RESEARCH REPORT 2008—2009

MAX-PLANCK-GESELLSCHAFT

MAX-PLANCK-INSTITUT FÜR WISSENSCHAFTSGESCHICHTE

Max Planck Institute for the History of Science

Cover:
Drawing table of the scientific illustrator Nils Hoff,
Museum of Natural History, Berlin 2006.
Foto: Barbara Wittmann

Back cover:
A section of the Peutinger table, an ancient road map representing the worldview of Roman travelers rather than a geographical mapping. The world, surrounded by water, is extremely distorted, favoring the east-west direction. The original size of the map was ca. 0.34 x 6.75 m. The section displayed here shows Italy and Africa divided by the Mediterranean Sea; it reaches from Lombardy (Insubria) on the left to the city of Milan (Mediolanum) on the right.

Most of the portrait photographs were done by Skúli Sigurdsson.

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Max Planck Institute for the History of Science

Introduction

The Max Planck Institute for the History of Science (MPIWG) comprises three Departments, each administered by a Director, and several Independent Research Groups, each led for five years by an outstanding junior scholar. Since its foundation in 1994 the MPIWG has investigated fundamental questions of the history of knowledge from the Neolithic to the present time. The focus is on the history of the natural sciences, but the history of the human sciences has also played an increasing role in recent research projects. Of central interest are basic categories of scientific thinking and practice as well as their transformation over time, such as, for instance, experiment, observation, space, motion, number or force. The research of the Institute pursues questions of philosophical epistemology historically. The common perspective of the diverse research activities is therefore often labeled as "historical epistemology."

The Library, which now holds over 60 000 volumes as well as the large number of digitized historical sources made openly available with the help of the Institute's Information Technology Group, significantly contributes to these broad-ranging historical inquiries. The approaches and methods used rely on a multitude of disciplines, ranging over the history and philosophy of science, the history of art and literature, cultural studies, the philologies of various languages, psychology and cognitive science to social anthropology and computer linguistics. Since current research projects take a comparative view of scientific developments, disciplines such as sinology, Mongolian and Islamic studies are becoming ever more important. Scholars working at the Institute accordingly have a diverse and often multidisciplinary background, many of them trained in the natural sciences—an important presupposition in particular for dealing with the challenges of recent history of science. This Research Report describes in detail the work of the different research units over the past two years. This work would not have been possible without the support of our Advisory Board. We hope that the results presented in this report will reward the reading.

The three Departments of the Institute approach questions of historical epistemology in different ways. The Departments are organized neither along disciplinary lines, nor according to historical periods. Their work embraces numerous scientific disciplines and large historical timescales. Department I, directed by Jürgen Renn, focuses on

structural changes in systems of knowledge and investigates long-term processes of changes in scientific knowledge. These processes are studied in all their dimensions, in particular with regard to cognitive, material and societal aspects. Scientific knowledge itself is understood as part of a more comprehensive societal system of knowledge. Longitudinal studies examining the development of scientific knowledge from ancient to modern times are being complemented by transversal studies dedicated to global processes of knowledge transfer and transformation. Department II, directed by Lorraine Daston, focuses on the history of the ideals and practices of rationality. It investigates the history of epistemic categories and practices that have become so fundamental for modern science and culture that they appear self-evident, including scientific objectivity and observation. Working Groups composed of scholars from a variety of specialties and national scholarly traditions investigate such the history of such epistemic categories across historical epochs and diverse cultural contexts. Department III, directed by Hans-Jörg Rheinberger, studies experimental systems and spaces of knowledge. The scope of its historical subjects is broad, with special emphasis on the history of the life sciences and the epistemology of experiments. Research projects of the Department also treat foundational cultural techniques of science, the emergence of scientific concepts, and reflections on historicity. The Department of Hans-Jörg Rheinberger will be completing its work in January 2011, while Hans-Jörg Rheinberger himself will remain at the Institute until 2014. In agreement with the rules of the Max Planck Society (MPG) the search for a successor has been initiated. The Independent Research Group I, led by Dagmar Schäfer, at the Institute since 2006, traces the history of innovation in China. It collaborates closely with a Partner Group at the Chinese Academy of Sciences in Beijing.

In their individual research projects the Departments raise complementary questions, which, also in their concrete research, often lead to cooperative ventures. Department I and Research Group I, for example, share an interest in the history of science and technology in China; Departments II and III have common interests in the history of scientific observation and the ways in which observations are registered. All research units have developed an interest in issues of intercultural knowledge circulation. Joint conferences have been dedicated to issues such as historical epistemology and digital publication. The entire Institute has also been involved in a Research Network on the History of Scientific Objects, funded by the Innovation Fund of the President of the Max Planck Society, that also links the MPIWG to major international centers in the history and philosophy of science and technology, both universities and museums.

Over the past years, local cooperation with Berlin universities has intensified, resulting in a formal cooperation agreement in 2007 involving the Max-Planck-Society, the Free University and the Humboldt University. The cooperation has prepared the creation of an International Center for the History of Knowledge in Berlin. The center represents an open forum for the history of science and pursues three closely connected goals: it aims at encouraging an interdisciplinary dialogue with the goal of developing an all-encompassing cultural history of knowledge, it favors the exchange among natural, social, and cultural sciences, and it supports the creation of international research networks.

The establishment of the new center takes place in the context of an upsurge in the history of science at the Berlin universities and a growing interest in this subject. In the past two years, first steps have been undertaken towards dual appointments at both the MPIWG and the Berlin partner universities. Together with the universities, the Max-Planck-Society selected Veronika Lipphardt as a new Independent Research Group Leader in 2009 who has launched her new group "Historicizing Knowledge About Human Biological Diversity in the 20th Century", and who is expected to be appointed as a W2-Professor for the History of Life Sciences at the Free University in 2010. Other new appointments made possible by the agreement included Mark Geller as professor for the History of Knowledge at the Free University, and a new junior professor for the History of the Human Sciences at the Humboldt University, due to be appointed in 2010. The *Kuratorium (Board of Trustees)* of the Institute as well as the Berlin center's cooperation council, established in 2007, supported these cooperation efforts. In this context, partners have begun to intensify cooperation in research, for example, in the contexts of the Excellence Cluster TOPOI and the Berlin School of Mind and Brain. The MPIWG will further strengthen its ties to its Berlin partners in the next years, including the joint appointment of another Independent Research Group Leader together with the Free University. An expansion of the agreement will include the Technical University as well. With additional support by the MPG, the instrument of Independent Research Groups, allowing young and exceptionally gifted researchers to develop their own research projects independently, has been extended even beyond these cooperations so that in 2010, two new Research Groups will be initiated at the MPIWG. Due to the continuing expansion of the Institute, new offices have been procured at the neighboring Harnackstr. 5.

