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COMMENTARY

"Natural drift" as a Post-Modern evolutionary metaphor

La "deriva natural" como una metáfora evolutiva Post-Moderna

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ABSTRACT

The shift in evolutionary metaphors, from the Darwinian *natural selection* to *natural drift* proposed by Maturana, Mpodozis and Varela conveys a turn in worldviews. We argue that the former metaphor retains links with a Modern worldview, while the second, in detaching itself clearly from the notion of progress, is characteristically Post-Modern. We suggest that metaphors represent a key for understanding the links between scientific explanations and the cultural and social contexts in which they are formulated. To explain and justify that suggestion we develop a conceptual framework defining within this commentary three complementary scientific perspectives that have acquired a preponderant role at different times in the history of Western science: Pre-Modern, with emphasis on observation; Modern, with emphasis on the cognitive priority of the scientist's mind; and Post-Modern, with emphasis on the cultural and social contexts of scientific practice. Under the Post-Modern perspective metaphors acquire a dynamic cultural significance as expressions of the worldview influencing the scientist, and reciprocally as cultural messengers produced by the scientist's theories that in turn influence his or her culture and worldview. The epistemological and sociological analysis presented here for the evolutionary metaphors, permits us to recover the link between science (with its ways of representing and understanding nature) and environmental ethics (ways we live and relate to nature, as modulated and regulated by social values and norms). We hold that the recovering of this link between science and ethics has both theoretical and practical value at the present time when ecologists are simultaneously involved in a kind of Kuhnian scientific revolution, and facing a major environmental crisis that calls for a cultural transformation.

Key words: natural drift, natural selection, evolution, progress, metaphors, environmental ethics, ecology, epistemology, Post-Modern science, Darwin.

RESUMEN

El cambio de la metáfora evolutiva de Darwin, *selección natural*, por la metáfora *deriva natural* propuesta por Maturana, Mpodozis y Varela, conlleva un giro en la cosmovisión. Argumentamos que la primera retiene sus vínculos con una cosmovisión Moderna, en cambio la segunda, al liberarse claramente de la noción de progreso, es característicamente Post-Moderna. Sugerimos que las metáforas representan una clave para entender los vínculos entre las explicaciones científicas y los contextos culturales y sociales en que son formuladas. Para explicar y justificar tal proposición, desarrollamos un marco conceptual definiendo tres perspectivas científicas complementarias que han adquirido preponderancia en diferentes períodos de la historia de la ciencia occidental: Pre-Moderna, con énfasis en la observación; Moderna, con énfasis en la prioridad cognoscitiva de la mente del científico; y Post-Moderna, con énfasis en los contextos culturales y sociales en que ocurre la práctica científica. Bajo la perspectiva Post-Moderna, las metáforas adquieren un dinámico significado cultural como expresiones de la cosmovisión que influye sobre el científico y, recíprocamente, como mensajeros culturales producidos por las teorías del científico que influyen a su vez sobre su cosmovisión y cultura. El análisis epistemológico y sociológico elaborado aquí para las metáforas evolutivas contribuye a recuperar el vínculo entre las ciencias (con sus modos de entender y representar el mundo natural) y las éticas ambientales (modos de vivir y relacionarse con el entorno natural, modulados y regulados por valores y normas sociales). La recuperación del vínculo entre la ciencia y la ética tiene valor teórico y práctico, en tiempos en que los ecólogos estamos inmersos en una revolución científica de tipo kuhniana, a la vez que confrontamos una crisis ambiental que demanda una transformación cultural.

Palabras clave: deriva natural, selección natural, evolución, progreso, metáforas, ética ambiental, ecología, epistemología, ciencia postmoderna, Darwin.

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INTRODUCTION

In 1992 Maturana and Mpodozis published an essay entitled *The Origin of Species by Means of Natural Drift.* This title, although it may appear pretentious because of the allusion to Darwin's paradigmatic book *The Origin Species by Means of Natural Selection,* proposes a fundamental turn by replacing a single word in the original. In the substitution of *selection* by *drift,* one worldview gives way to another. Natural selection was conceived by Darwin by analogy with artificial selection, an activity at the core of the spirit of a Modern worldview characterized by its aim of productivity & progress, an aim expressed in our century as that of economic growth. Natural drift is proposed by Maturana & Varela (1990) as an analogy with water drops that follow random paths, or a vagabond sculptor who walks without any direction, an image that resonates with a Post-Modern detachment from the notion of progress.

