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IN THIS ISSUE:

Some Themes in Intellectual Property and the Environment
Daniel Alexander

Biodiversity or 'Genetically Coded Functions': The Importance of Definitions
Joseph Vogel and Gordon Ingram

Intellectual Property in Genetic Sequences
Ian Walden

Plant Breeding and the UPOV
Noel Byrne

Indigenous Peoples, Biotechnology and Intellectual Property Rights
Farhana Yamin and Darrell Posey

Genetic Resources in the International Commons
Pat Roy Mooney

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Biodiversity or 'Genetically Coded Functions': The Importance of Definitions

Joseph Vogel and Gordon Ingram

■ Origin of the Term 'Biodiversity'

The year 1986 was a turning point in the mass extinction crisis not because it was finally contained, but because the crisis was finally publicised. In September 1986, a conference of over 1000 participants was held in Washington, D.C. under the auspices of the Smithsonian Institution and the National Academy of Sciences.[1] The organisers made clear that the 'National Forum on BioDiversity' was meant to be widely covered by the media, and it was. Not only did every major American newspaper cover the story, but journalists reserved the rainforest for feature stories in future issues. The word 'biodiversity' consequently entered the lexicon of millions of people.

After the term 'biodiversity' became widely used, a book called *Biodiversity* was published. It is a thick collection of articles written by expert conservationists who participated in the National Forum on BioDiversity.[2] The book was not, however, just a statement of the problem and a survey of the solutions. The collection had a distinct philosophical bent. Each article seemed to endorse government stewardship over the biota. Because any such stewardship would not likely have been well received under the policies of former US President Ronald Reagan and former British Prime Minister Margaret Thatcher, the contributors to *Biodiversity* chose another tactic. A heavy emphasis was placed on education. It can be summed up as 'Sensitise and Sacrifice'. Sensitise was the euphemism for inculcate; sacrifice, for tax. The thinking seemed to be that once the public became sensitised, the bitter pill of sacrifice would become palatable. So the book turned the word 'biodiversity' into a paradigm.

The emergence of biodiversity as a paradigm does not bode well for any solution rooted in 'selfish reasoning'.[3] Selfishness conflicts with stewardship. In exploring an alternative term to 'biodiversity' which lends itself to a paradigm of selfish reasoning, i.e. economic reasoning, one must ask 'what precisely is worth conserving?': A species? a race? an organism? a gene?

■ The Meaning of the Term 'Evolution'

There are many metaphors for evolution. Darwin saw it as a branching bush. All metaphors, however, constrict the phenomenon they attempt to illustrate, and the branching bush is no different. To the economist, evolution as a branching bush implies nothing for the cost/benefit analysis of development projects in the tropics. To find an alternative terminology, one must first understand how the present terminology of biology fails economists.

What is evolution? What is biodiversity? What is extinction? These are questions seldom asked, much less answered, in conservation literature. Scientists believe there is no need to construct

each argument from the ground up; some concepts are assumed common knowledge. However, there are small cracks in the foundations of biology that become fault lines in the complex discussion of conservation. The cracks are in the very terms evolution, biodiversity, and extinction. To appreciate the fault line we need to begin with the question least often asked: what is evolution?

An Accumulation of Genes

In the modern neo-Darwinian synthesis, evolution is defined as a change in gene frequencies. Over time, new genes appear through the process of mutation and existing genes disappear through the process of selection. There is no balance between the entry and exit of genes. On net, the slow accumulation of genes implies progress in the history of life. This progress does not occur continuously nor is it uni-directional: there have been periods of time when the total number of genes has decreased. The decrease may occur due to an ecological catastrophe or intense selective pressures of a few colonising species. Nevertheless, over geological time, i.e. hundreds of millions of years, ecosystems rebound from catastrophes and genetic diversity increases. Today we are witnessing one of those periods of time in which genetic diversity is decreasing at a rate probably unmatched since the age of dinosaurs 65 million years ago. The decrease today is almost wholly the consequence of one colonising species, ourselves.

