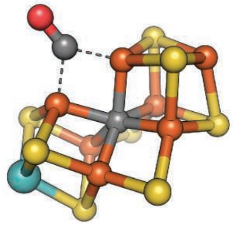
A monogenic theory of autoimmunity p. 1560

Reactive iron revealed in nitrogenase p. 1568



PERSPECTIVES

ECOLOGY

Whose conservation?

Changes in the perception and goals of nature conservation require a solid scientific basis

By **Georgina M. Mace**

Conservation biology is a mission-driven discipline (*1*) and is therefore subject to both drift and the periodic adoption of fads and fashions (*2*). Although many basic conservation principles, conservation organizations, and initiatives of global reach and impact have persisted almost unchanged for decades, the framing and purpose of conservation have shifted (*3*). These shifts mainly relate to how the relationships between people and nature are viewed, with consequences for the science underpinning conservation.

There have been four main phases in the modern framing of conservation in the developed world (see the figure). Conservation thinking before the 1960s was broadly of the "nature for itself" type, which prioritizes wilderness and intact natural habitats, generally without people, and has scientific underpinnings from wildlife ecology, natural history, and theoretical ecology. This thinking continued throughout the 1960s, with a focus on species conservation and protected area management, and remains a dominant ideology for many people today.

In the 1970s and 1980s, rapid increases in the impacts of human activity and awareness of the consequences of habitat destruction, overharvesting, and invasive species led to the emergence of "nature despite people" conservation. Here, the focus is on threats to species and habitats from humans, and on strategies to reverse or reduce them. Ideas concerning minimum viable population sizes and sustainable harvesting levels, as well as intense debates about community-based management and the sustainable use of wildlife, stem from this period (*4*) and persist to the present.

Tropical rain forest, Sinharaja, Sri Lanka. In recent decades, views of the relationship between humans and nature have changed in tandem with increasing impacts of human activities on natural systems.

CONSERVATION SERIES

By the late 1990s, there was ample evidence that pressures on habitats were ubiquitous and persistent, and that the best endeavors of conservation were failing; extinction rates were escalating and pressures on biodiversity increasing relentlessly (*5*). A realization developed that nature provides crucial goods and services that are irreplaceable yet had been consistently ignored (*6*). As the costs of environmental mismanagement started to accumulate, the potential benefits to be gained from taking more seriously these services from nature became clearer (*7*, *8*). Conservation thinking moved away from species and toward ecosystems as a focus for integrated management, with the goal of providing sustainable benefits for people in the form of ecosystem goods and services (*9*)—"nature for people."

The work on the Millennium Ecosystem Assessment (*10*) was a key driver of the widespread adoption of this way of thinking about the natural environment. Many of the ideas were quickly adopted into conservation practice and environmental policy, although not without strong and persistent detractors (*11*). A wider acceptance of the notion that people are part of ecosystems emerged, and the tendency to treat people and nature as separate units in discourse and analysis was much reduced, although not completely eliminated.

The focus on nature's benefits and ecosystem services has been very influential.

However, in recent years the emphasis has moved from a potentially overly utilitarian perspective—managing nature to maximize the overall value of the human condition—to a more nuanced one that recognizes the two-way, dynamic relationships between people and nature (*12*). This "people and nature" thinking emphasizes the importance of cultural structures and institutions for developing sustainable and resilient interactions between human societies and the natural environment. It operates at a range of scales from global to local and has intellectual origins in resource economics, social science, and theoretical ecology (*12*, *13*).

These shifts in focus have occurred over a relatively short period, resulting in a pluralism of views and motives that now underpin conservation. Current conservation science and practice includes all four framings, sometimes in mutually supportive implementations, but increasingly the differences in underlying ideologies can cause frictions and tensions. For example, the North American conservation NGO The Nature Conservancy recently moved away from a focus on preservation, toward exploiting opportunities for conservation outcomes that businesses will invest in for their own benefit. This move has led to lively debates in the literature between some strongly held and divergent viewpoints (*14*).

