idea systematically to biological organisms. I do not, of course, mean to suggest that Mandeville had any direct influence on Darwin (though David Hume probably had). But it seems to me that in many respects Darwin is the culmination of a development which Mandeville more than any other single man had started"³².

In other works, Hayek underlined the same conception, even in a more explicit way. He goes as far as to affirm that Darwin could have been inspired indirectly in the cultural evolution ideas of Mandeville and Hume: "The idea of cultural evolution is undoubtedly older than the biological concept of evolution. It is even probable that its application by Charles Darwin to biology was, through his grandfather Erasmus, derived from the cultural evolution concept of Bernard Mandeville and David Hume, if not more directly from the contemporary historical schools of law and language"³³. In addition, "Smith's work marks the breakthrough of an evolutionary approach which has progressively displaced the stationary Aristotelian view"³⁴.

³⁰ Cf. MIROWSKI, PH., *More Heat than Light. Economics as Social Physics: Physics as Nature's Economics*, Cambridge University Press, Cambridge, 1989, pp. 222-231.

³¹ Cf. HAYEK, F. A., *New Studies in Philosophy, Politics, Economics and the History of Ideas*, Routledge and Kegan Paul, London, 1978, p. 265.

³² HAYEK, F. A., *The Trend of Economic Thinking: Essays on Political Economists and Economic History*, Routledge, London, 1991, pp. 96-97.

³³ HAYEK, F. A., *Law, Legislation and Liberty. Volume 3: The Political Order of a Free People*, Routledge and Kegan Paul, London, 1979, p. 154.

³⁴ HAYEK, F. A., *The Fatal Conceit*, Routledge, London, 1990, p. 146.

However, paradoxically, Hayek does not analyze Herbert Spencer's work, which is quoted seldom and in passing, in spite of being one of the greatest theorists of cultural evolutionism. It is also surprising that Hayek dealt with the matter of evolutionism with almost no reference to Malthus, because this classical economist had clearly influenced Darwin. In fact, the allusions to Malthus in the *Autobiography*, *The Origin of Species* and other works by Darwin show that the Malthusian population principle was important for the formulation of the biological idea of evolution. It provided a general vision of "crowding and struggle" and enabled Darwin to identify an agent of "natural selection."

Darwin noticed that there were natural forces which acted in the same way as did farmers when they wanted to artificially modify the characteristics of domestic animals and plants. The farmer, for example, selects the few specimens of his flock which have the desired characteristics and allows them to mate, whereas in the wild, according to Darwin, there is a similar degree of selection if the animals procreate "geometrically." Then, there are more baby animals than can feed, and only the best adapted to environmental conditions survive³⁵. The "struggle for existence" throughout several generations will give rise to modified varieties, and even to the emergence of new species.

It is difficult to explain why Hayek forgets Spencer and Malthus when he discusses the evolution question. In the case of Spencer, his social theory was hardly appreciated in the twentieth century, even discredited. His name was linked to social Darwinism, which Hayek criticizes several times in his trilogy *Law, Legislation and Liberty*. On the other hand, it is true that Spencer and Hayek not only share a critical position of governmental intervention and judicial positivism, but also an idea of society as the unintended result of innumerable human actions.

Nevertheless, Hayek does not refer to a social *organism* which, like an individual organism, goes through different evolutionary stages towards an increasing degree of social complexity and differentiation. In the case of Malthus, this omission could be motivated by Hayek's interest in emphasizing the emergence of a spontaneous order, the market, whose functioning he is fully confident of. This would explain why Hayek prefers to underline the contributions of Smith or Hume instead of those of Malthus, as Malthus had focused on analyzing the problems of the market deriving from an insufficient demand and the negative consequences associated with an excessive demographic increase. Moreover, for Hayek, civilization was linked to the increase of population because this increase allows greater specialization and, consequently, greater productivity.

4. HAYEK'S IDEA OF EVOLUTION

As a member of Austrian School, Hayek has a clear starting point for his evolutionist ideas: the Austrian conception of social institutions and economic process, which was mainly developed by Menger. For Hayek, knowledge is contained in social institutions, which are adaptations to the environment deriving from human ignorance. Although his vision of socioeconomic and cultural evolution as a group adaptation process is certainly attractive and original, it has been criticized from different perspectives, particularly from an economic viewpoint.

³⁵ Cf. GORDON, S., *The History and Philosophy of Social Science*, pp. 541-542.

4.1. The Austrian Conception of Social Institutions: Spontaneous Order and Evolutionary Nature

The fundamental ideas of the Austrian School on the role and nature of social institutions derive from Menger,³⁶ although they fall within the tradition of spontaneous order represented, amongst others, by Mandeville, Hume, Ferguson and Smith. These ideas become important within a particular conception of economic process which is characterized by radical subjectivism and strict methodological individualism, rejecting macroeconomic aggregates and the use of mathematics as economic language.

In the neoclassical model, the rational agent with perfect information and in a static framework always chooses the best possible allocation which maximizes his utility. On the contrary, in the Austrian approach each individual looks for his own ends, draws up expectations and action plans, and tries to find out new opportunities according to his subjective evaluations and imperfect knowledge of a dynamic, constantly changing environment. In such a context, time, ignorance, error, habits and the unintended consequences of human actions turn out to be essential factors.

The radical subjectivism and the stress on the ideas of change and uncertainty lead Austrian economists to analyze how the individuals acquire information and how it spreads through society. As institutions perform a crucial role with respect to the production, transmission and use of information, from the Austrian viewpoint, it is especially relevant to have an appropriate theory on these. Tacit and practical knowledge is in part created and discovered constantly thanks to social interaction, but it is also present as habits, traditions and social institutions, passing from one generation to another. Precisely, the study of institutions was for Carl Menger the main task of social sciences, and he put it into practice, like Hayek, from an evolutionary perspective.

Menger thought that there existed an undeniable similarity between natural organisms and those social phenomena which were the unintended result of a historical development: "How can it be that institutions which serve the common welfare and are extremely significant for its solution of the most important development come into being without a common will directed towards establishing them? [...] The problems of the theoretical social sciences in general and of theoretical economics in particular is thus closely connected with the question of theoretically understanding the origin and change of 'organically' created social structures"³⁷.

That is to say, in Menger's opinion, to understand the operation of institutions was the key to explaining other economic phenomena which shared the same spontaneous nature, deriving from the interaction of any number of people acting in a self-interested way: "Law, language, the state, money, markets [...] are to no small extent the unintended result of social development. The prices of goods, interest rates, ground rents, wages, and a thousand other phenomena of social life in general and of economy in particular exhibit exactly the same peculiarity. Also, understanding of them [...] must be analogous to the understanding of unintentionally created social institutions"³⁸.

³⁶ Hayek and Mises would be the ones who develop these ideas later, with special reference to the market capacity for spreading information through the price mechanism.

³⁷ MENER, C., *Untersuchungen über die Methode der Socialwissenschaften und der Politischen Oekonomie insbesondere*, edited by Louis Schneider and translated by F. J. Nock: *Problems of Economics and Sociology*, University of Illinois Press, Urbana, 1963, book III, pp. 146-147.

³⁸ MENER, C., *Problems of Economics and Sociology*, p. 147.

Menger admitted that there were institutions which had a “pragmatic” or deliberate origin together with others of an “organic” nature, but he thought that the vast majority of social institutions (such as markets, money, language or informal rules of behavior) had a spontaneous origin. These were the ones which really had to be explained, given their relevance. Popper summarizes this central idea for the Austrian School: “*Only a minority of social institutions are consciously designed, while the vast majority have just ‘grown’ as the undesigned results of human actions.*”³⁹ That is, “undesigned social institutions may emerge as *unintended consequences of rational actions.*”⁴⁰ In this way, a social structure of great complexity arises as a result of individual actions.

In his *Principles of Political Economy*, Menger described the origin and evolution of money starting from his “organic” conception.⁴¹ But he did not do the same work with other institutions, such as the state, which for him also had a spontaneous origin,⁴² because it does not actually fit into an “invisible hand” interpretation.⁴³

4.2. Hayekian Evolutionism: Institutions as Knowledge

Without institutions there would be no society or economy. We could not interact in the way we do everyday, because uncertainty and transaction costs would be immeasurable, and we would have to process enormous quantities of information in order to make a decision, even though it is a simple one. These are the underlying basic ideas of the Hayekian conception of institutions.

Hayek holds that social institutions, habits, customs, traditions and other forms of regular behavior contained wisdom, action knowledge, “know-how,” accumulated experience by successive generations. In many cases, we do not know the reasons for

³⁹ POPPER, K., *The Poverty of Historicism*, Routledge and Kegan Paul, London, 1957, reprinted in 1969, p. 65 (italics in the original).

⁴⁰ POPPER, K., *The Poverty of Historicism*, p. 65, note (italics in the original).

⁴¹ Cf. MENER, C., *Grundsätze der Volkswirtschaftslehre*, W. Braumüller, Viena, 1871. Translated by J. Dingwall and B. Hoselitz: *Principles of Economics*, The Free Press, Glencoe, IL, 1950, pp. 257-271.

As Hodgson has pointed out, there are some similarities between Menger’s account of the emergence and evolution of money and that of the “old” institutionalists such as Veblen or Mitchell. But there are also two important differences. In the first place, for Mitchell the emergence of a monetary economy “cannot be explained simply because it reduced costs or made life easier for traders. The penetration of money exchange into social life altered the very configurations of rationality, involving the particular conceptions of abstraction, measurement, quantification and calculative intent. It was thus a transformation of individuals rather than simply the emergence of institutions and rules,” HODGSON, G., *Economics and Evolution*, pp. 118-119. In the second place, the “old” institutionalists such as Veblen or Mitchell see evolution as an unending process of cumulative causation, where institutions are both causes and effects. On the contrary, Menger sees the process of evolution as reaching an end state in which the monetary unit is established.

⁴² Cf. MENER, C., *Problems of Economics and Sociology*, p. 156.

⁴³ According to Hodgson, Menger does not distinguish properly between self-regulating institutions and those which require the most policing. For example, there are obvious incentives to drive on the same side of the road as others, to use the established railway gauges or computer software, or to conform to the linguistic norms. These norms and conventions reproduce themselves because of “network externalities” and widespread use. Once they become widely used then others have an incentive to do the same. However, the vast majority of laws and regulations, such as tax payments or speed limits, require some policing activity in order to prevent them being debased. In the same way, “the state or central banks are essential to the creation and survival of a viable monetary unit, even if the state (or central bank) may bring associated problems”, and modern markets “are necessarily supported by networks of other institutions, including the state,” HODGSON, G., *Economics and Evolution*, pp. 117-118.

their current form or their *modus operandi*, but we do know that they make social life possible⁴⁴. A good simile would refer to the tools which we often use: we ignore why they are made in a particular way rather than another because they are the result of the accumulated experience of previous generations. But each time we discover new improvements we add them to those tools and pass them on to the following generation. In this way, those tools will end up containing our experience together with the “knowledge” of preceding generations⁴⁵.

Therefore, according to Hayek, institutions are an essential resource for individuals, because they allow them to cope satisfactorily in a world which is known in a very imperfect way. Paloma de la Nuez summarizes this idea: “Knowledge is contained in rules, habits, conventions, traditions and every type of institutions, which actually are adaptations to the environment deriving from human ignorance. The greatest advantage of civilization lies precisely in providing everybody with that knowledge, so that it can be used individually to achieve personal ends [...] Civilization [...] implies, above all, a cumulative increase of knowledge. It is a costly process of trial and error, the addition of human experiences which pass on from one generation to another, either as explicit or as tacit knowledge.”⁴⁶

Hayek understands socioeconomic and cultural evolution as a *group adaptation* process instead of an individual one, in which there are no pre-established plans or directions. Evolution is never linear, continuous and uniform, since errors and backward movements sometimes happen.⁴⁷ Individuals adapt to the environment, to facts and specific circumstances through compliance with certain norms which shape their way of acting. These norms have not been deliberately designed because the profits associated with them in the future have been identified in advance. The norms of behavior are immersed in a *selection process*, involving trial and error, thus those who have contributed to the survival and expansion of a society will remain and will probably be imitated by other societies. Through experience, some behaviors are modified and other new ones are tried.⁴⁸

Cultural development is based on *heredity*, that is, the passing on of knowledge through generations.⁴⁹ It has been asserted that institutions, social habits, and organizational

⁴⁴ Cf. HAYEK, F. A., *The Constitution of Liberty*, Routledge and Kegan Paul, London, 1960, chapter II, § 3.

⁴⁵ Cf. BUTLER, E., *Hayek. His Contribution to the Political and Economic Thought of our Time*, Tempel-Smith, London, 1983, p. 42.

⁴⁶ DE LA NUEZ, P., *La política de la libertad. Estudio del pensamiento político de F. A. Hayek*, Unión Editorial, Madrid, 1994, p. 200.

⁴⁷ Cf. HAYEK, F. A., *Law, Legislation and Liberty. Volume I: Rules and Order*, London, Routledge and Kegan Paul, London, 1977, pp. 17-19. Although the concept of “group selection” has been much criticized from a biological point of view, it is suitable from a socioeconomic perspective.

⁴⁸ Cf. HAYEK, F. A., *Law, Legislation and Liberty. Volume I: Rules and Order*, p. 19. The process of institutional change is evolutionary, thus, in the long term the institutions survive and adapt while they are useful to society, contributing to the survival of an increasing population. There are certain similarities with the Popperian conception of the scientific process: ideas are constantly created and tested. The refutation of old ideas stimulates the development of new ones, which in turn will be tested. However, it must be taken into account that the Popperian method is “absolutist”: the new hypothesis is always better than the refuted one. On the contrary, institutions are not optimal, that is, it is better an institution than its absence.

⁴⁹ SCHUTZ, A., *Studies in Social Theory*, Martinus Nijhoff, The Hague, 1964, broadly develops this idea from a sociological perspective.

structures perform a role similar to genes with respect to the passing on of tacit knowledge. The key to cultural evolution is learning and imitation.

For Hayek, formal rules, deliberately chosen, are no more important than those which are implicit and which we conform to although we are unable to express them in words. Neither are they more important than those customary norms which we learn by the mere process of observing them in operation.

The informal rules, as a whole, make relations amongst people easier, thus nobody has to worry all the time about the way of behaving.⁵⁰ That is to say, these rules show us which is the correct way of acting under certain circumstances, despite the fact that generally individuals are not aware of these rules and cannot express them either.⁵¹ Since informal norms and moral values make the mutual adjustment and coordination of individual actions easier, they contribute to creating a general order in which individuals can act freely: our behavior is subject to rules, and thanks to this each individual knows that the others are going to conduct themselves in a regular and predictable way.⁵²

As can be deduced from the previous discussion, there are some interesting similarities between biological evolution and Hayek's ideas on socioeconomic and cultural evolution, which he developed in his trilogy *Law, Legislation and Liberty* and in *The Fatal Conceit*. Both biological evolution and cultural evolution are referred to concepts such as selection, heredity, competition and adaptation to the environment. In addition, both are experimentation processes, involving trial and error; that is, they are not linear, continuous and uniform. Neither biological evolution nor cultural evolution correspond to a pre-established plan or conscious direction, and for this reason it is not possible to forecast the future evolutionary development.

However, there are also differences which must be underlined. Cultural evolution, which is much faster than the biological one, is a group, not an individual, selection process: those human groups whose behavior rules, social customs and traditions allow them to adapt better to the environment are favored. That is, the "chosen" or selected norms are those which benefit more the group as a whole. On the other hand, cultural evolution heredity, which is the key to cultural development, is not genetically determined, but is based on learning and imitation. Finally, cultural evolution must be understood in a Lamarckian sense, because it is possible to pass on characteristics acquired by adaptation to the environment to the following generations: through experimentation, involving trial and error, the social group modifies old behaviors and creates new ones in order to adapt to the environment; later, those ways of behavior, in the shape of informal rules, will be left to the following generations.

⁵⁰ Cf. BUTLER, E., *Hayek. His Contribution to the Political and Economic Thought of Our Time*, p. 50.

⁵¹ At the beginning of chapter II of *The Constitution of Liberty*, Hayek quoted Whitehead's sentence which summarized this idea very well: "Civilization advances by extending the number of important operations which we can perform without thinking of them," p. 22.

⁵² Cf. HAYEK, F. A., *Law, Legislation and Liberty. Volume I: Rules and Order*, p. 19; DE LA NUEZ, P., *La política de la libertad. Estudio del pensamiento político de F. A. Hayek*, pp. 192-194. As North maintains, in situations of "impersonal" exchange institutions alter individual cost/benefit ratios in favor of cooperation. Otherwise, if there were no institutions, cooperation would not happen, because of the great number of "players", the lack of information which each "player" has about the others, and the unique nature of many interactions. Cf. NORTH, D. C., "Economic Performance Through Time," *American Economic Review*, v. 84, n. 3, (1994), p. 365.

4.3. Problems Associated with Hayekian Evolutionism

Hayek's approach has been criticized from different standpoints. For example, it has been stressed that Hayek's evolutionism moves away from rationalism, because the Austrian author defends compliance with impersonal rules which have not been consciously designed and which individuals are not able to understand completely. In the same way, the conservatism of the Hayekian theory has also been highlighted, because it implies a passive assumption (with no criticism) of inherited traditions owing to their mere survival throughout time.

