The Reciprocal Links between Evolutionary–Ecological Sciences and Environmental Ethics

BY RICARDO ROZZI

Confronted with the current environmental crisis, the academic community faces a conceptual and practical problem of dissociation: Ecologists approach nature with the aim of understanding it, whereas environmental ethicists approach nature asking how we should relate to it, or inhabit it. Ecology looks for the "is" of nature, and environmental ethics seeks an "ought" with respect to nature. How can these still largely disconnected and yet parallel courses be bridged? How can the is of ecologists and the ought of eco-philosophers be interrelated? More basically, how can the links between the cognitive–scientific and the practical–ethical spheres be recovered?

To describe my approach to these questions, I begin with an illustration. Figure 1a depicts at its center my thesis: that the ways in which humans dwell in the natural world inspire the ways in which we understand, explain, and look at the natural world. Conversely, the ways in which we represent nature (e.g., through scientific theories) constitute a kind of text or scenario that inspires our attitudes, behaviors, and ways of inhabiting nature. Therefore, changes in the scientific sphere suggest changes in the ethical sphere, and vice versa. If the way of dwelling in the natural world is viewed as an environmental ethos, we can in a broad sense refer to this ethos as an environmental ethic. If the way of understanding the natural world is called a science, we can broadly refer to this understanding as evolutionary–ecological sciences. With these definitions, the initial thesis illustrated in Figure 1a can be reformulated by affirming that environmental ethics and environmental sciences influence each other in a reciprocal and dynamic way. Ethics and science establish a dialectic interrelationship that evolves historically through mutual and successive modifications.

The continuous and reciprocal influences between ecological theories and ethical norms respecting nature take place within two broader environments: the cultural world and the natural world (Figure 1a). The reciprocal and dynamic influences between environmental ethics and sciences are, therefore, open to the influences of broader contexts. Both sociological and natural phenomena exert significant influences on the genesis of scientific conceptions of and ethical attitudes toward nature. Even more, as Figure 1a shows, the natural world constitutes a broader environment in which culture occurs.

In this article, I illustrate the reciprocal relationships between sciences and environmental ethics by examining the Darwinian theory of evolution and discussing its implications for ecologists and ethicists. Darwinian theory represents only an illustrative case; similar analyses could be done for other ecological theories, such as ecosystem theory or vegetation succession. However, the Darwinian theory of evolution is ideal for discussion of the interrelationships between ecological sciences and ethics, for three reasons. First, the social influences and historical circumstances that led Darwin to formulate his theory of natural selection have been examined and debated more than those leading to any other theory in the history of biology. Second, Darwinian theory constitutes a foundational basis for major strains of both ecology and environmental ethics. Third, Darwinian theory can stimulate contrasting environmental values and attitudes. It can encourage respectful treatment of the natural environment by weakening anthropocentrism in modern society with metaphors such as the "ecological web of life" and "the tree of the origin of life." But it can also favor patterns of overconsumption and exploitation of the natural environment by strengthening individualism and the idea of progress with metaphors such as the "struggle for existence" and "natural selection."

Interrelations among science and ethics in Darwin's theory

To understand the complex dialectic between environmental ethics and ecological–evolutionary sciences that take place within broader cultural and natural environments, I illustrate the case of Darwinian theory by modifying Figure 1a into Figure 1b. I begin by describing how culture, the natural world, and ethics influenced Darwin's formulation of the evolutionary theory (Figure 1b, arrows 1, 2 and 3, respectively). Then I analyze how Darwin's theory has, in turn, influenced ethics, modern culture, and human impact on the natural environment (Figure 1b, arrows 4, 5 and 6, respectively). Finally, I discuss how an understanding of the reciprocal influences between science and ethics contributes to a cultural transformation in our modes of viewing and relating to the natural world.

Influences of culture on science. Three distinct kinds of cultural influence were of particular relevance for Dar-

Ricardo Rozzi (e-mail: rozzir@ecostudies.org) coordinates the ecological education program at the Institute of Ecological Research Chiloé, Chile (Ancud, Chile), and serves as Regional Representative for South America in the International Society of Environmental Ethics. He is currently at the Departments of Philosophy and of Ecology & Evolutionary Biology, University of Connecticut, Storrs, CT 06269-3043.