The Institute continues to sustain collaborative research projects with other Max Planck Institutes such as the Bibliotheca Hertziana in Rome, the Max Planck Institute for European Legal History in Frankfurt am Main, the Kunsthistorisches Institut in Florence, the Fritz Haber Institute in Berlin, the Albert Einstein Institute for Gravitational Research in Golm, and the Max Planck Institute for Comparative Public Law and International Law in Heidelberg. International cooperations have been extended beyond the well-established close partnerships in Europe, for example, with the Institute and Museum for the History of Science in Florence, in the U.S., for example, with Harvard University, and in China, in particular, with the Chinese Academy of Sciences. Intensive scholarly relations have meanwhile also been established with colleagues and with institutions in Brazil, Canada, India, Israel, Mexico, Mongolia and Syria.

The MPIWG aims to innovate first and foremost in research, but it has also pioneered new forms of publication and the exploitation of new source materials. The MPIWG has created a new genre of publication, "working group volumes," which are the result of years of collaborative research by teams of scholars, in contrast to the more familiar conference proceedings or edited volumes. Further exploration of new channels of publication, making use of the rapidly developing electronic facilities, is planned. In the past years cooperation with museums and archives has intensified as well, including several exhibitions, in part also available in electronic form. Finally, all research

units are developing electronic research environments for historical work on science and knowledge on the basis of tools developed in cooperation with the Max Planck Digital Library. The Institute thus seeks to fulfill the pledge of the Berlin Declaration on Open Access to Science and the Humanities, launched by the Max Planck Society in 2001, to realize its part in the vision of a global and accessible representation of knowledge.

Obituaries

Blahoslav Hruška 5. 5. 1945 – 26. 6. 2008
At the Institute almost every year from 1995 (Dept. I)
Blahoslav Hruška, director of the Hussite Faculty of Theology at Charles University in Prague, passed away on 26 June 2008. A scholar of Sumerian, Akkadian, cuneiform writing, archaeology, ancient history and philosophy, he found international acclaim with his work on Mesopotamian agriculture. He taught for many years as a visiting professor at the Institute of Ancient Near Eastern Languages and Civilizations in Berlin, and was later involved in numerous international projects, for example, at Cambridge University and at the German Archaeological Institute in Berlin. Bibek, as he was known, was a regular guest of Dept. I where he contributed valuable work to the CDLI project and made substantial contributions to the history of agriculture in the Ancient Near East. An accomplished international research scholar and a kind and considerate person—he will be greatly missed by his many collaborators and friends at the Institute.

Lydia Marinelli 15. 7. 1965 – 8. 9. 2008
At the Institute from January to March 2001 (Dept. III) and
May to June 2008 (Dept. II)
Lydia Marinelli was trained as a historian at the University of Vienna where she received her PhD in 1999. From 1992, she worked as a curator at the Sigmund Freud Museum in Vienna and later served as its director of scientific research. She devoted much of her career to transforming this site from a mere tourist attraction into an institution with growing international prestige producing novel and serious scholarship. Her exhibitions, all realized at the Freud Museum, mostly under difficult conditions, were major contributions to a renewal of the image of Freud and psychoanalysis. She was the first to publish detailed studies on the role of the media and of material

culture in the making of psychoanalytic knowledge in a deep epistemological sense. Lydia was a frequent visitor to the Institute and it was with a deep sense of shock and loss that all those who knew her as a generous and gifted friend and colleague came to learn that she had taken her life on the 8th September 2008 in Vienna. Lydia Marinelli was one of the most brilliant Austrian historians of her generation and her loss is irreplaceable.

Malcolm D. Hyman 12. 11. 1970 – 4. 9. 2009
At the Institute from 2004 (Dept. I)
Malcolm Hyman was a historian of science, a linguist, a classical philologist, a Sanskrit scholar and an information scientist all combined in one person. For Dept. I and for the Institute as a whole he played a crucial role: he was a member of the Collaborative Research Centre 644 "Transformations of Antiquity," he was a key figure in the project on the globalization of knowledge and its consequences, he initiated a workshop series on multilingualism and linguae francae, he successfully led a very productive group in the context of the Max Planck Digital Library, he organized one of the Cross-Sectional Groups of the TOPOI Excellence Cluster, and he was always there to give advice, to help out, or to stimulate new ideas. He was an outstanding scholar and a warm and gentle human being, a unique mind whose loss is irreplaceable. He leaves behind his wife Ludmila and their one-year-old son, Stanley.

Naamah Akavia 18. 9. 1977 – 7. 2. 2010
At the Institute from January to March 2008 (Dept. II) and from October to November 2008 (Dept. III)
Naamah Akavia was a student in the Adi Lautman Interdisciplinary Program for Outstanding Students at Tel-Aviv University. She completed her MA thesis at the Cohn Institute for the History and Philosophy of Science and Ideas in 2003, for which she was awarded the Amos Funkenstein Prize. That same year, she was accepted as a Ph. D. student in the Department of History at the University of California, Los Angeles, where she started to work on her dissertation. She became particularly interested in the theoretical conceptualization and clinical practice of psychotherapy in Germany and Switzerland in the 1920s, in particular, in the motives of dynamism and motion so virulent in the work of Hermann Rorschach, Ludwig Binswanger, and Hans Prinzhorn, on whom her work came to focus. In 2008 Naamah spent time as a predoctoral fellow in Dept. II and was invited to continue work on her dissertation by Dept. III. Unfortunately her health condition forced her to return home to Tel Aviv for medical treatment, during which she was devoting all available time to the completion of her thesis. Naamah was able to send her completed work to the History Department of UCLA a few days before she died on 7 February 2010. We will keep her in our minds as a fine scholar and colleague.

