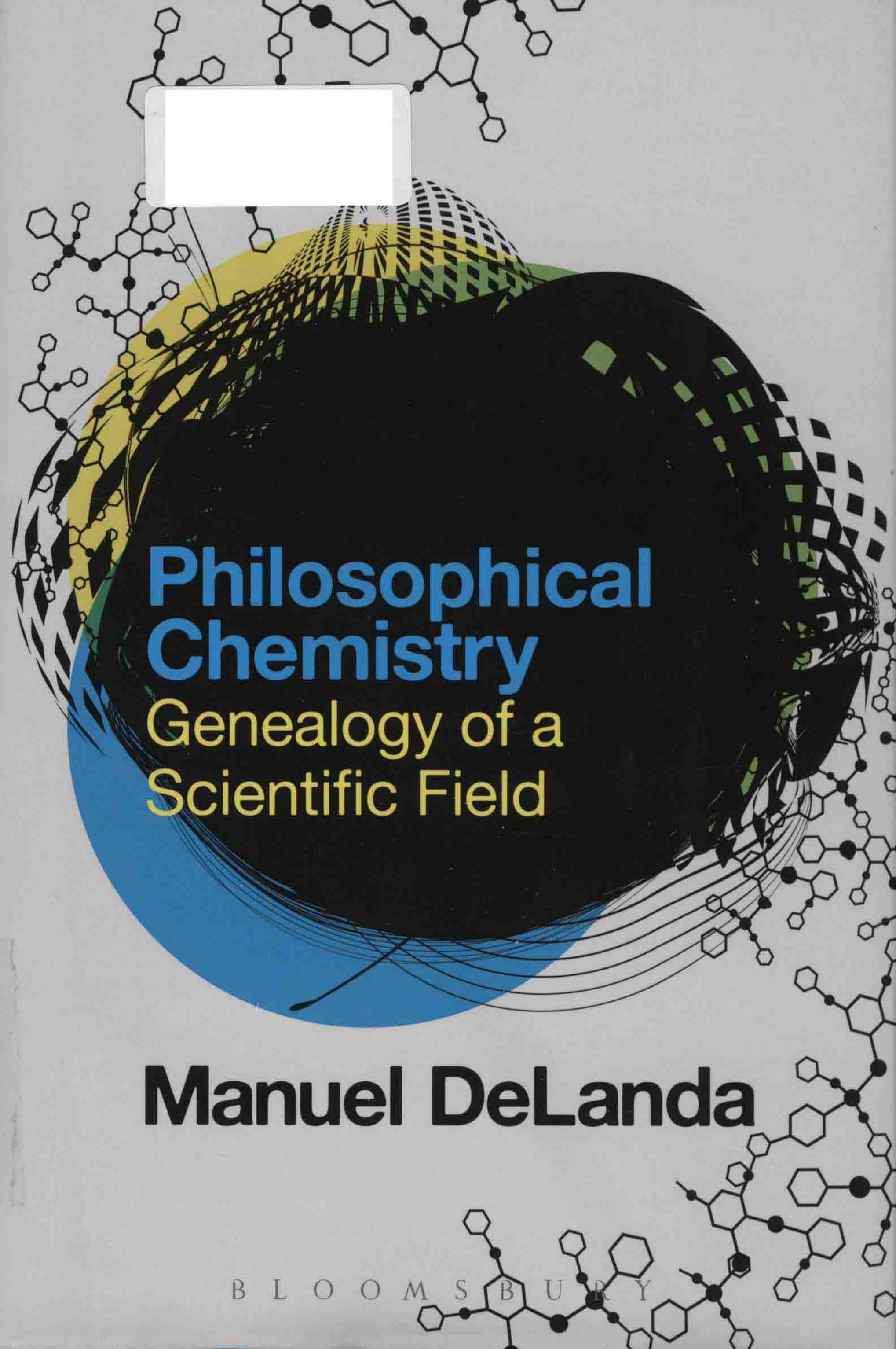

Philosophical Chemistry

Genealogy of a Scientific Field

Manuel DeLanda

BLOOMSBURY

PHILOSOPHICAL CHEMISTRY

Genealogy of a Scientific Field

Manuel DeLanda

Bloomsbury Academic
An imprint of Bloomsbury Publishing Plc
B L O O M S B U R Y
LONDON • NEW DELHI • NEW YORK • SYDNEY

