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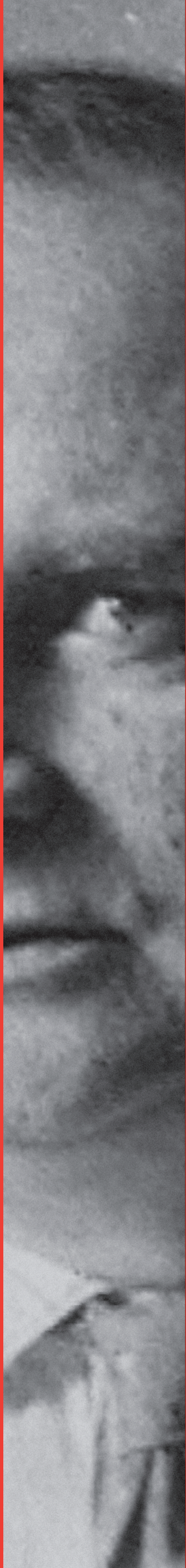

Manuscripts and Documents on the History of Physics: A Historical Materialist Textbook

Boris Hessen

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Boris Hessen

Edited by Pietro Daniel Omodeo
and Sean Winkler

FOREWORD

Verum Factum provides a transdisciplinary forum of discussions about the development, goals and consequences of epistemic activity. It fosters the publication of studies on the cultural-historical, socio-economic, environmental and especially the political dimensions of knowledge and scientific research.

The series starts with an unpublished work of a paradigmatic author, Soviet scholar Boris Hessen (1893-1936), who instigated the socio-political history of science. His famous essay on the “Socio-Economic Roots of Newton’s *Principia*” (1931) signalled—and at the same time inaugurated—a new era in science and technology studies. His relevance goes far beyond the sociological history of science, to which the appreciation of his legacy has often been limited, because he rather called for an integration of scientific education, socio-economic explanation, philosophical reflection, and political activism. He programmatically did so on Marxist grounds.

Hessen’s work raises the question about the collective praxis of knowledge and its underlying norms, aims and social orientation. In this regard, it is the ideal work with which to begin a series in historical and political epistemology, for which we chose the title *verum [ipsum] factum*, coined by Giambattista Vico. Accordingly, we aim to explore the emergence of knowledge cultures and techno-scientific societies from the global perspective of human activity and imagination. Hessen’s later synthesis of history of science and material history imbues Vico’s historicist position with concrete epistemological meaning by showing the relation of practical and conceptual aspects in the formation of scientific categories.

The present publication combines the transcript of the proofs for Hessen’s unpublished textbook, an English translation of selected parts and our appreciation of Hessen’s work within a broader historical and geographical picture.

Hessen’s textbook was an attempt to develop a historical-materialist model of scientific development in direct engagement with original source materials. In terms of Hessen’s oeuvre it may help to clear up at least two misunderstandings. First, it shows that his famous essay of 1931 by no means was an *ad hoc* improvisation; rather, it was based on years of preparation. Many of the texts he included in the textbook were translated by him and others for the first time into Russian, and presented classical physics as a crucial case study in the evolution of science and knowledge in general. Second, and more importantly, the textbook proves that Hessen was not so much trying to put forth an unduly reductionist view, constraining the dynamics of scientific development to economic impulses, but rather tried to take into account as many aspects as possible. This already went beyond a clear-cut distinction between internal and external factors in knowledge dynamics.

The commentary essays in this volume contextualise Hessen's work from different perspectives. The leading thread is the common interest in his approach, i.e. the methodological project concerned with the connections between capitalism and science at a material as well as ideological level. The essays range from the particular historical background of his work and life, to Hessen's work in physics and the general reception of his historical work, in particular in connection with the historiographic category of the Scientific Revolution. Indeed, Hessen did not limit himself to the English case nor to the seventeenth century as the time of emergence of Newton's physics. Instead, he broadened the scope of his spatial and temporal exploration, in order to present mechanics as just one aspect of a more complex historical and political diagnosis of the main trends of techno-scientific modernity. His textbook includes sources as varied as the scientist-engineers of the Renaissance, German rationalist philosophy and legal culture, French absolutist programs of science institutionalisation, mercantilism, and the beginning of colonial globalisation. From this perspective, a common multifaceted process shaped the forms of epistemic development fuelled by economic and political interests.

In methodological terms, Hessen's approach shows how historical and philosophical as well as scientific and socio-economic levels can be integrated into a complex picture of the formation of science in both ideal and material sense. Today, the inquiry into connections of science, knowledge and emancipation as the products of the historical metabolism between human societies and their environments, in which scientific truth and objectivity are grounded, is still a project of great cultural and political urgency. With this volume we intend to launch a book series that will support and contribute to this end.

Sascha Freyberg and Pietro Daniel Omodeo
for the editorial collective of *Verum Factum*

An Unpublished Manuscript by Boris M. Hessen: Materials and Documents on the History of Physics[1]

Rose-Luise Winkler

Boris Mikhailovich Hessen (russ. Gessen), the Soviet scientist, physicist, philosopher, sociologist and historian of science who came from the Ukraine, belongs to that generation of Marxist-oriented scientists who died tragically before their time. As we know today, B.M. Hessen was convicted on fabricated charges by the High Military Court of the USSR and executed on the same day. He was 43 years old.

His destiny is exemplary of many scientists who fell victim to Stalinist repression. The exact date of his conviction only became known through the publication of information from his investigative file from the central archives of the KGB via the work of Gennadij E. Gorelik in 1992.[2] Until this time, it was thought that he died in 1938,

1 The proofs were found by Vladimir S. Kirsanov in the estate of A.P. Juškevič in December 2004 and kindly made available to me after being transferred to a CD-ROM in the spring of 2005. This article is a shortened, revised version of my lecture "Boris Hessen and the Origins of Sociology of Science in the Soviet Union (Russia)" given at the XXII. International Congress of the History of Science, Beijing 24-30 July 2005. It was published in *Sitzungsberichte der Leibniz-Sozietät* 92 (2007): 133-152.
This presentation was given to the class in the social sciences and humanities on 14 December 2006, and was dedicated to Boris Hessen on the occasion of the seventieth anniversary of his death on 20 December 2006.

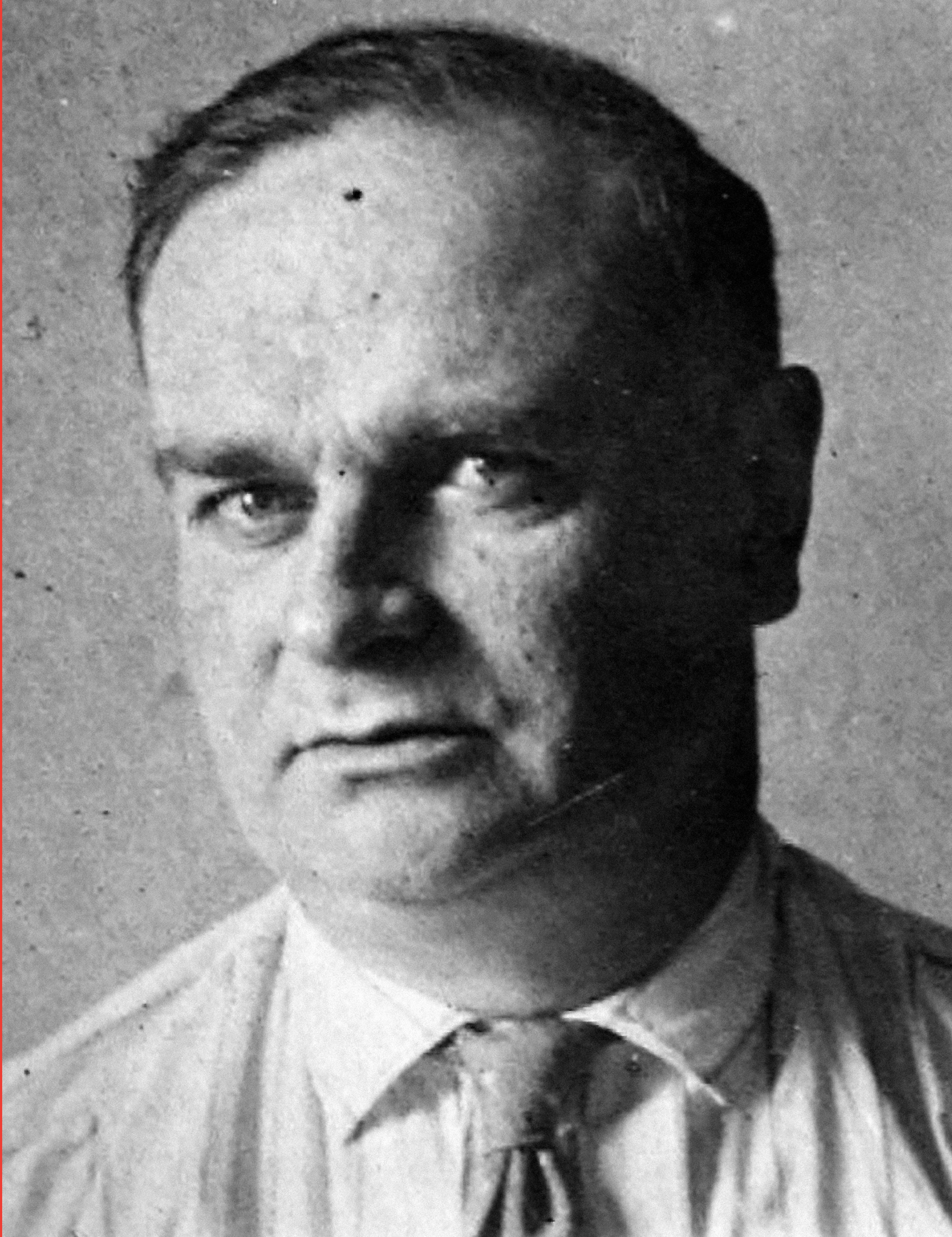
2 Г.Е. Горелик, "Москва, физика, 1937," *ВИЕТ*, № 1 (1992): 15–32; German: G. E. Gorelik, *Physicists under Stalin (*Braunschweig, 1995), 98–133.

but one can hardly ward off a macabre feeling today when these dates are falsely given in important publications.[3] The date of his death is falsely specified in earlier publications. This can be concluded from the very extensive documentation from the commission for the history of knowledge at the Academy of Sciences of the USSR, which appeared in 2003.[4] According to this information, Hessen was arrested no later than the 1st of September 1936 and then died in exile. Whether it is a case of conscious falsification of the data or only ignorance (more specifically, insufficient diligence) requires concrete evidence that is not available to me at the present time. The report referred to by G.E. Gorelik from the collection of the Physics Institute of the Academy of Sciences in Moscow (FIAN) from 1937 makes it clear that the participants did not know that Hessen was no longer alive at this time. Additionally, in the summer of 2005, Eugen L. Fejnberg[5] shared his memories of two general assemblies of students and doctoral candidates which took place at the Physics Faculty of the MGU. Fejnberg also had the opportunity to attend lectures given by Hessen between 1930-1935. According to him, the allegations against Hessen were never made public, though allegedly, he created a "treasonous teaching

3 Thus in the compendium *Академия наук. Персональный состав, vols. 1 and 2*, 2nd edition (Moscow: Publisher of Science, 1999), 176, one can find the following entry notes: Гессен, Борис Михайлович. Родился 28 августа 1883 г., Елизаветград Херсонской губ., Умер 9 августа 1938 г., Москва (?), Философ. Член-корреспондент по отделению общественных наук (философия), с 1 февраля 1933 г. This data can also be found in the CD-ROM "The Russian Academy of Sciences 1724-1999", in Russian and English (as well as in Internet publications): Boris Mikhailovich, Born on August 28, 1883, Died on August 9, 1938, Philosophy, Corresponding Member of the Division of Social Sciences, since February 1, 1933.

4 See Комиссия по истории знаний — 1921–1932 гг. Из истории организации историко-научных исследований в Акалемии наук. Составители: В.М. Орел, Г.И. Смагина. Изд.-во Наука (Ст. Петербург, 2003), 580, 681. The year given here, 1936, is correct, but the date of birth is wrong (1883). Ibid. Unfortunately, data is often adopted today without prior checking. In Hessen's case, this is also reflected in the international literature.

5 Evgenij L'vovic Fejnberg (1912 – 10.12. 2005), KM (1966) und OM (1997) of the Russian Academy of Sciences. At the beginning of August 2005, I spoke with Eugen L'vovič in his apartment in Moscow.



program of Physics".[6] The Physicist Grigorij S. Landsberg defended the program. According to Fejnberg, "He (Landsberg) had created the program, not Hessen."[7] Fejnberg could not be certain as to the exact time the general assemblies took place (1936?)[8]: "They spoke of ten years exile for such offences. Hessen had established a small circle for students to discuss philosophical questions concerning the natural sciences. He could have participated [in that circle], however he decided for another circle."

We cannot provide any answer to the question as to whether a definitive program of Hessen's underwrit these disputes, and whether this program already existed in the well-known lecture from 1931 or in the contents of the manuscript — which was not published but which we have received in the aforementioned proofs. Likewise, the most important witnesses of the time who could have provided information are no longer alive.

As the aforementioned source documents indicate, Hessen was excluded from the Academy of Sciences via a decree by the general assembly on the 29th of April, 1938.[9] A corresponding decree from the 5th of March in 1957 rehabilitated him.[10] According to statements of the Russian society, *Memorial*, the physical remains of B.M. Hessen, as well as those of Arkadij O. Apirin who was convicted with Hessen, lie in Donskoe cemetery in Moscow.[11] Branded as an enemy of the people and a traitor, his works were removed from the libraries of his home

6 Regarding this, compare Е.Л. Фейнберг, "Вавилов и Вавиловский ФИАН," in *Эпоха и личность. Физика. Очерки и воспоминания* (Москва: Физматлит, 2003), 241.

7 Ibid.

8 That could be true, because Hessen's arrest could not have gone unnoticed.

9 Compare Комиссия по истории знаний — 1921 – 1932 гг. Из истории организации историконаучных исследований в Акалемии наук. А.а.О.

10 Ibid. This was preceded by the rehabilitation decided upon by the Supreme Military Court of the USSR on April 21, 1956, by which Hessen's arrest was annulled for lack of a sufficient reason.

11 Internet publication by *Memorial* (http://www.memo.ru). Compare Boris Hessen, *Wikipedia*.

and he was also never mentioned again in Soviet scientific publications. Igor E. Tamm[12], above all, had urged for Hessen's rehabilitation; they had studied together in Edinburgh and were friends since childhood.[13] In the portentous years between 1936-1937, Igor E. Tamm lost not only Boris Hessen, who was one of his closest friends, but also his brother and many of his closest relatives and pupils.

Regarding the false entry of Hessen's birth date, the error[14] appears to be a result of his imprisonment as most of the information regarding him and his activities was deleted from the relevant archives and are no longer accessible. Some evidence has nevertheless been preserved: from the collections of the Communist Academy (Komakademija), there is a personal statement from 1924 (handwritten) and two of his CVs, one handwritten from 1924[15] and one typed from the handwriting department of the State Russian Library from 1930.[16] Both CVs contain an unambiguous birthdate of 1893.[17] One can also consult the matriculation certificate from 1913-1914 from the

12 I.E. Tamm (1895–1971), Nobel Prize for Physics 1958.

13 On the occasion of the 100th birthday of I.E. Tamm, the magazine *Priroda* published a special issue with memories from his contemporaries, students and a number of his original documents, in which the fate of Boris Hessen is also mentioned. Cf. К 100-летию Игоря Евгеньевича Тамма, *Специальный выпуск. Природа* № 7 (1995). See also Е.Л. Фейнберг, *Эпоха и личность.А.а.О,* 60.

14 This is probably a printing error. This date is also in the compendium: *Научные работники Москвы. Часть IV* (Ленинград, 1930), 63. There it states: Гессен Б.М. доц. Каф. Истории и философии естествознания при МГУ, н. сотр. Комакадемии; физика, методология точн. Естествознания, обоснование статистич. Механики и теории относительности. ~ Пл. Свердлова, 2-й дом Советов, кв. 21, тел. 2-80-77 (16 VIII 83 Елизаветград).

15 Compare Автобиография Б.М. Гессена. 8. VII. 1924. Архив АН СССР. Фонд 364 (Komakademie/IKP). Опись 3а. № 17. Л. 3. (reproduced in the Appendix).

16 Автобиография Б.М. Гессена. Отдел рукописей ВГБИЛ, Фонд 384 (В.И. Невский), папка 6, ед. Хр. 15

17 These two documents are based on my information about Hessen's year of birth. Cf. My short biography, "B.M. Hessen," in *Portraits of Russian and Soviet Sociologists*. *Special Issue* (Berlin-Moscow, 1990), 126-130, (German and Russian, 1987-1988: 208-210, 168-170). An abridged account is contained in *Социологи России и СНГ XIX -XX вв. Биобиблиографический справочник. Идиториал УРСС* (Москва, 1999), 64.

University of Edinburgh, where his name is written as Hessen and his age is given as 20 years old. This piece of evidence is handwritten as well.[18] We also have printed evidence of I.E. Tamm's studies in Edinburgh from 1913-1914 (non-graduation certificate, Faculty of Arts) with a signature from E.T. Whittaker.[19] One can assume that Hessen received such a certificate as well.

The sparse biographical accounts that we do have of Boris Hessen (no reliable information regarding his family can be ascertained, despite many attempts on my part) primarily concern details such as his fields of activity and publication areas, as indicated in the two CVs previously mentioned. We also have E. Tamm's reminiscences. Some additional fragments of information can be gleaned from consulting the archive of the Russian Academy. One depiction, which is given by Leonid V. Levsin in the book "The Deans of the Physics Faculty at Moscow University", is based on an evaluation of archival documents of Moscow University. It appeared in 2002 for the then-approaching 250-year celebration of the MGU in 2005.[20] His complete chronology of teaching in Physics includes a historical time period from 1756 until the present day. From 1805 to 1930, Levsin mentions the deans of the physics-mathematical *otdelenije* and later the faculty; an independent physics *otdelenije* came to be for the first time and was later remodelled into a faculty in 1933 with Boris Mikhailovich Hessen as the first Dean.[21] From February 1931 until November 1934, Hessen was Dean of the first independent Physics Faculty of Moscow University and

18 University of Edinburgh Matriculations (1913-1914), 45, No. 873. The University requires a sum of 12 pounds for a copy of this certificate. The copy is in my private archive.

19 Compare "И.Е. Тамм в дневниках и письмах," *К 100-летию Игоря Евгеньевича Тамма. А.а.О*: 137.

20 Л.В. Лёвшин, *Деканы физического факультета Московского университета* (Москва, 2002). Leonid V. Levšin has been the Director of the *Otdelenije* for experimental and theoretical physics at the MGU since 1969. The archive of the MGU was not accessible to me personally and closed in 2004-2005 due to relocation of the library to the new building.

21 Ibid., 18, 198–203.

from 1930 until his imprisonment, Director of the Physics Institute at the MGU. In 1934, FIAN was founded in connection with the relocation of the Academy from Leningrad to Moscow; its director, Sergej I. Vavilov, selected Hessen as his deputy. His successor in the office of Dean was the Physicist, Semen E. Chajkin.

Hessen was a member of various scientific committees (the natural sciences section of the Komakademie, the AdW of the USSR, and the GUS) and an editor at the following periodicals: The *Natural Sciences and Marxism* (Естествознание и марксизм), *Advancements in Physics* (Успехи физики), *Physics Journal of the Soviet Union* (published from 1932-1936 in Kharkov in German by the highest advisory body for economic organization in the USSR), the series *Biographies of Prominent People* (Биографии замечательных людей), the *Great Soviet Encyclopedia* (first edition) as well as the translation series *Classics of the Natural Sciences*.

From 1928, Hessen began publishing papers on questions in theoretical physics, on the methodology, philosophy and history of the natural sciences as well as on questions of teaching and formation (*Ausbildung*) in theoretical physics and in the natural sciences. The most-well known was his lecture "Социально-экономические корни механики Ньютона" (The Socio-Economic Roots of Newton's *Mechanics*)[22], which he presented at the 2nd International Congress for the History of Science and Technology in London.[23] Today, this lecture counts as a seminal work in science studies and the sociology of science. The lecture has been translated into six European languages

22 Published in 1933 and 1934 as a single publication. Reprinted in 1992 and 1998 in: R.-L. Winkler, *Из истории социологии науки: советский период 1917-1935, У истоков формирования социологии науки. Россия и Советский союз. Первая треть XX. века. Тюмень*.

23 Boris Hessen, "The Social and Economic Roots of Newton's *Principia*," in *Science at the Crossroads. Papers presented to the International Congress of the History of Science and Technology held in London from June 29th to July 3rd, 1931 by the Delegates of the URSS* (London: Russian Foreign-Languages Press, Kniga, 1931), 149–212.

as well as into Japanese, and has been repeatedly published.[24] The majority of the translations use the English version from 1931 as their foundation, which unfortunately contains a number of errors, above all in the reproduction of technical terms as well as in the erroneous entries of names of people and places.[25] The chosen topic, which is already clear in the title "socio-economic roots" is for example distorted in the German translation (by comparison with the English version), as the terms social and economic are separated.[26] Hessen understood these terms in a sense that can be traced back to Marx's formation theory approach, which is derived from the concept of the "economic formation of society" (*ökonomischen Gesellschaftsformation*). In the English translation, we find the expressions "economic formation of society" and "economical formation of society," which stems from Marx and Engels themselves.[27] By contrast, the concept of the "socio-economic formation" and the adjective "socio-economic" are not present. They are rather traceable to Hessen. These are equivalent to later descriptions of the question of societal determination by social phenomena (like science, art, culture, production, etc.) used in Marxist-oriented sociology and scientific research.

24 English (Sidney 1946, Lexington Mass. 1968, London 1971, New York 1971), Swedish (Stockholm 1972), German (Frankfurt a.Main 1974), Spanish (Havanna 1985, Montevideo 1988, Pentalfa, Oviedo 1999, Barcelona 2001), French (Paris 1978 & 2006), Italian (Bari: De Donato 1977), Japanese (S.R. Mikulinskij speaks of two editions: С.Р. Микулинский. Очерки развития историко-научной мысли. Москва 1989).

25 Various questions arising from the translation have been pointed out in different ways in the literature. However, the full scope of the shortcomings in the translation have only now been made clear through a comparison with the Russian version as well as an examination of Hessen's lecture. Efforts from GDR scientists to make a new translation and edit were unsuccessful up until the end of the 1980s.

26 J.G. Crowther's formulation from 1935, given in the German translation [translated here into English–Ed.], is even more meaningful: "The Social and Economic Causes of Newton's Principia". See the Introduction to *Great English Researchers: From the Lives and Work of Great English Scientists in the 19th Century* (Berlin, 1948), 10.

27 For help in finding the English terms in K. Marx and F. Engels regarding the concept of formation, I would like to thank Mrs. Regina Roth of the academy-project MEGA at the BBAW.

The fact that Hessen initiated such a widespread discussion despite the errors and weaknesses of the translations—as is given expression in the reception of his work since 1931—speaks for the productivity of his approach. The impact of his contribution is comparable with the concept of a paradigm shift from Thomas Kuhn in the history of science in the 60s and 70s. The concept of socio-economic determination was, in the following period, one of the most important foundational concepts for sociological analysis, because it translated assertions about the relationship between societal formations and science into empirically graspable and comprehensible facts. In so doing, Boris Hessen formulated one of the cardinal problems of scientific-sociological research and posed the relevant questions with a specific object in mind: Was Newton an exception? Can Einstein's theory of relativity be situated within this perspective today? How does the formation theory approach and its conception of modernity, which was shaped by Marxism, stand today? This question is rarely considered today, if not deliberately shunned. That it has not been solved is due neither due to limited theoretical interest nor from insufficient significance; rather, it constitutes one of the contemporary problems of the development of the social sciences.

Additionally, the Russian publication includes historical sources and bibliographical references that were not included in the English version and which are still of interest today.[28] One example is the satire, which is not known in German, entitled *Arrêt burlesque, donné en la grand'chambre du Parnasse, en faveur des maîtres-es-Arts, médecins et professeurs de V Université de Stagyre, au pays des Chimères: pour le maintien de la doctrine d'Aristote* (first published in 1671), written

28 A new transcription of the lecture into German was made by the author (forthcoming).

by Nicolas Boileau.[29] In the (retrieved) manuscript, Hessen elaborately describes the history of this satire as a small sociological lesson in the relationship between science and power in the overall struggles between the central government and the provinces. The play was translated from the French by a Russian physicist and published in a history of physics.[30] It castigated the behaviour of the Scholastic philosophers of nature vis-à-vis the experimental, empirical investigation of nature. The satire clearly asserts that scientific knowledge cannot be governed by the decisions of the state and other committees, and certainly not by the judgments of the courts. Questions about truth and falsehood in the process of scientific understanding cannot be regulated by court orders (such as those concerning forbidden teaching subjects). Analogous situations, such as those depicted in this satire, are arguably in no way rare in the history of science in other countries. This is also true for Hessen's time considering science in the USSR, at least partially: empirical sociological research was increasingly based on restrictions. In physics, for example, a dispute arose concerning the influence of bourgeois attitudes on Einstein's theory of relativity; a debate in which Hessen was publicly accused.

Hessen, who deployed sociological methods (such as time-budget analysis) in his scientific work in order to discuss problems of the scientific work of physicists, also intensively engaged with questions about the social organization of science. He was a member of the social-scientific class of the Academy (since 1933) and was actively involved in the centre of the physical work in the academy and in the university as a physicist. The discrepancy that exists in the history of

29 In 1671, theologians and physicians at the University of Paris demanded a government decision to condemn the teachings of R. Descartes. In a biting satire, N. Boileau ridiculed these demands of the learned Scholastics.

30 It comes from N.A. Ljubimov, as I now see in the unpublished manuscript. Compare Н.А. Любимов, *История физики. Vol. 3.* (St. Petersburg, 1896), 508-511 (from the edition: *Oeuvre De Boileau-Despreux* (Paris, 1798), 391).

the reception of the works of B.M. Hessen, which consists of an imbalanced portrayal of his creative work in all of its aspects—physical, philosophical, sociological, and in the history of science—becomes more apparent in this unpublished manuscript. Little is known about his work in physics, and not much has been preserved in written records. It can be considered a scholarly desideratum for future physicists, researchers into nature and those philosophers, sociologists and historians of science who are interested in the history of physics.

Hessen is eager to show the role of historical investigation for understanding the categories of physics. He places great importance on acquaintance with the original sources. Therefore, he presents the history of physics in combination with the original sources, which he divides respectively into three themes according to his program. The first theme is the *socio-economic preconditions* (Italics from the author) of the classics of physics. The second theme is the emergence and development of the major principles of classical mechanics and the disputes over them in the seventeenth century. The third theme is the problem of movement in Newtonian physics, and the struggle between materialism and idealism concerning this problem in the seventeenth century. Concerning the first and third themes, some sections of his communication from 1931 convey a deepened perspective, which can easily be ascertained on the basis of a comparison with the working out of his lecture. This means that the wording of the subheadings often agree.

Hessen extensively clarifies his approach in the contents of the extant foreword (pp. 6-7):

> "The following volume of documents and materials has the goal of making the reader familiar with the original sources in the history of physics. It can be differentiated from the analogous collections which exist in western-European literature–which, for the most part, are a compilation of excerpts

> from the classical works in chronological succession–above all through the selection and representation of the source materials. The material about physics is envisaged against the background of the *socio-economic relationships* [Italics by the author] of the relevant epochs. This is explained by bringing a large amount of economic and technical material into comparison with the usual history of physics. This volume does not envisage the task of providing a systematic depiction of the history of physics, but rather is dedicated to a range of themes, which are often from periods very distant to one another. This offers us the possibility of illuminating the *socio-economic preconditions and reproductions* of ideological disputes contained in single moments in the history of the development of science more completely and comprehensively."

As Hessen notes in the foreword, he used a range of available translations and checked them against the versions in the original language. A large part of the materials were translated into Russian for the first time. Each chapter is preceded by a short introduction, which justifies the selection of sources and includes a general description to orient the reader, wherein Hessen frequently provides extensive historical commentary. The second chapter represents a type of chrestomathy of the history of physics. Many of the first translations into Russian are, at least in part, still not available for the Russian reader (for instance, the article "Antique Dynamics" from A.E. Hass, the article "On Newton's and Descartes' Dynamics" by Johann Bernoulli, as well as Roger J. Boskovič, "On the Principles of the Construction of Mechanics", or the Boyle lectures from R. Bentley, which were first published by Ju.A. Danilov in 1993 in *ВИЕТ* 1 (1993): pp. 30–45, as well as his correspondence with Newton.)[31] Furthermore, the sources which Hessen used from the social sciences and economics were frequently recent ones. Whether or not Hessen knew about unpublished works from Karl Marx and Friedrich Engels cannot be determined from the available materials. For instance, *The German Ideology*, which Hessen draws upon in his lecture from 1931, was published in German by the Marx-Engels-Lenin Institute in Moscow in 1927 and later appeared in Russian in 1933.[32] This work belongs to the basic bibliography of social scientific knowledge; in Hessen's time, however, this was a new one, the understanding of which had hardly developed in the sciences. References to the Russian sources were added for the German reader, which are not generally reflected in analogous works in the history of physics.

The book conceived by Hessen therefore not only represents a new perspective on the history of physics in the 1930s, but can also be considered a pioneering work for the nascent scientific research of this time.

The manuscript must have gone to the publishers at either the end of 1935 or the beginning of 1936. Hessen sent a letter to J.G. Crowther on the 26th of June 1935, which said that he had prepared a third significant revision and expansion of his lecture and asked whether it would be accepted for an English edition.[33] V.S. Kirsanov guessed that the date was 1936, because according to his opinion the

31 Compare: В.С. Кирсанов, "Уничтоженные книги: эхо сталинского террора в советской истории науки," *ВИЕТ* №.4 (2005): 122.

32 The first publication took place in 1927 from D.B. Rjasanov. On the difficulty of the first publication of the "German Ideology" see: *Successful Cooperation. The Frankfurt Institute for Social Research and the Moscow Marx-Engels-Institut (1924-1928). Contributions to Marx-Engels research. New Series, Special Volume 2.* (Berlin/Hamburg: Argument, 2000).

33 C.A.J. Chilvers published this correspondence in 2003: "The Dilemmas of Seditious Men: The Crowther-Hessen Correspondence in the 1930s," BJHS 36.4 (2003): 432.

book would have already been on sale if it had been an earlier date.[34]

It is no longer possible to answer the question of who would have prepared the original sources for the translation, because the relevant information is not contained in the proofs. According to information from Kirsanov, the example of the proofs that is found in the papers of A.P Juškevič belonged to the prominent, outstanding translator Vladimir Solomonovič Gochman (1880-1956), Juškevič's father-in-law. However, Gochman's authorship cannot be established. The unpublished manuscripts from the 1930s discussed by Kirsanov[35] also contain a new translation of Newton's *Principia*, in which Hessen is designated as the editor. This work was conceived in a 7-volume complete works of Newton in 1934 by S.I. Vavilov and confirmed by the publishers.

The following pages reproduce the contents of the manuscript. A complete title as well as an index are not contained in the manuscript, which is, in addition, incomplete. Missing sections are noted. The page numbers correspond to the page numbers of the proofs.

34 Cf. С. Кирсанов, "Уничтоженные книги: эхо сталинского террора в советской истории науки," 122.

35 Ibid., 119–124.

Contents

Theme I. The Socioeconomic Preconditions of Classical Physics

Theme II. The Emergence and Development of the Main Principles of Classical Mechanics and the Arguments in the 17th Century thereupon

Theme III. The Problem of Movement in Newton's Physics: The Struggle of Materialism and Idealism for This Question in the 17th Century

Автобиография Б. Гессен

Родился в 1893 г. В 1913 г. окончил 8 классов гимназии. 1913-1914 г. Учился в Эдинбургском у-тете /Шотландия/ на математическом отделении / Faculty of Science department of Pure Science/. Послушал и сдал: Введение в анализ и I часть дифференциального исчисления у проф. Whitakera[1] и аналитическую геометрику у Dr. Carse. Распад частичных сил* и теплоту у проф. Barkla[2] и физический практикум Dr. Carse....Химию неорганическую и химический практикум Проф. Walke .. Dr. Dobbin. Во время им(п)ериалисткой войны вследствии невозможности попасть в Англию – два года 1914-1916 г. был студентом Экономического отделения Петроградского политехникума. Работал там по статистике у А.А. Чупрова[3] и Мареса, занимался также математической статистикой.
В тоже время работал на физ-мат. Петрогр. У-тета на который не был принят как еврей. За эти два года прослушал и отработал: Дифференциальное и интегральное исчисление, проф. Успенский ..В. и Селиванов. Приложение анализа к (гео?)..метрии, Адамов, Высшую алгебру Ю. Сокоцкий, теория определенных интегралов - Сокоцкий, Интегрирование дифференциальных уравнений - Стеклов[4].
Там предметы конечно сдать не мог. Кроме того самостоятельно занимался философией и немного историей математики.
Сначала революции на партийной и пропагандистской работе: в 1917 г. до октября секретарем организации интернационалистов в г. Елисаветграде[5] (Елизаветград), после Октябрьского переворота – секретарем совета рабочих депутатов, в 1919 г. ...– август член коллегии отдела народн. образов. там же.
1919-1921 в .сначала инструктором полит..работы вел в ... отдели и отделе подготовки персонала .
От 1921 до настоящего времени в У-тете Свердлова ....политэкономии и завед. экономическим циклом, (за?)..тем завед. Лекторским курсом.
Владею немецким, французским, английским и латинским языками.

8.VII. 1924 г. Личный почерк (Б. Гессен)

Appendix 1. Handwritten Curriculum Vitae of Boris Hessen (July 8, 1924) from the CV of the Komakademie: F. 364. Opis 3a. No.17. Bl.3.

Curriculum Vitae B. Hessen

I was born in 1893. In 1913 I finished the 8th grade of the gymnasium. From 1913-1914, I studied at the University of Edinburgh, Scotland, in the Faculty of Science, Department of Pure Science. I took the following lectures and tutorials there and passed the exams “Introduction to Analysis” and the first section on differential calculus with Prof. Whittaker and analytic geometry by Dr. Carse, as well as “Thermal Energy” with Prof. Barkla and an internship in physics with Dr. Carse. Inorganic chemistry and a chemistry internship with Prof. Walke .... Dr. Dobbin. Since it was not possible to reach England during the imperialist war, I studied for two years 1914-1916 at the Faculty of Economics of the Petrograd Polytechnic. There I worked on statistics with A.A. Čuprov and Mares, and also engaged with mathematical statistics.
In addition, I was an auditor at the Mathematical-Physical Faculty of the Petrograd University, where I was not accepted as a Jew. In these two years, I studied and worked on questions of differential and integral calculus, Prof. ... V. Uspenskij and Selivanov, application of analogues in the (geometry?) - Adamov, Higher Algebra - Ju. Sokockij, theory of determination of integrals, Sokockij, integration of differential equations - Steklov.
Of course, I could not take an exam for these subjects. Moreover, I studied philosophy independently as well as a little of the history of mathematics.
From the beginning of the Revolution, I was involved in party work and propagandistic work: From 1917 to October as secretary of the Organization of Internationalists in Yelisavetgrad, after the October transition as Secretary of the Council of Workers’ Deputies, 1919 from August - Member of the College for the Department of People’s Education. From 1919-1921 initially an instructor in political work and in the departments ... and the department of personal training. From 1921 until today I am at Sverdlov University working and teaching Political Economy, I am head of the curriculum in Economics and Lecturer Education.
I am proficient in German, French, English and Latin.

8 July 1924 signature (B. Hessen)

В Правление ИКП[6] Б. Гессен

План занятий по естествознанию на 1924/25 год.

В основу своего плана занятий мною положено те особенности моего естественно-научного образования, которые изложены в моем curriculum vitae: при сравнительно достаточной математической подготовке у меня нет систематических знаний по физике.

Кроме того семилетный перерыв (1917-1924) в моих занятиях делает небходимым многое повторить и снова привести в систему.

По математике: Основательное повторение дифференциальной геометрии и обыкновенных дифференциальных уравнений по .... Czuber[7].. Vorlesungen über Differential- und Integral Rechnung, по Стеклову – обыкновенные дифференциальное уравнения и элементы....... вариационнего исчисления. Лекции, читанные в Петерб.- У-тете 1912/13 гг.

По физике: Основательное повторение курса экспериментальной физике по Edser. Properties of Matter. Edser Heat. Эйхенвальд электричество. Теоретическая физика в обьеме Haas Einfü(h)rung in die theoretische Physik Bd. I (последне издание) Helmholtz. Dynamik der diskreten Massenpunkte.

Работа в Лаборатории несколько задач по экспериментальной физике (Общий практикум проделан мною в Англии) и практикум по электрическим колебаниям.

Ноябрь 1924 г. Б. Гессен

Appendix 2. Personal Work Plan concerning Natural Science 1924/25, Manuscript. Ibid: F. 364.Opis 3a.No.17. Bl.4, reproduced with kind permission of the Archives of the Russian Academy of Sciences in Moscow.

To the Leadership of the University for Red Professors B. Hessen

Personal Work Plan for Natural Science 1924/25

The bases for my work plan are the features of my natural science education, which are set out in my curriculum vitae: If I have a comparatively sufficient education in mathematics, I lack a systematic education in physics. In addition, the seven-year break (1917-1924) in my activities ensures that a revision and replenishment of my knowledge is necessary.

In Mathematics: a thorough revision of differential geometry and the common differential equations according to Czuber — lectures on differential and integral calculus, according to Steklov — the common differential equations and elements of the calculus of variations. Lectures held at St. Petersburg University in 1912/13.

In Physics: Thorough repetition of a course on experimental physics according to Edser, Properties of Matter. Edser Heat. Oak forest electricity. Theoretical physics in the range of Haas. Introduction to theoretical physics. Volume 1, latest edition.

Helmholtz. Dynamics of the discrete mass points.

Laboratory work: some experimental physics tasks (a general internship I completed in England) and practical exercises in electrical vibration.

November 1924 B. Hessen

Б. Гессен 4

План занятий по естествознанию на 1924/25 год.

В основу своего плана занятий мною положено не-
[д]остаточность моего естественно-научного образования,
[к]оторое изложено в моем curriculum vitae: при ~~[illegible]~~
[с]равнительно достаточной математической подготовке
[у] меня нет систематических знаний по физике.
[К]роме того семилетний перерыв (1917–1924) в моих
[за]нятиях делает необходимым многое повторить и снова
[при]вести в систему.

По математике: Основательное повторение дифференциальной геометрии и обыкновенных дифференциальных уравнений
[п]о Czuber Vorlesungen über differential und Integral Rechnung
[и] Стеклову – Обыкновенные дифференциальные ур-ния и
[э]лементы вариационного исчисления. Лекции читанные в
[П]етерб. У-тете 1912/13 гг.

По физике. Основательное повторение курса экспериментальной физики по Edser Properties of Matter
Edser Heat. Эйхенвальд Электричество.
Теоретическая физика в объеме Haas Einfurung in die theoretische physik Bd I (последнее издание)
Helmholtz Dynamik der Diskreten Massenpunkte.
Работа в Лаборатории несколько задач по экспериментальной физике. (общий практикум проделан мною в Англии)
[и] практикум по электрическим колебаниям.

[Ноя]брь 1924 г. Б. Гессен

Appendix 3. Reproduction of the document in Russian.
Evidence: photo. Archive of the MGU. F. 46. Opis 1. Ed. 52. L.1

Notes

* incomprehensible, presumably missing a phrase
.... undeciphered words

1 Sir Edmund Whittaker (1873-1956), fourteenth Prof. of Mathematics in 1912 in the Faculty of Science. He established the first mathematical laboratory for numerical computation. R.M. Birse, *Science at the University of Edinburgh 1583-1993. An Illustrated History to Mark the Centenary of the Faculty of Science and Engineering 1893-1993. The Faculty of Science and Engineering* (The University of Edinburgh, 1994) 97.

2 Charles Barkla, the eleventh Prof. of Natural Philosophy, chair of Physics at King`s College London since 1909, Nobel Prize for Physics 1917. Ibid.

3 Чупров, Александр Александрович (1874-1926), Russian mathematician and statistician. Taught 1902-1917 at the Faculty of Economics of the Polytechnic Institute in Petersburg.

4 Стеклов, Владмир Андреевич (1864-1926), Russian mathematician, OM (1912), Vice-President of the Academy of Sciences of the USSR 1919-1926, organizer and director of the Physico-mathematical Institute 1921-1926.

5 Ukrainian spelling in the original

6 (abbrev.) Институт Красной Профессуры

7 Czuber, Emanuel (1851-1925)

"A Pantheon of Great Ideas". Boris Hessen and the History & Philosophy of Science

Sean Winkler

§. Introduction

The publication of Boris Hessen's *Manuscripts & Documents on the History of Physics* (hereafter, "*Manuscripts*") with a partial English translation is an occasion worthy of celebration both for those interested in the study of Hessen's works as well as in the study of the history & philosophy of science in general. Best-known for his address to the 2nd International Congress of the History of Science & Technology in London, England in 1931, Hessen's "The Social and Economic Roots of Newton's *Principia*" (hereafter, the "1931 Newton paper") sent shockwaves through the intellectual community which continue to reverberate to this day.[1] But, in spite of Hessen's notoriety, for decades, the study of his work remained almost wholly restricted to his talk, with some notable exceptions aside. And while Hessen was a prolific author, his other works were generally considered unremarkable. In spite of this characterization, scholars nevertheless puzzled over what they took to be a tension in Hessen's oeuvre between the 1931 Newton paper, which appeared to espouse

1 Boris Hessen, "The Social and Economic Roots of Newton's *Principia*," in *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*, ed. Gideon Freudenthal & Peter McLaughlin and trans. Philippa Schimrat (Dordrecht: Springer, 2009 [1931]), 41 – 101.

a so-called 'externalist'[2] approach to the history & philosophy of science, while his other works appeared to espouse a so-called 'internalist'[3] approach. In recent years, however, we have seen a resurgent interest in Hessen's thought all over the world, with translations of the 1931 paper appearing in multiple languages, along with the first ever English translations of several others of his works, suggesting that the study of Hessen's thought is far from conclusive.[4] In fact, the more attention his writings have attracted overall, it becomes clear that while he certainly does emphasize different themes throughout his work, far from being in conflict with each other, his works seem to be characterized by a remarkable consistency. Across his articles, books, textbook, encyclopedia entries, prefaces, book reviews and talks, most of which were sole-authored while others were co-authored, he continually espouses different aspects of a dialectical materialist approach to the history & philosophy of science.

The release of the *Manuscripts* along with a partial English translation marks yet another milestone in furthering this study, and stands as a perfect opportunity to take a bird's eye view of Hessen's thought to reflect upon precisely what the *Manuscripts* contribute to

2 J.B. Morrell, "Externalism," in *Dictionary of the History of Science*, ed. W.F. Bynum, E.J. Browne & Roy Porter (London: The Macmillan Press Ltd., 1981), 145 – 146.

3 J.B. Morrell, "Internalism," in *Dictionary of the History of Science*, ed. W.F. Bynum, E.J. Browne & Roy Porter (London: The Macmillan Press Ltd., 1981), 211.

4 Among the English translations, see Boris Hessen, "Preface to Articles by A. Einstein and J.J. Thomson," trans. Sean Winkler, *Society and Politics* 13.1 (2019 [1927]): 87 – 102; Boris Hessen, "Materialist Dialectics and Modern Physics: Abstracts of the Report at the First All-Union Congress of Physicists in Odessa on 19 August 1930," trans. Sean Winkler, *Historical Materialism* 28.4 (2020 [1930]): 235 – 241; Boris Hessen, "Marian Smoluchoswki (On the 10th Anniversary of His Death)," trans. Sean Winkler & Alexei Kojevnikov, *Science in Context*: Forthcoming; Boris Hessen, "Mechanical Materialism and Modern Physics," trans. Sean Winkler & Alexei Kojevnikov, *Science in Context*: Forthcoming; Boris Hessen & Vasiliy Egorshin, "On Cde. Timiryazev's Attitude towards Contemporary Science," trans. Sean Winkler & Alexei Kojevnikov, *Science in Context*: Forthcoming; Olga Pattinson & Chris Talbot, eds. *Boris Hessen: Physics and Philosophy in the Soviet Union, 1927 – 1931; Neglected Debates on Emergence and Reduction* (Cham: Springer International Publishing, 2021).

our understanding therein. In this introductory essay, then, I present Hessen's thought by claiming that he stands out as the quintessential Deborinite dialectical materialist historian & philosopher of science. In other words, Hessen's position is defined by the contention that dialectical materialism is a philosophy in its own right, the development of which is essential to negotiating the construction of a new society against the backdrop of the relative limits of socioeconomic development and technological progress and the absolute limits of the laws of nature. The Introduction will proceed in the following steps. In §1, I provide a brief summary of the history Hessen's composition of the *Manuscripts* as well as the reception of the text. §2 lays out Hessen's argument in favor of treating contemporary scientific problems in light of the history of science, while §3 contends that Hessen supports a specifically Deborinite dialectical materialist approach to that history. From there, in §4, I will explain Hessen's argument for the root of classical physics in the socioeconomic development and technological progress engendered by early capitalism, while in §5, I chart his argument for how quantum mechanics and relativity theory are compatible with dialectical materialist philosophy and socialist construction. In support of my claims, I will draw from Hessen's oeuvre along with selections from the secondary literature.

§1. *Manuscripts & Documents on the History of Physics*

Hessen's *Manuscripts & Documents on the History of Physics* is a much fabled work. To this day, its composition and dissemination remain something of a mystery. But, while there is still much work to be done on understanding these matters, we nevertheless do have a sufficient amount of information to present a general narrative of Hessen's arrangement of the text and its transmission over the course of the past century; a story which I will outline in the following section.

We can say the following regarding Hessen's composition of the text with some degree of certainty. Even though the title page and the original table of contents of the work are missing (presumably censored), we know that Hessen meant for it to be titled *Manuscripts & Documents on the History of Physics*, based on the footer of p. 385.[5] Exactly when Hessen began working on the text remains unclear, but he appears to have commenced working on it in the late 1920s and to have completed it sometime between 1934 and 1936. All in all, the text consists of Hessen's prefaces and commentaries, as well as primary and secondary sources to present a socioeconomic reading of the history of science, with special attention to early modern mechanics. The text is believed to have been part of a larger effort to prepare anthologies on the history of science on behalf of the Department of the Dialectics of Natural Science at Moscow State University. Hessen likely received assistance from his one-time collaborator, V.P. Egorshin,[6] who would eventually betray him, along with an N.A. Isakovich, whose identity remains unclear, in his compilation of the text.[7] The original manuscript has been either lost or destroyed, meaning the extant version from which the partial translation is derived is the layout of the actual printed version of the work.[8] We are fortunate to have this at our disposal, but it nevertheless remains incomplete as pp. 177 – 320 are missing. There is some speculation that the missing pages most likely consisted of translations of works by Leibniz made by

5 Vladimir Kirsanov, *Izbrannyye trudy; Vospominaniya kolleg i druzey; Stikhi; Risunki* (Moskva: Izdatel'stvo im. Sabashnikovykh, 2010), 98 – 99.

6 Vasiliy P. Egorshin (1898–1985) was a Soviet physicist and historian & philosopher of science. He was a professor of physics at Moscow State University, whose primary specialization was the history of astronomy from a dialectical materialist point of view. He co-authored several articles in the late 1920s with Hessen, but would become one of Hessen's major opponents by the 1930s. Paul Josephson, *Physics and Politics in Revolutionary Russia* (Berkeley/Los Angeles/Oxford: University of California Press, 1991), 208; Sergei N. Korsakov, et al., *Boris Mikailovich Hessen. 1893 – 1936* (Moskva: Nauka, 2015), 90 – 91.

7 Sergei N. Korsakov, Private Email Correspondence, April 23, 2021.

8 Kirsanov, *Izbrannyye trudy*, 97.

Egorshin.[9] Several of the primary sources included in the text — particularly those in Theme #2 by Bernoulli, Boscovich, Haas and Leibniz — were translated into Russian for the first time, but because of the missing title page and table of contents, we can only speculate as to who might have undertaken them.[10]

With respect to the dissemination of the work, we can make some of the following claims. The text was never released, most likely because of Hessen's fate, though it was set for publication in 1936 by the [State] United Scientific and Technical Publishing House, which eventually ceased operations in 1938. It is unclear why the text was only censored and not destroyed, but in any case, the physical copy came into the possession of Adolf Yushkevich (1906 – 1993), a Soviet historian of mathematics, who specialized in mathematics in Eastern Europe during the Middle Ages, and was a recipient of the George Sarton Medal by History of Science Society in 1978.[11] Upon Yushkevich's death in 1993, the text then came into the possession of Sergei Demidov (1942 –), a Russian physicist and mathematician of Lomonsov University in Moscow.[12] Demidov then passed it on to Vladimir Kirsanov (1936 – 2007), who was a Russian historian of science; he was the First Vice President of the Division of History of Science and Technology of the International Union of History and Philosophy of Science and a member of the Department of History of Physics at the Sergei I. Vavilov Institute.[13] The first scan of the text was made by Rose-Luise Winkler, while it was in Kirsanov's possession. Kirsanov then handed off the text to Dimitri Bayuk, who is

9 Korsakov, Private Email Correspondence, April 23, 2021.

10 Kirsanov, *Izbrannyye trudy*, 100 – 101; Korsakov, et al., *Boris Mikailovich Hessen*, 146.

11 Isabella, Bashmakova, et al., "In Memoriam: Adolph Andrei Pavlovich Yushkevich (1906 – 1993)," *Historia Mathematica* 22 (1995): 113 – 118.

12 «S.S. Demidov», *Russian Academy of Sciences – Institute for the History of Science*, accessed November 23, 2021, old.ihst.ru.

13 Annette B. Vogt, "Eloge: Vladimir Semyonovich Kirsanov, 26 December 1936 – 12 May 2007," *Isis* 99 (2008): 803 – 805.

a specialist in Economic History, the History of Mathematics and the History of Science who works at the Department of Data Analysis, Decision Making, and Financial Technology at the Financial University Under the Government of the Russian Federation.[14] The first studies of the text appear to have been carried out by Vladimir Kirsanov and Rose-Luise Winkler; Kirsanov having produced a table of contents in Russian and Winkler a table of contents in German.[15] Currently, Sergei Korsakov (1973 –), a historian of science and philosopher and member of the Institute of Philosophy at the Russian Academy of Sciences,[16] is now conducting an intensive study of the text, while others at and in collaboration with Ca' Foscari University of Venice have studied it as well. Finally, Korsakov uploaded a copy of the scan to the website of the Institute of Philosophy at the Russian Academy of Sciences, where it is available for download.[17] The first English translation was completed by independent scholar, Giuliano Vivaldi, and then annotated and revised by Pietro Daniel Omodeo, Sascha Freyberg, Gerardo Ienna and myself.[18] Undoubtedly, this is only part of the *Manuscripts*' story, as surely new details of its past are bound come to light with further study.

§2. *Sonntagslektüre* or Pantheon of Great Ideas

Among the many reasons to celebrate the publication and partial English translation of the *Manuscripts*, one is that it helps bring to

14 "Dimitri Bayuk," *Research Gate*, accessed November 23, 2021, *researchgate.net*.

15 Dimitri Bayuk, Private Email Correspondence, April 19, 2021; Korsakov, Private Email Correspondence, April 23, 2021.

16 "Sergei N. Korsakov," *Institute of Philosophy of the Russian Academy of Sciences*, accessed November 23, 2021, eng.iphras.ru.

17 Boris Hessen, *Materialy i dokumenty po istorii fiziki (granki)* (Unpublished, 1936 [?]), accessed November 23, 2021, gessen-hrest.pdf (iphras.ru).