Table of Contents

Structure and Organization of the Institute

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Lorraine Daston

Department III
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Departments and Research Groups

Department I Structural Changes in Systems of Knowledge

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RESEARCH SCHOLARS *Dr. Peter Beurton* (associated), *Jochen Büttner*, *Giuseppe Castagnetti*, *Dr. Jacob Lebovitch Dahl* (until September 2008), *PD Dr. Peter Damerow* (associated), *Carmen Hammer*, *Prof. Dr. Dieter Hoffmann*, *Dr. Malcolm Hyman*, *Dr. Horst Kant*, *Dr. Falk-Juri Knauft* (since September 2008), *Prof. Dr. Wolfgang Lefèvre* (associated), *Dr. Christoph Lehner*, *Dr. Ernst-Wilhelm Osthues*, *Dr. Albert Presas i Puig* (since August 2008), *Simone Rieger*, *Dr. Matthias Schemmel*, *Dr. Arne Schirrmacher* (since December 2009), *Dr. Wolfgang Schmidle* (since September 2008), *Dr. Volkmar Schüller*, *Matteo Valleriani*, *Prof. Dr. Renate Wahsner* (associated), *Dr. Milena Wazeck*

Department II Ideals and Practices of Rationality

DIRECTOR *Prof. Dr. Lorraine Daston*

RESEARCH SCHOLARS *Dr. Charlotte Bigg* (until December 2008), *Dr. Grégoire Chamayou* (since September 2009), *Dr. Suparna Choudhury* (since September 2009: Research Group Leader), *Dr. Andreas Mayer*, *Dr. Tania Munz*, *PD Dr. Christine von Oertzen*, *Dr. Thomas Sturm* (until September 2009), *PD Dr. Fernando Vidal*, *Dr. Annette Vogt*, *Dr. Kelley E. Wilder* (until August 2008)

Department III Experimental Systems and Spaces of Knowledge

DIRECTOR *Prof. Dr. Hans-Jörg Rheinberger*

RESEARCH SCHOLARS *Dr. Dr. h. c. Hans Erich Bödeker*, *Dr. Christina Brandt* (since February 2006: Research Group Leader), *Dr. Bernd Gausemeier*, *PD Dr. Christoph Hoffmann*, *Prof. Dr. Ursula Klein*, *Dr. Julia Kursell*, *PD Dr. Sybilla Nikolow* (April– September 2009), *Dr. Irina Podgorny* (October 2009 – September 2010), *Dr. Henning Schmidgen*, *Dr. Alexander von Schwerin* (November 2008 – March 2009), *Dr. Barbara Wittmann*

Independent Research Group I (2006 – 2011)

Concepts and Modalities: Practical Knowledge Transmission

DIRECTOR *PD Dr. Dagmar Schäfer*

RESEARCH SCHOLAR *Dr. Martina Siebert* (until November 2009)

Independent Research Group III (2009 – 2014)

Historicizing Knowledge about Human Biological Diversity in the 20th Century

DIRECTOR *Dr. Veronika Lipphardt*

RESEARCH SCHOLAR *Dr. Susanne Bauer*

Administration, Coordination, Services

Hannah Lotte Lund (Coordinator of the Network "History of Scientific Objects"), *Claudia Paaß* (Head of Administration), *Jochen Schneider* (Research Coordinator), *Urs Schoepflin* (Head of Library) *Dirk Wintergrün* (Head of Information Technology Group), *Dr. Hansjakob Ziemer* (Cooperations and Public Outreach)

Members of Department I
(from left to right, top to bottom):
Albert Presas i Puig, Lindy Divarci,
Stefan Paul Trzeciok, Johannes Mücke,
Dennis Kirchhoff, Anna Holterhoff,
Martin Thiering, Mark Geller,
Florentina Geller, Jochen Büttner,
Beatrice Gabriel, Peter Damerow,
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Matthias Schemmel, Jürgen Renn,
Dieter Hoffmann, Christian Joas,
Oksana Kuruts

Department I

Structural Changes in Systems of Knowledge

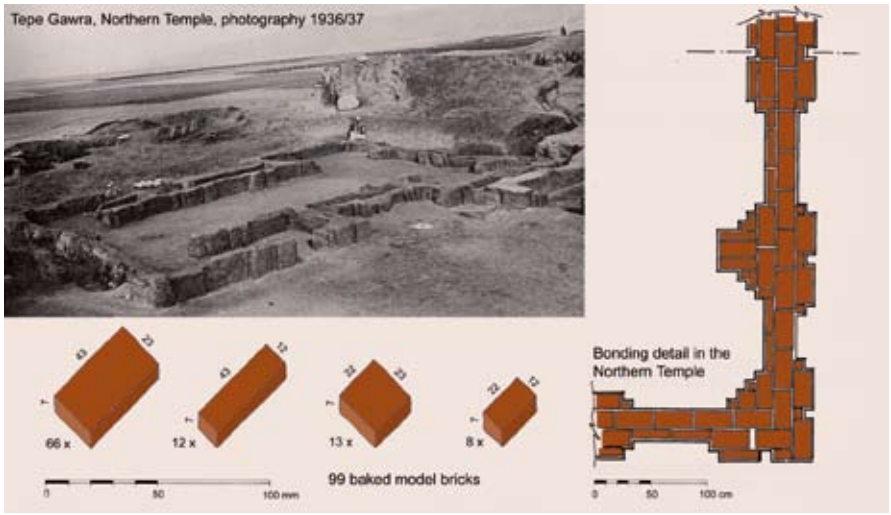
Director: *Jürgen Renn*

Research Focus

The work of the research group headed by Jürgen Renn is dedicated to understanding the historical processes of structural changes in systems of knowledge. This goal comprises the reconstruction of central cognitive structures of scientific thinking, the study of the dependence of these structures on their experiential basis and on their cultural conditions, and the study of the interaction between individual thinking and institutionalized systems of knowledge. This theoretical program of a historical epistemology is the common core of the different investigations and research projects pursued and planned by the research group. Historically, they stretch from ancient Babylonian mathematics and medicine to recent physics and institutional history of science.

