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Why genes are like lemons

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ABSTRACT

In the last few years, the lack of a unitary notion of gene across biological sciences has troubled the philosophy of biology community. However, the debate on this concept has remained largely historical or focused on particular cases presented by the scientific empirical advancements. Moreover, in the literature there are no explicit and reasonable arguments about why a philosophical clarification of the concept of gene is needed. In our paper, we claim that a philosophical clarification of the concept of gene does not contribute to biology. Unlike the question, for example, "What is a biological function?", we argue that the question "What is a gene?" could be answered by means of empirical research, in the sense that biologists' labour is enough to shed light on it.

1. Introduction

The debate around the concept of 'gene' – and in particular about the question "What is a gene?" – has a long history both in biology and in philosophy of biology (see, for example, Baetu, 2012; Buchanan, Sholtis, Richtsmeier, & Weiss, 2009; Gerstein et al., 2007; Gingeras, 2007; Portin, 2009; Scherrer & Jost, 2007; Stadler, Prohaska, Forst, & Krakauer, 2009). For our aims it suffices to recall the two dominant positions.[2] On the one hand, there are those who support the idea that it is possible to have a unitary definition of 'gene' (for example, Gerstein et al., 2007). Accordingly, they claim that this can be of some advantage for biological research, as it would eliminate the ambiguities around the concept itself, enabling a more fruitful communication among different fields of research. On the other hand, others argue that there is not a single definition (for instance Griffiths & Stotz, 2013). Supporters of this position embrace a sort of pluralism: it is possible to have definitions updated according to research improvements, but nonetheless some old definitions in certain fields may still hold. Hence, given a research context, there would be better or worse definitions, but none in general would be the right definition of 'gene'.

Beyond the differences, these two positions share the underlying assumption that a strong conceptual – and historically well-informed – analysis is necessary. Nevertheless, considering the status of the debate, someone has claimed that we are, intellectually, at a 'dead-end' that could be also harmful for any science based on genes, as genomics is. In particular, in a recent paper Perini (2011) proposes that the lack of a unitary notion of gene can be a potential flaw for any science whose purpose is to investigate the behaviour of the genome, both from a functional and evolutionary point of view. Therefore, in Perini's view, it seems that a philosophical analysis of the concept of gene could make a substantial contribution even to science. Differently, we think that this claim is unjustified and we want to challenge it. More precisely, we believe that the philosophical debate over the notion of gene, even if it could have an intellectual relevance, is rather disconnected from

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[2] Traditionally these positions are articulated among different fields of the life sciences (e.g. the gene in evolutionary biology versus the gene in developmental biology) but, as we will show, also within molecular biology and its subfields (e.g. structural biology, transcriptomics, networks biology).

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the real criteria scientists adopt, or should adopt, to define and identify genes. To put it differently, we claim that a philosophical analysis, in this case, help, *per se*, neither the scientific process, nor the scientific progress. Actually, we argue that the question 'what is a gene?' could be sufficiently answered by the scientific labour and that, at least in this case, philosophy may attend and record what is found. This position is based, as we will show, on the insight that unlike the debate on the notion of 'function' (Germain, Ratti, & Boem, 2014) – where different philosophical interpretations have fuelled a lively debate also among scientists – the philosophical quarrel about the notion of gene has had really a negligible impact on scientific practice.

Coming to the main point, we suggest that the term 'gene' has to be thought of as a natural kind, and not as a theoretical term. We are quite confident that the notion of gene has been adopted and conceived by scientist as if it were a natural kind. This deserves some clarifications. First, we do not want to embark ourselves in the debate on the meaning and on the metaphysic of natural kinds, but we want to rely on a well-known analysis of them, such as Kripke-Putnam's one. Next, we want to point to an important difference between natural kind and theoretical terms. Considering something as a natural kind means that investigations on the features of that particular natural kind depend on empirical research, which in turn influences semantic and epistemological issues. Instead, theoretical terms are prone to generate debates that can be disentangled by philosophical analyses, also due to the fact that their meaning depends on the assumptions of the theoretical framework in which they are inserted (see, for instance, Suppe, 1977). One may observe that this way of thinking could be associated with the outcome of Griffiths and Stotz's position, as they say that "[t]he development of the gene concept does not fit conventional philosophical models of the evolution of theoretical terms" (2013, p 222). In part this is right, even if our proposal and their approach differ in many relevant aspects. First, Griffiths and Stotz probably understand 'theoretical term' in the intuitive sense of 'unobservable entity'. On the contrary, we mean 'theoretical terms' as those scientific terms whose meaning depends strictly on the background knowledge of the framework where they are used. Next, we *do think* that the changes over time of the gene concept depend on the cumulative empirical knowledge provided by biologists. Instead, Griffiths and Stotz claim that they do not fit those "models which presume that conceptual evolution takes the form of growing knowledge about a single entity" (2013, p 222). This does not mean that we reject Griffiths and Stotz's pluralistic view. On the contrary, we endorse their position as a starting point, especially for all the details they provide about the history of the notion of gene.