18 I would like to extend our gratitude to Prof.'s Dimitri Bayuk and Sergei N. Korsakov for their invaluable help in documenting the transmission and content of this text.

light one of the central themes of Hessen's entire oeuvre. In the Preface to the text, Hessen evokes the following question: is the history of science a collection of mere artifacts or does it benefit contemporary scientific research? To stage the former view, he recounts a private conversation between himself and German philosopher of science as well as leading figure of logical empiricism, Hans Reichenbach during the 6th Congress of German Physicists in Königsberg, Germany (today Kaliningrad, Russia). Hessen quotes Reichenbach as having said the following: "For you [Hessen] the history of science is the key to knowledge about its real condition. For us, this is merely *Sonntagslektüre* [entertaining Sunday reading]; it cannot provide us with any real knowledge about today's situation in science."[19] In other words, for Reichenbach, while the history of science may be compelling, it ultimately bears little to no significance for addressing problems in contemporary scientific research; a view which, as Hessen points out, was a widespread sentiment in the early 20th century that culminated in neo-positivism.[20] To stage the latter view, he points out that this a-historicism was hardly always the prevailing belief and in fact, insofar that as then recent as the 19th century, scientists took for granted that the history of science was indispensable for grappling with the scientific problems of the day:

> **Nearly all of the most significant representatives of nineteenth-century classical physics (Ampere, Faraday, Maxwell, von Helmholtz, Boltzmann, Calvin) showed, to some degree, a keen interest in the history of their science and addressed this history not only in particular articles and research, but**

19 Boris Hessen, *Socio-Economic Prerequisites for the Emergence of Classical Physics*, in *Manuscripts and Documents on the History of Physics*, trans. Giuliano Vivaldi and ed. Pietro Omodeo & Sean Winkler (Venice: Verum Factum, 2022), 183 (hereafter, "*Socio-Economic Prerequisites*").

20 *Ibid*.

> also wove historical analyses of the issue into their main works.[21]

Hessen laments the former view, not only because he believes that the history of science is of intrinsic value, but because without it, it is impossible to understand contemporary science in a truly scientific manner. To properly understand the present moment of scientific research in such a way means first and foremost recognizing that it is itself not an endpoint, but a phase in an overall process of historical development. As he writes,

> [n]o matter how new and unusual the theories of contemporary physics may be, no matter how radically they differ from the outlook of classical physics, the contemporary stage of development in physics is still a historical phase of its overall development.[22]

By recognizing contemporary scientific research in such a fashion, one grasps a great deal more than just the passage of time. Indeed, it allows for the possibility of detecting patterns throughout history, such that the central problematics of science can be more readily distinguished from those more ephemeral. In this way, the history of science is not simply pleasurable reading for one's own enrichment, but a necessary component of understanding any and all scientific problems. As he writes,

> In acquainting ourselves with the history of physics, we can see that many fundamental issues had been raised earlier and, in some cases, the correct way of resolving these issues

21 *Ibid*.
22 *Ibid*.

> **had already been outlined. History is, after all, not a 'list of human errors, but a pantheon of great ideas.'**[23]

Note, however, that for Hessen, it was not enough to simply reconstruct a chronology of major figures in the history of science. On the contrary, Hessen shunned more conventional narratives which saw the history of science as a series of the contributions of great minds, as he maintains that this too was an insufficiently scientific approach to the essence of the enterprise. From where, then, does the history of science actually emerge? What actually charters the development of the history of science? To address these questions, Hessen proposes a different methodology for addressing these very questions.

§3. The Materialist Dialectic

From his 1931 Newton paper, we see precisely why Hessen objects to more conventional narratives in the history of science. First and foremost, he argues, such narratives treat the history of science as if it simply sprang from the minds of scientific geniuses.[24] While Hessen never denies that figures like Galileo, Newton, etc. were indeed brilliant, genius alone does not account for the proper origins of scientific problems. Likewise, conventional approaches mystify the upper and lower limits of scientific discovery; that is, why certain scientific problems seem to emerge suddenly and to likewise encounter certain major blind spots that are obvious to posterity.[25] Second, such narratives treat the history of science as if ideas alone animated development.[26] The problem is, however, that science deals precisely

23 *Ibid.*, 183 – 184.
24 Hessen, "The Social and Economic Roots of Newton's *Principia*," 41.
25 *Ibid.*, 43 – 61, 73 – 82.
26 *Ibid.*, 42.

with the material world, not to mention the fact that there is an astonishing parallel between changes in the material world, specifically, in socioeconomic development and technological progress, and ideas in the history of science. According to Hessen, these shortcomings can be properly rectified by a so-called 'dialectical materialist' approach to the history & philosophy of science.[27]

Now, today it has become rather difficult to imagine the merits of such a philosophy.[28] Indeed, what value is there in entertaining this philosophy at all and should it not simply be cast into the proverbial dustbin of history? I would argue, however, that it would be folly to assume that dialectical materialism was only ever one thing. Debates over what dialectical materialism actually was and how it should be applied were widespread throughout the 1920s. One could not go so far as to call dialectical materialism an empty signifier that meant whatever to whoever, but there were undoubtedly distinct camps of dialectical materialist philosophers, along with distinct individual flourishes to this way of thinking, by which one could hardly call them the same thing. That the meaning and significance of dialectical materialism was in flux is perhaps epitomized by the debate between two prominent camps of Soviet thinkers in the late 1920s: the mechanists and the Deborinites/dialecticians.[29] For the former, dialectical

27 *Ibid.*, 41 – 42.

28 There can simply be no avoiding the fact that as the official state ideology of the Soviet Union, dialectical materialism was an instrument of ideological indoctrination and at times, a pretext for exercising state terror. Even as a philosophical position, dialectical materialism was inflexible and unfalsifiable, in certain instances being an impediment to scientific progress, and at others, a pretext to catastrophe, as in the infamous 'Lysenko affair'. See Dominique Lecourt, *Proletarian Science?: The Case of Lysenko*, trans. Ben Brewster (Atlantic Highlands: Humanities Press, 2003 [1977]).

29 The Deborinites were so named after Abram Deborin, a Soviet philosopher and member of the Academy of Sciences of the USSR. Betweem 1926 – 1931, Deborin served as the editor to the prominent Soviet journal, *Under the Banner of Marxism*, which was a major battleground for the debate between the mechanists and the Deborinites. Brian Kassof, "A Book of Socialism: Stalinist Culture and the First Edition of the *Bolshaia Sovetskaia Entsiklopediia*," *Kritika* 6.1 (2005): 30.

materialism was a reductionist natural philosophy that resembled Newtonian mechanics (minus the theological elements) and was exceedingly hostile to any non-materialist positions.[30] For the latter, dialectical materialism was an anti-reductionist natural philosophy that continually evolved and saw it as necessary to entertain a more speculative approach to non-materialist positions.[31] While the Deborinites enjoyed a brief victory over the mechanists in the late 1920s, by the time Joseph Stalin initiated the 'Great Break' in 1929 — in light of the failure of other revolutions to metastasize, making the Soviet Union an isolated state, along with the country's need to modernize — the Deborinites were considered counterproductive to the efforts of socialist construction, with many being purged from positions of authority.[32] This change of fortune for the Deborinites is perhaps epitomized in a co-authored article by Mitin, et al. and the Deborinites' own response in the article, "On the Fight on Two Fronts in Philosophy".[33] The final nail in the coffin to the Deborinites and the debate over dialectical materialism overall came when Stalin codified it as a monolithic institution of thought in 1931, which was later published as *Dialectical & Historical Materialism* in 1938.[34]

Now, in spite of the shifting political terrain of his day, from beginning to end, Hessen's thought remained emblematic of the Deborinite approach to dialectical materialism; that is, he saw it as a philosophy which mediates socialist construction alongside the relative

30 J.M. Bochenski, *Soviet Russian Dialectical Materialism [Diamat]* (Dordrecht: D. Reidel Publishing Company, 1963), 34.

31 *Ibid*.

32 Loren R. Graham, "The Socio-Political Roots of Boris Hessen," *Social Studies of Science* 15 (1985): 709 – 710.

33 Mark Mitin, et al., «O novykh zadachakh marksistsko-leninskoy filosofii», *Pravda*, June 7, 1930, ?; Boris Hessen, et al. «O bor'be na dva fronta v filosofii», *Pod znamenem marksizma* 5 (1930): 139 – 149.

34 Joseph Stalin, *Dialectical and Historical Materialism*, trans. unknown (New York: Prism Key Press, 2013 [1938]).

limits of socioeconomic development and technological progress and the absolute limits of the laws of nature. In a passage co-authored with fellow Deborinite philosophers and scientists, Hessen et al. say as much, by writing that

> [t]he struggle for the philosophical materialism of Marx, i.e. for *dialectical materialism*, is the necessary link in the struggle for communism. . . . In the field of philosophy, it is that knot in which all the most important questions of the *theory and practice of the struggle of the proletariat in our era* are connected.[35]

And, as previously mentioned, he saw it as an anti-reductionist natural philosophy; Hessen's own anti-reductionism being exemplified in the following quote, where he writes that

> We cannot reduce or dissolve a higher form of motion into the sum of the lower forms of motion, since the specificity of the higher form of motion lies precisely in the fact that it represents not the sum of the lower forms, but their synthesis.[36]

Based upon these premises, Hessen's articulation of dialectical materialism can best be encapsulated under the following parameters.

First and foremost, he saw dialectical materialism as fundamental ontology; that is, a philosophy concerning the essence of reality itself. As he writes,

35 Hessen, et al. «O bor'be na dva fronta v filosofii», 139, 141. See also Boris Hessen & Ivan Podvolotskiy, «Filosofskiye korni pravogo opportunizma», *Pod znamenem marksizma* 9 (1929): 1 – 3.

36 Boris Hessen, "Mechanical Materialism and Modern Physics," Forthcoming.

> [s]tudying the real processes of the motion of matter and human knowledge leads us to believe that dialectical contradiction is the objective contradiction of all motion, and that 'dialectics reduced itself to the science of the general laws of motion, both of the external world and of human society [sic]' (Marx).[37]

By materialist, Hessen means that reality is a mind-independent, extended substratum, and by dialectical, he means that reality is defined by self-motion which is animated through the unity of opposites. In support of the former, he writes that reality is an "(extended) substance, objectively existing regardless of us,"[38] while in support of the latter, he writes that

> dialectics teaches us to consider each object in its development, its self-movement; to study the immanent laws of the development of the object. . . . The unity of opposites, the inconsistency of all the connections and relations of the object is the basis of its self-movement.[39]

While the synthesis of the terms may appear somewhat strange, we can perhaps better understand it by framing it as an 'anti-Platonic' position. Recall that, according to a rather elementary reading of Plato, physical reality is defined by contradictions, and it is because of these contradictions that the truth must lie in a transcendent realm

37 Hessen, "Materialist Dialectics and Modern Physics," 240 – 241.

38 Boris Hessen, «Predisloviye k stat'ya G. Miye «Problema materii»", *Pod znamenem marksizma* 1 (1927): 119.

39 Hessen & Podvolotskiy, «Filosofskiye korni pravogo opportunizma», 3. See also Boris Hessen, "On the Question of the Causality Problem in Quantum Mechanics. Preface to the 1931 Russian Translation of Arthur Haas, *Materiewellen und Quantenmechanik*," in *Boris Hessen: Physics and Philosophy in the Soviet Union, 1927 – 1931; Neglected Debates on Emergence and Reduction*, ed. and trans. Chris Talbot & Olga Pattison (Cham: Springer Nature, 2021 [1931]), 142.

of self-identical forms.[40] For a dialectical materialist, however, precisely because there is no transcendent realm, the contradictory nature of the physical world does not convey its deficiency as reality, but indeed, reality itself. One of the outcomes of this position is the argument that human nature must be understood from the perspective not of ideas, but of material praxis; that is, the social relations and technological forms from which human beings sustain themselves and shape their reality across history.[41]

Second, Hessen treats dialectical materialism not only as fundamental ontology, but also as an epistemological standpoint. This epistemological standpoint entails not only explaining reality in dialectical materialist terms, but also of reflecting upon the condition of the possibility of explaining reality in such terms. Hessen identifies this, then, as a two-fold program which he calls a 'Marxist classification of the sciences'. This program consists on one hand of a "study of the historical sequence of the forms of motion as they appear in the development of the science of physics in human society," while on the other hand, a "study [of] the 'natural science of the development of matter.'"[42] In other words, dialectical materialism explains how the perception of reality is rooted in socioeconomic development and technological progress, while also understanding that scientific theories unfold according to competing understandings of matter and motion.

In sum, then, the sufficient condition for the emergence of natural scientific theories depends on not only a historical standpoint, but such a standpoint which is grounded in dialectical materialist philosophy. Scientific theories independent of history cannot scientifically

40 Plato, *Republic*, in *Plato: Complete Works*, ed. John M. Cooper and trans. G.M.A. Grube & C.D.C. Reeve (Indianapolis/Cambridge: Hackett Publishing Company, 1997), 1132 – 1155.

41 Hessen, "Materialist Dialectics and Modern Physics," 240 – 241.

42 Hessen, "The Social and Economic Roots of Newton's *Principia*," 80.

explain their own emergence, nor can a conventional history of science. On the contrary, as Hessen argues, a scientific approach to scientific theories entails the assumption of an immanent, self-moving material reality, and as such, of human nature being fundamentally animated by socioeconomic development and technological progress, which is inherently historical. The emergence of scientific theories, then, requires basing them in the broader milieu of socioeconomic development and technological progress, along with seeing the historical development of ideas in natural philosophical and scientific theory must be grasped as competing theories in the development of the understanding of matter and motion.

§4. The Socio-Economic Roots of Modern Physics

I will now proceed to explain Hessen's arguments for the first prong of a Marxist classification of the sciences; namely, that socioeconomic development and technological progress provide the roots of scientific theory. Specifically, I will examine his position that the shift to early capitalism laid the groundwork for modern physics, primarily by analyzing the *Manuscripts*, while also alluding to notable differences with the 1931 Newton paper. Exegetically speaking, I contend that the *Manuscripts* is an elaboration upon the first two sub-theses of the 1931 Newton paper, though with some notable exceptions. Generally speaking, the 1931 Newton paper was designed to illustrate how the socioeconomic development and technological progress of early capitalism cultivated a milieu which was a necessary condition for the composition of a work like Sir Isaac Newton's magnum opus, *Philosophiæ Naturalis Principia Mathematica*. The *Manuscripts*, though affording no less significance to Newton, effectively makes this exact same argument, but with respect to the entirety of the Scientific Revolution. In this section, I will then outline Hessen's main arguments in the *Manuscripts*, noting major similarities with the 1931 Newton paper along the way, followed by what the Manuscripts teach us about Hessen's thought and concluding with some of the noteworthy differences between the two texts.

The *Manuscripts* elaborate upon the 1931 Newton paper to the extent that the central thesis of the two works is the same. In fact, they are basically identical, as Hessen argues that "[t]he remarkable flourishing of the natural sciences in the sixteenth and seventeenth centuries is due to the break-up of feudal ownership, and the development of merchant capital, international maritime transport and heavy industry (mining and metallurgy)."[43] In other words, from the breakdown of the feudal economy and the ascent of capitalism as the prevailing mode of production, the transition from a consumption-based economy to an exchange-based economy made for a different *modus operandi* of production and in which machinery began to take on a central function within economic production. These major shifts resulted in need to theorize over the nature of machinery from a mathematical perspective, laying the groundwork for classical mechanics.

In order to properly establish his primary thesis, Hessen contends that one cannot understand this process solely chronologically, but must rather see it from both diachronic and synchronic perspectives. Hessen chooses to take a thematic approach; the three themes of the *Manuscripts* effectively being a reformulation of sub-theses 1 and 2 of the 1931 Newton paper. The first thesis of the 1931 Newton paper consists of two moments, "The Economics, Technology and Physics of Newton's Era/The Physical Themes of the Era and the Contents of the Principia", where the former part shows the ways in which the breakdown of the feudal economy and the dawn of the capitalist economy established new technical demands, while the latter shows how these technical demands constituted the practical basis

43 Hessen, *Socio-Economic Prerequisites*, 186. See also Hessen, "The Social and Economic Roots of Newton's *Principia*," 44.

of what would become the theoretical problems of modern physics, thereby engendering the mechanistic conception of material causality.[44] These two components of the first thesis are transformed into two independent themes in the *Manuscripts*, such that "The Economics, Technology and Physics of Newton's Era" becomes "The Socio-Economic Prerequisites for the Emergence of Classical Physics" whereas "The Physical Themes of the Era and the Contents of the *Principia*" becomes "The Emergence and Development of the Main Principles of Classical Mechanics and the Arguments surrounding Them in the 17th Century". The second thesis of the 1931 Newton paper, "The Class Struggle during the English Revolution and Newton's Worldview", is designed to show because the mechanistic conception of materialist causality provided an inadequate conception of the physical world, natural philosophers and scientists invariably debated over the nature of divine and/or spiritual causes; often times, these divine and/or spiritual causes were rationalizations of religious beliefs among classes of thinkers.[45] This thesis effectively becomes "The Struggle of Materialism and Idealism concerning This Problem in the 17th and 18th Centuries". We note that there are also numerous places where Hessen extracts lines essentially verbatim from the 1931 text.[46] To do so, he presents primary sources in the history of physics, primary sources in the socioeconomic history, secondary sources in the history of physics and socioeconomic history, all of which he narrates with his own prefaces and commentaries.

44 Hessen, "The Social and Economic Roots of Newton's *Principia*," 43 – 52, 52 – 61.

45 *Ibid.*, 61 – 73.

46 There are at least 9 parallel passages between the *Manuscripts* and the 1931 text: "Trade and Transport," 5 – 6 [1931: 45 – 46]; technical problems related to transport, 19 [1931: 46 – 47]; technical problems of ballistics 22 – 23 [1931: 51 – 52]; mining industry, 23 – 24 [1931: 47 – 48]; practical tasks of mining industry 27 – 28 [1931: 48 – 49]; division of labour 40 [1931: 67]; university system vs. scientific societies 42 – 45 [1931: 53 – 56]; remark about Robert Boyle 66 [1931: 68]; Bentley and Newton 67 [1931: 68]). Further study of the text will surely reveal there to be other parallels.

In Theme #1 – "Socio-Economic Prerequisites for the Emergence of Classical Physics", Hessen explains how the breakdown of the feudal economy and the emergence of capitalism were the necessary condition for the rise of modern physics. As he states,

> **the first theme [is] aimed at showing how the break-up of feudalism and the development of a new mode of production brought a number of new technical tasks into existence and presented physics with a series of issues predominantly of a dynamic character.**[47]

This theme is broken up into four sub-themes, which can roughly be grouped into four categories: trade & transport, warfare, mining & metallurgy and engineering. Across these different sub-themes, Hessen shows how the dawn of the capitalist economy radically reshaped both the nature of the physical world as well as the ways in which we perceive it. To the extent that economic production was increasingly being governed by the merchant class and production organized for the sake of exchange, this created an increasing demand for improving trade routes by land and by sea. Where feudal lords had an incentive to retain shabby roads, given the *Grundruhrecht*, according to which lords had the right to any goods that fell on their land, with the dawn of capitalism, it became necessary to improve and construct new roads. Likewise, this created a demand to improve river and sea transport. In addition to improving shipbuilding to complete such journeys, this also led to the development of canal and lock construction along with the innovation of the pendulum clock to keep time while traveling at sea. Next, the development of capitalism coincided with the growth of powerful nation states and competition

47 Hessen, *Socio-Economic Prerequisites*, 186.

for foreign markets, hence accelerating the production of arms/artillery along with fortifications. Furthermore, the increased circulation of money required the greater extraction of copper, gold, iron and silver, thus leading to improvements in mining. Finally, the new world established the conditions for the emergence and predominance of engineering as a profession. In his summaries of each of these subthemes, Hessen consolidates the practical challenges and the theoretical questions that emerged therefrom.[48]

Theme #2 – "The Emergence and Development of the Main Principles of Classical Mechanics and the Arguments Surrounding Them in the 17th Century" explains how these various practical and theoretical tasks were consolidated into general theories of matter and motion. As Hessen points out, "This section provides a survey of the emergence and development of the main principles of dynamics."[49] Though the shortest of the three themes, Theme #2 primarily focuses on the way in which physicists' immersion in the practical tasks mentioned in Theme #1 provided the basis of their theoretical speculation. Likewise, Hessen points the domain of modern theoretical physics not as a static terrain, but rather, one infused with central tensions between major figures between, for instance, Descartes, Huygens, Leibniz and Newton, as well as between major concepts in physics regarding the conception and measurement of matter and motion; for instance, is matter active or passive, and is motion absolute or relative? Thus, in addition to the socioeconomic preconditions, Hessen shows the central tensions between different concepts animated the development of physics as well.[50]

Theme #3 – "The Struggle of Materialism and Idealism concerning This Problem in the 17th and 18th Centuries" shows the

48 *Ibid.*, 186 – 219.
49 *Ibid.*, 220.
50 *Ibid.*, 220 – 225.

different topics which fall under, what could be called in Marxist parlance, 'ideological struggle'. Herein, Hessen addresses effectively two dimensions of this ideological struggle: first and foremost, between feudal universities and scientific societies and second, the ways in which the limitations of the mechanistic conception of material causation left open the door to incorporate immaterial causes and therefore, provided ways of defending against atheism and materialism. To elaborate upon the first point, Hessen explains how the universities were effectively the bastion of feudal society, to the extent that they produced the elite of the day and through their studies, inculcated all scientific study with the theological principles and moral values of the Church. In this respect, they resisted the efforts of the emerging bourgeois class to promote their scientific studies, meaning that rather than becoming a part of the university system, they had to form their own societies. The most famous of these scientific societies were the Florentine Academy del Cimento, the London Royal Society and the Parisian Academy of Sciences. Such societies provided the ascendant merchant class with a means for institutionalizing their interests; namely, to gather to share knowledge on economic and technical matters and to disseminate such knowledge through their own publications. Hessen also notes, however, that in spite of the fact that these societies remained steadfast in their commitment to the new scientific worldview, because of the limitations inherent to empiricism and the mechanistic conception of material causation, the resistance to full-fledged atheism, debates arose over the relationship between material and spiritual and/or divine causation.[51]

I maintain that the *Manuscripts* confirm an argument that many Hessen scholars have long been making; namely, that the 1931 Newton paper was never nearly as simplistic of a work as it was often

51 *Ibid.*, 226 – 262.

made out to be.[52] While many have already detected this in the 1931 text itself or through the increased study of Hessen's other works, the *Manuscripts* only further confirms this in a number of different ways. Scholars have often argued that Hessen's oeuvre appeared to be plagued by an internal contradiction to the extent that the 1931 Newton paper defended an externalist approach to the history of science, while the rest of his oeuvre defended an internalist approach therein.[53] First and foremost, the *Manuscripts* confound the notion that the 1931 Newton paper was some kind of rushed exception to Hessen's overall project. Through reconstructing the chronology of Hessen's composition of the *Manuscripts*, we see that it appears to have been a project on which Hessen was working since the late 1920s, at a time during which he was composing those works which are often considered more internalist in nature.[54] That Hessen was composing these works side-by-side substantially mitigates the notion that he underwent some distinct break in his thinking. Second, the actual contents of the *Manuscripts* help to bridge the gap between the 1931 Newton paper and the rest of Hessen's oeuvre. But in the *Manuscripts*, we see Hessen placing both positions side-by-side. While sub-theses 1 and 2 roughly correlate to themes 1 and 2, in theme 2, Hessen, in mentioning a wider swath of thinkers, not only presents excerpts from classical works in modern physics, but isolates the major dialectical tensions between the systems of different physicists that propelled the theoretical debate forward. Third, while the *Manuscripts* certainly

52 See H.F. Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago/London: University of Chicago Press, 1994), 332. Cf. Gideon Freudenthal, "The Hessen-Grossmann Thesis: An Attempt at Rehabilitation," *Perspectives on Science* 15/2 (2005): 167; Gideon Freudenthal & Peter McLaughlin, "Classical Marxist Historiography of Science: The Hessen-Grossmann-Thesis," in *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*, ed. Gideon Freudenthal & Peter McLaughlin (Dordrecht: Springer, 2009), 32.

53 Graham, "The Socio-Political Roots of Boris Hessen," 113.

54 See §1 above.

confirm that Hessen saw socioeconomic factors as foundational to the birth of modern physics, the sheer length of the work allows Hessen's vision greater room to breathe. In this expanded form, we see Hessen presenting a picture of scientific work that is far less schematic and clean. This sense is perhaps furthered by the fact that the style of presentation is so different between the 1931 text and the *Manuscripts*. Even though Hessen narrates his standpoint in prefaces and narration, by including other authorial voices via lengthy quotations of primary and secondary sources in physics, sources in history, etc., most of which do not align with Hessen's ideological commitments, the reader both gets Hessen's interpretation of how socioeconomic forces as well as other authors' conceptions of what animates these transformations. This lends it a greater sense of the complexity and, to some degree, the contingency of how certain practical and theoretical developments ensued.

There are, likewise, several noteworthy differences between the two texts that invite further analysis. First and foremost, as previously alluded to, the *Manuscripts* do not incorporate any discussion of sub-theses 3 and 4 from the 1931 Newton paper. Sub-thesis 3, "Engels' Conception of Energy and the Lack of the Law of Conservation of Energy in Newton", refers to the upper limit of progress of early modern physics; that is, in spite of the genius of figures like Newton, they did not notice certain matters which would eventually become obvious in the discussion of thermodynamics. Hessen contends that this was not due to the fact that they were unintelligent, but rather, that the technological basis had yet to be furnished. Thermodynamics was not possible until the steam engine began to play a central role in economic production during the 2nd Industrial Revolution.[55] Sub-thesis 4, "The Machine-Wreckers in Newton's Age and the Present-Day Wreckers of

55 Hessen, "The Social and Economic Roots of Newton's *Principia*," 73 – 82.

the Productive Forces", refers to the way in which machine wrecking was a manifestation of workers enacting protest, while still imbued with bourgeois ideology which fixated on technology, rather than directing their attention to challenging class exploitation. The point here is to discuss how a transformation of socioeconomic relations would usher in a new perspective which would invariably construct the basis for a new type of science.[56] Once again, Hessen makes no mention of these topics in the *Manuscripts*. Another of the fascinating differences between the *Manuscripts* and the 1931 Newton paper is that Hessen's discussion of the struggle between the old university system and scientific societies is that the former treats it as part of the ideological struggle, while the latter treats it as part of the socioeconomic roots. Next, by virtue of the length, there are numerous historical details in the *Manuscripts* that are simply not mentioned in the 1931 piece (i.e. deliberate sabotaging of roads, design of fifth wheels on carriages, clocks, scientific societies beyond the London Royal Society), etc. Perhaps one of the more compelling is Hessen's inclusion of reference to Johannes Mathesius' *Sarepta*. This work incorporates a fascinating detail not mentioned at all in the 1931 Newton paper, namely, the way in which Protestantism was not simply a way of 'eternalizing' the capitalist order, but more concretely, of furnishing the religious sentiment which supplanted the ideological foundation for labor under capitalism. Take, for instance, Mathesius' line where he states that "God's mercy and gift is that, with the help of useful contraptions and tools, heavy labor carried out by the sweat of one's brow, imposed upon humankind for its sins, is eased".[57] Surely, further study of the 1931 paper and the *Manuscripts* side-by-side will reveal yet other subtle differences.

56 *Ibid.*, 82 – 89.
57 Hessen, *Socio-Economic Prerequisites*, 213.

§5. Quantum Mechanics & Relativity Theory

To complete my introductory account of Hessen, I will now show how his writings on quantum mechanics and relativity theory are thoroughly compatible with his 1931 Newton paper and the *Manuscripts*. Let us return for a moment to the mechanist-Deborinite/dialectician debate of the late 1920s; among the many factors precipitating this debate, two of the most central were the dawn of the revolutionary theories of quantum mechanics and relativity theory. Because both theories were developed by natural scientists in so-called 'bourgeois' contexts and embraced Machist epistemology, Soviet theorists were skeptical of the extent to which they were compatible with their political project. Those dialectical materialists of the mechanist persuasion specifically saw quantum mechanics and relativity theory as incompatible with the aims of a workers' state, precisely on the aforementioned grounds. Those dialectical materialists of the Deborinite persuasion, Hessen included, however, saw this wholesale rejection as crude and simplistic, and ultimately as detrimental to a workers' state.[58] Hessen specifically points out that the history of science betrays a cyclical pattern which would be perilous to ignore with respect to quantum mechanics and relativity theory. New scientific theories often first appear not as materialist, but as empiricist or idealist positions. This is for good reason, as radically new scientific theories tend to emerge from the discovery of new data that are incompatible with established conceptions of materialism.[59] To the extent that these theories are incompatible with such conceptions of materialism, they can often be understood as incompatible with materialism writ large. Time and again, however, the history of science shows that these more often than not become the germs of

58 Bochenski, *Soviet Russian Dialectical Materialism*, 34.

59 Hessen & Egorshin, "On Cde. Timiryazev's Attitude towards Contemporary Science," Forthcoming.

altogether new paradigms of materialism. As he & Egorshin write, citing Engels, "'[w]ith each epoch-making discovery even in the sphere of natural science ['not to speak of the history of mankind'], materialism has to change its form.'"[60] Thus, it would be fallacious, Hessen claims, to simply dispense with the wealth of scientific data and theorizing afforded by these theories. Following his Deborinite approach to dialectical materialist philosophy closely, he argues that one must first and foremost, grasp quantum mechanics and relativity as moments in the historical development of competing conceptions of matter and motion and second, grasp how a materialist conception of these would be possible in principle in the context of a workers' state.

A. Quantum Mechanics

Hessen sees the precedent for quantum mechanics in the history of science to the extent that he sees it as a continuation of competing conceptions of laws of nature, i.e. dynamical and statistical laws.[61] One can find Hessen's most fruitful engagement with quantum mechanics in his Preface to the Russian translation of Austrian physicist, Arthur Haas' *Materiewellen und Quantenmechanik* [*Wave Mechanics and the New Quantum Theory*]. In this piece, Hessen speaks to the ways in which dialectical materialism already aligns with quantum mechanics, most importantly in the consistency between the idea of the former that matter is simultaneously continuous and

60 *Ibid.*, 194. See also Friedrich Engels, *Ludwig Feuerbach and the End of Classical German Philosophy*, in *Marx & Engels: Collected Works, vol. 26; Engels 1882 – 89*, ed. Boris Tartakovsky and trans. Nicholas Jacobs, et al. (London: Lawrence & Wishart, 2010 [1886]), 369 – 370; V.I. Lenin, *Materialism and Empirio-Criticism: Critical Notes concerning a Reactionary Philosophy*, in *V.I. Lenin: Collected Works, vol. 14; 1908*, ed. Clemens Dutt and trans. Abraham Fineberg (Moscow: Progress Publishers, 1977 [1908]), 251.

61 Note that while Hessen sees quantum mechanics as primarily a continuation of the historical debate over laws of nature, i.e. dynamical and statistical, he also sees it as a continuation of debates over various other issues, such as individuals and aggregates/collectives, microcosm and macrocosm, etc. I only restrict my focus to the laws of nature for the sake of brevity.

discontinuous, and the idea of the latter that electron particles behave simultaneously as a particle and as a wave.[62] He goes on to point out that where the two theories do not intersect was due to certain shortcomings in quantum mechanics that could be remedied by a dialectical materialist approach. One of the central themes surrounding quantum mechanics in the early 20th century was that of its significance to the central principle of any and all scientific research, i.e. the law of causality.[63] According to certain interpretations of quantum mechanics at the time, it appeared as though electrons were capable of moving entirely at random. As English physicist, Paul Dirac puts it in a paper from the 5th Solvay Conference, nature "'makes a free choice.'"[64] This concept is exemplified in German physicist, Werner Heisenberg's concept of the 'uncertainty principle', which Hessen refers to as "[a]n increased precision in the determination of a particle's position is related to an increased lack of precision in the determination of the momentum and vice versa."[65] Heisenberg himself attributed the uncertainty principle to what would later be called the 'observer effect', according to which "in the micro-world . . . .[,] it is impossible to separate the measured from the measurer."[66] From this observation, many physicists — from Bohr, Dirac, Eddington, Haas, Heisenberg, Lorentz to Schrödinger — concluded that that the law of causality itself was at stake.[67] The position is perhaps best summarized by Schrödinger in his inaugural address upon his election to the Prussian Academy of Sciences, where he states that

62 Hessen, "On the Question of the Causality Problem in Quantum Mechanics," 143.

63 *Ibid.*, 144 – 151.

64 *Ibid.*, 151. As mentioned in the editors'/translators' note, 'free' does not appear in the original. See G. Bacciagaluppi & A. Valentini, *Quantum Theory at the Crossroads: Reconsidering the 1927 Solvay Conference* (Cambridge: Cambridge University Press, 2009), 405.

65 Hessen, "On the Question of the Causality Problem in Quantum Mechanics," 152.

66 *Ibid.*, 153.

67 *Ibid.*, 144, 145, 151, 152, 153.

> **‘[t]he most burning issue for us today is whether we should abandon, along with classical mechanics, also its basis and method i.e. that immutable laws unambiguously determine the outcome in each individual case depending on arbitrary values of the initial conditions. It is a question of whether it is expedient to preserve the inviolability of the causality postulate.’**[68]

From this ambiguity, many physicists adopted a kind of descriptive approach, whereas others went to great extremes of adopting more idealistic or spiritualistic approaches.[69]

For Hessen, however, one can see this tendency under a new light from a dialectical materialist standpoint, first and foremost by understanding it from a historical perspective. Indeed, throughout the history of modern physics, two kinds of laws continually reappear: dynamical and statistical. A dynamical law, Hessen writes, “is primarily based on the complete and unambiguous determination of a subsequent state by the previous one.”[70] One example of a dynamical law would be that of planetary orbit: “[a] planet’s position is unambiguously and precisely determined by its previous position and speed.”[71] Conversely, a statistical law, he notes, “is the supposition of no dependence of the subsequent state on the previous one.”[72] Take, for instance, a coin toss: “[w]hen a coin is tossed for the tenth time, heads or tails show *totally irrespective* of the result of the ninth toss.”[73]

68 *Ibid.*, 152 – 153. See Erwin Schrödinger, „Sitzungsberichte der Preussischen Akademie der Wissenschaften, 1929,“ in *Gesammelte Abhandlungen, T. 3* (Wien: Verlag der Österreichischen Akademie der Wissenschaften, F. Vieweg, 1984), 304.

69 Boris Hessen, «Idealisticheskiye techeniya v sovremennoy fizike i bor’ba s nimi», *Molodaya gvardiia* 3 (1929): 64 – 67.

70 Hessen, “On the Question of the Causality Problem in Quantum Mechanics,” 148.

71 *Ibid.*, 148.

72 *Ibid.*

73 *Ibid*.

And for centuries, by virtue of its establishing a 'necessary connection', dynamical law was seen as the proper expression of causation, whereas statistical law was seen as the placeholder for the heretofore undiscovered necessary connection.[74] In the case of quantum mechanics, however, statistical laws appear to have usurped dynamical laws altogether:

> the peculiarity of the modern problem is that unlike in classical physics, statistical laws are not subordinate to the dynamical ones, and do not stand alongside them but present the only method that is currently available in physics and that is able to express the internal atomic phenomena's laws.[75]

For Hessen, dialectical materialist philosophy presages an answer to this problem via Engels' account of the unity in opposition of 'chance' and 'necessity'. This is exemplified in Engels' quote where he writes

> '[i]f the fact that a particular pea-pod contains six peas, and not five or seven, is of the same order as the law of motion of the solar system, or the law of the transformation of energy, then as a matter of fact chance is not elevated into necessity, but rather necessity degraded into chance.'[76]

In other words, if one tries to explain chance entirely via necessity or vice versa, one not only eliminates the opposite category, but

74 *Ibid.*, 149.
75 *Ibid.*, 149.
76 Friedrich Engels, *Dialectics of Nature*, in *Marx & Engels: Collected Works, vol. 25 – Engels*, ed. Natalia Karmanova, et al. and trans. Clemens Dutt (London: Lawrence & Wishart, 2010 [1883]), 498 – 501. See Hessen, "On the Question of the Causality Problem in Quantum Mechanics," 150 – 151; Hessen, "Preface to Articles by A. Einstein and J.J. Thomson," 97.

one transforms the one category into the other. In this way, chance and necessity depend upon one another in order to be what they are in the first place. The same goes, Hessen contends, for dynamical and statistical laws. Any phenomenon depends upon the unity in opposition of dynamical and statistical laws, depending on what standpoint one adopts. They are not to the exclusion of one another, but on the contrary, necessarily interdependent such that understood together, they present a much richer conception of the causal relationships between phenomena. Hessen asserts that

> [t]herefore, if we reject the fatalistic concept of determinism on the one hand and accept chance as not simply a consequence of our ignorance but an objective category, then the opposition between dynamical and statistical laws is destroyed. They do not exclude but imply each other. They are both necessary and valid.[77]

Both dynamical and statistical law are abstractions; no circumstance where simply one is at work at the expense of the other.[78] If we return, for instance, to the example of planetary orbits, we find that they are in fact not such a simple expression of dynamical law. As Hessen writes as follows:

> [a] planet's motion is a dynamical law because we neglect its interaction with its environment. We would observe random variations similar to the ones we observe for a tossed coin if we look at an actual trajectory of a real planet and not at a

77 Hessen, "On the Question of the Causality Problem in Quantum Mechanics," 151.
78 *Ibid.*, 150.

> **trajectory of a physical point in mechanics; the aggregate of these variations can be expressed by a statistical law.**[79]

Likewise, concerning the example of coin tosses, we find that they too are not such a simple expression of statistical law. Hessen indicates as follows: "the initial orientation, initial impulse, ejector mechanism, air movement as the coin falls and the whole complex set of initial conditions of a single toss[; e]ach single toss is fully determined by this set of conditions."[80] Thus, there is no such thing as a simple expression of either dynamical or statistical law; all phenomena are intermixed.

Hessen proceeds to apply the same analysis to quantum mechanics, stating that

> **[a] single quantum's direction of motion is accidental not in the sense that it is not determined but because a single quantum's behavior is not essential for the entire aggregate of quanta; only the whole identifies a statistical law.**[81]

That is, while a single quantum may appear to behave in a random fashion, it is nevertheless simply a member of a larger aggregate of quantum behavior that expresses a statistical law. This, of course, does not resolve every single conundrum of quantum mechanics insofar as the issue of observability remains a problem, because the scale of the particles and the instruments available to measure them mean that it is near impossible to determine any dynamical conception of quanta.[82] Nevertheless, Hessen argues that we should treat this

79 *Ibid.*

80 *Ibid.*, 148.

81 *Ibid.*, 149, 151.

82 *Ibid.*, 154.

not as an *a priori* problem of observation as such, but as a limitation of the instruments of observation currently available and of current theories.[83]

B. Relativity Theory

Hessen sees the precedent for relativity theory in the history of science to the extent that he sees it as a continuation of competing conceptions of subject and object.[84] Hessen's perhaps best-known defenses of relativity theory can be found in his *The Main Ideas of the Theory of Relativity*. Hessen's primary thesis in this work is that dialectical materialism and relativity theory coincide to the extent that they share similar conceptions of space and time. From the perspective of Newtonian mechanics, space and time are objective realities, but they exist independently of one another and independently of matter and motion; understood metaphorically, they are like containers within which physical processes take place.[85] From the perspective of relativity theory, though, space and time are inseparable from each other and inseparable from matter and motion. Based on the results of the famous Michelson-Morley experiment in 1887, this lent plausibility to the idea of the constancy of the speed of light.[86] The constancy of the speed of light, of course, presented a considerable challenge to the laws of classical physics, to the extent that if light traveled at a constant speed regardless of the speed of the subject and

83 *Ibid.*, 155.

84 Again, note that while Hessen sees relativity theory as primarily a continuation of the historical debate over subjectivity and objectivity, he also sees it as a continuation of debates over various other issues, such as space and time, etc. I only restrict my focus to subjectivity and objectivity for the sake of brevity.

85 Boris Hessen, "(Selections from) *The Main Ideas of the Theory of Relativity*," in *Boris Hessen: Physics and Philosophy in the Soviet Union, 1927 – 1931; Neglected Debates on Emergence and Reduction*, ed. and trans. Chris Talbot & Olga Pattison (Cham: Springer Nature, 2021 [1928]), 115.

86 Albert A. Michelson & Edward W. Morley, "On the Relative Motion of the Earth and the Luminiferous Ether," *The American Journal of Science* 34.203 (1887): 332 – 345.

the object, this could not be accounted for. Einstein posited, then, that in order for the speed of light to remain constant that space and time had to contract and dilate. Hence, they are inseparable from one another and inseparable from the fabric of matter and motion.[87] Hessen then proceeds to argue that in this way, dialectical materialism and relativity theory coincide in at least two respects, as dialectical materialism too posits the inseparability of space and time and the inseparability of space-time from matter and motion. As he writes,

> dialectical materialism suggests the concept of *the unity* of space and time. . . . [I]n real moving matter, space and time are tied into one complex (synthesis). Matter exists not in two separate and independent forms – space and time forms – but in one space-time form. Space and time are not added mechanically but are inseparably tied into one synthesis in moving matter.[88]

Thus, "As far as physics is concerned the views of relativity theory on space and time generally coincide with the views of dialectical materialism on the relationship between space, time and matter."[89]

He goes on to say, however, that relativity theory had also precipitated an embrace of philosophical relativism, which Hessen describes as the idea "that cognition requires an available subject . . . . [but that it] cannot leave the boundaries of the subject. We cannot ascend to absolute cognition and cannot approach it."[90] Many had taken this to follow from relativity theory to the extent that this theory implies that there is no such thing as absolute space or time,

87 Hessen, "(Selections from) *The Main Ideas of the Theory of Relativity*," 115.
88 *Ibid*.
89 *Ibid.*, 117.
90 *Ibid.*, 118.

but only relative space and time.[91] For Hessen, however, this conflates two distinct conceptions of the notion of relativity, 'philosophical' and 'physical', where the former refers to the relativity of knowledge and the latter refers to the relativity of space-time intervals.[92] Philosophical relativism, of course, does not imply that knowledge is simply arbitrary, but rather that knowledge simply does not extend beyond description from the perspective of one's standpoint. Physical relativism, however, means that the object cannot be understood independent of its reciprocal relationship with the subject; that is, that there is a truthful determination of the relationship between the two.[93] He argues that many had assumed relativity theory to imply philosophical relativism because they had failed to adopt a proper conception of materialism. Relativity theory is incompatible with materialism only to the extent that one adopts a 'metaphysical' or 'mechanical/mechanistic' conception of materialism, according to which one can only cognize the object to the extent that one can conceive of it independent of the subject.[94] He notes that from a dialectical materialistic standpoint, one cannot omit the subject to the extent that the subject is itself material in nature and the extent to which phenomena are understood by way of their opposites. As he states, "[t]he thinking process as the highest form of motion and the most complex one is a process in a human brain that is inseparably tied with other processes there and is another side of a *material* process."[95] Consequently, grasping the nature of the object does not mean extricating the subject, but on the contrary, acquiring knowledge of the object through the subject: "[a]ccording to dialectical materialism, a subject is both a condition and the only *method* for the consistent coverage

91 *Ibid.*, 116.
92 *Ibid.*, 122.
93 *Ibid.*, 120.
94 *Ibid.*, 119.
95 *Ibid.*, 115 – 116.

and cognition of an object. The way towards absolute knowledge is through a subject."[96] The object exists independently of the mind, but truthful cognition is a relationship between a perceiving subject and an object; that is, according to dialectical materialism, there is a truth of the subject-object relation. Contrary to objectors, relativity theory and dialectical materialism share the idea that absolute knowledge is only possible from a relative standpoint. A reflection upon the nature of the subject, then, is not the obstacle to but the path towards asymptotically leading to absolute knowledge.[97]

* * *

For Hessen, just as the breakdown of feudalism and the dawn of early capitalism furnished the basis of classical mechanics via socioeconomic development and technological progress, so too the perceived breakdown of capitalism and the perceived dawn of socialism was furnishing the basis of a new science. Likewise, just as socioeconomic development and technological progress alone left certain physical questions unanswered which were dealt with via ideological struggle, the same would be the case for quantum mechanics and relativity theory. Just as the merchant class had formed scientific societies in the ideological struggle over the new science at the rise of capitalism, so to the working class would have to form their own institutions in the ideological struggle over a new science at the rise of socialism. This meant not completely objecting to the study of quantum mechanics and relativity theory, but rather, cultivating their study in the context of working-class scientific institutions facilitated by the cooperation with experts in their respective scientific fields.[98]

96 *Ibid.*, 119.
97 *Ibid.*, 119, 120.
98 Boris Hessen, «K voprosu o podgotovke nauchnoy smeny v oblasti teoreticheskogo

§. Conclusion

In this introductory essay, I provided a general survey of Boris Hessen's thought in order to properly contextualize our understanding of his *Manuscripts & Documents on the History of Physics*. I asserted that we can best grasp the *Manuscripts* as an expression of Hessen's commitment to a Deborinite dialectical materialist approach to the history & philosophy of science. This assertion was supported by providing a general account of Hessen's composition of the *Manuscripts* and its reception. Then, I proceed to enumerate Hessen's approach to contemporary scientific problems through an analysis of the history of science from a Deborinite dialectical materialist standpoint. The essay then went on to show how Hessen applied this approach to classical physics, along with quantum mechanics and relativity theory. Altogether, we saw the portrait of a philosopher who took dialectical materialism as a philosophy in its own right, which served the practical purposes of facilitating the birth of a new society in light of the limits of socioeconomic development and technological progress as well as of the laws of nature.

yestestvoznaniya», *Kommunisticheskaya revolyutsiya* 5 (1929): 62 – 67; Hessen & Egorshin, "On Cde. Timiryazev's Attitude towards Contemporary Science," Forthcoming; Boris Hessen & Ivan Luppol, «O kruzhkakh po izucheniyu dialekticheskogo materializma sredi molodykh nauchnykh rabotnikov», *Kommunisticheskaya revolyutsiya* 14 (1928): 77 – 83.

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The International and Interdisciplinary Circulation of Boris Hessen's Theses

Gerardo Ienna

Introduction

The reception of Hessen's famous essay titled *The Social and Economic Roots of Newton's Principia* has undergone various stages or, to put it in Bourdieu's terms, labeling processes (*marcature*) through which Hessen himself has come to be regarded as a precursor figure in a wide range of debates. Readers of his work have offered a variety of interpretations of it based on their specific positions within these debates.

In the following pages, I will outline the various phases of the circulation of Hessen's theses from the 1930s to the present day. I will first reconstruct the immediate reception in Britain of Hessen's theses during the conference and in the years immediately following. Subsequently, I will highlight how the legacy of Hessen and the readings of him by British Marxists went beyond the national borders of Britain to arrive, firstly, in the US and, secondly, back to the USSR through a process of reverse circulation of ideas. In both cases this complex form of dissemination of Hessen's theses led to different kinds of debates. I will also consider the positions of the detractors of the theses referred to in derogatory terms as 'externalist' by showing how Hessen's intervention in 1931 has been taken as the main polemical target of this current of research. In the second part of the text, I will move towards more contemporary debates highlighting how Hessen's thought has been rehabilitated since the 1970s as the inspirational father first of the Radical Science Movements and then showing how his theses have been taken up in the emerging debates in the field of Sociology of Scientific Knowledge and in the wider STS context. The anti-deterministic character of his theses will emerge clearly from the account of scholars interested in overcoming the debate between internalism vs. externalism. To conclude, I will trace the last phases of the international circulation of this author and the emergence of a more mature phase of canonization of his work. I will retrace the various translations that have been made of the famous 1931 speech and of other texts by Hessen that have only recently been published in languages other than Russian (and for this reason are little known at international level). The reconstruction of the international and interdisciplinary circulation of Hessen's famous essay is necessary for understanding how the evaluation of his intellectual legacy has changed over time.

The Debates in the United Kingdom Stemming from the London Congress

During the congress and in the following days, the theses supported by the Soviet delegates generated a strong debate. Its resonance was broadly perceived by those present at the event in London. At the time, there was a very active circle of scientists in the United Kingdom engaged in political leftism, whom Werskey called the 'visible college.'[1] This group included John Desmond Bernal, John Haldane, Lancelot Hogben,[2] Hyman Levy, and Joseph Needham. These authors had a common interest in the investigation of science's role

1 The concept of the visible college was coined by Werskey, echoing the expression "invisible college," which was employed by Robert Boyle to refer to a dozen natural philosophers gathered around him in 1660. Gary Werskey, *The Visible College. The Collective Biography of British Scientific Socialists in the 1930s* (New York: Holt Rinehart Winston, 1979).

2 He proposed the immediate publication of the texts of the Soviet delegation.

in society. Excluding Haldane,[3] everybody in this group was at the 1931 congress and remained strongly influenced by the talks of the Soviet delegation.

The intervention of the Soviet delegation was meant as a cultural-political operation and, for this reason, it was decided that the Soviet communications should be published in English in a volume titled *Science at the Crossroads*. During the course of the conference, a group of translators and proofreaders at the Russian Embassy worked hard to prepare the volume for print. On the morning of July 4, during the actual speech of the Soviet delegation, a first unbound version of the Soviet papers was distributed. The complete collection of the Soviet delegates' papers was published by the Russian Foreign-Language Press about ten days after the end of the conference. Despite numerous typographical errors and inaccurate linguistic revision of the translation, copies of the book quickly sold out[4]. An expanded version (with revisions) introduced by Paul Gary Werskey and including a preface by Joseph Needham appeared in 1971.[5]

The Marxist approach proposed by these delegates clearly separated them from the positivist and Comtian approach to understanding the history of science.[6] For a long time, this discipline had, in fact, been practiced as a secondary activity by professional scientists who

3 Haldane was the only one absent at the congress. He would only turn to Marxism after the Spanish Civil War in 1936.

4 Gideon Freudenthal and Peter McLaughlin, "Classical Marxist Historiography of Science: The Hessen-Grossmann-Thesis," in *The Social and Economic Roots of the Scientific Revolution*, ed. Gideon Freudenthal and Peter McLaughlin, (Dordrecht: Springer, 2009), 1-40.

5 Bukharin, *Science at the Cross Roads.* Only Hessen's text has been reprinted in a stand-alone edition in Sydney 1946. For an analysis of the various editions of the text cf. Gerardo Ienna and Giulia Rispoli "Boris Hessen al bivio fra scienza e ideologia," in *Le radici sociali ed economiche della meccanica di Newton* by Boris Hessen, ed. Gerardo Ienna (Rome: Castelvecchi, 2017), 39-41.

6 Jean François Braunstein, *L'histoire des sciences* (Paris: Vrin, 2008); Jerôme Lamy and Arnaud Saint-Martin, "La sociologie historique des sciences et des techniques. Essai de généalogie conceptuelle et d'histoire configurationnelle," *Revue D'histoire des sciences* 68, no. 1 (2015): 175-214.

had often not deeply reflected on the theoretical-historical model implicit in their construction of historical narratives. During the very early stages of institutionalization, the history of science thus crystallized around the celebration of great personalities, such as Galileo Galilei, Johannes Kepler, and Isaac Newton, who were often presented as intellectual figures capable of bringing a radical transformation to the sphere of human knowledge through their genial contribution. However, this approach underestimated the role played by certain forms of knowledge and certain types of actors (therefore marginalized in standard narratives) in enabling the social emergence of scientific activity. For the first time in the history of the historiography of science, the interventions of Bukharin, Hessen, Rubinstein, and others emphasized the role of technicians in the development of science, the impact of cultural-religious convictions on scientific practices, and particularly the determinations coming from the economic-social structure on the sphere of intellectual production.[7] All these elements mutually concur to form a system in equilibrium, as

7 In the same period in France the historiographic current of Annales founded by Marc Bloch and Lucien Febvre emerged. This tradition has had relevant intersections with the debates in the history and philosophy of science, especially in the context of the French *épistémologie historique* [cf. Enrico Castelli Gattinara, *Les inquiétudes de la raison: épistémologie et histoire en France dans l'entre-deux-guerres* (Paris: Vrin 1988)]. As pointed out by Maria Paula Diogo,"The Perfect Pair" authors gathered around the journal *Annales* have contributed in various ways to the history of science and techniques. These authors have proposed an approach based on the rejection of an event-based narrative (*histoire_ événementielle*). Their goal was rather to propose a historiographical model based on the concepts of *total history, history-as-problem (histoire totale*, and *histoire-problème)* aimed at proposing a long-term (*longue durée*) historical perspective on social and cultural phenomena. In analogy to what Hessen proposed in his speech in London, authors such as Braudel and Febvre devoted attention to the analysis of the material conditions of the emergence of technological forms as much as its effects on culture and society. This communion of purpose is also evident from the collaboration between the Bernalist authors Needham and Julian Huxley with Febvre in the context of the UNESCO project for the writing of the *History of Scientific and Cultural Development of Mankind* cf. Maria Paula Diogo, "The Perfect Pair." See also Elena Aronova, *Scientific History. Experiments in History and Politics from the Bolshevik Revolution to the End of the Cold War* (Chicago: University of Chicago Press, 2021), 87-131.

we outlined above, where science, technology, and society reinforce each other.

