The Ethical Implications of Organism-Environment Interdependency

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Modern ethical perspectives toward the environment often emphasize the connection of humans to a broader biotic community. The full intimacy of this connectedness, however, is only now being revealed as scientific findings in developmental biology and genetics provide new insights into the importance of environmental interaction for the development of organisms. These insights are reshaping our understanding of how organism-environment interaction contributes to both consistency and variation in organism development, and leading to a new perspective whereby an "organism" is not solely viewed as the adaptive product of evolutionary selection to an external environment over generations, but as continuously being constructed through systems of interactions that link an organism's characteristics developmentally to the physical and social influences it experiences during life. This newfound emphasis on "interaction" leads to an interdependency whereby any change to an "environment" impacts the interacting "organism(s)," and an alteration to the "organism" eventually affects its "environment." The causal reciprocity embedded within this organism-environment interdependency holds implications for our moral obligations to environments, given their compulsory role in shaping all organisms including ourselves.

INTRODUCTION

Conceptual insights from the science of ecology have infused ethical perspectives on environmental issues nearly since ecology's emergence as a scientific discipline of inquiry.[1] Given ecological science's focus on the relationships of living organisms with each other and with physical environments, the study of ecology contributed to the recognition that all species of plants and animals—including humans—are players in broader biotic communities that are maintained through complex networks of interactions. This awareness about the structure of biological communities contributed to a shift from a "human-and-nature" ethical perspective to a "human-in-nature" perspective within Western discourse,[2] and ultimately led

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[1] See, for example, Don E. Marietta, Jr., "The Interrelationship of Ecological Science and Environmental Ethics," *Environmental Ethics* 1 (1979): 195–207; Holmes Rolston, III, "Is There an Ecological Ethic?" *Ethics* 85 (1975): 93–109.

[2] Thomas B. Colwell, Jr., "The Balance of Nature: A Ground for Human Values," *Main Currents in Modern Thought* 26 (1969): 46–52.

to “the extension of *direct* ethical consideration from people to nonhuman natural entities.”[3] As stated by J. Baird Callicott:

> Ecology has made plain to us that fact that we are enfolded, involved, and engaged within the living, terrestrial environment—i.e., implicated in and implied by it. (This proposition is itself among the metaphysical implications of ecology.) Therefore, ecology also necessarily profoundly alters our understanding of ourselves, severally, and human nature, collectively.[4]

In addition to this recognition of humans as part of a broader community of life, ecological theory provided several other postulates that served as underpinnings for new philosophical perspectives toward the environment. For example, the early ecologist Frederick Clements thought biological communities would achieve functionally stable states through an almost development-like process; the communities might change with natural or human-induced disturbance, but they would eventually settle into a “fixed, normative balance state.”[5] Perhaps accordingly then, ethical perspectives informed by the study of ecology led to assertions of moral obligations toward maintaining “integrity” and “balance” within biotic communities: “Ethical treatment of the environment requires that human beings not disturb this homeostasis, but rather incorporate human activities into it.”[6] This emphasis on homeostasis and balance is explicitly encapsulated in Aldo Leopold’s land ethic: “A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.”[7] Accompanied by early “niche” concepts from the ecologists Joseph Grinnell and Charles Elton, who viewed communities as theaters of interacting species where each species occupied a “position” or “role” (aka, “niche”) in a larger “economy of nature,”[8] obligations toward the maintenance of community “equilibrium” or “stability” was thought to require the preservation of all the “pieces” that comprised that community. Again, as articulated by Leopold:

> The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism. Only those who know the most about it can appreciate how little we know about it. The last word in ignorance is the man who says of an animal or plant, ‘What good is it?’ If the land mechanism as a whole

[3] J. Baird Callicott, *In Defense of the Land Ethic* (Albany: State University of New York Press, 1989), p. 15.

[4] J. Baird Callicott, “The Metaphysical Implications of Ecology,” *Environmental Ethics* 8 (1986): 301–02.

[5] Giulio A. De Leo and Simon Levin, “The Multifaceted Aspects of Ecosystem Integrity,” *Conservation Ecology* 1 (1997): 3 at http://www.consecol.org/vol1/iss1/art3; see also J. Baird Callicott, “Conceptual Foundations of the Land Ethic,” in *In Defense of the Land Ethic,* pp. 87–90, for discussion of the influence of these early ecologists on Aldo Leopold’s development of his “Land Ethic.”

[6] Marietta, “Ecological Science and Environmental Ethics,” p. 197.

[7] Aldo Leopold, *A Sand County Almanac* (New York: Oxford University Press, 1949), pp. 224–25.

[8] Callicott, “Conceptual Foundations of the Land Ethic,” p. 82; see also Thomas W. Schoener, “The Ecological Niche,” in J. M. Cherrett, ed., *Ecological Concepts* (Oxford: Blackwell Scientific Publications: 1989), pp. 79–113, for further description of Elton’s and Grinnell’s “niche” concepts.

> is good, then every part is good, whether we understand it or not. If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.[9]

At this point, however, it is important to remind ourselves that—as is the nature of scientific inquiry—many of the original theories on the structure of biotic communities have been revised over time as ecologists gained a better grasp of how ecological systems function. For instance, today's ecologists recognize that variation and change hold key positions in the maintenance of biotic communities.[10] Communities are no longer viewed as "stable" or "balanced," but rather as capricious systems with many species interacting in complex and variable ways. "Optimality" and "stability" have been demoted from their previously held roles as essential attributes; rather, biological communities are now more commonly viewed as dynamic and open, with species and physical parameters in constant flux. Any semblance of "stability" in the biological community thereby arises from any of the multiple states that might be shifted between depending on inputs to the complex network of interactions within the community, as well as recent and historical events.[11] As a corollary to this change in our understanding of community ecology, it was recognized that organisms play active roles in community dynamics by altering environments to their own benefit. In the most robust scenarios, such organisms are considered "ecosystem engineers" or species that modify and create their habitats through their interactions with other organisms or the physical environment.[12] The North American beaver (*Castor canadensis*) is an exemplar ecosystem engineer; by damming streams and creeks, beaver engineer pond habitats. Likewise, humans have long altered habitats to suite their needs (e.g., using fire to keep grassland clear of trees and brush),[13] although it is important to note that the ability of modern humans to "engineer" environments is considered unprecedented.[14]

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[9] Aldo Leopold, *Round River* (New York: Oxford University Press, 1953), pp. 146–47.

[10] Anthony R. Ives, Stephen R. Carpenter, "Stability and Diversity of Ecosystems," *Science* 317 (2007): 58–62; Kevin Shear McCann, "The Diversity-Stability Debate," *Nature* 405 (2000): 228–33; Kevin McCann, Alan Hastings, and Gary R. Huxel, "Weak Trophic Interactions and the Balance of Nature," *Nature* 395 (1998): 794–98.