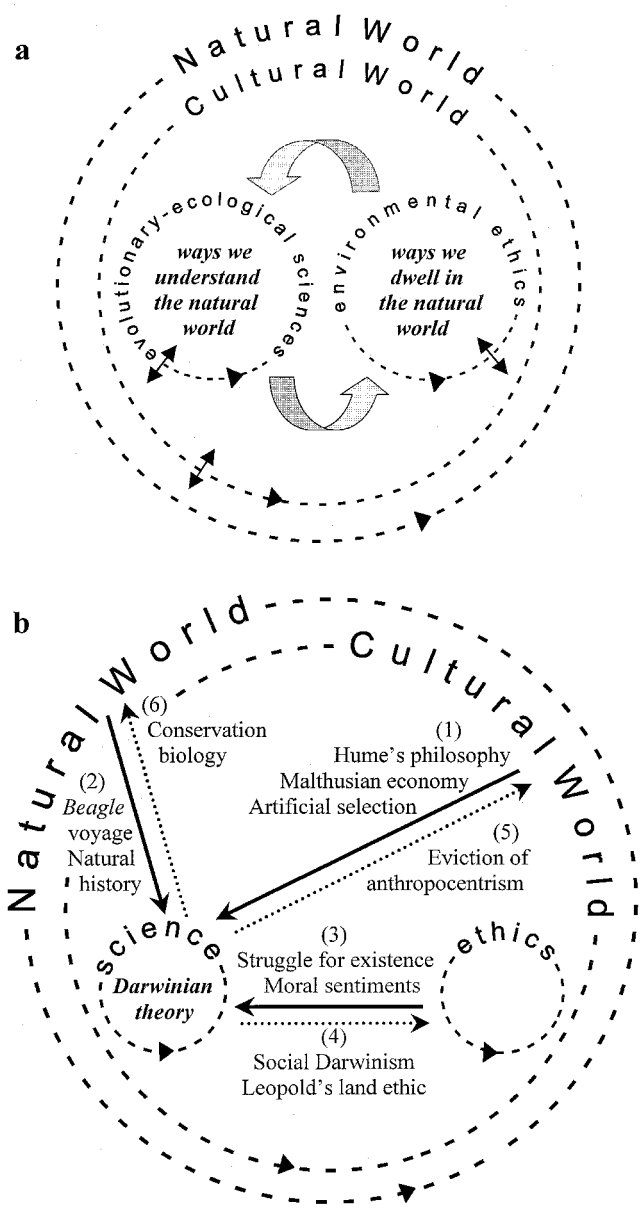

Figure 1. Reciprocal influences between evolutionary–ecological sciences and environmental ethics. (a) The ways in which humans understand the natural world (sciences) and dwell in it (environmental ethics) are intimately linked by reciprocal influences (broad gray arrows) that take place within two broader environments: the cultural world and the natural world. The short double arrows crossing the borders of each circle emphasize the openness of each domain to influences occurring among all domains. The arrowheads in each of the circles indicate the dynamic character of each domain. (b) This concept can be elaborated based on the case of Darwin's evolutionary theory. Solid arrows refer to influences on Darwin's evolutionary theory that derive from culture (1), observation of the natural world (2), and ethics (3). Dotted arrows indicate influences that Darwinian theory has had on ethics (4), modern culture (5), and human impact on the natural environment (6).

win's evolutionary conception: the philosophy of David Hume, the economy of Thomas Malthus, and the practice of artificial selection (Figure 1b, arrow 1). It is particularly significant that the basic notion of evolution came into Darwin's family via philosophy. The notion of evolution was suggested to Darwin's grandfather, Erasmus Darwin, by the British philosopher Hume (Harrison 1971). In Erasmus Darwin's first unequivocal evolutionary pronouncement—in a paragraph of his main work, *Zoonomia*—he quoted from Hume's posthumously published *Dialogues Concerning Natural Religion* (1779): "The late Mr. Hume...concludes that the world itself might have been generated rather than created" (Darwin 1794, pp. 245–246). Interestingly, Hume (1779) admitted in his *Dialogues* that he did not have the data to support his conclusion. Eighty years later, through the development of the theory of biological evolution, Charles Darwin—who at a young age carefully read his grandfather's *Zoonomia* (see Darwin 1892)—furnished the data requested by Hume. In this manner, the Darwinian theory of a common origin for all living forms was stimulated by Hume's philosophy (Huntley 1972); Darwinian theory provided, in turn, the empirical support requested by Hume's evolutionary thesis that criticized a prevailing creationist view in the eighteenth century (Ricardo Rozzi, unpublished manuscript).

Philosophy also appears to have stimulated Darwin's use of the term "evolution." In the entire book *On the Origin of Species*, Darwin used the word "evolution" only once, in the final sentence: "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved" (Darwin 1859, p. 490). Later, however, under the influence of his contemporary, philosopher Herbert Spencer, who used the term "evolution" extensively, Darwin employed it frequently to refer to his theory of natural selection in *The Descent of Man* and other works. Spencer seems to have borrowed the concept of life as progressive evolution from Samuel Coleridge, who in turn had adopted it from the German philosopher Friedrich Schelling (see Richards 1987, 1992). This flux of the term "evolution" illustrates how philosophy provided this basic notion for the conception of the Darwinian theory.

A broader historical perspective of the eighteenth and nineteenth centuries indicates a remarkable synchrony in the development of the notion of evolution among diverse natural and social sciences (Levins and Lewontin 1985,

Rozzi et al. 1996). In geology, James Hutton and Charles Lyell formulated the laws of Uniformitarianism, which explained the continuous processes of mountain building and erosion throughout the history of the earth. In astronomy, Pierre Simon Laplace proposed his nebular hypothesis about the origin and transformation of the universe. Sadi Carnot and William Thompson conceived the laws of thermodynamics, which provided a physico–chemical mechanism for the transformation of the universe and evolutionary processes. Among social sciences, both positivism and Marxism embraced an evolutionary worldview that was characterized by a notion of progress. Positivism (e.g., Auguste Comte, Spencer) described the progression in human knowledge from myth to religion, and from the latter toward science. Historical materialism (e.g., Karl Marx, Friedrich Engels) interpreted the course of human history as an evolutionary process toward a final state in which social classes would be abolished. In philosophy, Georg Wilhelm Friedrich Hegel's system, founded in a historical development of consciousness ("mind or spirit"), constituted a paradigmatic evolutionary conception.