Both, natural selection and natural drift, are proposed by their authors as evolutionary metaphors. We argue that these metaphors provide a key for analyzing the links between scientific explanations and the cultural and social contexts in which they are formulated. It is this metaphorical aspect that we will examine in this article, with the intention to provide a complementary approach to the valuable debate initiated by the commentary of Camus (1997) on the book of Manríquez & Rothhammer (1997) about the evolutionary theory of Maturana & Mpodozis (1992). We first develop a conceptual framework that permits us to understand how metaphors become involved in science. Then we discuss the social implications, particularly in regard to the notion of progress, of the Darwinian metaphor of "natural selection" and the contrasting metaphor of "natural drift" developed by Maturana, Mpodozis & Varela (see Maturana & Varela 1990, Maturana & Mpodozis 1992).

Both, Camus (1997) and Manríquez & Rothhammer (1997, chapter III) address the issue of metaphors in evolutionary biology, however they only touch on the subject without developing it. Camus (1997) interprets Manríquez & Rothhammer to suggest that all languages, including scientific language, are metaphorical. In spite of the relevance of this statement, Camus (1997) does not provide an analysis of it. Rather, he continues with his analysis of the book concluding that the "global objective" of Manríquez & Rothhammer's Chapter III is not clear. At the outset of Chapter III, the latter authors refer to Maturana & Mpodozis' criticism of Darwin's metaphor of "natural selection" as a "deceiving evocation." By citing Darwin himself, Manríquez & Rothhammer contend, however, that evolutionists are well aware of the problematic character of this metaphor. They close their considerations about metaphoric elements in evolutionary theory by referring to the metaphor of "natural drift" proposed by Maturana & Mpodozis, and stating the following question (p. 20): "Would this not be another sign that all languages, including that of scientists, are irreducibly metaphoric? (an answer to this question, originally posed by Hodge 1992, is found in 'Funes el Memorioso' by J.L. Borges [1942])."

This original question about metaphors, does not emerge with Hodge (1992), but rather is related to the philosophical interest in linguistics that has grown significantly since the end of the last century, and has been intensively analyzed with respect to cognitive process since the sixties (see Lakoff & Johnson 1980, Mac Cormac 1985, Kittay 1987). Recently, in their discussion of scientific theories, Pickett et al. (1994) pointed out the role of metaphors as raw material for the construction of ecological theories, describing them as "very closely related to the flashes of insight that identify novel problems or novel solutions to a problem and, therefore, are pre-theoretic" (p. 59). Under the views of science which

we discuss below, the role played by metaphors can be interpreted as even more pervasive and meaningful.

THREE HISTORICAL PERSPECTIVES OF SCIENTIFIC INQUIRY

In order to understand the role of metaphors in science, we develop a conceptual framework in which we define three scientific perspectives, that have acquired a preponderant role at different times in the history of Western science. We refer to them as: Pre-Modern, Modern, and Post-Modern conceptions of science. Under the Pre-Modern and Modern conceptions, metaphors are seen as characteristics of language alone, a matter of words rather than thought (see Lakoff & Johnson 1980). Metaphors become relevant to science only under the Post-Modern perspective that explicitly incorporates the cultural circumstances under which scientists work. In order to arrive at this stage, we will briefly describe each of these three historical perspectives. We illustrate them in Figure 1 by presenting the example of a scientist that studies a hummingbird visiting a flower.

We conceive these perspectives not as discrete moments of scientific work, which exclude or replace each other, but rather represent different and often complementary approaches. Neither do they represent distinct historical periods or exhaust all the complexity of scientific approaches. Instead, they are specifically intended to provide a conceptual platform for analyzing the meaning of metaphors in the practice of science.

1) Pre-Modern science: From the ancient texts to the observation of the natural world

As illustrated in Figure 1a, the Pre-Modern approach to science puts its emphasis on the natural objects that are being observed (hummingbird and flower), and little or no attention is given to the cognitive process associated with the scientist's observation.