[11] Ibid.

[12] Clive G. Jones, John H. Lawton, and Moshe Shachak, "Organisms as Ecosystem Engineers," *Oikos* 69 (1994): 373–86; Clive G. Jones, John H. Lawton, and Moshe Shachak, "Positive and Negative Effects of Organisms as Physical Ecosystem Engineers," *Ecology* 78 (1997): 1946–57; see also F. John Odling–Smee, Kevin N. Laland, and Marcus W. Feldman, *Niche Construction* (Princeton: Princeton University Press, 2003), chap. 2, for a discussion of "niche construction." The consequences of niche construction—defined as interactions between organisms and their local environments that modify some of the natural selection pressures of those environments—include the potential for ecosystem engineering.

[13] William M. Denevan, "The Pristine Myth: The Landscape of the Americas in 1492," *Annals of the Association ofAmerican Geographers* 82 (1992): 369–85; D. R. Horton, "The Burning Question: Aborigines, Fire, and Australian Ecosystems," *Mankind* 13 (1982): 237–51.

[14] See, for example, Bruce D. Smith, "The Ultimate Ecosystem Engineers," *Science* 315 (2007): 1797–98.

Accompanying these changes in ecological theory, the emphasis on maintaining "optimality" and "stability" has surrendered its position in ecologically based ethical perspectives. As pointed out by Colleen Clements, "The fairy tale ideal of an ecosystem of achieved and unchanging harmony goes aground on a number of biological and astronomical observations, and even, finally, on basic physical examples."[15] The ramification of that change was that moral obligations toward upholding new ecological concepts of "ecological integrity" and "ecosystem functioning" emerged in the conjoined fields of conservation biology and environmental ethics. As stated by Don Marietta, Jr., ". . . morally acceptable treatment of the environment is that which does not upset the integrity of the ecosystem as it is seen in a diversity of life forms existing in a dynamic and complex but stable interdependency."[16]

Based solely on the brief discussion above, it should be evident that ethical perspectives toward the environment have been amended over time to incorporate revised ecological concepts concerning the nature of biotic communities. Recollection of these amendments is important, for in an analogous way today our understanding of the interconnectedness between an "organism" and its "environment" is being revised in light of new insights from the scientific study of developmental processes, our understanding of which has leaped forward with the new tools of molecular biology and genetics. And, just as earlier ethical views incorporated new insights on the nature of biological communities, this newfound understanding of the interdependency of an "organism" and its "environment" holds significance for how we value the interactions that comprise our ecological community, as well as the influences of humans on the Earth system more broadly.

A SYSTEMS VIEW OF ORGANISM-ENVIRONMENT INTERDEPENDENCY

> *Organisms do not adapt to their environments; they construct them out of the bits and pieces of the external world.*[17]

Over the past few decades, subfields of ecological research such as "functional ecological genetics" and "developmental ecology" have explored the relationship between "organism" and "environment" in hopes of understanding the genetic and developmental bases for variation in phenotypic traits. The picture emerging from these areas of inquiry is bringing light on how influential environmental experience is to the development of organisms. It is now clear that an organism's phenotype—its morphological, behavioral, physiological, and life history characteristics—is shaped by the interactions and experiences that the organism has

[15] Colleen D. Clements, "Stasis: The Unnatural Value," *Ethics* 86, no. 2 (1976): 136.

[16] Marietta, "Ecological Science and Environmental Ethics," p. 197.

[17] Richard C. Lewontin, "Gene, Organism and Environment: A New Introduction," in Susan Oyama, Peter E. Griffiths, and Russell D. Gray, eds., *Cycles of Contigency: Developmental Systems and Evolution* (Cambridge: MIT Press, 2001), p. 64 (emphasis added).

earlier in life.[18] Environmental conditions—which include both internal factors (e.g., hormone signals, cellular oxygen tension) and factors external to the organism (e.g., environmental temperature, social interactions)—influence the complex dynamics of the intracellular state including gene expression, which subsequently shifts an organism's behavior, morphology, physiology, and life history.[19] A wide variety of environmental factors influence organism development and, depending on the scenario, these factors can shape characteristics from neural organization and behavior, to hormonal states and physiological scope, and even to morphology and life history (e.g., age of sexual maturation, how many offspring in a clutch or litter).[20]

Taken as a whole, this recent ascension of "interaction" is revising fundamental assumptions about the relationship between an "organism" and its "environment," and even uprooting prevailing thoughts on the distinction between these concepts.[21] The orthodox view of organism-environment relationships, whereby "the inside and the outside of organisms are regarded as separate spheres of causation with no mutual dependence,"[22] is based on an assumption of "externalism" where adaptation occurs primarily through the selective forces of external environmental factors. This "externalism" perspective, which views the dependency of organisms on their environments largely in the context of a species' reliance on resources (e.g., food, shelter) for survival and reproductive success, is derived from a perspective of inheritance that focuses on Mendelian particulate genes, and is often coupled with "gene centricism" and "gradualism" views of phenotypic change whereby conditions in the environment "select" for particular phenotypic traits and the particular forms of genes (alleles) that underlie those traits. Over generations, such selection in dissimilar environments leads to the divergence of populations and,

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[18] See, for example, Mary Jane West–Eberhard, *Developmental Plasticity and Evolution* (Oxford: Oxford University Press, 2003); Scott F. Gilbert and David Epel, *Ecological Developmental Biology: Integrating Epigenetic, Medicine and Evolution* (Sunderland, Mass.: Sinauer Associates, 2009).

[19] Ibid.

[20] See, for example, Sean C. Lema, "The Phenotypic Plasticity of Death Valley's Pupfishes," *American Scientist* 96 (2008): 28–36; Meredith J. West and Andrew P. King, "Deconstructing Innate Illusions: Reflections on Nature–Nurture–Niche from an Unlikely Source," *Philosophical Psychology* 21 (2008): 383–95; Mary Jane West–Eberhard, "Developmental Plasticity and the Origin of Species Differences," *Proceedings of the National Academy of Science USA* 120 (suppl. 1) (2005): 6543–49.

