

Nagel on reduction¹

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ABSTRACT

This paper attempts a critical reappraisal of Nagel's (1961, 1970) model of reduction taking into account both traditional criticisms and recent defenses. This model treats reduction as a type of explanation in which a reduced theory is explained by a reducing theory after their relevant representational items have been suitably connected. In accordance with the deductive-nomological model, the explanation is supposed to consist of a logical deduction. Nagel was a pluralist about both the logical form of the connections between the reduced and reducing theories (which could be conditionals or biconditionals) and their epistemological status (as analytic connections, conventions, or synthetic claims). This paper defends Nagel's pluralism on both counts and, in the process, argues that the multiple realizability objection to reductionism is misplaced. It also argues that the Nagel model correctly characterizes reduction as a type of explanation. However, it notes that logical deduction must be replaced by a broader class of inferential techniques that allow for different types of approximation. Whereas Nagel (1970), in contrast to his earlier position (1961), recognized the relevance of approximation, he did not realize its full import for the model. Throughout the paper two case studies are used to illustrate the arguments: the putative reduction of classical thermodynamics to the kinetic theory of matter and that of classical genetics to molecular biology.

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1. Introduction

Explicit philosophical discussion of reduction (and reductionism) in the sciences began with the seminal work of Ernest Nagel in 1949; the model outlined there was developed in much greater detail in *The Structure of Science* (1961) and slightly modified in 1970.² Essentially,

this model was the standard logical empiricists' deductive-nomological (DN) model of explanation with the *explanandum*³ being a theory rather than an individual fact.⁴ In the 1960s and 1970s, Nagel's model was modified and extended by several critical but ultimately sympathetic commentators⁵ but, especially since the late 1970s, it was also heavily criticized and typically rejected during an

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¹ For discussions, in some cases over many decades, thanks are due to Jordi Cat, Alan Love, Ken Schaffner, Abner Shimony, John Stachel, and Bill Wimsatt. Comments by participants of the Formal Epistemology and the Legacy of Logical Empiricism Workshop (University of Texas, Austin, Spring 2013) and the audience at a Philosophy Department seminar at the University of Sydney were also useful. For comments on previous drafts, thanks are due to Justin Garson and Thomas Uebel.

² See Nagel (1949, 1961, 1970); the last paper is also reprinted in Nagel (1979). A similar model was independently formulated by Woodger (1952, pp. 271–272); though that work was sometimes cited in the 1950s and 1960s (e.g., by Kemeny and Oppenheim [1956] and Schaffner [1967b]), it had little influence compared to Nagel's more comprehensive treatment. Nagel first presented an analysis of reduction (and autonomy) at the Eighth International Congress of Philosophy (at Prague, 2–7 September 1934) (Stadler [2001], p. 359) and published part of that analysis (though not the material on autonomy) in 1935 (Nagel, 1935); the (very incomplete) analysis presented there has little similarity with the later model and that paper will be not be considered any further here. However, these early forays into the topic do drive home the point as to how central the issue of reduction was to Nagel's thinking, with papers on the topic spanning 36 years.

³ The terminology here is that of Hempel and Oppenheim (1948) though the DN model goes back to Carnap (1939) (see Sarkar [2013]). Nagel (1961, p. 16 and elsewhere) idiosyncratically refers to the *explanandum* as the *explicandum*; the usage is idiosyncratic because he also invokes the standard (Carnapian) notion of explication (1961, pp. 37–42) which is distinct from explanation (see, in this context, Hempel and Oppenheim [1948], p. 136n2).

⁴ However, as Schaffner (2013) points out there is no clear historical evidence that indicates that Nagel explicitly had the DN model in mind when formulating his account of reduction. For the DN model, see Hempel and Oppenheim (1948) which immediately preceded Nagel's model (and thus could have served as an inspiration). Hempel and Oppenheim include reduction (though they do not use that term) as a form of explanation subsumed under the DN model insofar as they allowed the *explanandum* to be a regularity. Salmon (1989) provides a comprehensive critique of the DN model in his history of scientific explanation. Strangely, he misses the fact that the DN model originated with Carnap (1939).

⁵ See, for instance, Schaffner (1967b), Sklar (1967), Hempel (1969), Causey (1972a, b; 1977), and Nickles (1973).

era that was uncharitably prone to deny the relevance of almost every element of the logical empiricists' philosophy of science.⁶ Much work was also devoted to developing alternative analyses of reduction.⁷ However, reappraisals during the last decade—by Fazekas (2009), Klein (2009), Dizadji-Bahmani, Frigg, and Hartmann (2010, 2011), Needham (2010), Butterfield (2011), van Riel (2011), and Schaffner (2013)—have challenged the longstanding near-consensus about the lack of pertinence of Nagel's analysis. These works have defended major parts of Nagel's analysis but each has done so by rejecting fundamental aspects of Nagel's model.