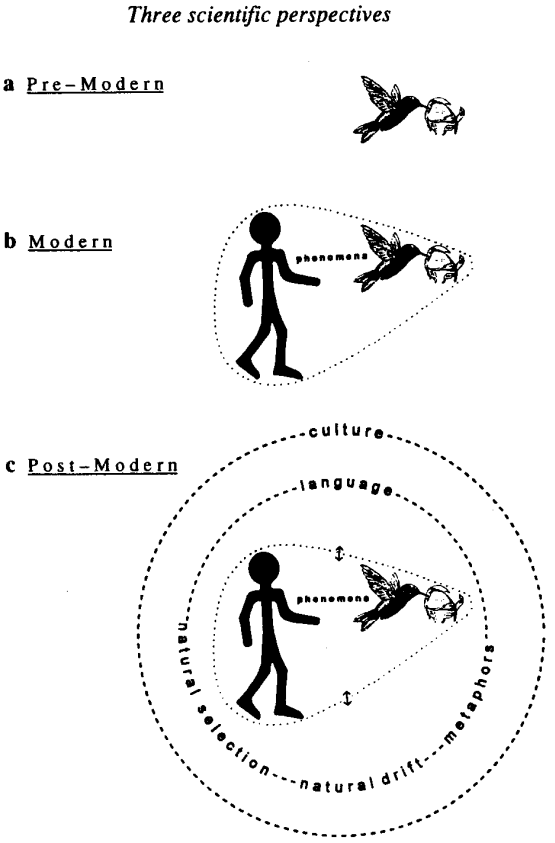

Fig. 1: We define three scientific perspectives that have acquired preponderance in different moments in the history of Western science. **a)** Pre-Modern, represents the emphasis on observation of the natural world started by scholars toward the end of the Middle-Ages. **b)** Modern, includes the scientist, who no longer perceives natural beings or processes in themselves but rather as *phenomena* represented in his/her mind, that may or may not correspond with the "external" material world. **c)** Post-Modern, emphasizes the influences of the social and cultural context upon scientific observations and explanations. The small arrows denote the bi-directional character of these relations, because the scientist affects, in turn, his or her cultural environments. Language and its metaphors, such as *natural selection* and *natural drift*, are key elements in these reciprocal influences between scientists, their society and culture.

Tres perspectivas científicas que han adquirido preponderancia en distintos momentos en la historia de la ciencia occidental. **a)** Pre-Moderna, representa el énfasis en la observación del mundo natural iniciado a fines de la Edad Media. **b)** Moderna, incluye al científico quien ya no percibe ni explica seres o procesos naturales en sí mismos sino *fenómenos* representados en su mente, que pueden o no corresponderse con el mundo material "externo". **c)** Post-Moderna, enfatiza las influencias de los contextos sociales y culturales sobre las observaciones y explicaciones del científico. Las flechas destacan el carácter bidireccional de estas relaciones, en que el científico afecta a su vez su medio cultural. El lenguaje y sus metáforas, como *selección natural* y *deriva natural*, son elementos claves en estas influencias recíprocas entre los científicos, su sociedad y cultura.

For this reason, the scientist is intentionally omitted in Figure 1a. Under this view, we do or teach science by focusing solely on natural entities or processes, thus emphasizing observation and data collection.

We call this perspective Pre-Modern, because it is the product of a scientific revolution that started during the XIIth-century, prior to the Modern Scientific Revolution. During that period, a growing interest in the scrutiny of the natural world developed in response to the movement of intellectual centers from monasteries to universities, and to the translation of Aristotle's remarkable work on Natural History into Latin. Scholars soon realized that ancient texts did not provide complete descriptions of the natural world, and they began in consequence to dedicate increasing amounts of time to the direct observation of nature. A paradigmatic figure in this naturalistic revolution was Albertus Magnus (1200-1280), who wrote *De Vegetabilibus et Plantis* and *De Animalibus,* commenting extensively on the work of Aristotle and his disciple Theophrastus. Driven by his critical analysis of these works and the popular Medieval *Bestiaries* and *Herbals,* Albertus Magnus felt impelled to elaborate careful descriptions of natural specimens (see Bowler 1993). This emphasis on systematic observation and description of material qualities of organic beings can be seen as the foundation for a scientific revolution, leading to the establishment of Natural History as a scientific discipline. This approach was later complemented with experimentation, and contributed to the emergence of empiricism as the prevalent way to inquire about the natural world.