The rhetoric of the scientific genius sent by God or appearing from nowhere is therefore deconstructed through the adoption of sociological tools of analysis capable of bringing to light a hidden side of the dynamics of scientific production and highlighting the communitarian structure of scientific activity.

It should also be emphasized that this historiographical model is not unrelated to a certain way of understanding the organization of scientific activity in contemporary times. The issues at stake in the science-at-the-crossroads debate therefore imply the discussion of two intimately connected aspects: on the one hand, the opposition between capitalist science and socialist science, and on the other hand, the opposition between internalist historiographic methodology and what has been called (not without discredit) externalist methodology.[8] The approach proposed by the Soviet delegates inaugurated a method of inquiry that allows us to see both the effect of science on societal transformation and the impact of society on the production of scientific practices. The entanglement of these two aspects still represents a fundamental theoretical background that Marxism has provided in order to understand the most urgent problems of our contemporaneity.

Among the members of this visible college, Bernal and Needham were particularly prolific in their work to further the perspective of the Hessen theses in the history of science.[9] Bernal was a strong supporter of the Soviet model in its promotion of a harmonious development of

8 Wolf Schäfer, "Boris Hessen and the Politics of the Sociology of Science," *Thesis Eleven*, 21, no. 1 (1988): 103-116, on 104.

9 Steven Shapin, "Hessen Thesis," in *Dictionary of the History of Science,* ed. William F. Bynum, (London: Macmillan, 1982), 185-186.

society and science.[10] In addition to his scientific studies about X-rays and molecular biology, Bernal authored several now classic texts, such as *Engels and Science* (1935); *The Social Function of Science* (1939); *Marx and Science* (1952); *Science and Industry in the Nineteenth Century* (1953); his monumental work in three volumes, *Science in History* (1954); and *Emergence of Science* (1971). Especially in his 1939 book, he tried to address the question—particularly important for Marxism—of science policy. In accordance with Bukharin's presentation at the London congress that focused on the relation between science and ideology, and theory and praxis, Bernal delineated a way to put scientific practice at the service of society.

In this regard, he clearly stated that the interest in dialectical materialism in the United Kingdom emerged from the congress of 1931. In fact, the Soviet delegation "showed what a wealth of new ideas and points of view for understanding the history, the social function, and the working of science could be and were being produced by the application to science of Marxist theory."[11] In a footnote, he also added an explicit reference to the Hessen theses: "Hessen—article on Newton— [...] was for England the starting point of a new evaluation of the history of science."[12] In this context *Science in History* served as a perfect example of how to provide a Marxist interpretation of the history of science. This text by Bernal would later become a classical point of reference within this discipline and considered by many a masterpiece.[13]

10 Serge Guérout, "Présentation," in *Les racines sociales et économiques des Principia des Newton*, Boris Hessen, (Paris : Vuibert, 2006), 1-67.

11 John D. Bernal, *The Social Function of Science* (London: Rutledge, 1946), 393.

12 Ibid., 406.

13 In fact, in 1981, on the occasion of the fiftieth anniversary of the London congress, the journal *Isis* dedicated a special part of its third issue to the theme of Marxism and history of science in which Jerome Ravetz and Richard Westfall contrasted precisely in attributing a different meaning to Bernal's science in history for the history of the discipline, cf. Jerome Ravetz and Richard S. Westfall, "Marxism and the History of Science," *Isis* 72, no. 3 (1981): 393-

At the same time, Joseph Needham was publishing his *Chemical Embryology* (in three volumes) in 1931. During the preparation of this book, he also had the possibility to meet Charles Singer, the president of the London congress. During the congress, Needham was particularly impressed by Boris Zavadovskij's talk. Indeed, Zavadovskij reached the same conclusions of Needham, even if the former was starting from the axioms of dialectical materialism. Nevertheless, Hessen's contribution played the most significant role in shaping Needham's thought. In his *History of Embryology* (1934)—a revised version of his text from 1931—Needham wrote, "further historical research will enable us to do for the great embryologists what has been so well done by Hessen for Isaac Newton."[14] In introducing the second edition of *Science at the Cross Roads*, he said, "This essay [by Hessen], with all its unsophisticated bluntness, had a great influence during the subsequent forty years, an influence still perhaps not yet exhausted."[15] Also, in his later works—like the monumental seven-volume *Science and Civilisation in China* (published between 1954 and 2004)—Needham expressed his debt to the stimuli received by Bukharin, Hessen, and the other Soviet delegates.

Among those attending the conference was also the scientific journalist James Gerald Crowther.[16] He was particularly active in

405. Consider also that the Society for Social Studies of Science, one of the major institutions in the field of STS, has awarded the J. D. Bernal Prize every year since 1981 to a scholar who has distinguished himself or herself by making a significant contribution to the study of the social dimension of science. Among the winners of this prize are: Robert K. Merton, Thomas Kuhn, Joseph Needham, Joseph Ben-David, Bruno Latour, David Edge, David Bloor, Harry Collins, Barry Barnes, Donna Haraway, Steven Shapin, Michel Callon, Sheila Jasanoff, Donald MacKenzie, Steve Woolgar, and Karin Knorr Cetina.

14 Gary Werskey, "Introduction," in *Science at the Cross Roads,* ed. N. Bukharin, (London: Frank Cass & Co. Ltd., 1971), XXII.

15 Joseph Needham, "Foreword," in *Science at the Cross Roads,* ed. N. Bukharin (London: Frank Cass & Co. Ltd., 1971), VIII.

16 Crowther was a correspondent for the *Manchester Guardian* and a secret member of the communist party. It was Crowther himself who revealed the real composition of the Russian delegation at least four weeks before the beginning of the conference.

politics and closely associated with Hessen, with whom he maintained correspondence from 1931 until the death of the Russian physicist.[17] Crowther was a very prolific scholar who represented a cardinal point in the evolution and dissemination of Marxist methodology in the history of science. By 1930, he had already published *Science in Soviet Russia* (his interest in this topic predated the congress). In *The Social Relation of Science*, Crowther also declared, "The movement, of which Hessen's essay was the most brilliant expression, transformed the history of science from a minor into a major subject." In particular, he declared that Hessen's perspective demonstrated how the history of science "was essential for the solution of contemporary social problems due to the unorganized growth of a technological society."[18] As will be explained in the next paragraph, this broad UK leftist movement in science took the name of Bernalism in the following years (from the name of Bernal, its major authoritative scholar).

In the same context in which the Hessen theses were disseminated in the United Kingdom, one must also consider the economic historian, George Norman Clark.[19] Despite being a detractor of Hessen's theses, he clearly declared that Hessen's work represented "the best available statement" of the relation between the rise of modern

17 Christopher A. J. Chilvers, "The Dilemmas of Seditious Men: The Crowther-Hessen Correspondence in the 1930s," *The British Journal for the History of Science*, 36, no. 4 (2003): 417-35.

18 James Gerald Crowther, *The Social Relations of Science* (New York, The Macmillan Company, 1941), 617.

19 Clark, who was the opening speaker of the first session of the London conference, was harshly criticized by the Soviet delegation. See Freudenthal and McLaughlin, "Classical Marxist Historiography of Science," 30. For the Russians, in fact, Clark's proposals (but also Hill's), went toward a new form of "the cult of heroes" of the history of science. From a Marxist point of view, it was considered necessary to break with individualistic and/or bourgeois philosophies of history, privileging instead studies that highlighted how the great scientists of the past had been influenced by the social and economic forces of their time. See Werskey, "Introduction," XXII.

science and the fall of the feudal economy.[20] But Clark's reception of Hessen's work was not without criticism. In *Science and Social Welfare in the Age of Newton* from 1937, he specified that in order to explain the success of natural sciences in those centuries, there were other factors to be considered in addition to those indicated by Hessen. Together with the rise of the bourgeoisie, Clark underlined at least six other factors: the role played by religion, the concern for treating the sick, the desire to win wars, artistic creation, and the pursuit of pure knowledge.[21] The third part of his book, titled *Social and Economic Aspects of Science,* is entirely dedicated to the discussion of Hessen's approach to the history of science. Various scholars have highlighted some of Clark's misunderstandings of Hessen's arguments (we will come back to this topic later) that were reproduced in the process of canonizing the author in the following years. Various scholars highlighted some of Clark's misunderstandings of Hessen's arguments—a topic that I will come back to later—that were reproduced in the process of canonizing the author in the following years. From this point of view, Clark made a serious mistake in assuming that the study of the determinant social factors of scientific thought should consist mainly in dissecting a scientist's personal motivation. On the contrary, Hessen and the Marxist tradition have explicitly criticized this point as an individualistic tendency in philosophy.[22] In particular, Clark argued that he would have used a "biographical"[23] and "psychological"[24] model in the history of science (i.e., precisely what the Russian authors criticized).

Although Clark's reading of Hessen's text is strongly critical and at times even a caricature, in our opinion it is necessary to consider

20 George Norman Clark, *Science and Social Welfare in Age of Newton* (Oxford, Oxford University Press, 1937), 63.
21 Guérout, "Présentation," 37; Clark, *Science and Social Welfare*, 89.
22 Freudenthal and McLaughlin, "Classical Marxist Historiography of Science," 30.
23 Clark, *Science and Social Welfare*, 86.
24 Ibid., 87.

that the English historian's objective is largely to overcome the 'crude' approach of the Soviets by means of a series of additions that allow him to go beyond the strictly economic interpretation of Newton's work. Clark also knew Max Weber, whom he quotes explicitly in his text (a year before the publication of Merton's theses.[25] Despite this, he recognized that the German author did not have a complete understanding of the relationship between religion, science, and technology. After having quoted *The Protestant Ethic and the Spirit of Capitalism,* he argued:

> It does not appear to me that this generalization is borne out by the facts. We have seen that Spain and Portugal were homes of the studies of navigation and medicine. In the sixteenth century Italy was the most fruitful field of science and technology; in the early seventeenth in France and the Catholic Netherlands had some great names; in the late seventeenth and eighteenth England and Holland had their turn. But there was a great deal more besides religion to account for this; many other elements of economic history were tending to the same result.[26]

Throughout the 1930s, the Marxist approach to science was developed even beyond the British borders. Authoritative authors coming from very heterogeneous intellectual backgrounds had, in fact, already worked in this direction, so that a strong historiographic tradition began to consolidate in the West.[27]

25 Robert K. Merton "Science, Technology and Society in Seventeenth Century England," *Osiris* 4 (1938): 360-632. See also Steven Shapin, "Understanding the Merton Thesis." *Isis* 79, no. 4 (1988): 594-605.

26 Ibid, 85-6.

27 From the context of the Vienna Circle and Austro-Marxism, Edgar Zilsel developed an original interpretation of the birth of modern science as the resolution of a class conflict. Edgar

From the ’30s to the ’50s: Beyond the U.K.

At the same time, the Hessen theses crossed the Britannic borders to arrive on the American side of the Atlantic Ocean. In this context, Merton played a central role in the dissemination of Hessen’s work and of a certain conception of science and technology studies. He defended his PhD thesis, *Science, Technology and Society in Seventeenth Century England*, in 1935 and published it in 1938. This work is considered the birth certificate of the sociology of science as an autonomous discipline, and it represents a cardinal moment for the *querelle* between internalism and externalism. This text is composed of two main parts: from paragraph 1 to 6, he develops what has been called the “Merton theses.”[28] In the same spirit of Weberian sociology, Merton establishes a connection between Protestant ethics and the emergence of modern scientific thought in England during the seventeenth century. On the contrary, in the second part of the essay

Zilsel, *The Social Origins of Modern Sience* (Dordrecht, Springer, 2013). Henryk Grossmann and Franz Borkenau, an economist and sociologist, respectively, were both affiliated with the Institut für Sozialforschung (Institute for Social Research) in Frankfurt under Carl Grünberg’s direction. These authors thus related in various ways to the nascent Frankfurt critical theory. Cf. Rick Kuhn, “Henryk Grossman and Critical Theory,” *History of the Human Sciences* 29, no. 2 (2016): 42-59; Gideon Freudenthal and Peter McLaughlin, eds., *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann* (Dordrecht, Springer, 2009); Valeria E. Russo, “Henryk Grossmann and Franz Borkenau A Bio-Bibliography,” *Science in Context* 1, no. 1 (1987): 181-91; Rick Kuhn, “Introduction to Henryk Grossman’s Critique of Franz Borkenau and Max Weber,” *Journal of Classical Sociology* 6, no. 2 (2006): 57–100. Within this special issue and other articles, Peter D. Omodeo has instead analyzed the perspective elaborated by Gramsci. Pietro D. Omodeo, “La via gramsciana alla scienza,” *Historia Magistra* 4 (2010): 53-68; Pietro D. Omodeo, “Egemonia e scienza: Temi gramsciani in epistemologia e storia della scienza,” *Gramsciana: Rivista internazionale di studi su Antonio Gramsci* 2 (2016): 59-86; Massimiliano Badino and Pietro D. Omodeo, *Cultural hegemony in a scientific world: Gramscian concepts for the history of science* (Leiden, Brill, 2020); Pietro D. Omodeo, “The Struggle for Objectivity: Gramsci’s Historical-Political Vistas on Science against the Background of Lenin’s Epistemology” *HoST-Journal of History of Science and Technology* 14, no. 2 (2020): 13-49. For a general perspective on these issues, cf. Ienna and Rispoli, “Boris Hessen At The Crossroads of Science And Ideology”.

28 At the time, Merton had already used Hessen’s work for an article dedicated to the analysis of the relation between science and military technique. R. K. Merton, “Science and Military Technique,” *The Scientific Monthly* 41/6 (1935): 542-545.

(from paragraph 6 to 11), the role of the Hessen theses is more explicit. In fact, in a footnote, Merton admits to closely following "the technical analysis of Hessen in his provocative essay."[29] In particular, he highlights how the Russian author's paper "provides a very useful basis for determining empirically the relation between economic and scientific development."[30] In one of the appendices of his text, Merton also emphasizes his dependence on Clark's interpretation of the Hessen theses. Clark suggests that Hessen "over-simplifies the social and economic aspect of the science." In contrast, Clark "points out that at least six major classes of influence outside of science proper were operative: economic life, war, medicine, arts, religion and most important of all, the disinterested search for truth."[31]

Merton chose an eclectic methodology for which—despite indicating some distance from a strictly Marxist approach—he recognized his debt to Hessen.[32] In chapters 7, 8, and 9, he reproduces Hessen's model. First of all, Merton highlights the needs and interests at work in the productive sector and, second, its associated technical problems. Only at the end does he discuss the emergence of the scientific problems derived from these factors. It is necessary to note that Guéroult identified how some of Hessen's historiographical errors were reproduced in Merton's essay without corrections.[33] The conventional narrative has crystallized (in the wake of Weber) the idea that the "Merton theses", as opposed to a Marxist theses, would have

29 R. K. Merton, "Science, Technology and Society in Seventeenth Century England", *Osiris* 4 (1938): 501-502.

30 Ibid.

31 Ibid., 565.

32 "We have already indicated that the preceding three chapters of the present study, despite certain differences of interpretation, are heavily indebted to Hessen's work." Ibid.

33 These errors had been broadly recognized by many scholars (for example, cfr. Needham, J., "Introduction," VIII). For his part, Merton reproduced some of these errors like writing "Herique" instead of "Von Guericke" (p. 507) or "the arsenal of Florence" instead of "the arsenal Venice" Guérout, "Présentation," 47.

given centrality to the superstructural elements, in this case, religion. As we will see, however, Hessen did not uphold a rigid deterministic relationship between structure and super-structure; in fact, quite the contrary. Therefore, Merton's debt to Hessen is even greater than has been previously thought. The idea that there is an opposition between internalism and externalism will come to be based precisely on this flawed interpretation. However, Merton's[34] and Clark's use of the Hessen theses has reinforced the canonization and dissemination of the Soviet author on a global scale. This process erected an image of Hessen as a precursor of various lines of research which, with some rectifications, have become known as "externalism". For subsequent generations, and to an ever-increasing extent, Hessen became a benchmark figure.

Another central contribution is that of Edgar Zilsel, one of the members of the Vienna Circle (later exiled to the U.S.). This author dedicated considerable attention to the sociological application of Marxist methodology to the history of science. Even if Zilsel never directly quoted Hessen's work, the theses of these two authors have frequently been juxtaposed based on the affinity of their ideas. The Viennese author's thesis tends to explain the emergence of science in the modern age in light of the resolution of social tension between, on one hand, the humanistic and university elite, and on the other, the engineers and the artisans living in more modest conditions.[35] Zilsel

34 The success of Mertonian sociology in the U.S. has made possible the institutionalization of sociology of science as an autonomous discipline: R. K. Merton, "The Sociology of Science: An Episodic Memoir," in *The Sociology of Science in Europe*, eds. R.K. Merton; J. Gaston (London-Amsterdam: Feffer & Simons, 1977); Ben-David, J. "Emergence of National Traditions in the Sociology of Science. The United States and Great Britain," in *Sociology of Science. Problems, Approaches and Research*, ed. J. Gaston (San Francisco-Washington-London: Jossey-Bass Publishers, 1978).

35 J. Lamy; A. Saint- Martin, "La sociologie historique des sciences et des techniques. Essai de généalogie conceptuelle et d'histoire configurationnelle," *Revue D'histoire des sciences* 68/1 (2015): 175-214.

and Hessen share common ground in the inversion of the canonical perspective on the history of science as a history of great personalities, great inventions and discoveries. From the Viennese author's perspective, the conditions of nascent capitalism and the bourgeoisie's needs made the affirmation of a new *scientific spirit* possible.[36] In this sense, the spread of capitalism necessarily required technological progress as a way of facilitating the development of the productive process. The social effects of these conditions allowed for the traversing of the social and cultural boundaries between academics and humanists, who were exclusively involved in the intellectual and university context, and artists and engineers, who were effectively engaged in manual work, like surgeons and barbers, manufacturers of measuring instruments, those employed in construction or engineering firms, etc. For Zilsel, the birth of modern science was represented by this cross-fertilization process.

In line with this theoretical endeavor, the German sociologist Franz Borkenau, a member of the Communist Party, argued that on the contrary, the emergence of modern science was the result of the passage from manual labor to new forms of uniform production, characterized by temporally segmented and quantitatively precise tasks.[37] In other words, work underwent a mechanical transformation, as seen with the abstraction and standardization of processes and for Borkenau, this was linked with the advent of the modern concept of natural law and mechanical philosophy.

Henryk Grossmann is another author often associated with Hessen.[38] Grossmann was an economist and statistician with communist sympathies. He had Polish-Jewish origins and migrated to Germany,

36 Zilsel, *The Social Origins of Modern Science*, 10.

37 Guérout, "Présentation," 42.

38 This connection had great success, especially for the edition that collects the texts of both authors under the direction of Freudenthal and McLaughlin.

but after Hitler's rise to power, he emigrated to the U.S. Many scholars have erroneously argued that he only knew Hessen indirectly (i.e. through Clark's interpretations). In 1938, Grossmann wrote a review of *Science and Social Welfare in the Age of Newton* by Clark,[39] in which he highlights how Clark only offered an interpretation of Hessen in light of the first of his three theses. Contrary to Clark's interpretation, Grossmann affords more prominence to the third thesis, in accordance with his interest in mechanical philosophy and physical movement. In this sense, Grossmann developed a kind of *technological determinism* according to which the emergence of modern science was a direct consequence of the state of then-existent technology.[40] He maintains that because the technology of the time hadn't exhibited any other kind of movement than those related to mechanics, science was then mainly dedicated to mechanical questions.

Back in URSS: A reverse circulation of ideas

In the years following the London congress, the debates certainly did not end. During the 1930s, the so-called visible college was transformed into a progressively larger cultural phenomenon known as Bernalism.[41] This name was motivated by the wide influence generated by *The Social Function of Science* in the British and intellectual field, which allowed it to establish itself as a reference manifesto

39 H. Grossman, "Review of G.N. Clark, Science and Social Welfare in the Age of Newton" in *The Social and Economic Roots of the Scientific Revolution*, eds. Gideon Freudenthal and Peter McLaughlin (Dordrecht/Boston: Springer, 2009), 235.

40 H. Grossmann, "The Social Foundations of the Mechanistic Philosophy and Manufacture," in *The Social and Economic Roots of the Scientific Revolution*, eds. Gideon Freudenthal and Peter McLaughlin (Dordrecht/Boston: Springer, 2009).

41 For Bernalism's dissemination, cf. Ravetz and Westfall, "Marxism and the History of Science"; Maurice Goldsmith and Alan Mackey, eds., *The Science of Science* (London: Pelican Books, 1966); Gary Werskey, "The Marxist Critique of Capitalist Science: A History in Three Movements?," *Science as Culture* 16, no. 4 (2007): 397-461; Aronova, *Scientific History*, 132-139.

for Marxism in scientific debates.[42] The sphere of intellectual debates of the 1930s that sprang from the 1931 London conference also had a *longue durée* effect over the following decades and fostered the Soviet reception of a wider range of intellectual debates.

Shortly before the London Congress, a new interdisciplinary field of research emerged in the Soviet Union. *Naukovedenie* (the science of science) stood at the crossroads of history, sociology, and epistemology. Russia's electrification plan, for example, was among the first objectives of *naukovedenie,* which became known as the study of the inherent nature of science and a general theory of scientific cognition. In 1926, Ivan A. Borichevsky described it as a study of the social purpose of science and its relations with other types of social creativity. According to Borichevsky, this area of knowledge did not yet exist, but it must. It was required by the very dignity of its object—the revolutionary power of exact knowledge.[43] With this early description, *naukovedenie* can even be considered as a sociology of science ante litteram.

The main goal of the *naukovedenie* was to analyze science and technology as institutions, combining what we would now call organization and management of science and social studies of science. In Soviet Marxist terms, science is thus interpreted as a strategic productive force for the progress of society. This branch of research had a twofold task: on the one hand, to improve the performance of scientific researchers, and on the other, to understand the cognitive dimension of science using all relevant human and social sciences. *Naukovedenie* was thus configured as a field at the intersection of the two cultures, that is, between the humanities and social sciences

42 Goldsmith and Mackay, *The Science of Science*, 9.

43 Ivan A. Borichevsky, "Naukovedenie kak tochnaya nauka," *Vestink Znanija* 12 (1926): 786; Yakov M. Rabkin, "'Naukovedenie': The Study of Scientific Research in the Soviet Union," *Minerva* 14 (1976): 61–78.

(providing the method) and the natural sciences (representing the object).[44] Apart from Borichevsky, the pioneering figures of *naukovedenie* in the 1920s include Bukharin and Vladimir Vernadsky. In 1916, the latter had already recognized the need to address the problem of the organization of research and scientific work in Russia and the importance of creating a network of research institutes across the country and even at a global level. He argued that science is a global phenomenon, thus in order to solve problems that pertain to contemporary society, a concerted effort at the transnational level is required. Moreover, organization is fundamental when it comes to obtaining scientific achievements in a quick and 'economic' way.[45]

Vernadsky worked to establish an institutional commission for the study of the history of knowledge at the Soviet Academy of Sciences.[46] One of the objectives of the commission was to study nature in relation to the evolution of society, a project Bukharin mentioned in his presentation in London. The commission addressed the importance of developing the field of the humanities, paying exceptional attention to the history and philosophy of science and sociology. Vernadsky believed that scientific work could only be clarified in a historical context because only then is it possible to understand emergent phenomena. Moreover, he argued that the study of history had revealed the need for a reconstruction of science as transdisciplinary

44 Elena Aronova, "The Politics and Contexts of Soviet Science Studies (*Naukovedenie*): Soviet Philosophy of Science at the Crossroads," *Studies in East European Thought* 63, no. 3 (2011): 175-202.

45 Vladimir I. Vernadsky, "Izbrannie nauchnye trudy akademika V.I. Vernadskovo," in *Trudy po istorii, filosofii y organizazii nauki, Tom. 8* (Fenics, 2012).

46 The first chair of the "History of Modern Scientific Thought," which discussed both the contributions of Soviet scientists and great classics such as Newton, was established in those years, and in 1927, the Institute of History of Science, as a part of the Natural Science Section of the Academy of Sciences, was taken over by Bukharin. The institute covered broad areas addressing the relationship between science, the arts, technology, scientific research methodology, and more.

knowledge and as a global phenomenon.[47] In this way, Vernadsky pointed out the problem of the rationalization of science that was at the base of scientific and economic planning in the 1920s and 1930s.

In the 1910s and 1920s, an interdisciplinary intellectual field emerged in Poland as well, called *naukoznawstwo* (also translated as the science of science or logology). The main authors of the *naukoznawstwo* were Stanislaw Michalski and some representatives of the philosophical school of Lvov and Warsaw, such as Kazimierz Twardowski, Maria Ossowska, Stanislaw Ossowski, Taddeusz Kotarbinski, Kazimierz Ajdukiewicz, and Florian Znaniecki.[48]

Although the genesis of Polish and Soviet science of science studies were relatively independent from one another, their disciplinary histories intertwined as they developed. During the Stalin era in the Soviet Union, the whole scientific field of science suffered various forms of censorship and purges, abetted by Lysenkoism[49]. Beside the most famous case, the Lysenko affair, in relation to which the geneticist Vavilov (one of the speakers at the '31 conference) was sentenced to death, many of the authors who participated in the London Congress were publicly discredited or, in the worst cases, purged.[50] The same fate impacted the institutionalization process of the *naukovedenie* and *naukoznawstwo* whose development came to an abrupt halt in the 1930s.[51]

47 Vladimir I. Vernadsky, "O Zadacach Komissii po izucheniu estestvennych proisvoditel'nich sil v dele organizazii spetzializirovannich issledovatel'nich istitutov," *Voprosiy istorii estestvoznaniya y techniki*, no 1 (1999 [1917]): 161-167.

48 Michał Kokowski, "The Science of Science (naukoznawstwo) in Poland: Defending and Removing the Past in the Cold War," in *Science Studies during the Cold War and Beyond*, eds. Simone Turchetti and Elena Aronova (New York, Palgrave MacMillan, 2016), 150.

49 Dominique Lecourt, *Lyssenko* (Paris: Maspero, 1976)

50 Needham, "Foreword," IX-X.

51 In Poland, this type of study had suffered a major setback due to the double invasion of Nazi Germany and the USSR and the subsequent closure of many universities, foundations, and scientific associations. Cf. Kokowski, "The Science of Science (naukoznawstwo) in Poland," 151; Tadeusz Krauze, Zdislaw Kowalewski and Adam Podgórecki, "The Sociology of Science in

For many years, the ideas of Bukharin, Hessen, Vavilov, and many others were banned in Soviet intellectual debates. Nevertheless, the kind of approach proposed by these authors and the *naukovedenie* and *naukoznawstwo* had already begun to circulate in Western countries. Because of these vicissitudes, Bernalism became, perhaps paradoxically so, the only survivor of the theories proposed by the Soviet delegates of London, which shortly in turn became a western version of the science of science.[52]

It was not until Stalin's death in 1953 and with the more moderate policies of his successor, Nikita Khrushchev and especially those of Leonid Brezhnev beginning in the 1960s, that this type of study began to attract new attention in the Soviet Union. For this reason, it is only at the end of the 1950s and the beginning of the 1960s that there was a real institutionalization of the *naukovedenie* label, which hybridized both Polish *naukoznawstwo* and Western science policy.[53] In fact, in 1965, the *International Congress on the History of Science* was held between Krakow and Warsaw with the participation of Soviet and Polish delegates, as well as scholars from the Western Bloc. The conference was opened by Bernal and Mackay's plenary lecture

Poland," in *The Sociology of Science in Europe*, eds. Robert K. Merton and Jerry Gaston, 193-223 (London-Amsterdam, Feffer & Simons, 1977), 204; Loren R. Graham, *Science in Russia and the Soviet Union: A Short History* (Cambridge, Cambridge University Press, 1993), 152.

52 Cf. Goldsmith and Mackey, *The Science of Science*; Derek De Solla Price, *Little Science, Big Science* (New York: Columbia University Press). Also, the classical article by Polish scholars Ossowska and Ossowski was translated and broadly disseminated in English by the journal Minerva: María Ossowska and Stanislaw Ossowski, "The Science of Science," *Minerva* 3, no. 1 (1964): 72-82.

53 It should be remembered that after the end of the war, Poland was completely annexed to the countries under Soviet influence, which led to massive control by the USSR over academic posts in the nation's universities. In those years, for example, the texts of Marx, Engels, Lenin and Stalin were translated into Polish, as were the most important contributions of scientists from the Soviet regime such as Zhdanov, Lysenko, Vladimir Alexandrovic, etc. As for the science of science, the previous generation of scholars had largely been relieved of their institutional positions, leading to a forced alignment in this field of research with Soviet orthodoxy (cf. Kokowski, "The Science of Science (*naukoznawstwo*) in Poland," 152-55).

entitled *On the Roads to a Science of Science*. This talk seems to have had an impact on the Soviets similar to that which Hessen's talk at the 1931 London conference had on the field of Anglophone scientific studies.[54] Bernal and Mackey's text was quickly translated and published shortly thereafter in a popular Russian journal [*Voprosy istorii estestvoznaniia i tekhniki*].

The Russian reaction was immediate and, as early as 1966, S. R. Mikulinsky[55] and N. I. Rodny published an article titled "Science as a Subject of Specialized Society" in which they defended a new stage of development and institutionalization of *naukovedenie*.[56] In this text, the *naukovedenie* are described as having two components: one stemming from the history of science, the other aiming at the study of social and economic conditions and the psychological dimension of scientific thought. This is a justification for the turn of the Institute of the History of Science, founded by Vernadsky, toward the new field of the *naukovedenie*.[57]

Bernal's texts, which were translated, thus established themselves in the Soviet Union as a central reference in this academic field. More than 100 people attended the same conference, including Derek J. De Solla Price (USA), Gennady M. Dobrov (USSR), Michajlowicz Kedrov (USSR) René Taton (France), and Ignacy Malecki (Poland).[58] In particular, it is to the fortunate meeting between Dobrov himself (author of *Science of Science: Introduction to General Science Policy Studies*) and De Solla Price that part of the expansion of Soviet

54 Cf. E. M. Mirsky, "Science Studies in the USSR (History, Problems, Prospects)," *Science Studies* 2, no. 3 (1972): 281-94; cf. Rabkin, "'*Naukovedenie*': The Study of Scientific Research in the Soviet Union."

55 Mikulinsky was the director of the Institute of History of Natural Sciences and Technology of the USSR Academy of Sciences.

56 Mirsky, "Science Studies in the USSR," 283

57 Rabkin, "'*Naukovedenie*': The Study of Scientific Research in the Soviet Union," 74.

58 Kokowski, "The Science of Science (*naukoznawstwo*) in Poland," 160.

research in the field of infometry should be attributed.[59] In 1966, thanks to the organization of a Soviet-Polish conference in Lvov,[60] a real meeting between the *naukovedenie* and the *naukoznawstwo* took place. At that time, according to Dobrov[61], it would seem that the emergence of the label *naukovedenie* covered not only the science of science (and naukoznawstwo), but also the concept of Science Policy that was starting to emerge in those years in Europe. In fact, in 1971 the International Council for Science Policy Studies (ICSPS) was founded in Moscow, the first effective international institution in the field of Science and Technology Studies (STS). This international institution played a strategic role in linking Western STS with Soviet *naukovedenie* and social studies on science in some Third World countries. At the time of its foundation, De Solla Price was appointed president and two vice presidents from both sides of the Iron Curtain were named: the Soviet Mikulinvski and the French Jean-Jacques Salomon. This organization included researchers from the Soviet bloc and others from the Western capitalist bloc at the same time. Among the most active members of the Soviet bloc in the ICSPS—engaged, obviously, with the *naukovedenie* and its variations— were Dobrov (USSR); Zdislaw Kowalewski, I. Malecki and Bohder Walentynowicz (Poland); Ladislav Tondl, R. Richta (Czechoslovakia); Nicola Stefanov (Bulgaria); Stefan Balan (Romania); Günter Kröber (GDR); and J. Farkas (Hungary). The spirit in which the ICSPS was born overcame the barriers of the cultural Cold War from the political-intellectual point of view related to techno-scientific questions. This association represented, on the one hand, one of the principal vectors of diffusion of

59 Linda Lubrano, *Soviet Sociology of Science* (Columbus-Ohio: American Association for the Advancement of Slavistic Studies, 1976), 9.

60 Cf. Gennady M. Dobrov, "The Sociology of Science in the URSS," *The Sociology of Science in Europe*, eds. Robert K. Merton and Jerry Gaston (London-Amsterdam, Feffer & Simons, 1977), 316.

61 Dobrov, "The Sociology of Science in the URSS," 316-34.

the *naukovedenie* and, on the other hand, one of the principal circuits by which some Soviets or Germans from the GDR had been able to enter into contact with the Western Science policy.[62]

The intuitions proposed by the Soviet delegates at the 1931 conference (later largely marginalized in the USSR) were re-proposed in an updated version by Bernal (and Bernalists like De Solla Price) who in the meantime had become intellectual points of reference—and privileged interlocutors—in the Soviet Union. In addition, the emergence of the new field of research, Science Policy, fostered an exchange of ideas between East and West. It is therefore a paradoxical dynamic of reverse circulation and of ideas and paradigms between the two sides of the Iron Curtain.[63]

The combined analysis of both the effects of science on social transformations and the impact of society in the production of scientific discourses still represents a fundamental theoretical contribution that Marxism has provided to understand the most urgent problems of our contemporary times. Following the legacy of the 1931 conference, science and technology must therefore be investigated both by researching its economic roots–according to Hessen's expression–and by analyzing and imagining what the social function of science might be today—as Bernal would put it.

62 Aant Elzinga, "The Rise and Demise of the International Council for Science Policy Studies (ICSPS) as a Cold War Bridging Organization," *Minerva* 50, no. 3 (2012): 277-305; Gerardo Ienna, "Science and Technology Studies. Socio-epistemologia storica delle negoziazioni disciplinari" (PhD diss., Alma Mater Studiorum Università di Bologna, 2019), 189-96.

63 For a general perspective on the international circulation of ideas, see Pierre Bourdieu, "Les conditions sociales de la circulation internationales des idée," *Actes de la recherche en sciences sociales* 145 (2002): 3-8 ; Gisèle Sapiro, Marco Santoro and Patrick Baert, eds., *Ideas on the Move in the Social Sciences and Humanities: The International Circulation of Paradigms and Theorists*, (Dordrecht, Springer Nature, 2020). Eglė Rindzevičiūtė, The *Power of Systems, How Policy Sciences Opened Up the Cold War World* (Cornell University Press, 2016).

Interlude: Internalism and Liberalism in Science during the Post-War Period

As we have seen in the previous paragraphs, Hessen's intervention in '31 gave way to two intellectual programs: "Bernalism" and "externalism." In the post-war period, two counter-movements emerged against the Hessen theses. The first type of detractors represented—from a methodological point of view—the internalist tendency in the history of science. The second type of detractors was a kind of political opposition to Bernalism represented by the liberal wave in science.

For internalism, science is an intellectual activity essentially isolated from its social, political, and economic context. From this point of view, the interpretive effort focuses on the intellectual aspects of the setting and the solutions to problems. The most influential thinker in this type of approach at the global level is Alexandre Koyré.[64] His development of the internalist line of thinking started in *Études Galiléennes* (published in 1938) and continued with *La revolution astronomique* (1961), which further deepened his elaboration of the topic. However, *From the Closed World to the Infinitive Universe* of 1957 is considered to be his masterpiece. Koyré's formulation of the concept of the *astronomic* or *scientific revolution* is mandatory knowledge for anyone that is engaged in the history of science (and has been totally absorbed into common sense). In his *Newtonian Studies* (published posthumously in 1965), one might read the following as a rejection of the Hessen theses and of the externalist program as a whole[65]:

64 On this point see also Pietro D. Omdeo, "*Boris Hessen's Philosophy of the Scientific Revolution*", in this volume

65 In a footnote, he mentioned Hessen, Clark, Grossmann, and Borkenau: cfr. A. Koyré, *Newtonian Studies* (London: Chapman & Hall, 1965), 6.

> The new science, we are told sometimes, is the science of the craftsman and the engineer, of the working, enterprising, and calculating tradesman, in fact, the science of the rising bourgeois classes of modern society.
> There is certainly some truth in these descriptions and explanations: it is clear that the growth of modern science presupposes that of the cities, it is obvious that the development of firearms, especially of artillery, drew attention to problems of ballistics; that navigation, especially that to America and India, furthered the building of clocks, and so forth–yet I must confess that I am not satisfied with them. I do not see what the *scientia activa* has ever had to do with the development of the calculus, nor the rise of the bourgeoisie with that of the Copernican, or the Keplerian, astronomy.[66]

From *Études Galiléennes* to his posthumous works, Koyré argued for the hypothesis that the experiments never played a significant role in the emergence of the scientific revolution. On the contrary, they were often an obstacle to it, and in their place, Koyré highlights the importance of mental experiments instead. Koyré's internalist thesis was received by an entire generation of historians of science, which included such prominent figures as Bernard Cohen at Harvard, Alfred Rupert Hall in London, Herbert Butterfield at Cambridge, Alistair Crombie at Oxford, Charles Gillispie at Princeton, etc.[67] In this period, as Werskey confirms: "the history of science emerged as a distinct academic discipline under the guidance of scholars supremely conscious of the Marxists' neglect of science as a body of ideas."[68] Marxist accounts of science provided the basis for internalists' treatment of science as simply a corpus of ideas.

66 Ibid.,5-6.
67 J.-F. Braunstein, *L'histoire des sciences* (Paris: Vrin, 2008), 92.
68 Werskey, "Introduction," XXIII.

In 1949, Butterfield published *The Origins of Modern Science,* one of the most important contributions to the internalist intellectual wave. He was well known for having introduced into the history of science a strong critique to the *Whig* interpretation of history, which was understood as the tendency to prize past revolutions as long as they were victorious. In this sense, a teleological principle was surreptitiously inserted into the historical dimension of science, and thus the existence of progress was presupposed in science. Butterfield's approach was continued by his disciple Alfred Rupert Hall in his *Ballistic in the Seventeenth Century*, in which Hall inverted Hessen's perspective. In this book, Hall argues that scientists' engagement with ballistics between the sixteenth and seventeenth centuries naturally emerged from their interests in the study of movement (which was, at the time, the most fruitful field of inquiry). In his article entitled "Merton Revisited", he identifies Hessen's intervention of '31 as a "collector's piece,"[69] and defines it as the first contribution to the externalist approach.

At the same time, opposition to the Hessen theses began to assume a political dimension. This opposition not only took the form of an internal question to the methodology of the history of science, but also of an antagonism toward so-called Bernalism (i.e., a socialist political model of science). After the end of WWII, liberal scientists were mainly concerned with the danger of giving up the freedom of science (e.g., *Lysenkoism*), as they believed that it would cause the end of "pure science." From this point of view, it is important to consider the foundation laid by Michel Polanyi and John Baker in the *Society for Freedom in Science*. Their program explicitly aimed to oppose the very tradition which Hessen had initiated. As Baker writes,

69 A. R. Hall, "Merton Revisited, or Science and Society in the Seventeenth Century", *History of Science* 2 (1963): 2

> The movement against pure science and against freedom in science was first brought to Great Britain by the Soviet delegation to the International Congress on the History of Science held in London in 1931. [...] Owing to the world-wide economic depression, attention in 1931 was naturally focused on economic matters, and this preoccupation lent impetus to the specifically Marxist doctrine, then brought to England from Russia, that scientific progress was really determined by economic causes and that all scientific work should be consciously and directly devoted, under central control, to the material service of the State.[70]

This interlude shows how the canonization process and the global circulation[71] of the Hessen theses were determined by the fact that the theses were understood in a polemical fashion by a whole intellectual current. This characterization, however, was based not so much on a genuine hermeneutic effort to understand Hessen's work, but on an extremely reductionist reading of it.

Forms of Bernalism during the 70s and Radical Science Movements

Bernalism, a sort of heir of 'Hessenianism', as a cultural phenomenon gradually expanded to involve both professional scientists engaged with the problem of the social responsibility of scientists and social scientists interested in studying science as a socio-cultural phenomenon. The wide influence of *The Social Function of Science* stemmed from Bernal's accurate prediction of the centrality that

70 J. R. Baker and A. G. Tansley, "The Course of the Controversy on Freedom of Science," *Nature* 158 (1946): 574.

71 Bourdieu, «Les conditions sociales de la circulation internationales des idées».

science would assume in the post-war politics that came to characterize the Cold War.[72] As more and more countries drifted toward fascism or toward socialism in the 1930s, Bernal observed how science took on a different role in capitalist societies. "Science is both affecting and being affected by the social changes of our times, but in order to make this awareness in any way effective, the intersection of the two needs to be analyzed far more closely than has yet been done."[73]

The so-called Radical Science Movements that emerged from the social and political movements of '68 became particularly sensitive to these aspects. In various national contexts, debates and movements based on the idea of the social and political non-neutrality of science rapidly emerged. The focus was the analysis of the social function of science in advanced capitalist society. For example: after its foundation in 1969, the British Society for Social Responsibility in Science (BSSRS) published its manifesto in 1970 in which the non-neutrality of scientific knowledge was clearly argued[74]. During the 1970 conference of the American Association for the Advancement of Science, a group of militant scientists distributed their "manifesto" titled "Toward a Science for the People" (which marks the birth of the homonymous movement).[75] These events consolidated radical science movements in the U.S. and in the U.K.[76] In the same period,

72 Werskey, "Introduction," XXIV.

73 Bernal, *The Social Function of Science*.

74 BSSRS, "'Manifesto', British Society for Social Responsibility in Science," 1970, *Constitution, Manifesto and Other Papers Relating to the Founding of the British Society for Social Responsibility in Science*, Reference K/PP178/11/1/3), Welcome Library Archive, Papers of M H F Wilkins.

75 Bill Zimmerman, et al., "Toward a Science for the People," in *Science for the People. Documents from America's Movement of Radical Scientist*, eds. Sigrid Schmalzer, Daniel S. Chard and Alyssa Botelho (Amherst - Boston: University of Massachusetts Press, 1970), 15–22.

76 Zac Bharucha, *The Radical Science Movement in the U.K. 1968-1978. Struggles Against the Impact of Capitalist Ideology on Science, Technology and Social Relations of Science* (Poland: Amazon Fulfillment, 2018); Sigrid Schmalzer, Daniel S. Chard, and Alyssa Botelho, eds., *Science for the People. Documents from America's Movement of Radical Scientist* (Amherst - Boston: University of Massachusetts Press, 2018).

it is also possible to date the birth of an Italian radical science movement with the writing of the so-called "Varenna Manifesto"[77] and the French movement known as "critique des sciences"[78].

Such forms of New Leftism in science needed to identify authoritative precursors in order to intellectually legitimate their own existence. From this point of view, the cultural and intellectual work carried out by Gary Werskey is one of the most significant. The latter was in fact at the same time embedded in the radical movements at the transnational level and in the process of birth of the new academic sector of the STS (as I will illustrate this in the next paragraph). Werskey entered Harvard as a graduate student in history in 1965, completing his doctorate in 1973 under the joint supervision of Stuart Hughes and Everett Mendelsohn. Between 1968 and 1987, he lived in the United Kingdom, where he taught, in addition to the Science Studies Unit of Edinburgh, "science and industrial sociology" at Leicester, then Bath, and finally at the University of London. During this time, he co-founded the *Radical Science Journal* in 1972 and actively participated in the activities of the BSSRS.

It was in these circumstances, and in the wake of these debates, that a new edition of *Science at the Crossroads* was reprinted in 1971 — on the occasion of the fortieth anniversary of the London congress. A new *Introduction* by Werskey and a *Foreword* by Needham (one of the few still alive among the congress's participants and in a position to provide testimony) were added to this publication. The anniversary edition was made in the middle of the Cold War, when

77 Gerardo Ienna, «Fisici italiani negli anni '70. Fra scienza e ideologia.», *Physis* LV, n. 1–2 (2020): 415–42.

78 Mathieu Quet, *Politiques du savoir. Sciences, technologies et participation dans les années 1968.* (Paris: Édition des archives contemporaines, 2013); Renaud Debailly, *La critique de la science depuis 1968. Critique des sciences et études des sciences en France après Mai 68* (Paris: Hermann, 2015). A specific analysis should be devoted to the relationship between Bernalism and rationalist movements in France Sylvain Laurens, *Militer pour la science. Les mouvements rationalistes en France (1930-2005)* (Paris: Éditions de l'EHESS, 2019).

the relationship between science, technology, politics, and the economy was a pressing topic. Technological and scientific development seemed to impose transformative changes upon the world, the military balance of power, political relations among nations, and even everyday life. During the postwar period and throughout the Cold War era, science became a new issue for public policy and a source of economic and military growth. In this context, a strong interest in the debates from the '30s and '50s began to resurface. Hessen's work was broadly considered one of the most striking examples among the interpretative proposals of that period. Needham expressed that Hessen's influence was "not yet exhausted,"[79] while also underlining that "The trumpet-blast of Hessen may therefore still have great value in orienting the minds of younger scholars towards a direction fruitful for historical analyses still to come."[80]

Thanks to this new edition, in the publications relating to the radical science movements of the '70s, references to Bernalism, to Hessen's theses and to the volume *Science at the Crossroads* became a constant point of reference. Bulletins and news journals such as the American *Science for the People* and the British *Science for People* and *Radical Science Journal* (now published under the new title *Science as Culture*) thus hinged on these new interpretative forms of 1930s scientific Marxism in light of the theoretical innovations of the New Left.

Throughout the 1970s, Werskey worked on the British Marxist debates that had emerged since the 1930s by reconstructing a "collective biography" of a group of socialist scientists such as Bernal, Haldane, Hogben, Levy, and Needham. In 1978, he published the already mentioned monograph titled *The Visible College* and various articles on this subject and on other related topics.

79 Needham, "Introduction,"VIII.
80 Ibid., IX.

The importance that Hessen obtained in the context of the radical science movements is also attested to by the references to this author that appear in two cardinal texts by Hilary and Steven Rose (that we therefore propose as examples). Both in *Political Economy of Science* and in *The Radicalization of Science* — both of which were widely considered to be intellectual cornerstones of the radical science movements — Hessen is mobilized in order to show his topicality and analytical potentiality in contemporary debates[81]. Here are two examples of these interpretations:

> The second strand raised the question of whether a socialist society would generate a specifically socialist science; was there an unique socialist biology, by contrast with bourgeois biology, for instance? In so far as Newtonian mechanics were seen by Hessen as the product of a particular historical period in bourgeois society, the answer to that must have been seen as in the affirmative; what Hessen's contribution in 1931 (and indeed subsequent Soviet discussions in this area) have not adequately analysed out, however, is the question of whether there is indeed a bourgeois, by contrast to a socialist, science. But the unravelling of this argument, though implicit in Hessen, was not perceived by the Marxist British scientists in the 1930s. Rather, like Haldane, they were

81 In the context of the Radical Science Movements we often refer in a broad sense to the contributions contained in *Science at the Crossroads* even if, both Rose and Rose, as well as other authors, have explicitly emphasized that Hessen's text was the most stimulating of all. "It was indeed from the Soviet Union that the second of our major themes, that of the ideological determination of science, was injected into the British debate with the appearance of the Soviet delegation at the 1931 London conference on the history of science. Although the delegation was headed by Bukharin, its major contribution was provided by a paper from Hessen on "The Social and Economic roots of Newton's *Principia*". Hilary Rose and Steven Rose, eds., *The Radicalisation of Science: Ideology of/in the Natural Sciences*, *Critical Social Studies* (London: Macmillan Press, 1976), 4–5.

> to spend their theoretical strength over the next few years in a relatively fruitless endeavour to demonstrate the negation of the negation, the interpenetration of opposites, and the transformation of quantity into quality in a variety of scientific developments. Only when, much later, Needham turned his attention to the history of Chinese science and technology and Bernal attempted first the seminal *Social Function of Science* (1939) and later the rather more synoptic and less satisfactory Science in History, was the Hessen experience to bear fruit[82].

In this passage, it clearly emerges how, compared to an "old left" model, the focus of radical science movements had shifted from the glorification of planned science typical of the socialist system to the elaboration of a critique of the capitalist system of scientific production. This change of axis determined the emergence of one of the thematic sites typical of the contributions of the 1970s, namely the relationship between science and ideology, or rather, the analysis of the ideology intrinsic to scientific activity in advanced capitalist societies. This point, rejected by the orthodoxy of the Soviet Diamat centered on Engels' *The Dialectic of Nature* and Lenin's *Materialism and Empiriocriticism*, represents one of the main tonalities of the new left in the scientific field.

> How has bourgeois history, philosophy and sociology of science come to ignore the unity of science and technology? We can see this in the case of a leading sociologist of science, R. K. Merton, whose early work, *Science, Technology and Society in Seventeenth century England* is a rejoinder to Hessen, a Soviet

82 Rose and Rose, eds., *The Radicalisation of Science*, 5–6.

physicist who, as part of the Bukharin-led delegation to the International Congress of the History of Science and Technology held in London in 1931, presented a classical Marxist thesis of scientific growth. Hessen took Newtonian mechanics and showed how it was developed directly in response to the needs of burgeoning capitalism. Whilst his internalist British critics at the meeting sought to correct Hessen on small points of 'fact', Merton responded to the theoretical challenge of what was to be called the 'externalist' theory of scientific growth. [...] Merton attempted to show that science develops not solely in response to economic needs, but also requires a supportive value system- namely Protestantism. While this comes close to arguing that the superstructure -in the form of religious ideology -determines the base, Merton was concerned to examine the base/superstructure relationship. However, the emphasis on religious ideology and its compatibility with the scientific ethos pushed the work away from any economic explanation into a form of sociological internalism, characterized by a preoccupation with science as a more or less autonomous subsystem. This preoccupation with the scientific ethos was paralleled by the philosopher Polanyi's conception of the scientific community as a self -governing collectivity. This variant of internalism, which dominated the academic sociology of science for thirty years, ceased to address itself to questions of the interpenetration of science and the social order at the cognitive level, or even of scientists and the social order at the structural level. [...] Thus the fundamental character of science and technology in their social functions was lost to sight[83].

83 Hilary Rose and Steven Rose, eds., *The Political Economy of Science* (London: Macmillan Education UK, 1976), 20–21.

In this quotation, it is possible to see the way in which Hessen's legacy was being re-actualized and operationalized among the militant scientists of the 1970s. Hessen's theses are used as the picklock to unhinge the then hegemonic research agenda of Mertonian-style sociology of science in order to actualize a Marxist view (thus based on a theory of conflict) of the relationship between science and society. In the passage just quoted, it is interesting to note how Rose and Rose -reading Merton's perspective as a form of 'sociological internalism'- place Mertonian sociology in a position of dialectical integration with Polanyi's perspective to which they oppose a rehabilitation of the study, in the Bernalian sense, of the social functions of science.

Another militant scientist who was active in the *Radical Science Journal* wasRobert M. Young, who moved in a similar direction. After defining Hessen's text as a "locus classicus of the base-superstructure approach to the history of science," Young attacks the "bourgeois" [84] perspective of Mertonian sociology.

> A similar path was taken by Robert K. Merton, the doyen of bourgeois sociology of science, whose original work in the 1930s was littered with footnotes and homages to Hessen. Merton focused on the origins, the class perspectives, the choice of topic, and other parameters of scientific knowledge while avoiding any commitment to seeing the resultant discoveries in ideological terms. The sociology of knowledge thereby became an elaborate study of the context of origination while carefully keeping away from the context of justification, the holy of holies which is so dear to non-Marxist philosophers of science. Within this framework of sociology of science as sociology of knowledge, quite subtle work has been

84 Robert M. Young, "Marxism and the History of Science," in *Companion to the History of Modern Science*, ed. R. C. Olby, et al. (London: New York: Routledge, 1990), 81.

> **done about scientific communities, patronage, honours, the culture of laboratories, scientific accountability (or the lack of it) to the rest of society, and other topics which take the existing mode of production as given[85].**

As I will highlight in the next section, this kind of criticism of the sociology of institutional science eventually led to the emergence of the Sociology of Scientific Knowledge (from now SSK). The latter is in fact a research program polemically in contrast to Mertonian sociology. If the latter had the ambition to describe the institutional structures within which science operates, SSK aspires to apply the sociological method to the very contents of science.

