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ARTICLE

Resolving debates around theories arising out of incommensurable meanings, to enable communication in science

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ABSTRACT

Communication is important in science. It not only serves as a way to let people know about science but also helps in doing science itself, thus at times enabling learners and practitioners of science to know about the nature of science itself. In *The Structure of Scientific Revolutions*, Thomas Kuhn talks about 'communication break' during periods of scientific crisis. Often, even during periods of "normal science" (as used by Kuhn), communicating science is a challenge, while still keeping intact the intended meaning. The incommensurability of meaning may lead to a communication break. Such a situation leads to a deadlock and resolving such debates becomes very difficult. This also takes a toll on the communication of the general idea of science being debated to the students, general public and even other researchers.

Using 'Do genes encode information about phenotypic traits?' a debate published in *Contemporary Debates in Philosophy* (ed. Hitchcock C. 2004), I try to look into how, even when both the debaters seem to understand the science correctly, do they reach at different conclusions in their debate. I also try to provide a solution to the debate, by looking at the relationship between the concepts being talked about in the debate. Resolving such debates is necessary as the science that forms the background of the debate is fairly old and robust and has made its way into textbooks and popular science journals long back. Thus, such debates may create negative perceptions among the students and general public, about the information being communicated to them in textbooks and popular science magazines, thus hindering further communication.

KEYWORDS: Philosophy of science, Philosophy of biology, Science communication, Debates in science, Gene, Protein, Phenotypic trait

Breaks in communication may lead to debates

Communication is important for the advancement of knowledge. Scientific knowledge is regarded as the truest form of knowledge accepted in current times. Communication, thus, is important for the advancement of science. It also gives the practitioners of science i.e. scientists, a view into the nature of science (Nielsen, 2013).

Science, in order to be communicated effectively must 'travel' well into the society. Travel not only in space but also in time. To travel thus, science needs to become a part of social interaction, which in essence requires commensurable meanings. In social interaction, semantic meanings (Carnap, 1975) and semiotic meanings (Haralambos and Heald, 1981) have been given utmost importance. Breaks in communication happen when the intended meaning of the term is not clear to the audience. This situation may lead to unnecessary debates to arise, even when both the sides involved in communication are clear about the knowledge (or the science) being discussed.

The debate in question here has been taken from Hitchcock, 2004. In this debate both the debaters are Philosophers of Science. Sahotra Sarkar is a professor at the Department of Philosophy, The University of Texas at Austin. The other debater, Peter Godfrey-Smith is a professor in the School of History and Philosophy of Science, University of Sydney. The debate entitled 'Do genes encode information about phenotypic traits?' has both these eminent philosophers engrossed at mainly two points:

1. Meaning of the term 'information' as coded by genes
2. Whether by coding for proteins by extension mean coding for phenotypic traits

In a way then, this debate arises due to different ways in which 'the communication at molecular level' has been communicated! It is important to note that communication at the molecular level is semiotic in nature and so is better explained by the 'communication theory' of Shannon (1948). Whereas when the debaters talk *about* communication at the molecular level, they indulge in semantic communication, the rules of which have been explained by Carnap (1975) in some detail.

Information transfer at the molecular level: understanding the debate

The basics of molecular biology are well explained in present times, so we cannot expect that the debate arose due to a science being new or a lack of understanding in the basic processes in molecular biology. The debate seems to arise from difference in understanding of the terms ‘information’ and ‘phenotype’, thus, making it an interesting matter to look into more closely.

The central dogma of molecular biology clearly states that genetic information flows from nucleic acid to protein but not *vice versa* (Crick, 1970). After the postulates of the central dogma were set out, over the next three decades enough work has been done to detail the mechanisms and machinery of the coding of information from nucleic acids to proteins.

Communication at the molecular level is semiotic in nature (Hitchcock, 2004 pp. 261-262). This is clearly shown by the evolution of a genetic code that requires ‘decoding’ the information contained in the nucleic acids (DNA) to be communicated through mRNA to the tRNA to form proteins. The communication theory (Shannon, 1948), briefly states that the *raw message*, from an *information source* is transmitted through a *channel* after being transformed by a *transmitter*. The *receiver* translates the *signal* to the original message as it reaches the destination. The noise factor is like an entropy factor and is present at the level of the *channel*. This description of communication theory sounds convincing in the context of genetic information as it is indeed *communicated* to the tRNA to form proteins.

