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## How Symbolic and Iconic Languages Bridge the Two Worlds of the Chemist

### *A Case Study from Contemporary Bioorganic Chemistry*

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Chemists move habitually and with credible success—if sometimes unreflectively—between two worlds. One is the laboratory, with its macroscopic powders, crystals, solutions, and intractable sludge, as well as the things that are smelly or odorless, toxic or beneficial, pure or impure, colored, or white. The other is the invisible world of molecules, each with its characteristic composition and structure, its internal dynamics and its ways of reacting with the other molecules around it. Perhaps because they are so used to it, chemists rarely explain how they are able to hold two seemingly disparate worlds together in thought and practice. And contemporary philosophy of science has had little to say about how chemists are able to pose and solve problems, and in particular, to posit and construct molecules, while simultaneously entertaining two apparently incompatible strata of reality. Yet chemistry continues to generate highly reliable knowledge, and indeed to add to the furniture of the universe, with a registry of over ten million well-characterized new compounds.

The philosophy of science has long been dominated by logical positivism, and the assumptions attendant on its use of predicate logic to examine science, as well as its choice of physics as the archetype of a science. Positivism thus tends to think of science in terms of an axiomatized theory describing an already given reality and cast in a uniform symbolic language, the language of predicate logic. (See especially the locus classicus of this position, Carnap, 1937.)

We here wish to question certain positivist assumptions about scientific rationality, based on an alternative view brought into focus by the reflective examination of a case study drawn from contemporary chemistry. Our reflections owe something to Leibniz (1686, 1695, 1714), Husserl (1922), Kuhn (1970), and Polanyi (1960, 1966), and draw on the earlier writings of both of us—Hoffmann (1995; Hoffmann & Laszlo, 1991) and Grosholz (1991; Grosholz & Yakira, 1998). We will offer a nonreductionist account of methods of analysis and synthesis in chemistry. In our view, reality is allowed to include different kinds of things existing in different kinds of ways; levels held in intelligible relation by both theory and experiment, and couched in a multiplicity of languages, both symbolic and iconic.

We argue that there is no single correct analysis of the complex entities of chemistry expressed in a single adequate language, as various reductionist scripts require; and yet the multiplicity and multivocality of the sciences, and their complex "horizontal" interrelations, do not preclude but in many ways enhance their reasonableness and success. Nor is this view at odds with our realism; we want to distinguish ourselves quite strongly from philosophers engaged in the social construction of reality (see, e.g., Pickering, 1992; Shapin, 1992; Fuller, 1994; for a balanced analysis of the problem, see Labinger, 1995). We understand the reality whose independence we honor as requiring scientific methods that are not univocal and reductionist precisely because reality is multifarious, surprising, and infinitely rich.

#### Formulating the Problem

The article drawn from the current literature in chemistry that we shall consider is "A Calixarene with Four Peptide Loops: An Antibody Mimic for Recognition of Protein Surfaces," authored by Yoshitomo Hamuro, with Andrew Hamilton, Mercedes Crego Salama, Hyung Soon Park, and published in December 1997 in the international journal *Angewandte Chemie* (Hamuro et al., 1997). We will refer to this article as Hamuro et al.) The subfield of the article could be called bioorganic chemistry. One way to look at biology is to examine its underlying chemistry, in a well-developed program that is both one of the most successful intellectual achievements of the twentieth-century, and a locus of dispute for biologists. For many years, organic chemists had let molecular and biochemistry "get away" from chemistry; recently, there has been a definite movement to break down the imagined fences and reintegrate modern organic chemistry and biology. The article we examine is part of such an enterprise.

We have learned something about the structure of the large, enigmatic, selectively potent molecules of biology. But describing their structure and measuring their functions do not really answer the question of how or why these molecules act as they do. Here, organic chemistry can play an important role by constructing and studying molecules smaller than the biological ones, but which model or mimic the activities of the speedy molecular behemoths of the biological world.

The article opens by stating one such problem of mimicry, important to medical science and any person who has ever caught a cold. The human immune system has flexible molecules called antibodies, proteins of some complexity that recognize a wide variety of molecules including other proteins.

The design of synthetic hosts that can recognize protein surfaces and disrupt biologically important protein-protein interactions remains a major unsolved problem in bioorganic chemistry. In contrast, the immune system offers numerous antibodies that show high sequence and structural selectivity in binding to a wide range of protein surfaces. (Hamuro et al., 1997, p. 2680)

The problem is thus to mimic the structure and action of an antibody, but antibodies in general are very large and complicated. Hamuro et al. ask the question, Can we assemble a molecule with some of the structural features of an antibody, simplified