[21] Operational definitions of *organism* have a highly debated history in the philosophy of science. Most of the current definitions of *organism* use criteria that are continuously variable, rather than categorical, and concern the idea of "individuality" and the functional integration of phenotypic characters. For further discussions about the concept of *organism* generally, see, for example, John W. Pepper and Mathew D. Herron, "Does Biology Need an Organism Concept?" *Biological Reviews* 83 (2008): 621–27. For further discussion of the relationship of "organism" and "environment," see Paul E. Griffiths and Russel D. Gray, "The Developmental Systems Perspective: Organism–Environment Systems as Units of Development and Evolution," in M. Pigliucci and K. Preston, eds., *Phenotypic Integration: Studying the Ecology and Evolution of Complex Phenotypes* (New York: Oxford University Press, 2004), pp. 409–31; Timo Järvilehto, "The Theory of the Organism–Environment System: I. Description of the Theory," *Integrative Physiological and Behavioral Science* 33 (1998): 321–334; Daniel K. Palmer, "On the Organism–Environment Distinction in Psychology," *Behavior and Philosophy* 32 (2004): 317–47.

[22] Lewontin, "Gene, Organism and Environment," p. 55.

ultimately, the astonishing diversity of species that has evolved over the history of life on Earth.

Since this "externalism" perspective was used in part as an underpinning for the modern synthesis of evolutionary biology, this frame has been prevalent in the scientific study of ecology for several decades.[23] Perhaps accordingly, contemporary ethical perspectives commonly view the organism-environment relationship through this same lens of "externalism," where populations and species have been and continue to be shaped in an evolutionary sense by their environments. For instance, J. Baird Callicott writes:

> From the perspective of modern biology, species adapt to a niche in an ecosystem. Their actual relationships to other organisms (to predators, to prey, to parasites and disease organisms, etc.) and to physical and chemical conditions (to temperature, radiation, salinity, wind, soil and water pH, and so on) literally sculpt their outward forms, their metabolic, physiological, and reproductive processes, and even their psychological and mental capacities. A specimen is, in effect, a summation of its species' historical, adaptive relationship to the environment.[24]

So while the adoption of an ecological perspective has indeed shifted our ethical considerations toward maintaining the integrity of "relationships" and "interactions" between the species or "components" of a biotic community—and indeed the adoption of an ecological perspective was key to formulating a more holistic view of the value in biological communities—prevailing ethical views continue to regard organisms largely as distinct from their environments except in a sense where evolutionary processes are molding the adaptations of populations or species over generations. But, what if this perspective of "externalism" is no longer sufficient to explain the prominence of organism-environment interaction in shaping organismal phenotypes ranging from plant flowering time, to animal behavior, to human disease?

The "externalism" perspective has shown weakness in its conceptual foundation for years as evident in contentious debates under the frame of the "nature-nuture dichotomy,"[25] and over the past few decades a new view of the organism-environment relationship has emerged from scientific studies in developmental ecology, where

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[23] Philippe Huneman, "Assessing the Prospects for a Return of Organisms in Evolutionary Biology," *History and Philosophy of the Life Sciences* 32 (2010): 341–72.

[24] Callicott, "Metaphysical Implications of Ecology," pp. 311–12.

[25] There is an extensive published record of discussion, sometime contentious, about the relative contributions of "nature" and "nurture," or "genes" and "environment," to the phenotypic diversity of individuals, populations and species. For a thorough summary of the conceptual issues and historical foundations for the questions contained within the "nature/nurture" debate, see Evelyn Fox Keller, *The Mirage of a Space between Nature and Nurture* (Duke University Press, 2010). For an additional perspective, see Daniel S. Lehrman, "Semantic and Conceptual Issues in the Nature-Nurture Problem," in Lester R. Aronson, Ethel Tobach, Daniel S. Lehrman, and Jay S. Rosenblatt, eds., *Development and Evolution of Behavior: Essays in the Memory of T. C. Schneirla* (San Francisco: W. H. Freeman and Co., 1970), p. 17–52.

problems concerning interaction between "organisms" and their "environments" have propelled scientists to abandon the "externalism" view and take a step further toward holism.[26] This perspective—sometimes called "developmental systems theory"—emphasizes interdependency, where "the nature of these environments is not independent of the organism because at every instance the life activities of the organism determine what constitutes the relevant combinations of external physical states and they simultaneously cause changes in those states."[27] The conceptual constructs of "organism" and "environment" are reformulated so that the "organism" becomes the outcomes of development, while the "environment" is viewed as the processes that produce, maintain, and alter those outcomes.[28] Organisms no longer exhibit particular phenotypic characteristics solely because those characteristics are adaptations to a particular niche. Instead, organisms are shaped developmentally by their interactions during development with the other components—both biotic and abiotic—of the community, and the niche itself is constructed by the activities of the organism (e.g., habitat selection, ecosystem engineering, etc.).[29] The organism becomes indivisible from its environment and experiences.

Under such a developmental systems perspective, interactions take primacy, since it is interactions that shape an organism's development.[30] This perspective contrasts with the orthodox view where "according to genic neo-Darwinism, nucleic acids are the sole units of heritable variation, the transmission of these units is independent of their expression, and the generation of genetic variations is not adaptively guided by the selective environment or the developmental history of the organism."[31] Eva Jablonka points out that the above "gene-centric" perspective, with its singular focus on genetic inheritance, is too restricted given current knowledge of inheritance mechanisms:

> This replicator-centered, gene-derived view of heredity is, however, not only severely limited, but also severely misleading. There are multiple inheritance systems, with several modes of transmission for each system, that have different properties and that

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[26] P. E. Griffiths and R. D. Gray, "Developmental Systems and Evolutionary Explanations," *Journal of Philosophy* 91 (1994): 277–304.

[27] Lewontin, "Gene, Organism and Environment," p. 55.

[28] Susan Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*. 2nd ed. (Cambridge: Cambridge University Press, 1985).

[29] Meredith J. West and Andrew P. King, "Settling Nature and Nurture into an Ontogenetic Niche," *Developmental Psychobiology* 20 (1987): 549–62.

[30] Lewontin, "Gene, Organisms, and Environment." Lewontin sums up the premises underlying a more active role for the organism as follows: (1) organisms determine what is 'relevant' in their environments; (2) organisms alter their external worlds, and therefore alter their environments; (3) organisms transduce the physical signals of the external world into internal responses (e.g., physiological and behavioral); and (4) organisms, through mechanisms such as habitat selection and varying degrees of habitat use, create a statistical pattern of environment different from the pattern in the external world. Note that parallels of this framework have also been provided by others, including the concept of "phenogenesis," or developmental construction of the phenotype as described in Gilbert Gottlieb, *Individual Development and Evolution* (Mahwah, N.J.: Lawrence Erlbaum Associates, 2002), pp. 137–157.

[31] Eva Jablonka, "The Systems of Inheritance," in Oyama et al., *Cycles of Contigency*, pp. 99–100.