The effect of the former social influences on the conception of the theory of biological evolution is historically supported by the simultaneous but independent formulation of the theory of natural selection by Darwin and Alfred Russel Wallace (White 1969). Furthermore, for both Darwin and Wallace, the work of Malthus was a major inspiration (Bowler 1990). In fact, Darwin referred explicitly to Malthus's theory in the introduction of *On the Origin of Species*, when he wrote that his theory of natural selection "is the doctrine of Malthus applied to the whole animal and vegetable kingdoms." Malthus had stated that the human population grows at a geometrical rate, whereas resources—such as food—increase at an arithmetical rate; consequently, a "struggle for existence" among humans is promoted. Darwin expanded Malthus's statement and projected it on "the whole animal and vegetable kingdoms" by inferring that "the Struggle for Existence amongst all organic beings throughout the world follows inevitably from the high geometrical ratio of their increase.... As many more individuals of each species are born than can possibly survive...it follows that any being, if it vary however slightly in any manner profitable to itself,...will have a better chance of surviving and thus be *naturally selected*" (Darwin 1859, p. 5).

Another cultural practice that inspired Darwin's conception of the evolutionary mechanism was the sophisticated practice of artificial selection. In his correspondence and *Autobiography* (Darwin 1892), Darwin referred to his conversations with skillful breeders and gardeners, which reinforced his conviction that species are mutable and stimulated his analogy between artificial and natural selection. Darwin pointed out this analogy throughout *On the Origin of Species*, concluding in the final chapter that "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 favoured individuals and races, during the constantly recurrent Struggle for Existence, we see the most powerful and ever-acting means of selection" (Darwin 1859, p. 467).

Darwin's statements illustrate how he took two conceptual and practical elements of his British culture—Malthusian economy and artificial selection—and saw "no obvious reason" not to project them onto nature to explain biological evolution. This cultural projection onto the natural world was soon noted by Engels, who wrote in *Dialectics of Nature* that "the whole Darwinian theory of the struggle for existence is simply the transference from Capitalist society and its economic theory of competition to organic nature" (Engels 1880, p. 584). Marxist philosophers and historians have further developed Engels' sociological interpretation in the twentieth century (Oldroyd 1983). Although insightful, Engel's interpretation seems incomplete, because for Darwin's formulation of his evolutionary theory his innumerable experiments and observations of the natural world represented a precious and essential key. Therefore, sociological influences do not fully explain the development of Darwin's scientific theory.

Influences of natural history on science. In his *Autobiography*, Darwin emphatically affirmed that "The voyage of the *Beagle* has been by far the most important event in my life, and has determined my whole career" (Darwin 1892, p. 28; Figure 1b, arrow 2). One can find in Darwin's *The Voyage of the* Beagle (1838; commonly referred to as Darwin's *Diary*), which describes his early experiences as a naturalist, concepts and metaphoric expressions central to his theory that were written almost identically in his major works 30 years later. For example, both the image of the "entangled bank" (mentioned at the end of *On the Origin of Species* to illustrate the ecological interdependence among species) and the notion of humans as evolved animals are recorded in his young impressions exploring the austral extreme of South America.

One day Darwin got lost in a deep ravine of Tierra del Fuego, and he was so challenged and impressed by the structural complexity of the austral forests that the entangled image would appear again and again in his *Diary*. Darwin (1838) wrote, "I began the most laborious descent through its entangled thickets," and later described "a little, dusky-coloured wren (*Scytalopus magellanicus*) [that] hops in a skulking manner among the entangled mass of the fallen and decaying trunks" (p. 226). These images reverberate with Darwin's metaphoric allusion in the last paragraph of *On the Origin of Species*: "It is interesting to contemplate an entangled bank, clothed with many plants,...birds...insects...worms crawling through the damp earth,...dependent on each other in so complex a manner" (1859, p. 489). Thus, this final passage, famous

for its conceptual richness and poetic beauty, suggests also a naturalistic source of inspiration for its composition.

With respect to the conception of human evolution, Darwin's encounter with the Fuegian Yamana Indians shook his Victorian beliefs in the gulf between humans and animals. In his *Diary*, Darwin described the arrival at Tierra del Fuego on 17 December 1832 as follows:

> While entering [the Bay of Good Success] we were saluted in a manner becoming the inhabitants of this savage land. A group of Fuegians partly concealed by the entangled forests was perched on a wild point overhanging the sea; and as we passed by, they sprang up and waving their tattered cloaks sent forth a loud and sonorous shout. The savages followed the ship, and just before dark we saw their fire, and again heard their wild cry.... It was without exception the most curious and interesting spectacle I ever beheld: I could not have believed how wide was the difference between savage and civilized man: it is greater than between a wild and domesticated animal, inasmuch as in man there is a greater power of improvement. (Darwin 1838, pp. 194–195)

Then, on 25 December 1832, Darwin continued:

> Viewing such men, one can hardly make one's self believe that they are fellow-creatures, and inhabitants of the same world. It is a common subject of conjecture what pleasure in life some of the lower animals can enjoy: how much more reasonably the same question may be asked with respect to these barbarians! At night, five or six human beings, naked and scarcely protected from the wind and rain of this tempestuous climate, sleep on the wet ground coiled up like animals. (Darwin 1838, p. 203)

It is difficult to imagine that a Victorian-era scientist would have ever arrived at the conclusion that *Homo sapiens* is an animal species—the product of biological evolution like any other species—in the absence of such a shattering experience. If Darwin had remained in the environment of British society, missing this view of naked forest-dwelling humans in the austral extreme of South America, he might never have conceived of the human species as an animal, a relative of other primates. Once again, this episode points out the importance of empirical and naturalistic experiences in the field.