Bloomsbury Academic
An imprint of Bloomsbury Publishing Plc

50 Bedford Square
London
WC1B 3DP
UK

1385 Broadway
New York
NY 10018
USA

www.bloomsbury.com

BLOOMSBURY and the Diana logo are trademarks of Bloomsbury Publishing Plc

First published 2015

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

ISBN: HB: 978-1-47259-183-8
ePDF: 978-1-47259-185-2
ePub: 978-1-47259-184-5

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress.

Typeset by Fakenham Prepress Solutions, Fakenham, Norfolk NR21 8NN
Printed and bound in Great Britain

PHILOSOPHICAL CHEMISTRY

BY THE SAME AUTHOR

Intensive Science and Virtual Philosophy
A New Philosophy of Society
Philosophy and Simulation

ALSO AVAILABLE FROM BLOOMSBURY

Being and Event, Alain Badiou
Conditions, Alain Badiou
Infinite Thought, Alain Badiou
Logics of Worlds, Alain Badiou
Mathematics of the Transcendental, Alain Badiou
Theoretical Writings, Alain Badiou
Theory of the Subject, Alain Badiou
Cinema I, Gilles Deleuze
Cinema II, Gilles Deleuze
Dialogues II, Gilles Deleuze
Difference and Repetition, Gilles Deleuze
The Fold, Gilles Deleuze
Foucault, Gilles Deleuze
Francis Bacon, Gilles Deleuze
Kant's Critical Philosophy, Gilles Deleuze

Logic of Sense, Gilles Deleuze
Nietzsche and Philosophy, Gilles Deleuze
Proust and Signs, Gilles Deleuze
Anti-Oedipus, Gilles Deleuze and Félix Guattari
A Thousand Plateaus, Gilles Deleuze and Félix Guattari
Barbarism, Michel Henry
From Communism to Capitalism, Michel Henry
Seeing the Invisible, Michel Henry
Future Christ, François Laruelle
Philosophies of Difference, François Laruelle
Essay on Transcendental Philosophy, Salomon Maimon
After Finitude, Quentin Meillassoux
Time for Revolution, Antonio Negri
Althusser's Lesson, Jacques Rancière
Chronicles of Consensual Times, Jacques Rancière
The Politics of Aesthetics, Jacques Rancière
Of Habit, Félix Ravaisson
The Five Senses, Michel Serres
Statues, Michel Serres
Times of Crisis, Michel Serres
Art and Fear, Paul Virilio
Negative Horizon, Paul Virilio

INTRODUCTION

There is no such thing as Science. The word "Science" refers to a reified generality that together with others, like Nature and Culture, has been a constant source of false problems: are controversies in Science decided by Nature or Culture? Avoiding badly posed problems requires that we replace Science with a *population of individual scientific fields*, each with its own concepts, statements, significant problems, taxonomic and explanatory schemas.[1] There are, of course, interactions between fields, and exchanges of cognitive content between them, but that does not mean that they can be fused into a totality in which everything is inextricably related. There is not even a discernible convergence towards a grand synthesis to give us hope that even if the population of fields is highly heterogeneous today, it will one day converge into a unified field. On the contrary, the historical record shows a population progressively differentiating into many subfields, by specialization or hybridization, yielding an overall divergent movement.

This book is an attempt at creating *a model* of a scientific field capable of accommodating the variation and differentiation evident in the history of scientific practice. This model can only be applied to concrete fields, so every aspect of it will be illustrated with examples from the history of chemistry. This particular field has all the necessary characteristics to serve as an exemplary case: it has undergone splittings through specialization (inorganic versus organic chemistry) as well as giving birth to hybrids with other fields (physical chemistry). The model is made of three components: a *domain of phenomena*, a *community of practitioners*, and a set of *instruments and techniques* connecting the community to the domain. The domain of a scientific field consists of a set of objective phenomena.[2] The term "objective phenomenon" refers to an effect that can emerge spontaneously or that, on the contrary, might require active interventions by an experimenter to refine it and stabilize it. The former case is illustrated by the celestial phenomena studied by astronomers, while the latter is exemplified by laboratory phenomena.