> interact with each other. They include the genetic inheritance systems (GIS), cellular or epigenetic inheritance systems (EIS), the systems underlying the transmission of behavior patterns in animal societies through social learning (BIS), and the communication system employing symbolical languages (SIS). . . . These systems all carry information, which I shall define here as the *transmissible organization of an actual or potential state of a system*.[32]

A developmental systems perspective thus requires us to take a broader view of inheritance with organisms playing a more active role. "Despite widespread talk of genetic blueprints and programs in contemporary biology, there is no scientifically defensible sense in which a subset of developmental resources contains a program or set of instructions for development."[33] Phenotypic consistency between generations and among related individuals therefore comes not only from genetic similarity, but from similarities in the overall developmental system, including similarities in environmental experience. The local environment—with its physical and social conditions—is inherited along with genetic material. Such local environments may have been altered by the organism's own activities or by the activities of past generations, which can lead to repeatable patterns of environmental inheritance. In the case of the North American beaver referred to earlier, the beaver both "engineers" its dam and pond habitat *and* raises its offspring in the habitat. Effectively, the engineered habitat constitutes a form of inheritance in that the pond habitat is essential to how young beaver learn dam- and lodge-building behaviors and preferences for particular aquatic plant foods.[34] As stated by Jablonka:

> In addition to the intrinsic properties of the different inheritance systems, the feedback loops formed between the organism's activities and its ecological and social environment often create conditions for the reconstruction of ancestral phenotypes in descendant generations. Developmental and ecological legacies may be said to be passed on between generations.[35]

Embracing a developmental systems perspective requires shifting viewpoints so that the organism—its behavior, physiology, morphology, life history—becomes a developmental result of joint determination by multiple causes. Understanding the constant, reciprocal interaction between the concepts of "organism" and "environment" as traditionally defined under an "externalism" perspective then

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[32] Ibid., p. 100. For elaboration on these multiple inheritance systems, see Eva Jablonka and Marion J. Lamb, *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral and Symbolic Variation in the History of Life* (Cambridge: MIT Press, 2005). See also the summary of this text conjoined with a discussion of the major challenges to this perspective: Eva Jablonka and Marion J. Lamb, "Précis of Evolution in Four Dimensions," *Behavioral and Brain Sciences* 30 (2007): 353–65, with a following discussion on pp. 365–89.

[33] Susan Oyama, Peter E. Griffiths, and Russell D. Gray, "Introduction: What is Developmental Systems Theory?" in Oyama et al., *Cycles of Contigency*, p. 5.

[34] See, for example, Dietland Müller-Schwarze, *The Beaver: Its Life and Impact* (Comstock Publishing Association 2011).

[35] Jablonka, "Systems of Inheritance," p. 100.

becomes the challenge. Susan Oyama and other developmental systems theorists refer to this interaction as a series of systems and feedback loops, so that "the developmentally relevant environment depends on the organism. This means that whether, and how, any aspect of the surround is involved in producing an organism is a function of that organism's characteristics and its activity."[36] Or stated in the language of gene centricism:

> The gene does not build organisms in some special centrally controlled way that other interactants do not. But then, the organism does not make (most of) its own environment, either, though it does select and alter its surroundings. Nor does "the environment' make organisms or adaptations over ontogenetic or phylogenetic time. The conjoining of construction to interaction and systems is meant to work against this persistent desire to meet the maker.[37]

Beyond implications for phenotype development, the developmental view based on systems of interaction and reciprocal causation between "organism" and "environment" has repercussions for our understanding of evolutionary processes.[38] If genetic and extragenetic sources of heritable variation act together to shape organisms, the dynamics of evolutionary change—and range of phenotypic possibilities that can result from changes in environmental conditions—are augmented. As articulated by Oyama, Griffiths, and Gray:

> Just as there are no preexisting representations or instructions that shape organisms from within, there are no preexisting niches or environmental problems that shape populations from without. Evolutionary change is the result of interactions in which outcomes are codetermined, or co-constructed, by populations and environments with their own, often intricately interrelated, histories and characteristics; outcomes are not imposed by or prefigured in only certain interactants. Extended inheritance both increases the range of developmental outcomes that can be given evolutionary explanations and alters our view of evolutionary dynamics. If evolution is change in developmental systems, then . . . it is no longer possible to think of evolution as the shaping of the organism to fit an environmental niche. Rather, the various elements of the developmental systems coevolve. Organisms construct their niches both straightforwardly by physically transforming their surroundings and, equally importantly, by changing which elements of the external environment are part of the developmental system and thus able to influence the evolutionary process in that lineage.[39]

Organisms thereby not only depend on their experiences for their survival and success in reproduction but—because of the varied systems mediating inheritance and their complex feedback loops laden with developmental and ecological legacies

[36] Susan Oyama, "Terms in Tension," in Oyama et al., *Cycles of Contigency*, p. 189.
[37] Ibid., p. 188.
[38] Kevin N. Laland, John Olding–Smee, and Scott F. Gilbert, "EvoDevo and Niche Constrcution: Building Bridges," *Journal of Experimental Zoology* 310B (2008): 549–66.
[39] Oyama, Griffiths, and Gray, "What is Developmental Systems Theory?" p. 6.

of the organisms' ancestors—organisms become multigenerational manifestations of their experiences. Conceptual distinctions between "organism" and "environment" become obscure, so that when "environments" change, so necessarily do the "organisms" conjoined to those environments, *and* vice versa.

ETHICAL IMPLICATIONS OF AN "INTERDEPENDENCY" PERSPECTIVE

If the nature of "organism" is intimately tied to "environment" via experience, do we have unappreciated ethical obligations to that interdependency? Given our ability as humans to change natural processes and "environmental" conditions, is it ethical to change "environments" if by doing so we will be changing "organisms?" At this time in our evolutionary history as a species, humans are considered to have reached a new milestone in our ability to impact environments. Human activity has become so widespread and extensive that it has now been suggested to "rival some of the great forces of Nature in its impact on the functioning of the Earth system."[40] This ability appears unprecedented, as it is thought that at no previous time in Earth's history has a single species attained—let alone exercised—the capacity to alter the Earth system to such a great extent and at so wide-reaching a scale.[41]

So, would an ethical construct that more fully recognizes the interdependency of "organism" and "environment" affect how we, as a species, behave? Do the new scientific insights from developmental ecology and genetics hold ethical implications for how we alter the Earth system to suite our needs? To begin answering these questions, we can look to real world examples of conservation challenges where environmental change is affecting species, including humans. In doing so, it becomes apparent that some of these conservation problems arise in part from an inadequate appreciation of the intimacy of interaction between "organism" and "environment." For instance, Rachel Carson, in one of the opening chapters of *Silent Spring*, wrote:

> The history of life on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and the habits of the earth's vegetation and its animal life have been molded by the environment. Considering the whole span of earthly time, the opposite effect, in which life actually modifies its surroundings, has been relatively slight. Only within the moment of time represented by the present century has one species—man—acquired significant power to alter the nature of his world.
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> During the past quarter century this power has not only increased to one of disturbing magnitude but it has changed in character. The most alarming of all man's assaults

[40] Will Steffen, Jacques Grinevald, Paul Crutzen, and John McNeill, "The Anthropocene: Conceptual and Historical Perspectives," *Philosophical Transactions of the Royal Society A* 369 (2011): 843.