Furthermore, it has been said that Hayek is too optimistic and ingenuous when he supposes that "the best adapted" norms always tend to take the place of those which are harmful to humankind. On the other hand, it is difficult to prove that the theory of cultural evolution is closely linked to the emergence of a spontaneous social order.⁵³ Other critics have described Hayek's explanation as "functionalist," because they consider that the contribution of a norm to the conservation system is not enough to explain its existence.⁵⁴ Finally, Hayek's ideas have even been criticized from an ethical viewpoint.⁵⁵ Nevertheless, from an economic perspective all these criticisms are perhaps less relevant than the three which will be dealt with below.

a) Intervention in the Evolutionary Process: The Institutional Reform Question

Hayek is skeptical about institutional reform. Although he admits that it can sometimes be necessary to modify the institutional framework, he distrusts these kinds of reforms because he thinks that it is easy to go beyond the required changes, giving free rein to "constructivist rationalism." According to Hayek, intervention in the institutional framework should always be very restricted, occasional and carefully considered, especially with reference to general behavior rules of spontaneous origin linked to the judicial process (*nomos* or *the law of liberty*). He clearly distinguishes between these kinds of rules, which are exemplified by the British common law, and legislation (*thesis*), the organization rules deliberately established by the legislative power.⁵⁶

However, as De la Nuez has shown, in Hayek's work the problem of intervention in the evolutionary process is not well resolved.⁵⁷ He never defended complete inactivity and a totally conservative attitude. But if one accepts some kind of intervention, even if it was slight and gradual, this implies knowledge of the end or process, or at least, the

⁵³ Cf. DE LA NUEZ, P., *La política de la libertad. Estudio del pensamiento político de F. A. Hayek*, p. 198.

⁵⁴ Cf. VANBERG, V. J., *Rules and Choice in Economics*, Routledge, London, 1994, pp. 77-94.

⁵⁵ Walker points out that the only end of Hayek's ethics is to perpetuate the social organization model which promotes the survival of the species; this becomes the only factor which justifies morality and law. Cf. WALKER, G., *The Ethics of F. A. Hayek*, University Press of America, Boston, 1986, p. 94.

Miller believes that Hayek only defends liberty as a means for the multiplication of the species, so he puts it on the same level as ethical value and evolutionary value. Moreover, he thinks that, in an evolutionary framework, it is difficult to justify the adherence to principles of universal validity, such as human freedom and dignity. Cf. MILLER, D., "The Fatalistic Conceit," *Critical Review*, v. 2, n. 3, (1989), pp. 312-318.

From an evolutionary perspective how institutions and behavior norms emerge can be accounted for, but it cannot justify them directly. However, the defense of freedom can be based on efficiency and utility reasons: evolutionism can be useful for showing that freedom is efficient as regards promoting knowledge, progress and civilization (which in the last of Hayek's writings is identified with demographic increase).

⁵⁶ Cf. HAYEK, F. A., *Law, Legislation and Liberty. Volume 1: Rules and Order*, pp. 124-126.

⁵⁷ Cf. DE LA NUEZ, P., *La política de la libertad. Estudio del pensamiento político de F. A. Hayek*, p. 199.

will to achieve a certain goal. And this does not correspond with some of Hayek's more characteristic ideas on human ignorance and uncertainty.

In contrast to the "organic" theory of Hayek-Menger on the emergence and evolution of social institutions, there are other explanations which highlight either the deliberate nature of the vast majority of institutions, or the possibility of a broad intervention in the institutional framework in order to improve it. Examples of these kinds of explanations are, respectively, the Commons' approach,⁵⁸ based on the idea of collective action, and Buchanan's contractual approach, which will be dealt with later.

According to Hayek, both positions would fall within the tradition of "constructivist rationalism," which arose with Cartesian rationalism and Rousseau's social contract. Both of them are the result of ignorance of the limits of human reason and the complex nature of knowledge in society. In fact, what had led to the errors of socialism had been the belief that it was possible to change broadly and at will the complex institutional structures which sustain the social order.

Hayek's rigid differentiation between evolutionism and "constructivist rationalism" does not leave room for deliberate constitutional design and reform in his theoretical scheme. For instance, Hayek praises the American Constitution as an example of a constitution of liberty. Although it is obvious that it was the result of a deliberate design, as Buchanan reminds us,⁵⁹ Hayek points out that it was developed from the traditional principles and experience of English people.⁶⁰

However, this argument is completely different to that based on a radical differentiation between evolutionism and "constructivist rationalism." On the other hand, Hayek contradicts his own evolutionary ideas when, in the third part of *Law, Legislation and Liberty*, he makes a constitutional reform proposal as regards the division of powers. This proposal could be described as an attempt at "constitutional engineering," which he detested so much. In fact, as De la Nuez says, his proposal is not a simple revision of habits and traditions: it is actually similar to the reform models of the "rational-constructivists" which he criticized.⁶¹

Faced with so many reform possibilities in the countries of East Europe after 1989, in which there were no markets or private property rights, Hayek found himself in a quandary:

⁵⁸ Commons defines an institution as "collective action in control, liberation, and expansion of individual action," COMMONS, J. R., *Institutional Economics. Its Place in Political Economy*, Macmillan, New York, 1934; published by The University of Wisconsin Press, Madison, 1959, p. 73.

This definition includes two ideas. In the first place, "how socially-enforced rules impose a constraint on the individual but, at the same time, by simultaneously constraining others it also 'liberates' the individual by securing a protected domain of action." Therefore, Commons is interested in what makes peaceful co-operation possible despite the conflicts of interest that result from scarcity: it is important to analyze "the process in which men come to establish and to maintain among themselves a system of rules for regulating these conflicts," VANBERG, V. J., *Rules and Choice in Economics*, p. 153.

In the second place, Commons shows "how, as a member of an organization, the individual is subject to certain rule-constraints while, on the other hand, organized collective action allows individuals to accomplish things and to realize gains which could not be achieved by separate individual effort." In this case, organizations are considered as "corporate actors", which play an essential role in the modern socioeconomic world. Cf. VANBERG, V. J., *Rules and Choice in Economics*, pp. 153 and 156-157.

⁵⁹ Cf. BUCHANAN, J. M., *Freedom in a Constitutional Contract*, Texas A&M University Press, College Station, 1977, p. 38.

⁶⁰ Cf. HAYEK, F. A., *The Constitution of Liberty*, chapter XII, § 2.

⁶¹ Cf. DE LA NUEZ, P., *La política de la libertad. Estudio del pensamiento político de F. A. Hayek*, p. 252.

on the one hand, the defense of the introduction of markets, and on the other hand, the opposition to substantial structural changes associated with “constructivist rationalism.”

b) Methodological Individualism and the Significance of Institutions: A Difficult Adjustment

As will be shown now, the ambitious Hayekian ideas on the role of institutions and his strict adherence to methodological individualism turn out to be incompatible. The Austrian School of Economics distinguishes between information (available sense data) and knowledge (information really apprehended). The availability of information does not mean, as appears to be deduced from some economic models, that the economic agents perceive this in the same way.

For Hayek, the facts are perceived through individual preconceptions and models of reality; that is to say, individuals to some extent “create” the reality in which they live. Since we are educated in a certain cultural and institutional environment, institutions would not only be restrictions to our possibilities for action, but would also contribute to some extent to shaping our preferences, helping us to select information in order to make decisions. That is, our preferences would not be autonomous, but would be conditioned by cultural and institutional factors. The cultural and institutional framework acts as a “filter,” which allows us to apprehend a little part of the enormous quantity of available information. To select and classify information we use concepts, symbols and rules which we have learned thanks to the socialization process.⁶²

However, these ideas on the significance of institutions, which appear to derive naturally from Hayek’s cultural evolutionism, do not fit in with Hayekian methodological individualism. Methodological individualism implies taking the individual for granted, as a starting point to inquire into the social phenomena. This means that his preferences, aims, interests, beliefs and so on are considered exogenous data. Although it is obvious that the institutional and cultural framework influences them, in practice this influence is not taken into account.⁶³ This position can be useful for the study of economic problems in the short term, but it is not suited to an evolutionary and dynamic perspective such as Hayek’s, in which much attention is given to stressing the importance of culture and institutions.

As Hodgson points out: “While rules are clearly objects of replication in [Hayek’s] socioeconomic evolution, humans are not ‘instructed’ by rules alone; they also make choices. If choice is made supreme in the human sphere, then the analogy between the chosen rule and the gene becomes imperfect [...] Hayek’s own explicit adherence to choice,

⁶² The socialization process consists of the acquisition of culture and “social” knowledge within a certain cultural and institutional framework. According to sociologists, during socialization we learn the cultural and institutional factors (symbols, norms, values, etc.) which define our environment so that we can adapt to it. Moreover, socialization is important in the process of personality formation. See ROCHER, G., *Introduction à la sociologie générale*, Hurtubise HMH, Montréal, 1992, chapter V.

The idea of socialization connects with Herbert Simon’s “bounded rationality”: since individuals have a “bounded rationality”, in order to make decisions they lean upon habits and previously learned ways of dealing with problems. Cf. SIMON, H. A., *Reason in Human Affairs*, Stanford University Press, Stanford, 1983.

⁶³ For Hayek, to explain conscious action was the task of Psychology, not of Economics. This attitude has been described as “psychologism” (Popper), and also as excessively narrow in the social sciences sphere. Other Austrian economists, such as Lachmann or Shackle, consider that the uncaused nature of imagination and expectations prevents any explanation: individuals, when they choose, make primary and spontaneous choices. However, it is not difficult to admit that at least some human goals and desires can be moulded or caused by institutions, culture, and so on. Cf. HODGSON, G., *Economics and Evolution*, pp. 153-156.

purposeful behavior and methodological individualism would seem to be inconsistent with his own supreme emphasis on the object of selection being rules.”⁶⁴

On the other hand, the idea of group selection, which is suitable from a socioeconomic perspective but not from a biological one, appears to move away from Hayekian methodological individualism, because the selection and efficiency criteria would refer to the group. It must be remembered that, according to the Hayekian approach, the selected or “chosen” behavior rules are those which benefit the group as a whole; that is, those human groups whose norms allow them to adapt better to a changing environment are favored.

c) Evolution, Progress and Efficiency

Hayek does not emphatically state, unlike Spencer, that evolution always involves progress and an increasing efficiency, although essentially he shares this idea. That is, Hayek, who had witnessed the totalitarian atrocities of the twentieth century, rejects that evolution leads *automatically* to progress. As it has already been mentioned, cultural evolution is not linear, continuous and uniform. There are errors and backward movements. Nevertheless, although some “parasitic” or even harmful institutions can survive for long periods owing to political factors, such as the existence of interest groups, if all the institutions of a specific human group are better adapted than others, that group will prosper.

For this reason, in a loose sense and in the long term, it could be affirmed, according to Hayek, that there is a connection between evolution and progress:⁶⁵ the institutional frameworks which are selected are those which favor the survival of an increasing population faced with more and more complex problems.⁶⁶ This idea would probably

⁶⁴ HODGSON, G., *Economics and Evolution*, p. 166.

⁶⁵ It is widely assumed that evolutionary processes lead in the direction of optimality and maximum efficiency. But this is a mistake, called the “adaptationist” fallacy. The process of natural selection can lead to improvement, because adaptation to the environment does occur, but it is not a strong optimizing force. In the first place, for evolution to work there must be always a variety of forms from which to select (the evolutionary process must involve ceaseless and systematic error-making). In the second place, it is the path dependency problem: the future development of a system is affected by the path it has traced out in the past. This involves inflexibility in the evolutionary process.

Technological development is a good illustration: “Once a technological paradigm is adopted, this predetermines a general direction or path of development” which “is not necessarily the most efficient,” HODGSON, G., *Economics and Evolution*, p. 206. Examples are the QWERTY typewriter keyboard, standard gauge railways, the VHS video system, etc. In conclusion, natural selection does not lead to the superlative fittest, only the tolerably fit. As he points out, “natural selection is always an imperfect instrument, and it can sometimes lead to clearly sub-optimal, even disastrous, outcomes,” HODGSON, G., *Economics and Evolution*, p. 197.

However, in Economics, authors such as Alchian or Hayek himself have held that the idea of natural selection in a competitive framework reinforces the assumption of the rational maximizing behavior of economic agents (individuals and firms). Cf. ALCHIAN, A. A., “Uncertainty, Evolution and Economic Theory,” *Journal of Political Economy*, v. 58, n. 3, (1950), pp. 211-221.

⁶⁶ This position should not be confused with another which is also controversial: the institutions best adapted to the environment at a certain time and in certain circumstances would survive. That is, institutions would be selected according to the favorable characteristics for their *own* survival, not by their contribution to socioeconomic progress. Therefore, the survival and expansion of many institutions might be caused precisely by their inefficiency.

In the same way as a bad educational system implies extending the training period, or as a bad penitentiary system, where criminals become worse, creates the preconditions for its own expansion, badly designed regulations require additional regulations and bad laws give rise to the need for new laws. It would be a sort of “Gresham Law” of institutions. But this appears to be hardly feasible as, in practice, the capacity of society to “sustain” parasitic institutions is limited. Cf. DE JASAY, A., *Social Contract, Free Ride*, Oxford University Press, New York, 1990, p. 77.

be disputed or qualified by current authors such as Williamson or North, especially, if institutional evolution is linked specifically with economic growth.⁶⁷ However, this idea is less controversial than the following one.

For Hayek, the norms which are the product of an evolutionary process (general behavior rules of spontaneous origin linked to the judicial process and exemplified by the British *Common Law*) are more efficient than those which are deliberately designed by the legislative power. The first are subject to a selection process, and in the long term only those which are useful to society survive. For this reason, these institutions, which are associated with a gradual evolution, are superior to those deliberately designed (which in modern societies tend to be an increasing part of the whole institutional framework).⁶⁸ This stance is also held by Richard Posner, one of the most important exponents of the economic analysis of law.⁶⁹

James Buchanan, Nobel Prize in Economics in 1986, shared with Hayek the adherence to liberal tradition and methodological individualism, but he does not agree with Hayekian optimistic evolutionism, even accepting that many social institutions have a spontaneous origin: “the forces of social evolution alone [...] do not guarantee that socially efficient results will emerge over time.”⁷⁰ Any institution can be the target of a deliberate reform. Moreover, it cannot be assumed, as Hayek does, that institutions associated with the “invisible hand” principle will be efficient, whereas those deliberately designed will tend to be inefficient. Before being able to make this kind of statement, it is necessary to specify an evaluation criterion for the existing norms and institutions, as well as for those which are proposed in the future.⁷¹

For Buchanan, the individualistic perspective, which both he and Hayek share, requires a contractual criterion: “we may evaluate any element of the existing legal structure in terms of its possible consistency with ‘that which emerges’ from a genuine ‘social contract’ between all the persons who are involved in the interaction.”⁷² That is, just as a voluntary exchange shows an agreement between the two parties concerned, thus the voluntary agreement is the final criterion to evaluate whether an exchange is efficient or not, in the case of collective choice the voluntary agreement between all the participants is also the criterion to evaluate its efficiency. A position based on individualism implies that efficiency cannot be judged “externally” to the individuals’ personal values. Therefore, the stated criterion is the only one which is really consistent with an individualistic stance.

⁶⁷ See, for example, NORTH, D. C., *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge, 1990, pp. 17-26. Since the information available to economic agents is incomplete (and even erroneous), their capacity to process it is limited, and there are transaction costs, the global institutional efficiency associated with a perfectly competitive world cannot be expected. North concludes that institutions are not created by force or to be socially efficient. Institutions, especially formal rules, correspond to the interests of those who have bargaining power to establish new norms.

⁶⁸ In particular, legislation, which Hayek calls organizational norms, is necessarily the product of a social process of collective choice, which can never be evolutionary. Therefore, in relation to the constitutional rules it is not suitable to use the term “constructivist rationalism.” According to Hayek, the constitutional rules are governmental organization rules, which determine the structure and functions of the government. Cf. HAYEK, F. A., *Law, Legislation and Liberty. Volume 1: Rules and Order*, chapter VI.

⁶⁹ See POSNER, R. A., *The Economic Analysis of Law*, 3rd ed., Little Brown, Boston, 1992.

⁷⁰ BUCHANAN, J. M., *Freedom in a Constitutional Contract*, p. 31.

⁷¹ Cf. *Freedom in a Constitutional Contract*, p. 32.

⁷² BUCHANAN, J. M., *Freedom in a Constitutional Contract*, p. 33.

Buchanan maintains that the efficient is what is born out of agreement, and hence, there is not an only efficient result, because agreement possibilities are not limited to one. As a consequence, there is not only one optimal set of institutions irrespective of agreement. Social reform is possible, and to implement this, perfect knowledge is not necessary, because it is not a question of achieving the social optimum, as many social reformers have sought to achieve.

