The Organic Codes

The genetic code appeared on Earth with the first cells. The codes of cultural evolution arrived almost 4 billion years later. These are the only codes that are recognised by modern biology. In this book, however, Marcello Barbieri explains that there are many more organic codes in nature, and their appearance not only took place throughout the history of life but marked the major steps of that history. A code establishes a correspondence between two independent "worlds", and the codemaker is a third party between those "worlds". Therefore the cell can be thought of as a trinity of genotype, phenotype and ribotype. The ancestral ribotypes were the agents which gave rise to the first cells.

The book goes on to explain how organic codes and organic memories can be used to shed new light on the problems biologists encounter in cell signalling, epigenesis and embryonic development. A mathematical model is presented to show how embryos can increase their own complexity by the use of a code and a memory.

This fascinating book will be of interest to all biologists and anyone with an interest in the origins and the evolution of life on Earth.

MARCELLO BARBIERI has conducted research on embryonic development and ribosome crystallisation at the Medical Research Council in Cambridge, UK, the National Institutes of Health in Bethesda, USA, and the Max-Planck-Institut für Molekulare Genetik in Berlin, Germany. He has published books on embryology and evolution, and has taught biophysics, molecular embryology and theoretical biology respectively at the Universities of Bologna, Sassari and Turin, Italy. Since 1992 he has taught embryology and conducted research in theoretical biology at the University of Ferrara, Italy.

THE ORGANIC CODES

An introduction to semantic biology

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FOREWORD

Most scientific publications deal with problems that can be explained in a straightforward manner and with solutions that can be evaluated as a matter of routine. But scientific progress often occurs when somebody tries to reformulate the problem, or to suggest a different kind of solution. When that happens, it may be necessary to dwell as much upon the questions as upon the answers, and to show how a novel approach might give further significant results.

Barbieri finds that biology has been able to deal with information and with structure, but not with the connection between them. Something has been left out, and that is meaning. Semantics is the branch of logic that deals with meaning: hence the term "semantic biology". Meaning is a difficult concept to analyse, even though we find it in everything we read or listen to, including imaginative literature. To understand a poem one needs all sorts of background information. Poetry is rich in literary allusions, so just knowing the words will not do. Meaning is largely a matter of context, and that makes it hard to pin down.

The contextuality of meaning may be called a "principle", for it is neither a brute fact nor a law of nature. But exactly what is meant by a principle is hard to specify. We can give some familiar examples of course. In ecology there is the well-known "competitive exclusion principle", which explains why organisms occupying exactly the same niche cannot coexist for more than a brief period of time. In logic we all use, whether we know it or not, the "principle of contradiction", which states that two propositions that really contradict each other cannot both be true. And since, by implication, at least one of them must be false, we justify the kind of hypothetico-deductive scientific

method that Barbieri (an admirer of Popper) endorses. Principles are very important in science, more important than may seem obvious. Usually we adopt them implicitly, without giving them much thought. Principles are perhaps the most important components of Barbieri's theoretical, or perhaps better, metatheoretical, system. One might even say that such principles are what the book is really all about.

Barbieri enunciates four general principles, all of which relate to the problems of development. He begins by considering epigenesis, and redefines it as the property of a system to increase its own complexity. He goes so far as to make the capacity for attaining such convergent complexity both a fundamental principle and a defining property of life itself. One might question that, but his definition is at least as good as any of the ones that are quoted in the Appendix. The second principle tells us that achieving such convergent complexity amounts to reconstructing a structure from incomplete information. That in turn provides a new definition of "epigenesis". Then we get a third principle, according to which organic epigenesis requires organic memories. Here "memory" is a technical term indicating that there has to be some repository of information. And as a final principle, such epigenesis requires organic codes. Indeed codes and memories exist only because they are necessary for producing epigenetic systems.