[41] Ibid.

> upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. This pollution is for the most part irrecoverable; the chain of evil it initiates not only in the world that must support life but in living tissues is for the most part irreversible. In this now universal contamination of the environment, chemicals are the sinister and little-recognized partners of radiation in changing the very nature of the world—the very nature of its life.[42]

As exemplified by Carson's statement above, in some ways, we have for years been asking questions about our responsibility to our natural surroundings and other organisms in a context of organism-environment interconnectedness. And yet, fundamental implications of this interdependency perspective have not been fully integrated into ethical views toward the environment. Below, I explore several current challenges in conservation and human health to illustrate how considering a fuller recognition of the intimacy of organism-environment connectedness might inform ethical questions about the human relationship with the Earth system.

Challenge 1: Chemical Pollutants in the Environment

In *Silent Spring*, Carson proposed that synthetic chemicals including pesticides, herbicides, and fungicides used in agriculture and industry can have detrimental impacts not only on fish, birds, and other wildlife, but also on humans in the forms of cellular metabolic changes, cancer, and death. The societal impact of *Silent Spring* was ground shifting, not only because it helped instigate a change in prevailing views concerning the value of synthetic chemical use, but also because Carson's argument had foundations in an ecological worldview:

> The earth's vegetation is part of a web of life in which there are intimate and essential relations between plants and the earth, between plants and other plants, between plants and animals. Sometimes we have no choice but to disturb these relationships, but we should do so thoughtfully, with full awareness that what we do may have consequences remote in time and place.[43]

Perhaps even more importantly, underlying Carson's thesis in *Silent Spring* was the notion that the organism is permeable to environmental influences so that any change in the health of the environment would, ultimately, translate into changes in the health of humans and wildlife.[44] Carson's argument against the wide use of synthetic chemicals—while supported by her extensive compilation of scientific evidence—was fundamentally an ethical one. She contended that it was immoral

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[42] Rachel Carson, *Silent Spring* (New York: Mariner Books, 2002), pp. 5–6.

[43] Ibid, p. 64.

[44] For examples, see Linda Lear, "Introduction," in Rachel Carson, *Silent Spring* (New York: Mariner Books, 2002), pp. xvi; and Lisa H. Sideris and Kathleen Dean Moore, "Introduction," in Lisa H. Sideris, Kathleen Dean Moore, eds., *Rachel Carson: Legacy and Challenge* (Albany: State University of New York Press, 2008), p. 9.

to put synthetic chemicals into the environment knowing that some chemicals had "broad lethal powers," and particularly so when some chemicals would knowingly persist in the environment for generations. Carson recognized the interdependency of "organism" and "environment," and used that connectedness as the foundation for her value-based assertion that it was unacceptable ". . . that we have allowed these chemicals to be used with little or no advance investigation of their effect on soil, water, wildlife, and man himself."[45] Carson contended that to allow synthetic chemicals, some of which had clear toxicity, to be released into ecosystems showed "our lack of prudent concern for the integrity of the natural world that supports all life."[46]

Since the publication of *Silent Spring* in 1962, a wide variety of synthetic chemicals have been demonstrated to impact brain development, cancer incidence, reproductive function, and hormone signaling leading to cognitive impairments, behavioral defects, and the reduced production and motility of sperm. It should be surprising then that almost all of those chemicals are still in use today as the issue of environmental contamination by chemical pollutants remains a serious problem for human and wildlife health, even more than fifty years after the publication of Carson's *Silent Spring*. There are likely several reasons for this, including economic and political rationalizations as well as, at least to some extent, scientific uncertainty. But a part of the explanation for the rigidity of this health and conservation challenge also lies with the dominant ethical perspective on environmental issues. When "organism" and "environment" are regarded as distinct through the lens of "externalism," questions about when it is morally acceptable to release chemicals into the environment often are phrased in the context of population-level or community-level effects. For instance, if a water quality board asks an environmental scientist whether it is acceptable for synthetic chemicals to be present in a river at certain concentrations, the response from the scientist will often be to ask whether wildlife in that river show adverse health impacts that might affect the viability of fish or aquatic invertebrate populations, and therefore the biological community of that river system. The response of the well-trained environmental scientist is currently grounded in an ecologically based ethic in which moral decisions regarding the environment are handicapped by the "externalist" demarcation between an "organism" and "environment"—where the external environmental change (synthetic chemicals or pollution, in this case) is only problematic if that change alters the survival or reproductive success of the organisms inhabiting that environment to, ultimately, disrupt the ecological integrity of the biotic community.

But, what if we instead view the issue of pollution through the lens of organism-environment interdependency? Rather than focusing on ecological integrity, the organism-environment interdependency perspective leads us to ask different

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[45] Carson, *Silent Spring*, p. 13.
[46] Ibid., p. 13.

questions. Is it ethical to expose living organisms to synthetic chemicals if those chemicals become a part of the tissues of "organism" itself? Do we have a moral right to release synthetic chemicals into the world if those chemicals become components within the complex inheritance systems (e.g., epigenetic, behavioral) of organisms exposed to those chemicals, and therefore alter the very "nature" of "nurture" for those organisms? Does our ethical responsibility change if not only the organisms exposed to the pollution might suffer health impacts, but also their offspring for many generations to come?

Toxicologists studying the effects of synthetic chemicals on organisms have established that, for many chemicals, exposure to a low continuous dose—which is the normative exposure scenario for humans and other organisms—is often not sufficient to trigger population declines or community collapses. So, low continuous exposure to synthetic chemicals may not have detectable impacts on the integrity of ecological communities. But, such exposures often still have measureable effects on individual phenotypes whether as health effects (e.g., reproductive abnormalities, metabolic alterations, etc.) or other phenotypic changes (e.g., osmoregulatory ability, behavioral changes). Within the last several years, it has even become evident that exposure to chemical pollutants can cause multigenerational health effects by triggering epigenetic change in organisms.[47] Epigenetic variation—broadly defined as heritable genetic modifications that alter gene expression without a change in DNA sequence—occurs via a variety of biological mechanisms including DNA methylation, covalent histone protein modification, and microRNA regulation.[48] Recent findings that chemical pollutants can cause epigenetic change to generate adverse health effects are of grave concern because the same health impacts that occur in the parental generation exposed to pollutants may persist many generations later, even though those subsequent generations never experienced the chemical pollutant. Epigenetic change is not broadly accounted for by the current ecology-based ethic, but it does fall clearly within the scope of the multiple inheritance systems of the developmental systems-based perspective (or, more specifically, the "cellular or epigenetic inheritance systems [EIS]" as described by Eva Jablonka).[49] The integration of a developmental systems-based perspective into an environmental ethic—one that would not only include the current ecologically based ethic's consideration of ecosystem and community integrity, but also a more formal recognition of the interdependency of the "organism-environment" relationship—could therefore shift the ethical debate concerning the use of synthetic chemicals.