Although for most contemporary scientists naive realism is outdated and their objects of study are not considered "things in themselves," the epistemological implications of this realization are not formally contemplated in today's university curricula or in contemporary ecological research. For example, no Graduate Program in Ecology in Chilean universities includes a formal course in Philosophy of Science, or explicitly addresses the role played by the scientist in the genesis of the explained phenomena (see Grez et al. 1995). In this sense the contribution of Dr. Humberto Maturana and his co-workers has been crucial to the development of an epistemological understanding in biological sciences in Chile and abroad. The treatment of the process of knowing and the explicit reference to the observer in the description of natural phenomena constitute significant merits in the formulation of the theory on the origin of species by *natural drift* (see Maturana & Varela 1990, Maturana & Mpodozis 1992).

2) Modern science: From the natural object toward reason

With Descartes, the mind of the scientist begins to play an explicit and central role in Modern science. We illustrate this change by showing the hummingbird, the flower, and their interactions, as phenomena occurring in the mind of the observer, the scientist (Fig. 1b). A landmark philosopher in this tradition is Kant, for whom reason acquired an *a priori* role in the process of knowing: "Nature is what reason puts in it" (see Kant 1787). For Kant space and time are not properties of the natural world, but categories of human sensibility under which we represent that world. Kant made the distinction between *phenomena* –mental representations which we know– and *noumena* –things in themselves which we cannot know, even whether they exist at all. Thus, in Figure 1b we would not know about the hummingbird, the flower, and their interactions in themselves, we do not know even if they exist beyond the perceived and explained phenomena.

The skepticism concerning the existence and knowledge of external natural beings was brought to an extreme by Hume, who questioned the notion of causality, as well as the presumed correspondence between

our logical –mathematical scientific statements and possible natural laws. Hume's skepticism –which departs from the Modern metaphysical worldview that identifies the structure of the natural world with that of reason- is expressed today in the epistemological and methodological caution of Popper's falsifiability criterion. This criterion, essential to the hypothetico-deductive method of science (see Armesto 1985), is well condensed and contrasted with an experimental verificationist logic by Camus (1997). Popper (1959) emphasizes the role of the scientist's mind, as shown in our Figure 1b. According to him the formulation of a hypothesis is a creative exercise of the imagination; it is not a passive reaction to observed regularities. As the next step, we proceed to the empirical test of the imaginary model or explanation of the phenomenon. Although critical of "verificationism," Popper remained centered, as his predecessors, on the problems of the internal logical consistency of theories, and the contrast between empirical observations and the laws derived from these scientific statements.

By remaining outside of the social context, and focusing on the internal coherence of theories and the empirical testing of them, Popper continued thinking of science as "value free." This latter notion, however, came under an intense critical review after World War II, as increasing attention started to be paid by other philosophers of science to the "external" connections of science with prevailing social values and cultural settings (see White 1949, Hanson 1958, Toulmin 1961, Kuhn 1962, Feyerabend 1962, Lakatos & Musgrave 1968). Present-day ecologists –who customarily utilize a Popperian hypothetico-deductive method (see Pickett et al. 1994)– are being challenged by the acknowledgment of the pervasive role of value-systems in the practice of science, which demands us to move beyond Popperian method.

3) Post-Modern science: From pure reason toward historical and social contexts of science

The recognition of the influence of historical, cultural and ideological circumstances on the formulation of scientific explanations gives rise to our third view of science, defined as a Post-Modern perspective. We illustrate this view in Figure 1c, by depicting the scientist and the hummingbird visiting the flower immersed in a cultural setting, which influences the representation and theoretical interpretation of the biological phenomena. Language and metaphors acquire here a dynamic cultural significance that moves bi-directionally (as denoted by the arrows in Figure 1c): As cultural determinants and expressions of the worldview influencing the scientist, and reciprocally, as cultural messengers produced by scientist's theories that in turn influence his or her culture and worldview. Figure 1c shows the two evolutionary metaphors, *natural selection* and *natural drift,* which we will discuss below as emerging from the work of scientists immersed in different cultural worlds.