Barbieri is a scientist, not a philosopher. He justifies his ideas on the basis of their ability to make sense out of the material universe. This he accomplishes by means of four "models", as he calls them. Why "models" rather than "theories"? Evidently because they serve to illustrate the principles. Of course it really matters whether the particular interpretations are correct. But the point of the book could be made just as well if the hypotheses being discussed were modified in some respects. The more basic message is not the examples as such, but rather the kind of theory that might be expected to emerge out of a semantic approach to biology. Let us have a brief look at these models from that perspective.

First, Barbieri presents a theory about the origin of life. Extant organisms possess both genotype, in the form of DNA molecules, and phenotype, in the form of proteins, cells, and other products of epigenesis. Previous scenarios treated proteins or DNA as coming

first. Both of these alternatives ran into difficulties because the one cannot exist without the other. For that very reason there must have been something additional to genotype and phenotype, which he calls the ribotype. It is RNA that bridges the gap between genotype and phenotype, and it does so by endowing the system with meaning. Cells contain all three. Those who want to define life as either as genes or as gene products will find no comfort in this view of it.

The second model illustrates the point that more than one kind of memory can be responsible for the reconstruction from incomplete information that takes place during the (epigenetic) formation of an organism. Barbieri proposes that two kinds of memory are in fact responsible for the development of multicellular animals – one for the earlier stages, the other for the later ones. He shows how the existence of these two kinds of memory might account for the pattern of macroevolution, notably the Cambrian explosion.

The third model is an application of similar considerations to mental development, especially with respect to language. One kind of organic memory accounts for the acquisition of the capacities that appear early in the ontogeny of language, then a second takes over. Again, codes are absolutely indispensable, and the emergence of new ones has been a key innovation in the history of both life and mind.

And finally, the semantic theory applies to culture as well. Cultures are like species, insofar as they are supraorganismal wholes, and real concrete things. There are codes in both life and culture, and both life and culture have evolved through natural selection and natural conventions. In culture we find something analogous to genotypes, though they depend upon an extrasomatic memory. We also find something analogous to phenotypes, such as artifacts. But, if we are to extend Barbieri's basic vision of organised beings to culture, there is also something more. Consider a village with its buildings. Is it blueprints that explain the existence of buildings, or buildings that explain the existence of blueprints? Barbieri suggests that we might ask more edifying questions.

Barbieri's most ambitious claim is that life evolves through natural conventions as well as natural selection. The importance of such conventions as major evolutionary innovations becomes increasingly

obvious as he discusses one example after another. Yet let us not get carried away. There is nothing here that portends the fall of Darwinism or its replacement by an alternative paradigm. The book is, after all, concerned with the fundamental principles of development, and with how they relate to the grand picture of evolution. It belongs to the mainstream of biological thought, and finds its proper place among the works of Karl Ernst von Baer, Charles Darwin, and August Weismann.

October 2001 *Michael T. Ghiselin*

DEDICATION

To *Karl Popper*
René Thom
Heinz-Günter Wittmann
and Elmar Zeitler

This book is an extension of *The Semantic Theory of Evolution* (1985) and is dedicated, with affection, to the four men who encouraged my long journey toward that view of life.

Karl Popper has been my most important spiritual referee, and his pronouncement, in a private letter, that the semantic theory of life is *"revolutionary"* gave me the strength to persevere.

René Thom has been the *deus ex machina* who actually engineered the publication of *The Semantic Theory* and gave it an impressive *imprimatur* by writing its preface.

Heinz-Günther Wittmann and **Elmar Zeitler** allowed me to perform the experimental research which led me first to the concept of *ribotype* and then to the idea of *evolution by natural conventions.*

It is from these good men that I learned what it takes to devote one's life to an idea, even if all seems to be destined to another generation of students. Which is what really matters, in the end, because a new idea is all the more beautiful the greater is its power to convince one that it really belongs to the future.

March 2002 *Marcello Barbieri*

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July 2002 *Marcello Barbieri*