Although Darwin's judgments about the Fuegian Indians are irritatingly Eurocentric, they can be reinterpreted from another angle as a redeeming disclosure by which modern Western society recovered an awareness of human's animal nature. The encounter with the Fuegians was such a defamiliarizing experience for Darwin as to modify and obliterate beliefs essential to Victorian culture. In *The Descent of Man* (Darwin 1871), the Fuegians constitute the most mentioned aboriginal group; as revealed in the following entry from one of Darwin's notebooks, they were central to his argument of a common ancestor for humans and other primates: "Let man visit Ourang-outang in domestication, hear its expressive whine, see its intelligence when spoken; as if it understood every word said...[then] look at savage, roasting his parent, naked, artless,...not understanding language of Fuegian[s], puts [them] on par with Monkeys" (Barrett et al. 1987, p. 264).

In addition to being exposed to field experiences and opportunities for detailed observations, Darwin was "thinking along" with other naturalists and scientists during the *Beagle* voyage. Two books—*Personal Narratives*, by Alexander von Humboldt, and *Principles of Geology*, by Charles Lyell—accompanied him throughout his travels, and Darwin was vividly aware of the combined relevance of naturalist observations and scientific readings, as expressed in the following passage of his *Autobiography*:

> I have always felt that I owe to the voyage around the world the first real training or education of my mind; I was led to attend closely to several branches of natural history, and thus my powers of observation were improved.... The investigation of the geology of all the places visited was far more important, as reasoning here comes into play.... I had brought with me the first volume of Lyell's *Principles of Geology*, which I studied attentively; and the book was of the highest service to me (Darwin 1892, pp. 28–29)

This expressive passage shows that Darwin clearly considered both natural history observations and scientific readings to have critical significance for his work. Throughout his life, Darwin meticulously compared his empirical results and conclusions with those of other scientists, and he took continuous inspiration from theories formulated by other members of the scientific community. Moreover, in his letters and autobiography, Darwin manifested public admiration for and gratitude to those scientists who inspired and accompanied him in the steps leading to the formulation of his evolutionary theory, especially Lyell. Thus, Darwin developed his evolutionary theory by exploring the natural world through laborious empirical inquiry and natural history work, carefully reflecting on and observing philosophical concepts (e.g., Hume), economical theories (e.g., Malthus), and social practices (e.g., artificial selection) and maintaining an active dialogue within his scientific community.

Influences of ethics on science. Philosophers and scientists have debated extensively about the split between fact and value, between "is" and "ought." Since the 1970s, eco-philosophers such as Baird Callicott have attempted to develop a sound environmental ethics that is informed by the is of ecology (e.g., see Marietta 1979, Callicott 1989). However, a full account of the interrelations between sciences and ethics needs to go not only from is to ought, but also from ought to is.

To understand the influences of ethical conceptions on a scientific theory, Darwin again provides a good example.

His evolutionary theory refers explicitly to two contrasting ethical conceptions: the community-oriented theory of moral sentiments, and the individualistically oriented notion of the struggle for existence (Figure 1b, arrow 3). In developing his concept of human social evolution in *The Descent of Man*, Darwin quoted and further elaborated the conceptions of moral sentiments of the eighteenth-century Scottish philosophers Hume and Adam Smith (see Callicott 1982, Sober and Wilson 1998). For Darwin, moral sentiments—such as fellow-feeling, sympathy, benevolence, affection, and generosity—coevolved within protohuman societies because they conferred survival advantages to those communities. Darwin (1871) reasoned that "social sentiments" and the "all-important emotion of sympathy" would have been "increased through natural selection; for those communities which included the greatest number of the most sympathetic members would flourish best, and rear the greatest number of offspring." Moral sentiments, Hume argued, depend not on reason alone, but on passion or feeling—in Darwin's terms, on instinct. Thus, as in the case of the notion of evolution itself, British philosophers provided a conceptual basis for Darwin's evolutionary argument. In turn, following the pattern of reciprocal relations proposed here, Darwin provided biological and evolutionary support to this philosophical view.

A second major and more discussed ethical influence on Darwin's theory has been the individualistic ethics of Victorian society, as stated in the Hobbesian conception of the liberal State and in the Malthusian conception of a social struggle for existence (see Young 1985). The British philosopher Thomas Hobbes affirmed in *Leviathan* (1651) that in the state of nature, "every man is in war against every man." Later, Malthus provided the economic argument that justified Hobbe's perspective, so that Darwin concluded: "the Struggle for Existence among all organic beings throughout the world follows inevitably from the high geometrical ratio of their increase" (Darwin 1859, p. 4). The pervasiveness of these Darwinian notions can be seen by looking at two texts that are considered to be foundational for ecological sciences and environmental ethics, respectively: *Generelle Morphologie der Organismen*, by Ernst Haeckel (1866), and *A Sand County Almanac*, by Aldo Leopold (1949).