In the uses of the new left, Hessen's theses and the interventions of *Science at the Crossroads* obtained, in the terms of Bourdieusian sociology, a new social and symbolic labelling[86]. From having been initially received in Europe as one of the canonical expressions of Soviet Marxism in its institutional version, in the hands of the radical science movements, these texts became the instrument to deconstruct the "old left" and also question some aspects of the same Soviet approach from which they came, thus affording thema new life.

Perhaps this passage is still evident if we look at the peculiar reception of this volume in the Italian cultural context. Among the European communist parties, the Italian one was one of the most developed and rooted in the territory at the level of cultural policies. For this reason, in this country, many Soviet works were translated and imported into the debate practically at the same time as they were published. However, this wasn't the case with *Science at the Crossroads*. Although the text had been commented upon and quoted by

85 Ibid., 84.

86 Cfr. P. Bourdieu, «Les conditions sociales de la circulation internationales des idées», *Actes de la recherche en sciences sociales*. N. 145, 2002.

Italian scholars (first of all Gramsci who criticized the approach developed by Bukharin[87]), the text was translated until 1977.

The meta-scientific debates of the 1970s in Italy were characterized by what I have called the "Italian Science Wars", or the wide series of *querelles* characterized by heated debate over the political neutrality/non-neutrality of science and technology[88]. This controversy — both academic and public — was characterized by the epistemological and political clash between the positions of Ludovico Geymonat (and his Milanese school), the positions of the philosopher and historian of science Paolo Rossi (and his school) against a large and varied group of scientists and militants of the extreme left inspired by 1968. Paradoxically, unlike the Anglophone "science wars", in the Italian context, it was the professional scientists (Radical Science Movements) who criticized the neutrality of science, while humanists (Geymonat and Rossi) defended its objectivity and a-political character[89]. The use of the theses of the Soviet delegates to the '31 congress found themselves, at one point, at the center of this debate.

The most attentive readers and major importers of the Soviet epistemological debate in Italy during those years were Geymoant and his student Silvano Tagliagambe (with particular emphasis on the history and philosophy of physics). The program developed by Geymonant's so-called "Milanese school" was largely centered on the attempt to find an intersection between dialectical materialism and the neo-positivism developed by the Vienna Circle. One might expect, then, that the reception (as well as the translation) of *Science at the*

87 Pietro Daniel Omodeo, «Egemonia e scienza. Temi gramsciani in epistemologia e storia della scienza», *Gramsciana* 2016, no. 2 (2016): 59–86.

88 Giuliano Pancaldi, «Purification Rituals: Reflections on the History of Science in Italy», in *Impure Cultures. Interfacing Science, Technology and Humanities* (Bologna: CIS, 2010); Ienna, «Fisici italiani negli anni '70. Fra scienza e ideologia».

89 Ienna, «Fisici italiani negli anni '70. Fra scienza e ideologia», *Physis*, LV, 1-2 (2020)415–42.

Crossroads might have been an initiative coming from this intellectual group. Consider in fact that Hessen had been one of the supporters and promoters of the reception of the innovations of the theory of relativity and quantum mechanics in the USSR despite the fact that these were judged to contradict *Diamat*. As is well known, Hessen's intervention in London had an ironic and provocative character and aimed to show that even the Newtonian physical theory (accepted in the USSR) had bourgeois roots. The criticism of the ideological drifts of the Soviet *Diamat* and the defense of the autonomy and neutrality of science (especially in relation to the debates in contemporary physics) was exactly one of the cardinal points on which the rehabilitation of dialectical materialism was based for the Milanese school.

However, it was rather the radical movements for science that cited this volume extensively and enthusiastically. Thanks to the publication of the new English edition in 1971, a group of militant physicists and Italian radicals had come into contact with this text finding its theses particularly stimulating. In *L'ape e l'architetto* (*The Bee and the Architect*) , a volume widely considered the manifesto of the Italian radical science movements, it is in fact possible to see this enthusiasm:

> Of great importance for us was therefore the recent discovery, through the re-edition in England of the interventions of the Soviet delegation at the Conference on the History of Science and Technology held in London in 1931, of a current of dialectical materialism apparently very much alive until the beginning of the Stalinist era, which explicitly and articulately supported points of view very close to those expressed in the works collected here. The volume mentioned is *Science at the Crossroads*, which appeared in 1971 and reached us less than a year ago.

In the wake of this enthusiasm, *Science at the Crossroads* progressively became one among the points of reference for Italian Radical Science Movements. It was in fact on the initiative of a group linked to the *L'ape e l'architetto* that the publisher De Donato of Bari published the first Italian translation of the text. The text [with the Italian title *Scienza al bivio*] appeared as the first volume in a book series titled "Storia e critica delle scienze" ("History and critique of science") conceived and directed by Giorgio Israel.[90] In the Italian editorial note it is possible to read a clear statement of how the interventions of "Science at the Crossroads" could be a cardinal theoretical resource in the debates on the "non-neutrality" of scientific knowledge:

> It is almost superfluous to underline the topicality of the themes that emerge from this book in a period such as this, in which the question of the "non-neutrality" of science, the relationship between science and society, the problem of whether scientific theories contain a planning aspect and whether this can be reduced to the subjectivity of scientists or to a class finalism, and finally what answers can be found on these themes in Marxian and Marxist thought are at the center of the debate. Around all this, the interventions contained in this book provide a precise answer that, whatever the judgment that can be given, addresses the issue of the specific contents of the sciences of the 1930s and engages in the lively scientific debate of that crucial period, referring to the concrete experience of the attempt to build socialism in the USSR.
> For all these reasons, it seems to us that this book can be an important instrument to critically reflect on the themes that

90 Luca Di Bari, *I Meridiani. La casa editrice De Donato fra storia e memoria* (Bari: Dedalo, 2012), 217.

are today at the center of a debate that has relevant theoretical and practical implications.[91]

Immediately after its publication, the text was panned with a review by Tagliagambe in the newspaper organ of the Italian Communist Party "l'Unità". While acknowledging the interest in the publication of *Science at the Crossroads*, Tagliagambe emphasized that the papers presented by the Soviets in London were "instruments that are by now dated or, in any case, marked by a distance that is anything but irrelevant with respect to the most advanced acquisitions of the current debate".[92] The review focuses on showing how dangerous it is to affirm the topicality of a text without having adequately reconstructed its socio-historical roots. This type of cultural operation "cannot but be considered a further and diseducative example of that halved and schizoid externism that, unfortunately, is experiencing in the cultural atmosphere of today's Italy its greatest splendor".[93] In fact, according to the author, there has been a "disconcerting nonchalance with which interventions tending to assert the need, for a historian of science, to take into account the political, economic and social conditions in which a specific scientific contribution has matured" have been presented "in a totally uncritical and ahistorical way".[94] On the contrary, Tagliagambe focuses his attention on the socio-historical context from which Hessen's intervention emerges as "anything but weak and inessential". In fact, the author highlights how Hessen was part of the group of dialectical materialists led by Deborin, whose objective was to "create a common front of philosophers and scientists

91 Nikolaj Ivanovič Bucharin, ed., *Scienza al bivio: interventi dei delegati sovietici al Congresso internazionale di storia della scienza e della tecnologia, Londra 1931* (Londra: Frank Cass and Company Limited, 1971; Bari: De Donato, 1977), 6.

92 Silvano Tagliagambe, «Scienziati e ideologi», *L'Unità*, 22 September 1977, 3.

93 Ibid.

94 Ibid.

committed, while respecting the autonomy of their fields of research, to the elaboration and diffusion of a new type of culture, capable of penetrating the masses and inspired by an open reflection, and above all free of preconceptions and dogmatic closures, on the relations between Marxism and science". [95] In this sense, being faithful to the theoretical orientation of the "Milanese school", Tagliagambe directs his reading towards an actualization of Hessen's theses as precursors of the epistemological positions in defense of the "neutrality of science".

In response to this, Diego De Donato, the director of the publishing house, sent a letter to the director of L'Unità Alfredo Reichlin in order to denounce "the more or less transparent reasons for such nonchalance in the service of such prejudicial animosity"[96]. In the actually published version of the letter, De Donato deconstructs Tagliagambe's assertions showing how the volume reported a historical framework in the translations of the preface and introduction by Needham and Werskey. It is also possible to read in the letter:

> The intentions behind the not easy undertaking of a series dedicated to the problems of contemporary science, of which *Scienza al Bivio* is only the first volume, are not to provide an additional tool to the spirit of controversy that seems to animate Prof. Tagliagambe, but to offer the possibility of a new way of thinking about the problems of contemporary science. Tagliagambe, but to offer safe points of reference (certainly, also "philologically") and a space that does not pretend to be neutral but neither predetermined in a summarily ideological way to a debate that registers so far, even in the ranks of the left, deep and openly irremediable divisions. [97]

95 Ibid.

96 This archival document is quoted in: Di Bari, *I Meridiani. La casa editrice De Donato fra storia e memoria*, 218.

97 Diego De Donato and Silvano Tagliagambe, «Scienza e società nell'URSS degli anni '30», *L'Unità*, 24 ottobre 1977, 3.

This letter was published with an additional response from Tagliagambe. Tagliagambe reiterated in his text how this publication had been "a missed opportunity" for a serious study of the relationship between science and society in the USSR: "On the contrary, it was decided not to insist on this theme, nor can it be said that the brief — and for other things taken for granted and not supported by a serious and thorough documentation — considerations of Werskey, constitute a satisfactory answer to the above-mentioned need".[98] These attacks were not without further defence by the Radical Science Movements. Marcello Cini wrote a review in *Il Manifesto*, Giorgio *Israel in Rinascita* and two critical notes appeared in the historic popular science magazine *Sapere* (which was also militantly oriented at the time).

The Institutional Dissemination of Hessen's Work between the '60s and '80s

As mentioned above, in the Anglo-Saxon context, the history of science became an institution and obtained disciplinary autonomy thanks to internalist scholars. On the other side of the Atlantic, the sociology of science and so-called externalism attained the status of a discipline, especially with Merton and the work of the Mertonians. Between the '60s and the '80s —after the institutionalization phase of the discipline—, there arose a clear need for interdisciplinary dialogue between philosophy, history, and sociology in science studies.

In order to understand this process, it is necessary to mention Kuhn, whose work is a cornerstone of all disciplinary studies of science. In his *Copernican Revolution* (1957)—a text which was strongly influenced by Koyré—, he extended the internalist approach, while trying to integrate it with the externalist approach. In 1972, Kuhn

98 Ibid.

mentioned the Hessen theses in a presentation at a conference[99] in which he tried to overcome the classical opposition between internalism/externalism, shifting the problem onto the debate about the unity or disunity of science.[100] In 1962, he published *The Structure of Scientific Revolutions,* a work universally recognized as one of the most influential in many disciplinary fields (thanks to the intrinsic functionality of concepts such as *paradigm, normal science*, and *anomaly*). From this point of view, *The Structure* opened a new vision of the social dimension of science during the '70s, even if he refused some sociological interpretations of his work as supporting a relativistic viewpoint.[101]

It is important to focus our attention on the emergent interest in the interdisciplinary studies of science (i.e. STS). In 1964, David Edge founded the *Science Studies Unit* in Edinburgh, recruiting young lecturers like Barry Barnes, David Bloor, Steven Shapin, and Werskey, whom we already mentioned. In this context, the basis of the "strong programme" in the SSK was developed. Through a careful commingling of the sociology of knowledge (Durkheim and Mannheim), the philosophy of Ludwig Wittgenstein, and the Kuhnian thesis, SSK proposed a new interdisciplinary program in the study of science (rhetorically conceived as an anti-Mertonian program).[102] The first aim of this new program was to establish a fruitful dialogue between history, philosophy, and the sociology of science.

99 Kuhn participated at the congress in honor of George Sarton with an intervention titled "Mathematical versus Experimental Traditions in the Development of Physical Science." cfr. T. Kuhn, *The Essential Tension* (Chicago: The University of Chicago Press, 1977).

100 Ibid., vi, 32

101 On this point see also Pietro D. Omdeo, "Boris Hessen's Philosophy of the Scientific Revolution", in this volume.

102 For the advocates of SSK, Mertonian sociology would have studied science only from the external point of view without raising the problem of the social conditioning of the internal content of scientific knowledge. For the vulgate of SSK, science is treated by Mertonians as a "black-box."

The U.K. academic context in which SSK emerged was characterized on one hand by a broad dissemination of Bernalism,[103] and on the other hand by the debate between internalist and externalist positions. As highlighted above, both Bernalism and externalism were recognized as a direct effect of Hessen's intervention in London. Among other references (like Durkheim, Mannheim, Wittgenstein, etc.), SSK recognized the Hessen theses as a precursor of their program.

Werskey was the most engaged figure in building a bridge between the Marxist tradition and STS scholars, as he dedicated a great number of articles to the intersection between the two domains as well as his *The Visible College* (1979), which was mentioned above. Among other contributions, he published a paper in 1971 titled "British Scientists and 'Outsider' Politics, 1931-1945" in the first issue of the field's "flag journal," *Science Studies*[104] (today known as *Social Studies of Science*). This text ends with the following reference to the '31 congress's collected interventions: "British science once again finds itself 'at the crossroads.'"[105] In a footnote, Werskey more explicitly recognizes the importance of this text, which he defines as an "invaluable document" that had "a profound impact on the thinking of Radical scientists."[106]

For his part, Barnes had contended that Marxism in science "found its most single-minded application" in the Hessen theses.[107]

103 For example, the *Rede lecture* of 1959 titled *The Two Cultures* by Charles Percy Snow gave a broad public, political and academic resonance to Bernalism. This lecture has also had the effect of stimulating the birth of many interdisciplinary programs or research units in U.K. Universities like that of Edinburgh. Furthermore, since 1981, the *Society for Social Studies of Science* has given out the *J. D. Bernal Prize* (the most important recognition in the field of STS) explicitly dedicated to the memory of this author.

104 It is remarkable that the first issue of the most prominent journal in the field provided a clear reference to this tradition. *Science Studies* was founded in 1971 by Edge and Roy MacLeod with a clear interdisciplinary aim. D. Edge and R. MacLeod, "Editorial," *Science Studies* 1/1 (1971): 1-2.

105 G. Werskey, "British Scientists and "Outsider" Politics, 1931-1945", *Science Studies*, 1/1 (1971): 83.

106 Werskey, "British Scientists and "Outsider" Politics, 1931-1945", 83.

107 B. Barnes, ed., *Sociology of Science* (Harmondsworth: Penguin; 1972), 18.

To this he added,

> When it was published in 1931 few were able to set aside their political commitments and evaluate it objectively, but it provided an influential theoretical model, and one may wonder how many of the empirical studies now used to illustrate its weakness would have existed in its absence. (p. 17-18)[108]

Along the same Kuhnian line of thinking, SSK also aimed to overcome the opposition between externalism/internalism. In doing so, authors like Bloor, Michael Mulkay, and Shapin deconstructed the inherited image of Hessen as an advocate of crude externalism. From this point of view, Bloor stressed that Hessen's work "is certainly crude, although by no means so crude as the parodies of it found in internalist criticisms would imply."[109] Mulkay clearly reverses the kind of superficial interpretations of the Hessen theses that were made by internalists, as he, after having synthesized the main aspects of Hessen's work, writes that

> Although the economic factor is fundamental to the materialist conception of history, this does not mean in Hessen's view that it is the sole determining influence upon any particular set of ideas. Accordingly, he attempts to complete his analysis of Newton's work by showing how Newton drew selectively upon the cultural resources available to a member of his class, for example, in the form of political, juridical, philosophical and religious beliefs, and by showing how these ideological elements influenced and limited Newton's thought.[110]

108 Ibid.
109 B. Barnes, *Scientific Knowledge and Sociological Theory* (London: Routledge 1974), 106.
110 M. Mulkay, *Science and the Sociology of Knowledge* (London-Boston: Allen & Unwin, 1979), 7-8.

Contrary to previous interpretations, Mulkay maintains that the Hessen theses allow one to open the "black box" of science and provide its sociological explanation (i.e. the first aim of SSK). In this sense, Hessen's work is used by the author as a good example of the potential of a Marxist approach in SSK:

> **It [Hessen's work] merely serves here to illustrate that Marx can be interpreted in a strong sense, that is, as implying that the content of established scientific knowledge should be treated to a considerable extent as the outcome of specifiable social processes.**[111]

From 1972 until 1989, Shapin—among those affiliated with the *Science Studies Unit*—was a professor at Edinburgh. For his course on the social history of science, he proposed various readings, including Hessen, Bernal, Needham, Zilsel, Ravetz, R. M. Young, etc.[112] In 1981, he authored three entries for the *Dictionary of the History of Science*: "Needham thesis," "Hessen thesis," and "Zilsel thesis." Moreover, in subsequent years, Shapin adopted a skeptical perspective on the opposition between internalism/externalism. In his historical treatment of this topic,[113] he referred to Hessen's work as a pivotal point from which various disciplinary debates in science studies have followed. Shapin remarked that the internalist interpretation of the Russian author was a parodistic version of the real text:

> **While Hessen's materialism informed his attack on the supposed absolute autonomy of ideas, neither he nor the**

111 Ibid.

112 S. Shapin, "A Course in the Social History of Science," *Social Studies of Science* 10/2 (1980): 231-258.

113 S. Shapin, "Discipline and Bounding: The History and Sociology of Science as Seen through the Externalism-Internalism Debate", *History of Science* 30 (1992): 333-369.

> historical materialist tradition from which he came ever proposed to reduce science totally to its economic foundation [....] From Marx and Engels onwards, materialists have always acknowledged that material influences proceed through culture and that cultural practices may come to have relative autonomy.[114]

On the same line, also in his bibliographical essay for *Scientific Reason*, he mentions Hessen's and Zilsel's works among the classics of the history of science.[115]

In 1984, another protagonist of STS, Simon Schaffer, published an article entirely dedicated to Hessen titled "Newton at the Crossroads" in the journal *Radical Philosophy*.[116] This text reconstructs Hessen's argument and addresses its uses by authors like Clark, Merton, Needham, Bernal, Hall, etc. Schaffer highlights two issues in particular. On one hand, he emphasizes Hessen's deconstruction of the notion of the scientific genius. The concept of the scientific genius starts to look erroneous and useless in light of any adequate contextualization of scientific, cultural, economic, and political practices. Even if naively, Hessen took into serious consideration the power structures underlying scientific knowledge to challenge this notion. On the other hand, Schaffer emphasizes Hessen's account of the social construction of science. In the same spirit as many others in STS who had appropriated Hessen's work, Schaffer tried to retrace an intellectual genealogy in order to legitimate STS as an intellectual field. Moreover, in the introduction to the second edition of *Leviathan and the Air-Pump*, both Shapin and Schaffer recognize their debt to Marxist methodology by arguing that

114 Ibid., 362.
115 S. Shapin, *The Scientific Revolution* (Chicago: The University of Chicago Press, 1996).
116 S. Shaffer, "Newton at the Crossroads", *Radical Philosophy* 37 (1984): 23-28.

> For many British historians, Marxism was a lingua franca, not necessarily providing a theoretical foundation for political projects but certainly constituting a loosely connected set of concepts and methodological sensibilities with which many historians felt they should engage even while their political affiliations diverged.[117]

The primary aim of *Leviathan and the Air-Pump* was to ascertain the implicit, though tangible, political significance of scientific development. In some way, this book is part of the materialistic line of research in the history of science.[118]

As in previous years, the Hessen theses were once again recognized during this period as an influential and innovative contribution to the description of the relation between science and technology. In *The Social Construction of Facts and Artefacts*, Trevor Pinch and Wiebe Bijker refer to Hessen's work as a "locus classicus" in technology studies, because he "argued that pure science is indebted to developments in technology."[119]

An Hessenian Renaissance?

The first edition of the text *The Social and Economic Roots of Newton's Principia* is the English the one of 1931 in the collective volume entitled *Science at Crossroads,*[120] whose editorial operation had

117 S. Shaffer and S. Shapin, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life, 2nd Ed.* (Princeton-Oxford: Princeton University Press, 2001): XXIV.

118 Lamy, J.; Saint Martin, A., "Marx, un spectre qui ne hante plus les sciences studies? Première partie: Marx, des campus aux machines," *Cahiers d'histoire. Revue d'histoire critique* 124 (2014): 161-182.

119 T. Pinch and W. E. Bijker, "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other", in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. W. Bijker, T. P. Hughes and T. J. Pinch (Cambridge-Mass: MIT press, 1987), 19.

120 B. Hessen, *The Social and Economic Roots of Newton's 'Principia'*, in *Science at the*

already been proposed by Hogben in the first days of the conference and published, with translations made in a very short time, at the Russian embassy in London a few days later. The same volume was then reissued in 1971 with contributions from Werskey and Needham[121]. In Russia, the first edition in of Hessen's paper to appear independently comes from 1933[122] of which an extract also appeared in the form of article in the magazine *Priroda*[123] (a second full version already appeared in print in 1934).[124] In 1946, an Australian publisher inSydney reprinted, this time independently, the text of Hessen in English.[125] In 1968, only an extract of the original text appeared in the United States in a collection edited by Basalla titled *The se of Modern Science: Internal or External Factor?*[126] Simultaneously with the second edition of all the Soviet contributions of 1971, Robert S. Cohen published a complete and independent version of the text of Hessen for a New York publisher.[127] In 1972, it was followed by the Swedish edition,[128] in 1974 by the German one edited by the sociologist Peter Weingart,[129] and in

Cross-Roads. Papers presented to the International Congress of the International congress of the History of Science and Technology, held in London from June 29th to July 3rd, by the delegates of the USSR (Kniga, London, 1931), 149-212

121 Ibid.

122 B. Gessen, «Sotsial'no-ekonomicheskie korni mekhaniki N'iutona», *Doklad na II meehdunarodnom kongresse po istorii nauki i tekhniki* (Moskva-Leningrad, 1933).

123 B. Gessen, «Klassovaia borba epochi angliskoi revoliutsii i mirovosreniie N'iutona», in *Priroda,* 1933, N. 3-4: 16-30.

124 B. Gessen, «Sotsial'no-ekonomicheskie korni mekhaniki N'iutona», *Doklad na II meehdunarodnom kongresse po istorii nauki i tekhniki* (Moskva-Leningrad, 1934).

125 B. Hessen, *The Social and Eonomic Roots of Newton's Principia* (Current Book Distributors: Sydney, 1946).

126 Basalla, ed. *The Rise of Modern Science: Internal or External Factors?* (D.C. Heath: Lexington, 1968) 31-38.

127 B. Hessen, *The Social and Economic Roots of Newton's Principia,* ed. R.S. Cohen (New-York: Howard Fertig, 1971).

128 B. Hessen, «De sociala och ekonomiska forutsättningarna för Newton Principia», in *Ide och klass*, ed. R. Ambjörnsson (Stockholm: PAN/Nordstedts, 1972), 90-145.

129 B. Hessen, «Die sozialen und ökonomiscbe Wurzeln von Newton's Principia» in *Wissenschaftssoziologie II*, *Determinanten Wissenscgaftkicher Entwicklung*, ed. P. Weingart (Frankfurt am Main: Athenäum Verlag, 1974), 261-325.

1977 by the Italian one that I already mentioned.[130] All three, however, were contained in larger collections which were not exclusively dedicated to Hessen. In 1985, Pablo Pruna realized the first Spanish edition published in Cuba in La Havana (the first from the Russian text of '33)[131] and in 1986, the first Japanese edition was published by Hōseidaigaku shuppan-kyoku and Hosei University Press.[132]

However, starting from the 90s, within the main theoretical formulations in the field of meta-scientific studies, references to Marxist terminology, especially the Hessenian one, decreased drastically. The fall of the Berlin Wall, the so-called "end of ideologies" and their consequences in the field of cultural production were certainly a determining cause of this loss of interest.

It is only since the 2000s that there has been a *nouvelle vague* of interest in the methodological perspective elaborated by Hessen. Compared to the previous ones, however, this new season of studies has had some notable points of originality. As I mentioned, until the end of the '80s, the reception of Hessen was limited to the reading of his famous *The Social and Economic Roots of Newton's Principia*. It is at this stage, in fact, at the end of a *longue durée* work of canonization of Hessen that the first critical editions of his work emerged, as well as the rediscovery and republication of other texts of this author that allow today a historiographically more solid interpretation of the same 1931 London intervention.

This new phase opened with the appearance of a 1999 publication in Spanish by Pablo Huerga-Melcon (the first accompanied by

130 B. Hessen, «Le radici sociali ed economiche dei *Principia* di Newton», in *Scienza al bivio*, ed. N. Bukharin (Bari: De Donato, 1977), 183-244.

131 B. Hessen, *Las Raices socioeconomicas de la mecanica de Newton*, ed. and trans., Pedro Pruna (La Habana: Academia, 1985).

132 B. Hessen, ニュートン力学の形成—『プリンキピア』の社会的経済的根源 (叢書・ウニベルシタス) 単行本, 東京 [Tokyo]: 法政大学出版局 (Hōseidaigaku shuppan-kyoku; Hosei University Press, 1986).

a careful critical reconstruction) that has the merit of looking at the figure of Hessen in a more complete and organic way. The full-bodied volume titled *La ciencia en la encrucijada*, in addition to including the text of 1931, also contains various other contributions by Hessen, presented for the first time in translation.[133] 2006 saw the first critical French edition edited by Serge Guérout and Christopher Chilvers[134] (the text of the translation had already been available in an unpublished version since 1979 to the users of the fund “science et societé” of the inter-university library of Jussieu)[135].

This renaissance of interest also extends toward a more detailed historiographical reconstruction of Hessen’s impact onmeta-science studies. An exemplary case from this point of view was the workshop titled “Science at the Crossroads: Geopolitics, Marxism, and Seventy-Five Years of Science Studies” (2006) organized at Princeton University and aimed at trying to retrace the history of Science Studies following the evolution and involution of Marxist theory. As can already be seen from the title, the references to the Hessenian text and to the famous London convention of 1931 were once again recognized and identified as the pivotal point from which to unravel a whole series of receptions of this type. Werskey, among those invited to the meeting, retraced a long historiographic path of the relations between Marxism and science studies, proposing a Visible College Revisited.[136]

133 B. Hessen, «*Las raices socioeconimicas de la mecanica de Newton*», in *La ciencia en la encrucijada*, ed. P. Huerga-Melcon (Oviedo: Pentalfa, 1999).

134 B. Hessen, *Les racines sociales et économiques des* Principia *des Newton*, ed. S. Guérout and rev. C. Chilvers (Paris: Vuibert, 2006).

135 Before being published, we have at least two instances where translations were circulated informally in library funds: B. Hessen, *Les fondements sociaux et économiques des* Principia *de Newton*, trans. Serge Guérout (Paris: Bibliothèque interuniversitaire scientifique de Jussieu, 1978 [Unpublished translation but made available to library users]) but also, B. Hessen, «Raices sociales y economicas de los *Principia* de Newton», in *Newton, el hombre y su ombra*, trans. H. Valanzano (E.U.B.C.A., 1988 [Version printed at the University of Montevideo]), 1-60.

136 Cfr. G. Werskey, *The Visible College Revisited: Second Opinions on the Red Scientists of the 1930s*, in *Minerva*, V. 45, N. 3, 2007, pp. 305-319; e Cfr. *The Marxist Critique of Capitalist Science: A History in Three Movements?*, in *Science as Culture*, V. 16, N. 4, 2007, pp. 397-461.

In 2009, we saw the appearance of the first edition of Hessen's speech of 1931 in modern Greek.[137] An important turning point in the re-circulation of Hessen's thought is to be found in the re-edition in English of Hessen's famous speech. In 2009, Gideon Freudenthal and Peter McLaughlin published in the Boston Studies in Philosophy of Science series of Springer publishers— therefore bringing the work into global circulation—an edition titled *The Social and Economic Roots of the Scientific Revolution* that collects and combines Hessen's text with a series of essays by Grossmann dedicated to modern science.[138]

Both editors of this volume are well immersed in German-speaking debates and are close to the research in German historical epistemology which developed around figures such as Peter Damerow, Wolfgang Lefèvre[139] and Jürgen Renn, and which then consolidated in the programs developed at Department I of the Max Planck Institute for the History of Science in Berlin on the material conditions of scientific production. The juxtaposition of the theses of Hessen and Grossmann, besides being justified by their consonance and integrability, is also motivated by further socio-historical reasons. In the German context, Grossmann's contributions to Marxist economics have been an important intellectual reference in the circles of the German post-Sixties New Left since the 1970s.[140] As already pointed out, Hessen had already been introduced into the German context by Weingart

137 B. Hessen, Οι κοινωνικες και οικονομικες ριζες των Αρχων Φυσικης Φιλοσφιας του Νευτωνα, ed. Dimitris Dialetis (Athens: Nefeli, 2009).

138 B. Hessen, *The Social and Eonomic Roots of Newton's Principia*, in *The Social and Economic Roots of the Scientific Revolution. Texts by Boris Hessen and Henryk Grossmann*, ed. G. Freudenthal and P. McLaughlin (Dordrecht/Boston: 2009).

139 The most notable attempt to rehabilitate the Marxist tradition in history and philosophy of science in the 1920s and 1930s is contained in Lefèvre's 1978 volumentitled *Natural Theory and Mode of Production (Naturtheorie und Produktionsweise).*

140 Boris Hessen and Henryk Grossmann, *The Social and Economic Roots of the Scientific Revolution*, ed. Gideon Freudenthal e Peter McLaughlin (Boston/Dordrecht: Springer Netherlands, 2009), 252.

in 1974 through the publication of the text of '31 in an anthology of texts on the sociology of science which probably had a smaller circulation than the works of Grossmann already available in the original German. The volume edited by Freudenthal and McLaughlin is therefore intended to give Grossmann greater legitimacy on the international level and, at the same time, to reintroduce Hessen's work in the German context.

It was probably also due to the new interest aroused by the resumption of the international debate on these topics that in 2013 Rose-Luise Winkler, one of the leading experts of Hessen's thought[141], published a new German language version of the 1931 London intervention.[142] Rose-Luise Winkler is also to be credited with the rediscovery of the anthology of texts from the history of modern science (which we publish here in English) that Hessen had compiled before his untimely death. This anthology collects all the sources that the author had used to develop the arguments presented in "The Social and Economic Roots of Newton's *Principia*".[143]

Such an international revival is probably also the basis of the revival of interest in this author in Russia. In 2015, the volume *Борис Михайлович Гессен (1893-1936)* was published, which aims to propose a general reconstruction of the figure of Hessen by providing a detailed reconstruction of his bibliography and a complete list of his

141 See Rose-Luise Winkler, 1987/88) "B.M. Hessen," in *Porträts russischer und sowjetischer Soziologen. Sonderheft Soziologie und Sozialpolitik. Beiträge aus der Forschung* (Berlin and Moskau: Akademie der Wissenschaften, 1987/88), 208–21 and Rose-Luise Winkler, *An den Urspüngen wissenschaftssoziologischen Denkens. Erstes Drittel des XX. Jahrhunderts (Russland/Sowjetunion)* (Berlin: trafo Wissenschaftsverlag, 2013).

142 B. Hessen, „Die sozialökonomischen Ursprünge der Mechanik Newtons." In *An den Ursprüngen wissenschaftssoziologischen Denkens: Erstes Drittel des XX. Jahrhunderts: Russland/Sowjetunion*, ed. R.L. Winkler (Berlin: Trafo Wissenschaftsverlag, 2013), 243-344.

143 Rose-Luise Winkler, "Ein unveröffentlichtes Manuskript von Boris M. Hessen: 'Materialien und Dokumente zur Geschichte der Physik.'" *Sitzungsberichte der Leibniz- Sozietät* 92 (2007): 133–152.

works both published and unpublished.[144] Between 2018 and 2019 the Russian open access journal *Epistemology & Philosophy of Science* re-published in the original language (with the addition of abstracts in English) three texts by Hessen allowing a greater global dissemination (many of the texts by this author are in fact not easily available).[145] At the same time, also in the Russian language, several articles and essays dedicated to Hessen have been published.[146]

After the aforementioned 1986 Japanese edition, Hessen's text continues to circulate in Asia thanks in part to the 2016 Korean translation of the 1931 intervention.[147]

In 2017, in collaboration with Giulia Rispoli and Pietro Daniel Omodeo, I edited the first critical and autonomous edition in Italian starting with a comparison between the English text of 1931 and the Russian text of 1933 (comparing it with the French, Spanish and Italian translations). In this context, we have deepened the biography of Hessen, his writings and the socio-political context in which it was situated, clarifying the misunderstandings related to the first English translation that have been perpetuated for many years. This collaboration opened up a still ongoing research project aimed at legitimizing Hessen as a cardinal author for historical epistemology and political epistemology (of which this volume is further evidence). We have published several papers on this line of research and others are still in the process of being published.

144 С.Н. Корсаков, А.В. Козенко, and Г.Г. Грачева, Г.Г., *Борис Михайлович Гессен (1893 – 1936)* (Москва [Moscow], Наука [Nauka], 2015).

145 Boris Hessen, «Выступление на заседании Президиума Коммунистической Академии. 1 августа 1931 г.», *Эпистемология и философия науки* 55, n. 3 (2018): 205–10; Boris Hessen, «Материалистическая Диалектика и Современная Физика. Тезисы Доклада на і Всесоюзном Съезде Физиков в Одессе 19 августа 1930 Г», *Эпистемология и философия науки* 56, n. 1 (2019): 209–15; Boris Hessen, «Выступление на Научной Сессии Института Философии, Посвящённой 25-Летию Выхода в Свет Труда в.и. Ленина "Материализм и Эмпириокритицизм". 22 июня 1934 Г», *Эпистемология и философия науки* 56, n. 1 (2019): 216–24.

146 Cfr. S. Winkler, *Selected Bibliography*, *Societate si politica*, XIII, no. 1 (2019): 103-109.

147 B. Hessen, 뉴턴 역학의 사회경제적 근원, 서울 [Seoul]: 북스힐 (Bugseuhil: Books Hill, 2016).

In 2019, Sean Winkler edited a special issue of the journal *Societate şi Politică* [*Society and Politics*] entirely dedicated to Hessen's thought. In addition to a number of interesting essays, this special issue published a translation of a text by Hessen in English titled "Preface to Articles by A. Einstein and J.J. Thomson" (translated and edited by S. Winkler). The latter helps to shed light on the approach of this author both in the field of the history of physics and in that of theoretical physics. In the same trajectory, in 2020 another paper by Hessen entitled Materialist Dialectics and Modern Physics: Abstracts of the Report at the First All-Union Congress of Physicists in Odessa on 19 August 1930 was translated into English for the journal Historical Materialism and accompanied by an essay by Winkler.

In 2021 Chris Talbot and Olga Pattison 2021 have translated and edited the first English edited volume of Hessen's contribution published before his famous '31 intervention: *Boris Hessen: Physics and Philosophy in the Soviet Union, 1927-1931. Neglected Debates on Emergence and Reduction*. This operation, together with the unpublished anthology that we are now publishing in English, lays the groundwork for a more complete and organic interpretation of the figure of Hessen. Both these volumes, if read at the same time, allow one to see how much Hessen's historiographical theses were embedded in deep reflections on the foundations of contemporary physics (especially quantum mechanics and relativity) and vice versa. The possibility of consulting these documents, so far unpublished, allows us to have a complete view of the integrated historical-epistemological approach proposed by Hessen.

Conclusion

How should Hessen being labeled the progenitor of these various debates about scientific knowledge be interpreted? From a methodological point of view, Koyré had strongly criticized the idea of the "precursor" in the history of science: "Rien n'a eu une influence plus néfaste sur l'histoire que la notion de 'précurseur.' Envisager quelqu'un comme 'précurseur' de quelqu'un d'autre, c'est, très certainement, s'interdire à le comprendre."[148] Nevertheless, it is very interesting to observe the process by which the figure of an authoritative "precursor" is constructed by an emergent field or debate that tries to legitimize itself. According to what Bourdieu called the social condition of international (but also interdisciplinary) circulation of ideas,[149] Hessen's work passed through various labelling phases.

The history and sociology of science has attributed to the Russian author the merit/demerit of having been among the first to open a new wave of studies, which were later labeled externalism. Nevertheless, it should be emphasized that Merton was the one who introduced terms such as internalism and externalism into debates about science. Moreover, the choice to line up on one side or the other, internalist or externalist, depends also on different disciplinary revindications that conditioned the process and the form of the institutionalization of specific disciplinary fields (we especially focused our attention on Anglo-American debates[150]). Also, Hessen's work had an extraordinary impact on the context of *science policy,* by laying the foundation of what came to be known as "Bernalism." This posture had a broad political impact on science studies, not only in the U.K. but also in the USSR and in Poland. Bernal's works had, in those cases, an impact as great as that of Hessen at the London congress in 1931,[151] and stimulated the renaissance of *naukovedenie*. There was,

148 Koyré, "Introduction," in *Des révolutions des orbes célestes (Du livre I, chapitres 1-11)*, by N. Copernicus (Paris: Librairie Félix Alcan, 1934 [1543]), 4.

149 Bourdieu, «Les conditions sociales de la circulation internationales des idées».

150 In other national cases, such as French or USSR debates, the institutionalization of disciplinary studies of science followed different trajectories.

151 E. M. Mirsky, "Science Studies in the USSR (History, Problems, Prospects)," *Science Studies* 2/3 (1972): 281-294; Y. M. Rabkin, "*Naukovedenie*: The Study of Scientific Research in the Soviet Union", *Minerva* 14/1 (1976): 61-78.

therefore, a sort of bidirectional circulation of research paradigms between the two sides of the iron curtain. During the post-'68 period, Radial Science Movements emphasized the importance of Hessen's work for the analysis of the entanglement between science, technology and socio-political contexts. In this phase, new forms of actualization of Hessen's theses emerged, aimed at showing the non-neutrality of scientific knowledge. Finally, Hessen's work had been perceived from the perspective of SSK as a theoretical source for unlocking the so-called "black box" of the social content of scientific knowledge. As we have seen, in this sense, the Hessen theses played a peculiar role in the closure of the debate between internalism/externalism.

As we have seen, there has been no single way of reading Hessen. Being identified as a stimulus for the construction of new paradigms of research and analysis, his theses have been constantly subjected to a labelling process that has led the Soviet author to be identified as a precursor and prophet of a vast number of intellectual positions, some of them contradictory.

What should be noted, however, is that even though Hessen has been repeatedly accused by mainstream scientific historiography as too 'crude' of an author, his legacy has not ceased to stimulate new forms of reflection for more than ninety years. This indicates that it is not as easy to curb his significance as the so-called internalist current would like. Nowadays, it is necessary to revisit the Soviet physicist's work in order to revive the critical spirit in which he interpreted the sciences, with the effort not only of trying to understand his underlying political values, but to historically and sociologically reconsider our own epistemologies as well.

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Boris Hessen's Philosophy of the Scientific Revolution

Pietro Daniel Omodeo

Preliminary Remarks

Boris Hessen is one of the most quoted historians of the Scientific Revolution but also one of the most controversial. His manifesto of Marxist historiography, "The Social and Economic Roots of Newton's Mechanics" (or "of Newton's *Principia*," depending on the edition and language of reference)[1] is still regarded — and often dismissed — as the most representative piece of 'externalist' history of science. First presented at the 1931 *International Congress of the History of Science and Technology* in London, his talk was met with the enthusiasm of a young generation of British Marxists, among whom we find John Bernal and Joseph Needham. These English-speaking scholars were much more active in continuing Hessen's project of a socio-economical history of science than their Russian counterparts, as the Stalinist purges set a brutal stop to the life and work of Hessen "according to the dreadful principle that *all revolutions devour their own children.*"[2]

Hessen, along with the other Soviet delegates who attended the London conference under the leadership of the Bolshevik intellectual and politician Nikholai Bukharin, opened up a line of inquiry into the societal meaning of science and its economic motivations that

1 For the sake of brevity, I will refer to it as *Social-Economic Roots* from now onwards.
2 J. Needham, New Foreword to *Science at the Cross Roads* (London: Frank Cass, 1971), ix.

renounced standard accounts of knowledge as the achievement of exceptional individuals of uncommon genius. In general, they raised the question of the social and political function of science. Hessen's essay on Isaac Newton had a particularly strong impact as it addressed a key figure of modern physics. It brought forward the thesis that ideas are not generated from other ideas. Instead of mental parthenogenesis, Hessen argued that we ought to explain the emergence of scientific knowledge through a close consideration of societal contexts and hegemonic interests. Scientific agendas are always connected with technological challenges and are closely tied to economic needs. According to Hessen, modern science and modern capitalism went hand in hand. Indeed, scientific knowledge was a major instrument of economic expansion under new economic settings that, in England, were first established in the passage from the sixteenth century to the seventeenth.

Yet, the strength of Hessen's emphasis on the dependency of modern science on economy also came to be seen as his major weakness, both by anti-Marxist (internalist and culturalist) historians of science as well as cultural Marxists. In both cases, Hessen was dismissed — or, better said, his stereotype image was dismissed — as an economic reductionist. Opponents accused him and his approach to be crude, limited and schematic. Idealist historians of science embraced this negative judgment in the wake of Alexandre Koyré's Platonic vision of intellectual progress.[3] Later, social-constructivist and social-democratic historians repeated this same critique. This was the case with Steve Shapin and Simon Schaffer's classic in Goffmanian historical sociology of science.[4] Their account of seventeenth-century

3 Cf. Wolfgang Lefèvre, "Galileo Engineer: Art and Modern Science," in *Galileo in Context*, ed. Jürgen Renn (Cambridge: Cambridge University Press, 2001), 11–13.

4 I take Goffman's sociology as the type of an approach that shifts the focus of the discipline from macro-sociological to micro-sociological interactions. Erving Goffman, *Stigma: Notes on the Management of Spoiled Identity* (New York: Simon & Schuster, 1963).

scientific culture in England, *Leviathan and the Air-Pump* (1985) shifted the focus of the sociology of science from socio-economic structures to the interactions of social actors. In this manner, they renounced a possible explanation of the Scientific Revolution in terms of emergent capitalism.[5] On the other hand, the general suspicion towards everything that stemmed from the Soviet Union, which is typical of cultural Marxists of the Frankfurt kind, led many to renounce not only communism in politics but also any attempts at a socio-economic investigation of science and, what is worse, epistemology tout court, as Jürgen Habermas's trajectory exhibits.[6]

As for the reception of Boris Hessen, whose Newton essay is possibly the most translated and reprinted work on the Scientific Revolution, its fate is indissolubly linked to political motives, which are exceptionally diverse. His essay has been seen as a socialist model of history-writing in the West, a point of reference for new attempts to build a leftist historiography, an instance of dogmatic economicism in the eyes of the idealist defenders of the purity of science, the work of a political opponent subjected to the merciless *damnatio memoriae* of Stalinist censorship, and a cumbersome presence to be relegated to a cabinet of antiquarian curiosities after the end of the Cold-War, when the neo-liberal consensus wiped out all Grand Narratives.

Hence, the following questions arise: What is still alive of Hessen's work and legacy? In our time, in which both economic analyses in the history of ideas and the concept of Scientific Revolutions are not fashionable anymore, what can still be learned from Hessen's much-discussed approach to these topics?

This publication of Hessen's anthology on early modern

5 Pietro Daniel Omodeo, *Political Epistemology: The Problem of Ideology in Science Studies* (Cham: Springer, 2019a), 14-21.

6 Andrew Feenberg, "Modernity, Technology and the Forms of Rationality," *Philosophy Compass* 6/12 (2011): 865-873.

physics, together with the English translation of some important sections, aims at a fresh reassessment of his thought, beyond the stereotypes. In recent years, his approach has been epitomized through a historical-epistemological phrase, the so-called 'Hessen-Grossman thesis'. According to this, "economics [...] *present[s]* demands, which *pose* technical problems, which *generate* scientific problems."[7] The present publication helps us to look at the deeper roots of the thesis and the broader historical interests behind his famous essay, *Social-Economic Roots*. The anthology shows that Hessen's conception of early-modern science was based on much historical research, a close reading of primary sources and a fair acquaintance with secondary literature. From the beginning of the text, Hessen makes his main goal clear: to integrate science with history and to reclaim the latter's role as an essential complement of knowledge theory. Against Hans Reichenbach's neo-positivist dismissal of history as a futile hobby, Hessen argues that physical research (as an instance of modern science in general) can only be understood and furthered from the diachronic perspective of transformation and revolutions. "This collection of documents and materials — as one reads — takes up the task of acquainting the reader with the history of physics through its primary sources." It also acquaints us with Hessen's engagement with the sources and debates of his time. In this light, his 1931 communication on Newton should be seen as no occasional writing. Rather, it was based on a lasting commitment to (what later came to be called) historical epistemology.[8]

7 Gideon Freudenthal and Peter McLaughlin, "Classical Marxist Historiography of Science: The Hessen-Grossmann Thesis," in *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*, ed. Gideon Freudenthal and Peter McLaughlin (Dordrecht: Springer, 2009), 4.

8 Hans-Jörg Rheinberger, *Historische Epistemologie zur Einführung* (Hamburg: Junius, 2007), 36; Pietro Daniel Omodeo, Gerardo Ienna and Massimiliano Badino, *Lineamenti di Epistemologia Storica: Correnti e temi*, *Preprints of the Max Planck Institute for the History of Science — Berlin* 506 (2021): 21-22.

Hessen's Approach to the Early-Modern Physics in His Classic Essay of 1931[9]

Before I consider the conception of the Scientific Revolution that emerges from Hessen's anthology, it is expedient to recount the main theses of his *Social-Economic Roots*, the talk he delivered at the London *International Congress of the History of Science and Technology* in 1931.[10] The two texts are closely interlinked. As Sean Winkler has already pointed out,[11] many sections of the anthology are literally taken from *Social-Economic Roots*. This word-by-word internal quotation by their author points to the fact that there is a common conception underlying them.

Among the communications of the Soviet delegates who were deputed to present and promote the Marxist approach of the history of science in London, Hessen's communication was among the most articulated. It went against semi-mythical accounts, according to which Newton was a lonely genius and his physics was a form of pure science detached from any worldly interests. By contrast, Hessen argued that his famous *Philosophiae naturalis principia mathematica* (*Mathematical Principles of Natural Philosophy*) (1687) constituted a scientific achievement as the synthesis of experiences and theories stemming from social, economic and technological contexts. Hessen's agenda was directed against idealistic accounts and even the banality of Providential-sounding narratives like that of Whitehead, who went

9 This section is a revision of Pietro Daniel Omodeo, "Socio-Political Coordinates of Early-Modern Mechanics: A Preliminary Discussion," In *Emergence and Expansion of Preclassical Mechanics*, Boston Studies in the Philosophy and History of Science, ed. Rivka Feldhay, Jürgen Renn, Matthias Schemmel, and Matteo Valleriani (Cham: Springer, 2018a), 58-62, and Omodeo, Political Epistemology, 100-105.

10 Hessen's essay was first published in *Science at the Cross Roads* (London: Kniga, 1931), reprinted in 1971 (London: Frank). I will quote it from the most recent edition in "The Social and Economic Roots of Newton's *Principia*," in *The Social and Economic Roots of the Scientific Revolution*, ed. Gideon Freudenthal and Peter McLaughlin (Dordrecht: Springer, 2009).

11 Cfr. *infra* Sean Winkler, "'A Pantheon of Great Ideas: Boris Hessen and the History & Philosophy of Science."

so far as to state that "our modern civilization is due to the fact that in the year when Galileo died, Newton was born."[12] In order to contrast such futile rhetoric, Hessen proposed to abandon the self-celebratory narrations of the elites and rather embrace the standpoint of the masses:

> [One] defect that Marx's theory removes is the view that the subject of history is not the mass of the people, but individuals of genius. In contradistinction to this view Marx examined the movement of the masses who make history and studied the social conditions of the life of the masses and the changes in those conditions.[13]

Hessen took Karl Marx's preface to *Zur Kritik der politischen Ökonomie* (*A Contribution to the Critique of Political Economy*) (1859) as a point of departure for his theoretical-political conceptions. He summarizes Marx's structure-superstructure distinction as follows: "The mode of production of material life *conditions* the social, political and intellectual life process of society."[14] Hessen clearly stressed the dependency of the cultural 'superstructure' on the economic 'basis'. However, he left open for debate the question of whether such conditioning is monocausal and deterministic or not. It is important to stress this aspect because such theoretical openness downplays the too-often repeated criticism of economic reductionism leveled against him.

To be sure, the leader of the Soviet delegation, Bukharin had a less nuanced opinion on this matter, especially in his popularizing

12 Freudenthal and McLaughlin, "Classical Marxist Historiography of Science." 28.
13 Hessen, "The Social and Economic Roots of Newton's *Principia*," 42-43.
14 Freudenthal and McLaughlin, "Classical Marxist Historiography of Science," 42, emphasis added.

works on historical materialism for the working class. In his introduction to Marxist philosophy *Historical Materialism* (1921), Bukharin had argued, on a materialist basis, for the naturalization of the laws of social development — a viewpoint for which historicist Marxists such as György Lukács and Antonio Gramsci harshly criticized him.[15] In London, Bukharin continued presenting himself as a champion scientist of historical materialism. Indeed, he regarded historical materialism as Marxist sociology *tout court*, that is to say, a scientific theory of society and its deterministic development. As he believed that determinism is an essential component of science in general, he thought of both natural and societal processes as necessary and independent of subjective factors: "in nature and society there is a *definite* regularity, a *fixed* natural law. The definition of this natural law is the first task of science. This causality in nature and society is objective."[16]

As a consequence of these premises, Bukharin asserted that even revolutions are predictable just like solar eclipses on the bases of astronomical knowledge or the boiling of water at 100° C. As it appears from Hessen's historical work, he refrained from such crude forms of naturalization. Rather, his reflection on the dynamics of science, economy, technology, politics, philosophy and religion was dialectical in the sense that he considered the dynamic interdependencies and reciprocal influences of the various material and cultural components of the historical process. He did not renounce the primacy of the economical but also considered the role of ideology as relevant to the explanation of science and society.

Newton's time was marked by the rise of early capitalism as a new economic and social formation, the expansion of merchant

15 György Lukács, "N. Bucharin: Theorie des historischen Materialismus," in *Werke, Frühschriften II*, *vol. 2* (Neuwied-Berlin: Hermann Luchterhand, 1968); Antonio Gramsci, *Quaderni del carcere* (Turn: Einaudi, 2007), Notebook XI.

16 Nikholai Bukharin, *Historical Materialism: A System of Sociology* (New York: International Publishers, 1934 [1921]), 20.

capital and manufacture. The development of communication, transport, industry and warfare were connected with the interest of the entrepreneurial classes of the late Middle Ages and early modernity. This is a theme that also underlies the anthology. In *Social-Economic Roots*, he detailed the technical problems raised by the expansion of these three areas (transport, industry and warfare) and the corresponding scientific fields that flourished during the sixteenth and seventeenth centuries in Europe. First, the needs of communication and transport, mainly maritime, required the improvement of vessels, the development of new navigation techniques, especially in the Oceans, and the building of canals and locks. In order to address the technical problems of navigation, improved hydrostatics and hydrodynamics were needed. Moreover, astronomical, geographical, mathematical and optical knowledge had to be augmented as a means to support navigation. The most important realms of industry were mining and war, the technical problems of which could be solved by chemical and mechanical experts of a variety of topics ranging from simple machines to hydro- and aerostatics and the science of materials. Third, the military requirements of a time marked by the introduction of firearms led to the perfection of ballistics and fortification techniques, the study of dynamics and the improvement of architecture. These areas of economy and technology also constitute the most important structural realms that Hessen explored in the first part of his unpublished anthology. As for the relevance of his approach, in particular of his idea of the 'socio-economic roots', this had such an impact in the discipline that, as Rose-Luise Winkler says, it "is comparable with Kuhn's concept of paradigm in the research on knowledge of the 1960s and 1970s."[17]

17 See Rose-Luise Winkler, infra as well as "Ein unveröffentlichtes Manuskript von Boris M. Hessen: 'Materialien und Dokumente zur Geschichte der Physik," *Sitzungsberichte der Leibniz-Sozietät* 92 (2007), 133–152: 139: "Die Wirkung seines Beitrages ist vergleichbar der

In *Social-Economic Roots*, after an overview of the economic, technical and scientific characteristics of Newton's age, Hessen offered a summary of the central problems faced by early-modern mechanics. The main issues can be enumerated as follows. A first area concerns simple machines, inclined planes and statics in general. A second area concerns the free fall and projectile trajectories. Thirdly, hydrostatics and aerostatics, atmospheric pressure and the motion of bodies through a medium constituted an important area of inquiry. Fourthly, heavenly mechanics and the theory of tides were significantly advanced. As collateral subjects, Hessen mentioned optics and magnetism. Additionally, he gave a list of the most renowned early-modern scientists. It comprised Leonardo da Vinci, Girolamo Cardano, Guidobaldo Del Monte, Simon Stevin, Galileo Galilei, Niccolò Tartaglia, Giovan Battista Riccioli, Otto von Guericke, Blaise Pascal, Pierre Boyle and Johannes Kepler.[18] He also mentioned Agricola, for mining, and Gilbert, for magnetism, a discipline whose economic-technological roots resided in navigation. According to Hessen, Newton brought most of these branches of physics to a theoretical synthesis but the brilliance of his intellectual achievement should not obscure the deep economic and technical roots of his science.