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[47] Michiel B. Vabdegehuchte and Colin R. Janssen, "Epigenetics and its Implications for Ecotoxicology," *Ecotoxicology* 20 (2011): 607–24; Moshe Szyf, "The Dynamic Epigenome and its Implications in Toxicology," *Toxicological Sciences* 100 (2007): 7–23.

[48] See, for example, Oscar Aguilera, Agustín F. Fernández, Alberto Muñoz, and Mario F. Fraga, "Epigenetics and Environment: A Complex Relationship," *Journal of Applied Physiology* 109 (2010): 243–51.

[49] Jablonka, "Systems of Inheritance," p. 100.

Challenge 2: Effects of Anthropogenic Environmental Change

Habitat change caused by anthropogenic activities is considered one of the foremost causes for declines in biodiversity.[50] As habitats change, the organisms that rely on these habitats are affected. In some cases, species may continue to persist in the altered habitat by shifting their behavior, food resources, or patterns of habitat use. In other cases, populations or even species may be extirpated. Under either scenario, the particular cause(s) for the decline or loss of a population may linger unknown, and even in cases when the population remains in the altered habitat, the phenotypic impacts for individuals continuing to occupy that altered environment are commonly unexpounded.

But, by adopting a view whereby the phenotypes of "organisms" are inextricably tied to "environmental" conditions, it becomes clear that developmentally mediated phenotypic responses are crucial for how a species will fare in an altered habitat. To illustrate how this alternate view can inform conservation approaches for imperiled species, we can look at conservation efforts that breed and rear animals in captivity for subsequent release into the wild. Animals such as the California condor (*Gymnogyps californianus*) and black-footed ferret (*Mustela nigripes*) that have been raised in captive-rearing conservation programs often show behavioral changes that may impede their survival after release.[51] These phenotypic changes are not limited to behavior, however, as changes in morphology and other characteristics have been observed as well.[52] Perhaps the best exemplar of a captive-rearing program is the breeding and raising of large numbers of fishes in hatcheries, which has long been an approach to supplement or restore depleted fish stocks. It is well established that fish that develop in the built environment of a hatchery can show behavioral differences from their wild counterparts, including changes in foraging preferences, social behaviors, and anti-predator responses.[53] Hatchery-reared

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[50] Edward O. Wilson, *The Future of Life* (New York: Vintage Books, 2002).

[51] M. P. Wallace, "Retaining Natural Behaviour in Captivity for Re–introduction Programmes," in L. M. Gosling and W. J. Sutherland, eds., *Behaviour and Conservation* (Cambridge: Cambridge University Press, 2000), pp. 300–14.

[52] See, for example, S. M. Wisely, R. M. Santymire, T. M. Livieri, P. E. Marinari, J. S. Kreeger, D. E. Wildt, and J. Howard, "Environment Influences Morphology and Development for *In Situ* and *Ex Situ* Populations of the Black–Footed Ferret (*Mustela nigripes*)," *Animal Conservation* 8 (2005): 321–28; Sean C. Lema, and Gabrielle A. Nevitt, "Testing an Ecophysiological Mechanism for Morphological Plasticity in Pupfish and its Relevance to Conservation Efforts for Endangered Devils Hole Pupfish," *Journal of Experimental Biology* 209 (2006): 3499–3509; Joanne D. Connolly and Alison Cree, "Risks of a Late Start to Captive Management for Conservation: Phenotypic Differences between Wild and Captive Individuals of a Vivaparious Endangered Skink (*Oligosoma otagense*)," *Biological Conservation* 141 (2008): 1283–92.

[53] See, for example, B. A. Berejikian, S. B. Matthews, and T. P. Quinn, "Effects of Hatchery and Wild Ancestry and Rearing Environments on the Development of Agonistic Behavior in Steelhead Trout (*Oncorhynchus mykiss*) Fry," *Canadian Journal of Fisheries and Aquatic Sciences* 53 (1996): 2004–14; B. L. Olla, M.W. Davis, and C.H. Ryer, "Behavioural Defitics in Hatchery–Reared Fish: Potential Effects on Survival Following Release," *Aquacultural and Fishery Management* 25 (1994): 19–34.

salmon, for example, often differ in body morphology and life history due to developmental responses to the hatchery environment,[54] and even have been shown to exhibit differences in the gross structure of their brains resulting from only one generation in a captive environment,[55] indicting fundamental shifts in inputs to the developmental systems mediating phenotypic expression.

What about organisms in the wild? Does human-caused environmental change trigger phenotypic change in that context as well? Available evidence suggests that it does, although controlled scientific experiments in the wild are less common than in the captive scenarios described above. Behavioral changes including shifts in the type and intensity of social interactions, movement patterns, and even reproductive timing have been observed in species living in environments with high anthropogenic activity.[56] Several species of birds living in human cities have been found to sing or call at different sound frequencies than their conspecific counterparts outside of cities; these changes in communication behavior are thought to be a response to the high levels of noise present in urban areas.[57] Such vicissitudes in acoustic communication behavior do not appear to be limited to birds, as analogous changes have also been observed in whales and amphibians, both of which use sound to communicate with other individuals of their species.[58]

Under current ecologically based ethical perspectives, such phenotypic change in response to an altered habitat may not be considered significant, and therefore not a moral issue, unless those phenotypic changes disturb the integrity of the ecological system. Indeed, it could be argued that supplementation of a wild stock with hatchery-raised fish is the morally appropriate conservation approach, if that

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[54] See, for example, B. A. Berejikian, E. P. Tezak, T. A. Flagg, A. L. LaRae, E. Kummerow, and C. V. W. Mahnken, "Social Dominance, Growth, and Habitat Use of Age–0 Steelhead (*Oncorhynchus mykiss*) Grown in Enriched and Conventional Hatchery Rearing Environments," *Canadian Journal of Fisheries and Aquatic Sciences* 57 (2000): 628–36.

