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J. Baird Callicott and Robert Frodeman
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BIOFUELS

SEE *Energy.*

BIOPHILIA

The Harvard biologist Edward O. Wilson, who popularized the term *biophilia,* describes it as an "innately emotional affiliation of human beings to other living organisms" (Wilson 1993, p. 31). Two aspects of that definition are especially important. First, Wilson argues that biophilia is innate and therefore part of humans' genetic heritage and evolved nature. Second, biophilia is an emotional response that can be an end in itself (feeling a sense of pleasure and well-being), or it can stimulate emotions that motivate various kinds of behavior (interest motivates exploration).

If biophilia is an innate human characteristic, how did it evolve? There is general agreement among researchers that Homo sapiens' long history as hunters and gatherers, intimately involved with nature, has influenced how humans perceive and respond to the physical environment. There are differences among researchers, however, about the nature of the adaptation and how it manifests itself. Wilson (1986) describes biophilia as a complex of learning rules that guide adaptive response to natural stimuli. The rules are reinforced through cultural adaptations, such as myths and stories. As Wilson notes, "When human beings

remove themselves from the natural environment, the biophilic learning rules are not replaced by modern versions equally well adapted to artifacts" (1993, p 31). Thus, the learning rules are fragile and need to be reinforced through contact with nature.

Tooby and Cosmides (1992) take a different perspective. Rather than possessing weak learning rules, the brain, in their view, is composed of thousands of modules designed to solve specific problems that have occurred regularly over the course of human evolution. In this version biophilia consists of hundreds of modules designed to solve problems regularly encountered in ancestral habitats: avoiding predators, separating toxic from nontoxic foods, using clouds to predict weather patterns, and using flowers to signal future resource availability. Each module is rich in content, with its own reasoning process and information-gathering structure. For instance, rules about selecting nutritional plant resources would be different from rules about predators because the problems posed by these two situations are very different.

At this time there is not enough research evidence to support one or the other perspective. However, there is good evidence from cross-cultural studies that the brain has an evolved intelligence that grew out of the need for detailed information about nature (Atran 1992; Mithen 1996). Mithen notes that all known cultures have notions of plant and animal "species," all cultures construct taxa based on morphological patterns, and all cultures have life-form groupings for animals (fish, birds) and plants (trees, flowers, grass).

Further evidence of evolved responses to nature comes from controlled laboratory studies. A series of conditioning experiments by Öhman (1986) showed that physiological and emotional responses to fear-arousing stimuli (snakes and spiders) can occur subliminally, with subjects having no conscious recognition of having seen the stimuli. Similar responses do not occur to modern threats such as guns.

THE SAVANNAH HYPOTHESIS

Humans have gradually come to occupy diverse biomes and habitats across the globe. Gordon Orians argues that the long period of evolutionary development in the savannahs of Africa should have left a positive mark on the human psyche (Orians 1980, 1986; Orians and Heerwagen 1992; Heerwagen and Orians 1993). According to the "savannah hypothesis," people should prefer to be in savannahlike environments because they once provided a better resource base than forest or desert biomes. Key characteristics of the savannah include the following:

- scattered clusters of trees that provided shelter fro the sun and protection from terrestrial predators,
- long-distant views that afford surveillance for predator detection and avoidance,
- even ground cover for efficient movement across t terrain,
- a rich diversity of plant and animal species,
- rock outcroppings for surveillance or sleeping,
- seasonal variation in fresh water availability becaus of rain patterns.

What evidence exists for the savannah hypothesi Do people prefer to be in landscapes that have the features? Studies in landscape planning unrelated to bic philia have consistently shown that people prefer sem open landscapes with large trees and water to either dens forests or deserts (Ulrich 1993); people consistently dis like scruffy, dense habitats with rough ground texture Similar results prevail across cultures.

The strongest results relate to water. Coss (2003 Coss and Moore 1990) argues that selective pressures t find sources of fresh water should have been particularl strong in the savannah habitats of Africa because of th strong seasonal variations in rain. Studies of water per ception (summarized in Coss 2003) show that peopl respond very positively to sparkle, reflections, and surface movements of water. Early humans may have used visual sparkle in particular as a cue to the location of wate because it can be seen in the distance, whereas reflections and water-surface movements can be seen only on closer inspection. Reflection and movement may have been used as indicators of water quality.