After considering the structure in which early modern mechanics was implanted, Hessen dealt with its superstructure, especially the philosophical-theological contexts. As he cautioned his listeners,

des von Thomas S. Kuhn eingeführten Paradigma-Begriff in der Wissensforschung in den 1960-70er Jahren. Der Begriff der sozialökonomischen Determination ist in der Folgezeit einer der wichtigsten Grundbegriffe für soziologische Analysen geworden, da er Aussagen zum Verhältnis von Gesellschaftsformationen und Wissenschaft empirisch erfaßbare und interpretierbare Sachverhalte übersetzt. Boris Hessen hat damit eines der Kardinalprobleme der wissenschaftssoziologischen Forschung formuliert und an einem prägnanten Objekt Fragen dazu aufgeworfen."

18 Hessen, "The Social and Economic Roots of Newton's *Principia*," 52.

> It would [...] be a gross oversimplification to derive *every problem* studied by various physicists, and *every task* they solved, directly from economics and technology. [...] The economic situation is the basis. But the development of theories and the individual work of a scientist are also affected by various superstructures, such as political forms of class struggle and its results, the reflection of these battles in the minds of the participants – in political, juridical, and philosophical theories, religious beliefs and their subsequent development into dogmatic systems.[19]

The political context of Newton was that of reformism, which was sanctioned by the Glorious Revolution of 1688. Hessen saw it as a compromise between the interests of the monarchy and those of the bourgeoisie that had heralded the English Revolution of 1648. According to Hessen, this climate of moderation and settlement (the "class compromise of 1688" as he called it) informed Newton's piety which, in turn, affected the philosophical views of the *Principia*. God and idealistic assumptions entered his conception of nature, although radical materialistic and mechanistic views were available in his time, such as those by Richard Overton, Thomas Hobbes, René Descartes and John Toland. Newton avoided theological, philosophical and political excesses. He assumed that a teleological principle of divine origin preserves the universe and its order. Moreover, he considered motion to be a mode superimposed on essentially inert matter and viewed space as a *sensorium Dei* (God's sensory) which is separable from matter. Thus, Hessen's considerations on superstructures and science, along with the cultural environment within which Newton operated mainly accounted for the perceived shortcomings

19 Ibid., 61.

of the latter's system, essentially its distance from an accomplished material and physical (as well as evolutionary) account of nature like the one that would be produced by Pierre Simon Laplace in the time of the French Revolution.[20]

It should be added that Hessen did not posit a unidirectional dependency of science on technology. Rather, he pointed out a possible feedback mechanism, that is, a dialectical reinforcement of technology through science and vice versa:

> **The immense development of technology was a powerful stimulus to the development of science, and the rapidly developing science in turn fertilized the new technology.**[21]

However, he did not go so far as to expand this idea on a more general explanatory level. In fact, he did not explicitly mention a similar dialectical loop between technology and economy and, even less so, between economy and politics, or politics and philosophy. In other words, his conception of the relation of structure and superstructure did not overtly challenge the primacy of economic causality. Nevertheless, he acknowledged that science is affected by the cultural element alongside the economic-technological. As he did not survive the Stalinist purges, he would never develop and circulate the details of his research program.[22] It was the task of American sociologist, Robert Merton to develop Hessen's insight by considering in more detail the incidence of technology, on the one hand, and Puritan ethics

20 A similar idea, that ideology only accounts for the shortcomings of science, has been defended by George Canguilhem, "Qu'est-ce qu'une idéologie scientifique?" in *Idéologie et rationalité dans l'histoire des sciences de la vie* (Paris: Vrin, 2009), 39-55.

21 Hessen, "The Social and Economic Roots of Newton's *Principia*," 84.

22 For the intellectual context of Hessen's work, see Rose-Luise Winkler, *An den Urspüngen wissenschaftssoziologischen Denkens. Erstes Drittel des XX. Jahrhunderts (Russland/Sowjetunion)* (Berlin: trafo Wissenschaftsverlag, 2013).

(distinct from theology), on the other, in the natural debates of Newton's time, in his classic of Weberian sociology of science, *Science, Technology and Society in Seventeenth Century England* (1938).

New Insights into Hessen's Views on the Scientific Revolution Based on His Unpublished Anthology

At his death, Hessen's anthology of sources relative to early modern science was almost ready for print. Herein, he gathered short texts relevant to the philosophy of science and its history from the socio-economic perspective he embraced. This collection, which we print here for the first time, was about six hundred pages long and, as it stands, presents the scholar with many difficulties. A major one concerns its bibliography. Hessen's quotations are seldom accompanied by exact references, if at all. Moreover, we could not establish which translations already existed — and which he simply appropriated — and which translations were completely new. Hessen generically mentions the fact that most of the translations into Russian were carried out for his anthology. Hessen also informed his reader, in the foreword, that he checked the translations against the originals:

> For this collection a number of translations available in Russian and checked afresh with the originals were used. The classics of natural science and especially physics were, unfortunately, very rarely translated into Russian so far, therefore, the major part of the material appears in Russian translation for the first time.

More work must be done in order to check the provenance of the sources that the collection comprises. The aforementioned defects can be ascribed to the fact that, although the book is in good shape and essentially completed, it never reached the final stage of publication. One additional problem for the reader is the absence of some sections about which we can only infer something thanks to the table of contents.

Marx and Engels are the political-philosophical authors of reference throughout the anthology. The old introduction to the *Dialektik der Natur* (*Dialectic of Nature*) together with excerpts from *Die deutsche Ideologie* (*German Ideology*) serve as an introduction to the first part, which is devoted to the "Socio-Economic Prerequisites for the Emergence of Classical Physics." A preface by Hessen and short texts of his are also inserted in the volume and are here provided to the reader in English translation. The anthology's first section brings together sources on what one would call today 'practical knowledge'. Hessen considered them sources on the socio-economic basis of early modern science and society as well as sources on the history of technology. They concern commerce, navigation, transport, naval engineering, warfare, military industry and metallurgy. It is without a doubt that Hessen's choice of these themes is closely connected with the program that he outlined in London in 1931 to investigate the socio-economic and technological roots of modern science. Indeed, *Social-Economic Roots* started from his consideration of the same realms with respect to Newton. They are the structural ground floor of society in accordance with the Marxist precept to investigate cultural phenomena starting from their 'basis.' The interpretative framework is clearly stated, among other places, at the beginning of the first part:

> The remarkable flourishing of the natural sciences in the sixteenth and seventeenth centuries is due to the break-up of feudal ownership, the development of merchant capital, international maritime transport and heavy industry (mining and metallurgy). The area of physics which developed earlier than the others and which reached the greatest development was mechanics.

The second thematic section deals with the conceptual (if one likes 'internal') aspects of the history of science, focusing on the developments of mechanics in modernity. It is devoted to the development of early-modern mechanics and includes excerpts from the best known physicists of the time such as Galileo, Huygens, Descartes, Leibniz, and Newton. The analytical development of the discipline is also taken into account through a selection from Bernoulli and D'Alembert. A historical overview of classical mechanics by Albert Einstein is also included, as a complement to the primary sources.

The third thematic section addresses the philosophical controversies related to science in the seventeenth and eighteenth centuries. This is the section devoted to problems of ideology, that is, to disputes on concepts and general worldviews. The Newton-Clark controversy over the philosophical fundamentals of physics is discussed to some extent, together with philosophical sources which Hessen deemed apt to offer an understanding of nature as an immanent realm without transcendence. Even the freethinker John Toland is given space in the collection. Immanuel Kant and Laplace are mentioned for their theories about the origin of the universe and its developmental nature. The philosophical endowment not only includes texts by Marx (*Die heilige Familie*) and Engels (*Dialektik der Natur* and *Anti-Dühring*) but even Hegel's remarks on empiricism.[23] Hessen believes that the philosophical controversies of the time can be brought back to a fundamental opposition between materialism and idealism. Theological biases, for instance those emerging from Newton's work or the Boyle lectures on science and faith, are a clear signal of 'idealism'. Moreover, this section deals with the institutional dimension of early-modern science: knowledge institutions such as universities and scientific academies, as well as issues of communication through scientific journals.

23 Winkler, "Ein unveröffentlichtes Manuskript von Boris M. Hessen," 143-146, offers a German translation of the table of contents of the anthology. Also see her essay, infra.

From this outline, the general structure of the volume should be clear. To sum it up, the first part deals with the economic and societal developments, technology and practices that constituted the basis of modern science. The second part deals with the development of scientific disciplines and theories — mechanics receives a special treatment among the sciences because, "of all the areas of physics, mechanics was the first to develop. It achieved before others a greater completion, and its influence strongly affected the other areas of physics." The third part deals with ideology, that is, with philosophy as a science of ideas (in accordance with the etymology: ideo-logy), and with the institutional-political settings of science, including universities and academies. In comparison to *Social-Economic Roots*, Newton occupies a less central place as he is only one of the authors that deserve attention among those who contributed to the Scientific Revolution. The whole progress of early-modern science — not only his *Principia* — needs to be understood on the basis of context, both material and ideological.

In order to exemplify Hessen's broad historical perspective, I would like to briefly discuss his presentation of two other early-modern scientists: Benedetto Castelli and Galileo Galilei. Both Italian Renaissance scientists are introduced in the first part of the anthology on the socio-economic roots of physics. Galileo's pupil Castelli, renowned for his works on mathematical physics, is here celebrated for his contribution to hydraulics as a response to the needs for improved transportation in connection with waterways. The foundational work in case is *Della misura delle acque correnti* [*On the Measurement of Running Waters*] (1628),[24] here extolled as a successful application of Galilean science to new fields:

24 Cf. Benedetto Castelli, *On the Measurement of Running Water*, trans. Deane R. Blackman (Florence: Olschki, 2007).

> Castelli's treatise on hydraulics was issued by the school of Galileo and emerged from Galileo's direct observations. They named it the "Golden Book". The great discoveries of Torricelli eclipsed this work, but its historical significance was even greater, for along with it the mechanics of liquids entered the field of physical laws, for the sake of which the empirical sciences had fought so stubbornly and unavailingly for two centuries. He is the first testimony to the successes of the Galilean approach to nature and a document of the dependence of the latter on the questions and needs of the time. The greatest service that Castelli had paid to scientific and practical hydraulics lay in the first principle of the dependence of the speed of the movement of water in rivers and canals on their width and height.

The significance of Castelli's science is not reduced to his discovery of some law or method for the quantification of running water taken in itself, but is connected with the socio-political relevance of his inquiries in a context in which the improvement of trade was crucial for securing economic growth in accordance with the interests of ruling mercantile classes. As the thesis goes, it was those interests that acted as drivers for the development of modern science. The development of hydraulics depended on massive interests to improve waterways and the regimentation of running waters for economic reasons.

Hessen regarded war as another crucial field which accounted for scientific expansion, as military needs dictated many research agendas. Galileo's work is first mentioned in this connection. The construction of fortresses and the use of firearms accounts for many of his scientific inquiries. Just as Newton, according to *Social-Economic Roots*, Galileo is here presented as an instance of how modern science emerged from social practices.[25]

25 On which, cf. Matteo Valleriani, *Galileo Engineer* (Dordrecht: Springer, 2010).

> The problems of the maximal conservation of energy and the effectiveness of machines, the precision of gunfire, the resistance of the fortifications – these were the same questions which had been discussed in technical literature for two centuries already.

However, this interpretation of Galileo is far from the reductionist image that is too often ascribed to Hessen. He neither reduces science to technology nor theory to practice. There is a gap between them and scholars like Galileo created bridges between the mathematical and natural reflection and workshops' experience as the new scientists codified practical knowledge at a more abstract level than that of the practitioner's labor.

> But Galileo approached the work done in the workshops, with which he was acquainted only thanks to his teacher mainly as a field for experiments and observations, which were to lead, above all, to the establishment of the theoretical foundations of the mechanical arts. Therefore, his formulation of these questions is fundamentally different, and their solution does not depend on any tradition of workshops and theorists, although his attention was constantly directed to the practical application of learning which had been established theoretically and experimentally.

In other words, according to Hessen, Galileo was not just an 'engineer' but a mathematician and philosopher who extracted and codified knowledge that he could derive from various fields of practice.[26] Hessen here mentions the Arsenal of Venice, the state-run navy

26 For considerations on the early-modern collaborative tension between engineers and mathematicians, see Cesare Maffioli, *La via delle acque (1500 - 1700): appropriazione delle arti e trasformazione delle matematiche* (Florence: Olschki, 2010).

shipyard, as a relevant place where a fruitful exchange between practitioners and the emerging figure of the modern scientist, a fact that Galileo extols at the beginning of his *Discorsi e dimostrazioni matematiche intorno a due nuove scienze* (*Discourses and Mathematical Demonstrations Relating to Two New Sciences*) (1638).[27]

Hessen considers mining to be another realm of practice, experimentation and knowledge extraction. He looks at the problems of the effective use of mines as the basis of technical and chemical developments, with special reference to Agricola.

In part two of the anthology, which deals with the history of physics from a more internal perspective (the genesis and development of the main principles of mechanics in early modernity), he refers to Joseph-Louis Lagrange and Albert Einstein to offer a general interpretative framework. The former's *Mécanique analytique* (*Analytical Mechanics*) (first published in Paris, in 1788) offers Hessen a systematic outlook on the development of the discipline of mechanics since antiquity. According to Lagrange's partition of the discipline, mechanics comprises two main areas, statics and dynamics; the main 'discoverers' and 'systemizers' which he lists are brief but accurate. His historical overview ranges from Archimedes to Newton, whose universal gravitation made mechanics into a new science (a *science nouvelle*).[28] While Lagrange serves the purpose of presenting the his-

27 Jürgen Renn and Matteo Valleriani, "Galileo and the Challenge of the Arsenal," *Preprints of the Max Planck Institute for the History of Science Berlin* 179 (2001), (https://www.mpiwg-berlin.mpg.de/sites/default/files/Preprints/P179.pdf) (accessed on 1 October 2021).

28 I summarized the schema that emerges from Lagrange's historical reconstruction in 2018 as an advancement in three steps: first, mechanics as the science of machines in the Renaissance systematization of ancient and medieval sources on statics and machines along with the emergence of dynamics as a new field for physical-mathematical investigation; second, the physical-mathematical science of balance and motion in general through a process of generalization leading to Newton's mathematical physics; third, mechanics as an analytical science coinciding with its complete transformation into a deductive mathematical discipline. See Pietro Daniel Omodeo, "The Social Position and Intellectual Identity of the Renaissance Mathematician-Physicist Giovanni Battista Benedetti: A Case Study in the Socio-Political History of Mechanics," in *Emergence and Expansion of Preclassical Mechanics*, Boston

torical genesis of mechanics, Einstein gives the coordinates for understanding its developments up to the most recent times. As Hessen writes:

> In order for the reader to gain some perspective on the further development of mechanics, we provide an article by Einstein, written for the Newtonian bicentennial anniversary. This paper gives a general perspective on the further development of Newtonian mechanics and relativity theory and a general evaluation of classical mechanics.

While dealing with the details of mechanics, the second partition follows the model of Ernst Mach's *Die Mechanik in ihrer Entwicklung historisch-kritisch Dargestellt* (*Science of Mechanics: A Critical and Historical Account of Its Development*) (Leipzig, 1883) in that certain fields of the scientific development are left at the margin. The most significant among them is Copernican astronomy. Hessen explains the choice as linked to the need to limit the scope of his anthology and to focus on a selected set of themes:

> Unfortunately, due to lack of space, we had to neglect Galileo's astronomical works, which played a significant role in the development of mechanics; just as in the selection of Newton's works, we nearly neglected all of his cosmogonic and astronomical works. This, however, made it possible to fully cover the development of the basic principles of dynamics.

The decision to leave astronomy out of the picture is strategic, as the detection of the socio-economic roots of modern science can

Studies in the Philosophy and History of Science, ed. Rivka Feldhay, Jürgen Renn, Matthias Schemmel, and Matteo Valleriani (Cham: Springer, 2018b), 181–213.

be much easier and more directly inferred from practical mechanics than from mathematical astronomy or cosmology. Yet, the latter fields, especially debates on the order of the cosmos and the boundaries of nature, would have been well suited for the discussion of problems of ideology and clashes of worldviews.

In the third part of the anthology, Hessen puts matter and motion at the center of his consideration of the ideological struggles on the main categories of physics. He is particularly interested in the connection of modern physics with the developments of materialism. In this respect, God's function in Newton's system responds to his theological concerns and affects his views on the maintenance of the order of the universe and fundamental concepts. Hessen here considers both the *Principia* as well as the correspondence between Newton's associate Clarke and Leibniz, especially from the viewpoint of their disagreements on God, matter and motion. Moreover, as one reads, "if Leibniz's criticism of Newton is conducted from an idealistic angle, then in a somewhat later period (at the beginning of the eighteenth century) we come up with a materialist critique of Newton's views on the part of Toland." The excerpt of the latter's *Letter to Serena* is missing from the extant copy of the anthology but we know that Hessen used it from the table of contents. From the table of contents, we also see that Toland's *Letter* was followed by two texts by Kant and Laplace on the origin of the world. These sources are missing, too. However, their relevance is explained against the background of a general interest in developmental materialistic conceptions of the world in which dynamism has become an intrinsic property of matter.

> In the extracts from his *Letters to Serena*, John Toland aims his sharp criticisms against the conception of the modality of motion. Motion, he claims, is an existing and indivisible feature of matter. It should be included as an integral part of its

> **definition. Only this conception, Toland justly affirms, provides a rational explanation of the law of the constant quantity of movement. It resolves difficulties regarding the moving force and the initial push. Thus, in the controversy between Leibniz and Toland with Newton, the problem of self-propulsion of matter was clearly posed, which received a definitive solution in the teachings of Marx, Engels and Lenin.**

The ideological struggles over matter and the divine are read against a more general conflict between the institutions of feudalism and those of capitalism. The two conflicting societal models and groups of interests, according to Hessen, had their special forms of knowledge. While the new science served the interests of the new emergent society, in particular those of the bourgeoisie, the old regime had its cultural bulwarks. In Hessen's view, universities essentially played the role of conservative intellectual institutions as they were hardly permeable to philosophical and intellectual novelties connected with the emergent leading classes in society. In view of today's historical sociology of knowledge, Hessen's judgment on medieval and early-modern universities looks too schematic as it neglects the university's societal function at large — for instance, as the educational centers of early modern intelligentsia in general, including the most celebrated scientists of the time — and reduces it to the issue of class struggle. Nonetheless, Hessen's discussion is significant in that it early on pointed to the relevance of considering teaching institutions in connection with the history of science and ideological struggles as an essential factor.

In Hessen's view, the medieval and early-modern Church was not simply a cultural institution that surveyed matters of theological conformity. It was first and foremost an economic institution, linked to a pre-capitalistic societal formation: "The Church was the international center of feudalism, and was itself a major feudal overlord, since it owned no less than a third of Catholic tenure." From this perspective, the defense of orthodoxy and that of feudal land interests are two sides of the same coin.

Scholastic philosophy can be seen as another expression of pre-capitalist corporate interests. "The struggle between university science and science beyond the university, serving the needs of a rising bourgeoisie, is a reflection in the ideological sphere of the class struggle of the bourgeoisie with feudalism." What Hessen calls "science beyond the university" is the emergent modern science. As he claims, its main cultural institutions were new creations: the Florentine *Accademia del cimento*, the French *Académie des Sciences* and the English Royal Society. The strengths and weaknesses of these institutions and the science they cultivated reflected those of the ascending bourgeoisie which "placed natural science at its service." On the one hand, they made the advancement of science possible, particularly in its experimental and mathematical form. On the other hand, radical forms of materialism were avoided and theological compromises were attempted, as can be evidenced by Bentley's Boyle lectures that are included in the anthology.[29]

Hessen also discusses the problem of early-modern censorship, in particular politically-led ones. Cartesianism in France is a case in point. The King's decree of 1671 which banned teaching Cartesianism from university is a historical example of institutional politics connected with the ideological struggle for the affirmation of a new culture and a new science.[30] This instance also serves Hessen's pur-

29 Among recent studies on science in early-modern academies, cf. Giulia Giannini and Mordechai Feingold, *The Institutionalization of Science in Early Modern Europe* (Leiden: Brill, 2020).

30 For an updated study on this topic, see Sophie Roux, "The Condemnations of Cartesian Natural Philosophy under Louis XIV (1661-91)," in *The Oxford Handbook of Descartes and Cartesianism*, ed. Steven Nadler, Tad S. Schmaltz and Delphine Antoine-Mahut (Oxford: Oxford University Press, 2019), 755-779.

pose of condemning the political imposition of philosophical orthodoxy in general. His reference to the dramatic evolution of the cultural-political climate of Soviet Union and the imposition of ideological conformity should be clear from statements as the following one, in which the meaning of Arnauld's parliamentary defense of Descartes goes beyond his time and the special circumstances in which it was pronounced:

> Arnauld presented a note to parliament, in which with great merit proved the impossibility of prohibiting the Cartesian doctrine and the harmful that such a measure would provoke. History, he stated, persuades us, that no law can force people to prefer one philosophy to another and that any attempt of such a kind can only undermine the authority of legislative power. Cartesianism is reproached in vain for the fact that it cannot be brought into compliance with the dogmas of the Church. The same can be said for any other philosophy.

Ideological Skirmish on the Scientific Revolution: Hessen's Externalist Legacy versus Internalism[31]

The fate of Hessen's contribution to the history of science is also linked to the rise and fall of the main historiographic concept of the Scientific Revolution, which looms large, although implicitly, over his work. The relevance of his argument concerning early modern science and Newton has long been perceived as a contribution to the debate about the origins of modern science — if not of science tout

31 This and the following two sections are a reworking of Pietro Daniel Omodeo, "Scientific Revolution, Ideologies of the," in *Encyclopedia of Early Modern Philosophy and the Sciences*, ed. Dana Jalobeanu and Charles T. Wolfe (Online: Springer, 2020a), 1-10.

court. Leftist and conservative scholars as different as the intellectual historian Alexandre Koyré and the sociological historian of science Edgar Zilsel, shared a common belief that the origins of science had to be searched for in the Renaissance, independently of the deep difference of their approaches. In recent years, though, the very idea of a unique break in history leading to the emergence of science has been cast into doubt to the point that sociologist of science Steven Shapin stated, in an introduction of his to this very topic, that "there was no such a thing as the Scientific Revolution, and this is a book about it."[32]

In spite of this bold statement, Shapin's introduction was not original as he presented standard authors and themes of science from the sixteenth and seventeenth centuries. Before him, others had established the canon. Hessen can be seen as one of those who challenged the hero's narrative, but not the most important steps and constituents of scientific modernity. Herbert Butterfield asserted the list of canonical authors and themes that any history of the Scientific Revolution ought to deal with in his own introduction to it, *The Origins of Modern Science* (1958). According to Butterfield, these must be comprised of Nicolaus Copernicus's heliocentric theory, William Harvey's theory of blood circulation, Francis Bacon's empirical method and experimentalism, Cartesian mechanism, modern physics (with particular attention to dynamics and universal gravitation), the birth of scientific societies, and modern chemistry. These themes, with small additions and variations, can be found in countless handbooks on the Scientific Revolution which appeared in the middle decades of the twentieth century. Hessen's Newton essay and anthology clearly constitute a precedent case in the choice of the fields of relevance for modern science.

Hessen does not stand alone as a founding figure of externalist

32 Steven Shapin, *The Scientific Revolution* (Chicago: The University of Chicago Press, 1996), 1.

historiography. Marxist historiography has further reference in authors such as the scholar linked to the Frankfurt Institute for Social Research Henryk Grossmann, the affiliate of the Vienna circle Edgar Zilsel,[33] and the aforementioned British leftists Bernal and Needham.[34] Among later contributions to a socio-political comprehension of science, one should add post-68 works stemming from Berlin and Rome such as Wolfgang Lefèvre's *Naturtheorie und Produktionsweise* (*Natural Theory and Mode of Production*) (1978) and *L'Ape e l'architetto: Paradigmi scientifici e materialismo storico* (1977) by a radical scientists' collective that comprised Giovanni Ciccotti, Marcello Cini, Michelangelo De Maria, and Giovanni Jona-Lasinio.

After Hessen invited historians to investigate the causal relation between social formations and cultural expressions and to look at the development of machine technology as the *conditio sine qua non* for the development of theoretical mechanics, Zilsel expanded Marxist sociology of science by looking at the social status of early modern scientists. In a widely circulated and often mentioned paper on the social roots of the Scientific Revolution, *The Sociological Roots of Science* (1942), he argued that the origins of modern science had to be traced back to incipient capitalism. Zilsel stressed the crucial role played by the craftsmen's experience and higher artisans in forming the basis for a new empirical, practice-oriented science. They lived in an age of valuation of practical knowledge and technical skills. He especially regarded Gilbert, Galileo and Bacon as the three main representatives of the empirical and theoretical science that emerged

33 Freudenthal and McLaughlin, "Classical Marxist Historiography of Science" and Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600* (Corvallis: Oregon State University Press, 2011), 11-22.

34 Robert M. Young, "Marxism and the History of Science," in *Companion to the History of Modern Science*, ed. Robert Cecil Olby, et al. (London/New York: Routledge, 1990), 77-86.

out of the new cultural context of their time.[35] More specifically, Zilsel argued that the persona of the modern scientist resulted from the fusion of three types: the craftsmen owing to their practical sense, the university professor for his systematic thought and the humanist elites for literacy.[36] Zilsel and his generation took it for granted that Europe was the place and early modernity was the time in which this particular socio-intellectual fusion occurred. The same assumption underlies the so-called 'Needham Question' of why science originated in Europe and not in China or other cultural contexts which, in the sixteenth century, had at their disposal technological knowledge that was similar, if not more advanced. The main difference, in Needham's view, was the presence, in Europe, of a capitalist (or proto-capitalist) society, the interests of which coincided with those of a bourgeoisie on the march towards its societal hegemony.

On the opposite ideological front of the Iron Curtain, another strand of historiography of the Scientific Revolution found a reference point in the idealistic-biased work of the philosophical historian of science Koyré. He was one of the most arduous supporters of the thesis that Scientific Revolution constituted an epochal break of philosophical import.[37] In his classical works on the history of science — *Études galiléennes* (1939), *From the Closed World to the Infinite Universe* (1957) and *Newtonian Studies* (1965) — he propagated the idea that the emergence of modern science in Europe occurred between the mid sixteenth-century and the end of the seventeenth century thanks to a series of intellectual heroes. In this sense, Koyré was a sort

35 Edgar Zilsel, "The Sociological Roots of Science," *Social Studies of Science* 30/6 (2000 [1942]): 935-939.

36 Omodeo, "Socio-Political Coordinates of Early-Modern Mechanics," 67–73.

37 Cf. Alexandre Koyré, "Galileo and Plato," *Journal of the History of Ideas* 4 (1943): 400: "The Scientific Revolution of the sixteenth century [has been] one of the profoundest, if not the most profound, revolution of human thought since the invention of the Cosmos by Greek thought: a revolution which implies a radical intellectual 'mutation', of which modern physical science is at once the expression and the fruit."

of anti-Hessen. His intellectual giants set the stage for a new vision of nature and the universe and provided the conceptual tools for the investigation of nature.

According to Koyré, the most important philosophical shift towards scientific modernity was conceptual. It concerned the passage from a qualitative, approximate approach to a quantitative one, together with the geometrization of space and the establishment of cosmological infinity. In addition, he regarded the codification of scientific ideas, such as the concept of inertia and the heliocentric planetary theory, as fundamental. In accordance with Koyré's understanding of science as a purely intellectual endeavor, he neglected and even explicitly rejected the idea that society and technology could account in any manner for its historical development. This led him to conclusions that were hardly tenable, for instance that Galileo's physics was a pure revolution of thought that did not presuppose any experimental work.

In his programmatic paper of 1943, "Galileo and Plato," Koyré explicitly dissociated himself from sociological and Marxists positions:

> This revolution [the Scientific Revolution] is sometimes characterized, and at the same time explained, as a kind of spiritual upheaval, an utter transformation of the whole fundamental attitude of the human mind; the active life, the *vita activa* [i.e., the πράξις] taking the place of the θεωρία, the *vita contemplativa*, which until then had been considered its highest form. [...] [According to this perspective,] the science of Descartes – and a fortiori that of Galilei – is nothing else than (as has been said) the science of the craftsman or of the engineer.[38]

38 Ibid., 400-401.

Koyré's opinion goes in the opposite direction. His main argument was, indeed, that Galileo's mathematized physics was a Platonic contemplation of numbers and geometries, which are revealed through the natural phenomena as their universal essences. The interpretation of Galileo as a Platonist supported the thesis that the Scientific Revolution fundamentally was a "spiritual revolution."[39] He dismisses practical interpretations of Galileo as a misled form of Baconianism: "The attitude we have just described is much more that of Bacon [...] than that of Galileo or Descartes."[40] But actually, if this remark had to be directed against Hessen and Marxist positions, it constitutes a typical misunderstanding, as the latter clearly distinguished between individual intentions, such as utilitarian motivations, and social functions. Hessen posited a distinction between the perception that people of the past had of their condition and the applications of their knowledge and the socio-economic factors which fostered their inquiries and the scientific practices. Additionally, Koyré argued that Galileo's and Descartes's "science is not made by engineers or craftsmen, but by men who seldom built or made anything more real than a theory."[41]

In a footnote of "Galileo and Plato,"[42] Koyré explicitly opposes the Marxist theses of Franz Borkenau's *Der Übergang von feudalen zum bürgerlichen Weltbild* (*The Transition from the Feudal to the Bourgeois Worldview*) (1934) relying on the criticism by Henryk Grossmann in "Die gesellschaftlichen Grundlagen der mechanistischen Philosophie und die Manufaktur" (The Societal Foundations of Mechanic Philosophy and Manufacture) (1935). Koyré does not mention here the fact that Grossman's criticism of Borkenau's image of "Descartes artisan" rested on a more nuanced form of Marxism, one that did not

39 Ibid., 403.
40 Ibid., 400-401.
41 Ibid., 401.
42 Ibid.

simply posit a morphological analogy between societal bases and cognitive structures but rather one which, similarly to Hessen, searched for the technological and practical roots of scientific codifications. Koyré also mentioned Leonhard Olschki's work on Renaissance science as linked to the technological culture of the late Middle Ages, as if it was just the same interpretative line of Borkenau and other Marxists. Among them, he dismisses Zilsel's paper on "The Sociological Roots of Science" for its emphasis on the "superior artisans" and their role in the development of the modern scientific outlook.

It is remarkable that, in this polemical context, Koyré does not mention the Soviet papers of 1931. Such silence must be explained by his profound aversion against all that is Marxist. He generally avoided mentioning the name of Marx, too, apart from a few exceptions. In a post-scriptum of 1961 to an essay of 1930, "Les études hégeliennes en France" (Hegelian Studies in France), he declared:

> […] last but not least, the emergence of Soviet Russia as world power and the victories of the communist armies and ideologies […]. Hegel generated Marx; Marx generated Lenin; Lenin generated Stalin.[43]

As a matter of fact, the success of Koyré's 'disembodied' history in Anglo-American scholarship was the product of an overdetermination. It was largely due to the perception that his intellectual historiography was a politically sound alternative to *socialist* externalist historiography. It was the most suitable approach for 'free' Western societies.

43 Quoted from Yehuda Elkana, "Alexandre Koyré: Between the History of Ideas and Sociology of Disembodied Knowledge," *History and Technology* 4 (1987): 141: "[…] enfin — *last but not least* — l'émergence de la Russie soviétique comme puissance mondiale et les victoires des armées et de l'idéologie communiste […] Hegel *genuit* Marx; Marx *genuit* Lenine; Lenine *genuit* Staline." After a turbulent youth, in which Koyré embraced socialist ideas, he later turned to Gaullism. See Paola Zambelli, *Alexandre Koyré In Incognito* (Firenze: Olschki, 2016).

Koyré's great admirer, the Harvard-trained historian and philosopher of science Thomas Kuhn, for one, lifted Koyré's historical interpretation of the Scientific Revolution to the level of a general theory of science.[44] According to him, 'revolutions' concern all of the identifiable turning points in the development of any scientific discipline. According to the epistemology that he expounded in his classic of historical epistemology, *The Structure of Scientific Revolutions* (1962), the history of science unfolded through long periods, in which 'normal' science advanced upon unquestioned and stable foundations, which were upturned by crises and revolutions of their supporting frameworks, or 'paradigms', and their eventual substitution with new paradigms.

Although Marxist scholars were in deep disagreement with Koyré on which *causes* could explain scientific advancements, they did not disagree with him on the *fact* that science was born at precise points in space and time. 'Socialist' externalists sought societal factors while 'liberal' internalists restricted their inquiry to the intellectual merits of individual minds and the contents of their pure science. Despite their interpretative differences, this ideology-laden opposition between the two camps did not cast the very idea of the Scientific Revolution into doubt. Instead, there was a struggle to define, explain and appropriate this concept. Internalists and externalists shared the conviction that the core of modern science was the advance of the physical-mathematical disciplines.

While Hessen's work can be read as an early contribution to the comprehension of the birth of modern science, the accurate determination of the causes and nuances behind such emergence constituted a sort of research program for most historians of science from the Fifties up to the Nineties. In a retrospective of those years, Simon

44 Kuhn explicitly praised Koyré as his *maître à penser*. See Thomas S. Kuhn, "Alexandre Koyré and the History of Science," *Encounters* 34 (1970): 67.

Schaffer and Steven Shapin have remarked that, still in the 1980s, the notion of the Scientific Revolution was, for many scholars, "the central organizing element in the grand narrative of science and its past — the moment when 'modern science' originated, when everything changed, and from which there was no return."[45]

The Crisis of the Scientific Revolution as a Historiographic Category

The definite end of the internalist-externalist divide, which was always disputed anyway, can be traced back to Shapin and Schaffer. Their best known work, *Leviathan and the Air-Pump* (1585), has been celebrated as the instigator of a cultural turn in the history of science. Although it emerged from Cold-War debates on the origins of modern science, the two authors were not satisfied with the state of the art of the debates about early-modern science. They took it upon themselves to question its framework, in particular the internalist-externalist debate, by replacing the grand narrative of modern science with micro-historical reconstructions. Instead of focusing upon structures, as earlier sociologists did, they focused on the ethos of the scientific community in its relevant context. They specifically dealt with the debate between the seventeenth-century English experimenters from the Royal Society and Thomas Hobbes's philosophical rationalism. In this manner, they relativized and localized the central figures, themes and institutions of the Scientific Revolution and transformed them into one case study among many other possible ones.

However, the success of their erosion of the Scientific Revolution narrative can neither be explained by their argumentative cogency nor by their exemplary historical analysis. Instead, their book

45 Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 2011), xxix.

should be seen as one that appeared in a timely moment when the criticism of the Scientific Revolution was gaining momentum from various directions and for different reasons.

One of the most controversial historiographical assumptions of the Scientific Revolution concerned the notion that there was a fundamental historical discontinuity between the old conceptions and the new world vision that emerged in early European modernity. Although medieval scholars and other nostalgic admirers of the 'premodern' world had previously argued for the continuity between Scholasticism and early-modern science,[46] their arguments rested on 'internalist' considerations about the generation of ideas from ideas (e.g., the principle of inertia and terrestrial motion from Scholastic disputes on the *impetus* imparted to moving bodies). In recent years, new arguments for continuity have been derived from institutional history, especially those arising from studies on scientific education, communication and circulation. As has been noted, traditional university teaching was the necessary background for the emergence of the new theories propagated by Galileo, Descartes, Newton and their like.[47]

A more destabilizing critique of the Scientific Revolution has come from the dismissal of the idea of modernity itself. This attack upon such a central historiographical category has come from at least two concurring tendencies: the reduction of historical inquiry to localized case studies or micro-histories and the post-modern rhetorical turn away from the trust in historical reconstruction towards

46 For example, Pierre Duhem, Anneliese Maier, Marshall Claggett and Edward Grant. See Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: The University of Chicago Press, 1994), 147–150.

47 See, among others, Charles Schmitt, *Studies in Renaissance Philosophy and Science* (London: Variorum Reprints, 1981) and Mordechai Feingold, *The Mathematicians' Apprenticeship: Science, Universities and Society in England, 1560-1640* (Cambridge: Cambridge University Press, 1984).

narrativism.[48] From the Nineties onwards, the classical connection between scientific progress, modernity and civilization has been seriously questioned. The critique of modern 'securities' in the name of post-modern 'freedom' has even undermined the belief in the solidity of modern science.[49]

Two additional critiques ought to be mentioned in regards to the epistemological assumptions behind the concept of the Scientific Revolution. One is that the Scientific Revolution assumes science in the singular but this should be substituted with sciences in the plural — and epistemology should be declined in the plural as well.[50] This pluralistic perspective eliminates the very possibility of detecting one single moment in history at which science emerged. Moreover, insofar as the sociology of science is concerned, social constructivism has questioned the objectivity of truth-claims in general.[51] Its most radical version has undermined the legitimacy of science's reference to a physical reality by reducing validity to social dynamics disconnected from material constraints.[52]

Yet, the most powerful cultural-political critique has come from post-colonial and global history: the allegation of Eurocentrism.[53] The Marxist historian of Chinese science Needham once justified

48 Omodeo, "Soggettività, strutture, egemonie: Questioni politico-culturali in epistemologia storica," *Studi Culturali* 15/2 (2018c): 211-234.

49 Cf. Bauman, *Postmodernity and Its Discontents*.

50 Peter Galison and David J. Stump, *The Disunity of Science: Boundaries, Contexts, and Power* (Stanford: Stanford University Press, 1996).

51 Cf. Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: The University of Chicago Press, 1994).

52 Luigi Pellizzoni, "Innocent, Guilty or Reluctant Midwife?: On the Reciprocal Relevance of STS and Post-Truth," *Tecnoscienza: Italian Journal of Science and Technology Studies* 10/1 (2019): 115-130.

53 See Dhruv Raina, "After Exceptionalism and Heritage: Thinking through the Multiple Histories of Knowledge," in *1001 Distortions: How (Not) to Narrate History of Science, Medicine, and Technology in Non-Western Cultures*, ed. Sonja Brentjes, et al. (Würzburg: Ergon, 2016), 25-38. See also Dipesh Chakrabarty, *Provincializing Europe: Postcolonial Thought and Historical Difference* (Princeton: Princeton University Press, 2000).

his studies on science and civilization in China by arguing that they would help understand why the Scientific Revolution took place in Europe in the first place. The new post-colonial perspective fosters comparative studies which do not share Needham's presuppositions about European exceptionality. It radicalizes Needham's own contention against "that fundamental insularity of outlook which is so difficult for Europeans, even those who have the best intentions, to discard."[54]

In connection with (and partially as a consequence of) the Eurocentric criticism, a new wave has emerged that aims to go beyond an 'exclusivist' history of science and embrace a more 'inclusive' history of knowledge:

> This capacious and usefully vague term [history of knowledge] has the advantage of nipping in the bud sterile, inconclusive discussions about whether Hellenistic alchemy or indigenous Peruvian botany or early eighteenth-century British steam technology is really science–the definition of which has proved to be as elusive as the Holy Grail or the Snark [...] it allows historians to follow practices wherever they may lead, however remote these may be from anything resembling latter-day science.[55]

While cognitive democracy may seem secure, the boundaries of science have become very blurred. Together with the suppression of the Scientific Revolution and modernity, post-modern epistemology and the ecumenism of global studies erode the trust that a clear-cut

54 Joseph Needham, *Science and Civilization in China, vol. 1* (Cambridge: Cambridge University Press, 1954), 3.

55 Lorraine Daston, "The History of Science and the History of Knowledge," *Know* 1/1 (2017): 142–143.

line can distinguish science from opinion. Such a post-truth predicament puzzles historians and philosophers of science. The current political climate has led to concerns about the political consequences of a social-epistemological relativism that can be easily instrumentalized for the purposes of propaganda (corporate, religious and electoral) while, simultaneously, new forms of social Darwinism reduce truth to the interest of the stronger.[56] In the current predicament, marked by post-modern skepsis and post-truth agendas, the question of the roots, validity and functions of science — all of which are crucially addressed in Hessen's work — acquire renewed cultural and political relevance.

New Prospects on the Scientific Revolution

If we were to assess the gains of the debates that questioned the idea of the Scientific Revolution, the debates of the last decades have offered us a broader understanding of science as a cultural phenomenon.[57] Additionally, studies on once-neglected disciplines such as astrology and alchemy are flourishing today.[58] Along with other mythological and ideological forms, religion has also come to the forefront as a crucial element of the early-modern scientific culture. This has likewise led to a renewed attention to the so-called 'Merton thesis.'

56 Naomi Oreskes and Eric M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (New York: Bloomsbury Press, 2010), and Pietro Daniel Omodeo "The Political and Intellectual Entanglements of Post-Truth: A Review of Steve Fuller's *Post-Truth: Knowledge as Power Game*," *Public Seminar: In the spirit of The New School for Social Research, informing debate about the pressing issues of our times* (http://www.publicseminar.org/2019/09/the-political-and-intellectual-entanglements-of-post-truth/) (18 September 2019b).

57 Moritz Epple and Claus Zittel, *Science as Cultural Practice* (Munich: Akademie Verlag, 2010).

58 See, for example, Darrel Rutkin, *Sapientia Astrologica: Astrology, Magic and Natural Knowledge, ca. 1250–1800*. *vol I. Medieval Structures (1250–1500): Conceptual, Institutional, Socio-Political, Theologico-Religious and Cultural* (Cham: Springer, 2019).

Merton argued in his seminal work *Science, Technology and Society in Seventeenth-Century England* (1938) for the relevance of 'Protestant ethics' as one of the main drivers behind much of seventeenth-century natural inquiry at the Royal Society. According to Merton, English classical science — that of Robert Boyle and Newton — grew on a terrain that had been constantly fertilized by Puritan ideas and habits about the investigation of nature as a means of glorifying God and improving the human condition at the same time.[59] It is interesting to note, in this context, that Merton explicitly acknowledged Hessen as his source for considerations about the relation of the science of Newton's age to technology and societal factors:

> In the discussion of the technical and scientific problems raised by certain economic developments, I follow closely the technical analysis of Professor B. Hessen in his provocative essay, "The Social and Economic Roots of Newton's *Principia*," in *Science at the Cross Roads* [...]. Professor Hessen's procedure, if carefully checked, provides a very useful basis for determining empirically the relations between economic and scientific development. These relations are probably different in an other than capitalistic economy since the rationalization which permeates capitalism stimulates the development of scientific technology.[60]

Although Merton did not acknowledge Hessen as a source of inspiration for his inquiry into the religious elements of the science of

59 Robert K. Merton, *Science, Technology and Society in Seventeenth Century England* (New York: Howard Fertig, 1970 [1938]), 80–136.

60 Robert K. Merton, *Science, Technology and Society in Seventeenth Century England*, *Osiris* 4 (1938): 501-502, no. 24.

Newton's times, possibly because his approach was rather Weberian than Marxist, it is still important to stress that both in *Social-Economic Roots* and this anthology of sources on the history of physics, Hessen devoted much space to religion in seventeenth-century England.

In recent years, post-Mertonian scholarship has gone much further in the reassessment of the role played by religions (in the plural) in the development of modern natural science. After the cultural turn of the Nineties, this line of thought has gone so far as to indiscriminately rehabilitate all sorts of religious agendas. Revisionist perspectives have reconsidered famous Inquisitorial trials on science, most notably the 'Galileo Affair', and deployed apologetic strategies to rehabilitate forms of scientific control, censure and propaganda.[61] In this manner, religiously-tinged approaches have questioned and reconsidered the meaning of modern scientific mentality in the name of the 'culturalist' principle that we should let the 'actors' speak on their own terms — which revives, on the methodological level, the positivistic prescription that the historian ought to be a transparent writer of unbiased reports.

Apart from a good dose of cynicism in their assessment of the power relations of early-modern science, such positions also neglect that a great part of the justification of early modern science was based on an unprecedented emphasis on experience, practice and effectiveness. As Hessen well knew and his anthology contributes to notice, Renaissance mathematicians were at the forefront in the defense of a conception of science which was at once theoretical and practical.[62] To give one example, the practical mathematician Bonaiuto Lorini

61 Omodeo, "'Jesuit Science' and Cultural Hegemony: A Political-Historiographical Critique," in *Cultural Hegemony in a Scientific World: Gramscian Concepts for the History of Science*, ed. Massimiliano Badino and Pietro Daniel Omodeo (Leiden: Brill, 2020b), 115-155.

62 Cf. Jürgen Renn, ed., *Galileo in Context* (Cambridge: Cambridge University Press, 2001).

expressed such an epistemology, which was typical for the mentality of his generation of 'scientist-engineers' as follows:[63]

> **Those who wish to deal with these [technical] works do not only need to know mathematics, in order to assess and realize them, but also have to be prudent and experienced mechanics.**[64]

The Neapolitan experimenter Giambattista Della Porta, one of the most prominent members of the scientific Academy of *Lincei*, expressed a similar idea in his renowned *Magiae naturalis libri viginti* (*Twenty Books on Natural Magic*) (1589). According to him, the new practice-oriented man of science whom he called the "natural magician",

> **must be a skillful workman, both by natural gifts, and also by the practice of his own hands; for knowledge without practice and workmanship, and practice without knowledge, are worth nothing; these are so linked together, that the one without the other is but vain, and to no purpose.**[65]

Such an awareness of effectiveness and the practical orientation of knowledge ultimately rested on the material experience of concrete scientific practices.[66]

63 Lefèvre, *Naturtheorie und Produktionsweise, Probleme einer materialistischen Wissenschaftsgeschichtsschreibung: Eine Studie zur Genese der neuzeitlichen Naturwissenschaft* (Darmstadt: Luchterhand, 1978), 96. The English translation is forthcoming in a volume along with other works of Lefèvre in the Verum Factum series.

64 Lorini, *Delle fortificazioni* (Venice: Rampazetto, 1596), 172.

65 Della Porta, *Natural Magick in XX Bookes* (London: Gaywood, 1658), 3.

66 For new perspectives on practical knowledge, see above all Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: The University of Chicago Press, 2004).

The reduction of the idea of the Scientific Revolution to historiographical distortion also neglects the early-modern roots of the idea of a break between the moderns and the ancients. The belief in the scientific-technical superiority of the moderns was symbolized by the three so-called 'Baconian technologies': gunpowder, typography and the compass. The celebration of this triad became a sort of commonplace among Renaissance thinkers concerning the practical roots of knowledge, among whom we find the Renaissance polymath Girolamo Cardano and the Royal mathematician in Paris Pierre de la Ramée.[67] In chapter 41 of his autobiography, *De vita propria liber*, Cardano presented gunpowder, the compass and the printing press as "natural prodigies observed, rare though, in my life." In his eyes, all of them were overshadowed by the geographical discoveries:

> Among the extraordinary, though quite natural circumstances of my life, the first and most unusual is that I was born in the century in which the whole world became known; whereas the ancients were familiar with but little more than a third part of it.
> […] We explore America […] Brazil, a great part of which was before unknown, Terra del Fuego, Patagonia, Peru […] Toward the East under the Antarctic we find the Antiscians [. . .] and some Northern people not yet known, as well as Japan […] all discoveries sure to give rise to great and calamitous events in order that a just distribution of them may be maintained.[68]

A world of possibilities was opened by the new geography. These commercial and colonial opportunities produced a novel "European

67 Ramus, *Scholarum mathematicarum libri XXXI* (Basel: Per Eusebium Episcopum et Nicolai Fratris haeredes, 1569), 65.
68 Cardano, *The Book of my Life (De Vita Propria Liber)* (New York: Dover Publications, 1962), 189–190.

self-definition" that reflected the establishment of global power relations.[69] Amerigo Vespucci, after whom America was named, started his *Mundus novus* (*New World*) (1503) with a note on the cultural consequences of his discoveries relative to the authority of the ancients:

> These [regions] we may rightly call a new world. Because our ancestors had no knowledge of them, and it will be a matter wholly new to all those who hear about them. For this transcends the view held by our ancients.[70]

A few years later, Copernicus found it convenient to refer to these claims of Vespucci's in order to introduce his daring cosmology which set the earth in motion around the Sun.[71] At the beginning of the next century, the telescopic observation of the surface of the moon, of new satellites, stars and celestial phenomena were often regarded as a furthering of the geographic conquest in the heavens.

Francis Bacon took inspiration from the Oceanic travels to foster the progress of knowledge in line with his well-known idea of the connection between science and power, which is aptly synthesized by the dictum "*Scientia et potentia humana in idem coincidunt*" (Human knowledge and human power come to the same thing).[72] He praised a form of knowledge which is useful, practical and empirical. Moreover, he saw his commitment to it as his institutional duty as an adviser to the King of England. In *The Advancement of Learning* (1605)

69 Vogel, "European Expansion and Self-Definition", in *The Cambridge History of Science,* vol. 3. *Early Modern Science*, ed. Katherine Park and Lorraine Daston (Cambridge: Cambridge University Press, Cambridge, 2006), Omodeo Senior, *Amerigo Vespucci: The Historical Context of His Explorations and Scientific Contribution* (Venice: Edizioni Ca' Foscari, 2020).

70 Vespucci, *The Mundus Novus*, transl. George Tyler Northup (Princeton: Princeton University Press, 1916), 1.

71 Copernicus, *De revolutionibus orbium coelestium* (Nuremberg: Petreius, 1543), 2*r.*

72 Bacon, *The New Organon*, ed. Lisa Jardine and Michael Silverthorne (Cambridge: Cambridge University Press, 2000a), 33. Cf. Pimentel, "The Iberian Vision: Science and Empire in the Framework of a Universal Monarchy". *Osiris* 15 (2001).

he tried to persuade King James to institutionalize science, because it was functional to the empowerment of the nation, which was, in truth, an imperial program of dominion over nature and rule over other people. Bacon equated his advice to James to the teaching that Aristotle imparted to Alexander the Great, which set the intellectual foundations of the Hellenic conquest of the world.[73]

In summary, the early-modern discourse on the superiority of the moderns — whether technological or scientific — received direct or indirect justification from European colonial expansion: cosmography produced the first globes, terrestrial and celestial, the compass permitted the navigators to cross unknown waters, gunpowder to conquer new territories, and the printing press to circulate knowledge. The historical-cosmological connection between scientific and technological progress, modernity and Eurocentrism are not an ungrounded historians' construct propagated by the Scientific Revolution narrative. Rather, these ideas were already interlocked at the beginning of a historical phase of global expansion. They expressed, at the level of individual and collective consciousness, the establishment of new world dominations, which secured some European nations a vantage point in relation to other cultures and their own past. Within this perspective, the Scientific Revolution should be seen as a historically grounded narrative of a phase of *scientific hegemony*, which coincides with Eurocentric modernity.

Today, the story of the Scientific Revolution looks like an origin myth. It refers to the beginning and essence of modernity.[74] In the

73 Bacon, "The Advancement of Learning", in *The Oxford Francis Bacon*, ed. Michael Kiernan, vol 4 (Oxford: Clarendon, 2000b), 10, B4*v*. Cf. Omodeo, "Bacon's Anthropocene: The Historical-Epistemological Entanglement of Power, Knowledge, and Nature Reassessed". *Epistemology and Philosophy of Science* 58/3: 148-170 (2021).