Concerning the structure of what follows, in §2 we introduce a way of considering a philosophical clarification of scientific concepts; in §3 we show how certain scientific concepts, for example that one of 'biological function', really need such a philosophical work; in §4 we introduce the problem of the gene through a brief historical sketch and we show how the development of the concept of gene has been dependent upon empirical discoveries; in §5 we show how the gene concept is shaped and developed by empirical discoveries also in contemporary biology by comparing three contemporary notions of gene.

2. The methodology

There is a long and established tradition in philosophy (since Plato's methodology of *diairesis*) according to which questions and problems can be analysed through their decomposition. Making distinctions is a central component of philosophical labour. Sometimes these distinctions are aimed at identifying different levels or layers of inquiry that also settle the horizon, the resources, and the sense of those questions. Accordingly, we start from the very intuitive idea that the question "What is a gene?" (but in general "What is x?") could be understood in at least three ways[3]:

(g1) semantic: What does the term 'gene' mean?
(g2) epistemological: How do we know that x is a 'gene'?
(g3) empirical: What kind of object in the world 'gene' corresponds to?

The first is about the meaning of a linguistic term and its correct use. The second typically pertains to the realm of epistemology and philosophy of science since it is about the construction of scientific knowledge. The third assumes that there is something in the world that should be empirically discovered. We are neutral with regards to the problem of whether there is a hierarchy of such questions, or if some of these questions are more important than others. On the other hand we intuitively claim that the first two interpretations of the question are commonly philosophical since they request some sort of conceptual clarification, while the third one, interpreted as empirical investigation of the natural world, is generally (but not always) a business for scientists. If we accept this tripartite framework, we need to provide arguments for the importance of a work concerning a conceptual clarification of the concept of gene. Actually there are no explicit arguments for this in the relevant literature, except for the acknowledgement of the lack of a unitary notion of gene. But this is quite unsatisfactory. Moreover, it appears that it is not particularly tricky to answer to (g1) and (g2), at least not more than answering to the question "what is a lemon?" interpreted as:

(l1) What does the term 'lemon' mean?
(l2) How do we know that x is a 'lemon'?

We assume that a conceptual clarification of a scientific concept in philosophy of science should explain why scientists endorse certain terminological and theoretical choices and how these choices affect their work. In particular, a conceptual clarification of a term belonging to the scientific realm is a philosophical contribution to scientific development if it shows how answers to question 1 will determine answers to question 2, which in turn will have important consequences on how we answer question 3. On the contrary, we maintain that a conceptual analysis of a term belonging to the scientific realm with negligible consequences for science would be that one showing how answers to question 1 and question 2 depend strictly on answers to question 3. Such an analysis would confine the work of philosophers to the formalization and systematization of scientific findings which could be interesting for philosophy *qua* philosophy but less interesting for science. In the following sections we will argue that answering to philosophical questions on the concept of gene (g1 and g2) is not different than responding to philosophical questions regarding lemons (l1 and l2).

Please note that the flow of reasoning from 3 to 1 or from 1 to 3 is an idealization or, let's say, a *regulative ideal*. In the history of science, there are many cases of concepts constantly shifting back and forth from 1 to 3 or *vice versa*. What is important is that the more the contribution of 1 and 2 to 3 is prominent, the more the philosophical contribution to science is remarkable. However, we also think that a considerably strict flow from 3 to 1 characterizes

[3] There might be other ways of understanding the question "what is a x?", but this distinction nicely captures three very common and uncontroversial ways of understanding questions.