Approach and Achievements

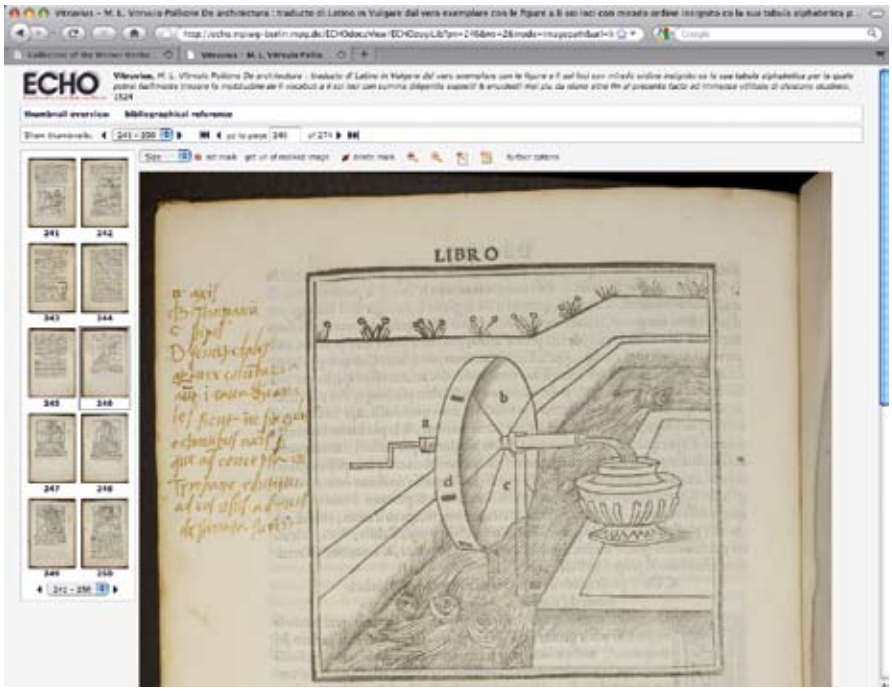
Department I understands its research program of a historical epistemology as contributing to an evolutionary history of knowledge but also to the reflectivity of present science and its institutions. The emphasis is on macro-studies to enable the identification of large-scale structures of knowledge development in social, technological, and cultural contexts. Approaches, methods, and objects of inquiry are taken from a large array of disciplines, ranging from the history and philosophy of science, technology and art, via the cognitive sciences and linguistics, to archeology, Middle Eastern studies, classics, Sinology, Indology, sociology, to physics, mathematics, chemistry, and other natural sciences. The creation of innovative IT instruments is essential for managing the concrete historical evidence for the research of Department I, provided by sources that are written in various languages and come from a broad range of historical periods, cultures, and fields. The work of the Department continues to take inspiration from challenges of the present and future development of science, tackling such issues as the role of the new information technologies, globalization, and the position of science in society. It thereby opens up opportunities for younger scholars of the Department in finding positions in a broad variety of fields, including science organization and dissemination, in addition to academic positions within and outside the history of science.



Preliminary planning in the 5th-millennium: complex bonding systems for bricks were laid out using small model bricks. Mesopotamia Tepe Gawra II, northern Iraq, chalcolithic period (ca. 4500–4500 BC). Partly redrawn after Arthur J. Tobler, *Excavations at Tepe Gawra*, 1950.

Research in Department I has led to the formulation of an overarching theoretical framework, offering cohesion to the wide spectrum of individual research activities realized under its auspices. Among past achievements was the filling of this framework with studies on the emergence of writing and mathematical thinking in ancient civilizations, investigations of the role of practical knowledge for the emergence of early modern science, a long-term history of mechanical thinking, a comprehensive analysis of the relativity revolution at the beginning of the 20th century, groundwork for a long-term history of the development of architectural knowledge, as well as studies of knowledge development in an intercultural perspective. The Department has thus contributed to extending the perspective of the history of science to include a broader range of knowledge.

As the research projects of Department I integrate insights from a wide range of disciplines, cultures, and historical periods, they are realized in cooperative networks extending well beyond the boundaries of the Institute. The Institute typically represents, however, a central node of such networks, bringing together scholars to form teams characterized by intense co-operation over longer periods of time. The challenges of cross-cultural comparisons, diachronic studies of historical developments, and the close integration of computer-assisted source analysis and scholarly interpretations



A rare historical source on the history of architecture: *Vitruvius' De architectura*, 1524 from the Werner Oechslin Library collection in Einsiedeln, digitized and made openly accessible via the ECHO research environment.

are addressed with the help of a combination of core teams, who bear the main responsibility for a project, and an array of informal working groups which are often independently funded, characteristically shaped by the interests of younger scholars and connected by weaker or stronger links to the activities of the core team. A scientific coordinator is assigned to supervise each of the four central projects. Exploring and validating theoretical conclusions with reference to the vast collection of primary sources, but also building upon the existing scholarly literature would be inconceivable without the support and substantial active participation of the Institute's library, and the information management facilities that were built up with the support of the IT group.

Two-volume edition of *Yuanxi Qiqi Tushuo Luzui*, 1627 (Collected Diagrams and Explanations of the Wonderful Machines of the Far West), the first Chinese translation of Western mechanical knowledge and machines. The first volume (left) comprises essays, the second (right), a facsimile reproduction, transcription and commentaries.

Cooperations with the other departments, with the Independent Research Groups, and with other Max Planck Institutes have proven particularly valuable for the research pursued in Department I. Questions concerning knowledge and belief but also the challenges of archival science have emerged as a common interest with Department II, while processes of intercultural knowledge transfer in modern science are jointly studied with other Departments and Independent Research Groups. Investigating the role of challenging scientific objects in various historical contexts has remained a common concern of all three departments. The ECHO (European Cultural Heritage Online) infrastructure maintained by the Department jointly with the IT group and the library, continues to serve as the basic model and as a sustainable framework for all research projects of the Institute that deal with the digitization of cultural heritage. Research on the history of Chinese knowledge and its interactions with European science has greatly benefitted from cooperation with the Independent Research Group led by Dagmar Schäfer, but also with the Institute's Partner Groups, both the former and the present one, at the Institute for the History of Natural Sciences of the Chinese Academy of Sciences in Beijing. One of the results is a two-volume book publication in Chinese on the interaction between European and Chinese mechanics.

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A common ongoing activity with the Independent Research Group and the present Partner Group headed by Sun Xiaochun focuses on the relation of ancient Chinese astronomy to the instruments used for astronomical observation documented by a text

of Shen Kua 沈括 (1031–1095), perhaps the earliest extant Chinese treatise on astronomical instruments. Furthermore, supported in part by the Strategic Innovation Fund of the President of the Max Planck Society, joint research endeavors have been undertaken also with other Max Planck Institutes, in particular with the Biblioteca Hertziana, the Fritz Haber Institute, the Kunsthistorisches Institut in Florenz, and the Max Planck Institute for Comparative Public Law and International Law. Resulting from the cooperation with the Biblioteca Hertziana, a major two-volume book publication has been dedicated to an epistemic history of architecture, conceived as the long-term history of the knowledge that has made the great architectural achievements of mankind possible. In cooperation with the Fritz Haber Institute a comprehensive history of quantum physics is in preparation.