74 Omodeo and Freyberg, "Die Kopernikanische Revolution als Geschichtszeichen: Zur Entstehung der Transformationskosmologie", in *Was ist Kosmos?*, ed. Peter König and Oliver Schlaudt (Heidelberg: Heidelberg University Press, 2021).

years of the Cold War, to side with a spiritual understanding of the history of modern science or to offer a socio-economic explanation à la Hessen meant to take sides in the cultural struggles that opposed incommensurable political paradigms, namely capitalism and real socialism. But, at a deeper level, the Scientific Revolution itself was the expression of an ideology, namely the Eurocentrism that it implicitly justified. Such ideology is not mere mystification — an intentional lie to be dispelled and corrected. Rather, it is a conception that constitutes political action. It reflects on society, justifying and redirecting it. Hence, the Scientific Revolution cannot be treated as a mere problem of historiography and epistemology to be revised and eventually substituted by a 'correct' narrative (or abandoned for no narrative at all) once a hypothetical agreement among the academic community of historians of science (perhaps 'historians of knowledge') has been reached. Rather, the Scientific Revolution should be understood as the cultural expression of specific relations of power and a specific historical arrangement of society at a global level. Its geo-historical coordinates correspond to European colonial expansion and the establishment of Europe-centered forms of global dominion. It is by no means accidental that the dawn of the Scientific Revolution coincided with the definitive end of European centrality in geo-politics and the establishment of a US-centric globalization.[75]

Thus, in political-epistemological terms, the Scientific Revolution ought to be understood as a problem of science and power, or in more precise terms as a historical-historiographical case for an inquiry into problems of scientific hegemony. It helps us to reflect on the socio-political and historical conditions, causes and implications of scientific (and scientific-technological) hegemony. Within this perspective, the problems linked to the history and philosophy of the

75 On the system cycles of hegemonies, see Arrighi, *The Long Twentieth Century: Money, Power, and the Origins of Our Times* (London: Verso, 1994).

Scientific Revolution have not lost their significance at all, as they are still at the center of science politics. The Scientific Revolution can maintain today paradigmatic relevance as a suited terrain to study the problem of scientific (and scientific-technological) dominion at a symbolic level (of ideology via historiography) as well as at the material level of political economy and global power relations. The crucial problem of the Scientific Revolution is that of the power relations that were established through early-modern knowledge hegemonies, and our positioning thereupon.

A Concluding Note: Hessen as a Reference Author of Political Epistemology

Hessen is certainly an intellectual ally for a materialist history of science, which looks at the world-transformative potential of science and the power relations in which it is inscribed. According to him, science never was a pure problem of ideas or ideology, but one of concrete organization and change both of the natural and the social spheres. In line with his approach, historiography cannot be seen as mere narrative. Rather, it is a form of reflection on the social roots of science, even an instrument of the societal 'metabolism' of natural resources. From today's perspective, it is important to reassess his legacy not only as an antidote against postmodern relativism and post-truth cynicism. Also, it can constitute a reference point for the emerging environmental paradigm in the humanities and natural sciences. In the context of the current Anthropocene debates, science and technology have become major factors of geological transformation to the point that a new geological epoch is presently under scrutiny by the geological community.[76] As Jürgen Renn has recently ar-

76 Zalasiewicz, *The Anthropocene as a Geological Time Unit: A Guide to the Scientific Evidence and Current Debate* (Cambridge: Cambridge University Press, 2019).

gued, the history of science is part of the material history of the earth system.[77] Indeed, the history of the earth in the Anthropocene is in many ways an epistemological history because the development of scientific knowledge cannot be separated from the material transformation of our environment at a local scale as well as at a large planetary one — marking the passage from generic anthropogenic impact to the specific stratigraphic discontinuity in the turn of the 1950s.[78] The related problematic is not a mere issue of narrative or abstract categorization (as has sometimes been claimed).[79] Rather, it is an urgent call for a revision of our relation to nature and the development of an appropriate science, one that considers humanity and nature as mutually effective — with science in-between. This is in large part a teaching that one can derive from Hessen's conception of science and its history. In the context of current debates about science and the environment, the historical and economic dimensions of the Anthropocene are often neglected. The problem is not a name, say 'Capitalocene', but the socio-economic dimension of world-transformation, capitalist or not. Indeed, the problem of a humanized world implies a criticism of our societal structures that does not dismiss science and its epistemology but rather co-opts it as an instrument of comprehension, orientation and aware decision. In this sense, the history of science as the history of world transformation makes the study of epistemic processes a crucial realm of politics. This was the spirit that animated Hessen and his commitment to epistemic history and sociology as two axes for the construction of a new emancipated and critical society.

77 Renn, *The Evolution of Knowledge* (Princeton: Princeton University Press, 2020).
78 Steffen, "The Trajectory of the Anthropocene: The Great Acceleration". *The Anthropocene Review* 2(1) (2015).
79 Moore, *Anthropocene or Capitalocene? Nature, History and the Crisis of Capitalism* (Oakland: Kairos, 2016) and Haraway, "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin", in *Environmental Humanities*, vol. 6 (2015). Cf. Bonneuil and Fressoz, *The Shock of the Anthropocene: The Earth, History and Us* (London: Verso, 2017).

Hessen's vision of science is that of a collective endeavor. The educational dimension of modern scientific culture, which was so much emphasized in the Thirties by the main theoretician of the *Denkkollektiv*, Ludwig Fleck, was a concrete program in Hessen's case. His anthology attests to his commitment to forge a new kind of scientist, who is trained in history and philosophy. The question of how a liberated science and science as a common good can be achieved is still the unsolved problem in our technoscientific society, one of the most urgent ones to be addressed.[80] Hessen's life experience and intellectual legacy can and should be reactivated to face the Anthropocene and the most pressing challenges of scientific modernity. Now as then, science stands at a cross roads.

80 Cf. Marcuse, *One-Dimensional Man. Studies in the Ideology of Advanced Industrial Society* (Boston: Beacon Press, 1964), and "Industrialisierung und Kapitalismus", in *Max Weber und die Soziologie heute: Verhandlungen des 15. deutschen Soziologentages in Heidelberg 1964*, ed. Otto Stammer (Tübingen: Mohr Siebeck, 1965); Ciccotti et al., *L'Ape e l'architetto: Paradigmi scientifici e materialismo storico* (Milan: Feltrinelli, 1977).

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Socio-economic Prerequisites for the Emergence of Classical Physics

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Социально-экономические Предпосылки Возникновения Классической Физики

Translation (selections)

PREFACE

Russian literature on the history of physics is really quite meagre, and in recent years few works of any significance have emerged on the subject, even in Western Europe. This situation is not accidental. Nearly all of the most significant representatives of nineteenth-century classical physics (Ampere, Faraday, Maxwell, von Helmholtz, Boltzmann, Calvin) showed, to some degree, a keen interest in the history of their science and addressed this history not only in particular articles and research, but also wove historical analyses of the issue into their main works. Unfortunately, this tradition has long passed into history. Nowadays, not only have historical considerations and analyses disappeared from the works of leading physicists, but there are even currents and schools which fundamentally reject the utility and need for any historical study of science at all.

"For you the history of science is the key to knowledge about its real condition. For us, this is merely *Sonntagslektüre* (entertaining reading on a Sunday); it cannot provide us with any real knowledge about today's situation in science." This is how Professor Reichenbach, a representative of neo-Machism with whom the author had the opportunity to speak at the 6th Congress of German Physicists in Königsberg, summarized our dispute.

The rapid replacement of theories which has been taking place in physics in recent years, and their radical distinction from the views and principles of classical physics, has led many representatives of contemporary science to look at classical physics as something which is now completely obsolete; like a majestic edifice which, unfortunately, belongs only in a museum.

This view is radically incorrect. No matter how new and unusual the theories of contemporary physics may be, no matter how radically they differ from the outlook of classical physics, the contemporary stage of development in physics is still a historical phase of its overall development. Therefore, knowledge of the history, of the origin, and development of physical theories not only aids in understanding its contemporary condition, but also helps to establish its historical roots and, by doing so, clears the way for new research.

The modern development of physics offers a wide variety of basic categories—causation, the laws of statics and dynamics, the issue of dimension—that require profound analysis. The role of historical research for understanding these categories is undeniable. In acquainting ourselves with the history of physics, we can see that many fundamental issues had been raised earlier and, in some cases, the correct way of resolving these issues had already been outlined. History is, after all, not a "list of human errors, but a pantheon of great ideas." How little we have tapped into this cache of treasures! What we know about the thoughts of the great architects of contemporary natural sciences is all too often limited to that which is laid out in our textbooks and books on the history of sciences, and often does not even remotely resemble the rich thought of the original. With very rare exceptions, we barely find any portrayal of that intense struggle taking place between different schools of physics and the process which forged its basic principles and laws.

This collection of documents and materials takes up the task of acquainting the reader with the history of physics through its primary sources. This collection differs from similar collections existing in Western European literature which are often represented by a collection of short excerpts from the classics arranged in chronological order, above all by its selection and design of the material. Physical material is provided against the background of socio-economic relations of the corresponding age. Hence, we have included a larger selection of economic and technical material compared to customary histories of physics.

Special attention was paid to the portrayal of the struggle between different schools of thought; the selection of material was often made from this perspective. The struggle between schools of thought cannot be fully understood unless we analyze the nature of the ideological structure which took (and continues to take) place around physical categories. Therefore, considerable space was afforded to the ideological struggle around categories in mechanics, thereby depicting the struggle between materialist and idealist ideas in the physics of the seventeenth century.

This collection does not take up the task of providing a systematic depiction of the history of physics, but takes a number of themes which are often separated from each other by significant periods. This allows us to fully and comprehensively highlight specific moments in the historical development of science, their social and economic prerequisites and the twists and turns in the ideological struggle.

Of all the areas of physics, mechanics was the first to develop. It came to greater completion before others, and its influence has strongly affected the other areas of physics. In its origin and development, mechanics evolved and developed the most significant categories of physics.

Therefore, the first part of the collection is allotted to the emergence and the first stage of the development of classical mechanics. The second part will be dedicated to the laws of the conservation and the transformation of energy, the development of the theory of the electromagnetic field and the problem of the structure of matter.

Each of the three themes comprising the first part of the collection is prefaced by a short text, providing an overview of the material which comprises this theme and an exposition of the main ideas which this material should illustrate. Within each theme, the material is organized by sections, each of which is itself prefaced by a short introduction.

Each major original work includes annotations and bibliographical references. The introduction and annotations should make it easier for the reader to use the material. The collection of material was conceived and executed according to a precisely defined plan, the main principles of which are set out in the introduction to the theme. Hence, nearly all of the excerpts and documents are internally linked with each other and can be read in succession. For the reader interested in the separate articles, links are given in the text to supporting material which will aid their reading. These links allow us to reduce any explanatory notes, which the reader can substitute with original articles and documents.

A number of translations available in Russian and checked afresh with the originals were used for this collection. Unfortunately, the classics of natural science and especially physics were very rarely translated into Russian. Therefore, the majority of the material appears in Russian translation for the first time.

I wish to thank N. A. Isakovich, a colleague from the Institute of Physics of Moscow State University, who rendered invaluable assistance to me in the selection of material, the compilation of the index and the preparation of the volume for publication.

Boris Hessen

Socio-Economic Prerequisites for the Emergence of Classical Physics

CONTENT OF THE FIRST THEME[1]

The remarkable flourishing of the natural sciences in the sixteenth and seventeenth centuries is due to the break-up of feudal ownership, and the development of merchant capital, international maritime transport and heavy industry (mining and metallurgy). The area of physics which developed earlier than the others, and which reached the greatest development was mechanics. Although some knowledge on thermal, electrical and optical phenomena was available from late antiquity, mechanics was the area of physics which gained the most significance and was more widely developed since ancient times. While statics largely managed to acquire maturity in the works of Archimedes, ancient dynamics constituted, by comparison, a series of often groundless guesses. The authentic development of dynamics only came into its own in modern times.

Documents and materials gathered in the first theme are aimed at showing how the break-up of feudalism and the development of a new mode of production brought a number of new technical tasks into existence and presented physics with a series of issues predominantly of a dynamic character. This triggered the swift development of dynamics, which attained provisional perfection in the works of Galileo, Huygens and Newton.

The development of communications and transport, and of long-distance maritime travel, as well as the growth of the mining industry and the arms industry (which received a huge boost from the invention of firearms), raised a series of (*mainly mechanical*) problems for physics. This explains the fact that the seventeenth century was largely the century of the formation and development of classical mechanics. This does not mean, of course, that other sections of physics did not also develop. In this period, optics developed rather swiftly and was

1 Content of the First Topic
F. Engels, Old introduction to *Dialectics of Nature*
K. Marx and F. Engels, excerpt from the *German Ideology*.
Trade and Transport in the Sixteenth and Seventeenth Centuries.
Warfare and the Arms Industry in the Sixteenth and Seventeenth Centuries.
Development of the Iron and Steel Industry in the Seventeenth and Eighteenth Centuries
Engineers and Engineering in the Sixteenth to Eighteenth Centuries.
(Chronological Overview according to Feldhaus)

enriched by a series of significant discoveries. However, its situation cannot be compared with that of mechanics, which had a powerful impact not only on other sections of physics, but also on other natural scientific disciplines.

The documents reproduced below illustrate the set of those issues in physics which form the basis of those technical tasks that advanced the development of the productive forces of that age, and show why that great constellation of natural scientists, beginning with Galileo and ending with Newton, chose the problems of terrestrial and celestial mechanics as the main themes of their research.

TRADE AND TRANSPORT[2]

Trade already reached a high level of development at the beginning of the Middle Ages. However, overland transport routes were in a pitiful condition. Roads were so narrow that not even two horses could share the same stretch of road. The ideal road was one where three horses could pass side by side, where, in the expression of those times (fourteenth century), "a bride could drive past without hooking onto the cart with a corpse."

There is little wonder why goods were transported in packs. Road construction was almost completely absent. The insularity of the feudal economy gave no impetus to its development. On the contrary, both the feudal lords and the inhabitants of those locations where commercial transport took place had an interest in keeping road conditions poor. The feudal lord's interest in this poor condition was due to the system of *Grundruhrecht*, which gave him proprietary rights over everything which fell on his lands from a cart or pack.

The speed of overland transport in the fourteenth century did not exceed 5-7 miles per day. Naturally, maritime and waterway transport played a large role, given the greater cargo capacity of ships, as well as a result of their greater speed of movement: the largest two-wheeled cart with 10-12 oxen could barely hold two tons of goods, whereas a ship of average size could hold up to 600

2 The section comprises the following topics:
1. The development of trade and trade relations in the sixteenth and seventeenth centuries;
2. Transport in the feudal era and its successes in the sixteenth and seventeenth centuries;
3. The development of river transport. The successes of hydrostatics and its links with the development of the construction of canals and locks;
4. Shipbuilding;
5. The significance of issues of longitude for the development of celestial mechanics.

tons. In the fourteenth century, goods from Constantinople to Venice were three times more likely to travel by sea than by land. However, maritime transport in this age was also very imperfect: since there were no good methods for orienting a vessel on open seas, they sailed close to shore, which slowed the speed at which they could move. Although the first mention of the compass, which can be found in the Arab book *The Merchant's Treasury*, dates to 1242,[3] it was not universally used until the second half of the fourteenth century. One sees the emergence of geographical maritime maps at that time. But, the compass and maps could only be used effectively alongside the skill of properly navigating the seas; that is, by being able to determine latitude and longitude.

The developing capitalist mode of production broke down the medieval isolation of the city and rural community, remarkably expanding the geographical horizon and significantly accelerating the pace of life. It needed more convenient transport links, better means of communication, more precise measures of time and, in connection with the accelerating pace of exchange, more precise methods of calculation. Special attention was paid to water transport; that is, to maritime transport as a means of connection with other countries and river transport as a means of connection within the country. The development of river transport was also facilitated by the fact that since antiquity, water routes were the most convenient and studied routes. The natural growth of cities was also associated with the system of river transport. Transportation by river was three times cheaper than animal-drawn transport. Canal construction was also developed as a supplementary means of domestic transport and as a means of connecting maritime transport with the domestic system of rivers.[4]

3 [The described book is most likely the *Treasure of the Merchants on the Knowledge of Minerals,* written by Baylak Al-Qibjāqī, a Muslim scholar from Cairo (fl. *ca*. 1250). It is said that "Baylak was the first author writing in Arabic to treat the use of the magnetic needle as a ship's compass". *Treasure of the Merchants* is in fact a mineralogical work whose part on the magnetic needle has been translated into French by Klaproth, and then by Clément-Mullet. We are thankful to Razieh-Sadat Mousavi and Bohloul Hamid for this information.]

4 See Boris Hessen, "The Social and Economic Roots of Newton's *Principia*," in *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*, ed. Gideon Freudenthal & Peter McLaughlin and trans. Philippa Schimrat (Dordrecht: Springer, 2009) 45 – 46.

TRANSPORT IN THE FEUDAL AGE AND ITS SUCCESSES IN THE SIXTEENTH AND SEVENTEENTH CENTURIES

Transport routes in the feudal age were in a wretched condition. Kulischer provides a set of data on the condition of transport.

He mentions the state of bridges, back to the thirteenth century and earlier in Italy and France. Even though their construction was considered a charitable deed and grounds for receiving indulgences, they emerged in only insignificant numbers and only where it was impossible to wade across the river. Bridges were wooden, and often a cart could not pass by on them at all; they were not intended for wagons: *non carribus* [not for carts]. In Avignon in the twelfth century, a bridge of 900 meters was built in the course of ten years; on the Rhône in the thirteenth century, a bridge of 1,000 meters was completed in 30 years. In the Hanseatic Region, we find several bridges in the fourteenth century: chroniclers make special mention of those 'perfect' constructions of stone bridges built at huge expense and see them as an extraordinarily important phenomenon. But even the 'remarkable' stone bridge in the town of Minden was wrecked by drifting ice; in the Mosel Region, the only existing bridge until the mid-fourteenth century was the stone bridge built by the Romans. Only in Northern Italy, it seems, were there bridges in somewhat better condition.

Road improvement was not seen as in the interest of the people in those localities through which a path lay, for the worse the conditions of the road were, the more supplementary horses were needed, the more income this brought to farriers for mending of carts, horseshoes and also, the more travelers spent on products while they stopped there. For lords, it was more advantageous not to build roads and bridges, but to worsen their condition and even destroy them, for — apart from the fact that a bad road facilitated raids and pillage — according to the principle of "what falls from the cart is then lost" (*Grundruhrrecht*), anything which had fallen to the ground, if the cart was broken or was overturned when an animal fell, then became the property of the landowner. Merchants were advised that "when you go to the fair, take a cart with small wheels and ensure that you do not have to pay *Grundruhr*, otherwise all your profits will disappear."[5] The longer the journey lasted, the larger the income would accrue to the landlord and the convoy; that is, those riders accompanying those travelling for the protection of people and their property. Besides, the convoy was often a so-called 'dead' convoy, where everything was limited to the receipt of the payment

5 <Source unknown>.

of convoy money. These receipts were then a simple means of extortion: in no way did they protect travelers. On the contrary, the feudal lord's men attacked those who paid and robbed them; warring parties paid no attention to any letters of unhindered passage, even if they were issued by the Emperor himself.

Often, feudal lords intentionally damaged roads and put all kinds of obstructions and barriers in place — they built bridges on firm land and stretched chains across the river, in order to secure charges when the travelling merchants passed through the numerous customs posts. For this last purpose, *Strassenzwang* (*nemini licitum sit per villas circumire*)[6] was established; that is, the prohibition to replace once and for all the worst road with a better and more direct way. For example, a mandatory roundabout route was established through Poznan, Głogów etc. to get from Poland to the Leipzig fair, which was three times longer than the direct route. To prevent the bypassing of roads and customs, the feudal lords built high towers dominating the entire neighborhood, and even concluded alliances with each other for this purpose, mandating stopsin certain places, and stripping merchants who had infringed upon their regulations of all their goods. This was connected to thecountless number of customs posts: in the fourteenth century, there were 64 posts on the Rhein, 35 on the Elbe and 77 on the Danube in Lower Austria; there were 24 posts around Nuremburg and of these, ten were within three miles of the city. As a consequence of those customs posts, transport on the Rhein was highly constrained. According to Karl Lamprecht, between Bingen and Koblenz, customs duties in the Rhein comprised more than two thirds of the price of a good. Mathias Paris speaks of the "*Furiosa Teutonicorum insania*" (the insanity of the German expressed in customs posts) for good reason. Of course, the speed of transport in similar circumstances could not be great: in the course of a day, according to Getz, they travelled an average of 5-7 miles; in the Alps, this was only possible with a change of horses.

The conditions of transport led to the fact that trading transactions could only be carried out very slowly. We can discern this from the correspondence of Hildebrand Wekinhusen, recently published by Shtid. Sending a letter from Danzig to Bruges in the best-case scenario took ten days, from Lübeck to Bruges it sometimes took 31 and 48 days, and from Riga to Bruges between 39 and 52 days and sometimes even 73 days. Even the short distance between Bruges and Cologne required 6-8 days. There was still no proper postal communication

6 [No one is permitted to go around cities.]

system; merchants used the services of individuals who were sent as and when needed.

The poor conditions of roads in England remained unchanged for many years. Even in 1662 this situation had not changed in the slightest, and so a court ruling announced that riding on main roads was "very dangerous and almost impossible." Thomas Macaulay provides a vivid picture of the conditions of English roads.

> "It was by the highways that both travelers and goods generally passed from place to place; and those highways appear to have been far worse than might have been expected from the degree of wealth and civilization which the nation had even then attained. On the best lines of communication, the ruts were deep, the descents precipitous and the way often such as it was hardly possible to distinguish, in the dusk, from the unenclosed heath and fen which lay on both sides. Ralph Thorseby, the antiquary, was in danger of losing his way on the great North Road, between Barnby Moor and Tuxford, and actually lost his way between Doncaster and York. Pepys and his wife, travelling in their own coach, lost their way between Newbury and Reading. In the course of the same tour, they lost their way near Salisbury and were in danger of having to pass the night on the plain.
>
> "It was only in fine weather that the whole breadth of the road was available for wheeled vehicles. Often the mud lay deep on the right and the left; and only a narrow track of firm ground rose above the quagmire. At such times obstructions and quarrels were frequent, and the path was sometimes blocked up for a long time by carriers, neither of whom would break the way. It happened almost every day that coaches stuck fast, until a team of cattle could be procured from some neighbouring farm, to tug them out of the slough.
>
> "But in bad seasons, the traveller had to encounter inconveniences still more serious. Thoresby, who was in the habit of travelling between Leeds and the capital, has recorded, in his Diary, such a series of perils and disasters as might suffice for a journey to the Frozen Ocean or to the Desert of Sahara. On one occasion, he learned that the floods were out between Ware and London, that passengers had to swim for their lives, and that a higgler had perished in the attempt to cross. In consequence of these tidings, he turned out of the high road and was conducted across some meadows, where it was necessary for him to ride

to the saddle skirts in water. In the course of another journey, he narrowly escaped being swept away by an inundation of the Trent. Afterwards, he was detained at Stamford for four days, on account of the state of the roads, and then ventured to proceed only because fourteen members of the House of Commons, who were going up in a body to Parliament with guides and numerous attendants, took him into their company. On the roads of Derbyshire, travelers were in constant fear for their necks, and were frequently compelled to alight and lead their beasts. The great route through Wales to Holyhead was in such a state that in 1685, a viceroy, going to Ireland, was five hours in travelling fourteen miles from Saint Asaph to Conway. Between Conway and Beaumaris, he was forced to walk a great part of the way and his lady was carried in a litter. His coach was, with much difficulty and by the help of many hands, brought after him entire. In general, carriages were taken to pieces at Conway and borne, on the shoulders of stout Welsh peasants, to the Menai Straits. In some parts of Kent and Sussex, none but the strongest horses could, in winter, get through the bog, in which, at every step, they sank deep. The markets were often inaccessible during several months. It is said that the fruits of the earth were sometimes suffered to rot in one place, while in another place, distant only by a few miles, the supply fell far short of the demand. The wheeled carriages were, in this district, generally pulled by oxen. When Prince George of Denmark visited the stately mansion of Petworth in wet weather, he was six hours in going nine miles; and it was necessary that a body of sturdy hinds should be on each side of his coach, in order to prop it. Of the carriages which conveyed his retinue, several were upset and injured. A letter from one of the party has been preserved, in which the unfortunate courtier complains that during fourteen hours, he never once alighted, except when his coach was overturned or stuck fast in the mud...

“The expense of transmitting heavy goods in this way was enormous. From London to Birmingham, the charge was seven pounds a ton; from London to Exeter twelve pounds a ton. This was about fifteen pence a ton for every mile, more by a third than was afterwards charged on turnpike roads and fifteen times what is now demanded by railway companies. The cost of conveyance amounted to a prohibitory tax on many useful articles. Coal in particular was never seen except in the districts where it was produced, or in the districts to which it could be carried by sea, and was indeed always known in the south of England by the name of sea coal."[7]

Domestic trade developed much more slowly than did foreign trade. It was hindered by those bad conditions in which it took place.

Henri Sée describes the condition of France in that time as follows.

"The roads are far from sufficient. Of course, during the age of Henry IV, serious steps were made to improve them, the great 'Master of the Roads', Duke Sully was engaged in repairing roads and bridges, abandoned during the thirty years of civil turmoil. But in the age of Richelieu and Mazzarino [Mazarin], works on road restoration were mainly neglected so that at the start of the absolutist reign of Louis XIV, the bad state of the main roads was noticeable everywhere in the country. Jean-Baptiste Colbert is credited with organizing the management of roads and bridges for which the *intendants des provinces* (provincial administrators) were now given a decisive role. Important roads were built. But towards the end of Louis XIV's reign, the decline of roads is once again noted (these were common complaints in the internal reports of the intendants for 1681[)]. Apart from this, nothing had been done to improve country roads.

When this was at all possible, it was preferred to use river transport, a far cheaper route. Therefore, navigation of the most important rivers was improved. The digging of canals was also undertaken on a large scale. The Briare Canal was begun in 1605, but work on it was abandoned between 1610 and 1638 and was completed in 1642; the Languedoc Canal, planned by Riquet and which was to connect the Atlantic Ocean with the Mediterranean Sea, was dug between 1665 and 1681. Colbert considered a number of other canal projects, but during the reign of Louis XIV, only those connecting Saint-Omer with Calais and the Loire with the Loing (a tributary of the Seine) through Montargis were dug.

Overland transport was still very primitive. Public postal carriages moved very slowly. From Paris to Orleans they took two days, to Lyon ten days, to Strasbourg 11, to Lille four days and to Calais five days. Road carriages

7 Thomas B. Macaulay, *The History of England from the Accession of James II, vol. 1* (Chicago: Donohue, Henneberry & Co., 1890), 339 – 341, 342.

were initially open carriages and were only equipped with leather curtains later to be replaced by wooden panels. As far as animal-drawn transportation was concerned, two or four-wheel carts were used which spent, for example, four days to travel between Orleans and Paris. However, there was considerable progress in the postal service which was reorganized first under Henry IV and then under Richelieu, and then further improved under Louis XIV. In 1672, new tariffs were established for the carriage of letters: a simple letter sent at a distance of fewer than 25 leagues cost 2 sous; at a distance of more than 80 leagues, the cost increased to 5 sous. The circulation of letters grew noticeably. In 1673, postal revenues comprised of 1,200,000 livres; in 1713, this reached the sum of 3,100,000 livres. As for the transportation of goods, its organization was still very imperfect."[8]

However, according to information from Kulischer, the successes in the field of overland transportation were, nonetheless, very significant. The invention of the 'fifth wheel' — an element, allowing the front of the cart to turn autonomously of its entire body — at the end of the sixteenth and beginning of the seventeenth century allowed the construction of a great variety of complex forms of coach. If at the end of the Middle Ages it was possible to travel at an average of no more than five miles a day, rarely 6-7 miles, then in the seventeenth and eighteenth centuries in England, the speed of not very bulky goods consisted of 7-8 miles a day, while in Germany they reached speeds of 9-10 miles with a change of horses. Thus, even compared to the sixteenth century, the speed of transport in the seventeenth century increased: from Strasbourg to Augsburg the transportation of goods in 1590 took 8 days, whereas it took 5 days in 1690; from Magdeburg to Hamburg it took 6 days in 1560, and 100 years later, it took 3-4 days. In France, a five-horse cart with a load of 6,000 pounds (lbs) could travel 8 miles a day, 9 even with a large quantity of horses and on good roads. But most drivers had only four horses and had to negotiate difficult road conditions, so 7 miles was considered sufficient and normal; from Paris to Lyon, the distance of 95 miles was completed in 12-15 days (in the winter it took even longer). All central pointshad many coaching inns, which contained horses; periodically, once or twice a week, an entire column of carriages was moved — carts drawn by four or eight horses loaded with 3-6 tons of goods.

8 Henri Sée, *L'Évolution commerciale et industrielle de la France sous l'ancien régime* (Paris: Marcel Giard, 1925), 91 – 93.

THE DEVELOPMENT OF RIVER TRANSPORT. SUCCESSES OF HYDROSTATICS IN CONNECTION WITH THE CONSTRUCTION OF CANALS AND LOCKS

Domestic waterways played a large role as a means of communication. Already in the fifteenth century, locks--at first, stone and then in the form of bridges--became a common phenomenon in the Italy of the fifteenth Century and had already been 'long in use' in the age of Leonardo Da Vinci.

According to data in Sombart, there were 9 orders for the improvement of rivers in the sixteenth century, 24 in the seventeenth century and 36 in the eighteenth century. Already by 1624, for example, the Thames became navigable to Oxford with the aim of transporting Oxford building stone to London, as well as coal and other necessary things to Oxford, which were then transported at a very high price ... navigable rivers were improved and another six were made navigable.

Bernstein-Kogan gives a brief survey of the development of domestic waterways in Europe.

> It is beyond question that the lock canal was introduced in France in the sixteenth century, and that from that period, the process of river canalization and the construction of genuine canals began. We know of the existence of lock canals in France from 1515. The first canal with locks was built in 1528. This is the so-called Canal de l'Ourcq on the river Marne, close to Paris.
> In 1538, work began on the canalization of the river Vilaine in the current department of the Lower Loire. The plan for thislock, completed only in 1575, was attributed to Leonardo da Vinci. At the same time, the canalization of the river Lot (a tributary of the Garonne) was carried out, replacing the primitive structures that were there previously. During the era of the Duke of Sully, the construction of the Briare Canal (connecting the Haute Loire with the basin of the Seine) and was 59 km in length. It was completed only in 1642. The seventeenth century is known for the construction of a grandiose structure for its time like the Canal du Midi which connects the Mediterranean Sea with the Bay of Biscay through the Garonne. The construction of this canal, 279 km long, was completed under Louis XIV in 1684. "[T]here is nothing more useful and profitable for the people, than navigation along rivers", Colbert wrote at the end of his life. In the same era, the Canal d'Orleans was completed (1679), with a length of 74 km and which supplemented the connection of the

Loire with the Seine through the Briare Canal, and the Neufosse Canal, 18km long, in the north around Lille was begun (1682). In the eighteenth century the following canals were built: the Canal du Loing (1719), 50 km long; the Saint Quentincanal (1732) with a length of 98 km, which was then linked to the Somme (1769), the Canal du Centre, 130 km long (begun in 1783), the Canal du Bourgogne (242 km, begun in the same year) and the canal in Franche-Comté Canal (now it is part of the canal between the Rhine and the Rhone). Construction of a canal in the Nivernais was begun (178 km). The Canal du Bourgogne connected the Seine with Rhône through the Seine and the Doubs, and the Nivernais Canal — where the upper reaches of the Loire with the Yonne, and, consequently, with the Seine again. The Saint Quentincanal opened access from the Seine through the Oise to the Flanders water network (through the Scheldt). Towards the end of the eighteenth century, the general length of canals in France consisted of around 1,000 km.[9]

The first attempts to improve the conditions of river navigation were made very early on in Germany, at the beginning of the fourteenth century. One can indicate a few cases of work on the construction of waterways (apart from the Stecknitz Canal, built between 1390 and 1398, and the Kraffohlkanal[10] completed in 1495). But, the first significant structures emerged in Germany at the start of the seventeenth century in the boundaries of the growing and developing Brandenburg. Above all, we mean the Finow Canal, which was begun in 1603 in the reign of Albrecht Achilles [of Brandenburg] and for the first time connected the basins of the Oder and the Elbe (through the Havel), and then the Müllroser Canal, which wasconstructed during the reign of the 'Great Electoral Prince' [Friedrich Wilhelm, der Große Kurfürst] between 1661 and 1668, and connected the Oder with the Spree. By 1668, there were 185.5km of canals and 329.7km of lock canalswith 72 locks.

In England, the need for the development of transport routes was provoked by the start of the industrial revolution in the second half of the eighteenth century. Until the beginning of the eighteenth century in England, the development of domestic waterways only went as far as the canalization of rivers. From the beginning of the fifteenth Century and until the end of the first half of the

9 <Page unknown>. Сергей В. Бернштейн-Коган [Sergei V. Bernstein-Kogan], *Очерк развития и современного состояния внутреннего водного транспорта в главнейших странах Западной Европы и в Северной Америке, В. I – II* (Санкт-Петербург, 1912 – 1913), ?.

10 [Today, Kanał Jagielloński]

eighteenth century, one can identify 21 cases in which permission was granted for the canalization of rivers, which in most cases was conducted by private entities. The most significant projects of this kind date to the first half of the eighteenth century.

The construction of canals and locks required knowledge of the basic laws of hydrostatics, i.e. the laws of liquid flow, since it was necessary to be able to calculate water pressure and the rate of its discharge. In 1598, Simon Stevin studied the issue of water pressure and he already saw how water can have a pressure greater than its weight on a vessel; in 1642, Castelli published a special treatise on the movement of water in canals depending on its section; in 1646, Torricelli studied the theory of fluid dynamics.

Leonardo Olschki has provided information about Galileo's work in this sphere. The school of Galileo issued Castelli's treatise on hydraulics, which emerged from Galileo's direct observations. They named it the "Golden Book." The great discoveries of Torricelli eclipsed this work, but its historical significance was even greater, for along with it, the mechanics of liquids entered the field of physical laws, for the sake of which the empirical sciences had fought so stubbornly and unavailingly for two centuries. It is the first testimony to the successes of the Galilean approach to nature and a document of the dependence of the latter on the questions and needs of the time. The greatest service that Castelli paid to scientific and practical hydraulics lay in the first principle of the dependence of the speed of the movement of water in rivers and canals on their width and height. As soon as Castelli's book appeared, Galileo had the opportunity to prove, with the aid of new methods of hydrodynamics, the enormous practical use of this science and thus publicly sanctified the new school of thought (in terms of its) technical tasks. While he corresponded with Castelli on its principles, the Tuscan government decided to canalize the Arno and its tributary, the Bisenzio, as their frequent overflowing persistently brought misery, and the danger of waterlogging of vast areas of fertile land became ever more threatening. This was a calamity that especially threatened the Florentine region and historians of the city wrote about when the damage exceeded the norm.

Whereas they had already set about controlling the flow of rivers in Lombardy long ago, in Tuscany they embarked on merely incidental works that lacked any broad outlook. Now, the Grand Duchy resolved to remedy this state of affairs and instructed its engineers to compose a plan for the control of both rivers. At the end of 1630, the preparatory work had progressed so much that Galileo, as court mathematician, was entrusted with providing feedback on the planned enterprise.

It seems that such tasks became particularly relevant in those years. Indeed, Galileo received a request from one of his most gifted students regarding the regulation of the flow of the river Arbia in the province of Siena; the Genoese patrician Baliani, who was already in correspondence with Castelli on the principles of hydrodynamics, turned to Galileo with a plan for the supply of water to his native city. Two young friends of our scientist, Andrea and Niccolò Arrighetti, both of whom were members of the Florentine Academy of Language [*Accademia della Crusca*] and respected scientists and politicians in Florence, carried long and passionate disputes about the principles of his mechanics and the possibilities of applying them to water facilities. Soon after, Galileo surveyed the project of the canalization of the Arno proposed by Sigismondo Coccapani, who was a respected painter and architect at the time. This was the same artist who proposed many projects for the façade of the Florentine Cathedral which Galileo was asked to judge along with the projects of other participants in the artistic competition. At the same time, the Bologna Inspector General for water structures, Cesare Marsili, with whom Galileo had been in lively correspondence over scientific issues and personal matters, enthusiastically greeted the publication of the small work on hydrodynamics and used it as the basis of the project to canalize the Reno. In Rome, this book was literally torn from Castelli's hands.

THE IMPORTANCE OF DETERMINING LONGITUDE FOR THE DEVELOPMENT OF CELESTIAL MECHANICS. THE DEFINITION OF LONGITUDE IN CONNECTION WITH THE DEVELOPMENT OF MARITIME TRANSPORT

The question of defining longitude on the high seas was one of the main questions that determined the fate of navigation. Brewster cites the history of this problem which played a huge role in stimulating the development of celestial mechanics.

> **"The great problem of the determination of the longitude at sea, to which the discoveries of Newton so greatly contributed, had begun, at this time, to attract the notice of English mathematicians. At an earlier period indeed, the subject was brought before the leading members of the Royal Society under very unique circumstances. Towards the close of 1674, Le Sieur de St. Pierre, a French charlatan, who commanded the interest of the Duchess of Portsmouth, had procured from the King a commission for examining a scheme for the discovery of the longitude.**

This commission, among other names, included those of Lord Brounck-er, Dr. Ward, Sir Christopher Wren, Sir Jonas Moore, and Dr. Hook. In February 1675, Flamsteed was on a visit to Sir Jonas Moore, and having accompanied him to a meeting of the commissioners, his name was added to their list. By his assistance the ignorance and presumption of the Frenchman were soon exposed; and the result, though mortifying to his patrons at court, proved highly advantageous to the interests of astronomy. Flamsteed had written a letter to the commissioners, and another to St. Pierre, explanatory of his views, and thus describes the origin of the Royal Observatory of Greenwich: "I heard," he says, "no more of the Frenchman after this; but was told that my letters being shown King Charles II, he, startled at the assertion of the fixed stars' places being false in the catalogue, (of Tycho,) and said with some vehemence, 'he must have them anew observed, examined, and corrected, for the use of his seamen;' and further, (when it was urged to him how necessary it was to have a good stock of observations taken for correcting the motions of the moon and planets,) with the same earnestness, 'he must have it done.' And when he was asked who could or who should do it? 'The person,' says he, 'that informs you of them.' Whereupon I was appointed to it." In the royal warrant for the payment of Flamsteed's salary, the astronomical observator, as he was then called, was commanded "to apply himself forthwith, with the utmost care and diligence, to rectify the tables of the motions of the heavens, and the places of the fixed stars, so as to find out the so much desired longitude of places for the perfecting the art of navigation."

No further steps seem to have been taken in this important matter till the 25th of May 1714, when several captains of her Majesty's ships, merchants of London, and commanders of merchantmen, presented a petition to the House of Commons, setting forth "that the discovery of longitude is of such consequence to Great Britain, for safety of the navy, for merchant ships, as well as of improvement of trade, that for want thereof many ships have been retarded in their voyages, and many lost; but if due encouragement were proposed by the public, for such as shall discover the same, some persons would offer themselves to prove the same before the most proper judges, in order to their entire satisfaction, for the safety of men's lives, her Majesty's navy, the increase of trade, and the shipping of these islands, and the lasting honor of the British nation." This sagacious petition, which proved to be a grand step in the advancement of astronomy, was submitted to a large committee, whose report was laid on the table of the House on the 7th of June, and taken into consideration on the 11th. The following is the report and resolution of the committee, which, as we shall see, forms an important event in the life of Newton.

> "Mr. Ditton and Mr. Whiston being examined, did inform the committee that they had made a discovery of the longitude, and were very certain that the same was true in the theory, and did not doubt but that, upon due trial made, it would prove certain and practicable at sea.
> "That they had communicated the whole history of their proceedings towards the said discovery to Sir Isaac Newton, Dr. Clarke, Mr. Halley, and Mr. Cotes, who all seemed to allow of the truth of the proposition as to the theory, but doubted of several difficulties that would arise in the practice."

Sir Isaac Newton, who attended the committee, said,

> "That for determining the longitude at sea there have been several projects, true in theory, but difficult to execute.
> "1. One is by a watch to keep time exactly; but, by reason of the motion of the ship, the variation of heat and cold, wet and dry, and the difference of gravity in different latitudes, such a watch hath not yet been made.
> "2. Another is by the eclipses of Jupiter's satellites; but, by reason of the length of telescopes requisite to observe them, and the motion of a ship at sea, those eclipses cannot yet be there observed.
> "3. A third is by the place of the moon; but her theory is not yet exact enough for that purpose. It is exact enough to determine the longitude within two or three degrees, but not within a degree.
> "4. A fourth is Mr. Ditton's project: And this is rather for keeping an account of the longitude at sea, than for finding it, if at any time it should be lost, as it may easily be in cloudy weather. How far this is practicable, and with what charge, they that are skilled in sea affairs are best able to judge. In sailing by this method, whenever they are to pass over very deep seas, they must sail due east or west, without varying their latitude; and if their way over such a sea doth not lie due east or west, they must first sail into the latitude of the next place to which they are going beyond it, and then keep due east or west, till they come at that place.
> "In the three first ways there must be a watch regulated by a spring, and

rectified every visible sunrise and sunset, to tell the hour of the day or night. In the fourth way such a watch is not necessary. In the first way there must be two watches, this and the other above-mentioned.

"In any of the three first ways, it may be of some service to find the longitude within a degree, and of much more service to find it within forty minutes, or half a degree if it may, and the success may deserve rewards accordingly.

"In the fourth way, it is easier to enable seamen to know their distance and bearing from the shore, forty, sixty, or eighty miles off, than to cross the seas; and some part of the reward may be given, when the first is performed on the coast of Great Britain, for the safety of ships coming home; and the rest, when seamen shall be enabled to sail to an assigned remote harbour without losing their longitude if it may be.

"Dr. Clarke said that there could no discredit arise to the Government in promising a reward in general, without respect to any particular project, to such person or persons who should discover the longitude at sea.

"Mr. Halley said, that Mr. Ditton's method for finding the longitude did seem to him to consist of many particulars which first ought to be experimented before he could give his opinion; and that it would cost a considerable sum to make the experiments, but what the expense would amount to he could not tell.

"Mr. Whiston affirmed that the undoubted benefit which would arise in the land, and near the shore, would vastly surmount the charges of experiments.

"Mr. Cotes said that the project was right in the theory near the shore, and the practical part ought to be experimented.

"And, upon the whole, the committee came to these resolutions: 'That it is the opinion of this committee that a reward be settled by Parliament upon such person or persons as shall discover a more certain and practicable method of ascertaining the longitude, than any yet in practice; and the said reward be proportioned to the degree of exactness to which the said method shall reach.'"

The House adopted this resolution unanimously.

This important bill, which, as predicted by British captains and merchants, has in various ways contributed "to the lasting honour of the British nation," contributes in no slight degree to the honour of Newton. Had the evidence of the different witnesses in Parliament been recorded without their names, it would not have required the sagacity of Bernoulli to have discovered the testimony of Newton, — the “lion from his claw.” The most distinguished of his successors, with all the lights of a century and a half, could not have stated more correctly the true and the only methods of finding the longitude at sea. The method by chronometers has been brought to the highest perfection, and is doubtless the most correct and infallible. The method “by the place of the moon,” has, by means of his own lunar theory, perfected by his successors, become second only to that of the watch.

So as early as 1696, a report was spread among the members of the Royal Society that Newton was occupied with the problem of finding longitude at sea; but as the report had no foundation, he requested Halley to inform the members “that he was not about it.” Long after this, however, he directed his attention to the invention of an instrument for determining longitude by the position of the moon; and, in the year 1700, he communicated to Dr. Halley the description of a reflecting sextant for observing the distance from the moon from the fixed stars at sea.

After Newton’s death, the problem of finding longitude at sea became a subject of general interest throughout Europe. Various acts related to it were passed in England. In 1726, our countryman, John Harrison, produced a timepiece of singular accuracy, and after many trials, during one which it gave the longitude within 10' 45" of accuracy, he was granted £10,000; half the reward was offered in Queen Anne’s Act and the other half was promised when he or someone else should make an equally good timepiece, upon the same principle. Mr. Kendal, who was appointed to make such a watch by the Board, succeeded so completely, that after it had been around the world with Captain Cook in the years 1772-1775, Mr. Harrison was given the second £10,000. In order to further encourage inventions for the discovery of longitude, a new act was passed in 1774, which offered a reward of £5,000 for a chronometer or timepiece that would determine the longitude within a degree, or sixty geographical miles; — of £7,000 for determining it within two-thirds of a degree, or forty miles; and £10,000 for determining it within half a degree, or thirty miles. The very same rewards were offered for any other method by which the same accuracy was obtained; and a special reward of £5,000 was promised to the author of such solar and lunar tables that were sufficiently exact to show the distance of the moon from the sun and stars, within fifteen seconds of a degree,

> **«*such tables were constructed entirely upon the principles of gravitation laid down by Sir Isaac Newton*, except with respect to those elements which must necessarily be taken from astronomical observations.”**

Based on this Act, the widow of Tobias Mayer received £3,000 for his lunar tables, and Euler received £300 for the theorems on which they were founded.

The Board of Longitude in France [*Beaureau des Longitudes*], which was established to promote the same objective as the English Board, rewarded Euler for the new tables that he published in 1771. During the rest of the eighteenth century, and the first quarter of the nineteenth century, these two Boards tried to promote all those scientific objects which were designed to improve the instruments and methods for determining longitude at sea. The French Board, which was composed of the most distinguished astronomers in France, existed in all its original activity and utility; but, the British Board was abolished in 1828, as if we had ceased to be a maritime nation — it was the only scientific Board in the kingdom which afforded salaries for scientific men.[11]

The methods for determining longitude which were provided by celestial mechanics, for example, the movement of the moon, were insufficiently satisfactory; therefore, scientists did not cease researching and looking for more reliable means of determining longitude. A reliable means for determining longitude was discovered in the pendulum clock, which was invented and researched by Huygens. Thus, this issue influenced not only the development of celestial mechanics, but also more general research into mechanics, because Huygens' treatise on the pendulum clock provides a solution to the most significant mechanical tasks (See Theme 2 below).

Huygens himself points to the significance of the issue of determining longitude for the development of his research in mechanics.

The first clocks on ships which served to determine longitude were to be found on the English merchant ship. One Scottish seafarer, who sailed at the head of a flotilla of three ships from Guinea to the Islands of St. Thomas, located near the Equator, tells of how he, setting the clocks clockwise, sailed 700 miles back and once again set offto the shores of Africa. Having sailed in this direction for 200-300 miles, he changed his course and headed for the island of Barbados. The calculations of the distance they had to travel were different for the captains of the two different vessels from those of the owner of the pendulum clock: one calculated 80 miles, another 100 and a third an even greater distance. By his clock, he concluded that it was a maximum of 30 miles to the Cape Verde islands, and he was proven right.

11 Sir David Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton, vol. 2* (Edinburgh: Thomas Constable and Co.; London: Hamilton, Adams, and Co., 1860), 257 – 265.

At that time, Holland and France also carried out experiments to check the accuracy of determining longitude with the aid of the pendulum clock. The Duke of Belfort commissioned his astronomer to carry out observations during his journey to Crete. He determined the longitude of all those places where they went ashore, through which they passed and the longitudes which they did not know precisely, and they always found that the difference in longitude corresponded to the difference calculated on their best maps. For example, the difference in longitude between the port of Toulon and the city of Candia (Heraklion) was determined at 1 hour 22 m., that is 20°30', and on the return journey this distance was again determined, and the same result was obtained, thus indicating the precision of the calculation.

> **" [...] One cannot consider the ordinary pendulum a trusted and precise measure of time, because large swings require a longer time, than lesser swings; however, I discovered with the help of geometry a previously unknown means of pendulum suspension: I investigated the curvature of a curve, which, remarkably, fittingly provides its movement with the desired regularity.**
> **After I applied this method of suspension to the clock, its movement became so regular and precise, that after innumerable tests on land and on water it became clear that these clocks could serve astronomy and navigation with extreme precision."**[12]

The development of trade relations posed the following technical problems for transport:

1. *Increasing the capacity and speed of the vessel.*
2. *Improving the floating aspects of the vessel:* its stability, its maintaining a fair speed, low magnitude of oscillationgood steering and ability to maneuver; something particularly important for military vessels.
3. *Convenient and reliable ways of orienting in the sea:* a means of determining latitude and longitude, magnetic variation and the times of high and low tides.
4. *Improvement of the domestic water systems and connection with the sea*: the construction of canals and locks.

12 Christiaan Huygens, *Horologium oscillatorium: Sive de Motu Pendulorum ad Horologia Aptato Demonstrationes Geometricae* (Paris: Apud F. Muguet, 1673), 1 – 2.

Let us sort out what physical preconditions were necessary for resolving these technical problems.

1. To increase the carrying capacity of a vessel, knowledge of the basic laws of navigation of bodies in liquid since to calculate carrying capacity one needs to know how to calculate the displacement of vessels. This is a problem of hydrostatics.
2. To improve the floating features of the vessel it is necessary to know the laws of motion of bodies in liquid. This is a particular form of the problem of the laws of motion of bodies in a resistant medium — one of the main tasks of hydrodynamics. The problem of the vessels stability and the periodicity of its oscillationis one of the basic tasksof themechanics of materialpoints.
3. The problem of determining longitude is reduced to the observation of celestial bodies and requires the existence of optic instruments, as well as knowledge of the maps of celestial bodies and their movement for its resolution. The problem of determining longitude can be most easily and simply resolved with the existence of the chronometer. But since a reliable chronometer was only invented in the 1730s after the publication of the works of Huygens, then the measurements of the distance of the moon from the immobile stars could be used to determine longitude. All of this is the task of celestial mechanics.
4. The construction of canals and locks requires knowledge of the basic laws of hydrodynamics, and the laws of liquid flow since it is necessary to know how to calculate water pressure and its rate of discharge.

As one can see, the problem of the construction of canals and locks led to a focus on hydrostatics and hydrodynamics in mechanics.[13]

MILITARY AFFAIRS AND THE ARMS INDUSTRY[14]

The formation and growth of powerful states and their competition in foreign markets as well as in colonial countries led to a number of serious military conflicts, especially to naval wars (cf. *Marx*, the excerpt above from "German ideology", pp. 33 and ff.)

13 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 46 – 47.

14 1. From the history of military affairs in the sixteenth and seventeenth centuries.
2. Theoretical research into military affairs.

Military affairs and military equipment reached great heights of development and had a tremendous influence on the development of a number of problems in physics, primarily connected with problems of ballistics.

THEORETICAL RESEARCH IN MILITARY AFFAIRS

The development of military affairs confronted scientists with a number of technical problems. Galileo paid a great deal of attention to them. Below, we cite some data on work in this field by Olschki.

Galileo followed the same path (as did his teacher, Ricci), until he devoted himself entirely to the scientific problems posed by the theory of constructing fortresses and firearms.

This can be seen from his invention of the military geometric compass around which his first public polemic ensued. Galileo defended his rights as an inventor. The fruits of his specific technical training are both surviving treatises on the art of constructing fortresses, which clearly show the influence of Florentine methods and theories on Galileo. In them, we find, among other things, Dürer's method for constructing a pentagon which Florentine mathematics teachers learned for practical purposes and which was also taught by Ostilio Ricci, alongside the Euclidean methods in his treatises.

His intention to write several books for soldiers in order to acquaint them with the theory and also to communicate precise knowledge to them of all mathematical issues deserving their attention (for example, the technique for digging trenches, combat formation, the building of fortifications, topographical surveys, artillery, the use of various instruments, etc.) showed how strongly he was affected by the details of his youth education. If this was his intention and did not acquire a literary and systematic realization, other indications attest to the existence of a continuous connection between the thought and work of Galileo in his mature years with his first youthful impressions and pursuits, and also with the traditions of the artists and engineers of the Renaissance. In the same year, when Galileo proposed these plans to the Florentine court, he outlined a curriculum for the newly founded Academy, which was to train the military. Galileo demanded

> **"knowledge of arithmetic, geometry and solid geometry, the mechanical sciences in their widely differing applications, artillery sciences along with knowledge of the many different circumstances in this field, knowledge of the compass and other instruments for drafting plans, the**

measurement of distances, heights and depths and furthermore — the rules of perspective in order to correctly portray any real or fictitious object, like, for example, fortifications and their sections or of any kind of military machines, and, finally, knowledge of military architecture."[15]

Nowhere could Galileo have indicated more clearly, directly and persuasively the path of his scientific development than here, in the introduction to his last work, in which he constantly upholds his perpetual connection between empirical practice and natural scientific theory. But it was characteristic for Galileo from the very beginning, in this persistent combination of theoretical and practical interests, to give precedent to theoretical issues over technical ones. Galileo's scientific research differed from the works of his predecessors and contemporaries, who posed analogous questions and resolved them in an amateurish and random fashion. The problems of the maximal conservation of energy and the efficiency of machines, the precision of gunfire, the resistance of fortifications; these were the same questions which had already been discussed in the technical literature for two centuries. But when Galileo approached the work done in the workshops, with which he was only acquainted thanks to his teacher primarily as a place for experiments and observations, these were to lead, above all, to the establishment of the theoretical foundations of the mechanical arts. Therefore, his formulation of these questions is fundamentally different, and their solution does not depend on any tradition of workshops and theorists, although his attention was constantly directed to the practical application of learning which had been established theoretically and experimentally.