However, looking more closely there are two major differences. One, the specificity on genetic information is not determined at the channel level i.e. the mRNA level. It is determined beforehand by the genetic code and directly manifests itself at the translation stage when tRNA adds amino acids to form an elongated primary polypeptide, the precursor to the protein. Two, in the communication theory, the information that is coded is again decoded into the *original* form at the receiving end whereas at the molecular level, the genetic information (nucleotide sequences) that is coded is decoded in the form of amino acid sequences at the receiving end. Both the polymeric molecules *viz.* nucleotide sequences and amino acid sequences are very different both structurally and functionally and thus have different physical and chemical properties.

Therefore Sarkar, in Hitchcock (2004 pp. 262), goes beyond the communication theory to discuss the semiotic aspects of genetic information as coded and decoded in molecular biology. He later explains that in molecular biology, the coding and related aspects are empirical, not conceptual relations (Hitchcock, 2004 pp. 269). Further, he mentions that environmental factors play a role (less so in prokaryotic genetics than eukaryotic genetics) in genes coding for protein. Thus, a trait (more technically *phenotype*) is defined as a sum total of the interaction between genes (more technically *genotype*) and environment. Also, the proteins (and their functions) are themselves affected by the environment. Thus, he concluded that almost always, the genes code information for the trait, not the protein; as the trait, in the end is a product of genetic information.

Godfrey-Smith, in Hitchcock (2004 pp. 279), seems to pick up the point made by Sarkar, but in a very different manner. He seems to be saying that *since* the trait is a product of interactions between genes and the environment, genes only code for proteins and nothing further. Once the protein is coded for, it interacts with other molecules (including both nucleic acids and proteins) and the environment to express the trait or the phenotype. Godfrey-Smith, first, distinguishes between the two senses of the term 'information'. He illustrates that information may mean any correlations between the two states in question e.g. dark clouds contain information about rain (Hitchcock, 2004 pp. 276). The second sense of information is as a representation of a concept and carrying a semantic content about that concept, e.g. considering rings in the trunk of a tree to contain information about the age of the tree. He says that rings of tree in this case are not *representation* of the life of the tree. They are just *indicators* useful to observers. Secondly, he also discusses what is meant by the term 'phenotypic trait' in the context of the present debate. He explains that in the broad sense 'phenotype' means any physical or chemical property of the organism. This includes proteins as well as the transcription and translation machinery also. But he makes it clear that for the purpose of the debate, he means the overall affect that the proteins have on organisms (e.g. shape, size, color, height etc.) (Hitchcock, 2004 pp. 276). From the above discussion it appears that both the philosophers are ending with the same argument that proteins themselves are not phenotypes. But they conclude differently as their definition of 'information' is different. Sarkar takes the indication form of information to mean that genes code for information regarding phenotype just like rings of a tree 'code' for information regarding the age of the tree. Godfrey-Smith on the other hand uses the correlational form of information, leading to a conclusion that genes code information for just manufacturing proteins, by the cellular machinery. The phenotype, according to him develops due to interaction of proteins with each other and with the environment.

Changes in intended meanings may lead to communication breaks

May Brodbeck, in her essay titled 'Meaning and Action' (Nidditch, 1968 pp. 123), has explained that the intended meaning (m_3) of a term may be different from the conventional meaning (m_1) or even factual meaning (m_2) of the term. Here, it is important to understand that the debate itself has arisen due to differences in m_3 i.e. intended meaning of the term 'information'. This shows the importance of commensurability of intended meanings while communicating science. Thomas S. Kuhn, in his famous essay *The Structure of Scientific Revolutions*, says: "They speak, (that is), from what I have called incommensurable viewpoints." (Kuhn, 1994 pp. 200). Here he is describing a situation that has arisen as a result of a crisis in a scientific field. He is referring to two scientists, proponents of two different theories, arguing about which theory can lay the claim to be the new paradigm. However, as exemplified by the presently mentioned debate, such incommensurable viewpoints can arise even during the periods of normal science, where the argument is not about a new paradigm but simply of understanding and communicating the intended meaning of the term 'information' correctly and hence concluding whether genes code information for phenotypic traits or not.