The domain of any actual field will typically contain phenomena that exist between the two extremes of the given and the fabricated, the combinations being so varied that few general statements can be made about all domains. One generalization is that the contents of a domain must be *publicly recognizable, recurrent, and noteworthy*.[3]

The domain of chemistry is composed of substances and chemical reactions. A good example is the reaction of an acid and an alkali, and their transformation into a neutral salt. The chemical reaction itself had been publicly recognized to exist for centuries before chemistry became a field. The powerful effervescence produced when acidic and alkaline substances come into contact, suggesting an internal struggle or even a battle, had been considered noteworthy since ancient times. But once chemistry came into being, additional phenomena began to accumulate around this one, enriching the content of the domain. One was the effect produced when acids or alkalis interacted with vegetable dyes, acids changing them to blue, while alkalis changed them to red. This effect began as a phenomenon but it was rapidly harnessed as a tool, a reliable indicator of the acidity or alkalinity of a substance. By the middle of the eighteenth century, the products of the chemical transformation, neutral salts, had proliferated and become the most important member of the domain: the chemist had learned to synthesize a neutral salt not only by the reaction of acids with alkalis, but also by reacting acids with metals and other bases. From those early beginnings, the chemical domain has evolved into a highly complex entity. By one calculation, the domain included over 16 million substances at the close of the millennium, with as many as a million new substances added to it every year.[4] Thus, unlike the concept of Nature, which suggests a fixed object of study in which everything is given, a domain is a growing and changing target, never ceasing to pose problems to practitioners, and constantly eluding the goal of a final and definitive account.

The second component of a field is a community of practitioners whose personal practices are shaped by a variety of *cognitive tools*: the concepts they use to refer to phenomena and their properties; the set of statements they accept as true; the taxonomies they use to give order to the domain; the significant problems on which they are working at any one time; and the explanatory strategies they use to search for solutions to those problems.[5] These various cognitive tools are what is produced by the community of practitioners, but it is also what guides and gives regularity to their daily activities. The term "tool" is used deliberately to suggest that concepts, statements, problems, explanatory and taxonomic schemas must be deployed *skillfully* to have a real effect on a field. The role of manual skills in the laboratory has been greatly emphasized in the last few decades, as has their mode of transmission: skills are taught by example and learned by doing. But skills are not the monopoly of laboratories. Any cognitive tool must be applied using abilities that are also acquired by training. In addition to this, the set of cognitive tools available to a community at any one point in time will be modeled as forming a heterogeneous collection of individual items not a monolithic theory. An apparent exception to this is cognitive content that has been given an axiomatic form, transformed into a set of statements (axioms), the truth of which is beyond doubt, from which many more statements (theorems) can be mechanically derived. But far from constituting an exception, concrete axiomatizations should be considered an additional cognitive tool added to the rest, rather than the final polished form that all cognitive content should take.

The third component of a field is the instruments and procedures that act as an interface between a community and a domain. Sometimes instruments are developed by practitioners as part of a well-defined line of research. In this case, they play the role of mere tools, increasing the accuracy of measurements or reducing the noise in the information that is extracted from a phenomenon.[6] But often instrumentation plays a larger role, that of *enabling experiments* that would not be possible to perform otherwise.[7] A good example is the electrical battery (the Volta pile), an experimental device used by physicists to produce phenomena related to electricity, but that became a powerful analytical instrument in the hands of chemists. The continuous electrical current created by the battery, when transmitted through a liquid solution in which certain chemical reactions were taking place, allowed chemists to disintegrate even the most stubborn compound substances, greatly increasing the power of chemical analysis and creating an entire subfield with its own phenomena crying out for explanation: electrochemistry.