The basic structure within which our interaction takes place can be modified by consensus. When this consensus refers to constitutional or fundamental norms, not to ordinary policy-rules, it can be reached through unanimity. In fact, when it is chosen rather than alternative constitutional rules, the possibilities of consensus are greater than in the field of ordinary policy: uncertainty about the operation of increasingly more general and permanent rules means that it is difficult to identify the future personal and group interest under such norms. The economic agents then try to prevent a disastrous result, such as the lack of agreement.⁷³

As Buchanan says, the contractual criterion is not an arbitrary instrument to justify any type of legal reform. To assume a “hypothetical contract” allows us to conjecture on possible failures and improvements regarding the system of rules, but the effective modification of rules should be subject to the evidence of an explicit agreement made by the parties concerned⁷⁴. Buchanan calls this position “contractualist constructivism.”

To sum up, the main difference between Hayek and Buchanan is that Buchanan does not admit that the efficiency of institutions of spontaneous origin and of an evolutionary nature, and the inefficiency of deliberately designed institutions must be presupposed. Not only is it possible to design new rules which are efficient, but it is also possible to broadly redefine the existing ones in order to improve them. However, in any case it is necessary to evaluate the norms, and Buchanan suggests a contractual criterion for this purpose.

5. CONCLUSION

This paper was focused on evolutionism in Hayek’s work. In the first place, it has been shown that Hayek’s evolutionary approach is singular in the history of economic thought, because, until the 1980s, evolutionary economics did not arouse the interest of economists. In fact, the majority of economists still remain faithful to the mechanical and static analogy. Until the 1980s, some authors —such as Veblen, Menger, Marshall or Schumpeter— formulated ideas which suggested the possibility that an evolutionary approach in economics could be developed. However, they either did not develop their proposals, or did so in a way which was not consistent.

Hayek, on the contrary, developed a theory of socioeconomic and cultural evolution following Menger, which was complete and coherent enough, and in which institutions performed an essential role. In any case, the feature common to all these attempts to link economics and biology was a wider vision of economic science, which moved away from the approach which had been dominant since the end of the nineteenth century (focused on comparative static analysis and equilibrium in the short term).

⁷³ Cf. BUCHANAN, J. M. and BRENNAN, G., *The Reason of Rules*, Cambridge University Press, Cambridge, 1987, pp. 54-58 and 104-109.

⁷⁴ Cf. BUCHANAN, J. M., *Freedom in a Constitutional Contract*, p. 33.

In the second place, it has been shown that Hayek considers that the idea of evolution in social sciences in the broad sense was previous to the biological one. He even points out that Darwin could have indirectly inspired the cultural evolution ideas of Mandeville and Hume to develop his own theory. However, paradoxically, Hayek ignores Malthus, who clearly influenced Darwin, and Spencer, one of the greatest theorists of cultural evolutionism. Although it is difficult to explain these omissions, in this work some possible reasons have been suggested.

Finally, it has been shown that Hayekian evolutionism can only be understood within the Austrian approach to the economic process, characterized by uncertainty and constant change. From this perspective, the acquisition of information on the part of individuals is an essential question, and institutions, in fact, perform a fundamental role in the production and transmission of knowledge. In particular, informal institutions, whose origins are spontaneous, contain knowledge and accumulated experience, which pass from one generation to another through imitation and learning.

Cultural evolution implies a group selection process, thus those human groups whose norms, customs and traditions enable them to adapt better to the environment are favored. In this way, the rules which have contributed to the survival and expansion of a certain society will remain and will probably be imitated by other societies. There are parallelisms between the Darwinian idea of biological evolution and the Hayekian idea of cultural evolution because both refer to concepts such as selection, heredity, competition and adaptation to the environment. However, there are also important differences: cultural evolution is much faster, is based on group selection, is not genetically determined, and must be understood in a Lamarckian sense.

Hayekian evolutionism has been criticized from different perspectives, but this work has focused only on three criticisms which are especially relevant from an economic point of view. First, there is the question of institutional reform or the intervention in the evolutionary process since Hayek makes a radical distinction between evolutionism and “constructivist rationalism.” Second, the difficult adjustment between Hayek’s strict adherence to methodological individualism and his dynamic and evolutionary perspective, in which institutions perform a fundamental role, should be stressed. Finally, the Hayekian idea, according to which the norms derived from an evolutionary process such as British Common Law, are superior to (or more efficient than) those which are the result of a deliberate design has been questioned.

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IV

Epistemology and Evolutionism

8. Biocosmological Evolutionism and Evolutionist Epistemology in Popper

9. Rationality as Evolutionary Adaptation in Herbert A. Simon.
A Comparison with Karl Popper and Reinhard Selten

BIOCOSMOLOGICAL EVOLUTIONISM AND EVOLUTIONIST EPISTEMOLOGY IN POPPER

JUAN ARANA

1. THE PROBLEM OF REDUCTION IN BIOLOGY

In September 1972, Theodosius Dobzhansky and Francisco Javier Ayala organized in Bellagio, Italy, an international conference about "The Reduction Problem in Biology," with the attendance of a select group of scientists and philosophers. Minutes of that meeting were published in a volume entitled *Studies of Philosophy of the Biology*.¹ Karl Popper appeared among the guests and his presentation, that was later included as an addendum in *The Open Universe*,² played a discordant note in the bosom of such erudite meeting. The hosts were part of the most old-fashioned Neo-Darwinist observance, and, even while the programme covered a wide spectrum of positions, almost everyone agreed on their vision of the core problem. Popper did not even line up with the few dissenting voices. Without entering casuistries that now would be bothersome, I will try to summarize the positions of both sides.

It is necessary to distinguish two fundamental aspects in the problems of reduction in biology: the ontological and the epistemological. On the one hand, it is necessary to decide if the living organisms contain ingredients, dynamisms or entities different from the ones appearing in inorganic bodies, or to say it in a simpler way, if bacteria, animals and plants are made of different stuff than stones. On the other hand, it is of interest to know if to give an accurate explanation of the phenomena studied by the biologists it is necessary to resort to concepts, principles and laws that are not defined or deducted from the ones used by chemists and physicists. The fact of being a reductionist or not from the ontological point of view, does not prejudice if someone is also one (or not) from an epistemic sense. Combinatory gives us, then, four possible alternatives, and the one chosen by Popper is the most unusual. But let us see the other ones before.

Firstly, it is possible to be an antireductionist both in the logical and ontological fields. Many ancient and medieval thinkers were ones, in line with the predecessor of biological studies. Aristotle, in effect, thinks that the presence or absence of the soul determines the border between the two big kingdoms of nature, and confers to the concept an unequivocal ontological consistency: "so the soul must be substance in the sense of being the form of a natural body, which potentially has life."³ But it also constitutes a capital epistemic instrument: "The soul is the cause and first principle of the living body."⁴

¹ See POPPER, K. R., "Scientific Reduction and the Essential Incompleteness of All Science," in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology*, University of California Press, Berkeley, 1974, pp. 258-284.

² Cf. POPPER, K. R., *The Open Universe*, Hutchison, London, 1982, pp. 131-162.

³ ARISTOTLE, *On the Soul*, Harvard University Press, Cambridge, 1975, 412a.

⁴ ARISTOTLE, *On the Soul*, 415b.

Opposite to the Aristotelian position appears double reductionism, defended by many modern thinkers. Descartes, for instance, dedicated his *Treatise on Man* to emulate every organic function by means of mechanical devices. He finishes his book with the following thesis: “it is not necessary to conceive of this machine as having any vegetative or sensitive soul or other principle of movement and life.”⁵ He conceives, as a matter of fact, the animals as artifacts impelled by the heat of the cardiac viscera, transformed in movements through a system of injection of fluids. Every explanation method used comes from mechanics, and even the key notion of “animal spirits” refers to a simple distillate of blood.

Despite the fact that during the 17th and 18th centuries, iatromechanism progressed rapidly, most naturalists kept using explanatory procedures very different from physics, because the final causes, almost forbidden in that science, had extensive circulation in the field of biology. This factual situation did not change until Darwin, who, far from excluding the epistemic teleological approaches, just separated them from the antireductionist ontological compromises.

Thomas Huxley, as his authorized speaker, bears witness of this: “perhaps the most remarkable service to the philosophy of Biology rendered by Mr. Darwin is the reconciliation of Teleology and Morphology, and the explanation of the facts of both which his views offer. The Teleology which supposes that the eye, such as we see it in man or one of the higher Vertebrata, was made with the precise structure which it exhibits, for the purpose of enabling the animal which possesses it to see, has undoubtedly received its death-blow. But it is necessary to remember that there is a wider Teleology, which is not touched by the doctrine of Evolution, but is actually based upon the fundamental proposition of Evolution.”⁶

Popper himself bore in mind this point several times in his works. At the Spencer lecture, delivered in 1961 and later added to his book *Objective Knowledge*, he maintains: “nevertheless, Darwin’s revolutionary influence upon our picture of the world around us was at least as great, though not as deep, as Newton’s. For Darwin’s theory of natural selection showed that it is *in principle possible to reduce teleology to causation by explaining, in purely physical terms, the existence of design and purpose in the world.*”⁷

At the Bellagio meeting, Popper stressed again that: “it was of course Darwin’s great achievement to show that it is possible to explain teleology in non-teleological or ordinary causal terms. Darwinism is the best explanation we have. At the moment there are no seriously competing hypotheses.”⁸ We will later see the theoretical use that Popper wanted to extract from this point. For the moment, it is enough to keep in mind that the creator of the Theory of Evolution opened the door to a mixed solution for the reductionism problem. Since then, any biologist can be a reductionist on ontological matters and an autonomist on epistemological ones. An example of this position was shown by Dobzhansky himself, who, in the meeting mentioned above stated the following:

⁵ DESCARTES, R., *L’Homme*, in: *Oeuvres de Descartes*, ed. Ch. Adam and P. Tannery, Vol. XI, Vrin, Paris, 1974, p. 202.

⁶ HUXLEY, T. *Genealogy of Animals*, The Academy, London, 1869, quoted in DARWIN, CH., *The autobiography of Charles Darwin*, Selection of F. Darwin, Collins, London, 1958.

⁷ POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, Clarendon, Oxford, 1979, p. 267.

⁸ POPPER, K. R., *The Open Universe*, Hutchison, London, 1982, p. 150.

“Most biologists, I believe all those gathered around this table, are reductionists to the extent that we see life as a highly complex, highly special and highly improbable pattern of physical and chemical processes. To me, this is ‘reasonable’ reductionism. But should we go farther, and insist that biology must be so reduced to chemistry that biological laws and regularities could be deduced from what we shall learn, about the chemistry of life processes? This, I think, is ‘unreasonable’ reductionism. The most spectacular advances in biology in our time were unquestionably those in molecular biology. Yet it does not follow that organismic biology is from now on unproductive, or that all of us should work exclusively on molecular biology. Should not organismic and molecular biology both continue to develop, because one without the other can only give a distorted view of life? Should the philosophy of biology deal with organismic, or with molecular aspects, or with both?”⁹

The confidence that the lecturer showed when appealing to the consensus of everyone present, certified that this was a ‘politically correct’ position. During the last century, double antireductionism has been defended by the vitalists, and this position is in obvious decline, as asserted by Francis Crick in his book: *On Molecules and Men*.¹⁰ Double reductionism keeps being promoted by the most enthusiastic advocates of the explanatory capacity in molecular biology, but, in general, the mixture of ontological reductionism and ontological antireductionism is proposed as the most civilized formula to face this matter. This way is used, for instance, by John Maynard Smith in *The Problems of Biology*.¹¹

2. POPPER’S ATTITUDE

Popper, however, follows an utterly opposite line, running out of combinations he opts for combining methodological reductionism and ontological antireductionism. Even if his decision lacked further merits, at least we are not entitled to deny its originality, because very few have followed this path. And despite his isolation, he is emphatic: “philosophical reductionism is, I believe, a mistake. It is due to the wish to reduce everything to an ultimate explanation in terms of essences and substances, that is, to an explanation which is neither capable of, nor in need of, any further explanation.”¹²

It is scarcely necessary to add that what is referred to as “philosophical reductionism” consists in the denial of the existence of the worlds 2 and 3, and that it coincides with what I have described as “ontological reductionism,” term that I have taken from Ayala.¹³ Popper sees in it an example of metaphysics in the worst sense of the term: he tries to catch the essence of reality through an aprioristic exercise of the reason that surpasses everything that experience teaches us, getting safe from any possible empirical denial. No matter which facts may be recorded in the future, it will always be possible to postulate for hidden

⁹ DOBZHANSKY, TH., “Introductory Remarks,” in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology*, p. 1.

¹⁰ CRICK, F., *On Molecules and Men*, University of Washington Press, Washington, 1966.

¹¹ MAYNARD SMITH, J., *The Problems of Biology*, Oxford University Press, Oxford, 1986.

¹² POPPER, K. R., “Scientific Reduction and the Essential Incompleteness of All Science,” in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology*, p. 279.

¹³ AYALA, F. J., “Introduction,” in AYALA, F. J. and DOBZHANSKY, TH. (eds.), *Studies in the Philosophy of Biology*, pp. viii-xiii.

dynamisms that would supposedly explain the apparent irreducibility of the biological phenomena. To state such thing is proof of a deeply rooted belief that might be historical, but that in no case constitutes an exercise of critical rationality.

Therefore, what in the ontological field unveils a gratuitous dogmatism, in the methodological field results not only justifiable, but required, because of the very nature of the scientific enterprise: "...I will suggest that scientists, whatever their philosophical attitude towards holism, *have* to welcome reductionism as a *method*: they have to be either naive or else more or less critical reductionists; indeed, somewhat desperate critical reductionists, I shall argue, because hardly any major reduction in science has ever been *completely* successful: there is almost always an unresolved residue left by even the most successful attempts at reduction."¹⁴

Popper's observance is interesting for more than one reason. The problem of ontological reductionism goes beyond knowing if animals and plants are assimilable to stones. From a practical point of view, this problem is used to try to reduce the living beings to theoretical and conceptual models that the Western tradition of thinking has created to explain the non-living ones. It must be said —following Popper— that even the stones cannot be reduced to physical and chemical concepts, because the real thing we refer to with that substantive ("stone") falls beyond the precise meaning that we tried to impose on them through different theories. On the other hand, to discuss if biology is (or not) reducible to physics and chemistry is a more feasible matter, although of less theoretical importance. The specificity of the concepts, laws, language and methodology of the sciences that study life of other kinds of objects is historical, relative and circumstantial. It is then, something respectable but provisional. The transformation of the limits between sciences into permanent ones must be avoided, or we would be enshrining historical forms, turning them into absolute and untouchable, when the truth is that sciences evolve as its content evolves.

How can we explain, for instance, that chemistry must be confined within physics? Why is it limited by mechanics, electromagnetic theory or thermodynamics on one side, and by atomic, nuclear and particle physics, on the other? If in the mid 19th century, the border between both subjects was at the molecular level, why was the subatomic world attributed to physicists? The answer is that it was the consequence of a historical accident: the electron was discovered by electricity specialists like J. J. Thompson, that were studying the behaviour of cathodic rays. The birth of molecular biology is also an example on how a border territory was colonized by opportunists with a variety of backgrounds: physicists like Delbrück y Crick or chemists like Pauling.

All things considered, the relevant question is not to know if the laws of biology are (or not) reducible to the ones of chemistry or physics, because it is always possible to redefine, from a wider logical approach, a law concept able to comprise any rule, no matter what phenomenical world is involved or the formalisms used. The important thing is to know whether reality can or cannot be reduced to a given corpus of laws, or what we call "reality" is in fact so complex that will always surpass any finite rationalization used to seize it. Everything else is guild quarrels, feud disputes; topics to be debated by trade unions.

¹⁴ POPPER, K. R., "Scientific Reduction and the Essential Incompleteness of All Science," p. 260.

The philosopher must be less worried about deciding if thinking is reduced to the integrated functioning of a group of neurons, or if life is something more than the concurrence of a bunch of molecules than about knowing if our concepts of neuron or molecule comprise faithfully the reality that they are supposed to objectify. I suspect they do not. Quantum mechanics has already questioned the objective truth value of the concepts that refer to the most elementary levels in the material world. It would be incongruous for ingenuous realism to receive a validation where a highest grade of complexity appears.

3. THE EPISTEMOLOGICAL STATUS OF DARWINISM

When encouraging the methodological reductionism and condemning the philosophical one, Popper is coherent with the principles of his epistemology. Even more, he is able to organize his own position to face the Theory of Evolution, which is quite ambivalent. The difficulties that many philosophies of science had to face to classify the Darwinist theory are well known, as in many aspects it results unclassifiable. It is indubitable that it does not meet the test of falsifiability, and therefore, it fails to observe the key criteria to grant it scientific status.