[55] R. L. Kihslinger, S. C. Lema, and G. A. Nevitt, "Environmental Rearing Conditions Produce Forebrain Differences in Wild Chinook Salmon, *Oncorhynchus tshawytscha*," *Comparative Biochemistry Physiology Part A* 145 (2006): 145–51.

[56] See, for example, Erin E. Boydston, Karen M. Kapheim, Heather E. Watts, Micaela Szykman, and Kay E. Holekamp, "Altered Behaviour in Spotted Hyenas Associated with Increased Human Activity," *Animal Conservation* 6 (2003): 207–19; Kathryn E. Lacy and Emília P. Martins, "The Effect of Anthropogenic Habitat Usage on the Social Behaviour of a Vulnerable Species, *Cyclura nublia*," *Animal Conservation* 6 (2003): 3–9; Jesko Partecke, Thomas Van't Hof, and Eberhard Gwinner, "Differences in the Timing of Reproduction between Urban and Forest European Blackbirds (*Turdus merula*): Result of Phenotypic Flexibility or Genetic Differences?" *Proceedings of the Royal Society of London B* 271 (2004):1995–2001.

[57] See, for example, Hans Slabbekoorn and Margriet Peet, "Birds Sing at a Higher Pitch in Urban Noise," *Nature* 424 (2003): 267; M. Katti and P. S. Warren, "Tits, Noise and Urban Bioacoustics," *Trends in Ecology and Evolution* 19 (2004): 109–10; Hans Slabbekoorn and A. den Boer–Visser, "Cities Change the Songs of Birds," *Current Biology* 16 (2006): 2326–31.

[58] Lawerence A. Rabin and Correigh M. Greene, "Changes to Acoustic Communication Systems in Human–Altered Environments," *Journal of Comparative Psychology* 116 (2002): 137–41; A. D. Foote, R. W. Osborne, and A. R. Hoelzel, "Whale–Call Response to Masking Boat Noise," *Nature* 428 (2004): 910; T. Lengagne, "Traffic Noise Affects Communication Behaviour in a Breeding Anuran, *Hyle arborea*," *Biological Conservation* 141 (2008): 2023–31.

approach helps mitigate or "rebalance" an already disturbed ecological system. But, are the salmon released from a hatchery really the same fish as their wild counterparts, if they look differently, grow differently, act differently? When we take an organism out of its natural habitat—even only for a part of its developmental life—is it still the same organism when we return it to the wild?

These questions lead to a more fundamental query: what is it that we are aiming to conserve? Should conservation efforts hold the maintenance of ecological integrity as paramount? Should conservation efforts be directed at preserving the genetic distinctiveness of a species, which (under a "genetic determinism" perspective) is often considered a proxy for the distinctiveness of a species? Or, alternatively, should we be conserving the unique phenotypic characteristics of a species within its inherited system of interdependency, which includes genetic, epigenetic, behavioral, and habitat influences? An ecologically based view that recognizes "organism" as associated with "environment"—*but* that falls short of seeing organisms as inseparable from their experiences—provides only a partial answer to this question, even though habitat preservation is now ubiquitously seen as critical to the continued persistence of species in the wild. In some cases, an insufficient appreciation for the importance of the organism-environment relationship has led to conservation approaches that disconnect conservation of the organism from the conservation of that organism's environment. The captive breeding of fishes for stock enhancement or restoration is one such example; such fish are raised in captivity where they develop morphologically, physiologically, and behaviorally under conditions quite different from those found in wild streams. Such captive hatchery rearing may increase population numbers, but this method paradoxically creates fish mismatched phenotypically to the rivers and streams—whether pristine or ecologically restored through parallel conservation efforts—where they will be released. Such hatchery approaches have been employed for years for fish stock enhancement or conservation at significant financial cost, and yet, the inadequacy of such an approach becomes immediately apparent when one views the method from the interdependent systems view where "organisms" are considered inseparable from their "environment."

Challenge 3: The Relevance of "Natural Experiences" for Human Health

There is a growing indication that interaction with the natural world may have beneficial effects for human health. "Health" is defined by the World Health Organization's charter of 1946 as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."[59] Under this definition, an organism's state of "health" may be affected not only by pathogens (e.g., bacterial, viruses) and other customarily recognized external influences (e.g.,

[59] World Health Organization, *Charter of the World Health Organization* (Geneva, Switzerland: WHO, 1946).

nutritional deficits, tobacco smoke, chemical pollutants, radiation exposure, etc.), but also by a variety of environmental experiences that are often overlooked by medical practitioners.

Research in environmental psychology is increasingly linking what are often regarded as "nature experiences" to measures of physical and mental health.[60] Some of these links have been recognized for some time; for example, it is well accepted that persistent loud noise—whether caused by heavy automobile traffic, airplanes, or even the neighbor's use of a lawn mower—can induce physiological responses indicative of stress and lead to sleeplessness, increased blood pressure, elevated risk of heart attacks and changes in the ability to focus attention and learn.[61] Other links may be subtler but are nonetheless increasingly being identified. For instance, several studies indicate that increased interactions with "nature" in the forms of gardens, parks, and wilderness areas can have beneficial influences on mental health, including reduced negative emotions such as anger, sadness, anxiety and fatigue, and enhanced feelings of well being.[62] These mental health changes may be underpinned by changes in physical health as well, although it is important to point out that studies using short-term physiological indicators have sometimes had difficulty identifying consistent effects.[63] Visual access to natural landscapes, in forms ranging from window views of farmland and trees to photos of "nature" scenes, may also influence health parameters. In one classic study conducted over a ten-year-study period, patients recovering from gallbladder surgery that had views of deciduous trees from their hospital rooms exhibited shorter hospital stays with less need for pain medication compared to patients recovering in rooms with views of brick walls.[64] In other studies, window views of natural landscapes have been indicated to have lessening influences on the frequency of hospital visits for prisoners housed in cells, as well as on the occurrence of headaches and other stress indicators by employees at work and students at school.[65] Although much more research remains to be done in this area, there are studies suggesting that "natural

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[60] See, for example, Howard Frumkin, "Beyond Toxicity: Human Health and the Natural Environment," *American Journal of Preventive Medicine* 20 (2001): 234–40; Diana E. Bowler, Lisette M. Buyung–Ali, Teri M. Knight, and Andrew S. Pullin, "A Systemic Review of Evidence for the Added Benefits to Health of Exposure to Natural Environments," *BMC Public Health* 10 (2010): 456; Cecily Maller, Mardie Townsend, Anita Pryor, Peter Brown, and Lawerence St. Leger, "Healthy Nature Healthy People: 'Contact with Nature' as an Upstream Health Promotion Intervention for Populations," *Health Promotion International* 2 (2005): 45–54; Stephen Kaplan, "The Restorative Benefits of Nature: Toward an Integrative Framework," *Journal of Environmental Psychology* 15 (1995): 169–82.