Since the intended meaning m_3 of the term 'information' has been understood very differently by both the philosophers, the overall incommensurability of their viewpoints has arisen, giving rise to the debate. This has ultimately led both of them to answer the final question i.e. 'whether genes code information for phenotypic traits?' very differently. It is important to note that the different final answer is a result of the factual meaning m_2, of 'phenotypic trait', being changed in each case depending upon the intended meaning m_3, of 'information'.

Since the debate has arisen due to a difference in the intended meaning of the terms 'information' and 'phenotype', the debaters find themselves coming to different end results even though both are talking about the similar conclusion. This lack of commensurability in the meaning of the terms makes it difficult to resolve the debate. Thus, we have to look at the debate from an angle of relationships between the theories being debated about. 'Information', as used by the debaters in the present context, is a concept in molecular biology. Whereas phenotypic traits, as used by debaters is an older concept, a part of classical Mendelian genetics.

The concepts of information and phenotype need to be accessed carefully to provide a possible solution to the ongoing debate. One possible reason that may be leading the two debaters to form incommensurable meanings of the terms is the apparent reduction of the concepts of classical genetics to the terms in molecular biology. Let us have a look at how reduction of concepts of fields within biology can lead to a perception that may cause clash between two intended meanings of a term (factual or conceptual).

Relationship between complex scientific theories

It has often been observed that scientists try to reduce complex problems and try to fit them in categories, in order to study them in some detail. While the original intent of reduction was creating ease of analysis of complex systems, over time reduction has come to mean something different from that captured in formal philosophical accounts. Often even the most seasoned scientists and philosophers of science have started looking at one to one correspondence between terms that have been used to describe the concepts of two different fields within a subject. In biology, there is often an attempt to reduce the terms of classical Mendelian genetics to molecular biology. But such reductions, though they may help in elucidating a concept, have led to complexities due to attempts of one to one literal mapping of components of former with the latter.

> *"Even if all gross phenotypic traits are translated into molecularly characterized traits, the relations between Mendelian and molecular predicate terms express prohibitively complex, many-many relations. Phenomena characterized by a single Mendelian predicate term can be produced by several different types of molecular mechanisms. Hence, any reduction will be complex. Conversely, the same types of molecular mechanisms can produce phenomena that must be characterized by different Mendelian predicate terms. Hence, reduction is impossible." (Hull 1974, pp. 39 in Darden, 2006 pp. 104)*

Therefore, formal reductionism does not work in complex biological theories. Some researchers argue that reductionism may be used for explanatory purposes. This kind of reduction may help in a search for lower level mechanism to explain an upper level phenomenon. An example may be molecular biology being used to explain complex phenomena at the cellular level. There are several instances of such explanatory reductionism, the most famous being that of "crossing over" of chromosomes during meiosis being explained by Holliday model of general molecular recombination. It often appears that there is a kind of an elegant unification between theories of one or more than one fields of biology. One might be tempted to look at the above example in a way that what happens at the level of chromosomes in the cells, the same phenomenon happens at the level of DNA during molecular recombination. Another very important example is that of the analogy between chromosome replication and DNA replication to correspond perfectly. However, when one goes into the details of molecular biology, the details of the mechanisms tend to destroy the apparent elegant unification.

> *"Such unification would be lost if attention was focused on the gory details at the molecular level. The cytological level thus constituted an 'autonomous level of biological explanation'" (Kitcher 1984, pp. 371 in Darden, 2006 pp. 107).*

Therefore, reduction of biological theories to explain complex behavior of one through another is not a very useful approach. One might instead choose to look at the relationship between the various theories instead of trying to reduce one to the other. Different mechanisms have different 'working entities' and operate at different times and in different spaces. To discern a mechanism it is important to correctly find the working entities and the level at which they are operating (Darden, 2006 pp. 108).

It is not surprising that genes are not the working entities in any hereditary mechanism except for gene expression, the process that leads to the formation of proteins. It is important to understand that molecular biology concepts are not reduced versions of the concepts of classical genetics; instead molecular biology comes up with mechanistic schemas to explain the concepts of classical genetics. One must therefore guard against the temptation of using interchangeably the concepts and molecules of molecular biology and the theoretical concepts of classical genetics. For example, the expression of a protein does not necessarily mean the expression of a 'phenotypic trait', the former being a molecular entity and the latter a theoretical concept of classical genetics.