BENEFITS OF NATURE

Since the mid 1980s, research in a variety of fields has shown that contact with nature generates emotional, physiological, and social benefits. Research on this topic has been conducted in workplaces, hospitals, urban environments, and experimental laboratories. The findings point consistently to the value of features of nature such as large trees, flowers, and water. Studies also show that benefits of nature occur in many ways: through direct contact (sitting in an outdoor garden), indirect contact (through a window view), and from simulations using nature decor (such as posters or paintings).

Nature through the Window Ulrich's research (1984) was the first to focus on the links between nature, emotional functioning, and health associated with window views. His study found that hospital patients in rooms with views of trees had a better recovery from surgery than a matched group of patients whose view was a brick

wall. Patients with the nature had shorter hospital stays, needed less medication, and drew more positive reactions from the nursing staff about their recovery. Studies in office settings have also found reduced stress associated with window views of nature (Kaplan 1992).

Simulated Nature Ulrich's studies have included laboratory experiments using photos and videos in which he has consistently found that subjects recover from stress more quickly and are in more positive moods if they are shown nature scenes or urban scenes with nature rather than urban scenes devoid of natural elements (Ulrich 1993).

Others have shown that nature contact, whether real or simulated, can be beneficial. For instance, a study of windowed and windowless offices by Heerwagen and Orians (1986) found that people in windowless spaces used twice as many nature elements (posters and photos especially) to decorate their office walls than those who had views of natural areas outdoors. A laboratory study of "green exercise" tested the effects of projected scenes on the physiological and psychological outcomes of subjects on a treadmill (Pretty et al. 2005). They found that all subjects benefited similarly in physiological outcomes but that subjects who viewed pleasant nature scenes (both rural and urban) scored higher in measures of self-esteem than those viewing totally urban scenes or "unpleasant" rural scenes with destroyed landscapes.

Outdoor Nature and Gardens Urban nature also has benefits for health and well-being. For instance, a study of public housing projects in Chicago found that large trees had a significant impact on residents' social behavior (Kweon et al. 1995, Sullivan et al. 2004). Using behavioral observations and interviews, the researchers found that housing developments with large trees motivated people to be outdoors and that, once there, they talked to their neighbors and developed stronger social bonds than people in similar housing projects without green space and trees.

There is also growing evidence that both active and passive contact with gardens provides psychological, emotional, and social benefits. Cooper-Marcus and Barnes (1995) found that the benefits of gardens include better recovery from stress, having a place to escape to, and improved moods. Benefits also occur with horticulture therapy, especially in clinical settings and nursing homes. Studies described in Morris (2003) show that dementia and stroke patients who engage in gardening show improved mobility and dexterity, more confidence, and improved social skills.

Indoor Vegetation Indoor plants are commonly used in many workplaces as enhancements of the aesthetic and psychological atmosphere. Researchers in Norway found that plants also had physiological benefits. The field experiment in an office environment found that workers who had a cluster of plants near their desks showed a decrease in neurophysiological symptoms (with the greatest decrease in fatigue) and a decrease in mucous-membrane symptoms when the plants were present (Fjeld et al. 1998).

Outdoor Green Space Researchers in the Netherlands conducted a nationwide study of the benefits of green space—which they call Vitamin G—at the household, community, and regional levels (Groenewegen et al. 2006). Using national health survey data arrayed on a geographical information system, the researchers have found preliminary evidence that residents who are closer to green spaces enjoy better health than residents who are farther away. The data analysis has controlled for socioeconomic factors that have known links to health.

Cognitive Benefits In addition to the emotional and physiological benefits from nature contact, there is some evidence of a linkage to cognitive functioning. Lohr and her coauthors (1996) found that subjects working in a windowless room with plants completed a series of computerized tasks faster, had lower blood pressure readings, and felt more attentive than subjects working in the same room without plants. In study of window views, Tennessen and Cimprich (1995) found that people whose view was predominantly natural had higher scores on a survey assessing directed attention and attention recovery. Hartig and his coauthors (1991) report similar results in a field experiment. People who went for a walk in a mostly natural setting performed better on an editing task than those who walked in a predominantly built setting or who quietly read a magazine indoors. Although the mechanisms underlying the links between nature and cognitive performance are obscure, there are several hypotheses. The first, proposed by Kaplan (1995), focuses on attention. Kaplan argues that visual contact with everyday nature reduces fatigue associated with intense concentration and thereby replenishes the attention system, enabling people to refocus easily after short nature breaks.