Camus (1997; p. 16) does not enter into this sociological level of analysis, deferring it to Kolakowski (1988) and concluding that such questions "have not acquired sufficient force and presence in biology." Manríquez & Rothhammer (1997) merely provide an allusion to this perspective when they include (p. 37) the concept of positioning of a theory in a diagram based on Kuhn (1977). Certainly no other philosopher of science has done more than Thomas Kuhn to direct the attention of scientists to the influential role of worldviews, culture, and values. His book *The Structure of Scientific Revolutions* (1962) has helped to transform our conception of what science is and how it works.

Kuhn and Lakatos made a useful distinction between "internal" and "external" history of science by defining the first as the historical process of scientific knowledge as resulting from the

empirical work, elaboration and testing of theories within each discipline, and the second as the history of the social and cultural circumstances under which science has developed (see Lakatos 1974). This second focus has promoted an interest on detailed study of the history of science (Brown 1979), resulting in new journals and disciplines analyzing the connections between ecological theories and the cultural and social environments in which they were conceived (Worster 1990). Under this analysis, we came to realize that the description of natural phenomena reveals as much about human society and its changing concerns as it does about nature (see Worster 1994). This awareness is certainly not new in philosophy. For example, during the last century, Schopenhauer criticized the mechanistic interpretation of nature raised by Modernity, remarking that "the idea of nature-as-a-machine was a human construction imposed on an independent or autonomous other" (Oelshlaeger 1991; p. 125; see also Foucault 1970).

We refer to the third conception as Post-Modern science because under this view two essential notions of Modern science –universality of reason and scientific progress– are called into question. First, the universality of Modern reason is disrupted by the intrusion of particular social factors and cultural circumstances (Latour & Wolgar 1979). Scientists should now make explicit their worldviews when describing and explaining biological phenomena (see Allen & Hoekstra 1992, Ahl & Allen 1996). Consistent with a Post-Modern conception of scientific rationality, we develop an interpretation of *natural selection* and *natural drift* as metaphors conveying different social and historical values. Second, the understanding that scientific theories are social and cultural constructions undermines the belief in historical improvement in knowledge through accumulation of facts. In passing from one form of society to another we shift from one belief system to a different one, leading to Kuhn's proposition that different scientific paradigms are incommensurable (see Feyerabend 1970). Kuhn rejects in this manner the notion of accumulation of knowledge and scientific progress (see Lakatos 1970). Our subsequent analysis of the meaning and implications of the evolutionary metaphors of *natural* selection and *natural drift* stems from this fundamental problem with the Modern notion of progress.

"NATURAL SELECTION" AND "NATURAL DRIFT" AS EVOLUTIONARY METAPHORS

To what extent does the metaphor of "natural selection" convey the sign of Modernity and the notion of progress? This is a difficult question to answer. Looking first in the direction of the influences of society on Darwin's theory of evolution, we find that the circumstances that led Darwin to formulate his theory of natural selection form one of the most studied and debated areas in the history of science (Bowler 1993). A well-documented aspect of this historical discussion has focused on the extensive influence that Victorian society and Malthusian economy exerted on Darwin's theory (see Kohn 1985, Richards 1989, 1992, Young 1995, Rozzi et al. 1996). With respect to "natural selection," the simultaneous and independent formulation of this principle by two British naturalists, Darwin and Wallace, has been presented as strong evidence for how scientists are influenced by their social and cultural setting (Kleinert 1985, Kottler 1985, Bowler 1990).

Looking in a reverse direction, that of Darwin influences on society, we also realize that there is an endless array of literature (see Huxley 1947, Flew 1967, Rotgers 1972, Nitecki & Nitecki 1993). We note that these influences are open and non-deterministic, giving rise to a diverse array of views and doctrines. For example, Social Darwinism emphasized the aspect of "struggle for existence," promoting a strong

sense of competition and individualism (Rotgers 1972). In contrast, other views such as Aldo Leopold's *Land Ethics* have emphasized the sense of community derived from the Darwinian notion of the "web of life." Leopold (1949) appeals further to the Darwinian thesis of a common origin for all biological species to promote a sense of "kinship" that goes beyond human society to include the whole biotic community (see Callicott 1989).