Moreover, inter-field theories like chromosome theory have linked 'genes' and 'chromosomes' as a part-whole relationship. And the operon theory in bacterial genetics has linked the gene expression (molecular biology) to metabolite use (biochemistry) in a cause-effect relationship. Instead of reduction on one complex system to another, theories in biology may be better seen as bridging the two fields e.g. Classical genetics and Molecular biology (Darden, 2006 pp. 145).

An attempt to solve the debate

Using the above discussion about relationship between theories of different fields in biology, let us try to look at our debate 'Do genes encode information about phenotypic traits?' As already mentioned, the debate arises due to difference in intended meanings of terms ‘information’ and ‘phenotypic trait’ as used by the debaters Sahotra Sarkar and Peter Godfrey-Smith. When we look at the concept of phenotypic trait and try to establish its relation to the molecular result of gene expression, it is clear that ‘trait’ is just a theoretical concept of classical genetics. However, protein is a macromolecule that is produced as a result of molecular biology mechanism. Therefore, to say that ‘genes code information about proteins’ and ‘genes code information about phenotypic trait’ are the same thing would be incorrect. A protein, once manufactured by the molecular machinery, is exposed to the cellular environment.

From this point onwards, the gene is *not* a ‘working entity’ in any mechanisms that the protein takes part in, to determine the overall phenotype. The ‘phenotypic trait’ is thus a collective outcome of multiple proteins coming together, the immediate cellular environment and the changes that take place at the level of tissue, organ and even organism. The final determination of the ‘phenotypic trait’ is when the organism interacts with the natural environment. In none of these processes, the gene is the working entity.

Therefore, the claim that ‘genes code information for phenotypic trait’ is not a valid statement to make. Resolving this debate through the argument of both the debaters was very difficult due to difference in intended meanings of certain terms. Instead, looking at the debate from the point of view of the relations between the two terms ‘proteins’ and ‘phenotypic traits’ helps us to reach a conclusion that the two terms are not the same and that protein expression explains the molecule level mechanistic details of phenotypic trait but the genes have no role to play in determining the final outcome of a phenotypic trait.

Conclusion

Such debates are very important to resolve as molecular biology is a science that is already in public domain. It is not the case of a crisis, a stage for scientific revolution, to select a new paradigmatic theory, as meant by Kuhn (Kuhn, 1994). It is taught to students in schools and institutions and even the common populace is interested in knowing about molecular biology and genetic engineering, making it 'normal science'. This debate is a result of the incommensurable intended meaning that both the debaters have given to the terms 'information' and 'phenotypic traits'. A debate around such an elementary question might raise some doubts about the science or some specific theories within the broad subject.

When a debate arises due to incommensurable intended meaning, it is often futile to convince the other party about the meaning, as intended by one party. In such a case, it is useful to look at the major contributors of incommensurability, from a different perspective. Here, rather than going into the details of intentions and meanings, one possible solution to the debate was suggested by looking at it from the perspective of relationships between concepts of various theories within a field of scientific inquiry. The philosophers of science or practicing scientists should try to resolve such debates among them so as to effectively communicate the science further into the public domain. It is important to resolve the debate, as this is essential for communicating science.

References

Carnap R. (1975). Meaning and necessity: a study in semantics and modal logic, 2nd ed., 7. impr. ed, A Phoenix book Philosophy. Univ. of Chicago Press, Chicago.

Crick F. (1970). Central dogma of molecular biology. *Nature*, 227, 561–563.

Darden L. (2006). Reasoning in biological discoveries: essays on mechanisms, interfield relations, and anomaly resolution. Cambridge University Press, New York.

Haralambos M., Heald R. (1981). Sociology: themes and perspectives, 1st ed. Oxford University Press.

Hitchcock C. (Ed.) (2004). Contemporary debates in philosophy of science, Contemporary debates in philosophy. Blackwell Pub, Malden, MA.

Kuhn T.S. (1994). The structure of scientific revolutions, 2nd ed., enlarged ed, International encyclopedia of unified science foundations of the unity of science. Chicago Univ. Press, Chicago, Ill.

Nidditch P.H. (1968). The philosophy of science, Oxford readings in philosophy. Oxford U.P, London.

Nielsen K.H. (2013). Scientific Communication and the Nature of Science. *Sci. Educ.* 22, 2067–2086. https://doi.org/10.1007/s11191-012-9475-3

Shannon C.E. (1948). A mathematical theory of communication. Bell Syst. *Tech. J.* 27, 379–423, 623–656.