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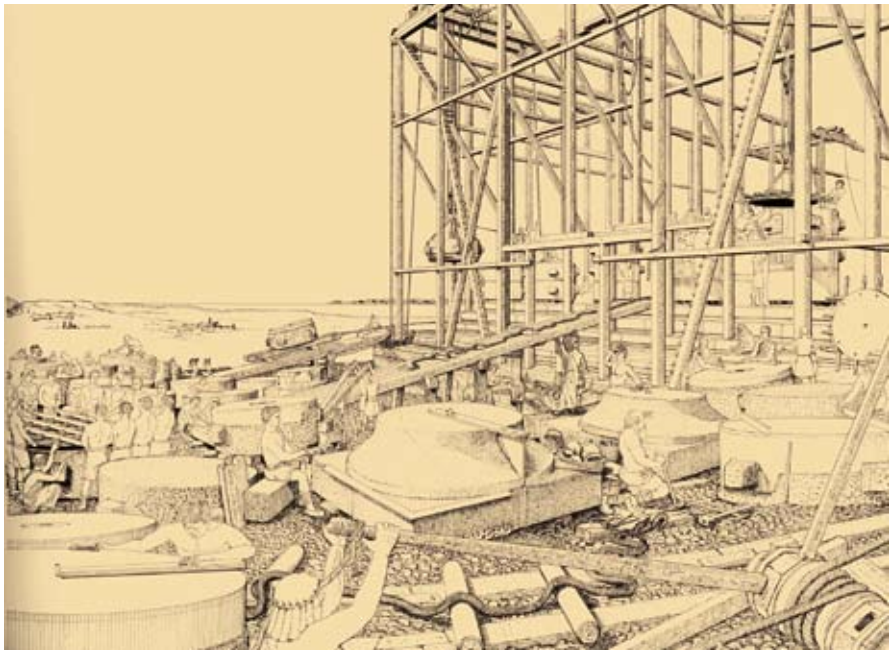
As will be discussed more extensively below, the Department is also involved in institutionalized cooperations with other research centers both in Berlin and worldwide, benefitting from additional funding from the Deutsche Forschungsgemeinschaft, from the Humboldt Foundation, the German Academic Exchange Service, and from other sources. One major cooperative venture is the *Project Cluster of Excellence TOPOI–The Formation and Transformation of Space and Knowledge in Ancient Civilizations.*



Construction of the Older Parthenon on the Athenian Acropolis: Erection of the outer colonnade, shortly before 485 BC: Carving, surface-dressing, hoisting and placing of column drums and capitals. Drawing by Manolis Korres in M. Korres, *From Pentelicon to the Parthenon*, 1995.

The Cuneiform Digital Library Initiative (CDLI) was launched by the Institute together with the University of California at Los Angeles, with support from the US National Science Foundation (NSF) and is now co-funded by the Mellon Foundation.

Completed Project: Epistemic History of Architecture

This joint project with the Biblioteca Hertziana in Rome and a team of scholars from several universities and institutes has completed its research in 2009. In the same year, a final internal workshop was held near Berlin, and some of the findings were presented at a symposium at Einsiedeln/Switzerland organized by the 'Bibliothek Werner Oechslin' and the Institute. The project was dedicated to establishing a long-term epistemic history of architecture, a new approach which focuses on knowledge as a crucial factor for the development of the building trade, in addition to the material, logistic, financial and personal resources involved. The historic periods covered by the project start with the very beginning of stone architecture in the Neolithic era and comprise the early civilizations in the Middle East and Egypt, Ancient Greece

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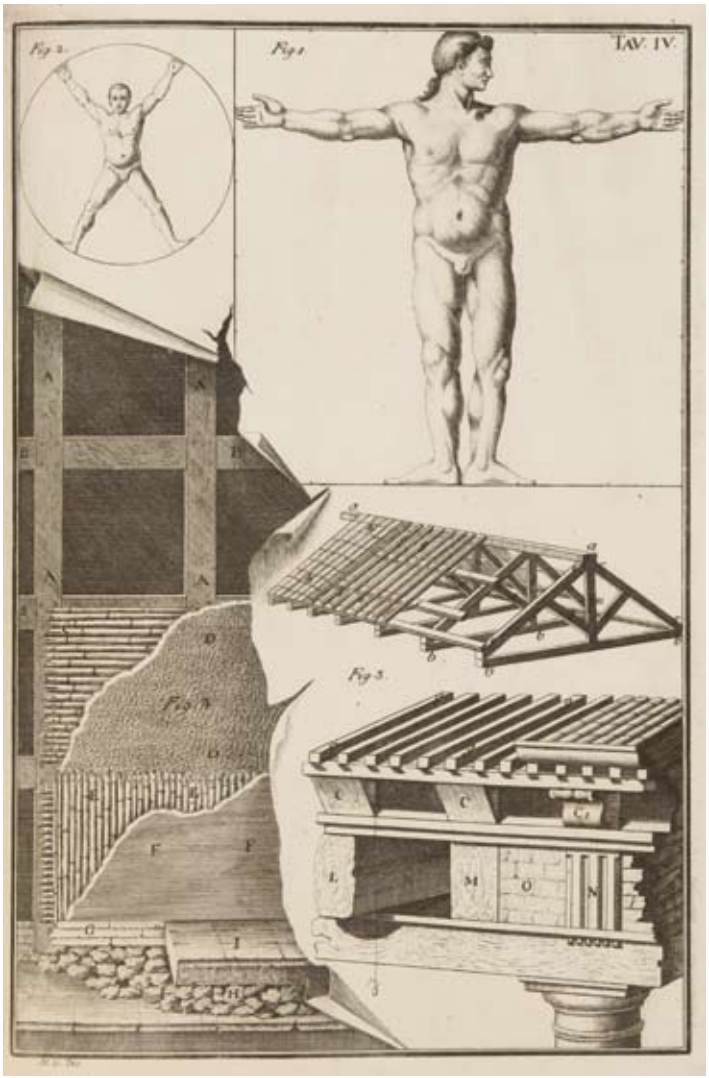
and Rome, the Medieval period in northern Europe and the Italian Renaissance. The findings of the project for the various periods investigated provide new insights into the specific qualities of practical knowledge.

The final publication comprises three major sections. In the first section, the theoretical and methodological framework is presented, which focuses—for the first time—on knowledge as a decisive resource for the history of architectural development. An explanation is also given of the dual structure of the work, i. e., the distinction between contributions labelled as 'basics' or 'specials': the 'basic' contributions essentially represent review or survey papers and cover entire periods following a homogeneous set of fundamental topics and questions, whereas the 'special' contributions constitute more specialized contributions dedicated to key issues that called for substantially novel research because of their impact on building knowledge.