The purpose of this paper is to continue the trend towards a more reasoned reassessment of Nagel's analysis. Part of the appeal of Nagel's analysis is that it seems to capture what the mechanical philosophy of the seventeenth century was about; what Maxwell, Clausius, and Boltzmann attempted to do with thermodynamics in the nineteenth century; and what Pauling and Crick promoted through the molecularization of biology in the twentieth century. In contrast to the analyses cited in the last paragraph, this paper defends Nagel on several issues on which those analyses depart from his model, in particular, about whether reduction should be construed epistemologically (*contra* van Riel [2011]), whether reduction must be explanation (*contra* Dizadji-Bahmani et al. [2010], Butterfield [2011], van Riel [2011]), and the nature of the relation between the reduced and reducing theories and the concepts in them (*contra* Dizadji-Bahmani et al. [2010], Needham [2010], Butterfield [2011], van Riel [2011], and Schaffner, [2013]). With respect to the nature of this relation, the analysis below mostly agrees with the conclusions of Fazekas (2009) and Klein (2009) though for different reasons.⁸

Most importantly, however, and again in contrast to all but one of these recent analyses, a major focus of this paper is on Nagel's analysis of the substantive (what he called nonformal) conditions that a reduction must satisfy in order to be significant.⁹ That part of Nagel's discussion makes it clear that he intended the formal model be regarded as an ideal to which reductions in practice should aspire, rather than as a description of even the most successful reductions. Nagel's analysis of these substantive conditions provides several insights that have gone unnoticed to the detriment of many subsequent discussions of reduction and reductionism. In particular, the analysis below pays detailed attention to the nature of approximation.

Any appraisal of Nagel's analysis should recognize two extreme positions:

A. Nagel's analysis of reduction is essentially correct and applicable to most (if not all) cases that are (pre-systematically¹⁰) accepted as being reductions.

B. Nagel's analysis of reduction is incorrect because it is not applicable to many important cases that are (pre-systematically) accepted as reductions.

The purpose of this paper is to defend position A using, among other examples, two potential reductions that have long been staples of the literature of reductionism: the putative reduction of thermodynamics to the kinetic theory of matter and the putative reduction of classical genetics to molecular biology.¹¹ Details of these cases will be introduced below.

Positions A and B do not exhaust the logical space. It is possible to hold a position that Nagel's analysis of reduction is essentially correct but not applicable to many exemplary cases of reductions. For instance, Wimsatt (1976) argued that Nagel's analysis should be restricted to what he called intra-level reduction (for instance, that of Newtonian gravitational theory to general relativity or of phenotypic variability to heritability analysis [Sarkar, 1998]). Kitcher (1984) assumed that Nagel produced a correct analysis of reduction but, on that assumption, denied the reduction of classical genetics to molecular biology. Such an intermediate position with respect to Nagel's model duly noted, in the discussion that follows, position A will be contrasted only to position B. A successful defense of position A logically excludes intermediate positions such as those espoused by Wimsatt and Kitcher.

Nagel's analysis of reduction had two components: a formal model and an extended discussion of nonformal conditions that scientifically significant reductions should satisfy. These nonformal conditions are better regarded as substantive assumptions about reduction (Sarkar, 1998).¹² The relevant distinction is sometimes put forward as one between syntactic and semantic conditions.¹³ This is misleading since the relevant nonformal or substantive assumptions do not generally consist of interpretations (models) of uninterpreted structures; rather they often introduce new claims including contextual criteria about the roles and value of theoretical developments. Moreover, the theories considered by Nagel and others (such as Hempel) in this context emerge from intended interpretations which are part of the discussion.¹⁴ Much of the discussion of Nagel's analysis, both when it was mainly criticized and now, when it is often defended, has focused solely on the formal model. Section 2 of this paper will deal with issues that are principally connected with the formal model though some substantive issues will require attention.¹⁵ Section 3 will turn specifically and exclusively to Nagel's substantive conditions.

2. Formal characterization

Nagel's formal model viewed reduction as a relation between theories. Whether this relation should be that of explanation and whether explanations should be construed purely epistemologically are questions taken up in Section 2.1. Nagel distinguished between two situations¹⁶: *homogeneous* reductions in which the

⁶ The critics were legion and many of them will be discussed below in the text. Of particular importance were Hull (1972), Fodor (1974, 1975), Wimsatt (1976), and Kitcher (1984). Perhaps the most extreme position is that expressed by Primas (1998), though from much later: "there exists not a single physically well-founded and nontrivial example for theory reduction in the sense of... Nagel (p. 83)." (The absurdity of this claim will become manifest as this paper progresses.) What is unfortunately typical of much of the writing from the 1970s is inaccurate or uncharitable interpretation of the positions held by the logical empiricists. For instance, on reduction, Suppe (1977) claims: "Nagel's analysis is based Kemeny and Oppenheim's (1956) classic treatment of the subject (p. 55n)," whereas Nagel's work came earlier and Kemeny and Oppenheim's work was an *alternative* model as both Kemeny and Oppenheim (1956) and Nagel (1970) explicitly recognize.

⁷ See, in particular, Wimsatt (1976), Hooker (1981), and Balzer and Dawe (1986a,b). Sarkar (1989, 1992, 1998) provides a summary of this literature.

⁸ Moreover, similar arguments were developed earlier by Marras (2002).

⁹ The exception is van Riel (2011). Sarkar (1989) discussed Nagel's nonformal conditions extensively; see, also, Waters (1990).

¹⁰ Here "pre-systematic" is being construed to refer to the situation before reduction is explicitly explicated.

¹¹ Nagel (1949, 1961) initiates the discussion of the potential reduction of thermodynamics to the kinetic theory of matter.

¹² The term "substantive" is sometimes used in the sense of this section by Nagel (e.g., 1961, p. 30) though he generally calls the assumptions discussed here "nonformal" (e.g., 1961, pp. 358–366).

¹³ See, for example, Cat (2007) who calls the substantive conditions for reduction "semantic."

¹⁴ Hempel (1969) uses "linguistic" rather than "formal" but the point being made is the same.

¹⁵ Nagel (e.g., 1961) was also particularly prone to integrate formal and substantive discussions and the analysis here will follow his lead.

¹⁶ This distinction goes back to Nagel (1949) and is emphasized in all subsequent versions of his analysis.

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