The other leading hypothesis, proposed by Ulrich (1993), argues that contact with nature improves cognitive performance through effects on mood. He draws heavily on research by Isen (1990), whose numerous experiments show that subjects in positive moods perform better on tests of creative problem solving than those who are in neutral or negative moods. Isen speculates that positive moods increase the tendency to "break set" and to see relatedness between divergent events or appearances; because good feelings promote diffuse rather than focused attention, people in a good

mood search more broadly for solutions and alternative interpretations. Joseph LeDoux (1996), one of the nation's leading brain researchers, cites neurological evidence to support this hypothesis. He has found that positive feelings lead to heightened activity of the right parietal brain region—the section of the brain that is associated with a more global, expansive cognitive style. Thus, positive feelings directly affect brain processes related to performance on tasks requiring creativity and novel problem solving.

BIOPHILIA AND SUSTAINABILITY

The human desire for contact with pleasant natural settings has many benefits but also presents a potential dilemma for sustainable living and for urban spaces. Humans' innate attraction to water, distant views, and lush vegetation often leads to unsustainable design practices. People create water features and lush gardens in the desert; they raze hilltop forests to build hotels and houses that take advantage of panoramic views. They build expensive houses and resorts along waterfronts rather than creating public access spaces or wildlife refuge. The desire to enhance the biophilic experience is reinforced by economic benefits. Houses and commercial buildings command higher prices and rents when they are located near water and green spaces and/or have lush landscaping (Heerwagen 2006).

Urbanization also presents a dilemma for biophilia. Ironically, it is in urban environments that contact with green spaces, trees, flowers, and water would be most beneficial as an antidote to urban noise, pollution, and other stressors. Yet green spaces and vegetation are not equally distributed in urban neighborhoods. The economically advantaged live in houses and condominiums bordering parks or the water's edge, whereas poorer neighborhoods often are devoid of such amenities. To overcome this deficit, planners, health practitioners, and landscape architects in New York City have banded together to promote the Restorative Commons (Meristem 2006) to bring nature amenities to all neighborhoods. Researchers in Sweden propose a similar idea: to "design communities that balance settlement density with satisfactory access to nature experience" (van den Berg et al. 2007).

SEE ALSO *Built Environment; Landscape Architecture, Design, and Preservation; Sustainability; Sustainable Agriculture; Sustainable Development; Urban Environments; Wilson, Edward O.*

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Judith Heerwagen

BIOSECURITY

Biosecurity is a concept that bridges national security, disaster studies, and, in broader definitions, access to food and biological resources in general. After the terrorist attacks of 2001 in the United States and the subsequent mailing of letters containing anthrax spores, biosecurity increasingly was defined against the risks of premeditated attacks with biological weapons or the risks of disruptive events such as natural disasters. In some circles, such as the Food and Agriculture Organization (FAO), biosecurity continues to be used to refer to a broader array of issues that affect human health and well-being, such as food safety, animal and plant health, and environmental risks, but without mention of bioweapons or bioterrorism or environmental ethics.

DEFINITIONS AND CONSEQUENCES

The more narrow usage is still very broad, including a discourse on dual-use technologies, evaluation of state programs for biological weapons and biodefense, analysis of the capacity and motivations of terrorists, debate over the value of international law in reducing the threat through treaties such as the Biological Weapons Convention, assessment of the environmental harm that could arise from bioweapons programs, and similarities between bioattacks and natural disasters, along with the policy implications of all those issues. This discourse is saturated with ethical judgments and dilemmas, although they rarely are identified as such. Indeed, the addition of environmental impacts to the list of issues under discussion can be seen as a proxy for the trade-offs among competing values across domains that the shift to a national security discourse has entailed.

Because biotechnology is inherently dual-use—that is, it can be used for both civilian and military ends—regulation of military applications is likely to affect civilian uses. Biosecurity in this context means protection from the misuse of knowledge and technology in the life sciences, and policies to enhance biosecurity include regulation of access to pathogens, background screening of laboratory employees, possible censorship of journal articles, and the development of professional codes of conduct and education in ethics. In addition, surveillance measures to detect biological attacks have been introduced in many public places in the United States, and funds have been allocated to develop new vaccines and treatments, build high-security laboratories, and improve the ability of local communities to respond to emergencies. Although historically the main threat has come from state-sponsored programs for biological weapons, assessments since 2001 have been dominated by the risk of bioterrorism. Unfortunately, the U.S. policy responses to that risk have had the unintended consequence of multiplying the number of weapons-relevant facilities, biological agents, and trained personnel; this development may pose an increased security risk because of the increase in opportunities for diversion to weapons use.

Natural disasters may produce many of the same risks as biological attacks without the element of intentionality. Outbreaks of new virulent diseases or the spread of those diseases across national borders may pose a serious threat to human health regardless of whether they originate in an enemy attack or occur in the