The second section comprises the main contributions and opens with a basic review of the Neolithic era in South-West Asia (Dietmar Kurapkat). Others are devoted to ancient Mesopotamia: a basic overview (Uwe Sievertsen) is complemented by special contributions dealing with cuneiform sources on architecture (Markus Hilgert), architectural drawings (Claudia Bührig) and the building trade in the older Babylonian period (Rosel Pientka-Hinz). A special contribution on Egypt (Ulrike Fauerbach) is followed by two basic surveys on Greece and Ancient Rome, together with an in-depth study of visual refinements in canonical architecture (Wilhelm Osthues). Further basic reviews cover the Middle Ages in Northern Europe (Günther Binding) and the early modern period (Hermann Schlimme, Dagmar Holste, Jens Niebaum). Related specials contributions study the documents of the erection of the famous Cupola of the Florentine cathedral (Margaret Haines), the role of architects as researchers, the complex design of profiles for column shafts (Antonio Becchi), and the architectural knowledge contained in German 'Hausväterliteratur' (Torsten Meyer). The final section is dedicated to the overall interpretation and discussion of the project's findings about the long-term development of building knowledge. A collection of relevant sources on the epistemic history of architecture was made freely available via the ECHO website. Work on this subject is being continued in the context of the collaboration with the Werner Oechslin Library in Einsiedeln.



Bones, muscles, ligaments of the construction and a new interpretation of the Vitruvian man. From B. Galiani, *L'architettura di M. Vitruvio Pollione, colla traduzione italiana e comento del Marchese Berardo Galiani,* 1758. Courtesy of the library of the Max Planck Institute for the History of Science. Courtesy of the library of the Max Planck Institute for the History of Science.

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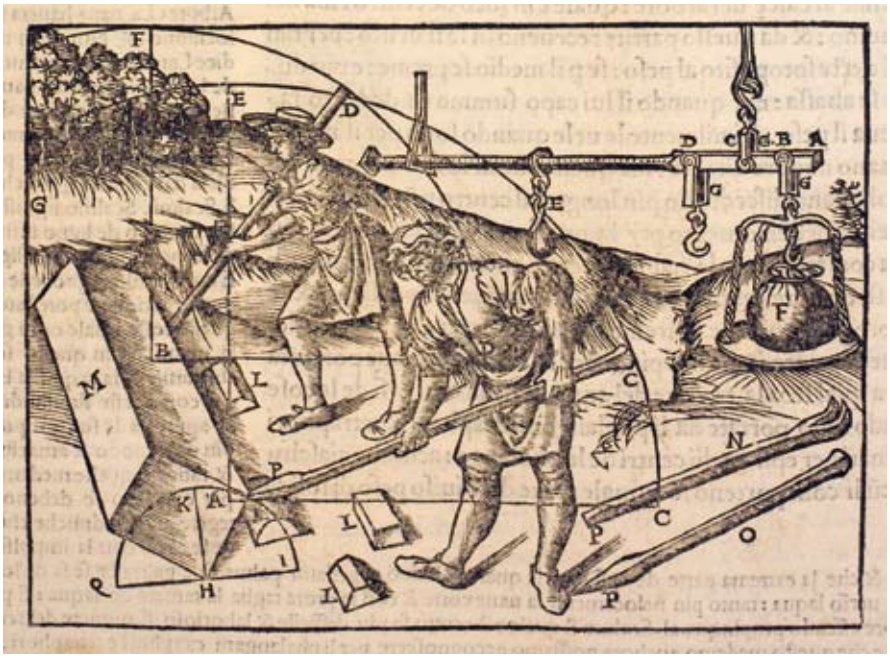
Ongoing Projects

Present research focuses on four central projects and on a cluster of activities directed at new forms of creating access to the empirical basis as well as to research results of the history of science. Each of the projects is coordinated by a research fellow and involves its own forum of discussion (project colloquium), while overarching issues are being discussed at team meetings involving the scholars responsible for the individual projects.

1. Mental models in the history of knowledge: the relation of practical experience and conceptual structures in the emergence of science



Geometrical analysis of circular motions in the employment of basic mechanical devices such as the lever. Illustration by C. Cesarino, Vitruvius, 1521. Courtesy of the library of the Max Planck Institute for the History of Science.

The aim of the project has been to study the origins and long-term development of scientific knowledge and to analyze the role of practical experience for the emergence and development of fundamental scientific concepts, such as those of weight, force, and motion. The project seeks to understand the emergence of such fundamental concepts as a result of reflecting on practical experiences, prior to the period in which experiments became the dominant experiential basis of science.

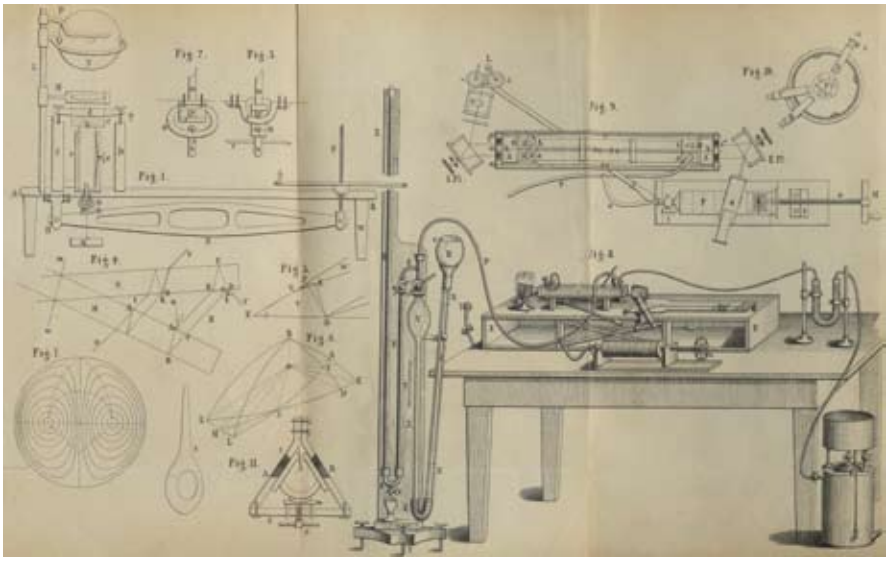
The project is in the final phase of publishing its results, in particular, in a book series entitled *The Historical Epistemology of Mechanics* issued as part of the *Boston Studies in the Philosophy of Science*. At the same time, a number of follow-up studies have been undertaken in the framework of institutional cooperations, which made it possible to approach new subjects such as the emergence of modern hydromechanics in relation to pre-existing practical knowledge. In the report period the project has particularly benefitted from the support of the German Israeli Foundation (GIF) and the German Research Foundation (DFG) in the context of the Research Center—*Transformations of Antiquity* (coordinator: Matteo Valleriani).

2. Reorganizing knowledge in developed science: the history and foundations of quantum physics

The second project studies the reorganization of knowledge in developed science in the case of the development of quantum mechanics. It thus continues earlier studies on the relativity revolution in reconstructing the conceptual revolution of modern physics. A deeper understanding of this conceptual revolution requires tracing its roots in the established concepts and foundational debates of classical science. The project

studies the empirical evidence and theoretical conflicts that led to a need to reassess established knowledge, and follows the conflicts about the reinterpretation of this knowledge within new conceptual frameworks.