[61] W. Passchier–Vermeer and W. F. Passchier, "Noise Exposure and Public Health," *Environmental Health Perspectives* 108 (suppl. 1) (2000): 123–31.

[62] Frumkin, "Human Health and Natural Environment"; Bowler, Buyung–Ali, Knight, and Pullin, "Benefits to Health of Natural Environments."

[63] Bowler, Buyung–Ali, Knight, and Pullin, "Benefits to Health of Natural Environments."

[64] R. S. Ulrich, "View Through a Window May Influence Recovery from Surgery," *Science* 224 (1984): 420–21.

[65] E. O. Moore, "A Prison Environment's Effect on Health Care Service Demands," *Journal of Environmental Systems* 11 (1981–1982): 17–34; Phil Leather, Mike Pyrgas, Di Beale, Claire Lawrence,

experiences" can modulate how a person responds physiologically to external stressors.[66]

But, would a greater focus on organism-environment interdependency really change how we view both the causes and the treatments of disease? A broader conceptualization of "human health"—such as that proposed under an interdependent systems view of human biology whereby "any noxious influence from the environment involves the organism as a whole, including the psychological state and the social and cultural conditioning of the person"[67]—could lead to a fuller integration of the human organism with its social and ecological dimensions. Such integration has the potential to shift the focus of biomedicine more toward "asking why a disease occurs, and trying to remove the *conditions* that lead to it"[68] and drive new inquiry into the environmental context of disease. As just one example of the potential within this approach: data collected recently from human cultures around the world suggests that higher levels of outdoor activity, which includes a range from outdoor sports to leisure time, is associated with lower incidence of myopic vision (nearsightedness) in adolescents.[69] All told though, if interactions with "natural" environments affect our mental and physical disease states, then maintaining and promoting interactions with natural environments may hold significance that we scarcely grasp.

CONCLUSIONS

We already view exposure to some environmental conditions as unethical. Raising a child in an environment of physical abuse or parental neglect is considered immoral, so we create laws to protect children from being exposed to such conditions. Similarly, conditions of famine and poor nutrition resulting from extreme poverty or war are considered intolerable morally because such conditions lead to

"Windows in the Workplace: Sunlight, View, and Occupational Stress," *Environment and Behavior* 30 (1998): 739–62; S. Kaplan, "The Psychological Benefits of Nearby Nature," in Diane Relf, ed., *Role of Horticulture in Human Well–Being and Social Development* (Arlington, Va.: Timber Press, 1992), pp. 125–33.

[66] See for example, Nancy M. Wells, and Gary W. Evans, "Nearby Nature: A Buffer of Life Stress among Rural Children," *Environment and Behavior* 35 (2003): 311–30;

[67] Fritjof Capra, *The Turning Point* (New York: Simon and Schuster, 1982), p. 151.

[68] Ibid., p. 150 (emphasis added). In chaps. 5, 9, and 10, Capra discusses the historical basis for the dominant Cartesian reductionist paradigm in biomedicine, and outlines an alternative paradigm that is holistic and ecologically based.

[69] Kathryn A. Rose, Ian G. Morgan, Jenny Ip, Annette Kifley, Son Huynh, Wayne Smith, and Paul Mitchell, "Outdoor Activity Reduces the Prevalence of Myopia in Children," *Ophthalmology* 115 (2008): 1279–85; Pei–Chang Wu, Chia–Ling Tsai, Chia–Huo Hu, and Yi–Hsin Yang, "Effects of Outdoor Activities on Myopia among Rural School Children in Taiwan," *Ophthalmic Epidemiology* 17 (2010): 338–42; M. Dirani, L. Tong, G. Gazzaard, X. Zhang, A. Chia, T. L. Young, K. A. Rose, P. Mitchell, and S. M. Saw, "Outdoor Activity and Myopia in Singapore Teenage Children," *British Journal of Ophthalmology* 93 (2009): 997–1000; Jenny M. Ip, Kathryn A. Rose, Ian G. Morgan, George Burlutsky, and Paul Mitchell, "Myopia and the Urban Environment: Findings in a Sample of Twelve-Year-Old Australian School Children," *Investigative Ophthalmology and Visual Science* 49 (2008): 3858–63.

suffering and health impacts including deficient growth, impaired reproduction, and behavioral problems. What we do not always consider, however, is that our ethical perspectives on these scenarios are based in part on a view of organism-environment interdependency: that exposure to those environmental conditions alters phenotypic development—and correspondingly "health"—in such a harmful way that we consider that particular organism-environment experiential combination unethical. To some extent, then, we have already integrated a semblance of an interconnected systems perspective into our ethics on the human relationship with the Earth system. But do we, and should we, have parallels for other species?

Thinking broadly about this question reveals real-world scenarios that might help provide answers. We often take action when a population of wildlife (e.g., sea turtles, marine mammals) is found with a high rate of cancerous tumors or other disease; our response, and sometimes our indignation, is comparable to how we react when we identify a high incidence of cancer in a human community. Similar situations have occurred with wildlife in both terrestrial and marine habitats: a high incidence of bacterial-caused disease in wildlife downstream of sewage outflows, the increased frequency of coral bleaching events due to the effects of marine pollution and rising sea surface temperatures, or the declining health condition of polar species (e.g., polar bears, penguins) as climatic conditions shift in those regions of the globe. In each of these scenarios, we can see moral obligations to the detrimental impacts of the altered organism-environment interaction because it is a change in environment caused by our own actions as a species that has led to the harmful impacts.

David Orr wrote that the current "ecological emergency is about the failure to comprehend our citizenship in the biotic community. From the modern perspective we cannot see clearly how utterly dependent we are on the 'services of nature' and on the wider community of life."[70] A fuller appreciation of that dependency needs to include a recognition that organism-environment interconnectedness is embedded within the processes of inheritance and development that are fundamental to life. Development joins organism and environment in ways that link our very phenotypic characteristics as humans to the Earth system, just as it does with other species. As that system continues to be altered by our activities, an emerging recognition of the mutual interdependency that constitutes the organism-environment relationship may become vital for humans to perceive the moral obligations that we have toward *how* we modify "environments," including how we construct our own built habitats as humans. It may be that only through a more enriched knowledge of the intimacy contained within that relationship will modern humans surmount the challenge of recognizing just how reliant all species, including ourselves, are to the biotic and abiotic interactions that comprise the "wider community of life."[71]

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[70] David Orr, *Earth in Mind* (Washington, D.C.: Island Press, 1994), p. 32.
[71] Ibid.