The meaning of the metaphor of "natural selection" does not escape to this broad spectrum of interpretations (see Mayr 1982, Nitecki 1989, Hodge 1992, Young 1995). The diversity of opinions about the link between the notions of progress and natural selection, can be arrayed between two poles: one associated with the Modern notion of progress, and the other closer to a "Post-Modern" non-progressive interpretation of evolution. Flew (1967) pointed out that Darwin himself was not altogether free from an ambivalence in his view of evolutionary progress. We argue below that this ambiguity is particularly present in his metaphor of natural selection, which conveys evident links with concepts of biological and social progress.

We propose to start our examination of the Darwinian notion of evolutionary progress by looking at the writings of Charles' grandfather. A most significant and expressive text that illustrates Erasmus' thinking during the "Enlightenment" period of Modernity is found in the following passage of his book *Zoonimia:*

"The late Mr. David Hume ...concludes that the world itself might have been generated rather than created; that is, it might have been gradually produced from very small beginnings, increasing by the activity of its inherent principles, rather than by a sudden evolution of the whole by the Almighty fiat... Thus it would appear, that all nature exists in a state of perpetual improvement by laws impressed on the atoms of matter by the great cause of causes; and that the world may still be in its infancy, and continue to improve for ever and ever" (E. Darwin 1794; p. 245-246).

Two aspects of this first unequivocal evolutionary pronouncement made by Erasmus Darwin (see Harrison 1971) are most relevant to our argument here: First, Erasmus displays a vehement faith in progress. Second, the idea of evolution emerged in the intellectual tradition of Darwin's family via philosophy. Charles' grandfather took the notion of evolution from Hume, who stated that "the world itself might have been generated rather than created" in his book *Dialogues Concerning Natural Religion* (1779). This source of inspiration for Erasmus, which Charles read extensively later (see Gruber & Barrett 1974), manifests how dynamic and intricate the flow of ideas between natural sciences and other disciplines can be.

Turning to Charles Darwin, his famous reminder: "Never use the words 'higher' and 'lower'" (quoted in Sober 1985), seems to reflect his non-progressive interpretation of evolution. However, when we look particularly at his metaphor of natural selection the prejudice against progress becomes less clear. In developing the analogy between natural and artificial selection in a passage of *The Origin of Species* Darwin (1859) writes:

"If it profits a plant to have its seeds more and more widely disseminated by the wind, we can see no greater difficulty in this being effected through natural selection, than in the cotton-planter increasing and improving by selection the down in the pods on his cotton-trees." (p.86)

Just as the planter selects for improving the size of pods and cotton productivity, in Nature those characteristics that help individuals to maximize the number of descendants are selected. In the last Chapter of the *Origin of Species,* Darwin suggests more explicitly a relationship between artificial and natural selection in regard to progress by affirming:

"...Man can and does select the variations given to him by nature, and does

accumulate them in any desired manner. He thus adapts animals and plants for his own benefits and pleasure... *There is no obvious reason why the principles which have acted so efficiently under domestication should not have acted under nature.* In the preservation of favored individuals and races, during the constantly-recurrent Struggle for Existence, we see the most powerful and ever-acting means of selection" (p. 467, emphasis added).

Here we interpret Darwin as seeing no obstacle for "projecting" his conception of artificial selection onto Nature. In this act of cultural projection, Darwin transfers to nature a realm of progress, which is explicit at the end of his book, when he concludes that:

"...As natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection" (p.489).

In later works, "Darwin's cultural projection onto nature," already carrying the values of his society, allows him to reinforce the Victorian ideals and belief in progress. In the following passage of *The Descent of Man,* Darwin (1871) projects back onto society his theory of natural selection by writing:

"The remarkable success of the English as colonists over other European nations, which is well illustrated by comparing the progress of the Canadians of English and French extraction, has been ascribed to their 'daring and persistent energy'; but who can say how English gained their energy. There is apparently much truth in the belief that the wonderful progress of the United States, as well as the character of the people, are the results of natural selection" (p. 179).

In this passage his metaphor of natural selection acquires an eloquent social dimension promoting the ideals of Modern progress. Thus, *natural selection* as a metaphor conveys at least certain ambiguity of interpretation in the writing of Charles Darwin himself, because its strong links with the notion of progress in the social and biological realms are evident. The ongoing debate about the relationship between natural selection and the notion of progress notwithstanding (see Williams 1966, Mayr 1982, Nitecki 1989), the quoted passages of Darwin offer an undeniable evidence for that relationship.