When Haeckel coined the term "ecology" in the middle of the nineteenth century, he defined it in the following terms: "By ecology we mean the body of knowledge concerning the economy of nature,...in a word, ecology is the study of all those complex interrelations referred to by Darwin as the conditions of the struggle for existence" (Alle et al. 1949, p. v). And when Leopold coined the term "land ethic" in the middle of this century, he defined ethics in the following terms: "An ethic, ecologically, is a limitation on freedom of action in the struggle for existence. An ethic, philosophically, is a differentiation of social from anti-social conduct" (Leopold 1949, p. 238).

In these seminal texts, both Haeckel and Leopold assumed that the struggle for existence is the essential state of nature. Leopold presupposed that this struggle and an antisocial state of being are inherent dispositions that ethics evolves to restrict. Thus, ethics is conceived as a restriction that is imposed over primitive individualistic tendencies. But a historical perspective shows that the struggle for existence is only one particular mode of representation of natural relationships, a mode derived from the Modern–Liberal social relationships as paradigmatically stated by Hobbes in *Leviathan*. Misleading interpretations arise when ecologists or environmental ethicists suppose this essentially social worldview to be a fact of nature as well. For example, the evolutionary biologist and ecologist Jared Diamond has written:

> For a century after the publication of *On the Origin of Species*, field biologists took literally the expression 'the struggle for existence'.... They looked around them to see individuals of different species but similar trophic roles fighting, rarely saw it, and concluded that competition was unimportant. Just imagine what errors you would commit if...you would see Hertz and Avis counters adjacent at airports, would note that the ladies dressed in yellow were not fighting with the ladies dressed in red, and would conclude that Hertz and Avis do not compete. In fact, Hertz and Avis compete intensively for a shared resource, customers. But the mechanism of competition consists of trying harder for customers so as to starve out the rival's resource base, and not of fighting.... (Diamond 1978, p. 329)

This kind of analogy between biological and economic competition allows for a reciprocal reinforcing. Liberal ideology is scientifically legitimized when ecologists see nature through an "economic lens" because its competitive economic model can appeal to a nature constructed in its own image. If competition were a natural and inherent property of humans and other animal species, then a cultural transformation would seem hopeless.

This "naturalization" of the dominant cultural model is a circular interpretation that represents a serious impediment to the aim of transforming humans' relationships with the diversity of biological species and ecological phenomena. If scientists continue apprehending nature through the lenses of this Modern worldview, we will remain trapped in its forms of representation and, therefore, in its forms of relationship. As Engels (1880) indicated a century ago, once the Darwinian theory of the struggle for existence and the economic theory of competition have been transferred from capitalist society to organic nature, "it is very easy to transfer these theories back again from the natural world to the history of society" (p. 584).

Influences of science on ethics. Diamond's example shows how Darwinism has contributed to reinforce an ethics based on the notion of social struggle for existence,

or survival of the fittest, thereby promoting competition among persons, institutions, and countries. Social Darwinism constitutes an expression of this ethics that can be traced back to Hobbes (Figure 1b, arrow 4). It is noteworthy, however, that the Darwinian theory has also served as a foundation for a very different ethical theory, one that promotes a sense of respect for all living beings. This ethical view is illustrated by two metaphors used by Darwin: the "tree of life" and the "web of life." These metaphors also synthesize two central threads for both evolutionary–ecological sciences and environmental ethics (Rozzi 1997). The tree of life metaphor depicts ongoing research in evolutionary–systematics sciences and provides an image that inspires the ethical notion of intrinsic value based on kinship among living beings. The web of life metaphor depicts ongoing research in community and ecosystem ecology and provides an image that clarifies the notion of instrumental value based on the interactions among living beings in biotic communities and ecosystems. At the end of chapter 4 of *On the Origin of Species*, Darwin wrote:

> The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species.... As buds give rise by growth to fresh buds, and these, if vigorous, branch and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications. (Darwin 1859, pp. 129–130)

Later, in chapter 13, Darwin added:

> ...all these modified descendants from a single species, are represented as related in blood or descent to the same degree; they may metaphorically be called cousins to the same millionth degree.... (Darwin 1859, pp. 420–421)

This metaphor of the tree of life was soon depicted in the famous drawing by Haeckel that reconstructed the history of life on Earth. That image of the tree is still appealing to contemporary evolutionary biologists and taxonomists, who build phylogenetic trees based on morphological, embryological, molecular, biogeographical, and paleontological evidence. By representing *Homo sapiens* as belonging to the same evolutionary tree as all other biological species and participating in the same evolutionary process, Darwin not only stimulated a new scientific understanding but also triggered an ethical reconsideration of the kind of relations humans establish with other species. A century after the publication of *The Descent of Man*, the evolutionary biologist and conservationist Edward O. Wilson opened his landmark book, *Biodiversity*, with the Darwinian affirmation that an effective conservation of biological species "will come down to a decision of ethics—how we value the natural worlds in which we evolved.... We are fundamentally mammals and free spirits who reached this high a level of rationality by the perpetual creation of new [evolutionary] options" (Wilson 1989, p. 16). At the end of the 1980s, similar views also became frequent within nonscientific literature. For example, the social and nature writer Alice Walker argued for a shift toward vegetarianism based on the view of "chicken and fish [as] sister/fellow travelers on the planet" (Walker 1991).