The mathematical education which he received relatively late in his youth remained Galileo's starting point (due to his studies in both pure and applied mathematics and mechanics), insofar as it introduced him into the theoretical literature of his time; doubt about the accuracy of traditional physical concepts was combined with criticism of purely technical experience. Thanks to Ricci's teaching, Galileo was able to understand this literature, which would not have been so easily accessible to him without knowledge of the practical questions of mechanics. This is confirmed by the choice of problems that became the themes of Galileo's first works.

In the following excerpt from *Discorsi*, Galileo talks about the importance of weapons production for the development of scientific research.

15 Leonardo Olschki, *Geschichte der Wissenschaftlichen Neusprachlichen Literatur, T. 3: Galilei und Seine Zeit* (Halle: Max Niemeyer Verlag, 1927), 154.

“SALVIATI. The constant activity which you Venetians display in your famous arsenal suggests to the studious mind a large field for investigation, especially that part of the work which involves mechanics; for in this department, all types of instruments and machines are constantly being constructed by many artisans, among whom there must be some who, partly by inherited experience and partly by their own observations, have become highly expert and clever in explanation.
SAGREDO. You are quite right. Indeed, I myself, being curious by nature, frequently visit this place for the mere pleasure of observing the work of those who, on account of their superiority over other artisans, we call “first rank men.” Conference with them has often helped me in the investigation of certain effects including not only those which are striking, but also those which are recondite and almost incredible.”[16]

In 1607, the Venetian republic chose Pietro Duodo as the commander of troops in Padua. Soon after taking office, Duodo decided to establish a military academy, where noble Paduans who were training in gymnastics and fencing could take a course in the sciences, which were in some way or another related to military affairs. Therefore, the college’s statute (named the *Academia Delia*) required that there be a course “in serious subjects, mainly from the field of mathematics.”

The management of the academy only undertook to effectively implement this regulation at the beginning of 1610. In the correspondence which they conducted regarding this, a short note by Galileo has been preserved; the manuscript has been kept in the file on the Academy at the communal archive in Padua. The note is not signed with the author’s name, but the handwriting so clearly belongs to Galileo that there can be no doubting the authenticity of this document. There is a note written in Duodo’s hand with the phrase: “Memory aid for mathematics teachers.” It is not clear whether Galileo wrote this note due to prompting by Duodo, who had wanted to receive information from him on those mathematical topics which a soldier needed to know, or if he was presenting a study program which he would have conducted if he were chosen to teach there.

The development of military affairs poses the following technical issues:

16 Galileo Galilei, *Dialogues Concerning Two New Sciences*, trans. Henry Crew & Alfonso de Salvio (New York: Dover Publications, Inc., 1954), 1

Internal ballistics

1. The study of processes occurring in weapons when being fired, and their improvement.
2. The strength of a weapon at its lowest weight.
3. Features for convenient and good aim

External ballistics

1. The trajectory of a projectile in the void.
2. The trajectory of a projectile in the air.
3. The correlation of air resistance to the speed of a projectile.
4. The deviation of the trajectory of a projectile.

The physical bases of these technical problems are as follows:

1. The study of the processes occurring in the instrument requires the study of the process of the compression and expansion of gases — basically a mechanical task, as well as the study of the phenomenon of delivery (the law of action and reaction).
2. The strength of the weapon poses a problem for studying the resistance of materials and testing their strength. This problem, which is of great importance for the art of construction at this stage of development, is solved by purely mechanical means.
3. The problem of projectile trajectory in the void comes down to solving the problem of the free fall of bodies under the influence of gravity and the composition of translatory motion with free fall.
4. Regarding the flight of a projectile in the air, there is the particular form of the motion of bodies in a resistant medium and of the dependence of resistance on speed.
5. The deviation of the projectile from the calculated trajectory can occur due to changes in the initial velocity of the projectile, changes in atmospheric density and the influence of rotations of the earth. All of these are purely mechanical problems.
6. Tables for aiming can be correctly composed by solving the problem of external ballistics and a general theory of projectile trajectory in a resistant medium.

Thus, we see that if we set aside the process of producing weapons and projectiles, which is the task of metallurgy, the main problems posed by the artillery of that period are at their core of the problem of mechanics.[17]

17 See Hessen, “The Social and Economic Roots of Newton’s *Principia*,” 51 – 52.

THE DEVELOPMENT OF MINING AND IRON AND STEEL METALLURGY IN THE SIXTEENTH AND SEVENTEENTH CENTURIES

The Influence of this Development on the Formulation of Scientific Problems:

By the end of the Middle Ages (fourteenth-fifteenth centuries), the mining industry had already developed into a major industry. The growth of the circulation of money motivated the extraction of silver and gold. If "the discovery of America was due to the thirst for gold [...] because the enormously expansive European industry of the fourteenth and fifteenth centuries and the trade corresponding to it demanded more tools of exchange", then, on the other hand, the demand for gold forced them to pay special attention to the operation of pits and of gold and silver mines.

The rapidly growing arms industry, which had made great strides since the invention of firearms and the introduction of heavy artillery, was a significant impetus for the extraction of iron and copper. Already by 1350, firearms had become common for the armies of Eastern, Southern and Central Europe. In the fifteenth century, heavy artillery reached a rather high level of perfection. In the sixteenth and seventeenth centuries, the arms industry made great demands on the metallurgical industry. In March and April 1652 alone, Cromwell needed 335 cannons, while in December, he required another 1,500 weapons, weighing 2,230 Tons, and an additional 117,000 shells and 5,000 hand-made bombs.

Clearly, therefore, the problem of the most effective use of mines loomed large. Above all, it posed the issue of deep cast mining. But the deeper the mines became, the more difficult and dangerous it was to work in them. A number of devices were required for pumping water from the ventilation shafts and lifting ore to the surface. Moreover, it became necessary to lay the mines and to navigate them.

Already at the beginning of the sixteenth century, mining reached an impressive level of development. Agricola left a detailed encyclopedia of mining, from which one can see the many technical devicesadopted therein. Pumps and hoisting devices (winches, horizontal screws) were developedfor lifting iron ore and water. The mining industry was already a complex organism in the sixteenth century, which demanded a significant amount of knowledge for its organization and administration. Therefore, it immediately grew into a major industry, unencumbered by any guild system and thus devoid of the typical inertia of the latter. Technically, it generated the most progressive and significant revolutionary elements of the medieval working class: the miners. Laying tunnels required extensive knowledge of geometry and trigonometry. Scientist-engineers were already working in the mines by the fifteenth century.[18]

In his *Sarepta*, a collection of sermons given in Joachimstal between 1553-1562, the pastor Mathesius, a preacher in Joachimstal between 1553-1562, gives a lively and succinct description of all devices used in mining. He speaks about the compass in these phrases:

> **"These are great instruments worthy of praise and gratitude. For they lead not only travelers on land and seafarers on the high seas, but also for you, miners, located underground, they indicate which way the passages lead to and where you should go."**[19]

From this, we can conclude that mines were already extremely complex. It is easy to get lost there. A compass is much-needed during the installation of ventilation for new paths, the determination of the mine's definition, borders and so on.

> **"It is especially necessary in the noble art of the surveyor, without which it is impossible to do anything in mining, wanting to work for the benefit of the owner of the mine, wanting to correctly set the direction of workings for their connection, to delay the flow of water, to direct a jet of air on the workings, to protect themselves from invasion from adjacent mines and so on. Surveying students were to diligently study Euclidean and basic geometry, learn the techniques of measurement, study the mechanisms applicable with these devices, and only masters of their craft were able to understand triangulation and its proportions."**[20]

Mathesius admired the engineers. There were many of them and they were extremely highly valued for their field of labor. He finds that he should "praise the labor and work of the artisans and prefer[s] such miracle-workers who possess the truth to other mining techniques which can only restore the old mine. Indeed, princes and gentlemen also know how to appreciate such

18 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 47 – 48.

19 Johannes Mathesius, *Sarepta oder Bergpostill: sampt der Jochimßthalischen kurtzen Chroniken* (Nürnburg, 1562), <page unknown>.

20 Ibid., <page unknown>.

skilled people, whom God and nature preferred to others. The Emperor Maximilian managed very well with his adepts. So, when a man, equipped with atrade in Innsbruck, constructing water drainage machines in Kuttenberg and draining a large lake with syphon-like machines, met with some abusive behavior and complained to the Emperor, then the pious Emperor stated:

> **"These people do not know how to deal with smart people."**
> **"But since in our time, thank God, surveying and other free arts are studied along with the gospel in schools, and many people already know their benefits, as well as how to use quadrangulation and triangulation for measuring the earth, then the owners of mining and mining cities should promote and help smart heads, capable and prone to this, loving mathematics and art, so that they could thoroughly study the art of surveying and invent useful and durable machines, so that at an inexpensive price it was possible to constantly extract water and ore."**[21]

Free from guild customs and restrictions, mining developed into a major industry. Technically, it was the most progressive. The machine-making industry was also very highly developed. This is what Mathesius has to say:

> **"The work of the miner is very heavy and many are so overstrained, moving the heavy gate, extracting ore and water that they have blood coming from the throat; many even pay with their lives because they have to stand naked all day, pumping water and carrying out the compulsory job. God's mercy and gift is that, with the help of useful contraptions and tools, heavy labor carried out by the sweat of one's brow, imposed upon humankind for its sins, is eased; that he instead of humans harnesses horses and with the aid of fine contraptions, by means of water, wind and fire raises water and ore from thegreatest depths, so as to reduce costs and more speedily extract the hidden treasures to the surface.**
> **A true blessing, for which both God and men should be given thanks, is that animals and the elements are also brought into service, and that many sagacious heads profitably are employed in the mining business with their inventions. The bread one procures is not sweet, standing a whole day over the pulley and making many rounds for one pfennig, enduring constant blows and jolts of the pulley and the handle. When the**

21 Ibid., <page unknown>.

two of us have to take out many tubs of water in one shift (with each tub containing almost an entire bucket), this too is a hard job sucking the brain out from one's bones and shortening life. But God afforded the experts who thought up good help and attached a handle to the pulley and arranged lifting wheels so to ease the work and make it more productive. There are also lifting wheels with pulleys (*Scheiben*) and handles (*Scheibenpulsen*), stepped wheels, so that not only the arms and shoulders, but also the legs and the whole body participated in the raising of ore and water — and this is also worthy of gratitude. The vertical winch is also a wonderful thing for with its help, water and ore can be raised to the surface by horses; moreover, in one shift, one can take out more than twenty by hand pulleys. The application of a horse-powered brake pulley (*Bremsscheibe*) is also convenient. It would also be convenient and advantageous for you to suspend shafts (*Welle*) and crossbeams (*Stempel*) in the mine, so as to have spikes (*Brustwinden*), logs (*Kloben*) and wind poles (*Windstangen*). The miners also have furs (*Bulgen*; *Utres* in Agricola), leather bags in which they bring ore from the high mountains to houses in the winter, and carts on which empty bags are transported back to the mountains.

A wide and well-constructed shaft tunnel with a gutter for water composes a wonderful drainage structure in the mine, since water and bad air escape through it while ore is delivered in concrete skips and carts. For this, our miners should thank God and willingly, swiftly and unflinchingly pay their dues – the fourth and ninth Pfennig. But where it is impossible to construct a shaft, the latter (with great advantage) is replaced by a special drainage structure, raising the water in buckets by means of a horse-drawn pulley and special wheels driven by wind or water. On the surface, the water flowing in the ravines raises of its own accord and proceeds to the castlesand mountainous areas. In the mine, such structures are impossible, because for them to work it is necessary to carry a much larger amount of water to the surface, than that which rises to the surface. The owner of the Pithi Mine died from grief from his inability to drain out the water. To raise the water from underground, you need to conduct the water to the mine from above, as was done in Pithi's mines, where the rich owner died from grief. But scientists and engineers have come up with many useful drainage facilities, especially pumps, with the aid of which the mine water appearing is pumped out by hand, horse, wind and other propellants.

> You miners should sing in your songs the glory to the good man who now arranges the raising of ore and water with the help of the wind. They say that now the water is pumped out with the help of fire..."
> Finally, since I am talking about different structures, I, as a priest in the mining industry should thank God for the wonderful machinery that makes it possible to conduct fresh air into the tunnels and drive out the foul air. This is done with the aid of air pipes (in Agricola, *canalis longus*, as stated in Latin), blast engines and fans. Indeed, it is not difficult to arrange apipeline from boards over the shaft, cover the cracks in it with clay, so that clean air can penetrate into the mine, and the foul air exit through the air-purifying channel; especially where the foul air is blown by bellows, it is quickly replaced by clean air, because nature does not tolerate any place remaining empty and unoccupied.
> It is said that in Kuttenberg, foul air is discharged through large pipes, similar to chimney stacks, especially when fires are lit; thus, clear air is conducted to the mine to a depth of five hundred lachters and even deeper; we, in Joachimstal, have recently constructed a similar facility, and also with the help of blast engines, conduct clear air into depths of several hundred lachters, having to build two tunnels, one on top of another, at great cost."[22]

The treatment of metals was also undergoing a great transformation. The invention of the method of melting ore by using coal was a huge step forward. The patent issued to Lord Dudley, states that he "found the secret of the art, the method and the means for smelting iron ore in furnaces with bellows, using sea or mine coal, and turning it into casting or bars of the same quality as when using charcoal."[23]

Of no lesser significance, although of another kind, was the invention of amalgamation for the extraction of silver in 1507, which made American mines very profitable. Iron processing also underwent a significant transformation: galvanizing (the first half of the sixteenth century), rolling (1615), a 6-10 quintal hammer for the manufacturing of anchors and cannons, machines for the drilling of gun muzzles all appeared in the sixteenth and seventeenth centuries. Even

22 Ibid., <page unknown>.

23 Edward Lord Dudley, "Letters Patent, 22nd February, 19 Jac. I. A.D. 1622, to Edward Lord Dudley," in *Reports and Notes of Cases on Letters Patent for Inventions*, by Thomas Webster (London: Thomas Blenkarn, 1844), 14.

more important for the economic life of this period were improvements in the processing of precious metals, starting with the calender roll of the Frenchman Brulet in 1552 and culminating in the invention of the coil edge mill (for finishing the edges of coins), in France in 1685 thus permitting an exact mintage of coinage, and which was first used in England under Cromwell.

The development of exchange and military equipment posed the following technical problems for the mining industry:

1. Raising ore from great depths.
2. Ventilation devices in the mines.
3. Pumping water from the mines in water discharge facilities — the problem of pumps.
4. The transition from the Catalan forges method of production, which prevailed until the fifteenth century, to the blast furnace production, an integral part of which, apart from ventilation, is the problem of the blowing facilities.
5. Ventilation through means of air drafts and special blowers.
6. The processing of ore and iron with stamp millsand dividing machines.

We will now consider the physics which lay at the basis of these technical tasks:

1. Ore lifting and the task of constructing hoists, is just a simple matter of calculating the pulleys and blocks, that is, varieties of simple mechanical machines.
2. Ventilation devices require traction, i.e. their operation comes down to aerostatics, representing a particular problem of statics.
3. Pumping water out of mines and the construction of pumps, especially piston pumps, requires a great deal of research in the field of hydro-and aerostatics. Torricelli, von Guerike and Pascal grappled with the problem of raising liquids in pipes and atmospheric pressure.
4. The transition to the blast furnace immediately brought large blast furnaces into operation on outbuildings, water wheels, ash-pit bellows, stamp mills and heavy hammers.

The design of blowers for blast furnaces required the study of air movement and its compression, and posed the same physical problems as mine ventilation.

As with other facilities, the construction of stamp mills and heavy hammers, which operated by the force of falling water (or horsepower), required a complex calculation of gears and transmission mechanisms, which is also essentially the task of mechanics. The theory of friction and the mathematical calculations ofgear transmission were developed in the construction of mills.

Thus, if we set aside the great demands that the mining and metallurgical industries of that period placed on chemistry, the whole complex of physical problems did not go beyond mechanics.[24]

ENGINEERS AND ENGINEERING IN THE SIXTEENTH AND SEVENTEETH CENTURIES[25]

1196	ALAMANNUS DE GUITELMUS The term ‘engineer’ (*encingerius*) was first used in *Annales Placentium Guelfi*, where Guitelmus was designated as the engineer of the city of Milan. He built the ditches and palisades of Vicenza. In the next century, we find several occurrences of the word ‘engineer’ originating from the common root in-*cingere* (surround a city with fortifications).
1540	There has also been conjecture that the title ‘engineer’ first appeared in 1540 to refer to the designers of military weapons and that it came from the Italian ‘ingegnos’ or the Spanish ‘engennos’ (machine, appliance).
1621	In German, the word ‘engineer’ first appeared in a letter which mentions an illustrated technical manuscript *Ingenieur Buch* (*Engineering Book*)
1685	The creator of the fountains of Versailles was named the steward of machines (*Maschinen Gouverneur*)

24 See Hessen, “The Social and Economic Roots of Newton’s *Principia*,” 48 – 49.

25 Chronology designed according to Franz Maria Feldhaus, *Ruhmesblätter der Technik*, 2nd ed. (Leipzig: Brandstetter, 1926), Vol. 2, pp. 15-24. [Hessen’s reference integrated]

1697 KONRAD KYESER

The title ‘Chief Engineer’ appears in a book on military disciplines by Johann Sebastian Gruber. The post of major or chief engineer is mentioned among other military positions. “He must not only thoroughly know geometry and fortifications for his position, and not only be a good theorist and armchair ‘engineer’, but, in addition to all this, he must be an experienced practitioner,” Gruber states.

The introduction of firearms immeasurably expands the engineer’s field of work. During this period, countless technical books, nearly always illustrated, appear, many of which were on weapons.

The first extant German illustrated manuscript of this kind was compiled by Konrad Kaiser from Eichstätt. One can trace this engineer’s school back to 1540.

1422 MARIANO DI JACOPO FROM SIENA

In 1422, Mariano di Jacopo from Sienacompiled an illustrated technical manuscript.

1471 MARTIN MERTZ

In 1471, Martin Mertz compiled an illustrated technical manuscript.

1460 ROBERTO VALTURIO FROM RIMINI

The first printed book on engineering was compiled by Roberto Valturio in 1460, and was printed in 1472. It was republished several times until 1555.

1474 LUDWIG HOHENWANG

The first German printed technical book was published by the Augsburg printer, Ludwig Hohenwang. This was a translation of the fourth century B.C. author Vegetius, to which were added drawings by Valturio.

Leonardo da Vinci wrote a number of books on engineering (1452-1519).

1549 VANNUCCIO BIRINGUCCIO
For the first time, technical matters were separated from military affairs in a book by Vannuccio Biringuccio. The book enjoyed great success for a hundred years and was republished many times.

1556 GEORGIUS AGRICOLA
In Germany, Agricola's book about ore mining saw wide circulation.

1578 JACQUES BESSON
Jacques Besson, the engineer of the French king and who had replaced Leonardo da Vinci in this position, opens his book about machines to a series of plush editions on technical matters.
Most attention is drawn not to the text, but to the drafts and drawings.

1595 In 1595, Besson's book was released in German.
After Besson, a whole number of engineers published books on technical issues and the art of engineering. These books did not represent systematic works on technical matters, but gave merely an incidental description of machines, apparatuses, etc. See below for a chronological list of these books:

1588 Ramelli
1597 Lorini
1605 Veranzio
1607 Tsonka
1613 Ziesing
1615 De Ko
1618 Strada
1629 Branka
1661 Bekler
and others

For a long time, indeed for centuries, engineers were only hired when it was necessary to produce a specific work. Later on, engineers became civil servants.

1745	In 1745, Germany's first educational institution (independent of the University) was founded in Braunschweig, which taught technical subjects. From this school arose the contemporary Braunschweig higher technical school.
1776	In 1776, Friedrich the Great founded a technical college in the royal palace. Its eventual fate is unknown.
1799	In 1799, a Building Academy was founded in Berlin, where mathematics, machine science, mechanics, hydraulics and technical drawing were all taught.

The Emergence and Development of the Main Principles of Classical Mechanics and the Arguments Surrounding Them in the 17th Century

CONTENTS OF THE SECOND THEME[26]

This section provides a survey of the emergence and development of the main principles of dynamics, starting from the works of Galileo. A lack of space does not permit us to pay sufficient attention to Galileo's forerunners,

26 Arthur Erich Haas – Ancient Dynamics
Joseph-Louis Lagrange – On the Main Principles of Statics and Dynamics (Analytical Mechanics)
1. On Different Principles of Statics
2. On Different Principles of Dynamics
Alexander Stoletov – The Mechanics of Leonardo Da Vinci
Galileo Galilei – Studies on Mechanics
Christiaan Huygens – Studies on Mechanics
Rene Descartes – On the General Principles of Mathematics
Gottfried Wilhelm Leibniz – Studies on Mechanics: [*1. Letter on the Question of the Expansion of Bodies. 1691; 2. Brief Proof of Descartes's Memorable Errors 1686; 3rd Essay on the Dynamics of Laws of Motion (1691); 4. Letter to Christiaan Huygens of October 1690*]
John Smeaton – On Two Measurements of Movement (MOTION???)
Isaac Newton – On the Laws of Motion (*Isaac Newton. Philosophiae naturalis principia mathematica. Translation by A.N. Krylov. (Foreword to First Edition, Definitions, Axioms or Laws of Motion*)
Friedrich Engels – On the Foundations of Mechanics (*Excerpts from the "Anti-Dühring" and the "Dialectics of Nature": 1. Basic Forms of Movement; 2. Measure of Movement – Labour; 3. Space and Time (Comments on the Anti-Dühring): 1. Force; 2. Indestructibility of Movement; 3. Movement and Balance; 4. Mechanical Movement*)
Johann Bernoulli. On the Dynamics of Newton and Descartes.
Roger Joseph Boskovič. On the Principles of the Construction of Mechanics.
Jean le Rond d'Alembert – On the Foundations of Dynamics
Albert Einstein – Newton's Mechanics and their Development (*Newton's Mechanics and their Influence on the Design of Theoretical Physics (from: The Natural Sciences 12/1927*)
Richard Glazebrook. The Most Important Development Stages of Optics (*from: Nature, June 1905*)

even those such as Leonardo da Vinci. Another reason that we abandoned the idea of including the works of Leonardo here was that they played no role in the development of dynamics since they were not published until much later. We limit ourselves to publishing a speech given by Stoletov, which outlines the most important aspects of Leonardo's work. A survey of ancient dynamics is provided in the article by Haas.

Due to a lack of space, we were constrained to choose whether to present the principles of statics or of dynamics. We chose dynamics not because statics is of no interest, but because with the formulation of the principles of virtual displacements, statics reaches a sufficiently complete form, while the principles of dynamics have a much more complex history and play an incomparably more important role in the development of general physical and philosophical views and theories.

This gap in the history of the principles of statics is, to some extent, filled by a remarkable chapter from Lagrange's *Analytical Mechanics* which provides a concise survey of the principles of statics from a historical perspective, which is unrivalled in its clarity.

We preface the original works by the architects of modern mechanics with Lagrange's overview of the principles of mechanics, taken from "Analytical Mechanics" and which is a fine introduction to the whole theme.

Particular attention was paid to covering the development of the principles of mechanics when choosing the excerpts.

The development of mechanics in the seventeenth century rested not only on the question of the perpetual refinement, systematization and design of its principle foundations, but also on the disputes between different schools of thought.

One of the main objectives of this theme is to show these disputes, over the course of which the basic foundations of mechanics were crystallized. There are two fundamental axes upon which this struggle over the principles of mechanics took place: between the school of Descartes on the one hand, and those of Huygens, Leibniz and Newton on the other. Leibniz's dispute with Descartes primarily revolves around two fundamental problems: those concerning matter and motion and the measures of motion. Leibniz contrasts his own conception of matter as an active substance to a purely geometric understanding of matter endowed with a passive ability for mechanical displacement.

Descartes' view here represented by the second part of the *Principles* is countered by Leibniz's view which is given in extensive form in his article, "A Brief Demonstration of a Notable Error of Descartes", which served as a starting point for the entire dispute concerning the two measures of motion, in "Considerations on Dynamics" and in the letter on whether "The Essence of Matter Lies Only in Its Extension."

The dispute over the two measures of motion was not only of fundamental significance for contemporaries, but also something of great practical interest. The article by Smeaton (a famous researcher and developer of steam engines), "An Experimental Examination of the Quantity […] of Mechanic Power", provided below, shows that even in a later period, the problem of the two measures of motion occupied not only the minds of theoreticians but also of those of technical engineers.

D'Alembert's interpretation of this problem can be found in the preface to his famous *Treatise on Dynamics*, provided below.

The reader will find Engels' interpretation of the two measures of motion in the corresponding articles from his *Dialectics of Nature*.

In the dispute between Leibniz and Descartes, the significance of mass emerges as one of the basic categories of mechanics, while the significance of the law of kinetic energy (*vis viva*) acquires its full development in the works of Huygens and Bernoulli. Additionally, Leibniz clarifies the vectorial nature of the law of the conservation of the quantity of motion and thus frees the Cartesian formulation of the law from its inherent limitations.

Descartes' *Principles* is greatly significant with respect to the development of the foundations of mechanics, since it provides further development of the law of inertia — which Galileo had expressed fairly cogently (cf. *Dialogue on the Two Chief World Systems*) —, and developed the principles of relative motion — also provided by Galileo (cf. ibid) and so brilliantly and systematically used by Huygens to address the issue of the impact of bodies at rest and centrifugal force.

In the works of Galileo, the most important principles of mechanics are contained in a more or less developed form. The selection of excerpts from his works aims to provide an idea of the development of the main principles of dynamics. Therefore, his *Discourses and Mathematical Demonstrations* is presented here in a much fuller form than his famous *Dialogue on the Two Chief World System*, from which we provide only those sections where Galileo expounds his principles of relativity, and where he introduces his idea of centrifugal force. Galileo had a clear idea of centrifugal force, but he was wrong with respect to its magnitude and believed that any small force of gravity could counterbalance its action. Huygens was the first to provide a correct theory of centrifugal force. Unfortunately, due to a lack of space, we had to neglect Galileo's astronomical works, which played a significant role in the development of mechanics; just as in the selection of Newton's works, we omitted nearly all of his cosmogonic and astronomical works. However, this made it possible to fully cover here the development of the basic principles of dynamics.

Huygens's works in the field of mechanics differ from Newton's not only in the way they were constructed, but also in the basic principles that underlie their study.

Huygens was a direct successor to the works of Galileo. The principle of relative motion, the law of inertia and the laws of centrifugal force are all brought to culmination in his works.

While Galileo's mechanics are essentially the mechanics of material points, Huygens is the first pioneer in the mechanics of a system of material bodies (of material points). That is why Huygens could not be satisfied with those principles provided by Galileo alone. In solving the problem of the center of the oscillations of the system of material bodies in general terms, he had to resort to a new principle.

This principle is expounded by Huygens in the fourth part of the excerpts from his *The Pendulum Clock*, which are provided below. Huygens places at the foundation of his study the principle that while moving freely a center of gravity cannot rise above that position which it occupied at the beginning of the movement. However, this provision was not only met with general rejection, but was strongly attacked by Newtonians. This controversy is represented here by a number of letters. Apparently, even Newton himself was not inclined to afford this principle with much significance, and in the first edition of his *Principles*, he provides a result that contradicts it in his discussion of the displacement of water from a vessel (cf. the letter of Huygens given on page ?). Though this was corrected in the subsequent editions of *Principles*, it seems that Newton did not change his attitude towards Huygens's principle.

Newton's work is represented by a lengthy excerpt from his *Principles*. In contrast to the work of Huygens, who developed his principles of mechanics in connection with solutions to concrete problems (on the motion of bodies in collision, on centrifugal force, on the complex pendulum), the work of Newton takes up the task of attempting to provide a system of mechanics.

Mechanics finds its preliminary culmination in the *Principles*. The principles of mechanics which had been developed by Newton's predecessors are combined and systematized in this work. Here, we see the birth of that tendency in mechanics inextricably linked with the name of Newton and which was the reigning school of thought in physics for more than two centuries. That is why it is particularly interesting to compare Newton's conception of mechanics with those of Leibniz and Huygens, which represent their own particular schools of thought.

There is no doubt that Newton's law of gravitation and his astronomical works made a much greater impression on his contemporaries than the fundamentals of his mechanics. Here, however, we will be exclusively concerned with the fundamentals of mechanics provided there.

The ideas of celestial mechanics and, above all, the role played by the central forces therein as well as in all of Newton's mechanics, had a profound influence on the development of his physics and a particularly strong impact on the development of electromagnetism. A special topic in the second part will be devoted to Newton on the problems of long-range and short-range actions.

In Newton's *Principles*, the problem of space and time as physical categories is posed in its entire scope for, perhaps, the first time. We have therefore provided the relevant passages from the *Principles*, leaving a detailed analysis of this problem to the second part, where it will be provided in connection with the principle of relativity. Here, we provide Engels' statements about space and time as well as about the main categories of mechanics.

The disputes over the conceptions of physics between Cartesianism and Newtonianism are not merely over their positions on the conceptions of matter, but also over the question of the causes of gravitation and of long-range and short-range actions.

Despite their struggle against the physics of Descartes, when it comes to the nature of gravity and of long-range and short-range actions, Leibniz and Huygens mainly align with the thought ofDescartes. Leibniz and Huygens tried to develop a vortex theory of gravity, but without much success. (Huygens devoted a special work to this question: *On the Cause of Gravity*).

The struggle between these conceptions will be presented in detail in the topics about short-range and long-range actions and in the history of the development of views on the nature of force. In this theme, we provide only a few letters by Leibniz to Huygens directed against the theory of gravity and the force of long-range action.

The further development of the struggle between Cartesian and Newtonian schools, particularly in eighteenth-century France, represents one of the most interesting pages in the history of physics, to which we also refer in the second part. In order to give some idea of this dispute, we provide excerpts from the work of Johann Bernoulli, which provide a comparison between the systems of Descartes and Newton. Unfortunately, Bernoulli's voluminous mathematical calculations relating to the calculation of the orbits of the planets, had to be omitted due to a lack of space, limiting us solely to that section of the text which sets out the fundamental formulation of the question.

The most extreme tendency in the theory of long-range action, combined with the pure dynamism that brings the matter to unextended centers ofpower, appears in the work of Vescovini, from which we have provided excerpts from the first part.

All preconditions for an analytical interpretation of mechanics were created in works of Galileo, Descartes, Huygens and Newton.

One of the first systematic works on analytical mechanics (after Euler), and which lays out mechanics mainly in the form that we know it today, is the famous treatise by D'Alambert. We provide the whole preface to this treatise, in which D'Alembert raises the most fundamental questions about the categories and principles of mechanics.

In order for the reader to gain some perspective on the further development of mechanics, we provide an article by Einstein, written for the Newtonian bicentennial anniversary. This paper provides a general perspective on the further development of Newtonian mechanics and relativity theory and a general evaluation of classical mechanics. This problem will be covered in more detail in the second part, in the topic of the theory of relativity.

The seventeenth century was an epoch of great discoveries in the field of optics, especially in physical optics. However, as a physical discipline in this age — both in terms of its relative significance, and in its impact on the development of other subfields of physics —, it cannot be compared with mechanics. Therefore, we discuss the development of optics, as well as the doctrine of electricity and magnetism, in the second part, where the general development of the doctrine of light will also be presented, starting from mechanical theories (Huygens, Young, Newton and Fresnel) and ending with the electromagnetic theory of light.

In order to give the reader a general idea of the development of optics, we include in this theme an article by Glazebrook, which contains a concise overview of the most important stages of its development.

The Problem of Matter and Movement in Newton's Physics. The Struggle of Materialism and Idealism Concerning This Problem in the Seventeenth and Eighteenth Centuries

CONTENT OF THE THIRD THEME[27]

The second theme offers a portrayal of the disputes between the schools of thought in physics. The third theme aims to show the ideological struggle concerning these basic categories in physics.

Freeing natural science from theology was a huge impetus to its development. However, this liberation was not accomplished immediately, and the theological elements were quite strong even among the leading natural scientists of this age.

One of the main objectives of this theme is to show the struggle of materialistic schools of thought against the idealistic and theological aspects of the physics of the XVII century. It is not possible to represent this struggle in all of its detail given the unusual amount of the material. Therefore, we selected the Newtonian conception as it had the most influence on the subsequent development of natural science. The problem of matter and motion in the Newtonian conception is highlighted.

The general features of the philosophical schools of thought in this age are provided in Herzen's remarkable *Letters on the Study of Nature*.

After this, follows the fine history of the development of materialism in England and France, provided by Marx in his *German Ideology*.

Newton's worldview took shape and developed in the age of the intense class struggle of the English Revolution. Engels' preface to the English edition

27 Characteristics of the Main Schools of Thought in the Seventeenth and Eighteenth Centuries.
Struggle for A New Natural Science Conception of Matter and Motion in Newton. Theological Motifs of His World Outlook.
Materialist Critique of The Newtonian Conception of Matter and Motion.

of *From Utopia to Science* provides a picture of the class struggle at the time of the English Revolution and explains the characteristic features of the mindsetof English natural scientists, including that of Newton.

Excerpts from Engels' "Natural Science in the Spirit World" provide a concise and vivid characterization of empiricism as a scientific method and explain why consistent empiricism leads to theology and mysticism. Herzen's *Letters* and the excerpts from Hegel's *Encyclopædia* also provide general characterizations of the empiricism, which was so typical of natural scientists of this age. The seventeenth century was a time of fierce conflict between the universities and the progressive science outside the university, centered in the scientific societies emerging at the time. We devote a special section to the features of this struggle. Scientific journals played a significant role in the dissemination of scientific knowledge and the development of a new form ofcommunication between scientists and scientific institutions in this age, the development of which is represented by a number of materials.

The significance of Newton's "*Principles*", of course, is not limited to their significance for technology. The very title of Newton's main work indicates that he provides a system, a worldview. One of the main ideas of Newton's cosmogony consists in representing the movement of the planets as a consequence of the combination of two forces: one, the central one, directed towards the sun, and the other, a tangential one, comprised of an 'initial' impulse. Newton left it to God to carry out this initial impulse, though he "forbade him any further interference in his solar system."[28]

In this singular 'division of labor' regarding the management of the universe between God and mechanical causality resides the interweaving of religious dogmas with the materialistic principle of causality, which is typical of many English natural scientists.[29]

Regarding the problem of the relation between matter and motion, Newton views it from the point of view of the pure modality of motion. Therefore, he searches for the initial cause of the origin of planetary motion; and, because this motion cannot be explained by the force of gravity alone, he introduces the creator, who gives matter the initial impulse. The idea of a deity in Newton's system is not incidental, but closely related to his concept of matter and motion.

28 Friedrich Engels, *Dialectics of Nature*, in *Marx & Engels: Collected Works, vol. 25 – Engels*, ed. Natalia Karmanova, et al. and trans. Clemens Dutt (London: Lawrence & Wishart, 2010), 480.

29 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 67.

These theological aspects of Newton's system are very vividly expressed in the third book of the *Principles*, of which we have included excerpts, as well as in the well-known questions of his *Optics*.

But apart from this, there are even more significant documents which show Newton's orientation towards the theological and his relation to materialism, which gained wide popularity in England at that time. Here, we refer specifically to Newton's famous letters to Bentley, which we include in full along with one of Bentley's letters to Newton.

The dispute between Leibniz and Clarke regarding the Newtonian conception of divinity and matter and motion is of equal interest. Although Newton himself did not participate in this dispute, Clarke served as his official representative. Clarke's letters to Leibniz were looked over by Newton. The dispute with Leibniz is essentially a continuation of the polemic regarding the two measures of motion, along with other matters.

Based on theological argumentation, Leibniz challenges Newton's idea of the indivisibility of motion (its efficacy) from matter.

If Leibniz conducts his criticism of Newton from an idealistic standpoint, then in a somewhat later period (at the beginning of the eighteenth century), we find a materialist critique of Newton's views on the part of Toland.

In the excerpts from his *Letters to Serena*, John Toland aims his sharp criticisms against the conception of the modality of motion. Motion, he claims, is an actual and indivisible feature of matter. It should be included as an integral part of its definition. Only this conception, Toland justly affirms, provides a rational explanation of the law of the constant quantity of movement. It resolves difficulties regarding the motive force and the initial impulse. Thus, the problem of the self-motion of matter was clearly posed in the controversy between Leibniz and Toland with Newton, and received a definitive solution in the teachings of Marx, Engels and Lenin.

Newton's deity has two functions: it provides the initial impulse to matter and puts the disturbed orbits of celestial bodies in order (see Leibniz's correspondence with Clarke). In other words, God is necessary for Newton not only as a first mover, but also as a factor ensuring the lengthy stability of the solar system which Newton considered unstable.

Laplace's critique of Newtonian cosmogony proceeds along these two lines. Firstly, Laplace proves that the solar system is stable in itself, and secondly that the construction and origin of the solar system can be accounted for without any divine initial impulse, if one accepts that motion is an original aspect of matter.

Thus, Laplace proceeds along the same position outlined by Toland, though on a purely physical plane.

But, the work of Laplace and Kant is important not only in this respect. As Engels points out (see the old introduction to the *Dialectics of Nature*), the cosmogonic hypothesis of Kant-Laplace made a breach in the worldview that nature has gone unchanged since time immemorial.

Together with their works in natural science is included the idea of development, which will later become the guiding thread of the whole study of nature.

CHARACTERISTICS OF THE MAIN PHILOSOPHICAL SCHOOLS OF THOUGHT IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES[30]

STRUGGLE FOR A NEW NATURAL SCIENCE

The development of productive forces set before science a number of practical goals whichrequired their resolution with urgent necessity. Official science, which was concentrated in the medieval universities, not only made no effort to solve these tasks, but actively opposed the emerging natural science. The universities of the fifteenth to the seventeenth centuries served as a bulwark of feudal mores. They were not simply bearers of feudal traditions, but also their active defenders. In 1655, during the struggle between guild masters and the workers associations, the Sorbonne actively sided with the masters and the guild system, supporting the masterswith proofs from science and Holy Scripture."

The whole doctrinal system of the medieval universities was an accomplished scholastic system. Natural science had no place in the universities of

30 *Alexander Herzen.* Letters on the study of nature (scholasticism, rationalism, empiricism)
First Letter. Empiricism and Idealism
Fifth Letter. Scholasticism
Sixth Letter. Descartes and Bacon.
Seventh Letter. Bacon and his School in England.
Karl Marx. The Holy Family (on English and French materialism). Critical comparison with French materialism.
Friedrich Engels. Excerpts from the "Dialectics of Nature" and *Anti-Dühring*.
1. Natural Science in the Spirit World
2. Old Introuction to *Anti-Dühring*.
Hegel. On Empiricism. Excerpts from the *Logic*. Encyclopaedia of Philosophical Sciences.
Friedrich Engels. Preface to the English edition of The Development of Socialism from Utopia to Science. (Class struggle in the era of the English Revolution).

the Middle Ages. In Paris in 1355, teaching Euclidean geometry was only permitted during the holidays. The books of Aristotle constituted the main disciplines of "natural science", and all living content was eviscerated from them. Even medicine was taught as a logical science. No one was allowed to study medicine unless they had studied logic for three years. Admittedly, for acceptance into medicine, a certificate was required, but not one of any relevance; rather, it was a testimony to the fact that the student had come from a legal marriage. But clearly, one of these non-logical arguments was insufficient for medical knowledge. The well-known surgeon, Arnold Villeneuve from Montpellier, complained that even the professors from the Faculty of Medicine not only could not cure patients of the most ordinary illnesses, but that they were even unable to give their patients an enema.[31]

> **"Anything which is not in Aristotle does not exist for them."[32]**

When Galileo invented the telescope and discovered the phases of Venus, trading companies turned to him for his telescope (which surpassed those manufactured in Holland), while University philosophers did not want to hear about these new facts.

With the same force that the fading feudal order waged in the struggle against the new progressive means of production, the feudal universities stood up against the new science.

> **"We will laugh, my Kepler" Galileo wrote bitterly to Kepler on the 19th August 1610 "at the extraordinary stupidity of the multitude. What do you say to the leading philosophers of the faculty here, to whom I have offered a thousand times to show my studies but who with the lazy obstinacy of a serpent have never consented to look at planets, nor at the Moon, nor even the telescope itself. Verily, the eyes of these men are closed to the light of truth. Remarkable as it is but they do not occasion any surprise. People of this kind think that philosophy is a book of some sort [...] and that the truth is not to be sought either in the world or in nature but by comparing texts!"[33]**

31 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 53 – 54.
32 Ibid., 54.
33 Galileo Galilei, Letter to Kepler (19 August 1610), in *Le Opere di Galileo Galilei, vol. 10*, ed. Antonio Favaro, et al. (Florence: Barbèra, 1890 – 1909), 421 – 423. See Hessen, "The Social and Economic Roots of Newton's *Principia*," 54.

When Descartes resolutely came out against the Aristotelian physics of hidden qualities and against university scholasticism, he encountered fierce resistance on the part of the Vatican in Rome and the Sorbonne. In 1671, theologians and physicians of Paris University solicited a government resolution, which condemned the teachings of Descartes.

In a caustic satire, Boileau ridicules the scholastics' petitions made to the scientists. We present in full this remarkable document, which superbly illustrates the situation in medieval universities.

Still in the second half of the eighteenth century in France, Jesuit professors could not yet come to terms with Copernicus's theory. In 1760, Fathers Le Seur and Jacquier considered it necessary to make the following observation in the Latin edition of Newton's *Principles* in 1760:

> **"Newton in his third book accepts the hypothesis of the movement of the earth. The proposition of the author cannot be explained except on the basis of this hypothesis. We have therefore been forced toact from a position not our own. But, we openly declare that we follow the decree released by the Supreme Pontiffs against the movement of the Earth."**[34]

The universities almost exclusively prepared theologians and lawyers. The Church was the international center of feudalism, and was itself a major feudal overlord, since it owned no less than a third of Catholic tenure.

Medieval universities were a powerful weapon for the domination of the Church. However, those technical problems which we outlined in the first theme required a tremendous amount oftechnical knowledge, and significant mathematical and physical training. If the sciences began to develop with miraculous speed after the dark night of the Middle Ages, then we owe this to the development of industry (Engels).

Since the Crusades, industry began developing in tremendous strides and acquired a wealth of new facts (metallurgy, mining, the arms industry, the dyeing trade) which not only supplied new material for observation, but also new methods of experimentation as well as the construction of new tools. One can say that a systematic experimental science has only been possible since that time. Furthermore, the great geographical discoveries, which were also

34 Thomas Le Seur & François Jacquier, Preface to *Philosophiae Naturalis Principia Mathematica, vol. 3, 2nd Ed.* by Isaac Newton, ed. Thomas Le Seur & François Jacquier (Cologne: Sumptibus Cl. & Anti. Philibert bibliop, 1760). See Hessen, "The Social and Economic Roots of Newton's *Principia*," 54.

ultimately determined by productive interests, delivered a tremendous amount of material, which had previously been inaccessible, in the fields of physics (e.g., magnetic declination), astronomy, meteorology and botany.

Finally, in the middle of the fifteenth century, a powerful weapon emerged in the distribution of knowledge, namely the printing press.

The construction of canals, locks and vessels, the laying of tunnels and mines, their ventilation and pumping out of water, the calculation and the building of firearms and fortresses, the problems of ballistics, the production and calculation of navigational instruments, the development of methods to orient the vessels; all this required an entirely different type of people than those being prepared in the universities. Already during the third quarter of the sixteenth century, Johannes Mathesius, in listing the minimum knowledge necessary for a surveyor, shows that he should fully possess the method of triangulation, should be well-acquainted with Euclid's geometry, know how to use a compass well (which was necessary for laying tunnels), be able to calculate the correct direction of the mine and know the structure of pumps and ventilation equipment. He points out that theoretically educated engineers were needed for the laying of tunnels and the development of mines, as these affairs are far superior to the forces of a simple uneducated miner. Of course, all of this could not be learned in the universities of that time. The new science grew up as an extra university science through the struggle with universities.

The struggle between university science and the science beyond the university, which served the needs of a rising bourgeoisie, is a reflection of the class struggle of the bourgeoisie with feudalism in the ideological sphere.

Step by step, a thriving bourgeoisie proceeded with the rapid development of science. The bourgeoisie needed a science for the development of its industry which investigated the properties of material bodies and the manifest forms of the forces of nature. Prior to then, science had been a humble servant of the church and was not permitted to go beyond those limits established by faith. The bourgeoisie needed science and science rose up against the church alongside the bourgeoisie. So, the bourgeoisie came into conflict with the feudal Church (Engels). In addition to professional schools (surveying schools, schools for trained gunners), the centers of new science (new natural science) were also the non-university scientific societies.

In the 1650s in Florence, the renowned Florentine Accademia del Cimento was founded, which aimed to study nature through the means of experimentation. On its team, it boasted such scientists as Borelli and Viviani. The Accademia was the spiritual heir to Galileo and Torricelli, and continued their work.

Its motto is "provando e riprovando" (to check and check again, experimentally).

In 1645, a group of natural scientists emerges in London, who met up daily to discuss scientific issues and new discoveries.

The Royal Society was born from this group in 1661. It united the most advanced and outstanding scientists in England and in opposition to university scholasticism, taking as its motto "*nullius in verba*" (take nothing at its word).[35] Robert Boyle, William Brouncker, Christopher Wren, Edmond Halley and Robert Hooke all took an active part in the Society. One of the leading members of the Royal Society was Newton.

We see how the ascending bourgeoisie placed natural science at its service; that is, at the service of the development of productive forces. Being the most progressive class at the time, it thus required the most progressive science.

The English revolution provided a powerful impetus to the development of productive forces. There was a need not only to solve individual problems empirically, but also to lay a sturdy theoretical foundation for solving the general methods of the whole ensemble of physical problems, which in turn fostered the development of productive forces and new technology.[36]

OLD UNIVERSITIES AND THE STRUGGLE AGAINST THE NEW SCIENCE

By the seventeenth century, universities founded in the Middle Ages were bulwarks of scientific reaction and scholasticism. The disciplines taught in the university in no way responded to new demands.

If we move on to consider, Mullinger asserts, this and to what extent the courses taken a the student [in the seventeenth century], differ from the courses, considered in the analysis of the Middle Ages, then we see that the anti-conservativism in the field of the secular sciencesis almost as surprising as the innovation in the theological sciences. We already saw that, according to the Statutes of 1549, the study of mathematics was replaced by that of grammar. In the Elizabethan statutes, mathematics was not at all obligatory for students of the course. It is true that a professor of mathematics was still teaching, but there is no information of whether attending these lectures was in any way

35 Horace, "To Maecenas," in *The Epistles of Horace, vol. 1*, ed. and trans. Evelyn Shirley (Cambridge: Cambridge University Press, 1888), 1.

36 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 54 – 56.

obligatory; those attending them turned out to be second year students or bachelor students of the arts. It is, perhaps, not superfluous to note that the volume of information which they were able to receive, was destroyed. They were lectured on the principal rules of arithmetic, set out by Cuthbert Tunstall or Girolamo Cardano. In terms of geometry, they could go as far as Euclid's definitions, axioms and some theorems of the first book [of the *Elements*]. The information that could be obtained from cosmography and astronomy was even less satisfactory because not only were they meager, but were for the most part simply incorrect. In the century of Galileo and Kepler and almost a hundred years after Copernicus arrived at his great discovery, the students of Oxford and Cambridge still drew their knowledge about the celestial system from Ptolemy's *Almagest*; and although no less time had passed since Magellan and Vasco da Gama had circumnavigated the southern continent, these students were still turning to Plato's *Timaeus* for information about cosmography and for geographical information they turned to pagan writers of the first century; Strabo or Plinius or to those short essays in which Pomponius Mela summed up the geographical knowledge of the Romans of the Claudian age.

The explanation for this surprising indifference to the sciences, then called "mathematical", was not to be found in the spirit of conservatism alone. The statements of the great mathematician Wallis, who entered the College of Emmanuel in 1632, illuminates this question in another way. "Even in that time," he tells us, "the mathematicians in London were studying in London more than in any other university,"[37] because the subject matter denoted by this term was considered to belong to practical life rather than to the usual university program; that is, to that class "of mechanical disciplines, that is to say, to that class of "mechanical objects (of study)" which, in the expression of Bacon, were considered by those if there were "a shame for science to lower itself to research or consider them [...]."[38]

The place of "mathematics" was taken by rhetoric. The most assiduous and bright recipients of a bachelor's degree clearly wished to combine the study of the traditional ethics, physics and metaphysics of that time with their narrow education.

But, in order to prevent that exaggerated impression which certain terms which are full of significance in the present day, one should remember that the

37 John Wallis, "Dr. Wallis's Account of some Passages of his own Life," in *Peter Langtoft's* Chronicle, ed. Thomas Hearne, M.A. (Oxford: The Theater, 1725), cxlviii.

38 <Source unknown>.

scholastics were still thought of as the main authorities in these questions and that when it came to the research of some disputed issue in physics, the statements of a Roman or Greek Church Father were often considered to have the last word.

Every new opinion was forbidden. The following excerpt from the *Ratio studiorum* of the Jesuit Acquaviva offers a certain idea about the spirit of teaching at that time:

> **"The teacher is not to permit any novel opinions or discussions to be mooted; nor to cite or allow others to cite the opinions of an author not of known repute; nor to teach or to suffer to be taught anything contrary to prevalent opinions of acknowledged doctors current in the schools. Obsolete and false opinions are not to be mentioned at all even for refutation nor are objections to received teaching to be dwelt on at any length [...]. In philosophy Aristotle is always to be followed, and Thomas Aquinas in general [...]."**[39]

For a long time, the situation of the universities did not change at all. No changes were made to the Oxford statues from 1570 up to 1859, just as there were no substantial changes in the organization of Leipzig University from 1558 until 1830. In the regulations of the Theological Faculty of Bologna University, nothing changed from 1360 until 1783. Indeed, universities in the eighteenth century surpassed all records for conservatism. In Germany, for example, while on the one hand, 1733 saw the founding of Göttingen University, which was to prove a safe haven for the sciences, on the other hand, in 1740, the University of Innsbruck refused to open a department of botany and chemistry, and the study of the latter was to take place in pharmacies. In Erlangen, the Professor of Chemistry had to conduct all laboratory classes at his own home and with his own equipment from 1754 to 1769.

> **"The universities — writes Monroe — responded much less quickly to new educational ideas than the secondary institutions. Theological-classical scholasticism controlled German universities throughout the seventeenth century; but in 1694, the University of Halle was founded chiefly**

39 Thomas S. Baynes, ed., "Jesuits," in *The Encyclopædia Britannica: A Dictionary of Arts, Sciences, and General Literature, 9th Ed., vol. 13* (Edinburgh: Adam and Charles Black, 1881), 651.

as a protest against the old university. Halle is considered the first modern university, for there saw first the 'real' subjects taught with the new method and in the modern tongue. Franke mentioned in connection with the real schools, and Thomasius, who had been expelled from Leipzig because of their too liberal ideas, made Halle the center of the new influence. The costume of using German in the university lecture room, introduced by Thomasius, who also produced the first German magazine, soon spread, as did also the university teaching of the natural sciences and a more liberal philosophy.
In 1737, the University of Gottingen became a second such center of these same influences. By the close of the century, the conquest of all universities, at least of Protestant Germany, was complete.
The conservative English universities responded much more slowly and much less thoroughly to the new influences. During the professorship of Isaac Newton (1669-1702) and the headmastership of Richard Bentley (1740-1742), Cambridge was given the strong mathematical bent, which it has retained ever since, while the mathematical and physical sciences were also fostered. During the eighteenth century, the Georges founded a number of royal professorships in history and the sciences. But unlike Germany, there was no such renovation of the university there according to the new spirit until late in the nineteenth century."[40]

Vladimir Guerrier offers a picture of university life and the struggle between scholasticism and humanism in France:

Like other medieval institutions of France, for example the parliament, the university was born under the tutelage of royal power and was on the receiving end of its centralizing principle. In France there were several parliaments, but the Parisian parliament was the main one; that is, the highest legal and governmental institution of the whole state. In the very same way, the Parisian University was the highest scientific institution for the entire kingdom, and its history coincides with the history of the French Enlightenment. The remaining universities were nothing more than its provincial affiliates. French universities have yet another similarity with its parliaments. The latter acquired such a rigid organization,

40 Paul Monroe, *A Text-Book in the History of Education* (London: Macmillan & Co., Ltd.; New York: The Macmillan Company, 1909), 501 – 502.

and were shielded by such secular privileges and supported by such extensive class interests, that they became almost inaccessible to the influence of time and new arrangements. The university even lagged behind society at large.