In contrast, the evolutionary metaphor of *natural drift*, proposed by Maturana and co-workers, clearly frees itself from the notions of biological & social progress. Indeed, Maturana & Varela (1990) affirm: "We propose that evolution occurs as a phenomenon of structural drift... without progress or optimization of the use of the environment, but only conservation of adaptation and *autopoiesis*, in a process where organism and environment remain in continuous structural coupling" (p.76). Living beings are understood as self-organizing *autopoietic* systems. *Autopoiesis* means literally self-production (see Maturana & Varela 1980). The process by which an organism -or *autopoietic* system- follows a path of structural change, which results from its dynamics of interactions while conserving its organization, through a relation of operational congruence with the environment, is denoted by the word *drift* (Maturana & Mpodozis 1992).

Maturana & Varela (1990) introduce their notion of *natural drift* by means of an analogy with a hill with multiple valleys and ravines through which water drops flow. Each drop follows a slightly different course. In a similar manner the different paths followed in their natural drift by living beings would give origin to the diversity of evolutionary lineages. Maturana & Varela (1990) did not discuss the underlying biological evolutionary mechanisms. Although this represents a limitation, we prefer not to focus on this problem, but rather to focus on the view of the natural and social worlds evoked by their metaphor. When Maturana & Varela (1990) originally proposed this evolutionary metaphor, they evoked the following social image:

"Evolution resembles rather a vagabond sculptor that walks through the world and takes this thread here, this piece of metal there, this piece of wood here, and puts them together in a way that their structure and circumstances allow, without any other reason than just putting them together. And so, in the course of his vagabond walk intricate forms composed by parts harmonically interconnected are being produced, that are not the product of the design, but of a natural drift."

The walking of a vagabond without direction contrasts sharply with that sense of progress in Darwin's English colonists. These two contrasting passages –in Darwin's *Descent of Man* and in Maturana & Varela (1990)– illustrate in a most meaningful form how a theory that aims to explain an attribute of nature –in this case biological evolution– is suggested by and, in turn, affects historical social values and worldviews. To what extent was Darwin inspired by his social ideal in formulating his evolutionary theory of natural selection, or to what extent has Darwin's theory contributed to constructing and modifying his social world, are still open questions. At the same time, we understand that science and society do not form a closed system of deterministic mutual influences. Each has its own internal historical dynamic, and both are open to multiple and unpredictable influences (Rozzi 1998a). It is evident in the case of the natural sciences that scientists open the circle of relations between culture and science by looking at the natural world. In metaphorical terms, Prigogine (1997) says that scientists engage in a *dialogue with nature* in their search for natural patterns and processes.

Our examination of natural selection and natural drift provides, however, clear evidence to affirm that scientific theories and social values are intimately interrelated. Consequently, the notion of science as "value free" is no longer tenable. Even beyond this, under the evidence illustrated by the proceeding analysis and quoted texts of Darwin and Maturana et al., we are invited to recover the link between our ways of knowing and living. We say *recover* because the split between the two, i.e. fact and value –the schism between "objective knowledge" and "subjective morality"– occurred just recently, especially since the last century, due to the prevalence of Empiricism and Positivism in sciences (Hargrove 1996).

From an applied point of view, the need to recover the link between the ways we understand Nature through science and the way we relate to it, modulated by social values and regulated normatively by an environmental ethics, has been profusely demanded by ecologists and other scientists confronting the current global environmental crisis (Bormann & Kellert 1991, Primack 1995, Odum 1996, Meffe & Carroll 1997). The detachment of evolutionary theory from the notion of biological progress could contribute to a broader cultural detachment from that Modern ideal of progress, and could in this way provide a key step toward sustainability (see Gowdy 1994). In this respect, the metaphor of *natural drift* is congruent to, and resonates with, an emerging Post-Modern worldview. Both leave behind the notion of progress, essential to the exploitative attitude of Modern society toward the natural world. From the perspective of human impact on the environment, the metaphor of *natural drift* appeals to a less consumerist model of society, which could represent a crucial step to overcome the current environmental crisis (Daly & Townsend 1994).

