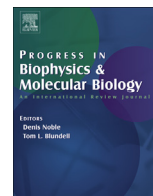


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Self-reference, biologic and the structure of reproduction



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ABSTRACT

In this paper we explore the boundary shared by biology and formal systems.

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1. Introduction

This paper concentrates on relationships of formal systems with biology. In particular, this is a study of different forms and formalisms for replication. The paper is based on previous papers by the author (Kauffman and Kauffman, 1994; Kauffman, 2002a; Kauffman et al., 2004). We have freely used texts of those papers where the formulations are of use, and we have extended the concepts and discussions herein considerably beyond the earlier work. We concentrate here on formal systems not only for the sake of showing how there is a fundamental mathematical structure to biology, but also to consider and reconsider philosophical and phenomenological points of view in relation to natural science and mathematics. The relationship with phenomenology (Heidigger, 1927/1962; Merleau-Ponty, 1945; Husserl, 1936/1970; Hide, 1977; Badiou, 2007; Rosen, 1994; Marchal et al., 1992; Ryan, 1974; Tarnas, 1991) comes about in the questions that arise about the nature of the observer in relation to the observed that arise in philosophy, but also in science in the very act of determining the context and models upon which it shall be based. Our original point of departure was cybernetic epistemology (von Foerster, 2003; Varela, 1979; Spencer-Brown, 1969; Maturana et al., 1974; Kauffman and Grossing, 2012; Kauffman, July 2009; Kauffman, 2005, 2012a, 2004,

1985, 1987a,b,c, 2002a; Kauffman et al., 2004; Kauffman and Kauffman, 1994) and it turns out that cybernetic epistemology has much to say about the relation of the self to structures that may harbor a self. It has much to say about the interlacement of selves and organisms. This paper can be regarded as an initial exploration of this theme of mathematics, formalities, selves and organisms – presented primarily from the point of view of cybernetic epistemology, but with the intent that these points of view should be of interest to phenomenologists. We hope to generate fruitful interdisciplinary discussion in this way.

Our point of view is structural. It is not intended to be reductionistic. There is a distinct difference between building up structures in terms of principles and imagining that models of the world are constructed from some sort of building-bricks. The author wishes to make this point as early as possible because in mathematics one naturally generates hierarchies, but that does not make the mathematician a reductionist. We think of geometry as the consequences of certain axioms for the purpose of organizing our knowledge, not to insist that these axioms are in any way other than logically prior to the theorems of the system. Just so, we look for fundamental patterns from which certain complexes of phenomena and ideas can be organized. This does not entail any assumption about “the world” or how the world may be built from parts. Such assumptions are, for this author, useful only as partial forms of explanation.

We examine the schema behind the reproduction of DNA. As all

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observers of science know, the pattern of the DNA reproduction is very simple. The DNA molecule consists of two interwound strands, the Watson Strand (W) and the Crick Strand (C). The two strands are bonded to each other via a backbone of base-pairings and these bonds can be broken by certain enzymes present in the cell. In reproduction of DNA the bonds between the two strands are broken and the two strands then acquire the needed complementary base molecules from the cellular environment to reconstitute each a separate copy of the DNA. At this level the situation can be described by a symbolism like this.

$$DNA = \langle W|C \rangle \rightarrow \langle W|E|C \rangle \rightarrow \langle W|C \rangle \langle W|C \rangle = DNA \ DNA.$$

Here *E* stands for the environment of the cell. The first arrow denotes the separation of the DNA into the two strands. The second arrow denotes the action between the bare strands and the environment that leads to the production of the two DNA molecules.

Much is left out of this schema, not the least of which is the ignoring of the word *interwound*. Indeed the DNA molecule is a tight spiral winding of its two interlocked strands and so the new DNA's would be linked around one another if it were not for the work of other enzymes that mysteriously manage to unlink the new DNA's in time for cell division to occur. We discuss this briefly in Section 2 of the present paper. Nevertheless, this is the large scale description of the replication of DNA that is fundamental to the division of cells and to the continuance of living organisms.