Although these three components would suffice to model a field and follow its changes through time, a fourth one must be added for the model to be complete. This is the component that replaces the reified generality Culture. Much as the members of a scientific community must be pictured as being *embodied*, possessing the necessary skills to deploy the available cognitive tools, so the community itself must be viewed as *socially situated*. In particular, the practitioners of a field typically work in an institutional organization—a laboratory, a university department, a learned society—and organizations possess an authority structure that must be legitimate (therefore involving social values) and must have the capacity to enforce its mandates (therefore involving practices that are non-cognitive). These institutional organizations interact not only with one another—as when laboratories attempt to replicate or falsify the findings of other laboratories—but with governmental, ecclesiastical, and industrial organizations as well. In these interactions, practitioners must be able to justify their claims to knowledge, a justification that often involves a variety of rhetorical strategies. As the organizations evolve in time, they also tend to develop myths about their origins that play an important role in the legitimation of their authority. This fourth component of the model is the least important because although social values and professional agendas do affect the *focus of research and its rate of advance*, it can be shown that their effect on the cognitive content of a field is minimal.[8] This statement goes against the grain of most of the sociological literature on Science produced in the last few decades, so it will have to be defended. The necessary arguments, however, will be postponed until the last chapter of the book, after we have examined what really matters for a model like this: the contingent development of the cognitive tools produced by successive communities of practitioners, as well as the contingent evolution of the domain and instrumentation.

The fourth component of the model impinges on another question: through their personal practices, members of a scientific community can improve previously developed cognitive tools, and invent entirely novel ones, but these achievements can be lost unless they are consolidated into a *consensus practice*.[9] Personal practices are extremely varied, but according to contemporary evidence this variation leads to disagreement mostly over the content of *frontier* research. The same evidence shows that over time, as the research ceases to be the cutting edge, not only can collective agreement be reached but the agreed upon content can become accumulated in textbooks.[10] Textbooks are notoriously unreliable when it comes to questions of the history of a field (mythologized genealogies often find a home in these teaching aids) or questions about scientific methodology (justificatory rhetoric often accompanies the discussion).

But once we get rid of myth and rhetoric, the content of textbooks can serve as an important guide to what has become collectively accepted, and what is being taught to the next generation of practitioners, at any one point in time.[11]

The strategy followed in this book is to use a series of textbooks, separated from each other by 50-year periods, to follow the historical formation of consensus. Chemical textbooks from 1750, 1800, 1850, and 1900 will be used to sample the content of consensus practice at regular intervals. But why stop at 1900? Because the cognitive tools that shape personal practices are characterized by both their properties as well as by their dispositions. Unlike properties, which if they are real they are also actual, dispositions can be real but not actual if their exercise is delayed or obstructed, so their full reality is only revealed with the passage of time. One disposition in particular, a cognitive tool's *improvability*, can only be documented once the tool has built a track record. Stopping the historical narrative in 1900 will allow us to use the track record that concepts, statements, problems, taxonomic and explanatory schemas have created in the twentieth century as an additional factor in the evaluation of their cognitive value.

The book is organized into three main chapters, each one dealing with one subfield of chemistry in the century in which it was developed. Eighteenth-century inorganic chemistry is discussed in the first chapter, followed by nineteenth-century organic chemistry in the second, and by nineteenth-century physical chemistry in the third. Each chapter has two sections, one dedicated to analyzing the cognitive tools characterizing each subfield in a deliberately impersonal tone, the other placing the cognitive tools in a historical context, describing how they governed the personal practices of the community—represented by chemists who played the role of exemplars of good practice—as well how they became part of the consensus. The fourth chapter confronts the question of the role of social conventions and values, authority relations and political alliances, in the history of a field. Positivist and constructivist skeptics alike use a famous philosophical problem, the problem of the *underdetermination* of theory choice by laboratory evidence, as their strategy to undermine claims to scientific objectivity. But the problem as traditionally stated is a false problem. The cases of underdetermination that can be found in the historical record are always local and transitory; that is, they always involve a few plausible rivals and are often resolved once novel evidence becomes available. The chapter concentrates on dissolving this false problem, but it also has some positive content. Social conventions may not play the constitutive role that positivists and constructivists claim, but they are real and their role in scientific practice must be evaluated. And similarly for questions about rhetoric and authority.