The project, coordinated by Christoph Lehner, is a joint venture of Department I with the Fritz Haber Institute of the Max Planck Society (MPG), funded by the Strategic Innovation Fund of the President of the Society. It has established itself as the center of a large international network of historians, physicists, and philosophers. Through regular meetings and collaborative publications, it aims at establishing a continuing dialogue about the history of the conceptual foundations of quantum physics, transcending traditional disciplinary boundaries.



Technical illustration showing a Jamin interferometer for the measurement of optical dispersion. E. Ketteler *Beobachtungen über die Farbenzerstreuung der Gase*, 1865.

Just as the previous project on the relativity revolution, the project collects and digitizes key sources in the history of quantum mechanics. This includes the digitization of the existing microfilm archive for the history of quantum physics and the cataloging and digitization of Erwin Schrödinger's papers. The aim is to make these sources openly accessible.

3. TOPOI—Historical Epistemology of Space: Experience and Theoretical Reflection in the Historical Development of Spatial Knowledge

The project on the historical epistemology of space is part of the Department's broad involvement in the Excellence Cluster 264, TOPOI: *The Formation and Transformation of Space and Knowledge in Ancient Civilizations,* which is a cooperative venture of the Free University, the Humboldt University of Berlin, the Berlin Brandenburg Academy of Sciences and Humanities, the German Archeological Institute, the Prussian Cultural Heritage Foundation, and the Max Planck Institute for the History of Science. Its long-term aim is to establish a lasting institutional structure for research on Antiquity: the Berlin Antiquity College.

Two dimensional models of spaces with different curvatures (Euclidean; spherical; hyperbolic). In 20th-century relativistic cosmology, it turned out that physical space is not Euclidean, but can only be adequately described as a curved four-dimensional Riemannian manifold. The modern transformations of ancient concepts of space are a central concern of the project on the *Historical Episemology of Space*.

From the beginning of the TOPOI initiative in 2007 to the present, the Department has actively participated in forming the cluster. It is represented in the cluster's executive board (Jürgen Renn, member, and Matthias Schemmel, deputy) and in its organizational infrastructure, Jürgen Renn being the spokesperson of Area E, one of the five research areas of the cluster, jointly with Ernst Osterkamp of Humboldt University. The Area is central to the cluster in at least two respects: (1) It is the only research area whose historical subject goes beyond antiquity, investigating the later transformations of ancient spatial knowledge until the present. It therefore offers a reflective perspective on ancient knowledge which is of crucial relevance for the cluster at large. (2) It contains the so-called Cross-Sectional Groups which have the explicit mission to integrate research from different areas of the cluster by reflecting upon their results against the background of more general questions of the history of knowledge, and to feed back their results into the more specialized research projects. Within Area E, a series of working meetings has been held furthering the cross-fertilization of the research activities on space as transformed in the history of science centered at the Department on one hand and those on the transformation of spatial concepts in literature, art, and architecture centered at the Humboldt University on the other.

The TOPOI project cluster further provided a framework for those research activities of the project *The Globalization of Knowledge and Its Consequences* that relate to the ancient world. Thus, work on the spread of knowledge through ancient cultures particularly focused on the role of writing, language, and multilingualism in the framework of a TOPOI Cross-Sectional Group. Contributions to the project by Manfred Krebernik, Mark Geller, and Mark Schiefsky were completed during their stay at the Institute.

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4. The Globalization of Knowledge and its Consequences: The Transfer and Transformation Processes of Knowledge across Different Cultures

The fourth project, coordinated by Milena Wazeck, focuses on the conditions, pathways, and consequences of globalization processes of knowledge. The project aims at developing a new framework: a comparative history of knowledge on a large scale in which present processes of globalization are conceived as the outcome of historical developments and their interactions.

Transmission of knowledge by teaching. In an Islamic Madrasa, Al-Harir, *Maquamat*, Bagdad 1237 (left) © bpk-images; during the Renaissance, depicted on a marble panel by Luca della Robbia, ca. 1438 (right).

The four research foci of the project address historical phases in which knowledge production, transmission and transformation were critical for advancing processes of intercultural transmission. The first focus investigates a series of processes in the very early phases of globalization from the transmission of practical knowledge to the emergence of science. The second focus explores how knowledge was

disseminated as a consequence of the spread of power and belief structures on the Eurasian continent. The third focus deals with the encounters between culturally specific knowledge and globalized knowledge. The fourth focus is dedicated to the great challenges such as energy supply and climate change that humanity faces today when dealing with knowledge.
The research network established in 2007 has since been expanded. The participating scholars have collaborated in a variety of workshops and meetings on developing a theoretical framework and on producing a series of publications dedicated to an integrated and coherent history of the globalization of knowledge.

History of Science in Action: Alternative Forms of Dissemination
Further areas of work belong to what may be called "history of science in action" and are coordinated by Simone Rieger. Alternative forms of dissemination have been adopted to investigate the potential of the history of science as a mediator between science and society by exploring new forms of combining scholarly communication with public outreach, also in the service of the Max Planck Society as a whole. New forms of dissemination include the development of advanced tools for an historical epistemology: New electronic media have been used and developed—in close cooperation with the library and the IT group of the Institute—to explore innovative ways of creating access to the empirical basis and the research results of the history of science.

Training session at the Mongolian Academy of Science 2008: Simone Rieger (center) showing Mongolian historians how to use the virtual spaces tool for a future virtual exhibition of historical Mongolian photo collections.

Events and Developments

The period of the report was mainly characterized by a consolidation of the new projects, in particular the quantum project and the project on the globalization of knowledge, and by substantial efforts invested in collaborative research on ancient science and its transformations, in particular in the context of the TOPOI-project and the Research Center—*Transformations of Antiquity.* Both projects successfully underwent external evaluations within this period. The sudden death of Malcolm Hyman in 2009, collaborating with both projects, as well as with the globalization project, was a major loss for the Department.
In 2008, Arne Schirrmacher was awarded the publication prize of the Deutsches Museum for his article "Der lange Weg zum neuen Bild des Atoms." In 2009 Milena Wazeck was awarded the Georg-Uschmann prize for the history of science from the German Academy of Sciences, Leopoldina for her thesis on Einstein's adversaries. In the same year, Julia Damerow received a special award for an outstanding contribution to computational science from the Heinz-Billing-Foundation of the Max Planck Society for her diploma thesis "Entwicklung eines MDD-Tools für eine virtuelle Ausstellung." Miki Elazar was awarded the 2009 Funkenstein Prize of the Tel Aviv University for his doctoral dissertation "Honoré Fabri and the Concept of Impetus: A Bridge between Paradigms". Together with Susan Neiman, Iris Nachum and Barbara Hahn, Peter McLaughlin received the 2009 Margherita-von-Brentano-Preis for the comprehensive edition and publication of the Nachlass of Margherita-von-Brentano.