CONCLUDING REMARKS

Integration of the three presented perspectives of scientific work

The three perspectives of science discussed above (Fig. 1), are not mutually exclusive, but they correspond to different dimensions of our discipline. In arguing for their

integration, it is interesting to note how clearly manifested are these three perspectives in the work of Charles Darwin. For the first one, with an emphasis on observation, his meticulous field notes during the voyage of the Beagle allowed him to discover similarities and differences between biota of diverse and distant regions. This biogeographical approach was a fundamental source for Darwin's theory of evolution (see Bowler 1993). For the second perspective, with an emphasis on the cognitive process, it is remarkable how carefully Darwin read Hume's and Kant's work while conceiving his evolutionary theory (see Darwin's Notebooks 1836-1844, Darwin 1871, Huntley 1972, Rozzi 1998b). Finally, for the third perspective, with an emphasis in linguistics and culture, several scholars have commented that the exceptional literary beauty of Darwin's writing, particularly in the case of *The Origin of Species,* could have been a key to the success of his work (see Bulhof 1992). Darwin's literary esthetical preoccupation together with his inexhaustible imagery gave rise to rich metaphors such as the *tree of life*, which connects all living beings in a common evolutionary trunk; the *entangled bank* which emphasizes the ecological connectivity of all living beings; and the previously discussed *natural selection*. This aspect of Darwin's work shows that he was concerned with language and metaphors, as central elements for conceptualizing and formulating his evolutionary theory.

In this way, Darwin's work illustrates how the previously defined Pre-Modern, Modern, and Post-Modern scientific perspectives are not mutually exclusive. Nor are they historical paradigms that replace each other in time. They are complementary insights that enrich our scientific endeavor. However, the second and third perspectives of this contemporary understanding of science need to be integrated into undergraduate and graduate programs in ecology.

Integrating ecology and ethics

Under the third perspective of science (Fig. 1c), we make explicit how scientists can influence and, in turn, are influenced by their cultural environments. This conception shows how the ways of knowing about the world –through science– and the way of inhabiting that world –ruled by ethics– are interconnected by dynamical and reciprocal relationships that take place in a broader cultural medium. These links between ecological science and environmental ethics appear as particularly relevant to biologists now confronting the current environmental crisis.

Wilson (1991) calls for a "sound ethics of biodiversity ...[that] must reach further and incorporate the very meaning of human existence." Likens (1991) points out emphatically the necessity of reforms in study programs: "Students must learn more about environmental issues and ethics in order to develop a 'meaningful philosophy of life'... Universities should increase course offerings about the relationship between ethics and the environment, and they should require students to take them." Maturana and his collaborators have worked on these issues and taught about these links since the seventies, and their evolutionary metaphor of *natural drift* could contribute to de-emphasizing the notion of progress, which in Chile has been, and still is driving a rapid and widespread process of biological and cultural homogenization (Rozzi et al., in prep.).

Integration and innovation in ecology

As Camus (1997) declares in his subtle metaphor of "some dry parts of angiosperms," theoretical discussions of the philosophical assumptions and implications of our every day practice of science are too often dismissed as irrelevant by some ecologists. This attitude is changing rapidly, however. New institutions, such as the *National Center for Ecological Analysis and Synthesis*

(University of California, Santa Barbara, USA), new scientific journals, such as *Conservation Ecology,* are calling for innovation and integration in ecology. But innovation is risky. Holling (1997), in the editorial of the first issue of *Conservation Ecology*, indicates that 100% of the papers submitted were initially rejected. He explains that many articles were written by well known ecologists –although that fact was hidden by a double-blind review process– and he attributes this 100% rejection to resistance to "novelty, synthesis and well-grounded speculation." In the same tone, Pickett (1997) in arguing for the need of ecological synthesis counsels that "...caution in discarding ideas too early seems appropriate. Identifying barriers to synthesis, especially those supported by defunct philosophies, will help to clarify the way for synthesis. Tolerance of and interest in new ideas, ... must be embraced to enhance synthesis." This forum in *Revista Chilena de Historia Natural* opens a meaningful space for a refreshing debate and reflection in a time when ecologists are involved, in our view, in a kind of Kuhnian scientific revolution, looking for theoretical synthesis, and facing a major environmental crisis that calls for recovering the link between science and ethics.

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