Summing up his different thoughts, which he possibly recalled over and over again through many years, Popper relates in his intellectual autobiography that “the question of the scientific status of the Darwinian theory becomes an interesting one.”¹⁵ He adds below, “I have come to the conclusion that Darwinism is not a testable scientific theory,” what can be regrettable from several points of view, but he immediately reshapes it: “but a *metaphysical research programme* —a possible framework for testable scientific theories.”¹⁶

Doubting about the epistemic precision of Darwinism is considered somehow scandalous, given that it is the foundation pillar for contemporary world conceptions, these being supposedly scientific. Popper dares to touch a point that many minds would consider unbearably sore, but, as the good late Enlightenment thinker that he claims to be, he saves *in extremis* the surrounded fortress by granting it the honorary rank of “metaphysical research programme,” i.e., of something that is not refutable, but that may endure certain rational discussion. In a subsequent paragraph, he compares it with theological conceptions, and considers Evolution preferable to those, due to the following reasons:

“Its theory of adaptation (Darwin’s) was the first nontheistic one that was convincing; and theism was worse than an open admission of failure, for it created the impression that an ultimate explanation had been reached. Now to the degree that Darwinism creates the same impression, it is not so very much better than the theistic view of adaptation: it is therefore important to show that Darwinism is not a scientific theory but metaphysical. But its value for science as a metaphysical research programme is very great, especially if it is admitted that it may be criticized and improved upon.”¹⁷

¹⁵ POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, Open Court, La Salle, IL, 1982 (first edition, 1974), p. 168.

¹⁶ POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, p. 168.

¹⁷ *Unended Quest. An Intellectual Autobiography*, p. 172.

Popper is an enemy of enclosures: he proposes an open society and believes that the world is wide open and he demands that theories and subjects should also have an open character. He opposes theological explanations, because, in his opinion, it is incompatible with any attempt of critical reevaluation, and he pretends to fully stop inquiry dynamics. It would be interesting to discuss if every religious and theological conception is heading, out of necessity, towards confinement into an acritical self-affirmation. It is indubitable that some of them already do so, these being the ones we can define as theological fundamentalisms. Popper is wondering whether some representatives of Darwinism are not falling under the same bad habit. He believes that the bad side of a theory is not so much the lack of empirical contrast, i.e., the fact of being of metaphysical nature, but the lack of rational contrast, that is, unable to endure criticism and to be subject for improvement.

4. NATURAL SELECTION AND FALSIFICATIONISM

The possible interest of this comparison is surpassed, at least in what regards personally to Popper, by another one: the comparison that he establishes between the Darwinist theory and its own epistemology, as both present surprisingly common features. In *The Logic of Scientific Discovery* he had already drawn attention over this point: “we choose the theory which best holds its own in competition with other theories; the one which, by natural selection, proves itself the fittest to survive. This will be the one which not only has hitherto stood up to the severest tests, but the one which is also testable in the most rigorous way.”¹⁸

Later on, in *Unended Quest*, he confirms this relationship: “should the view of Darwinian theory as situational logic be acceptable, then we could explain the strange similarity between my theory of the grow of knowledge and Darwinism: both would be cases of situational logic.”¹⁹ Such similarities indicate that both Darwin’s and Popper’s theoretical proposals have to overcome the same obstacles and answer to similar criticism related to their justification and solvency. None of them is subject to empirical falsification, and this grants them some metaphysical, or even metatheoretical, character. Popper wishes to locate them in the theoretical matrix of specific scientific knowledge.

Both are sources of inspiration for possible theories, for future experiments, and thus are presented as “Theory of Evolution of Species” and “Evolutionary Theory of Knowledge.” Also, they serve as protocols to comprehensively articulate the past of the processes contemplated, as History of the Evolution of Life on one side and as History of the Evolution of Knowledge on the other. In 1989, Popper delivered a lecture in the London School of Economics where he went deeply into these considerations. He gave it the significant title of “Towards an Evolutionary Theory of Knowledge.”²⁰

Parallelism between Popperian falsificationism and Darwinian Evolutionism are evident, they are born from the symbiosis of a random element and a necessary one. The unknown sources of hereditary variations match with the no less mysterious forces that inspire new hypothesis. To inquire in the etiology of specific mutations is a not

¹⁸ POPPER, K. R., *The Logic of Scientific Discovery*, Hutchison, London, 1959; revised edition in 1968, reprinted in 1980, p. 108.

¹⁹ POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, p. 169.

²⁰ Cf. POPPER, K. R., *A World of Propensities*, Thoemmes, Bristol, 1990, pp. 27-51.

very promising task, and the same happens when the context of discovery is studied. Maybe there is a cause explanation for these events: there is the study of mutagenesis and the psychology of invention to try to find it. But, for practical purposes, biological evolutionism, together with the epistemological one, might consider them random. The important is that both biological species and subjects of knowledge are able to learn from their mistakes and start a rectifying dynamic to fulfill an increasingly excelling path. The fight for life and the empirical contrast are in charge of this expedient, due to an element of negative rationality endowed with indubitable efficiency. Disadvantaged living organisms succumb, inefficient theories too.

Any comparative analysis risks making do with vaguer analogies and ending up tied to tangential similarities. On the other extreme, it may artificially pretend the existence of formal identity. In the present case, it is easier to fall into the first than into the second, because there is, at least, a crucial difference: while most part of the ancient and modern Darwinists were ontological reductionists and epistemological antireductionists, Popper defends the opposite option: "my position may thus be described as one that upholds a theory of *irreducibility and emergence*."²¹ In these conditions it would be desirable to reach two things: First, not to agree with the verification of common features, but to investigate their source. Second, to explain why, after starting from very close premises, gets driven to such different conclusions.

To grant a bigger entity to the coincidences between evolution by natural selection and falsificationism, what Popper does is to generalize some gnoseological notions, such as "knowledge" and "a priori." This way, he is almost able to turn his knowledge theory into ontology, or even a conception of the world. As a first step, he attributes knowledge not only to humans, but to animals, too. "The proposition that *animals can know something* completely revolutionizes the theory of knowledge as it is widely taught."²² It is a semantic extension in full order, because, by taking a step further, he attributes it also to plants and to any organism. "Can only animals know? Why not plants? Obviously, in the biological and evolutionary sense in which I speak of knowledge, not only humans and animals have expectations and therefore, (unconscious) knowledge, but also plants; and, indeed, all organisms."²³

Are we in front of a case of anthromorphism, or is it unanthromorphism? Does Popper project human prerogatives to the outside, or, on the contrary, he deduces them from non-contrastable biological attributes? It seems that the latter is his intention, because he asserts: "all adaptations to environmental and to internal regularities, to long-term situations and to short-term situations, are kinds of knowledge, kinds of knowledge whose great importance we can learn from evolutionary biology."²⁴ We know he is a partisan of Tarski's theory of truth, what allows him to recover Aristotle and his doctrine of truth as an adjustment. However, this adjustment does not have to be restricted to a premeditated adaptation of mental forms to things that are external to the mind, as any proposal can be satisfied or frustrated, even if it is unconscious or innate.

²¹ POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, p. 178.

²² POPPER, K. R., *A World of Propensities*, Thoemmes, Bristol, 1990, p. 30.

²³ *World of Propensities*, Thoemmes, Bristol, 1990, p. 35.

²⁴ POPPER, K. R., *World of Propensities*, p. 38.

5. EVOLUTIONARY CONCEPTION OF KNOWLEDGE

According to Popper, human knowledge is no more than a particular case of adjustment to expectations. That is why he even states that: “thus, the origin and the evolution of knowledge may be said to coincide with the origin and the evolution of life, and to be closely linked with the origin and the evolution of our planet earth.”²⁵ I wonder the reason why, as he is generalizing, he stops at this point, and he does not state, for instance, that the electron is predisposed to rotate around the atomic nucleus, and in this sense, “holds certain knowledge” of the quantum orbitals, etc. The frontiers of knowledge could then enlarge considerably and even reach the very origin of the universe. Without going that further, the fact of releasing knowledge from consciousness allows preserving for the man an exclusive prerogative and turns knowledge into the key of an omnicomprehensive evolutionism.

Every living being interplays with the environment, sets off by testing a set of formulas that are its innate endowment, and those receive along its existence a positive or negative sanction, on which the survival of the proposer depends, as well as the enshrinement or rejection of the innovations embodied in them, and the subsequent evolution of the living or cognitive systems involved. Here, Popper builds a bridge towards Kant, revaluing his notion of “a priori”: “in my opinion, Kant anticipated the most important results of the evolutionary theory of knowledge. But I am going much further than Kant. I think that, say, 99 per cent of the knowledge of all organisms is inborn and incorporated into our biochemical constitution.”²⁶

It is obvious that Popper’s Kantism is quite unorthodox, because in the creator of idealism he criticized the resort to the “a priori” as a way of overcoming the necessity (apodicticity) of certain knowledge, while his Austrian follower equalizes the aprioric with the merely conjectural, which translates into mere risky prejudices, that despite everything are useful to build a rigorous epistemology with uncertain materials.

Let us illustrate it with a pair of specific cases. A tiger born in a world without edible prey would receive its paws and teeth as a hereditary flaw soon to be eliminated from the scene. Nor will prosper whoever has been imbued during his childhood with absurd prejudices about decisive matters. What happens is that the members of the human species have a much higher possibility of surviving their own mistakes than animals or plants. It must be bore in mind that the “subjects” of biological knowledge are not the individuals, but the species of, even more, the phylogenic lines while in the case of “human” knowledge, the subjects are the individuals and, through diversion, the schools, thinking traditions, and as a last resort, cultures. Thanks to this difference, our theories die for us, as Popper states so graphically, except —it is possible to add— that we tie up to them as a captain to his boat. But we all have to learn. Adventurous conjectures —in fact gratuitous— are the compulsory starting point, unless we count on the ancestral failures of our stock.

Natural selection is the procedure to incorporate to our genes that lesson, in the sense that none of the ancestors of any living being was eliminated in the fight to get on living. As Dawkins indicates, “genes that penetrate into the future are not an aleatory simple, but an elite. They have survived glaciations and draughts, plagues and predators, demographic

²⁵ *World of Propensities*, p. 39.

²⁶ POPPER, K. R., *World of Propensities*, p. 46.

increasing and decreasing.”²⁷ In what affects the man, critical rationality is, in Popper’s opinion, the best expedient to avoid risking one’s life to find the unknown. But no one has a direct line with truth, so everything is reduced to biological or gnoseological techniques to opt for the less advisable prejudices.

For Popper, “The invention of the eye is thus an invention of a new theoretical *a priori* knowledge, on an adaptation to the environment. It was from the first an adaptation to a long-term environmental structure: to the existence of potentially edible sunlight, in thus incorporates knowledge of this environmental structure. It is theoretical knowledge of a high degree of universality, almost like Kantian knowledge of space and time.”²⁸

6. THE REAL AND THE RATIONAL

Considered from a certain angle, both the Darwinist theory of evolution as the Popperian theory of gnoseological evolution are so plausible that they can be considered trivial. If hereditary variations and preferential elimination of the less fit exist, positive variations are obviously cumulative. If new hypothesis are constantly emerging and all of them are tested somehow, errors keep being discarded. These theses are as obvious as geometrical theorems. The only doubt in both cases is if this planet is a scenery with the degree of transparency and rationality that Darwin and Popper presuppose.

It must be remembered, however, that Darwin had less confidence than his followers in the goodness of natural selection. Popper does not think, either, that humanity is habitually governed by falsificationism criteria, but in his opinion this circumstance does not invalidate it, just retards its operability. The problem comes when efficiency at the time of discard bad options is low, because the job to be fulfilled threatens to become too arduous. The number of harmful biological variations and epistemic errors is infinite, incommensurably higher than the number of viable solutions and correct statements. From a combinatorial point of view, the task becomes overwhelming and the weight of random is difficult to counterweight with necessity. Unless, of course, that there exist servomechanisms to increase exponentially the discriminatory virtues of natural selection and falsification.

Neo-Darwinists believe that the cumulative nature of natural selection is enough to reestablish the balance. Selection does not face the whole spectrum of possible variations at a time, but it actuates generation after generation under the principle of “all or nothing.” This allows to thoroughly eliminating the sequels left by harmful variations, in a manner that, in time, the number of options to be scrutinized will decrease in geometrical proportion. Nevertheless, the matter is still a controversy, especially because the strength of the argument depends on the strict continuity in the process of appearance and filtering of variations, which is not clear at all from the available data (due to genetic derivation, mass extinction events, vertiginous hatching of new species, etc.).

Surprisingly, over the Evolutionary Theory of Knowledge are looming some parallel threats. It would be easier to believe in the explanatory virtues of falsifiability if the progress of learning would have followed a less inconsistent rhythm of growth, if interferences of

²⁷ DAWKINS, R., *Climbing Mount Improbable*, Penguin Books, London, 1997.

²⁸ POPPER, K. R., *World of Propensities*, p. 49.

every kind would not have tarnished over and over again the methods of confronting the hypothesis with the experience, if the heuristic processes were less complex and closer to the logic of random.

The fact that Popper appeals, with more and more stress every time, to speculative theoretical frameworks, like the “metaphysical research programmes,” obscures the pure dialectics of random-necessity from his Evolutionary Theory of Knowledge and contaminates it with what I would name “orthogenetic tendencies” at the time of exploring new paths in the road to knowledge. It is like the blind mechanism of empirical falsification is not enough and the investigator had to appeal to some sort of metempirical intuition to guess where future conjectures should point to. To go on with evolutionary biological analogies, it is like if Dawkins’ blind watchmaker was cheating and looking under the mask that covers his face.

7. ORTHOGENESIS

The most curious of all this is that Popper tries to reintroduce the orthogenetic point of view in evolutionary biology. In the Spencer lecture of 1961 he made a proposal in this direction. He demonstrated to be quite daring, given that he was far from being an authority on this subject. In fact, he confesses in an appendix written a decade later that certain specialist discouraged the publication of the article.²⁹ But by acting in this way, he was following the steps of another big meddlesome and amateur, physicist Erwin Schrödinger, whose book *What is Life?* played a controversial role in the origin of molecular biology.³⁰

Popper has confessed the influence that this author had over his thought, with whom he also sustains big disagreements.³¹ The truth is that in the field of analogies, the Austrian physicist had already explored the ones existing between Darwinism and statistical mechanics.³² In reference to orthogenetic debate, “Schrödinger sustained that from a philosophical point of view, Darwin’s solution turns out to be pessimistic and discouraging (due to the passivity implied on the living being with respect to evolution), while Lamarck’s is, on the contrary, beautiful, encouraging and invigorating (because it grants a central role to organisms in the improvement of the descent).”³³

To recover this richness lost in the development of the Theory of Evolution, he proposed a middle solution, the adaptation efforts of the living beings do not alter its genetic material, but certain decisions, like moving to a different habitat, may modify the conditions in which natural selection occurs, as selection pressures change substantially (for instance, the ones related with climate, food, predators, etc).³⁴ The first chaffinches that migrated from the American continent to the Galapagos Islands, to put an example, did not change

²⁹ POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, p. 281.

³⁰ SCHRÖDINGER, E., *What is Life? The Physical Aspect of the Living Cell*, Cambridge University Press, Cambridge, MA, 1944.

³¹ Cf. POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, pp. 135-138.

³² Cf. ARANA, J., “Erwin Schrödinger, filósofo de la Biología,” in ARANA, J. (ed.), *Los filósofos y la Biología*, monographic issue of *Thémata*, Sevilla, 1998, pp. 171-172.

³³ ARANA, J., “Erwin Schrödinger, filósofo de la Biología,” p. 172.

³⁴ SCHRÖDINGER, E., “The Future of Understanding,” in SCHRÖDINGER, E., *Gesammelte Abhandlungen*, vol. 4, V. O. A. W., Vienna, 1984, pp. 468-473.

their genes, but they made natural selection to act upon them in a very different manner from the one they underwent in the original place.

The Popperian proposal keeps certain relationship with the one from his distinguished fellow countryman, even though it carries the mark of theoretical ambition typical of the philosopher, does not stop in “rescuing” Lamarck, as it also tries to rehabilitate options so discredited like Vitalism and Animism: “to put it briefly, my dualistic hypothesis allows us, in principle, to accept not only simulated Lamarckism, but also a simulated vitalism and animism; and it thus ‘explains’ these theories as first approximations. It thereby allows us, in principle, to explain the evolution of complex organs such as the eye by many steps leading in a definite direction.”³⁵

The master idea of this recover is substantially the same as in Schrödinger’s: The living being behaviour does not influence in the conformation of its seminal fluids, but it alters the external circumstances that surround its existence. Consequently, the selection mechanisms that lie upon the future mutations will favour those that align with the new conditions. There is no “inheritance of the acquired characters,” but it is possible to choose and bequeath the dynamism that will enshrine the characters that are advisable to obtain.