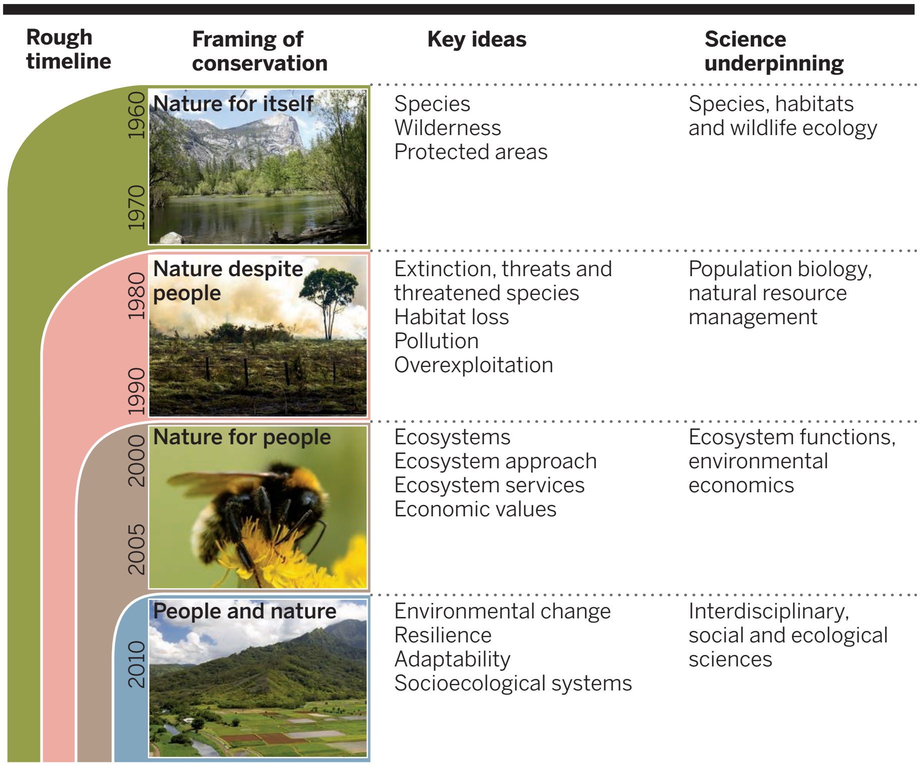
The multiple framings also have consequences for conservation science, because the scientific tools and techniques have not always kept pace with the concepts and objectives. There are many implications, as shown in the three activities highlighted here: measuring conservation success, designing ecosystem management, and assigning economic value to nature.

Under a "nature for itself" framing, conservation success can be measured with well-established metrics based, for example, on changes in the number of species listed in the IUCN Red List of Threatened Species or on the coverage of protected areas (*15*). In "nature despite people," these measures can be separated by threat type, and efforts made to report on species and areas that are not yet at risk but will soon be if pressures do not abate. But the ecosystem-based framings—"nature for people" and "people and nature"—require metrics that link nature to human well-being, explicitly identifying benefits needed and received by people (*16*). These metrics are very different from those of species and protected areas.

Measuring conservation success is surprisingly difficult when nature and people are considered together. For example, it is widely assumed that conserving the greatest numbers of wild species and intact habitats will be consistent with maximizing the ecosystem services that these areas provide to people. Yet, although most ecosystem functions are enhanced with more ecological and species diversity (*17*), adequate supplies of food or clean water for growing human populations have come from converting intact wilderness into land for agriculture, and canalizing or even draining many rivers and wetlands, thus reducing diversity. The ways in which nature contributes to human well-being are complex (*18*), and the commodification of nature, even with the best intentions, will have unintended and potentially deleterious outcomes for conservation (*11*).

The "people and nature" framing rejects the linear relationship characteristic of "nature for people," instead envisaging a much more multilayered and multidimensional relationship that is difficult to conceptualize, let alone to measure. Attempts to develop large-scale metrics for conservation thus result in a plethora of measures. The strategic plan for the UN Convention on Biological Diversity includes 20 targets and some 100 indicators that include addressing the underlying causes of biodiversity loss, reducing direct pressures on biodiversity, promoting sustainable use, safeguarding ecosystems, promoting species and genetic diversity, and enhancing the benefits to all people (*19*). Given the complex processes and interactions behind these indicators, contradictory messages will inevitably emerge, and unambiguous signals for policy are likely to be hard to find.