To interpret evolution as increases or decreases in the total number of unique genes is to interpret evolution in terms more amenable to economics. Discussion in these terms would be a step in the right direction. However, there is no need to stop at the level of the gene. From biochemistry we know that genes are a sequence of purine and pyrimidine bases bonded on a backbone of phosphate sugar molecules. As a sequence, genes can theoretically be assigned probabilities of occurrence. These probabilities can in turn be quantified as information by the Boltzmann equation of thermodynamics or the equivalent Shannon-Weaver equation of information theory.[4]

Genetically Coded Functions

To reduce the meaning of evolution to changes in information is to take the high road in scientific reduction. It is also beyond the state of the art. So this line of argument would seem to be a detour from the practical economics of conservation. Surprisingly, it is not. Evolution is about the flow and accumulation of information. Conservation is about the retention of information. However, conservation is not concerned with the retention of information per se; it is concerned with the functions coded in that retained information. Retention is desirable because information codes for functions. Therefore, the term 'genetically coded function' (GCF) answers the question 'what precisely is worth conserving?' Unfortunately, 'biodiversity' is not synonymous with GCFs.

■ The Meaning of the Term 'Biodiversity'

The word 'biodiversity' has passed the test of popularity with the general public. It has gained currency worldwide and will soon find its way into dictionaries. However, the word 'biodiversity' has yet to be tested for meaningfulness. In science, that test is formal logic, which dictates that definitions be broad enough to capture the essential attributes of the thing defined yet narrow enough to discriminate it from other things.[5] One can easily show that by the criteria of logic, i.e. breadth and discrimination, 'biodiversity' must be rejected.

With respect to breadth, most people misinterpret 'biodiversity' as species diversity. This misrepresentation is referred to by some of the contributors to *Biodiversity*. G. Carleton Ray put it plainly: 'It surely is not merely species variety, as some of the public may be led to believe'.[6] If 'biodiversity' is left undefined, then people will assign their own meaning to it. Usually that meaning will be species variety. As such, 'biodiversity' would exclude races, i.e. subspecies. However, there is a great deal of wealth in races, so we might want to include them. But why stop at races? If they are to be included, why not individuals? There can also be a great deal of value in individuals. For example, the tissue taken from the recovered leukaemia patient, John Moore, is worth billions of dollars (see box below). But if we include individuals then 'biodiversity' means the same thing as 'biota' and there is no need for a new word.

With respect to discrimination, 'biodiversity' provides no mechanism to discriminate between the twin attributes of the biota essential for identifying the need for their conservation: function and uniqueness. Each is necessary and neither is sufficient. For example, every reader of this article is a unique constellation of genes, and as such is an endangered piece of the biota. But one's tissue

Functions at all levels
Rethinking taxonomy

Family (*Formicidae*)
Of the known 8,800 ant species in the family *Formicidae*, all provide the GCFs of recycling natural wastes. Inasmuch as agriculture would be impossible without ants, their commercial value is incalculable. It is no hyperbole that the survival of man depends on the GCFs of ants (Holldobler & Wilson, 1990).

Genus (*Ursus*)
Six of the eight bear species in the genus *Ursus* are being poached. Bear paws fetch as much as US$ 800 to Korean and Japanese diners; gall bladders command US$ 50/gram throughout Asia (Mills, 1991). Both paw and bladder can be considered GCFs.

Species (*Zea diploperennis*)
In 1979 a wild species of maize, *Zea diploperennis*, was discovered in Mexico (Iltis et al., 1979, Benz et al., 1990). Unlike domesticated maize, the wild species is perennial and highly viral resistant. Two economists estimate the value of perennial characteristics, just one of the GCFs, at US$ 6.82 billion (Hanneman & Fisher, 1985).

Subspecies (*Solanum melongena*, 418 landraces)
Specimens of the 418 landraces of *Solanum melongena* are stored at the Southern Regional Plant Introduction Station of the US Department of Agriculture in Griffin, Georgia. Some contain genes that code for resistance to *Verticillium* wilt and *Lygus lineolaris* (Bettencourt & Konopka, 1990). Worldwide consumers eat over US$ 100 billion in potatoes.