To reinforce this thesis, Popper bases himself in the idea of “hopeful monster” proposed by Richard Goldschmidt,³⁶ transforming it into the model of “behavioral monster.” Simplifying a lot, it is equivalent to saying that there were not mere mutations the ones that turned regular squirrels into flying squirrels, but that some of those began to live in environments where the ability to glide constituted a decisive survival factor. Their mutations continued to be as fortuitous and unpredictable as always, but the mechanism that turned them into part of the common core of the group had been reoriented in the most favorable direction. Thus, the living beings cannot determine the variations of their descent, but they can determine the sort of variations that will be generalized among their descendants as soon as the opportunity arises:

“I thus submit a variation of Darwinism in which behavioural monsters play a decisive part. Behavioural novelty leads, if successful, to the selection of those ecological niches which in their turn operate selectively-operate, that is, to make use of these behavioural novelties and thus exert a selection pressure in a partly predetermined direction: in the direction determined by some genetically possible undetermined *aim*, for example a taste for a new kind of food, or an enjoyment of utilizing light-sensitive regions of the skin. Thus we may get orthogenesis which, after all, was Goldschmidt’s main problem. (...) The anatomical structure can change only slowly, in the main. But its changes will for this very reason remain insignificant if they are not guided by those in aim-structure and skill-structure. Thus the evolution of a genetic apparatus establishing a primacy of aim-structure and skill-structure over anatomical structure might, in principle, be explained on Darwinian lines. (...) It will be seen that this Darwinian. theory of hopeful behavioural monsters ‘simulates’ not only Lamarckism, but Bergsonian vitalism also.”³⁷

³⁵ POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, p. 279.

³⁶ Cf. GOLDSCHMIDT, R. B., *The Material Basis of Evolution*, Yale University Press, New Haven, CT, 1940.

³⁷ *Objective Knowledge. An Evolutionary Approach*, pp. 283-284.

The capacity of generalization is one of Popper's most characteristic features as a philosopher. He proposes a Lamarckism without Lamarck, a Vitalism without vital principles or entelechies, and an Animism without soul. In fact, it is the same thing that Darwin did with teleology thanks to natural selection: to sponsor a finalism without ends. The speculation is daring but by no means rejectable. Popper's problem is that sometimes he is not able to restrain himself and enters excessively into first-line scientific debate. The same happened to him during the discussions that followed the development of quantum mechanics: instead of moving carefully in the field of metatheoretical reflections, he had to proposed a "mental experiment" to mediate in the controversy between Einstein and Bohr, incurring in a beginner's mistake, that —he expressed later— plunged him into a deep depression, and, dissuaded him from entering into this topic again for years.³⁸

In the field of biological studies he also carried out certain incursions that I do not believe were in favour with the professionals of this field. Such is the conjecture of "genetic dualism," which consists in distinguishing, within organisms, the part that controls the behavior and the executive part, to state immediately afterwards that hereditary mutations are transmitted separately on each of the two subsystems.³⁹ With this, he pretends to grant organic status to his Neo-pseudo-Lamarckism, and also to introduce a biological proto-dualism that is the prelude to the old distinction between body and soul. Other proposals are ever more daring, and possibly reveal the impatience to enter the field of facts in a philosopher of his kind, that can properly be described as an "enlightened empiricist" (i.e. "all for the experience, but without the experience."

That is the way I understand his impetuous discussion of the explanations about the origin of life on Earth, where he aligns in favour of certain options and against some others with excessive vehemence.⁴⁰ On the other hand, he maybe has been a victim in all these passages of an excess of intellectual probity: given that he defends an epistemology of the risk in which theories do not avoid, but rather search for occasions of being refuted by the facts, maybe he applied this precept to himself with similar boldness, without totally assuming that —after all— he was also moving within the framework of "metaphysical research programmes."

8. THE LIFE TREE AND THE KNOWLEDGE TREE

I have one last point before finishing this presentation. I stated before that Popper detected a deep parallelism between his Theory of Knowledge and Darwin's Theory of Evolution. Nevertheless, his position in front of the problem of reduction is opposite from the one of most part of Darwinism representatives. Should we reason about this discrepancy? In *The Self and Its Brain* he summarized the reasons that backed him:

"However, I think that it is important that we note that there are *two different* ways by which we can search for simplicity. They may be called, briefly, philosophical reduction and scientific reduction. The former is characterized by an attempt to provide bold and testable theories of high explanatory power. I believe that the latter is an

³⁸ Cf. POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, pp. 92-94.

³⁹ Cf. *Objective Knowledge. An Evolutionary Approach*, pp. 272-273.

⁴⁰ POPPER, K. R., *World of Propensities*, pp. 40-44.

extremely valuable and worthwhile method; while the former is of value only if we have good reasons to assume that it corresponds to the facts about the universe.”⁴¹

Einstein disbelieved that God decided by throwing the dice. He thought that he was subtle but not evil. We must suppose that in his opinion to play dice is a feature of evil if it is God who plays. Popper, who disagrees with Einsteinian determinism, possibly considers it a detail of sophistication.

On the other hand, after deepening into the similarities of Darwinian evolution and of knowledge, he finds a clear difference between them: “The evolutionary tree grows up from a common stem into more and more branches. It is like a family tree: the common stem is formed by our common unicellular ancestors, the ancestors of all organisms. The branches represent later developments...”⁴² The growth of applied knowledge follows a similar path, but pure knowledge evolves rather towards simplicity, towards theories more and more integrated:

“Assuming the same upward direction of time, we should have to represent the tree of knowledge as springing from countless roots which grow up into the air rather than down, and which ultimately, high up, tend to unite into one common stem. In other words, the evolutionary structure of the growth of pure knowledge is almost the opposite of that of the evolutionary tree of living organisms, or of human implements, or of applied knowledge.”⁴³

It is a bit difficult to envision this image, but in short, what we have is an upside down tree, with the branches pointing down and the common trunk stemming from the structure like an arrowhead pointing towards the impossible culmination of truth, that is always further away from our inquiries. On the other hand, the truth is that common trees also develop underground, in the roots. That is why is a mirage to believe that branches stem from a single principle, according to the rules of monistic simplicity. In the tree of knowledge everything is at first sight. That is why the roots are up in the air and the crown does not exist: it is just an aspiration and a promise.

Both in biological evolution and in gnoseological evolution there exists a synthesis of unity and diversity, of trunk and branching, of necessity and contingency. Likewise, in both there is something that we do not see, in one case it is the roots —the ultimate principle where life comes from— and in the other it is the branches the absolute truth towards we try to direct our steps. We do not see them because, as Kant would say, these are regulatory principles and because both the world we live in and the world of knowledge are structures of impossible culmination, realities that will always be open.

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⁴¹ POPPER, K. R. and ECCLES, J. C., *The Self and Its Brain*, Springer, Berlin, 1977, p. 60.

⁴² *Objective Knowledge. An Evolutionary Approach*, p. 262.

⁴³ POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, pp. 262-263.

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RATIONALITY AS EVOLUTIONARY ADAPTATION IN HERBERT A. SIMON. A COMPARISON WITH KARL POPPER AND REINHARD SELTEN

FRANCISCO J. CASTRO

Evolutionism has impregnated multiple aspects of the philosophy and methodology of science. Among its areas of influence are epistemology, in a case as representative as rationality, and the methodology of social sciences, especially in psychology and economics. One of the authors in whom this phenomenon can clearly be distinguished is Herbert Simon, winner of the Nobel Prize for Economics in 1978, who developed a theory of “adaptive rationality.” This author in turn influenced Reinhard Selten, winner of the Nobel Prize for Economics in 1994 and proponent of rationality as an adaptive toolbox. The present study analyzes how human rationality is seen in evolutionary terms as adaptation and on some of the consequences that stem from this approach.

1. AN ALTERNATIVE MODEL OF RATIONALITY: ADAPTIVE RATIONALITY

In *Reason in Human Affairs*, a book published in 1983, Simon offers three possible alternatives when it comes to “rationality.”¹ He thus presents three different manners of understanding how human beings make decisions. It is a question of an attempt to include the most representative types of processes for the making of rational decisions. He calls the first form the “Olympian model.” It is rationality that supports the mainstream current in economics, the neo-classical trend, where it is assumed that human beings always look for an optimization of the expected subjective utility.² The second type he refers to as the “behavioral model.” This model understands that, in the decision-making process, human beings use a *bounded rationality*, due to the limitation of their cognitive and computational capacities.³ In Simon’s opinion “there is a great deal of empirical evidence supporting this kind of theory as a valid description of how human beings make decisions.”⁴ The third possibility is the “intuitive model.” This approach highlights the processes of intuition that intervene in the decision-making process, although he is of the opinion that the intuitive model is but one more component of the behavioral theory of rationality.

¹ Cf. SIMON, H. A., *Reason in Human Affairs*, Stanford University Press, Stanford, CA, 1983, pp. 34-35.

² Simon also calls this type of rationality “Robinson Crusoe’s Rationality.” Cf. SIMON, H. A., “Some Strategic Considerations in the Construction of Social Science Models,” in LAZARSFELD, P. (ed.), *Mathematical Thinking in the Social Sciences*, The Free Press, Glencoe, IL, 1954. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, The MIT Press, Cambridge, MA, 1983 (2nd reprint), pp. 215-217.

³ Cf. SIMON, H. A., “Bounded Rationality,” in EATWELL, J., MILGATE, M. and NEWMAN, P. (eds.), *The New Palgrave: A Dictionary of Economics, vol. 1*, Macmillan, London, 1987. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 3: Empirically Grounded Economic Reason*, The MIT Press, Cambridge, MA, 1997, p. 291.

⁴ SIMON, H. A., *Reason in Human Affairs*, p. 34. For him, limitations in human rationality are expressed in that: 1) the agent only has an incomplete information regarding the possible alternatives; and 2) the limitations introduced by the environment prevent the chooser from calculating which would be the best course of action, bearing such limitations in mind. Cf. SIMON, H. A., “Theories of Bounded Rationality,” in McGUIRE, C. B. and RADNER, R. (eds.), *Decision and Organization*, North-Holland, Amsterdam, 1972. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 410-411.

To these three visions of rationality he adds a fourth approach: *rationality as evolutionary adaptation (evolutionary model of adaptation)*, where an epistemological and evolutionary influence can be appreciated. In this approach, the evolutionary process is, in itself, a model of rationality, since the organisms that adapt to the environment with the aim of surviving act *as if* they were rational. They select the most appropriate means of adapting to their environment.

1.1. Bounded Rationality and Rationality as Adaptation

Simon seeks to examine whether this kind of rationality is applicable to human rationality and to what extent. He thus tries to connect this fourth possibility to his theory of bounded rationality, whereby the human beings follow a rationality circumscribed by the limited capacity of processing information when it comes to making rational decisions.⁵

Through its epistemological conception, Simon insists that there is a limit to the rational ability of human beings. Human beings are only able to make a calculation taking into account a limited number of variables relevant to a situation; their cognitive limitations prevent them from knowing all the variables that come into play.⁶ They are limitations that affect, on the one hand, the agent himself who makes decisions and, on the other, the agent who tries to predict the decision that the other will make. The first is affected because he has limitations of calculation, which prevent him from making the most profitable decision for him; and the second agent also is limited: he cannot know all the characteristics of the *environment* in which the decision will be made and the *perception* that the agent has of this environment.

Simon highlights a fundamental distinction that neo-classical theory fails to make: the difference between the objective environment that surrounds the individual and this person's perception of the above-mentioned environment;⁷ and this is more relevant in complex situations.⁸ In my opinion, this has a decisive effect on the possibility of

⁵ For Simon, the idea that human rationality is bounded is not recent, but had already arisen in classical times, since at that time attention had been paid to rational human limitations. Cf. SIMON, H. A., "Bounded Rationality in Social Science: Today and Tomorrow," *Mind and Society*, v. 1, (2000), pp. 26-27.

⁶ These limitations also prevent the human being, in Simon's opinion, from realizing all the calculations that would be necessary to predict with certain guarantees a certain social situation. Cf. SIMON, H. A., "Rationality," in GOULD, J. and KOLB, W. L. (eds.), *A Dictionary of the Social Sciences*, The Free Press, Glencoe, IL, 1964, pp. 573-574. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 405-407.

⁷ Cf. SIMON, H. A., "Economics and Psychology," in KOCH, S. (ed.), *Psychology: A Study of a Science*. Vol. 6, McGraw Hill, New York, 1963. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, p. 342. For him, in neo-classical theory such a distinction is not made, since if it is assumed that the individual has unlimited rationality, he will perceive the world as it is: he will have an objective perception of the world and not a merely subjective one. Cf. SIMON, H. A., "Rationality in Psychology and Economics," *Journal of Business*, v. 59, (1986). Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 3: Empirically Grounded Economic Reason*, pp. 368-370.

From Simon's point of view, rational behavior is as determined by the "internal environment" of the people's minds as by the external environment of the world in which they act. Cf. SIMON, H. A., "Bounded Rationality in Social Science: Today and Tomorrow," pp. 25-26.

⁸ Cf. SIMON, H. A., "Rationality as Process and as Product of Thought," *American Economic Review*, v. 68, n. 2, (1978). Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 451-452.

making *predictions* about the agent's behavior, because the objective characteristics of the environment are not the same as those perceived by the individual.

Herbert Simon is an open critic of the model of rationality underlying the neo-classical trend in economics, namely rationality as optimizer of expected subjective utility, in which human beings always seek the optimal outcome when making decisions. He criticizes this kind of rationality because he understands that it "assumes that the decision maker contemplates, in one comprehensive view, everything that lies before him."⁹ In other words, the rational agent is not only aware of all the possible alternatives that fit at any one time, but is also capable of capturing those alternatives that, with greater or lesser probability, could appear in future states of the world.¹⁰

For Simon, the theory of maximization does not describe real human behavior. He questions it because human beings do not have the necessary power of reasoning to take into consideration all the possible variables and alternatives, not even in situations of relatively simple choice.¹¹ In contrast to this model, which he calls "Olympian," Simon sustains that the "behavioral model" is closer to the real way in which humans make decisions. It is a model based on bounded rationality, in that our computing and decision-making capacity is limited and "the choices people make are determined not only by some consistent overall goal and the properties of the external world, but also by the knowledge that decision makers do and don't have of the world ..."¹²

When he offers this "behavioral version" of bounded rationality, Simon relies on two affirmations: a) there is enough empirical bases to sustain that this is how, in fact, people make decisions and solve problems. He considers that it is a theory that irrefutably describes human behavior;¹³ b) this theory would explain also how organisms actually survive in such a complex and constantly evolving world, in spite of their limited calculating capacity.¹⁴ With these ideas he indicates why he prefers the model that seeks to satisfy our needs, rather than the model based on the optimization of the expected subjective utility.¹⁵

This behavioral model that he uses with regard to economics has links with psychology and takes into consideration the bounded rationality of agents, particularly in choices where there is a degree of uncertainty.¹⁶ The substitution of the supposition

⁹ SIMON, H. A., *Reason in Human Affairs*, p. 13.

¹⁰ Cf. *Reason in Human Affairs*, p. 13.

¹¹ In his view, the real world is so complex that the theory of the maximization of utility is therefore of little relevance when making real choices. Cf. SIMON, H. A., "Theories of Decision-Making in Economics and Behavioral Science," *American Economic Review*, v. 49, n. 1, (1959). Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 292-293.

¹² SIMON, H. A., "Bounded Rationality in Social Science: Today and Tomorrow," p. 25.

¹³ Simon is aware of the difficulties in discovering the bases that govern the behavior of human choice. Cf. SIMON, H. A., "Decision-Making and Problem Solving," *Interfaces*, v. 17, n. 5, (1987), p. 20.

¹⁴ Cf. SIMON, H. A., *Reason in Human Affairs*, pp. 22-23.

¹⁵ Herbert Simon mentions six variables to bear in mind in the study of economics based on the theory of bounded rationality: i) continuous changes in knowledge and information regarding economics and the world; ii) changes in the human ability to estimate the consequences of actions; iii) changes in the institutional environment in which economic behavior takes place; iv) variations in the area of attention and in beliefs and expectations; v) changes in human altruism; and vi) modifications in group identity. Cf. SIMON, H. A., "Economics as a Historical Science," *Theoria*, v. 13, n. 32, (1998), pp. 241-260, especially pp. 251-258.

¹⁶ Cf. SIMON, H. A., "Economics and Psychology," pp. 330-337.

of “maximization” in favor of the idea of “satisfaction” is the axis around which Simon’s methodological approach to economics revolves. He proposes this alternative on the basis of the empirical observation that, in his view, has shown that when making rational decisions individuals seek merely to satisfy, rather than maximize expected subjective utility.¹⁷

He appreciates that there is a close analogy between human behavioral rationality and the Darwinian model of evolution. Thus, in behavioral theory, a selective search is needed in order to make a rational choice: an adaptive response to the environment that satisfies our needs has to be selected, in accordance with the agent’s “level of aspiration.” For Simon, this mechanism by which human agents relate to the environment “is the direct analogue, in the behavioral theory of rationality, of the variation-selection mechanism of the Darwinian theory.”¹⁸

Simon thinks that rationality is adaptive, both in the Darwinian theory of evolution and in the behavioral theory of human decision-making. For him, organisms adapt to *satisfy* certain needs and aspirations, not to *optimize* subjective utilities.¹⁹ In the case of human rational decisions there comes into play, in his view, a rationality that does not seek optimization, but rather alternatives that enable aspirations to be satisfied and provide a solution to the problems of adaptation affecting organisms.²⁰ In this respect, he maintains that the rationality that supports evolutionary processes is a rather “myopic” one:²¹ it is not a process of optimization but only a process of *improvement*, that seeks to satisfy needs. Thus, Simon argues that “the outcome of evolutionary processes may be regarded as a form of rationality.”²²

Simon believes that *optimization* or maximization is based on conscious deliberation and foresight and intuition, whereas *adaptation* always requires *survival* and *movement* towards *equilibrium*.²³ For him, optimizing behavior denotes a conscious search for the best choice, whereas what adaptive behavior shows is a movement towards something better, without the conscious intervention of any type of optimizing mechanism.²⁴

¹⁷ Cf. SIMON, H. A., “From Substantive to Procedural Rationality,” in LATSIS, S. J. (ed.), *Method and Appraisal in Economics*, Cambridge University Press, Cambridge, 1976. Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 430-432. Here he gives his famous example of chess players, who as soon as they find an alternative that satisfies their expectations, their “level of aspiration,” cease to look for other alternatives. Cf. SIMON, H. A., “A Behavioral Model of Rational Choice,” *Quarterly Journal of Economics*, v. 69, (1955). Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 250-251.