Grounded in a similar perspective, Leopold aimed to change the path of human-driven extinction by seriously considering the ethical implications of Darwinian evolutionary theory. In his essay "On a Monument to the Pigeon," dedicated to the extinct passenger pigeon, Leopold wrote, "it is a century now since Darwin gave us the first glimpse of the origin of species. We know now what was unknown to all the preceding caravan of generations: That men are only fellow-voyagers with other creatures in the odyssey of evolution. This knowledge should have given us, by this time, a sense of kinship with fellow creatures; a wish to live and let live; a sense of wonder over the magnitude and duration of the biotic enterprise" (1949, pp. 116–117). Despite the interesting gender difference between Walker's "sister/fellow travelers" and Leopold's "men...fellow-voyagers," both writers appeal for an ethical and practical shift associated with the Darwinian evolutionary metaphor of kinship: "cousins to the millionth degree" (Darwin 1859).

A more ecological metaphor that Darwin adopted and expanded is the web of life (see Hagen 1992). This metaphor also illustrates Darwin's influence on twentieth-century scientists and nature writers. In *On the Origin of Species*, Darwin provided the following picture of the ecological interconnections among coexisting species that are remotely related in the evolutionary tree of life:

> I am tempted to give one more instance showing how plants and animals, most remote in the scale of nature, are bound together by a web of complex relations.... I have found that the visits of bees are...highly beneficial to the fertilisation of our clovers; but humble-bees alone visit the red clover (*Trifolium pratense*),.... The number of humble-bees in any district depends on the number of field-mice, which destroy their combs and nests.... Now the number of mice is largely dependent, as every one knows on the number of cats.... Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district. (Darwin 1859, pp. 73–74)

Ninety years later, this Darwinian portrait of biological interactions was reworked by Leopold. With an ecological perspective absorbed from the innovative ideas of his

friend and colleague Charles Elton, Leopold redrew the image of the web of life in the section of his essay "The Land Ethic" titled "The Land Pyramid," explaining that "a plant layer rests on the soil, an insect layer on the plants, a bird and rodent layer on the insects, and so on up through various animal groups to the apex layer, which consists of the larger carnivores" (Leopold 1949, p. 252). A decade later, the charismatic biologist and writer Rachel Carson appealed again to this Darwinian image in *Silent Spring*:

> Over three quarters of a century ago, Charles Darwin published a book titled *The Formation of Vegetable Mould, through Action of Worms, with Observations on Their Habits.* In it he gave the world its first understanding of the fundamental role of earthworms as geologic agents for the transport of soil.... Water, soil, and the earth's green mantle of plants make up the world that supports the animal life of the earth.... The earth's vegetation is part of a web of life in which there are intimate and essential relations between plants and earth, between plants and other plants, between plants and animals. (Carson 1962, pp. 55, 63–64)

Carson's passage calls to mind the famous scene of Darwin's last paragraph in *On the Origin of Species*:

> It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. (Darwin 1859, p. 489)

Metaphors used by Darwin have clearly become "cultural messengers" from science to ethics. The tree of life and the web of life provided inspiration for the imagery of environmentalists in our century. The common trunk of the evolutionary tree became a visual representation of Darwinian evolutionary theory, which emphasizes the common biological nature of, and the origin humans share with, all living species. It further stimulates a sense of kinship that challenges traditional Western morality by demanding an extension of ethical respect beyond the boundaries of our own species. This extension leads to a biocentric approach of environmental ethics that supports the notion of intrinsic value of nonhuman life. On the other hand, the metaphor of the web of life can lead to a complementary environmental ethics based on the instrumental value of biodiversity for human survival. Based on an ecological understanding of the interactions between coexistent species, Carson (1962) noted that "the earth's vegetation is part of a web of life...[and] although the modern man seldom remembers the fact, he could not exist without plants that harness the sun's energy and manufacture the basic foodstuff he depends upon for life" (pp. 63–64).

Today, this appealing view of the web of life is quantitatively analyzed by ecological economics in an effort to assign monetary values to multiple ecosystem services and goods (see Daly and Townsend 1994, Daily 1997). Broader utilitarian approaches based on this metaphor state that biological species and physical components of ecosystems (such as waters, soils, and atmosphere) need to be protected to continue the flow of benefits emanating from the ecological web of life, which are essential to ensure the well-being of present and future human generations (see Norton 1991).

Influences of science on culture. Among the vast and multifaceted implications of Darwinism for theology, art, politics, philosophy, and other sciences, two implications are crucial for the cultural influences discussed in this article. First, for Victorian society, the Darwinian theory represented a cultural earthquake that promoted a revolution as monumental as the Copernican revolution. Both theories evicted human beings from their central place in nature. The theory of evolution disabuses human beings of the belief that we are uniquely created in God's image. By proposing a common origin for all living beings that positions *Homo sapiens* as one animal species among many, differing only in degree but not in kind from other biological species (see Rachel 1990), the Darwinian theory effected a kind of biologically based dissolution of anthropocentrism (Figure 1b, arrow 5).