In the beginning of the sixteenth century, the University of Paris became the bulwark of scholasticism against the influence of humanism. King Francis I, as a patron of humanism, had to create a special institution, independent of the university, to support it. This was the famous Collège de France, which exists to this day. The college originally consisted of twelve professors who were appointed by the king himself. They did not belong to the university and their lectures were both public and free. Here, for example, a fearless champion of humanism, of genuine philosophy and of sound pedagogical instincts against vacuous scholasticism like Pierre de la Ramée [*Petrus Ramus*] found refuge from the persecution of offended scholastics. De la Ramée had to struggle throughout his life with his enemies from the universities and perished from their revenge during the St. Bartholomew's Day Massacre. The University showed the same tenacity later in the struggle against the Jesuits who wished to subordinate popular education to their will and to infiltrate the university. Despite having the support of the government, the Jesuits managed only after great efforts to acquire their right to open schools and public courses. Their struggle did not end there, as the university did not permit young people to enter the Jesuit courses to enter the magisterial exams. It was only during the reign of Louis XIV that the Jesuits finally prevailed over the resistance of the university.

In its struggle with the Jesuits, the university was concerned about its own monopoly and not in some substantial difference in the direction and method of teaching. As far as the latter was concerned, enmity was much fiercer, and the university directed such enmity towards Cartesianism.

Humanism was odious to the university because it insisted on a classical education, and based its instruction on the study of the best writers of Greek and Latin literature; so too was Cartesianism, because it placed mathematics and physics in the forefront, and rejected all the scholastic trash which was supported by the authority of the great Aristotle and required [...] dialectical artifice in the place of physical experiments and anatomical specimens. These innovations scared those who lived complacently in the world of *substantial forms* and for the sake of their bizarre metaphysics garbled the Latin language just as they distorted the simple meaning of man. These philosophers had not wanted to recognize any truth in these innovations.

All candidates for philosophy degrees were obliged to acquire their first laurels in the struggle against Cartesianism and to speak out against the new doctrine with the rusty weapon of scholastic dialectics. But, the doctrine soon began to infiltrate the ranks of its opponents, and this only further hardened the university's stance.

When the Archbishop of Paris conveyed the King's decree to the university in 1671, according to which any new doctrines departing from received teachings should be excluded from university teaching and that not a single proposition drawn on these new doctrines should be discussed in scholastic debates, all the faculties (led by the Theological Faculty) hastened to declare their submission and their zeal in prosecuting any innovation. The Medical Faculty did not lag behind the Theological Faculty and the enquiry from Reims Medical Faculty over whether one should reject debating a medical thesis, in which the influence of Cartesianism was reflected, replied that this should not be permitted and that one should respectfully comply with the Royal decree. But, the opponents of Cartesianism were not content with these administrative measures alone: they wanted to obtain a formal prohibition from parliament against disseminating Descartes' doctrines within the kingdom under pain of severe punishment. The university was already preparing a petition along these lines, and the first President of the parliament, Lamoignon, told his acquaintances that there was no way he could not carry out the university's wishes. But to the honor of the university, such an edict was not enacted. Some passionate adherents of Descartes were among its members. And eventually, this whole affair precipitated grave concern in broader society. Arnauld presented a note to parliament, in which he proved with great merit the impossibility of prohibiting the Cartesian doctrine and the harm that such a measure would provoke. History, he states, persuades us that no law can force people to prefer one philosophy over another, and that any such attempt can only undermine the authority of legislative power. Cartesianism was reproached in vain for the fact that it could not be brought into compliance with Church dogmas. The same can be said for any other philosophy. This originates from the fact that any doctrine based exclusively on conclusions drawn from reason is insufficient and cannot satisfy the requirements of faith. If one is to preserve inviolate the principles of faith from the conclusions of reason, then any philosophical system really based on the laws of reason can be made to concord with faith.

A perhaps stronger effect than these philosophical proofs was exerted on public opinion and parliament by the satire written by Boileau together with Racine and Bernier. In this satire which Boileau introduced to his friend

Lamoignon the poets lampooned parliament's regulation against Cartesianism in favor of university scholasticism even before its enactment.

In light of such a strong feeling in society, the University of Paris stopped short of submitting its petition (prohibiting the teaching of Cartesianism) and the Parliament's decision was never enacted. But the example of the main university affected the provincial ones. The University of Angers was to distinguish itself in its prosecution of the new philosophy. Cartesianism was especially prevalent there, due to the activity of several professors who belonged to the Order of the Oratorians and who, therefore, were less dependent on their scholarly colleagues. André Martin was one of the first proponents of Cartesianism, although he found it necessary to work under a pseudonym. His successor in the department, Bernard Lamy, acted even more audaciously. Coquery, the principal of the college who established the order of the Oratorians at the university, also belonged to the adherents of Descartes. In 1675, Angers University received a royal message which, using the example in line with the University of Paris, instructed that the dissemination of new doctrines should in no way be allowed in lectures. Upon the receipt of this message, the whole university decided to take heed and put it in the archive. They then gathered all the rectors of the college, the professors of philosophy and the abbots at the monastery, in order to oblige them to fall in line with the university's decision and finally, to henceforth subject all theses and handwritten textbooks of philosophy to censorship by a special commission appointed by the University. Only Coquery protested and appealed to the Parisian parliament. There in the previous three years, Cartesianism had made great strides, for the parliament annulled the resolution of Angers University and summoned it to court for its abuse of power. But because of this decision, the Parliament itself came into conflict with the government, and at a time when absolutism was in full swing. Shortly before this, the young Louis had appeared at parliament in a hunter's costume and with a whip in his hands. Therefore, following the verdict of the parliament, a royal decree was issued, which annulled this verdict and confirmed the prohibition imposed by the University of Angers against Cartesianism and against its adherents in the Oratorian order.

The universities' opposition against Cartesianism was particularly rigid in character as a result of the fact that the Faculty of Theology was dominant, and because the majority of theologians considered Cartesianism to be incompatible with Christian religion, as it rejected the metaphysical scholastic explanation of the doctrine on transubstantiation. Just as humanism, being outcast by universities, had to search for another body, thereby giving rise to the Collège de France, so too Cartesianism found shelter outside the university and was the cause of the emergence of new scientific institutions. It found this refuge in academic societies, a new phenomenon characteristic of this age. Such societies became legion; in Paris alone, there were around twelve of them. Initially, they had no clearly defined organization, but several of them soon acquired a more coherent character. Eventually, the government turned its attention towards them and under its patronage, formed the Academy of Sciences in 1666 which brought about a fruitful outcome.

We encounter a similar phenomenon in England. There too, the need to find new bodies besides the antiquated universities to successfully develop mathematics and the natural sciences led to the organization of scientific societies and finally, to the establishment of the London Royal Society, which was soon to become famous due to the name of Newton. In France, even in Descartes' lifetime, societies and assemblies of scientists existed which were dedicated to developing his philosophy and which attempted to confirm its outcomes through physical experiments and anatomical research. The Parisian scholars gathered around either Father Mersenne in the Franciscan monastery (*aux Minimes*), or at the place of Abbot Picot's, where Descartes would stay when he came to Paris, or at the place of Habert de Montmor, a member of Parliament. The latter was so devoted to the new doctrine that he begged Descartes to accept a cottage from him as a gift, which would earn an income of 3,000 to 4,000 livres. The members of the society gathered every week at Monmort's to expound and explain Descartes' philosophy. But, Descartes' followers were not content with the scientific societies being accessible only to a few; they disseminated the new philosophy with the aid of public lectures and discussions at which members of all social strata attended. The well-known physicist Rohault, one of Descartes' most scholarly and talented followers, held a public meeting every Wednesday in his house which was attended by bishops and abbots, court doctors, philosophers, mathematicians, teachers, students, provincial Frenchmen, foreigners and artisans; in a word, people of all ages, genders and ranks. In this society, 'ladies came first'. Rohault presented physics at these gatherings, beginning with theory and supporting it with the most precise experiments. Moreover, he allowed everyone to interrupt him with questions and objections. Régis (Pierre-Sylvain) emerged from this school, and went on to read similar public lectures in Toulouse and Montpellier. Upon his return to Paris and after Rohault's death, he renewed his public lectures in 1680 with such success that he harmed his own cause. The Archbishop of Paris, alarmed by the commotion caused by these courses, ordered them to be closed after six months. In his eulogy to Régis, Fontenelle tells us that the interest which they stirred was so great that one needed to arrive long before the start in order to find a free place.[41]

THE STRUGGLE AGAINST FEUDAL UNIVERSITIES

Ratke, Bacon, Comenius and other advocates of progressive ideas of the seventeenth century conducted their work outside the university which had little sympathy for new ideas. Neither the philosophers Descartes, Hobbes and Locke, nor the scientists Harveyand Boyle, nor Bacon (who represented both science and philosophy) were close to the university milieu. Thus, it turned out that new ideas came to fruition in secondary schools and other organizations. The first Academy of Natural Sciences was founded In 1619 in Rostock. During the reign of Frederick the Great (1740-1786), the Berlin Academy was a powerful agent of new ideas.

At the end of the Thirty Years' War (1648), the Ritterakademien (literally 'Knight Academies', which were high schools that specialized in educating the sons of the nobility) once again played a role and became the agent for disseminating rationalist and practical new ideas in contrast to the scholastic and formalistic universities and gymnasia.

In England, Hobbes conducted the struggle against scholasticism and the old universities.

We know that Cromwell wished to establish a new university in the North of England. Hobbes, on the other hand, thought that transforming old universities and freeing them from scholasticism would be, if not easier then at least more feasible. Through his friend, Henry Stubbe, a scholar and physician, Hobbes took part in the Oxford controversy of 1659. One of the disputants, William Dale, used arguments and certain typical expressions taken from the *Leviathan*. And while John Webster's *Academicarum* elicited a reciprocal apologia with the astronomer Seth Ward, in a special "Appendix" to the *Vindiciae Academicarum* (1654), the latter made a point of starting a dispute with Dale and Hobbes (obviously considering the latter his main support). At the same time, Hobbes was drawn into a number of other disputes.

Finally, in London in 1655, the first part of his philosophical system *De Corpore* was published, containing sections on logic, metaphysics and natural

41 Владимир Герье [Vladimir Guerrier], *Лейбниц и его век: Отношения Лейбница к России и Петру Великому, т. 1* (Санкт-Петербург: Наука, 2018 [1868]), 162 – 168.

philosophy. In his dedication (to the Earl of Devonshire) and in a number of paragraphs from the text, the author declares war against theology. He compares it with Aristophanes's Empusa, or, an evil spirit, who roams on bronze donkey legs; like her, theology too has one sturdy leg, the Holy Scriptures, and one lame, metaphysical philosophy.

> **"Leviathan has made all the clergy my foe, — writes Hobbes, — Each nest of theologians was hostile [...]. At first, they wrote libels of *Leviathan* and this only caused it to be read all the more. It gave it a greater force and it will, I hope, be eternally significant and will not need anyone's further defence."**[42]

The dispute with the Oxford Professor John Wallis on the principal questions of mathematics (as a mathematician the latter proved to be right) began at this time and only ended with Hobbes's death. It had a malign impact on Hobbes's relation with a number of friends. This dispute was "directly connected with the dispute about the universities." Wallis and Ward formed an alliance. Wallis belonged to the party of Presbyterians. He attacked his dangerous opponent at his weakest point — in the realm of geometry. Ward went on to attack the foundations of Hobbes's philosophy. Both books came out at the beginning of 1656. In the same year, Hobbes released the English translation of *De Corpore*, in which several chapters on mathematics were revised and added "Six Letters to the Professors of Mathematics [...]" in the form of an appendix. Here, he fiercely defends himself from his attackers, who had moved on to attack the application of algebra and geometry; a realm where Wallis had particularly distinguished himself. In a letter which dates from this time, Hobbes states that he started a dispute with Wallis only because the latter was the mouthpiece of the ideas of the united clergy of the whole country, and hence, addressing Ward, he not only exposed himself to his criticism, but to the *Vindex* (the university defender). This statement is all the more interesting because the dispute occurred in the heyday of Cromwell's power.

Hobbes was accused for having recommended that (the doctrines in) his appendix to the *Leviathan* were to be taught at university and referred to existing universities "shops and workshops of the clergy." He did not want to strike

42 Thomas Hobbes, "The Life of Thomas Hobbes of Malmesbury," trans. J.E. Parsons, Jr. & Whitney Blair, *Interpretationes* 10.1 (1982): 5.

against the university as a corporation, but only aimed at some individuals who wished to preserve there the authority of the Church independently from the State.

> **"Whatever hue and cry you raise, — he wrote — and instead of recommending the teaching of my *Leviathan* in universities, I would propose to organize a new, secular university, where only laymen would teach physics, mathematics, moral philosophy and politics, just as earlier the clergy solely taught theology. Still, it would be useful and without particular expenditures would be of great profit for the improvement of education. Only one building and several principal faculties would be required. It would be good for students to learn as best they could if no-one had arrived at the university sent their parents for students, just as for the learning of a craft so that later one could earn one's bread from this knowledge; but for a university to be a place where richly gifted persons worked who could dispose of their time as they wished, and loved truth for its own sake."**[43]

Here, we see most clearly how far Cromwell's plans coincided with Hobbes' thought.

Hobbes goes on to point out that geometry probably owes more to Gresham College or private individuals in London, Paris and other cities (who never passed through or taught in any universities) than to any university.

There arose a need for new technical schools. Descartes proposed a project for such a school.

Pierre D'Alibert, France's State Treasurer, was one of Descartes' closest friends; he considered Descartes the most suitable person to make useful to society part of that wealth which providence had entrusted to him. He tried many times to tempt him in the same way that Alexander had once tempted another philosopher. Descartes had always defended himself with the same force but, admittedly, with less brilliance than Diogenes. But at least partially succumbing to those noble impulses which D'Alibert had in sacrificing part of his own wealth for the sake of mankind, he persuaded him to establish an institution for the improvement of the arts in Paris.

43 Thomas Hobbes, *Six Lessons to the Savilian Professors of the Mathematics*, in *The English Works of Thomas Hobbes of Malmesbury, vol. 7*, ed. Sir William Molesworth, Bart. (London: Longman, Brown, Green, and Longmans, 1845), 345.

He advised building large halls for craftsmen (each hall being dedicated to a separate craft) at the Royal College and at other institutions intended for the public. Each hall was to be attached to an office, where mechanical instruments (necessary or useful for that art which would be taught there) were to be located. (Monetary) Funds were to be raised, sufficient not only for the expenses needed for experiments, but also to pay for teachers or professors, the numbers of which would be equal to the number of arts which would be taught there. These professors would need to know mathematics and physics so well that they could answer all the questions of the craftsmen and to enlighten them about everything and that clear understanding which would allow them to make new discoveries in art. It should only give public lectures on holidays and Sundays after morning service, so that every craftsman would have the possibility to attend them, with no detriment to their work. Descartes, who proposed this endeavor, assumed that the court would agree to this and that the Archbishops would see in this proposal a good means for distracting people from the drunkenness and debauchery, which are so common on feast days. The decision to implement these great plans was taken by D'Alibert during Descartes' last visit to Paris, but its execution was delayed until his return from Sweden from where he hoped to come and settle in Paris as soon as the city was put at ease with his presence. However, Descartes's death put an end to all these fine projects. D'Alibert was constantly distracted by other affairs, until other friends of Descartes, reminding him of these noble intentions, instilled in him the idea to do something positive that would perpetuate the memory of this recently departed, illustrious figure.

McCauley provides an extremely vivid picture of the interest in science observed in seventeenth-century England:

> **The year 1660, the age of the restoration of the old constitution, is also the age from which dates the ascendancy of the old philosophy. In that year, the Royal Society, destined to be a chief agent in a long series of glorious and salutary reforms, began to exist. In a few months, experimental science became all the mode. The transfusion of blood, the ponderation of air, the fixation of mercury, succeeded to that place in the public mind which had been lately occupied by the controversies of the Rota. Dreams of perfect forms of government made way for dreams of wings with which men were to fly from the Tower to the Abbey, and of double-keeled ships which were never to founder in the fiercest storm. All classes were hurled along by the prevailing sentiment. Cavalier and**

Roundhead. Churchman and Puritan were for once allied. Divines, jurists, statesmen, nobles, princes, swelled the triumph of the Baconian philosophy. Poets sang with emulous fervor the approach of the golden age. Cowley, in lines wright with thought and wit, urged the chosen seed to take possession of the promised land flowing with milk and honey, that land which their great deliverer and lawgiver had seen, as from the summit of Pisgah, but had not been permitted to enter. Dryden, with more zeal than knowledge, joined his voice to the general acclamation, and foretold things which neither he nor anybody else understood. The Royal Society, he predicted, would soon lead us to the extreme verge of the globe, and there delight us with a better view of the Moon. Two able and aspiring prelates, Ward, Bishop of Salisbury, and Wilkins, Bishop of Chester, were conspicuous among the leaders of the movement. Its history (that of the Royal Society. *Ed*) was eloquently written by a younger divine, who was rising to high distinction in his profession, Thomas Sprat, afterwards Bishop of Rochester. Both Chief Justice Hale and Lord Kepper Guildford stole some hours from the business of their courts to write on hydrostatics. Indeed, it was under the immediate directions of Guildford that the first barometers ever exposed to sale in London were constructed. Chemistry divided, for a time, with wine and love, with the stage and the gaming table, with the intrigues of a courtier and the intrigues of a demagogue, the attention of the fickle Buckingham. (Prince) Rupert has the credit of having invented *mezzo tinto;* and from him is named that curious bubble of glass which has long amused children and puzzled philosophers. Charles himself had a laboratory at Whitehall and was far more active and attentive there than at the council board. It was almost necessary to the character of a fine gentleman to have something to say about airpumps and telescopes; and even fine ladies, now and then, thought it becoming to affect a taste for science, went in coaches and six to visit the Gresham curiosities, and broke forth into cries of delight at finding that a magnet really attracted a needle, and that a microscope really made a fly look as large as a sparrow.[44]

It must be emphasized here that experimental science naturally would find its appeal among a vastly larger group of people than that technically

44 Thomas Babington Macaulay, *The History of England from the Accession of James II, vol. 1* (Chicago: Donohue, Henneberry & Co., 1890), 369 – 370.

called the "intellectual class" of the seventeenth century. From the nature of their teachings, scholasticism and humanism had created almost a cast of the learned and molded the realm of mental activities into an oligarchy or aristocracy; experimental science, on the other hand, stood from its earliest stages for the popularization and hence the democratization of knowledge. While previously the topics and modes of contemplation had been removed from everyday objects and the affairs of men and confined to regions of speculation barred from most minds, now the subjects and methods of investigation became closely connected with those of homely life. Moreover, the facts of experimental science were of such a nature that they could be comprehended not by a few highly trained individuals, but by a large number of people of clear mind and comparatively little education.

Whereas before, all intellectual activity had been connected with a mastery of Latin and Greek — an insurmountable barrier to those whose circumstances or inclination had prevented them from learning those languages in youth — now the vernacular, at everyone's command, was sufficient linguistic preparation for anyone to join in the study of the sciences. Before, years of preparation had been necessary to give one the hope, not of adding to, but merely of comprehending the thoughts of those who had gone before them. Now, it had appeared that the possession of "a faithful hand and an observing eye"[45] (Hooke) put the possibility of sharing in discoveries and sharing in valuable work within the reach of vast numbers. Thus, experimental science entered the ranks in competition with scholastic learning and made its strongest appeal not to the erudite university man, who was wedded to accepted tenets and proud of his place in the oligarchy of the learned, but to the *unzunftigen* (non-professional laymen) hitherto excluded from the privileges of mental activity. Indeed, this appeal seemed to arouse tremendous passion at times. Sprat says (1667): "The love of this science is so strongly roused in the century in which we live, that there seems nothing more in vogue in Europe."[46] The development of this love of science among non-university men created the type of the science-loving amateur, which was so characteristic of the latter half of the seventeenth century.

45 Robert Hooke, *Micrographia, or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries Thereupon* (London: J. Martyn and J. Allestry, 1665), viii.

46 Thomas Sprat, *The History of the Royal Society of London for the Improving of Natural Knowledge* (London, 1722 [1667]), <page unknown>.

Amateurs in science — 'amateurs' in the accepted sense of the word, denoting those that practice their art 'not as a livelihood but for the love of it' — were to be found in many places and among many classes of people in the latter half of the seventeenth century. Mainly, of course, they were to be found in circles which were sufficiently wealthy so as not to feel the immediate urgency of gaining a livelihood, and had therefore sufficient leisure to follow their inclinations. As these conditions existed, on the one hand, in the larger commercial centers in England and the Netherlands, on the other, in the homes of the nobles and the privileged classes, it was in these places that such an interest was most conspicuous.

An exhaustive study of the amateur scientists of this age, however interesting, is from the nature of this study, impossible. I shall merely take up a few individual instances to show how broad the interest was, and to illustrate the various types of men who became devotees of the new knowledge.

In Italy, Ferdinand and Leopold Medici found a pastime in experimenting, had a laboratory and a collection of instruments, devised experiments and had a glass blower. Count Federico Cesi, early in the century, was a great lover of science. Count Marsiglio in Bologna was a great experimenter, who gathered men of similar interests around him, and finally bequeathed his home to the university as a laboratory.

In France, the Duke of Orleans, brother of Louis XIV, had a well-equipped chemical laboratory and loved alchemy, but as Saint-Simon says, "not to find gold but to amuse himself with curious experiments." He owned a convex lens of great power, the focus of which would melt and volatilize metallic gold. He also had his own chemists who worked with him. Likewise, he was a great lover of botany and he summoned the prominent English botanist Morison to supervise his gardens at Blois.

France was home to one of the most famous amateurs of all time, Peiresc, the parliamentarian. He was a friend of Galileo, and a frequent correspondent of learned contemporaries. A constant observer of the stars, he bought forty telescopes until he acquired one good enough to follow the observations of Galileo's *Sidereus Nuntius*, though he was unhappy that he missed a transit of Mercury. He was equally interested in the shape of snow crystals, fossilized rocks, fish and plants. His main business was that of assisting learned men, as he is depicted by his friend and biographer, Gassendi. He was so interested in physiology that he conducted experiments on a man to test Harvey's discovery. But France, on the whole, produced few amateur experimenters. There, interest in science often took the form of merely attentive watching of other experimenters' progress, as is seen in the case of Colbert and Denis de Sallo, the learned founder of the *Journal des Sçavans*.[47]

Throughout the seventeenth and the eighteenth centuries, the Dutch were famous for their skill in making fine instruments; in a most real sense, every lens grinder was an amateur scientist. The famous Leeuwenhoek, a linen merchant, was self-taught and indeed so little educated that he understood no language but Dutch. He was, nevertheless, gifted with great manual skill, having made a microscope solely for his own amusement. Gradually, he perfected this skill so that it magnified to 160 degrees and enabled him to study infusoria. He had so many microscopes that he kept one microscope for one or two specimens in his investigations.

Huygens was an amateur in the same sense as Robert Boyle, having dedicated his whole life to science, though not being affiliated with any university. Von Helmont was also a very rich man who had his own laboratory.

In Germany, there are famous instances of amateur interest. The Fuggers, who were rich merchants, took the scientist L'Ecluse along on their travels. There was also Guericke, who, even as mayor of Magdeburg, continued his interest in experimental science, such that when the city was plundered during the Thirty Years' War, he turned to his skill in engineering to earn a livelihood. There was Hevelius (1611-1679), the son and heir of a rich brewer in Danzig, who in 1641 built for himself an observatory, which was the best-equipped of the time, and who ground his own lenses. Furthermore, there was Tschirnhausen, the Saxon Duke, who owned three glass factories, and was not only devoted to science, but the originator of famous physical discoveries. Above all, there was Leibniz, who earned his livelihood as librarian at the Court of Hannover, but constantly worked at physical and mechanical problems.

An odd example of the popular interest in science to which the modern word "fad" might apply were the anatomical dissections open to the public.

There is another mode of gauging the amateur interest of the nations in experimental science other than that of a biographical enumeration of such amateurs. Both in France and in Germany, 'popular' work on experimentation was widely read and released in many editions. In 1624, Leurechon published his *Récréation mathématicque composée de plusieurs problèmes plaisants et facétieux en faict d'arithméticque, géométrie, méchanicque, opticque, et autres*

47 Martha Ornstein, *The Role of Scientific Societies in the Seventeenth Century* (Chicago: The University of Chicago Press, 1928), 53 – 56 [Starting with "It must be emphasized . . . ."].

parties de ces belles sciences. The book was published in seventeen editions in the next year, and saw six French and four English translations, one of which was especially noteworthy, and one into German by Schwenter *Deliciae physico-mathematicae* (1651). It is one of the most instructive books along this line of inquiry. A perusal of its pages gives a clear idea of how much of physics and chemistry may have been within the possession of the interested amateur. We have the description of the experiments made by Schwenter, partly according to Leurechon's direction — all written down avowedly not for study, but for amusement; the experiments are entertaining tricks, not investigations.[48]

SCIENTIFIC SOCIETIES

Scientific societies grew widely in the seventeenth century. The new science was cultivated in them, and not in the universities.

They made every effort to foster the cause of experimental science. This was the touchstone, the charter of their existence, the motive underlying their every activity. Their efforts may be epitomized as follows: The societies concentrated groups of scientists at one place, performed experiments and investigations impossible to individuals, encouraged individual scientists and gave them both opportunity and leisure, often through financial support, for scientific work.

They became centers of scientific information, as they published and translated scientific books, and periodically disseminated scientific discoveries, thus coordinating the scientific efforts of the various progressive European countries. They concerned themselves with matters of domestic interest such as trade, commerce, tools and machinery, and tried to improve the everyday by the light of science. They contributed to the general enlightenment by dispelling popular errors, and at times endeavored to reach the public by means of lectures. But first and foremost, they developed the scientific laboratory, created the national observatory, devised, perfected and standardized instruments, devised and promoted exact methods of experimentation, and thus established the laboratory method as the only true means of scientific study.

Clearly, the conclusion follows that the organized support which science needed in order to become a part of peoples' thought and lives was not obtained from universities, but from activities of scientific societies.[49]

48 Ibid., 64 – 66.
49 Ibid., 259 – 260.

FLORENTINE ACADEMY DEL CIMENTO

In the 1650s in Florence, under the patronage of Ferdinand II and with the participation of his brother Leopoldo De' Medici, the famous Florentine Accademia del Cimento (Cimento meaning experiment. *Ed*) was formed. The main task of the academy was to study nature exclusively through experiments. The influence of Galileo and his disciples was reflected in the new institution. In it, the spirit of Galileo rose from the ashes.

There were only nine members of the academy. The originality of the establishment, which existed for only ten years from 1657 until 1667, consisted in the close unity of the participants, such that each person's individuality was lost and they appeared before the scientific world as one collective person. Works were published on behalf of the collective without designating to which of the members the experiment belonged.

An account of the experiments was published in Florence in 1667, and then in a new edition in 1692 under the title *Saggi di naturali esperienze fatte nell' Academia del Cimento*. The book was dedicated to the Grand Duke of Tuscany.

The Academy opened on 19 June 1657. Sessions took place in the Court of Prince Leopoldo, who was always present. But in Rome, a scientific academy devoted to the study of nature in the spirit of Galileo was met with little favor. When Prince Leopoldo started to cover a cardinal's cap, the condition given to him was that he had to dissolve the academy first. The Prince yielded. To accommodate Ruina, the academy was closed in 1667. In his readings on the history of physics (*Geschichte der Physik*: *Vorlesungen*. Leipzig 1879, posthumous edition), Poggendorf subjects the activity of the members of the academy and the results of their combined works to an extensive examination. The nine members were, in alphabetical order, Giovanni Borelli, Candido del Buono, Paolo del Buono, Lorenzo Magalotti, Alessandro Marsili, Francesco Redi, Carlo Rinaldini, Antonio Uliva and Vincenzo Viviani. Among these, the main figures of the academy were Borelli and Candido del Buono. Magalotti was, as it were, the secretary of the assembly. The *Saggi* were mainly set out by them. We should add that the majority of the members of the academia were of aristocratic origin. These included the Del Buono brothers, Magalotti, Marsili and Redi.

Scientific experiments — and exclusively, experiment without theory and hypotheses, and without mathematical development — was the academy's task; "testing and retesting" (*provando e riprovando*); such was its motto. It was not in the character of the academia, so it was said in the description of the experiments, to argue about the causes of phenomena.

The *Saggi* are composed of thirteen chapters. The first deals with measuring devices and their use; It describes the thermometer and alcohol with an arbitrary scale; a hydrometer, a hygrometer based on the precipitation of air moisture on the surface of a conical vessel, is cooled by filling it with ice. They measured how long the flowing water filled the substituted vessel or parts of it. Apart from the devices, it describes the pendulum as a solid body, hanging on two threads. The experiment protocols note that the pendulum hangs on one thread, and changes the direction in which it swings (as with Foucault's experiments in the future). The second chapter is devoted to numerous experiments on air pressure and the formation of the Torricellian vacuum. Various observations of phenomena in airless space are provided, comparing them with the way they occur in air. The third chapter describes the experiments with artificial freezing; the fourth deals with natural ice; the fifth chapter studies the expansion of metals and other bodies from heat; in the sixth — water compressibility; the seventh provides a proof that there are no absolutely light bodies and that the ascent of light bodies upward is explained by the surrounding pressure, a rather more severe environment; in the eighth, experiments with magnets are described, although nothing substantially new is provided here; in the ninth — experiments with rubbed amber (incidentally, an experiment with the disappearance of the electric state, if the rubbed amber is hung over a flame); the tenth chapter involves a study of the color of some liquids (incidentally, it describes the red color acquired by a solution of litmus from the action of an acid). Experiments on the speed of sound by observing gunshots, made before the opening of the Academy in 1656 by the works of Borelli and Viviani, is described in the eleventh chapter. Chapter eleven is devoted to experiments on falling bodies and air resistance. Academicians made, among other things, experiments on the gun, fired from a moving vessel. Chapter thirteen mentions various experiments, and, among other things, an attempt to measure the speed of light. It also describes observations of phosphorescence and experiments with incendiary mirrors.

THE FOUNDING OF THE LONDON ROYAL SOCIETY

Gresham College is so intimately connected with the early history of the English society that a few words must be said about it here. In his will (1575), Sir Gresham left valuable property to the citizens of London to provide them with a college in his former mansion. Seven professors were to live there in commodious apartments and were to deliver daily lectures to citizens of London on divinity, astronomy, music, geometry, law, physics and rhetoric; indeed, conveying a remarkable interest in the spread of science, and in an attempt to reach the unlettered people.

The group of scientists who regularly gathered at Gresham College later turned into the London Royal Society. These people opposed the old scholastic knowledge. The following lines, excerpts from a poem probably written by William Glanville[50] and dedicated to Gresham College, were very typical of its attitude.

> *In praise of the choice company of Philosophers' and Witts who meet Wednesdays weekly at Gresham College.*
>
> At Gresham College a learned nott
> Unparalleled designs have layed
> To make themselves a corporation
> And know all things by Demonstration
>
> These are not men of common mould;
> They covert fame but condemn gold
> This College Gresham shall hereafter
> Be the whole world's University
>
> Oxford and Cambridge are our laughter,
> Their learning is but pedantry
> These new Collegiates do assure us
> Aristotle's an ass to Epicurus.[51]

Neither the London Royal Society nor the Academie des Sciences was brought to life by a sovereign power, as was the Cimento by the Medici, but rather arose out of informal, spontaneous gatherings of devotees to experimental science, scholars and amateurs. The Royal edict did not create them, but simply

50 Dorothy Stimson would later note that the "Ballad of Gresham College" was most likely penned by Joseph Glanvill. See Dorothy Stimson, "Ballad of Gresham College," *Isis* 18.1 (1932): 104.

51 Charles R. Weld, *A History of the Royal Society with Memoirs of the Presidents, vol. 1* (London: John W. Parker, 1848), 79 – 80n10. For the complete poem, see Stimson, "Ballad of Gresham College," 108 – 117.

gave them a definite, but more enduring, form to their previous organization.

The interests of both of these bodies were not as scientific as those of the Cimento; they were well-nigh all-comprehensive. Purely scientific problems went side-by-side with a consideration of matters pertaining to trade, commerce and manufacture, and it was this phase of their interests which, especially in the first instance, won them royal patronage.

> **"We then discussed — wrote Wallis in his autobiographical note — the circulation of the blood, the valves in the vein, the lymphatick vessels, the Copernican hypothesis, the nature of the comets and new stars, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots in the sun, and its turning on its own axis, the inequalities and the selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes, and grinding of glasses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian experiment in quick-silver, the descent of heavy bodies, and the degrees of acceleration therein; and divers other things of like nature. Some of which then were but new discoveries, and others not so generally known and embraced, as now they are, with other things appertaining to what hath been called the *New Philosophy*, which from the times of Galileo at Florence and Sir Francis Bacon in England, hath been much cultivated in Italy, France, Germany as well as other parts abroad, as well as with us in England […]. About the year 1648-1649, some of our company were removed from Oxford; above all Doctor Wilkins and then Doctor Goddard. Our company split. Those in London continued to meet as before (and we with them, when we had occasion to be there), but our part constantly met at Oxford."**[52]

In 1661, the king granted a Royal Charter to the society, thus codifying its existence in law. Two years later, on April 22, 1663, the Charter was replaced by a new, broader one, which still constitutes the main statute of the society. According to the charter, the Society is composed of the president, the council and its fellows (members): *praesis consilium et sodales Regalis Societatis Londini pro*

52 John Wallis, "Dr. Wallis's Account of some Passages of his own Life," clxiii – clxiv. See Weld, *A History of the Royal Society, vol. 1*, 31 – 32.

scientia naturale promovenda. The king declared himself the founder and patron of the society. As its motto, the society chose a shield with the caption, "*Nullius in verba* (Take nobody's word for it)." There were many proposals for the motto, but the simplest one was chosen. Some proposed to portray a vessel with the caption, "*Et augebitur scientia* (And knowledge will be increased)"; others proposed two telescopes, the earth and the planets with the caption, "*Quantum nescimus* (How little we know)"; another proposal was for the Sun on a shield with, "*Ad majorem lumen* (To the greater light)" and the verse "*Quis dicere falsum audeat* (Who dares speak falsehood)"; on the coat of arms, a caption from the epistles reading "*Omnia probate* (Examine everything)."

Here is an excerpt from the Charter of Charles II, on the foundation of the Royal Society from 15 July 1661:

> Insofar as we are aware that a number of persons of high education, inventiveness and merit, and whose interests and research in these fields converged, have for some time given heed to a custom of meeting weekly and have organized for the discussion of hidden reasons with the aim of establishing definite and correcting undefined philosophical theories, thus to be, owing to their work in the field of inquiry of natural phenomena, the benefactors of mankind; and having already made significant progress through various useful and wonderful discoveries, inventions and experiments in mathematics, mechanics, astronomy, navigation, physics and chemistry — we decided to bestow our Royal blessing, protection and a particular commendation of this eminent society as a useful and laudable enterprise.[53]
> "We have long and fully resolved with Ourself to extend not only the boundaries of the Empire, but also the very arts and sciences. Therefore, we look with favor upon all forms of learning, but with particular grace we encourage philosophical studies, especially those by which actual experiments attempt either to shape out a new philosophy or to perfect the old. In order, therefore, that such studies, which have not hitherto been sufficiently brilliant in any part of the world, may shine conspicuously amongst our people, and that at length the whole world of letters

53 See Weld, *A History of the Royal Society, vol. 1*, 121. This passage does not feature in published copies of the First Charter.

may always recognize us as a Defender of the Faith, but also as a universal lover and patron of every kind of truth: [...] Know that we [...] do ordain, that there shall be a Society, consisting of a President, Council and Fellows, which shall be called and named the Royal Society [...] the Council shall consist of twenty one fellows (of whom we will the President to be always one [...] and that all and other singular persons, who within one month ...shall be received and admitted by the President and Council...whom the more eminently they are distinguished for the study of every kind of learning and good letters, the more ardently they desire to promote the honours, studies and advantage of this society [...] the more we wish them to be especially deemed fitting and worthy of being admitted into the Number of the Fellows of this society."[54]

"The business and design of the Royal Society", writes Hooke, is:

"To improve the knowledge of all naturall things, and all useful Arts, Manufactures, Mechanick practices, Engynes and Inventions by Experiments (not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rhetorick or Logick).
To attempt the recovering of such allowable arts and inventions as are lost.
To examine all systems, theories, principles, hypotheses, elements, histories, and experiments of things natural, mathematicall, and mechanicall, invented, recorded or practiced, by any considerable author, ancient or modern. In order to the compiling of a complete system of solid philosophy for explicating all phenomena produced by nature or art and recording a rationall account of the causes of things.
In the meantime this Society will not own any hypothesis, system, or doctrine of the principles of natural philosophy, proposed or mentioned by any philosopher, ancient or modern, nor the explication of any phenomena whose recourse must be had to originall causes (as not being explicable by heat, cold, weight, figure, and the like, as effects produced thereby); nor dogmatically define, nor fix axioms of scientificall things, but will question and canvass all opinions, adopting nor adhering

54 King Charles II, "Translation of First Charter, granted to the President, Council, and Fellows of the Royal Society of London," *The Royal Society* (1662). https://royalsociety.org.

> to none, till by mature debate and clear arguments, chiefly such as are deduced from legitimate experiments, the truth of such experiments be demonstrated invincibly.
> And till there be a sufficient collection of experiments, histories, and observations, there are no debates to be held at the weekly meetings of the Society, concerning any hypothesis or principal of philosophy, nor any discourses made for explicating any phenomena, except by special appointment of the Society, or allowance of the President. But the time of the Assembly is to be employed in proposing and making experiments, discoursing of the truth, manner, grounds, and use thereof, reading and discoursing upon letters, reports and other papers concerning philosophicall and mechanicall matters, viewing and discoursing of curiosities of nature and art, and doing such other things as the Council or the President shall appoint."[55]

It was typical for the kind of people who joined the society to pursue exclusively practical aims. Sprat (the historian of the Royal Society) described their part of the work in this respect:

> "They raised the issue of the composition of a catalogue of all crafts and industries [...] noting down all physical formulae or know how (manufacturing secrets), apparatus, tools, machines and manual production methods requiring a special skill [...]. They recommended expanding the production of tapestries, silk, smelting ore with coal... to put to the test in various places in England to find out whether its application perfect pottery. They compared the soil and clay of different sorts so as to discover which produced the best bricks and tiles. They engaged in the spreading of the potato crop and set about experimenting so as to obtain oil from tobacco."[56]

Research was also carried out in the field of improving wine varieties, improving methods of cooking and beer, manuring lime, as well as designing a

55 Robert Hooke, British Museum MSS 4441. See Weld, *A History of the Royal Society, vol. 1*, 146 – 148.

56 Thomas Sprat, *The History of the Royal Society of London for the Improving of Natural Knowledge*, 190 – 192. See Ornstein, *The Role of Scientific Societies in the Seventeenth Century*, 120.

new cider press and a lamp for hatching eggs. They studied the means for the production of rapiers in Germany and questions relating to the construction of wagons. Sir William Petti's ship aroused much interest. Winthrop read a report on the convenience of building vessels in some areas of North America, owing to the presence in these places of large reserves of good oak, pine trees and sawmills. On 15 October 1662, the King published a decree, stating that no invention in physics or mechanics could be patented without prior approval by the society. As a result of this, a whole series of machines were submitted for approval; one, for example, for the production of linen, which was interesting for the fact that it was the prototype of Hargreaves's machine. Samples of machines, and in particular, a printing press, arrived for the society's consideration even from Germany.[57]

Wishing to imagine what these collections of the XVII century were like and, in particular, the gatherings of the young Royal Society, it is not necessary to compare them above all with the meetings of our modern academies, since there is no similarity between them. One should note that most of the reports in our academies are the result of observations and experiments. Also, it is very rare for these experiments to be carried out during gatherings, especially since our requirements for experiments and the progress of modern physics are such that even the simplest of them require such care and sometimes such a long amount of time for preparation, as well as that it impossible to think of carrying them out and reproducing them in the presence of members of this gathering. The members of the Royal Society, on the contrary, mainly went to witness the experiments, in which they were interested as much as they were in the conclusions. Wishing to oppose the old method — which considered the description of experiments as blather —, they deemed it not to be trusted. Their main pursuit was experiments, and they sometimes made several of them, in a muddled way, investigating any "rarity in sight." "The Secretary records the results of the experiments, Monconi says, "regardless of their success, so as to be able to detect false assumptions and use correct ones."[58] At the end of each session, they decided what experiments would be conducted in the near future. The members of the society also carried out many experiments in their houses. If the object of investigation was very small or if it was possible to share it, it was left up to Hooke to examine under a microscope. The clerical servant of the society,

57 Ornstein, *The Role of Scientific Societies*, 120 – 121.
58 <Source unknown>.

a courageous old hand, received two pounds of maintenance a year, and was later entrusted four pounds, i.e. about 40 rubles, for his preparation of experiments and the delivery of live animals…, in addition to clerical work. The beginnings of the Royal Society's activities were similar to seminars, where everyone brings their personal work and summarizes the work of others, but they mainly prepared and organized experiments. Reading the book of Birch, accurate and truthful, as all the special magazines, one is present in spirit at the discussions or, better, interviews with well-informed people captured directly, sharing their curiosity about a variety of issues. No matter how humble and primitive all of these studies and experiments were, the germ of the newest science nevertheless rested within them.

In 1684, the Society appointed curators to whom it entrusted (who were charged with) organizing and conducting experiments: the first curators were Robert Hooke and Denis Papin. In the same year, the Royal Society set upeight commissions:

1. Mechanical, which was charged with investigating and improving all inventions in mechanics; it was comprised of 69 members and Lord Brouckner was its chairman;
2. the astronomical and optics panel was comprised of 15 members under the presidency of Doctor Goddard;
3. the anatomical committee was under the presidency of Doctor Ent; all medics and another three members were included in his team;
4. a chemical committee, also comprised of all the medics and another 7 members, was under the presidency of Doctor Goddard;
5. a commission for rural economy (agriculture) with 32 members under the presidency of Goddard;
6. a technological (Histories of Trade) committee of 35 members, presided over by Doctor Merret;
7. a committee of 21 members under the presidency of John Hoskins; it was entrusted with "collecting all the observations of natural phenomena and all experiments already carried out and described;"
8. a commission of 20 members presided over by Poveywho were entrusted with the Society's correspondence.

In addition to those experiments that the Royal Society could undertake domestically, it tried to organize questionnaires abroad.

Thus, from 1661, that is, before receiving the Royal Charter, Lord Brouncker and Robert Boyle were instructed to make an extensive program of meteorological and physical experiments on the peaks of Tenerife. In the same year, before the establishment of the commissions mentioned above, the Society appointed another Commission to draw up a series of questionnaires for foreigners, travelers, etc. So, for example, they learned that Count Sandwich was going to Lisbon, and so members of the Society suggested that he conduct oceanographic research. Travelers and captains who arrived from distant countries were questioned, so that information could be elicited from them. At the onset of winter, a program of refrigeration experiments were planned, since they did not know at that time how to artificially create cold; they asked questions concerning this topic to travelers going to the Netherlands; they petitioned the Lord Lieutenant and the East India company for members of the Royal Society to have permission to be placed under their officers' custody.

Questions of technology were of great interest to our academicians; undoubtedly, as people of business, they had purely practical and material reasons for being interested in these questions, and apparently, by some kind of trustworthy instinct, they understood that artisans and Industrialists kept a lot of valuable and positive information, perfected by thousands of years of practice and which they continued to develop independently of science; this seemed to constitute an enormous arena for scientific achievements; scientific discoveries were possible in workshops and factories just as they were during long journeys. From one Protocol of 1667, we learn that Howard was charged with studying new and old methods of tanning leather, Hooke with those of making soap and hats, Gill with the manufacturing of paper and Thomas Cox of refining sugar. They learned the preparation of cider, discussed the method of preserving and improving wines, the cultivation of melons [...]. They were even interested in how to fashionsteel and brass plates; how to weave wool and the preparation of marbling paper. Reading Birch's or Weld's history of the Society, it is very interesting to see how it gradually developed detailed rules, how important traditions were established; in short, to see how the organism of the Society developed and was determined. These readings lead one to feel in the presence of the continual perfection of a scientific organization. Much more serious thought was given to the recruitment of new fellows and admission to the Society became an ever more arduous process.

FOUNDATION OF THE PARISIAN ACADEMY OF SCIENCES

In the time when the Royal Society was founded in England, in Paris, France, a meeting of scientists assembled weekly to talk about their research and to communicate their observations and discoveries. These gatherings initially took part at the home of one amateur, Monmort and then at that of Melchisedech Thevenot. The latter, an extremely inquisitive man, was interested in all areas of knowledge: he studied history, geography, physics, mathematics, languages and philosophy.

Among those who belonged to this private and free academy were Descartes, Roberval, Blondel, Mersenne, Blaise Pascal and his father. Hobbes was accepted into this society during his stay in Paris in 1640, and it was there where Mersenne introduced him to Descartes. Colbert, seeking all possible means to spread and develop the sciences, realized the benefits the state could reap from this society, and cemented a plan to consolidate its existence through its transformation into a royal institution. Louis XIV approved this plan, and the Academy of Sciences was founded.

The king secured pensions for the academicians and bestowed upon them the decree of being the capital for conducting experiments and for the purchase of instruments. Alongside this, Colbert added a number of young people who wished to devote their life to science with the title of adjuncts (adjoints) and who would work with the Society as helpers in the difficult and complex tasks of the Society. On 22 December 1666, the Academy opened its assembly in one of the halls of the Royal Library. It was established that the Academy would meet twice a week: mathematicians on Wednesdays, naturalists and physiologists, then designated by the common name of physicists, on Saturdays.

BENTLEY'S BOYLE LECTURES AND HIS CORRESPONDENCE WITH NEWTON

Robert Boyle, who died in 1692, appointed the sum of 50 pounds sterling in his will for the organization of lectures, which were to be read annually in one of the churches of England. In these lectures-sermons it was proposed to "set out the arguments in favor of the irrefutability of Christianity and of refuted the unbelief" (proving the Christian religion against notorious Infidels).[59] Bentley was chosen to be the first lecturer, a chaplain of the Bishop of Worcester. As the basic theme of his lectures, Bentley chose *The Confutation of Atheism*. Atheism and materialism were widespread (circulated widely) during this period in England, and caused alarm among the clergy and the ruling classes. Monk, Bentley's biographer, describes the spread of materialist doctrines as follows:

59 <Source unknown>. See Hessen, "The Social and Economic Roots of Newton's *Principia*," 68.

> "It may be observed that the doctrines of Spinoza and Hobbes had made considerable progress in that age among the higher classes of society and were particularly dangerous from the insidious way in which they undermined all belief in natural and revealed religion. Both these writers professed indeed to acknowledge the existence of a God; but by denying the Divine Providence in the government of the world, and by representing the existence of the universe as the result of necessity, they conducted their disciples to the very depths of atheism. The metaphysical subtilty of their reasonings, the assumption of a calm and philosophical tone of enquiry, and the apparent novelty of their dogmas, combined to mislead the unwary. The positions of Hobbes had been ably combatted by Cudworth in his "Intellectual System" and Cumberland in his book *De legibus naturae,* but these works were not sufficiently popular to resist an evil, which had spread so far as to become seriously alarming [...]."[60]

He was deeply compelled by the need to overturn Hobbes's system, of which "the taverns, and coffee-houses, nay, Westminster Hall and the very churches"[61] were full. From personal observation, he was convinced that "not one Infidel in a hundred was other than a Hobbist";[62] and that they all knew well that his theory of a corporeal God was a pretence to elude the premises of the law, or to use Bentley's own expression "a mere sham to get his book printed";[63] for in those days, it seems, religion could not be made the object of open attacks and insults [...][64]

Atheistic writers had propounded that the creation of the world out of chaos, and the subsequent maintenance of our System, were explained by, what they termed, "natural causes." Such schemes, which wholly excluded the immediate agency of the Divine will, had become numerous; but the fact was, that they all contradicted the laws of nature, upon which they pretended to be founded, as completely as was done by the Epicurean hypothesis of atoms descending down an infinite space by an inherent principle of gravitation tending

60 James H. Monk, *The Life of Richard Bentley, D.D., vol. 1* (London, 1833), 38 – 39.

61 Richard Bentley, "R. Bentley to E. Bernard – May the 28th," in *The Correspondence of Richard Bentley, D.D., vol. 1*, ed. Christopher Wordsworth (London, 1842), 39.

62 Ibid.

63 Ibid.

64 Monk, *The Life of Richard Bentley, D.D., vol. 1*, 41.

not towards other matter, but towards a *vacuum*. The erroneous but prevalent system of Descartes, which supposed the planets to be carried by the force of vortices around the Sun, afforded too great a handle for atheistic proponents, not to be pressed into their service."[65]

Concurring with Locke that the concept of deity is not innate, Bentley sought evidence for the existence of the deity in the manifestations of human thought, in the organization of nature and in the structure of the universe. Bentley decided to devote the seventh and eighth lectures to the deduction of the proof of existence of the deity from the structure of the universe, and decided to draw on the basic material for proofs from consideration of the physical principles of the structure of the world as they are provided in Newton's *Principles*. To prepare for this task, he turned to Newton himself, from whom he received a list of books necessary to study the question.

In preparing his lectures for the press, Bentley encountered a number of difficulties and he turned to Newton for their clarification.

Newton was very attentive to Bentley's questions and set out his views on the proof of the existence of God in the following four letters.[66]

65 Ibid., 42.
66 See Hessen, "The Social and Economic Roots of Newton's *Principia*," 68.

Boris Hessen

Boris Mikhailovich Hessen (russ. Gessen) was born 1893 in Elisavetgrad, in the Kherson Governorate of the Russian Empire (now Kropyvnytskyi, Ukraine) to a Jewish middle class family. He studied physics and natural sciences at the University of Edinburgh (1913—1914) together with his school friend and future nobel prize laureate Igor Tamm. He went to study at the St. Petersburg University (1914—1917) and then enlisted in the Red Army in the Russian Civil War. He joined the Communist Party in 1919 and became a member of the Revolutionary Military Council (1919—1921) and worked at the Party School. He also continued his physics studies at various places eventually graduating from the Institute of Red Professors in Moscow in 1928. After working in the institute for two more years, he became a physics professor and the chair of the physics department at the Moscow State University in 1931. In 1933 he was elected a member of the Russian Academy of Sciences.

From 1934 to 1936 Hessen was a deputy director of the Physics Institute in Moscow headed by S.I. Vavilov. On 22 August 1936 Hessen was arrested by the NKVD. He was secretly tried for terrorism by a military tribunal together with his gymnasium school teacher Arkadij O. Apirin. They were found guilty on 20 December 1936 and were executed by shooting the same day. On 21 April 1956 both Apirin and Hessen were rehabilitated (posthumously exonerated).

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The long lost textbook by Soviet scholar Boris Hessen (1893-1936) provides a backdrop for his attempt to develop a historical materialist account of physics as a model for the history of early modern science. It shows that this attempt, signaling the rise of the social history of science, took the complexities of scientific development seriously, in order to provide a deeper understanding of science as such, not only for Marxists. Hessen claims that historical knowledge and its sources provide a rich reservoir, without which science education remains incomplete:

> No matter how new and unusual the theories of contemporary physics may be, no matter how radically they differ from the outlook of classical physics, the contemporary stage of development in physics is still a historical phase of its overall development. Therefore, knowledge of the history, of the origin, and development of physical theories not only aids in understanding its contemporary condition, but also helps to establish its historical roots and, by doing so, clears the way for new research.

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