¹⁸ SIMON, H. A., *Reason in Human Affairs*, p. 40.

¹⁹ Cf. SIMON, H. A., “Rational Choice and the Structure of the Environment,” *Psychological Review*, v. 63, n. 2, (1956). Reprinted in SIMON, H. A., *Models of Bounded Rationality. Vol. 2: Behavioral Economics and Business Organization*, pp. 259-260.

²⁰ Cf. SIMON, H. A., *Reason in Human Affairs*, pp. 41 and 73-74.

²¹ Cf. *Reason in Human Affairs*, p. 66.

²² *Reason in Human Affairs*, p. 38.

²³ Cf. SIMON, H. A., “Some Strategic Considerations in the Construction of Social Science Models,” pp. 217-221.

²⁴ Cf. “Some strategic considerations in the construction of Social Science Models,” pp. 219-220.

1.2. Instrumental Rationality and Evaluative Rationality

Simon maintains that a special kind of teleology applies to the evolutionary process, since there is no concrete goal. The only evolutionary aim corresponds to the organism in its search for the best means that allow it to adapt to its environment. We are dealing with a rationality that goes from means to ends. Simon therefore understands that “evolution is sometimes regarded as a preferred explanation for rationality precisely because it doesn’t require a detailed explanation of process; the important thing is adaptation... Evolution permits one to postulate the end without specifying the means.”²⁵

For Simon, rationality implies the type of appropriate behavior that leads to the attainment of ends that have already been stated.²⁶ In the concept that he defends, rationality is a rationality of means, in other words “may provide powerful help in finding means to reach our ends, it has little to say about the ends themselves.”²⁷ It is an instrumental reason: it indicates the means for reaching an end, but not the end itself, be it good or bad. In his view, reason “can’t select our final goals... All reason can do is help us reach agreed-on goals more efficiently.”²⁸

In this regard it should be mentioned that this position, as Wenceslao J. Gonzalez has pointed out,²⁹ implies an unnecessary restriction of the field of rationality and that the position held by Nicholas Rescher is undoubtedly a step forward due to its having incorporated a wider vision of rationality. We should therefore talk of three types of rationality: i) a *cognitive* rationality, present in Simon’s approaches, which turns on what should be accepted or believed in both theoretical and empirical knowledge; ii) a *practical* rationality, which decides on the actions to be performed, whose existence it also accepts, and iii) an *evaluative* rationality, or a rationality of ends,³⁰ which does not appear in his writings, this rationality deciding what ends or goals should be preferred or valued, taking into account the means at our disposal. The absence of a rationality of ends in his approaches supposes a limitation in his point of view on economics understood as a science of artificiality. Design implies the existence of a complementarity between a rationality of means or instrumental rationality and a rationality of ends or evaluative rationality.³¹

²⁵ SIMON, H. A., *Reason in Human Affairs*, p. 70.

²⁶ Cf. SIMON, H. A., “Theories of Bounded Rationality,” pp. 408-411.

²⁷ *Reason in Human Affairs*, p. 7.

²⁸ SIMON, H. A., *Reason in Human Affairs*, p. 106.

²⁹ Cf. GONZALEZ, W. J., “Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos,” in GONZALEZ, W. J. (ed.), *Racionalidad, historicidad y predicción en Herbert A. Simon*, Netbiblo, A Coruña, 2003, p. 71.

In scientific rationality in general, and in economic rationality in particular, we are faced with a rationality of means, which leads towards choosing the best means to reach foreseen ends. There is, however, also a rationality of ends or evaluative rationality, that helps to choose the adapted ends for the activity that it develops, cf. GONZALEZ, W. J., “Racionalidad científica y actividad humana. Ciencia y valores en la Filosofía de Nicholas Rescher,” in RESCHER, N., *Razón y valores en la Era científico-tecnológica*, Paidós, Barcelona, 1999, pp. 11-44.

³⁰ Cf. RESCHER, N., *Rationality: A Philosophical Inquiry into the Nature and the Rationale of Reason*, Clarendon Press, Oxford, 1988, p. 3.

³¹ Cf. GONZALEZ, W. J., “Rationality and Prediction in the Sciences of the Artificial: Economics as a Design Science,” in GALAVOTTI, M. C., SCAZZIERI, R. and SUPPES, P. (eds.), *Reasoning, Rationality and Probability*, CSLI Publications, Stanford, 2008, pp. 165-186.

It is significant that the idea of “evaluative rationality” is accepted *de facto* by Reinhard Selten. On the one hand, he assumes the existence of bounded rationality, based on Simon’s approaches, whilst on the other he clearly admits the presence of a rationality of ends or evaluative rationality in a science like economics.³² In fact, he accepts it in the field in which he works, i.e. experimental economics.³³ Thus, Selten moves away from the dominant current in economics —the neo-classical trend— at the same time as he develops a wider notion of rationality than that proposed by Simon.³⁴

Accepting an evolutionary point of view with regard to rational processes undoubtedly has its implications. The most relevant of these, within the present context, are the following: i) Accepting an evolutionary rationality implies assuming the idea of mobility: in other words an adjustment to an imperfect environment that is in continuous movement, so that it is “a target that is itself continually moving;”³⁵ and ii) Following an evolutionary model of rationality —an adaptive rationality— does not provide a “particular mechanism for the rational process” in the making of rational decisions.³⁶ The model only indicates the different directions and alternatives that this process can take, not which is the best.³⁷ It is a question of a permanently open process of choosing means.

In Simon’s view human behavior is always adaptive: human beings are seen as adaptive organisms that has to continually solve problems in order to survive,³⁸ instead of being achievers of ideal outcomes. What is more, human adaptive behavior connects directly with the frequent inability of human beings to predict with accuracy what will be relevant to them in the future.³⁹ The choice that human beings can make is marked by a *procedural* rationality instead of a *substantive* rationality.

Its origin is paradoxical: procedural rationality seeks to discover the most appropriate adaptive behavior, which makes behavioral prediction by an agent in a constantly evolving and changing environment an extremely difficult task.⁴⁰ In other words, Simon is more interested in the process that human beings carry out when making decisions than

³² Cf. GONZALEZ, W. J., “Rationality in Experimental Economics: An Analysis of Reinhard Selten’s Approach,” in GALAVOTTI, M. C. (ed.), *Observation and Experiment in the Natural and Social Sciences*, Kluwer, Dordrecht, 2003, p. 75.

³³ Cf. GONZALEZ, W. J., “Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos,” p. 79. Experimental economics has helped to clarify the distinction and complementarity between evaluative and instrumental rationality. Cf. GONZALEZ, W. J., “Rationality and Prediction in the Sciences of the Artificial: Economics as a Design Science,” pp. 176-179.

³⁴ Cf. “Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos,” p. 81.

³⁵ SIMON, H. A., *Reason in Human Affairs*, p. 72.

³⁶ Cf. *Reason in Human Affairs*, p. 72.

³⁷ Cf. SIMON, H. A., *Reason in Human Affairs*, p. 72.

³⁸ Cf. “Some Strategic considerations in the construction of Social Science Models,” pp. 217-221.

³⁹ Cf. “From Substantive to Procedural Rationality,” pp. 437-439. Simon does not deny the ability of the social sciences to make predictions, but rather is of the opinion that individual as well as social processes are predictable in the same way as in the natural sciences. Cf. SIMON, H. A., “Accurate Predictions and Fixed Point Theorems: Comments,” *Social Science Information*, v. 25, n. 4/5, (1982), pp. 605-612.

⁴⁰ Cf. GONZALEZ, W. J., “Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos,” pp. 76-77.

the decisions themselves.⁴¹ In his view, “human reason is less a tool for modeling and predicting the general equilibrium of the whole world system... it is a tool for exploring specific partial needs and problems.”⁴²

In Simon’s approach, the emphasis is clearly on the subject: on his cognitive capacity and on his relation with the environment. He thinks, in effect, that it is the subject who, using a bounded rationality, chooses the option that he thinks is best adapted to the medium. A very different conception of rationality than that proposed by Karl Popper. In the latter it is not the subject who chooses some theories instead of others, there instead being a process of “natural selection” in which the best hypotheses are those that survive, with the less suitable ones falling by the wayside.

2. RATIONALITY AND EVOLUTIONARY EPISTEMOLOGY IN KARL R. POPPER

An author who was also interested in evolutionary aspects is Karl R. Popper, particularly during a specific stage of his philosophy —from 1960 to 1969— when he developed his Evolutionary Epistemology. Scientific knowledge and how it progresses, its evolutionary character, are the fundamental axes that focus the interest of his thought in this period.⁴³ Nevertheless, Popper approaches evolutionism from a very different angle to that used by Simon: they openly differ with regard to the role of the knowing subject in epistemology.

2.1. *The Turn Towards Evolutionary Epistemology*

In the stage that goes from 1960 to 1969, Popper’s general philosophical conception experiences, in effect, a change of approach with regard to the perspective of his approach. In this period he gives an “epistemological turn” to his philosophy and methodology of science, putting forward his conception of an Evolutionary Epistemology, which goes beyond the epistemological plane and affects his entire philosophy and methodology of science.⁴⁴ And he does so after decades of putting a logical-methodological emphasis on his approach to science.

When Popper proposes his Evolutionary Epistemology he highlights that the process of the knowledge takes place in time:⁴⁵ it is a problem-solving dynamic. Problems are solved through a process in which theories or hypotheses are elaborated and then subjected to

⁴¹ Cf. SIMON, H. A., “Bounded Rationality,” p. 293.

⁴² *Reason in Human Affairs*, p. 105.

⁴³ In the 60s, Popper is interested in how objective knowledge increases. He holds, in addition, that we can only study subjective knowledge by means of objective knowledge. Cf. POPPER, K. R., *Knowledge and the Body-Mind Problem. In Defence of Interaction*, edited by Mark Notturmo, Routledge, London, 1994, p. 4.

⁴⁴ This turn in Popper’s thinking has also received the name of “biological turn.” Cf. QUERALTO, R., *Karl Popper: De la Epistemología a la Metafísica*, Publicaciones de la Universidad de Sevilla, Seville, 1996, p. 232. For W. W. Bartley III, Popper unifies his thought thanks to his studies of biology. Cf. BARTLEY III, W. W., “Philosophy of Biology versus Philosophy of Physics,” in RADNITZKY, G. and BARTLEY III, W. W. (eds.), *Evolutionary Epistemology, Rationality, and the Sociology of Knowledge*, Open Court, La Salle, IL, 1987, (3rd reprint, 1993), pp. 18-20.

⁴⁵ The type of “Evolutionary Epistemology” that Popper proposes should, in the opinion of D. Campbell, be called “a natural selection epistemology.” Cf. CAMPBELL, D., “Evolutionary Epistemology,” in SCHILPP, P. A. (ed.), *The Philosophy of Karl Popper*, Open Court, La Salle, IL, 1974, vol. 1, p. 437. For a major study on Popper’s Evolutionary Epistemology, cf. CURRIE, G., “Popper’s Evolutionary Epistemology: A Critique,” *Synthese*, v. 37, (1978), pp. 413-431.

critical discussion and evaluation, followed by a phase of critical testing,⁴⁶ looking for their falsification.

Accepting this evolutionary approach implies assuming the ontological “emergency” of biological innovations, which is the consequence of the unpredictability of evolutionary changes.⁴⁷ The innovation with regard to his previous conception lay in that Popper introduces the “emerging” nature of scientific theories. He establishes a parallelism: just as historical and evolutionary changes are emerging and scientifically unpredictable, so are the theories proposed for adapting to these changes equally emergent and, in principle, unpredictable.⁴⁸

Popper was initially distrustful of evolutionary theories, including Darwin’s conception, and this becomes apparent when reading his texts on “historicist” doctrines.⁴⁹ Historicism—in the Popperian view—implies that human society, throughout history, follows an evolution. This evolution becomes predictable to the extent that the laws that govern such an evolution are discovered. Evolutionism and historicism can thus be associated, which make him cautious on the topic of evolutionism throughout the 1940s and a large part of the 1950s.⁵⁰

It is necessary to add that it is not until 1977 when Popper awards the theory of natural selection the status of a scientific theory, although it is a theory that in his view is falsified.⁵¹ Until then he had thought that evolutionism, due to it being an isolated historical fact and the unrepeatable nature that the evolutionary process necessarily implies, was a hypothesis

⁴⁶ Cf. POPPER, K. R., “Epistemology Without a Knowing Subject,” in VAN ROOTSELAAR, B. and STAAL, J. F. (eds.), *Proceedings of the Third International Congress for Logic, Methodology and Philosophy of Science: Logic, Methodology and Philosophy of Science III*, North-Holland, Amsterdam, 1968. Reprinted in POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, Clarendon Press, Oxford, 1972 (5th revised ed., 1979), p. 142.

Popper thinks that the preference for one theory over another is not subjective, but answers to objective considerations. Cf. POPPER, K. R., “Epistemology Without a Knowing Subject,” p. 142. He understands that it is different to justify why a theory is preferred, at a given moment, over another one, than to justify a theory. In other words, the preference for one theory instead of another rival one is determined because, at least at that moment, one theory is considered to be nearer to the truth, be more credible, than another. On the other hand, to justify a theory means, for him, to demonstrate that it is true. This rational justification of theories does not fit in Popperian thought, since all theories are conjectures. Cf. POPPER, K. R., *Knowledge and the Body-Mind Problem. In Defence of Interaction*, p. 138.

⁴⁷ Cf. POPPER, K. R., “Scientific Reduction and the Essential Incompleteness of All Science,” in AYALA, F. J. and DOBZHANSKY, T. (eds.), *Studies in the Philosophy of Biology*, Macmillan, London, 1974. Reprinted in POPPER, K. R., *The Open Universe. An Argument for Indeterminism. From the Postscript to The Logic of Scientific Discovery*, edited by W. W. Bartley III, Hutchinson, London, 1982 (4th reprint, Routledge, London, 1998), p. 145n.

⁴⁸ Cf. POPPER, K. R., “A Realist View of Logic, Physics and History,” in YOURGRAU, W. and BRECK, A. D. (eds.), *Physics, Logic and History*, Plenum Press, London, 1970. Reprinted in POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, p. 298. For a comparative study on the concept of prediction in social sciences held by Karl Popper and Herbert Simon, cf. CASTRO, F. J., “La predicción científico-social en K. Popper y Herbert A. Simon,” in GONZALEZ, W. J. (ed.), *Racionalidad, historicidad y predicción en Herbert A. Simon*, pp. 235-278.

⁴⁹ Cf. SCHWARTZ, P., “Karl Popper y la Teoría de la Evolución,” *Enrahonar*, v. 11, (1985), p. 44.

⁵⁰ In the 40s, Popper held that both evolutionary biological innovations and social innovations were only historical phenomena. In consequence, both phenomena were absolutely unpredictable. Knowledge of innovations—historical or biological—did not allow future events, whether human or natural, to be inferred. Cf. POPPER, K. R., *The Poverty of Historicism*, Routledge and K. Paul, London, 1957, 3rd ed., 1961 (Routledge, London, reprinted in 1999), p. 109.

⁵¹ POPPER, K. R., “Natural Selection and the Emergence of Mind,” *Dialectica*, v. 32, (1978), pp. 339-355 (*First Darwin Lecture*, given in Darwin College, Cambridge, on 8 November 1977). Reprinted in RADNITZKY, G. and BARTLEY III, W. W. (eds.), *Evolutionary Epistemology, Rationality, and the Sociology of Knowledge*, pp. 139-153.

that was difficult to test and therefore an unscientific one, according to the Popperian criterion of the demarcation of science.⁵²

During the 1960s Popper changed his mind with regard to evolutionary theories and the Darwinian theory of evolution itself.⁵³ In fact, in a lecture given in 1961, he re-formulates Darwin's theory and proposes his own evolutionary theory.⁵⁴ In this period he also partly retracts what he had said in previous decades, especially concerning evolutionary theories and the attempt to predict evolutionary changes through discovery of the laws that govern evolution.⁵⁵ This is a clear turn towards a new approach that is visible in a reduced interest in historicist doctrines.⁵⁶

After embracing Evolutionary Epistemology Popper changes in several important aspects. In the 1940s he affirmed that there were no laws in evolution:⁵⁷ no law could be called an "evolutionary law," since both the evolution of life and that of human society were seen as unique and unrepeatable processes, and therefore not subject to laws.⁵⁸ Later, after having progressed to an Evolutionary Epistemology approach, in the 1960s, Popper holds that human beings attempt to solve their problems and to obtain tentative solutions to solve them within a process of the elimination of mistakes;⁵⁹ the most

⁵² Cf. MARTINEZ SOLANO, J. F., "El puesto de la Biología en la Epistemología y Metodología de la Ciencia de Karl Popper," *Thémata*, v. 20, (1998), pp. 189-193. It should be pointed out that throughout his philosophical career Popper was interested in distinguishing in what way scientific knowledge differs or not, whereas Simon showed interest in demonstrating what scientific thought has in common with other creative processes of thought having to do with invention or design. Cf. DASGUPTA, S., "Multidisciplinary Creativity: The Case of Herbert A. Simon," *Cognitive Science*, v. 27, (2003), p. 686.