Second, with respect to the notion of biological and social progress and hierarchy, Darwin exhibited complex ambiguities: he was not always a conceptual revolutionary, and neither was he totally consistent. In spite of his famous reminder to "never use the words 'higher' and 'lower,'" Darwin compared the Fuegian "savages," or "barbarians," with lower animals. Moreover, he judged not only Indians, but also different classes of European colonists under those Victorian hierarchical standards, as he stated in *The Descent of Man*:

> 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 the 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. (Darwin 1871, p. 179)

Influences of science on human impacts on the natural environment. Darwin marveled at ecological "webs of complex relations" and understood the implications of interdependence. Following his depiction of complex interrelations in which red clover plants depend on "humble-bees" for pollination, Darwin noted that "humble-bees alone visit the red clover.... Hence I have very little doubt, that if the whole genus of humble-bees became

extinct or very rare in England, the heartsease and red clover would become very rare, or wholly disappear" (Darwin 1859, pp. 73–74). This comprehension that the loss of one species could have a cascading effect that results in the extinction of other species has developed into community and ecosystem approaches in contemporary conservation biology. To protect or reintroduce individual species, it is necessary to understand their place in the web of life and to conserve or restore their biological communities and ecosystems (see Thompson 1997).

Darwin also referred to the converse effect—how the spreading of one species can lead to the extinction of another. In *On the Origin of Species*, he noted that "the recent extension over the United States of one species of swallow has caused the decrease of another species. The recent increase of the missel-thrush in parts of Scotland has caused the decrease of the song-thrush. How frequently we hear of one species of rat taking the place of another species under the most different climates!" (Darwin 1859, p. 76). Darwin's perception of the exclusion of one species by another is substantiated by contemporary ecological analyses of invasive species, a major threatening factor for native animal and plant species (Simberloff et al. 1997). Thus, although Darwin never used the word "conservation," his theory continues to provide key concepts to the new field of conservation biology, contributing to efforts to regulate human impact on the natural environment (Figure 1b, arrow 6).

Implications of the reciprocal influences between science and ethics

Analysis of Darwinian theory leads to a number of conclusions about the reciprocal influences of science and ethics. First, it is possible to find explicit references to cultural models and social practices in the genesis of this scientific theory. Second, naturalist observations and empirical experiences were essential to Darwin's conception; it is likely that *The Descent of Man* would have never been written had Darwin not encountered the Fuegians. Third, the influences between science and culture, ethics, and the natural environment reveal bidirectionality in the relationship between evolutionary–ecological sciences and environmental ethics. Fourth, these interrelations between science and ethics are not deterministic or necessary in a logical sense because, as demonstrated above, Darwinian theory has been a source of inspiration for such contrasting ethics as social Darwinism and Leopold's land ethic (Figure 1b, arrow 4).

Finally, notwithstanding the diffuse character of the complex interrelations among science, ethics, culture, and the investigated natural world, it is possible to distinguish reciprocal influences between sciences and ethics. The interpretation of these interrelations as nondeterministic and open to multiple and dynamic influences should inhibit dogmatic excesses such as the lamentable case of the Soviet agronomist Lysenko, who for ideological reasons used political power to force Soviet scientists to reject Mendelian genetics and abandon natural selection (see Lewontin and Levins 1976). Instead, it is possible to attempt an integration in which both scientific theories and ethical conceptions are continuously reevaluated and reconsidered. The analysis of these reciprocal influences between sciences and ethics is of theoretical value for a post-Kuhnian epistemology and of practical value for confronting the current global environmental crisis.

Epistemological implications. Darwinian theory shows how a scientific theory embodies values belonging to the culture within which it was conceived. The theory of natural selection can be interpreted as functional and useful to particular goals of nineteenth-century British capitalistic society—goals that, due to the global economy, are even more widespread and prevalent at the end of the twentieth century. The description of natural processes by means of economic models facilitates the use of nature for economic purposes, and the explanation of nature by means of husbandry analogies rationalizes a relation between society and nature that is oriented toward productive goals. For example, Darwin (1859, p. 86) wrote that "if it profits a plant to have its seeds more and more widely disseminated by the wind, I 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."

This image can be interpreted as the projection of a social economic conception and its goal of productivity onto nature. Natural selection seems to enhance the profits of the plant in the economy of nature, just as artificial selection increases the profits of the cotton-planter. Rather than an essential property of nature, this projected "natural mechanism" seems to be a useful explanatory mechanism for the agricultural and economical purposes of the cotton-planter. This model provides farmers and industrialists with an operative mechanism that could assist in the design and implementation of practices aimed at increasing productivity. Through the theory of natural selection, Darwin thereby contributed to the naturalization of a set of values pertaining to British capitalism, as well as the practice of artificial selection.

At an epistemological level—that is, for understanding the origin, process, and limitations of scientific knowledge—the analysis of the Darwinian theory in this article shows that ethical and social conceptions can permeate explanatory theories that scientists formulate and test. Consequently, ethics is relevant not only for its applied dimension but also for its influence on explanations of the natural world. This understanding of the interrelations between ethics and science conceptualizes the interplay between cultural, ethical, and naturalist domains in the genesis of scientific assumptions and paradigms. The recognition of these complex interrelationships aims not to lead to ideological fixations in science (as in the case of

Lysenko) but rather to provide scientists with additional elements for critical revision of scientific assumptions within cultural contexts.