The different framings also have implications for ecosystem management. In the "people and nature" view, the science has moved fully away from a focus on species and protected areas and into a shared human-nature environment, where the form, function, adaptability, and resilience provided by nature are valued most highly. However, these terms mean something else in human societies than in ecology. In human societies, a simple behavior change or technological innovation can enhance adaptability and resilience, but for species, ecological communities, and ecosystems, adaptability and resilience result from biophysical processes that require the right components to be in place over scales of space and time that may not be amenable to human management. For example, reversing long-term declines in old-growth forests or recovering the full extent of marine trophic systems may take centuries, far beyond the normal time scale for environmental policies. In these natural systems, once lost, there are complex processes to be recovered that are often not well understood,



Changing views of nature and conservation. Over the past 50 years, the prevailing view of conservation has changed several times, resulting, for example, in a shift in emphasis from species to ecosystems. None of the framings has been eclipsed as new ones have emerged, resulting in multiple framings in use today.

Centre for Biodiversity and Environment Research, Department of Genetics, Evolution and Environment, University College London, London WC1E 6BT, UK. E-mail: g.mace@ucl.ac.uk

PHOTOS: THINKSTOCK/GETTYIMAGES

and a long-term commitment is required to restore or recover them.

A third implication of the multiple framings concerns the role of valuation. Most environmental decisions are made on the basis of economic arguments that consider costs and benefits, usually based on monetary values. By not having good metrics or by rejecting the idea of valuation in principle (*20*) because of its stark formulation in a "nature for people" framing, conservationists may cause nature to be excluded from such decisions. If the benefits provided by nature are assigned no value, they are treated as having no value, and current trends in the decline and deterioration of natural systems will continue.

The differences among the framings are not as stark as they appear. Despite its strong focus on humans, "people and nature" may actually be very similar to "nature for itself." Both framings can include people's hopes and desires about the environment that they wish to live in and leave to their descendants. "People and nature" has traction with other societal needs from the environment and connects better to policy because it has a broader focus. Yet there is a risk that any implementation of "people and nature" will lack the analytical foundations that made the earlier framings both deliverable and measurable.

Hopefully the many important features of "people and nature" will continue to be the focus for conservation over the coming decades. By sustaining a coherent and inclusive focus and by developing the relevant science, tools and decisions should emerge that can ensure a better future for people and nature. ■

REFERENCES

1. M. E. Soulé, *Bioscience* **35**, 727 (1985).
2. K. H. Redford *et al.*, *Conserv. Biol.* **27**, 437 (2013).
3. W. M. Adams, *Against Extinction: The Story of Conservation* (Earthscan, London, 2004).
4. J. Hutton *et al.*, *Forum Dev. Stud.* **32**, 341 (2005).
5. S. L. Pimm, G. J. Russell, J. L. Gittleman, T. M. Brooks, *Science* **269**, 347 (1995).
6. G. C. Daily, *Nature's Services: Societal Dependence on Natural Ecosystems* (Island, Washington, DC, 1997).
7. R. Costanza *et al.*, *Nature* **387**, 253 (1997).
8. A. Balmford *et al.*, *Science* **297**, 950 (2002).
9. R. K. Turner, G. C. Daily, *Environ. Resour. Econ.* **39**, 25 (2008).
10. Millennium Ecosystem Assessment, *Ecosystems and Human Well-Being: Synthesis* (World Resources Institute, Washington, DC, 2005).
11. K. H. Redford, W. M. Adams, *Conserv. Biol.* **23**, 785 (2009).
12. S. R. Carpenter *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **106**, 1305 (2009).
13. E. Ostrom, *Science* **325**, 419 (2009).
14. M. Soule, *Conserv. Biol.* **28**, 637 (2014).
15. S. H. M. Butchart *et al.*, *Science* **328**, 1164 (2010).
16. B. Fisher *et al.*, *Ecol. Appl.* **18**, 2050 (2008).
17. B. J. Cardinale *et al.*, *Nature* **486**, 59 (2012).
18. G. M. Mace *et al.*, *Trends Ecol. Evol.* **27**, 19 (2012).
19. *UN Convention on Biological Diversity: Strategic Plan for Biodiversity 2011–2020* (Montreal, 2010).
20. D. J. McCauley, *Nature* **443**, 27 (2006).