⁵³ Cf. POPPER, K. R., *Of Clouds and Clocks: An Approach to the Problem of Rationality and the Freedom of Man*, Washington University Press, S. Louis, MI, 1966. Reprinted in POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, p. 241.

⁵⁴ Cf. POPPER, K. R., "Evolution and the Tree of Knowledge," expanded version of the *Herbert Spencer Lecture*, given in Oxford in 1961. Reprinted in POPPER, K. R., *Objective Knowledge. An Evolutionary Approach*, pp. 272-280. Popper adds a new conjecture to evolutionary theory: variability. He thus holds that it is possible to predict that there will be variations in an organism throughout its biological evolution, and the range of possible variations that a certain organism would have would be governed by natural selection.

⁵⁵ Cf. POPPER, K. R., "Of Clouds and Clocks. An Approach to the Problem of Rationality and the Freedom of Man," p. 241. In this regard, it has been pointed out that this change of approach on the part of Popper takes place in the context of a wider change in his thinking, namely the introduction of metaphysical elements in his philosophy of science. Cf. MARTINEZ SOLANO, J. F., "El puesto de la Biología en la Epistemología y Metodología de la Ciencia de Karl Popper," p. 177.

⁵⁶ The notion of "historicism" in Popper has a specific character, different from that in the historical bibliography. On his concept of "historicism," Cf. GONZALEZ, W. J., "La interpretación historicista de las Ciencias Sociales," *Anales de Filosofía*, v. 2, (1984), pp. 109-137; especially, pp. 123-137.

⁵⁷ Cf. *The Poverty of Historicism*, p. 117.

⁵⁸ The introduction of evolutionary elements in Popper's Epistemology and Methodology is to a certain extent paradoxical or even contradictory. According to Popper, neo-Darwinist theories are metaphysical, insofar as they are unfalsifiable; nevertheless, at the same time, he seems to affirm that Darwinian theories give testable predictions, predictions about gradual changes in evolution. This, in Michael Ruse's opinion, means that if they are testable predictions they are not metaphysical, even though these predictions are false. Cf. RUSE, M., "Karl Popper's Philosophy of Biology," *Philosophy of Science*, v. 44, (1977), p. 650.

⁵⁹ In Springer's opinion, Popper overlooks the fact that not only do the proposed theories take place inside a basic theoretical frame, but that the critiques made of these theories that have been proposed also take place inside a specific theoretical scheme. Cf. SPRINGER DE FREITAS, R., "Back to Darwin and Popper. Criticism, Migration of Piecemeal Conceptual Schemes, and the Growth of Knowledge," *Philosophy of the Social Sciences*, v. 27, n. 2, (1997), pp. 160-161.

satisfactory solutions or hypotheses are those that survive the process of elimination of mistake and criticism.⁶⁰

Although Popper does not begin to develop his Evolutionary Epistemology until 1960, Donald T. Campbell is of the opinion that in the 1930s Popper had already made his first contributions to what would later be his Evolutionary Epistemology. He does so, in Campbell's view, when he contemplates the process of the succession of theories in science as a process of the selective elimination of hypotheses,⁶¹ in which some theories fight to survive in the face of others.⁶² Popper later added a new element to this evolutionary process of scientific knowledge: he admits, as a fact, that the progress of knowledge is not irrational. Thus, the acceptance of theories takes place in a rational way, through trial and error, i.e. through the method of proposing theories, trying to demonstrate that they are erroneous, and tentatively accepting them, at least until our attempts to falsify them prove fruitless.⁶³

This procedure of the progress of knowledge is, in Popper's opinion, common to both human beings and animals.⁶⁴ This means that he coincides with the underlying naturalism of evolutionism, since, in his attempt to solve the problems put to them, human beings and animals will have shared patterns of behavior. The difference between human and animal knowledge is in the critical attitude: scientists, unlike animals, consciously seek to find the errors in their theories, and this is why they try to test them as severely as possible.⁶⁵

Popper's Evolutionary Epistemology assumes that the process of knowledge is a process of the selective elimination of hypotheses.⁶⁶ It is therefore a Darwinism regarding means. In Popper's view there is a process of selection of the best hypotheses, in which the fittest survive. He thus establishes an analogy between the evolution of knowledge and Darwin's biological evolutionary process,⁶⁷ the final result in both cases being open-ended rather than known in advance.

Increased knowledge as the result of an evolutionary process has important consequences for the predictive aspect of science. From Popper's point of view, both the

⁶⁰ Cf. "Evolution and the Tree of Knowledge," p. 261.

⁶¹ Cf. CAMPBELL, D. T., "Evolutionary Epistemology," p. 415. Cf. POPPER, K. R., *The Logic of Scientific Discovery*, Hutchinson, London, 1959 (6th reprint, Routledge, London, 2001), p. 108. Popper says: "We choose the theory which best holds its own in competition with other theories; the one which, by *natural selection*, proves itself the fittest to survive." POPPER, K. R., *The Logic of Scientific Discovery*, p. 108. The italics are mine.

⁶² Cf. *The Logic of Scientific Discovery*, p. 42.

⁶³ Cf. POPPER, K. R., "Philosophy of Science: A Personal Report," in MACE, C. A. (ed.), *British Philosophy in the Mid-Century: A Cambridge Symposium*, George Allen and Unwin, London, 1957. Reprinted in POPPER, K. R., "Science: Conjectures and Refutations," in POPPER, K. R., *Conjectures and Refutations. The Growth of Scientific Knowledge*, Routledge and K. Paul, London, 1963; 5th revised ed., 1989 (reprinted in Routledge, London, 2000), p. 51.

⁶⁴ Cf. POPPER, K. R., "Science: Conjectures and Refutations," p. 52.

⁶⁵ Cf. "Science: Conjectures and Refutations," p. 52.

⁶⁶ Cf. CAMPBELL, D. T., "Evolutionary Epistemology," p. 415.

⁶⁷ Cf. CASTRODEZA, C., "De la Epistemología popperiana a la Epistemología darwinista," in SCHWARTZ, P., RODRIGUEZ BRAUN, C. and MENDEZ IBISATE, F. (eds.), *Encuentro con Karl Popper*, Alianza Ed., Madrid, 1993, pp. 147-149.

evolution of knowledge and biological evolution itself are unique processes and, therefore, unpredictable.⁶⁸ For him, there are no logical grounds that enable the growth of knowledge to be predicted, due to the human capacity for innovation. The evolution of knowledge always implies novelty, and is therefore unpredictable on any logical basis. Products created by the human mind, such as scientific theories, are of an emerging nature.⁶⁹ They are essentially unpredictable.⁷⁰

The uniqueness of the process of scientific knowledge and its innovative character are the reason that Popper adduces for denying the predictability of cognitive evolutionary processes. These processes lack universal laws. From his point of view there cannot be laws governing unique processes. Therefore, he thinks that there is no such thing as evolutionary laws: neither regarding the evolution of history, nor the evolution of knowledge (nor regarding biological evolution, either).⁷¹ In the same way that cannot know how our scientific knowledge will progress, we are also unable to know in advance what part of our current knowledge will fail at a given future moment.⁷²

The evolutionary approach to knowledge has two sides for Popper: one that can be properly defined as epistemological and another that is methodological. The epistemological aspect derives from the concept of “adaptation:” the purpose of knowledge, whether human or animal,⁷³ is to allow its possessor to adapt to the environment. The methodological facet of Evolutionary Epistemology, on the other hand, is the notion of “selection:” hypotheses are subject to a process of “natural selection,” with the result that only the best survive, whilst false theories or hypotheses are rejected and eliminated.

Epistemological or evolutionary growth implies that the growth of scientific knowledge occurs as a result of criticism and the elimination of mistakes in theories, which leads, in turn, to the consideration of new solutions to new problems.⁷⁴ This is an aspect that

⁶⁸ Popper had already indicated in *The Poverty of Historicism* that the evolution of knowledge is unpredictable, because, to him, it is a unique process, as is biological evolution. Cf. POPPER, K. R., *The Poverty of Historicism*, pp. 108-109.

⁶⁹ Cf. POPPER, K. R., “A Realist View of Logic, Physics and History,” pp. 297-298.

⁷⁰ Cf. *Knowledge and the Body-Mind Problem. In Defence of Interaction*, p. 71. For a major study on prediction in Karl Popper, as well as its characteristics and stages, cf. GONZALEZ, W. J., “The Many Faces of Popper’s Methodological Approach to Prediction,” in CATTON, PH. and MACDONALD, G. (eds.), *Karl Popper. Critical Appraisals*, Routledge, London, 2004, pp. 78-98.

⁷¹ Popper’s fundamental argument for denying the predictability of evolutionary processes is their uniqueness. For this reason, criticism directed towards opposing this Popperian affirmation have taken the direction of denying that evolutionary processes should be considered to be unique, as Popper maintains. Cf. OLDING, A., “A Defence of Evolutionary Laws,” *The British Journal for the Philosophy of Science*, v. 29, n. 2, (1978), pp. 134-135.

⁷² Cf. *The Poverty of Historicism*, pp. 108-109.

⁷³ Cf. POPPER, K. R., “Towards an Evolutionary Theory of Knowledge,” reprinted in POPPER, K. R., *A World of Propensities*, Thoemmes, Bristol, 1990 (1st reprint, 1995), p. 32.

⁷⁴ Cf. POPPER, K. R., “Epistemology Without a Knowing Subject,” p. 107. Popper does not clarify why the elimination of mistakes in theories that have been proposed as a solution to the problems raised gives rise to the consideration of “new problems,” nor does he even clarify why only a limited number of theories postulated as a solution to a problem can be considered at any one time. The fact that Popper does not explain why new problems arise can lead us to think, according to Springer de Freitas, that the growth of scientific knowledge is not a cognitive but a sociological phenomenon. Cf. SPRINGER DE FREITAS, R., “Back to Darwin and Popper. Criticism, Migration of Piecemeal Conceptual Schemes, and the Growth of Knowledge,” pp. 158-159.

separates Popper's approach from Simon's, since from the Popperian point of view the preference for the best theories is a critical and objective one, not a subjective choice, whereas Simon is of the opinion that it is the subject who, with limited reasoning capacities, selects the theory that best fits the environment.

2.2. The Rational Process as an Equivalent of Natural Selection

When Popper's thought took its epistemological turn in the 1960s, its novel contribution was to consider that the growth of knowledge follows a process similar to the theory of natural selection proposed by Darwin.⁷⁵ Popper thus admits a "natural selection of hypotheses,"⁷⁶ so that the best hypotheses or those that prove to be the fittest are selected, since they have better withstood the testing to which they have been submitted.

That Popper sticks fast to an evolutionary approach is a widely controversial aspect of his thought. He had initially thought that Darwin's theory of "natural selection" was a quasi-tautological one. This led him to catalogue the Darwinian theory as a "metaphysical research programme," a program that is only capable of predicting that evolutionary changes will take place on a gradual basis.⁷⁷ He later changed his opinion, indicating that he saw Darwin's theory not as a universal truth, but at least as a testable theory.⁷⁸

By introducing the evolutionary perspective into his epistemology, Popper attempts to distance himself from those authors who in his opinion were more inclined towards a "traditional" (or, to be more accurate, modern) conception of knowledge,⁷⁹ this being an epistemology that is interested in World 2, the world of subjective beliefs. Thus, both some rationalists and, particularly, some empiricist authors, see knowledge as a type of belief, and—I add—insist on the idea of the concept as a "mental representation" of the subject. In their view, the adoption of the best theories and the elimination of false theories takes place subjectively, not objectively. For this reason Popper considers that they are unable to explain how the development of scientific knowledge really occurs, this being by means of the critical attitude adopted by scientists towards their own theories.⁸⁰ Here we find a difference with the view of a writer on epistemology of

⁷⁵ Cf. POPPER, K. R., "Evolution and the Tree of Knowledge," p. 261. "All this may be expressed by saying that the growth of our knowledge is the result of a process closely resembling what Darwin called 'natural selection'; that is, the *natural selection of hypotheses*: our knowledge consists, at every moment, of those hypotheses which have shown their (comparative) fitness by surviving so far in their struggle for existence; a competitive struggle which eliminates those hypotheses which are unfit," POPPER, K. R., "Evolution and the Tree of Knowledge," p. 261. The italics are in the original.

⁷⁶ Cf. "Evolution and the Tree of Knowledge," p. 261. Nevertheless, this idea of "natural selection" of theories is already present in his earliest papers, because, in Popper's opinion, we choose the theory that proves to be the fittest for survival. Cf. *The Logic of Scientific Discovery*, p. 108.

⁷⁷ Cf. POPPER, K. R., *Unended Quest. An Intellectual Autobiography*, Fontana/Collins, 1976 (extended edition, Routledge, London, 1992; 1st reprint, 1993), p. 168. Cf. CORCO, J., "La selección natural en Popper y Peirce," *Anuario filosófico*, v. 34/1, n. 69, (2001), pp. 140-141.

⁷⁸ Cf. POPPER, K. R., "Natural Selection and the Emergence of Mind," p. 145.

⁷⁹ Popper mentions Locke, Berkeley, Hume and Russell as supporters of this epistemology, cf. "Epistemology Without a Knowing Subject," p. 108.

⁸⁰ Cf. POPPER, K. R., "Epistemology Without a Knowing Subject," p. 122.

an empiricist tendency —Herbert Simon—,⁸¹ a thinker who criticized Popper for his conception of the process of scientific discovery.⁸²

Contrary to Popper, Simon holds that rationality is neither abstract nor impersonal; and, also unlike Popper, he does not conceive his epistemology without a knowing subject. This can clearly be seen in his studies on Economics, since he does not think that economic processes are foreign to the human undertaking. Simon's epistemology differs from Popperian epistemology in that it highlights human cognitive capacity. Bounded rationality is a subjective rationality, whereas Popper's epistemology develops without taking into account the role of agents, the role of the subject that knows and tries to be, in effect, an *objective* rationality.

Nevertheless, Popper and Simon coincide in seeing knowledge as a human product. But they differ in that, for the former, as soon as it has been created it becomes an objective and autonomous knowledge: knowledge, theories and scientific hypotheses form part of World 3; and World 3 is *eo ipso* autonomous. Thus, for Popper, the growth of knowledge is not a process that is *eo ipso* accumulative, but rather a process of criticism and elimination of errors.⁸³ In other words, with regard to the rejection of what is false, it is more of a process of Darwinian selection than of a Lamarckian instruction.⁸⁴

The process of knowledge in Popper is the result of proposing multiple hypotheses and retiring those that turn out to be falsified, in order to arrive at a theory that is as close as possible to the truth.⁸⁵ With the survival of the theories that prove to be the fittest, what is obtained is, in Popper's view, a better approximation to the truth, a greater verisimilitude of the hypotheses.⁸⁶

Nevertheless, it must be pointed out that when Popper introduces the theory of verisimilitude, in this process of eliminating errors in order to gain in verisimilitude

⁸¹ It should be borne in mind that H. Simon was born in 1916, fourteen years after Karl Popper. For a major study on Simon's philosophical career and life, cf. GONZALEZ, W. J., "Herbert A. Simon: Filósofo de la Ciencia y economista (1916-2001)," in GONZALEZ, W. J. (ed.), *Racionalidad, historicidad y predicción en Herbert A. Simon*, pp. 7-63, particularly pp. 8-14. Selten also grants empirical knowledge a greater importance than theoretical knowledge. Cf. "Rationality in Experimental Economics: An Analysis of Reinhard Selten's Approach," p. 72.

⁸² Simon holds, in opposition to Popper, that scientific discovery is analyzable from a logical point of view. Cf. SIMON, H. A., *Models of Discovery*, Reidel, Dordrecht, 1977, p. 326. In this regard, cf. CASTRO, F. J., "El proceso de descubrimiento científico: De Karl Popper a Herbert Simon," in GONZALEZ, W. J. (ed.), *Karl Popper: Revisión de su legado*, Unión Editorial, Madrid, 2004, pp. 267-295.

⁸³ J. Blachowicz objects to the fact that Popper does not take into account a certain type of elimination, namely corrective elimination. In other words, for Popper there is no room for the alteration of hypotheses that have been refuted. Cf. BLACHOWICZ, J., "Elimination, Correction and Popper's Evolutionary Epistemology," *International Studies in the Philosophy of Science*, v. 9, n. 1, (1995), pp. 5-17; particularly, p. 9.