Indeed, empirical–naturalist work and philosophical–sociological analyses are both essential and interactive components of scientific research. Exclusion of one of these components, as naturalistic (e.g., Popper 1972) and sociological (e.g., Restivo 1994) schools of the philosophy of science tend to do, is detrimental to scientific research because it overlooks the effects of the fertile and dynamic interrelations between science, society, and the natural world. Analyses of the "internal" and "external" histories of science (in which the history is centered, respectively, in the theories supported, empirical data collected, and experiments performed by the members of a given scientific community, and in the relations between those communities and their broader cultural environments) are complementary rather than exclusive (cf., Bunge 1993, Lakatos 1993).

Ethical implications. Darwinian theory, with its contrasting metaphors (the struggle for existence, the tree of life, and the web of life) also shows how evolutionary–ecological theories can either reinforce or undermine cultural values and social attitudes. Thus, ecologists can contribute either to a cultural retrenchment or to a cultural transformation. Ecologists are not neutral scientists, nor are they observers of nature who are passively influenced by their culture; instead, by providing scientific views of nature, ecologists play a central role in shaping social attitudes toward nature. The outcome of scientific influences is not univocal, and social attitudes are influenced by multiple factors, not only science. Nevertheless, some ways of observing and understanding the natural world are more concordant with the styles of life and the kinds of relations that societies establish with the natural world. If the goal is to maximize profits, then Darwin's analogy of the cotton-planter and his theory of natural selection could constitute an appropriate way to explain and understand nature. However, if the goal is freedom from aspirations for profit and maximization of productivity, then other evolutionary metaphors might be more consonant and could enrich the explanatory picture of the natural world.

For example, in the case of evolutionary theory, the Chilean biologists Humberto Maturana and Francisco Varela have proposed the metaphor of "natural drift." In contrast to Darwin's conception of natural selection, which proposes that selective pressures lead to gradual modification, natural drift focuses on the conservation of a body plan, physiological and genetic homeostasis, and evolutionary changes based on stochastic processes (Maturana and Varela 1990, Rozzi et al. 1998). These Chilean biologists also introduced their metaphor by means of an image: Evolution is represented as a vagabond sculptor who walks through the world without any direction while producing his pieces of art. There could not be a more contrasting image to those tenacious English colonists of North America that Darwin lauded as the successful products of natural selection.

Analyses similar to the one developed in this article for the Darwinian theory could be explored for other evolutionary or ecological theories, and even for nonscientific modes of understanding and inhabiting the natural world. For example, the subtitle of ecosystem ecologist Frank Golley's book *The History of the Ecosystem Concept* (Golley 1992) is "More than the sum of the parts," a notion borrowed from holistic philosophy. In turn, ecosystem theory has provided a scientific support to approaches of environmental ethics, such as deep ecology (Golley 1987, 1992). An example of nonscientific traditional ecological knowledge and practices is provided by the very same Indians that Darwin met in Tierra del Fuego. The Fuegian Yamana cosmology shares Darwin's notion of a common origin of human and nonhuman living beings, and Yamana social order is interwoven within a complex web of ecological interactions taking place in the same ecosystems and landscapes that inspired Darwin's entangled bank image (Ricardo Rozzi, unpublished manuscript).

Critical thinking concerning the consonance between scientific theories and environmental ethics complement efforts to confront the global environmental crisis. By examining how particular ways of knowing about and living in the natural world are linked, scientific/ethical interanalyses enable a discussion that goes beyond a mere "problem-solving" approach, which can be caricatured as a trilogy of endeavors: struggling for survival, searching for purely "technical environmental solutions," and not questioning the current dominant model of "developed" society. An approach that integrates the interrelations between science and ethics enriches ecological reflection and creativity about the modes of human existence, avoiding the frequently uncritical adherence to the dominant economic and instrumental paradigm.

Although the market economy is being globalized, it constitutes only one among the infinite possible paradigms for knowing and living. A systemic approach that interrelates ecological–evolutionary theories and environmental ethics within particular cultural contexts and natural environments, as illustrated in Figure 1, could permit ecologists and philosophers to explore collaborative analyses. Such analyses of the interrelations between the ways of knowing and inhabiting the natural world could also be extended to a multiplicity of cultural traditions—within and outside Western civilization. Through this integration of the scientific and ethical spheres, scientists and environmental professionals would be better prepared to understand and respect biological and cultural diversity, preventing the undesirable homogenization of both the cultural and biological worlds (Rozzi 1998).

Scientific theories and worldviews do not constitute purely cognitive structures; they provide guides for social and individual behavior. Metaphorically, they constitute

scripts for people's actions and life histories. Ecologists, by detaching themselves from the presumption of a type of objectivity associated with a non–historical/cultural conception of science, gain greater flexibility for building multiple and distinct theoretical and practical modes of relating to the natural world. Thus conceived, environmental ethics is not an external normative corpus within which ecological sciences should be clothed—not just another tool applied to "solve" the current environmental crisis. Instead, the interrelations between ecological–evolutionary sciences and environmental ethics can be understood as a dynamically and intimately bonded unit: Ecologists construct their scientific theories influenced by particular ethical values, and ethicists value nature based on particular scientific theories. Under this unifying perspective, ecologists and eco-philosophers can overcome the schism between objective knowledge and subjective morality, recovering the link between theory and praxis, between the ways of knowing about nature and the ways of inhabiting the natural world.

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