Individuals (John Moore)
John Moore is a recovered leukaemia patient who had an interesting spleen. The diseased cells of the spleen were harvested and grown in the laboratory. The resultant cell line was patented as 'MO' and has multiple uses for combating immune deficiencies. The market value is estimated at US$ 3 billion (Hamilton, 1990).

should not be preserved simply because she or he is unique. Uniqueness must be coupled with function, as was the case with John Moore's spleen.

Unlike the word 'biodiversity' the term 'GCF' discriminates by function among the attributes of the biota to identify those needing conservation. That discrimination is by function irrespective of the taxon in which the function occurs (see text box above). One sees that one of the most valuable GCFs for human society is the waste recycling task of ants. This GCF occurs at the taxon of the family with its some 8,800 species. Even though waste recycling is priceless, no one ant species should be preserved because of it; there are 8,799 other species providing, to some degree, the same GCF. Only if we exterminate ant species by the thousands will function couple with uniqueness and warrant the conservation of ant species. The ant argument is less true for the bears. The paws and bladders of the bears are valuable GCFs throughout Asia. But like waste recycling among the genera of the family *Formicidae*, Asians will still enjoy ursine delicacies, to some degree, as long as every one of the eight species of the genus *Ursus* is not exterminated.

Valuing Unique GCFs

As we rethink taxonomy, the same logic holds. The reason for protection at the species level is the uniqueness of a GCF at that level. The example in the figure is maize. Over the past century, there have been exhaustive searches for wild species of maize and almost always the searches have been to no avail. So it is fairly safe to say that the GCFs of *Zea diploperennis* are unique at the level of species.

Fortunately, the uncertainty regarding the distribution of GCFs is not absolute. We do know that there is a correspondence between GCFs and the taxon in which they are found. For example, one can say that the likelihood of a GCF unique to an individual is slim (albeit there will be some individuals like John Moore). It seems reasonable *a priori* that no single organism among a species need be conserved. Or in the rhetoric of formal economics, the expected gain from preservation is less than the cost. However, if one discovers that genes code for function at the level of the individual, then uncertainty is removed and the genes should be

preserved. *A fortiori* the gain outstrips the cost. This was the case with John Moore.

Prioritizing Conservation

As a general rule, GCFs at the level of the individual are most likely shared by other individuals of the same race, so they will take lowest priority for conservation. Individuals are substitutable. Much higher priority is given to protection of individuals from an endangered race. On average, these individuals are less substitutable with individuals from different races. Even higher priority is given to individuals from an endangered species. On average, these individuals are much less substitutable with individuals from different species but the same genus. And still higher priority is given to individuals from an endangered species which has no other species in its genus. The highest priority should be given to individuals from an endangered species which is the last of its genus and the last of its family.

Extinction by Degree

Rephrasing evolution and biodiversity in terms of GCFs has direct implications for conservation policy. If not yet clear, it will become obvious as we answer the last of the three questions posed earlier: what is extinction? In the terminology of biology, extinction is abrupt: it is the loss of species. But in the alternative terminology presented here, extinction is a matter of degree; it is the loss of GCFs that can occur at any taxon – from the individual down to the order. On an expectation basis, the loss of an individual which is the last specimen of its order is the multiple loss of GCFs – a tragic winnowing of options for economic and social development. However, on an expectation basis, the loss of an individual within a healthy race is a loss of options so negligible that it can be ignored.

■ The Purpose of the Term 'GCF'

Although the term 'GCF' can help the economist rank the conservation value of genetic information from ants to human tissue, the term still cannot assist her or him, in any meaningful way, in quantifying those benefits. David Ehrenfeld expresses this point in *Biodiversity*:

> There are two practical problems with assigning value to biological diversity. The first is a problem for economists: it is not possible to figure out the true economic value of any piece of biological diversity, let alone the value of diversity in the aggregate. We do not know enough about any gene, species, or ecosystem to be able to calculate its ecological and economic worth in the larger scheme of things . . . I cannot help thinking that when we finish assigning values to biological diversity, we will find that we won't have very much biological diversity left.[7]