In this respect, it has been thought that a fundamental methodological principle in Popper, other than the anti-dogmatic principle present in Popperian methodology, is the so-called "principle of elimination." This principle prescribes that, to the extent that the conclusion has been reached that a hypothesis has not withstood certain tests, (i.e. a theory has been experimentally proved to contain real false formulations), this theory must be refuted and retired. Cf. MEANA MENENDEZ, L., "Crítica, falsación y eliminación," *Teorema*, v. 14, n. 1-2, (1987), p. 93.

⁸⁴ Cf. POPPER, K. R., "Epistemology Without a Knowing Subject," p. 144. Cf. POPPER, K. R., "Replies to my Critics," in SCHILPP, P. A. (ed.), *The Philosophy of Karl Popper*, Open Court, La Salle, IL, 1974, vol. 2, p. 1060.

⁸⁵ POPPER, K. R., "Evolution and the Tree of Knowledge," pp. 261-262.

⁸⁶ Cf. MARTINEZ SOLANO, J. F., *El problema de la verdad en K. R. Popper: Reconstrucción histórico-sistemática*, Netbiblo, A Coruña, 2005, pp. 223-224.

there is—in my opinion—a certain degree of accumulation. The progressive approach to the truth in the Popperian sense implies not leaving many branches open: there is one branch that acquires greater relevance by possessing greater verisimilitude and, therefore, being closer to the truth. So, the very content of evolutionary knowledge would not be merely Darwinian but would rather be a Lamarckian process of instruction. Popper, unlike Darwin, is of the opinion that the “tree of knowledge” is reversed. In other words, multiple hypotheses, through criticism and the elimination of errors, will be unified in a single theory, that which is closest to the truth.⁸⁷

Popper always insists on the idea of knowledge as an active process: knowledge is a product created by the human mind in order to find solutions that are suited to its problems.⁸⁸ It is an element of Popperian World 3,⁸⁹ the world of objective knowledge, and is at the same time an evolutionary knowledge, one that is not static but dynamic. He sees the process of human knowledge as a process of adaptation, because human beings formulate scientific theories in order to adapt to the environment in which they live.⁹⁰ It is also a process of selection, since hypotheses are selected: there is a “fight for survival”, where the fittest hypotheses or scientific theories remain and the unsuitable ones are rejected.⁹¹ Furthermore, Popper maintains that “we can let our objective theories die in our stead.”⁹²

For Popper, objective knowledge is independent from the subject, and therefore knowing is not a subjective belief, but an objective fact. Popper affirms that Knowledge in the objective sense is “*knowledge without a knower*: it is *knowledge without a knowing Subject*.”⁹³ What is more, in his opinion, knowledge in the subjective sense is irrelevant for the study of scientific knowledge.⁹⁴ This assumes that epistemology has priority over any other contribution of the Theory of Knowledge in general.

⁸⁷ Cf. MARTINEZ SOLANO, J. F., *El problema de la verdad en K. R. Popper: Reconstrucción histórico-sistemática*, p. 223.

⁸⁸ Cf. POPPER, K. R., “A Realist View of Logic, Physics and History,” p. 289.

⁸⁹ Popper has received open criticism regarding his conception of World 3 and the links that it has with evolutionary epistemology. For L. J. Cohen, Popper is incoherent for having compared the development of knowledge with the Theory of Evolution, since they follow different guidelines. This author considers that, whereas the fight for life of the species follows an irrational dynamics (interaction with the environment being the prevalent feature), the development of knowledge is, for Popper, a rational process. Cf. COHEN, L. J., “Third World Epistemology,” in CURRIE, G. and MUSGRAVE, A. (eds.), *Popper and the Human Sciences*, M. Nijhoff, Dordrecht, 1985, p. 9.

⁹⁰ Cf. POPPER, K. R., “The Rationality of Scientific Revolutions,” in HARRÉ, R. (ed.), *Problems of Scientific Revolution. Progress and Obstacles to Progress in the Sciences*, Clarendon Press, Oxford, 1975. Reprinted in POPPER, K. R., *The Myth of the Framework. In Defence of Science and Rationality*, edited by Mark Notturmo, Routledge, London, 1994, p. 2.

For him, “from a biological or evolutionary point of view, science, or progress in science, may be regarded as a means used by the human species to adapt itself to the environment: to invade new environmental niches, and even to invent new environmental niches,” POPPER, K. R., “The Rationality of Scientific Revolutions,” p. 2.

⁹¹ Cf. MARTINEZ SOLANO, J. F., “El puesto de la Biología en la Epistemología y Metodología de la Ciencia de Karl Popper,” p. 179.

⁹² Cf. *Knowledge and the Body-Mind Problem*, p. 12. In this respect, Popper establishes an analogy between the human elaboration of theories and a mutation. Thus, human beings, instead of having biological mutations in their own bodies, create new products or instruments with which to solve their problems. Cf. *Knowledge and the Body-Mind Problem*, p. 34.

⁹³ POPPER, K. R., “Epistemology Without a Knowing Subject,” p. 109. The italics are those of the author. Some authors have proved to be critical with this Popperian position. Cf. HAACK, S., “Epistemology *With* a Knowing Subject,” *Review of Metaphysics*, v. 33, (1979-1980), pp. 309-335.

⁹⁴ Cf. POPPER, K. R., “Epistemology Without a Knowing Subject,” p. 111.

All in all, according to Popper what counts is the study of World 3, the sphere of objective knowledge:⁹⁵ scientists act on the basis of conjectures, subjective beliefs; they look for hypotheses that, in principle, could provide more knowledge or results within World 3 (that of objective knowledge).⁹⁶ The study of World 3 provides us with knowledge of the thought processes of scientists, but there is no *vice versa*: the study of World 2 does not provide a greater knowledge of World 3, since the latter is to a great extent autonomous, objective knowledge is independent from the knowing subject,⁹⁷ exactly the opposite of what Simon maintains.

3. BOUNDED RATIONALITY AS “ADAPTIVE TOOL”

Following Simon’s approach of adaptive rationality of a subjective nature and Popper’s view on the natural selection of theories it is now appropriate to go further into bounded rationality as influenced by an evolutionary approach. As we have seen, Simon raises an adaptive rationality of a restricted nature, which thus maintains a close relationship with the environment of the individual agent. Several years later, Reinhard Selten returned to the concept of *bounded rationality*⁹⁸ and taken it to areas hitherto unexplored by other authors.

3.1. Selten’s Advances in the Field of Rationality: A Comparison with Simon

Reinhard Selten agrees with Simon as to the principal factors that constitute bounded rationality, of which there are three: a) there is a search for alternatives, i.e. the different alternatives that exist in a rational type of choice are not given, but have to be discovered by means of a search process; b) the agent does not seek to maximize the expected subjective utilities but merely seeks to satisfy;⁹⁹ and c) there is, on the part of human beings, an adaptation to their levels of aspiration.¹⁰⁰

Selten coincides with Simon in that human beings do not possess a complete rationality, in the sense that they have unlimited cognitive capacities.¹⁰¹ But he has gone further than Simon because he does accept the existence of an evaluative rationality dedicated to the ends, together with that of a practical rationality regarding the means

⁹⁵ Popper says: “But the characteristic thing about specifically human knowledge *science* is that it is formulated in a descriptive and argumentative language, and that the problems, theories, and errors which are embedded in this language stand in their own peculiar relations, constituting what I call ‘world 3,’” POPPER, K. R., “Replies to my Critics,” p. 1060.

⁹⁶ Cf. POPPER, K. R., “Epistemology Without a Knowing Subject,” p. 111.

⁹⁷ Cf. “Epistemology Without a Knowing Subject,” p. 112.

⁹⁸ Reinhard Selten admits that he departed from the theory of expected subjective utility after reading Herbert Simon’s book *Models of Man*. From that moment onwards he realized that economic behavior has to be explained from the approaches of bounded rationality. Cf. SELTEN, R., “In Search of a Better Understanding of Economic Behaviour,” in HEERTJE, A. (ed.), *The Makers of Modern Economics*. vol. 1, Simon and Schuster, New York, 1993. Reprinted in SELTEN, R. (ed.), *Game Theory and Economic Behaviour. Selected Essays*, vol. 1, E. Elgar, Northampton, MA, 1999, p. 5.

⁹⁹ R. Selten gives the name “ingenuous rationalism” to the point of view according to which the agent always looks for the maximization of the expected subjective utility. Cf. SELTEN, R., “New Challenges to the Rationality Assumption,” *Journal of Institutional and Theoretical Economics*, v. 150, n. 1, (1994), p. 42.

¹⁰⁰ Cf. SELTEN, R., “What is Bounded Rationality?,” p. 14.

¹⁰¹ Cf. SELTEN, R., “Evolution, Learning, and Economic Behaviour,” *Games and Economic Behaviour*, v. 3, (1991). Reprinted in SELTEN, R. (ed.), *Game Theory and Economic Behaviour. Selected Essays*, vol. 1, p. 162.

and an epistemic rationality. As Wenceslao J. Gonzalez has indicated, Selten constitutes an advance with regard to Simon: his approach of economic rationality admits a rationality of ends or evaluative rationality,¹⁰² which were certainly not present in Simon's purely instrumental rationality.¹⁰³

Another aspect that Selten proposes and which supposes an improvement with regard to Simon is in the field of the motivational component in rational decisions. Thus, the bounds of rationality are not only of the cognitive type, due to the restricted human capacity for thinking and making computational calculations, but there are also, in his view, motivational limits, which are exemplified in the failure of the agent to behave in accordance with his or her rational insights.¹⁰⁴ "It is not a lack of cognitive power but rather a failure to behave according to one's rational insights that is important here."¹⁰⁵

For Selten, when there is a lack of control over behavior, this is due rather to limitations of a motivational nature than to cognitive limitations.¹⁰⁶ He also introduces the emotional aspect into rationality: he does not think that emotions are the contrary of rationality.¹⁰⁷ In this respect, rationality can be accompanied by affective or emotive aspects that modulate the decision of the individual agent. Simon does not give this aspect of the emotions so much importance within his scheme of bounded rationality.¹⁰⁸

Selten and, to a lesser extent Gigerenzer, has managed to go further than Simon, because he offers a specific vision of bounded rationality: the notion of *adaptive toolbox*, which classifies the evolutionary component as heuristic. Reason as an adaptive tool has a series of relevant characteristics: i) it refers to a series of heuristic rules more than to a general algorithm for decision-making; ii) it is a heuristic of *parsimonious factors* "*fast, frugal and computationally cheap*"; iii) these heuristic rules are adapted to particular environments, past and present, both physical and social; and iv) this set of heuristic rules is directed by some type of mechanism.¹⁰⁹

¹⁰² Cf. GONZALEZ, W. J., "Racionalidad y Economía: De la racionalidad de la Economía como Ciencia a la racionalidad de los agentes económicos," pp. 81-82.

¹⁰³ Cf. GONZALEZ, W. J., "Rationality in Experimental Economics: An Analysis of Reinhard Selten's Approach," pp. 74-76.

¹⁰⁴ Cf. SELTEN, R., "In Search of a Better Understanding of Economic Behaviour," pp. 20-21. Also, cf. GONZALEZ, W. J., "Análisis de la racionalidad y planteamiento de la predicción en Economía Experimental," in GONZALEZ, W. J., MARQUES, G. and AVILA, A. (eds.), *Enfoques Filosófico-Metodológicos en Economía*, F.C.E., Madrid, 2002, pp. 145-172; particularly, pp. 155-156.

¹⁰⁵ SELTEN, R., "In Search of a Better Understanding of Economic Behaviour," p. 21.

¹⁰⁶ Cf. SELTEN, R., "What is Bounded Rationality?," in GIGERENZER, G. and SELTEN, R. (eds.), *Bounded Rationality. The Adaptive Toolbox*, The MIT Press, Cambridge, MA, 2001, p. 15.

¹⁰⁷ Cf. GIGERENZER, G. and SELTEN, R., "Rethinking Rationality," in GIGERENZER, G. and SELTEN, R. (eds.), *Bounded Rationality. The Adaptive Toolbox*, p. 9.

¹⁰⁸ See, for example, SIMON, H. A., "Motivational and Emotional Controls of Cognition," *Psychological Review*, v. 74, (1967), pp. 29-39. Reprinted in SIMON, H. A., *Models of Thought*, Yale University Press, New Haven, CT, 1979, pp. 29-38.

¹⁰⁹ Cf. "Rethinking Rationality," p. 9.

3.2. Characteristics of the Adaptive Toolbox

Building on the foundations of Simon's bounded rationality, Selten proposes the "*Aspiration Adaptation Theory*," a theory that in his view has not yet been proved to be an empirically valid theory to describe human behavior in the decision-making process. He admits that it is a theory that is still in need of certain modifications.¹¹⁰

This theory assumes that the agent has an appraisal of a series of goals or final aims: he possesses some levels of aspiration. Thus, Selten thinks that, when making decisions, the agent has a previous level of aspiration. When a person chooses a given decision alternative, a new level of aspiration arises. Selten thinks that the choice is made on the basis of the alternative that satisfies the new aspiration level.¹¹¹

With the theory of the *adaptive toolbox* there comes a series of simple criteria to detain this process of searching for alternatives.¹¹² This is not the case in the theory of limited rationality originally proposed by Simon, where the search for alternatives ends with the appearance of the first one to satisfy the agent's aspiration level. In Selten's theory there are three premises: 1) The aim of the theory is to understand how agents make decisions, considering that have a series of restrictions, such as limited time and limited, as well as limited computational capacities; 2) The theory offers an heuristic that refers to a specific sphere; and 3) The rationality in this heuristic is an *ecological rationality*, i.e. it is not an omniscient rationality, as it is in theory of the maximization of the expected subjective utility.

The success of this heuristic lies in its degree of adaptation to the structure of the environment, be this physical or social.¹¹³ The "adaptive tools" that this position offers are but a means for reaching certain goals, but the latter include a learning mechanism that allows for an adjustment of these "tools" when the environment changes.¹¹⁴ Thus, Gigerenzer, coinciding with Selten, understands that the function of the above-mentioned theory is to provide a series of strategies: cognitive, emotional and social, which have to allow the handling of a multitude of aims or goals in order for a rational choice to be made swiftly and accurately.¹¹⁵

This theory includes improvements on that put forward by Simon, but based on his idea of bounded rationality. In this *fast and frugal heuristics* not only is there a search for alternatives, in order to satisfy the expected utility, as is the case with Simon, but there is also an evaluation of the different alternatives. This appraisal of the means includes the affective or emotional aspect: for Selten people have evaluative feelings when they make decisions. But this is not the only influence on the behavior of human choice, since other

¹¹⁰ Cf. SELTEN, R., "What is Bounded Rationality?," p. 18.

¹¹¹ Cf. "What is Bounded Rationality?," p. 19.

¹¹² GIGERENZER, G., "The Adaptive Toolbox," in GIGERENZER, G. and SELTEN, R. (eds.), *Bounded Rationality. The Adaptive Toolbox*, pp. 44-45. Cf. GIGERENZER, G., *Adaptive Thinking. Rationality in the Real World*, Oxford University Press, New York, 2000, p. 167.

¹¹³ Cf. "The Adaptive Toolbox," p. 38.

¹¹⁴ Cf. GIGERENZER, G., "The Adaptive Toolbox," p. 40.

¹¹⁵ Cf. "The Adaptive Toolbox," p. 43.

factors also intervene, such as social rules, moral limitations or simple routines.¹¹⁶ None of these aspects ever appear in Simon's writings.¹¹⁷

It seems, therefore, that the behavioral model proposed by Simon, being based on his theory of bounded rationality, supposes an improvement with regard to the neo-classical approaches in economics, principally with regard to the substitution of the assumption of rationality as maximization by the criterion of rationality as satisfaction. Undoubtedly, his approach provides a more credible description of how agents act when they make decisions rationally and incorporates a component of adaptation to the environment, of evolutionary inspiration.

Simon's adaptive rationality, in which the organism seeks to satisfy its expectations and needs, in order to adapt to a changing environment, therefore constitutes an advance with regard to the Popperian positions, which are expressed in an evolutionary epistemology. In the Popper's case rationality is taken as something abstract, alien to the knowing subject. The emphasis that Simon places on human cognitive limitations better reflects real human behavior when making decisions, and this can be tested empirically. This, in turn, makes it possible for disciplines such as Economics, and the processes occurring in them, to be seen as a human undertaking and not as something that is impersonal or timeless.

Nevertheless, in my opinion Simon barely appreciates that in situations of rational choice not only do limitations of a cognitive nature intervene, but there can also be real limitations of both a motivational and emotional nature. In this respect, the theory put forward by Selten appears to provide a better description of the way in which human beings make decisions. From my point of view, Selten —like N. Rescher— is correct when he sees the need to further adopt a rationality of ends or evaluative rationality, so that the agent is able to evaluate the different goals or aims instead of only focusing on the selection of the best means.

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¹¹⁶ Cf. SELTEN, R., "New Challenges to the Rationality Assumption," pp. 42-43.

¹¹⁷ Cf. GIGERENZER, G., "The Adaptive Toolbox," pp. 43-44.

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