The abstract structure of this DNA replication schema makes it a pivot to other models and other patterns. To see this most clearly, suppose we have *O* and *O** algebraic entities such that $O^*O = 1$ where 1 denotes an algebraic identity such that $1A = A1 = A$ for any other algebraic entity *A*. Assume that juxtaposition (multiplication) of algebra elements is associative. Let $P = OO^*$. Then

$$P = OO^* = O1O^* = OO^*OO^* = PP.$$

Thus we have a general algebraic form for the self-replication described above. Note that in algebra we do not choose a direction of change. Thus we have $1 = O^*O$. In the replication scenario this is replaced by a process arrow.

$$1 \rightarrow O^*O$$

generalizing the arrow

$$E \rightarrow |C \rangle \langle W|$$

where the environment *E* can supply Crick and Watson strands (via the base pairing) to the opened DNA. Thus algebra provides a condensed formalism for discussing self-replication. See Section 9.1 of the present paper for examples (via the Temperley-Lieb algebra) that follow these algebraic patterns.

In the DNA formalism above, we can reverse the roles of *C* and *W* and use instead of $DNA = \langle W|C \rangle = \langle W||C \rangle$,

$$DNA = |C \rangle \langle W|$$

and the dual assumption that the environment *E* is like an identity element in context where $E = \langle W|C \rangle$. Then we would have

$$DNA = |C \rangle \langle W| \rightarrow |C \rangle E \langle W| \rightarrow |C \rangle \langle W|C \rangle \langle W| \\ = |C \rangle \langle W||C \rangle \langle W| = DNA \ DNA.$$

We can choose either pattern as is convenient. The reader will find that we use both of these formalisms in the paper.

We now invite the reader to examine the form of the science involved in this well-known description. We speak of the DNA

molecules as though we could see them directly in the phenomenology of our ordinary sight. Some science does involve the direct extension of sight as the experience of looking through a telescope or a light microscope. But in the case of the DNA one proceeds by logical consistency and the indirect but vivid images via the electron microscope and the patterns of gel electrophoresis. In the case of electron microscope images there is every reason to assume (that is, it appears consistent to assume) that the objects shown can be taken to be analogous to the macroscopic objects of our perception. This means that one has the possibility of observing “directly” that DNA molecules can be knotted. I do not say that one can observe directly the coiling of the Watson and the Crick strands, but the full DNA can be observed as though it were a long rope. This rope can be seen to be coiled and knotted in electron micrographs such as the one shown here in Fig. 3. Even this “showing” requires a difficult technique beyond the usual techniques of the electron microscope. The DNA was coated with protein by the experimenters so that it became a chain of larger and more robust diameter. Then the electron microscope revealed the patterns of knotting in an apparent projection of the coated DNA from three dimensional space to the two dimensional space of the image.

Scientists strive to make this information consistent and repeatable. This means that whether or not a scientist believes that the microworld of the DNA is just like our world of objects, he can nevertheless assent to the facts shown by the observations that if we assume object behavior similar to our realm for the DNA realm, then these instruments reveal knotting and other forms of geometric patterning. A phenomenologist can criticize the lack of direct perception in this form of science, but in fact it is remarkable how consistent is the hypothesis of indirect perception on which the work is based. Most working biologists would not question the basis of their biological perceptions direct or indirect. But they would instantly question the bases of the experiments and their consistency. For those who are philosophically inclined there is a lesson to be learned here about experimental phenomenology (Hide, 1977). One wants to know how far a world-view can be extended before it disintegrates. A phenomenological theme is illustrated here in that what we see in the electron micrograph is deeply shaped by the complex story of biological experiment that surrounds it. This is a deep example of the same type shown in more elementary circumstances by Hide (1977) in discussion the Necker Cube and multiple interpretations associated with it and dependent on stories related to it. In the body of the paper, I shall make other phenomenological remarks about the various aspects and themes of the paper.

Along with these forays into experimentation, there are also analogous forays into the limits of logic. Here we meet the replication schema again. Replication in logic is intimately related to self-reference and to formalisms that, if not properly interpreted, can

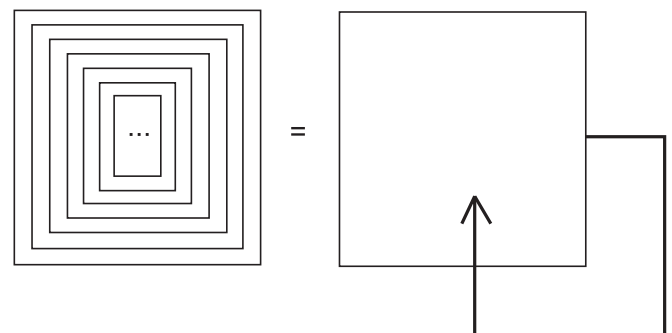


Fig. 1. An infinite fixed point.

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