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DISCUSSION NOTE

Commentary on "The transmission sense of information" by Carl T. Bergstrom and Martin Rosvall

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Debate about the nature of evolutionary and developmental information has, until now, reliably foundered between the Scylla of meaning and the Charybdis of causation. The idea that the genome carries semantic information promises an attractive conceptual analysis of talk about genes for eye colour or for breast cancer. This analysis has proved elusive. Genes are not invested with meaning in the way that words and symbols are invested with meaning. Even if a single gene produced my blue eyes, that eye colour would not be a cause of me coming to have the gene concerned in the way that, for example, mountains are a cause of us coming to have a word that represents mountains. No amount of genetic material represents fully formed morphological or physiological traits in the way that "mountain", represents mountains. However, genes are reliable causes of traits, or at least reliable parts of causes of traits. Mathematical information theory, interpreted as the statistical analysis of correlation, applies easily to evolution and development. Indeed, it applies too easily. Fitness enhancing traits and the developmental cascades that produce them are correlated, not just with genetic makeup, but with all manner of cytological and environmental factors.

A persistent theme in debates about information in development and evolution has been a sort of *reductio ad absurdum*:

> Clearly the genome plays a special informational role in evolution and development.
> Therefore any account of biological information which implies that it does not must be false.

It is this application of conceptual analysis that has produced the choppy waters between information and meaning. Peter Godfrey-Smith and others argue that genes carry semantic information about the proteins for which they code, but they do not

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carry semantic information about the characteristics of the organisms whose developments they underpin. So, understood semantically, the genome does not play enough of an informational role in evolution and development. Conversely, Godfrey-Smith (2008) along with Griffiths and Gray (1994) and Oyama (1985) argue that genes carry causal information about organisms but in just the same way as such information is carried by food sources and nest sites and parasites, indeed anything that regularly influences the development of individuals and populations. Hence, on this account the informational role played by the genome is real but insufficiently special.

Bergstrom and Rosvall's proposed transmission sense of information is a genuine alternative to both the above accounts. It is not semantic because it is agnostic about the content of signals from genome to developing organism or to future generations. It is not causal information (in the sense described above) because it is not a "shallow" application of mere correlation between source and receiver. This new account exploits the features of informational systems designed or evolved to maximise the transmission of information. The genome is special, on this account, because mechanisms such as data compression, error correction and noise reduction maximise its efficiency as a transmitter and hence, make it a particularly powerful and reliable source of biological information. Unlike genes, on this account, many non-genetic developmental resources are little better than sources of gossip about biological form and function.

Bergstrom and Rosvall's account is not unique in claiming that genes are super-efficient mechanisms for the transmission of biological information. A contrasting account is provided in Kim Sterelny's "Hoyle's World" thought experiment in his "Niche Construction, Developmental Systems, and the Extended Replicator" (2001), but Bergstrom and Rosvall are distinctive in giving an account that rests solely on engineering considerations that flow directly from Shannon's (1948) Mathematical Information Theory.

So why should we adopt Bergstrom and Rosvall's analysis of information? One answer might be that it makes good sense of the way that biologists talk about information. This conceptual analysis justification appears in a number of places in Martin and Rosvall's paper, but we should be suspicious of it. Many of those engaged in debates about biological information (e.g. Sarkar 2005) point out that biological uses of "information" are often either incoherent or simply unanalysed. Famously, the cognitive ethology of the 1950 and 1960s rested heavily on the notion of genetic information even though central figures in that literature (such as Konrad Lorenz) provided no explanation as to the nature of such information.

Perhaps a better justification for Martin and Rosvall's account is that it is a coherent, available and distinctive analysis that addresses a lacuna in the debate so far. The existence of this lacuna is best spelled out by way of an analogy. Clearly university libraries are repositories of information. By reductio, any account of information that denied this claim would have to be false or at least inappropriate to the purpose of analysing university libraries. But there are several senses in which we might take libraries to carry information. Firstly, the their books contain information about things in the world as well as varioius abstracta such as logical principles. This is semantic information imparted by authors and digested by

readers. Secondly, libraries are also informational in the causal relationships between them and the universities they serve. Debates about cuts in library spending are not debates about the content of books, but about the causal consequences of having fewer books. But there is a third sense, which we might call "the librarian's sense" which corresponds exactly to Martin and Rosvall's sense of information. We are convinced libraries are repositories of information because they are clearly designed to transmit that information. Principles of grammar, syntax, cataloguing and physical library design are clearly designed to maximise the ability of readers to extract from a library the information they want.

To carry the analogy a little further—To date, debate about biological information has centred on either the meanings of genes and genomes or on the outward physiological and morphological effects of having the genes and genomes that we have. As it has turned out, many genes are about nothing. Some are about amino acids and some regulatory. If they were books, they would be books about amino acids. Debates about the overall physiological and morphological effects of having particular genes and genomes, have turned out to be a little bit like debates about spending on university libraries. Libraries matter to the life of a university, but many other things matter also and just how much libraries matter in comparison to those other things has turned out to be difficult if not impossible to determine.

So what then of the prospects for the biological use of the librarian's sense of information? The first thing to say is that it survives the *reductio ad absurdum* mentioned above. It does not fall foul of the paucity of meaning or of the ubiquity of information understood as mere correlation. That said, Martin and Rosvall's interpretation of biological information will seem recondite to many. Readers care deeply about the content of books. Academics, educators and policy makers care about the effects of having libraries within the community. But the cataloguer's art is one that only a librarian could love. In part this is because the mechanisms of information transmission systems, if effective, tend to be invisible. Humans notice noisy systems, not systems with good noise reduction. Systems used by library cataloguers have no effect on the semantic information contained in their books. Nor, with all due respect to librarians, do they have much effect on the causal consequences of having a library at all or of having a small one as opposed to a large one. In short then, Martin and Rossvall's account of biological information is available and coherent. It will be of great interest to whose whose main interest is gene expression. However, it remains to be seen how relevant it will turn out to be in the life sciences as a whole and in wider academic debate.

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