Market Value for GCFs

The purpose of introducing the term 'GCF' is not to assist cost/benefit analysis. The purpose is to obviate the need for cost/benefit analysis. By thinking in terms of GCFs, the product of evolution, i.e. genetic information, becomes a commodity. By creating intellectual property rights over that commodity (e.g. patents, copyrights, trademarks, and trade secrets), the market will bid up the value of habitats on the likelihood of GCFs. The complexities have been fleshed out in the forthcoming book *Genes for Sale: Privatisation as a Conservation Policy*.[8] The book anchors the concept of genes as intellectual property[9] in the efficiency criterion of property rights analysis:[10] one who controls an asset should derive benefits from that asset. In the case of in situ conservation[11] one who controls genetic information should receive some monetary benefit from the functions coded in that information. Today, under international law, such information is considered 'the common heritage of mankind'. As such, one receives no benefit.

■ Conclusion

Perhaps unlike the phenomenon it describes, the word 'biodiversity' will become a permanent part of our vocabulary. It has ease of expression and is connoted with the laudable ethics of the paradigm of biodiversity. Indeed it has become a rallying cry to sensitise a materialist society to undertake sacrifice for future generations. Because both sensitisation and sacrifice are desperately needed, 'biodiversity' should remain in the non-scientific lexicon despite the logical inconsistencies of its various definitions.

However, in the marketplace of science, the term's illogicality has not escaped notice. A major scientific symposium has already been held to sort out its many meanings and eliminate the inconsistencies.[12] The alternative terms suggested here, 'genetically coded functions' of 'natural genetic information', meet the criteria of breadth and discrimination as dictated by formal logic in the crafting of new definitions. From these alternatives, a conservation policy emerges rooted in selfish-

ness rather than sacrifice. That policy turns on the creation of intellectual property rights over natural genetic information.

As a final note, criticism of the word 'biodiversity' should in no way be interpreted as a criticism of the conservationists who coined and promoted it. Nor is there any regret that this illogical term entered the vernacular. Had the organisers of the National Forum on BioDiversity merely deliberated over definitions in 1986 much of the biota would now be forever lost.

Notes

1. Tangley, L., 'Biology Diversity Goes Public'; 36 (No. 11) *Bioscience* 708–715 (1986).
2. Wilson, E.O. (ed.), *Biodiversity*, (Washington, D.C., National Academy Press, 1988).
3. Just four years earlier, Wilson had advocated a conservation ethic based on 'selfish reasoning'. Wilson, E.O., *Biophilia*, (Cambridge, Massachusetts, Harvard University Press, 1984), pp. 131–132.
4. Shannon, C.E. and Weaver, W., *The Mathematical Theory of Communication*, (Chicago, Illinois, The University of Illinois Press, 1949).
5. Copi, I.M., *Introduction to Logic*, (London, The MacMillan, 1966).
6. Ray, C., 'Ecological Diversity in Coastal Zones and Oceans' in Wilson, E.O. (ed.), *Biodiversity*, see n. 2 above.
7. Ehrenfeld, D., 'Why put a value on biodiversity?'; in Wilson, E.O., (ed.), *Biodiversity*, see n. 2 above.
8. Vogel, J.H., *Genes for Sale: Privatisation as a Conservation Policy*, (New York, Oxford University Press, to be published 1994).
9. Kloppenburg, J., *First the Seed: The Political Economy of Plant Biotechnology*, (Cambridge, U.K., Cambridge University Press, 1988) and Juma, C., *The Gene Hunters: Biotechnology and the Scramble for Seeds*, (Princeton, New Jersey, Princeton University Press, 1988).
10. Barxel, Y., *The Economic Analysis of Property Rights*, (New York, Cambridge University Press, 1989).
11. *Strategies for the Establishment of a Network of in situ Conservation Areas*, Food and Agriculture Organization of the United Nations, Commission on Plant Genetic Resources, Fourth Session; CPGR/91/6 (1991) and Ingram, G.B., 'The need for knowledge from indigenous communities in planning networks of protected habitat for the conservation of biological diversity: Three island settings', in Plotkin, M.J., (ed.), *Ethnobiology: Implications and Applications*. Proceedings of the First International Congress on Ethnobiology, Part 2 87–105 (1988).
12. Gee, H., 'The Objective Case for Conservation', 357:639 *Nature* (1992).

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