10.1126/science.1254704

IMMUNOLOGY

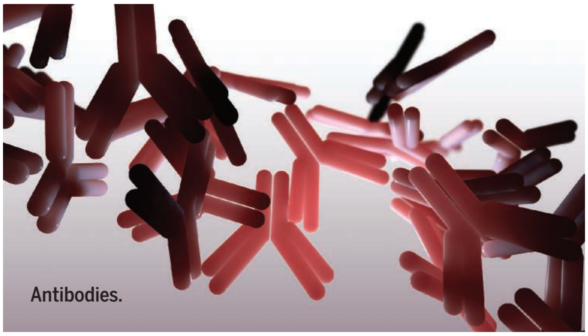
Autoimmunity by haploinsufficiency

Partial deficiency in the protein CTLA4 underlies severe autoimmune disease with incomplete penetrance

By Frédéric Rieux-Laucat[1,2] and Jean-Laurent Casanova[2,3,4,5]

Autoimmunity arises from self-reactive T and/or B lymphocytes, and underlies a wide range of conditions, from endocrine disorders to blood cytopenias. Genetic epidemiological studies have long suggested that many autoimmune conditions have an inherited component. Autoimmunity is often described as having polygenic or complex inheritance. However, both descriptions are too general to adequately describe the considerable heterogeneity in patients and conditions. Spectacular progress in the genetic dissection of autoimmunity has come from Mendelian studies of young patients with rare, distinctive conditions. Less has been learned from population-based, genome-wide association studies of more common, clinically less homogeneous conditions. The three best-characterized monogenic autoimmune disorders are autoimmune polyendocrinopathy syndrome type 1, X-linked immunoproliferative enteropathy, and autoimmune lymphoprolierative syndrome (*1*). On page 1623 of this issue, Kuehn *et al.* (*2*) add to this list. Patients with only one functional copy of the gene encoding cytotoxic T lymphocyte antigen 4 (CTLA4) suffer from severe autoimmunity. These heterozygous mutations result in a new phenotype, with infiltration of nonlymphoid organs, such as the intestine, lungs, and brain, by hyperactive T cells and B cells, along with more classic signs of autoimmunity.

CTLA4 is expressed on the surface of T cells. It competes with CD28 to bind B7 molecules expressed on antigen-presenting cells and its activation inhibits the proliferation of effector T cells and stimulates the suppressive functions of regulatory T cells (*3*). These effects help maintain tolerance to self-antigens, as shown by the severe autoimmunity in mice lacking both copies of the *Ctla4* gene (*4*). The physiological importance of human CTLA4 was recently highlighted by the success of treatments based on CTLA4-blocking antibodies in patients with some cancers (*5*). Kuehn *et al.* report that patients heterozygous for a loss-of-function *CTLA4* allele have a phenotype similar to that of mice homozygous for a loss-of-function *Ctla4* allele, whereas heterozygous mice have no detectable phenotype (*2*, *4*). Moreover, autosomal dominant *CTLA4* deficiency displayed incomplete penetrance, as some heterozygous individuals were asymptomatic. This illustrates the similarities and differences between the small number of inbred mouse strains studied in experimental conditions and the large numbers of outbred human kindreds observed in natural conditions (*6*).



Antibodies.

Since the identification of mutations in the *ADA* gene encoding adenine deaminase as causal for severe combined immunodeficiency in 1985 (*7*), the genetic basis of more than 250 inborn errors of immunity has been determined. Studies initially focused on the conditions underlying severe infections described in the 1950s, but then shifted to the analysis of inherited forms and combinations of infection, allergy, autoinflammation, and autoimmunity (*8*).

The field of primary immunodeficiencies has also diversified considerably in terms of the modes of inheritance. The autosomal dominant pattern of inheritance is common to only about 50 immunological conditions, most of which have been discovered in the past decade. Even more unusual is the underlying mechanism of haploinsufficiency, which was first reported in 1989 for a condition called angioedema (*9*). Haploinsuf-

ILLUSTRATION: V. ALTOUNIAN/*SCIENCE*

Whose conservation?
Georgina M. Mace
Science **345**, 1558 (2014);
DOI: 10.1126/science.1254704