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Justifying molecular images in cell biology textbooks: From constructions to primary data

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ABSTRACT

For scientific claims to be reliable and productive they have to be justified. However, on the one hand little is known on what justification precisely means to scientists, and on the other the position held by philosophers of science on what it entails is rather limited; for justifications customarily refer to the written form (textual expressions) of scientific claims, leaving aside images, which, as many cases from the history of science show are relevant to this process.

The fact that images can visually express scientific claims independently from text, plus their vast variety and origins, requires an assessment of the way they are currently justified and in turn used as sources to justify scientific claims in the case of particular scientific fields. Similarly, in view of the different nature of images, analysis is required to determine on what side of the philosophical distinction between data and phenomena these different kinds of images fall.

This paper historicizes and documents a particular aspect of contemporary life sciences research: the use of the molecular image as vehicle of knowledge production in cell studies, a field that has undergone a significant shift in visual expressions from the early 1980s onwards. Focussing on textbooks as sources that have been overlooked in the historiography of contemporary biomedicine, the aim is to explore (1) whether the shift of cell studies, entailing a superseding of the optical image traditionally conceptualised as primary data, by the molecular image, corresponds with a shift of justificatory practices, and (2) to assess the role of the molecular image as primary data. This paper also explores the dual role of images as teaching resources and as resources for the construction of knowledge in cell studies especially in its relation to discovery and justification. Finally, this paper seeks to stimulate reflection on what kind of archival resources could benefit the work of present and future epistemic historians in particular those interested on the role of images as sources of training and knowledge production in scientific disciplines.

1. Introduction

For scientific claims, such as hypotheses and theories, to attain the status of scientific knowledge they have to be justified.[1] However, what justification means for scientists and how precisely they justify the images they use as sources to produce new knowledge in different scientific fields and disciplines are topics that remain under-examined by philosophical and historical studies of science.

In analysing cases of scientific justification philosophical studies have customarily focused on the written form (textual expressions) of scientific claims, a situation that has resulted in a neglect of the role of images in this process. In view of the increased recognition of the capabilities of images for promoting particular epistemologies, for acting as text-independent tools for visual thinking, and for

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[1] In epistemology, a long dated assumption is that knowledge is justified true belief. This tripartite assumption, which was first credited to Plato (427-347 BCE). Gail (2003), Bonjour & Sosa (2003), pp. 1, and found a modern expression, in the work of the philosopher Alfred Jules Ayer (1910–1989, 1956), pp. 31–35, despite genuine critics on its insufficiency Gettier (1963), pp. 53–54, is considered by and large, by epistemologists as 'roughly correct', Neta & Pritchard (2009), pp. 5, in that it remains an important bedrock assumption in epistemology, philosophy of science and science itself. Justification, because of its multiple meanings and associations with, for instance, validation, verification, truth, demonstration, reliability, explanation, etc., has remained a highly debatable issue in epistemological discussions Alston (1989), Neta & Pritchard (2009), Moser (1996), Landesman (2002), Musgrave (1993).

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embodying scientific claims,[2] this lack of critical examination of how scientific images are justified has become untenable. This is especially so when considering the relentless proliferation of their diverse forms alongside novel pedagogical trends in scientific disciplines in general and bio-disciplines in particular throughout the late twentieth century and up to the present. Moreover, due to this proliferation of visual expressions it is unclear how scientists epistemologically differentiate them in particular concerning the important distinction identified by Bogen and Woodward (1988) between 'data' and 'phenomena' (see also Woodward, 1989). These authors proposed a distinction between 'data' that is, all those observable instrument-derivable 'inscriptions' (Latour & Woolgar, 1986) obtained in experimental instances and non-explained by the theory under test, and 'phenomena', a feature of the world, usually unobservable, which is created from those instrument derivable observations and is used as explananda for the theory under test. The question is then in which side of this key philosophical distinction scientists locate the different kinds of images they work with.

Besides these two important questions, there is that of the relationship between pedagogy, discovery and justification, and to what extent all these epistemic activities could be of any value for the constitution of image-based archives. Images play a key role in training future generations of scientists and, in this regard, the textbook emerges as a particularly unexplored source in the historiography of science. Textbooks, and the role of their illustrations in justifying scientific discoveries and transmitting them to younger scientists, deserve examination, particularly for those scientific fields that are highly dependent on images.

One such scientific field is cell studies,[3] for it is a field that has undergone a major quantitative and qualitative visual transformation between the 1950s and the 2000s. In effect, during that period cell studies have undergone a representational shift entailing a superseding of images obtained with microscopes—images traditionally conceptualised as extension of naked eye vision and as primary data; by molecular images, that is pictorial representations constructed from the outputs (primary data) of one or more set of instruments other than microscopes aimed at describing the molecular interactions assumed to be at the basis of anatomical and functional changes in cells (Serpente, 2011a, 2011b). This shift towards the prevalence of constructed images invites reflection in several fronts. First, the way these two kinds of images are justified; second, how scientists categorise them, for instance, whether 'constructed' images, such as molecular images are regarded as data or phenomena; third, how the justification process works on the making of textbooks; fourth, and last what role if any pedagogy plays for justification.