The bulk of the book is spent discussing the cognitive content of the field of chemistry, and half of this discussion is historical. This raises the question of why a book of philosophy should concern itself with a subject that professional historians handle so much better. The answer is that if a book's strategy is to eliminate reified generalities like Science, Nature, and Culture, it must replace them with *singular individuals*, that is, with historically unique entities: not only persons pursuing scientific careers, but individual communities and organizations, individual fields, domains, and cognitive tools. Once such an ontology is adopted, there is no choice but to take history seriously, since the identity of the entities that figure in explanations is entirely contingent. Moreover, given the reality of local and transitory underdetermination, paying attention to historical detail is not enough: *temporal periods long enough* to allow for the consequences of underdetermination to play themselves out must be studied. The choice to track the chemical field for 200 years was made for this reason, since analyzing scientific controversies over shorter periods of time has often led to erroneous conclusions. Following this strategy will force philosophers of science to master the existing historical literature, but this can only be a good thing for philosophy.

CONTENTS

1 CLASSICAL CHEMISTRY

A Multiplicity of Cognitive Tools

We must begin by exploring the question of whether the different components of a scientific field can *be improved over time*: can domains increase in complexity and order? Can instruments and techniques get better at producing information about the domain? Can the personal practices of members of the community be extended and perfected? Of these three questions the easier to answer is the second, because each laboratory instrument has its own criterion of improvement: balances improve if they can be used to determine smaller weight differences; thermometers improve if they can be used to detect smaller temperature differences; microscopes improve if they can resolve smaller details. A similar point can be made about the cognitive tools governing personal practices. If what changes over time is considered to be an overarching theory, a general criterion to determine whether it is a real improvement over a rival can be hard to find. But replacing a monolithic theory with a variety of individual cognitive tools makes answering the third question easier because the improvement of each of these tools can be judged by its own local criterion: the procedures to *fix the referents* of concepts, to *establish the truth* of statements, to *assess the significance* of problems, to *judge the explanatory power* of schemas, and to *guide the extension* of classifications can all be specified, and fallible criteria for improvement can be given. The main purpose of this chapter is to illustrate this thesis by discussing concrete examples of the different cognitive tools used by eighteenth-century chemists. After that we will explore a closely related question: granting that personal practices can improve, can these gains be consolidated and passed to future generations or communities? Can improved personal practices become improved consensus practice?

Let's begin by discussing in more detail the three components of the field of classical chemistry: its domain, its instrumentation, and the cognitive tools deployed by its community of practitioners. The domain of chemistry, as we said, is constituted by *substances and their chemical reactions.*[1] The term "substance" refers to a macroscopic entity, like a gallon of pure water in a container, not to the molecules that compose it. A population of molecules has properties of its own, such as temperature or pressure, that cannot be reduced to its components, in the sense that a single molecule cannot be said to possess a given degree of temperature or pressure. Single molecules do have properties of their own, properties like kinetic energy or momentum, but only as part of a large enough population do these molecular properties become temperature or pressure.[2]

A similar point applies to the different collective states in which water can exist—steam, liquid water, and ice: single molecules cannot be said to be in a gaseous or solid state; only large enough clusters of molecules can have those states. In the eighteenth century, chemists interacted with those emergent macro-properties not with molecules, and this despite the fact that the substances in their domain were made out of molecules.

Chemical substances are sometimes given, like water, but in most cases they are produced in a laboratory. For this reason, the chemical domain is in constant growth, as substances that do not exist naturally are synthesized and added to it, leading to an exponential increase in the number of substances.[3] Substances that are manipulated in laboratories are typically defined *instrumentally*, by the kind of process needed to produce them in purified form. Separation and purification techniques were greatly improved during the eighteenth century, but some of the distinctions that were necessary to order substances according to their purity, such as the distinction between mixtures and compounds, took much longer to be clarified. Ignoring this complication for the moment, the separation and purification techniques can be described like this. Starting with a raw material from vegetable, animal, or mineral origin, physical operations like filtration or cutting are applied to separate homogenous from heterogeneous substances. Then, using operations like distillation and condensation, homogenous substances are separated into uniform mixtures and pure substances. Finally, using either chemical reactions or operations like electrolysis, pure substances are separated into compound substances, like water, and elementary substances, like oxygen and hydrogen. This results in a hierarchical ordering of the types of substances belonging to the domain: