Poincaré, Philosopher of Science

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Poincaré, Philosopher of Science

Problems and Perspectives

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Preface

This volume grew out of the Project "Poincaré, Philosopher of Science"[1] of the *Centro de Filosofia das Ciências,* the Center for the Philosophy of Science, at the University of Lisbon. Over several years, in various colloquia and conferences, Poincaré scholars and philosophers of science from around Europe and the Americas joined with the Poincaré Project's members in Lisbon, to consider novel perspectives on all the facets of Poincaré's thought on the philosophy of mathematics and natural science and to try to find a coherent perspective on Poincaré's philosophy of science as a whole. This volume reflects the most important facets of Poincaré's contributions to the philosophy of science, by bringing together some characteristic papers from the Poincaré Project. It is by no means a complete record of the work of the Project, nor can it claim to contain all of the most important papers that eventually emerged from it; many of these have been published in other venues and reached other audiences. The purpose of the volume is, rather, to exhibit the impact of the Poincaré Project on contemporary interpretations of Poincaré's thought, through a broad sample of the innovative scholarship that the Project has fostered—and, even more, to exhibit the extraordinary breadth and depth of Poincaré's work in the foundations of mathematics and science and to encourage the growing interest in the philosophical importance of his work.

The editors would like to thank everyone who participated and assisted in the Poincaré Project, in addition to those whose papers are collected here, but in particular Professor Augusto Franco de Oliveira, leader of the Poincaré Project, and Olga Pombo, head of the *Centro de Filosofia das Ciências,* for their inspiration and support. We would also like to thank Lucy Fleet of Springer for her untiring support of this volume.

Lisbon, Portugal María de Paz

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Introduction

The work of Henri Poincaré (1854–1912) extends over many fields within mathematics and mathematical physics. In mathematics, he was instrumental in the development of the theory of functions, mathematical logic, topology, and, most famously, non-Euclidean geometry; in physics, he played a role in the development of celestial mechanics, thermodynamics, statistical mechanics, and electrodynamics. It is therefore somewhat astonishing, in retrospect, to reflect on the magnitude and importance of Poincaré's contributions in all these fields. A survey of his original scientific work would indeed be a history of the transition from the nineteenth century to modern mathematics and physics. But his scientific work was inseparable from his groundbreaking philosophical views, and the scientific ferment in which he participated was inseparable from the philosophical controversies in which he played a pre-eminent part. The subsequent history of the mathematical sciences and the philosophy of the mathematical sciences were deeply affected by Poincaré's philosophical analyses of the relations between and among mathematics, logic, and physics, and, more generally, the relations between formal structures and the world of experience.

During the twentieth century, some standard interpretations of Poincaré's philosophical views emerged which, a century after his death, are ripe for reassessment. For example, his philosophy of mathematics is mainly negatively characterized by his rejection of logicism and formalism understood as pure manipulation of symbols. His conventionalist view of the foundations of geometry and physics, too, has yet to be fully clarified; it had a decisive influence on the views of Einstein and the logical positivist movement, but in recent debates over the fate of logical positivism and the foundations of science, Poincaré's original insights into the relation between mathematical structures and experience have not been adequately appreciated. Thus in philosophy of science as in philosophy of mathematics, contemporary debates center on questions whose formation was profoundly affected by Poincaré's work and which can still be further illuminated by a better understanding of what Poincaré contributed.

The essays in this volume are divided by the broad topics of foundations of mathematics, foundations of physics, and general philosophy of science. It might seem, on the one hand, that this division is artificial, because the boundaries cannot be very precisely drawn; Poincaré's foundational work in mathematics is never remote from his interest in physical application, and his work in the foundations of physics always involved reflection on mathematical methods; both were thoroughly colored by his broader philosophical interests. And his philosophical reflections always originated in reflections on specific problems in physics and mathematics, their logical, epistemological, and practical foundations. On the other hand, the inseparability of mathematics, physics, and philosophy within Poincaré's thinking is a central part of the motivation for this entire project and therefore of this volume.

Poincaré's philosophy of science is primarily thought of in connection with his celebrated defense of conventionalism, particularly concerning physical geometry. His argument that our knowledge of the structure of space and time depends on conventional choices—on "definitions in disguise" that assign empirical significance to geometrical concepts—undoubtedly accounts for much of his influence on the evolution of the philosophy of science in the twentieth century. It suggested that because of the crucial role of definitions in applying geometry to the world, the choice between different theories is like the choice between different languages to express the same physical facts. There might be compelling grounds for a particular choice, but these can only come from considerations of simplicity and convenience; there can be no meaningful question of truth. The intrinsic philosophical interest of Poincaré's conventionalism arises from the light that it shed on the relation between physical laws and the definitions of the physical concepts that those laws employ. The idea that the fundamental principles of physics play a peculiar role, distinct both from logical principles and from empirical laws, was a fairly old one going back (at least) as far as Kant's theory of the synthetic a priori: such principles appear to have the force of necessity, yet also to describe the contingent world of empirical facts. The best example was Euclidean geometry, seen as resting on universal and necessary principles that, nonetheless, describe the space of our experience. Kant's explanation was that such principles are determined by the form of our spatial intuition. By Poincaré's time, however, this view appeared to be fatally undermined by the development and the empirical application of non-Euclidean geometry. The first step in this process was the empiricist view of Helmholtz. Where more traditional empiricists, like Mach and Mill, treated the fundamental principles of geometry as inductive generalizations, Helmholtz argued that their inductive basis lay in more primitive physical principles: the free mobility of rigid bodies and the rectilinear propagation of light. Geometry is both formal and empirical, according to Helmholtz, because it is the formal development of postulates whose empirical content ultimately derives from these elementary physical facts.

What distinguished Poincaré's approach was that it offered an explanation of the necessary aspect of geometry, without appealing to the notion of synthetic a priori knowledge. Here there is no need for a detailed account of Poincaré's conventionalism, which is discussed at length in the essays by Folina and De Paz. Nor is it necessary to try to represent conventionalism as a general guiding principle throughout Poincaré's philosophical reflections. Conventionalism, taken in its simplest sense as an account of the role of free choice in the empirical interpretation of mathematics, is only one aspect of Poincaré's thinking. A more important aspect is his emphasis on those fundamental principles that provide criteria for the interpretation and application of fundamental concepts. One role of these principles is to provide implicit definitions of the concepts that occur in them. For example, Newton's second law does not begin from a precisely defined concept of force; it specifies precisely what force is as a measurable theoretical magnitude, by identifying acceleration, as its geometrical correlate. Yet is more than a definition, and so is more than an analytic principle in Kant's sense, that is, a mere exposition of what predicates are "contained" in the concept of force. The empirical content of the law consists in the program that it defines, for determining the forces of interaction among bodies from their observed relative accelerations; it makes their relations intelligible *as* interactions. The form of necessity that it imposes lies in its strict requirement that absolutely every component of every accelerated motion can be traced to a physical source, thus completing an action-reaction pair. In principle, one might be tempted to call this an unfalsifiable claim, compatible with any finite body of empirical evidence. In practice, it defines the perturbation theory for Newtonian mechanics. Within the framework defined by Newton's laws, the investigation of any interacting system can start from the simplest idealized model, and every deviation from the ideal behavior is informative, giving rise to a succession of corrections to the initial simplified estimates of the properties of the system.

We thus see that Poincaré's conventionalism is one facet of a broader philosophical orientation that defines, not only an approach to general questions in the philosophy and methodology of science, but also a perspective on foundational problems in mathematics and mathematical physics, from which the role of formal principles appears in a particularly revealing light. Poincaré's technical researches were never completely detached from his appreciation of the general structural principles that organize particular fields of inquiry and define their fundamental questions. In the foundations of geometry, this orientation directs Poincaré not only to the explicitly philosophical questions surrounding the nature of space and time and the empirical status of non-Euclidean geometry, but also to the exploration of Klein's group-theoretic conception, the connections between geometry and formal logic, and the generalization of geometry through the development of *analysis situs* and the first steps toward modern topology. This expanded conceptual framework for geometry, in turn, enabled Poincaré to develop his distinctive group-theoretic approach to electrodynamics, a clear forerunner to Einstein's theory of relativity. The same philosophical orientation appears in Poincaré's studies on the foundations of probability theory and his uses of probabilistic considerations as a framework for thinking about the foundations of thermodynamics, statistical mechanics, and celestial mechanics.

This complicated mixture of detailed conceptual analysis, in the foundations of science, with reflections on the most general problems in the philosophy of science—methodological, epistemological, and even metaphysical—is an essential feature of Poincaré as philosopher and is therefore the central motivation for the present collection of essays. It starts with a set of essays on general aspects of Poincaré's philosophy of science—beginning with his early philosophical education—and proceeds to essays on some aspects of his work in the foundations of mathematics and physics. It is not meant to offer a complete picture of Poincaré's philosophy, but, rather, a framework for further study of the interactions between philosophical and scientific inquiry that gave his scientific work, remarkable as it was from a purely scientific perspective, its distinctive philosophical character and its enduring relevance to the philosophy of the exact sciences.