The aim of this paper is to study the process of justification behind the molecular image in cell studies and with it, to create ground for reflection on the importance of images as archival sources for further epistemological enquiry. The pictorial work of two textbooks that have proved foundational for cell studies is analysed here: *The Machinery of Life* (TMoL) by David Goodsell (first published in 1983) and *Molecular Biology of the Cell* (MBoC), by Bruce Alberts, Dennis Bray, Julian Lewis, Martin Raff, Keith Roberts and James D. Watson (first published in 1983). The objective of this analysis is to explore both the question of what counts as data and phenomena, and the position that conceptualises textbooks, in contrast to scientific papers, as sources for more established and hence more reliable forms of knowledge.

All in all this paper will argue for a complex picture in the production of microscopic and molecular imagery in cell studies, a picture where apart from the conventional set of criteria established by philosophy of science for the acceptance of scientific claims, pedagogy and other factors play a crucial role. By assessing images as primary sources of knowledge, this study highlights the importance for archivists and historians of cataloguing images, including the hidden questions and constrains that stand behind their design. As such, and in line with other contributions to this special issue, it addresses the difficulties in interlinking archival images and text and advocates for a productive crosstalk between archivists and historians on how to create resources from where future generations of academics could rescue the visual 'craft-like' aspects of scientific practices that are more difficult to reconstruct from written sources.[4]

2. Discovery/justification and the visual nature of scientific claims

Of particular relevance for the history of justification in science was its demarcation from discovery, a demarcation credited to Hans Reichenbach (1891–1953), a key member of the logical empiricist school of philosophy.[5] Reichenbach's idea was to separate the rational steps based on formal logic and inductive and deductive arguments (the relevant) from the psychological, sociological and historical aspects (the anecdotic) when granting new proposed hypotheses or theories the status of knowledge. In consonance with the critical view of Kuhn and others on this strict demarcation, this study assumes that, rather than being

[2] The examples here are numerous, but the following would clearly highlight the point: a) the case of Alfred Wegener drawings on the movement of continents to visually express the theory of continental drift. Robin (1992), pp. 210. b) The series of drawings used to represent the phenomenon of cell division of pre-reproductive cells (meiosis) to visually express the Mendelian theory of inheritance. For more examples on the inference of theories from images and the construction of phenomena out of data see the cases discussed by Brown. Brown (1996), pp. 250–268. In Baigrie (1996). A typical example of images as independent of textual expressions are the drawings of Leonardo Da Vinci. For cases of images promoting particular epistemologies see Zampieri, Zanatta, and Bonati (2012), pp. 121–144. In Fangerau, Chhem, Muller, & Wang (2012).

[3] The term 'cell studies' attempts to embrace the history of studies of cells from the formulation of the cell theory in the 1840s to the present regardless of the changes in name that the discipline underwent, first in the 1960s from cytology to cell biology, and second in the 1980s from cell biology to molecular cell biology. 'Cell studies' also embrace disciplines involving the study of cells interacting such as plant and animal development and immunology.

[4] On images and text as sources for archives see de Chadarevian, 'The future historian: Reflections on the archives of contemporary life sciences', 2016. On the process of establishing and cataloguing an archive see Shaw, 'Documenting genomics: Applying archival theory to preserving the records of the Human Genome Project' 2016. On the necessity of interactions between historians and archivists see Garcia-Sancho, 'The proactive historian: Methodological opportunities presented by the new archives in modern genomics, 2016. On the hidden and informal activities that doing science entails and the difficulties in documenting them see Aicardi, 'Francis Crick, cross-worlds influencer: Reflections on the archives of contemporary life sciences', 2016.

[5] Reichenbach (1938), pp. 5–8 and 381–384. As remarked by Hoyningen-Huene (1987), pp. 502–503, implicit and/or related versions of the distinction can be traced back to Whewell's The *Philosophy of Inductive Sciences*, which was published in 1847, and also to other members of the logical empiricist school during the late 1920s, as well as to Karl Popper in 1935 (translated in English in 1959). The view of Whewell's philosophical work as a forerunner and himself as an advocate of the distinction between both contexts has been contested by Jutta Schickore. Schickore & Steinle (2006). The discovery/justification relationship is a theme that has kept attracting intellectual interest throughout the years. See, for instance: Hanson (1960), Kordig (1978), Nickles (1980). Hoyningen-Huene (1987 and 2006), Schickore & Steinle (2006). A typical argument of the relevance of justification over discovery found in science is that if a key idea/theory X has not been proposed by scientist A in year 1 it would have been discovered by scientist B or C in year 2.