Title page of Milena Wazeck's book *Einsteins Gegner*.

Collaborative Ventures

The ongoing investigations of the Department have once again been expanded with collaborative ventures supported by third-party resources. Several major research initiatives have been launched, such as the Excellence Cluster TOPOI or joint research ventures in Brazil, India, Israel, Mongolia and Spain.

Frontispiece of the Jesuit scientist Mario Bettini's *Aerarium philosophiae mathematicae*, 1648.

Since January 2005, the Department has been part of the Research Center—*Transformations of Antiquity* at the Humboldt University in Berlin, which concentrates on the transformation processes by which European cultures, arts, and sciences were formed in a continuation of the cultures of antiquity. The scholars of the Department taking part in this venture focus in particular on the conceptual structural changes in ancient knowledge as a result of its transmission. Within the framework of this cooperative venture, a special initiative has been launched with the Garden of Pratolino in Florence to investigate the transmission and transformation of the technical knowledge of antiquity. Its aim is to enable a comparison of the conflict between technical and theoretical knowledge during the Renaissance and during antiquity.

The cooperation on *Jesuit Mechanics in the Seventeenth Century: Scientific Education in a Catholic Context,* launched in 2008, is partly funded by the German Israeli Foundation for Scientific Research Development (G.I.F.) and undertaken with the Cohn Institute for History and Philosophy of Science and Ideas at Tel Aviv University. It continues to examine an important aspect of the development of mechanical knowledge: the dissemination and transmission of scientific knowledge in the early modern period through the highly developed communicative network of Jesuit colleges and universities. A further cooperation with the Biblioteca Nacional de Portugal (BNP) was established to digitize and make openly accessible the Jesuit Coimbra Commentaries on Aristotle.

In addition to the ongoing collaborations of the project on the *History of Quantum Physics*, a new cooperation was launched with the Universidade Federal da Bahia in Brazil to research the history of the interpretational debates in quantum physics.

In the frame of the Department's cooperation with the Centre for Logic, History and Philosophy of Science at the University of Rostock, a new study was launched in January 2009 on the reorganization of knowledge in the life sciences.

Also in 2009, a new Minerva Center for the Humanities, headed by Rivka Feldhay, was founded at Tel Aviv University. In collaboration with Department I and oth-

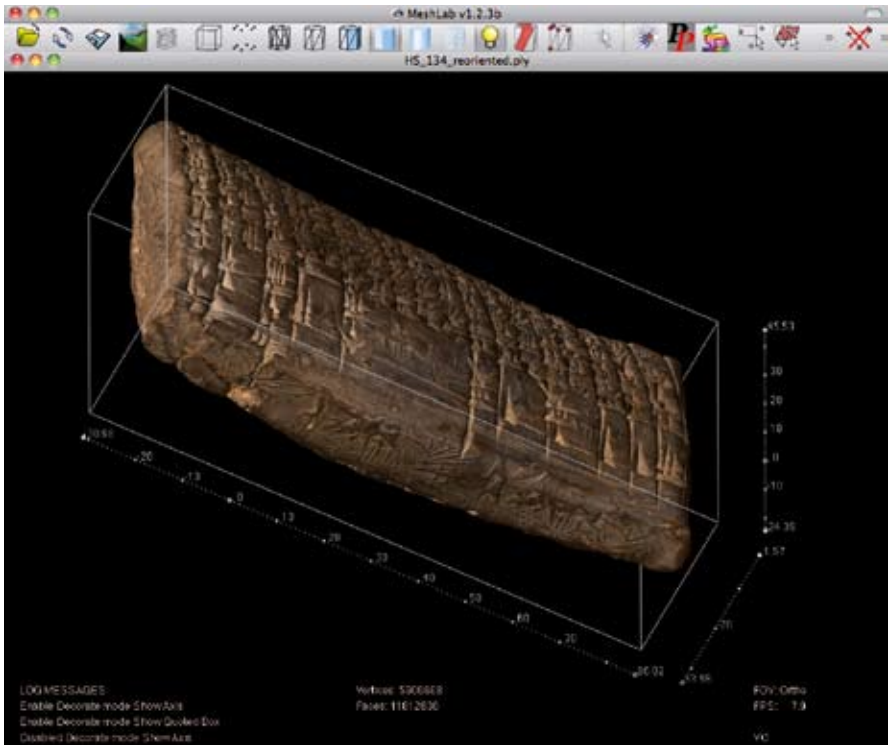
er international research institutions, the section on *Migrating Knowledge* will explore knowledge in its dynamic dimensions focusing on a series of historical cases of knowledge transmissions between Europe and the Middle East and between Asia and Europe. → p. 55

The Department's activities in developing an innovative digital infrastructure to support its research have continued in close cooperation with the Max Planck Digital Library (MPDL), a central body for scientific information management, which the Institute has helped to set up.

Several institutes of the MPG, among them the MPIWG, are developing a close cooperation with the Mongolian Academy of Sciences. A competence center for the digitization of Mongolian cultural heritage at the Mongolian Academy of Sciences is being established with the support of Department I and the Institute's library. This center supports the preservation of Mongolian cultural heritage by making it freely available in digital form using the advanced infrastructure developed within the Max Planck Society for such purposes, in particular the ECHO environment.

In cooperation with the Independent Research Group led by Dagmar Schäfer and Department II, an initiative was launched by the Max Planck Society in India to set up a new Partner Group to undertake research on the historiography of knowledge in different cultural contexts. → p. 178

A research venture "Convivencia" has been launched together with the Spanish Consejo Superior de Investigationes Científicas (CSIC) by the Human Sciences Section of the MPG, following an initial proposal by the Kunsthistorisches Institut in Florence together with Department I. A preparatory conference took place in 2009 that investigated from a multidisciplinary perspective a formative period of the European world with its cultural and religious heterogeneity: the encounters and exchanges between



3D-scan of a sealed cuneiform tablet from the Hilprecht Collection at Jena.

Jewish, Christian and Islamic communities and elites in the millennium between the decline of the Roman empire and the beginning of the early modern period.
The ongoing collaboration between the MPIWG and the CDLI continues to augment the efforts of an international group of Assyriologists, museum curators and historians of science to make openly available through the Internet images and content of cuneiform tablets dating from the beginning of writing, ca. 3350 B. C., until the end of the pre-Christian era, cataloging cuneiform collections and capturing images of the cuneiform tablets. In the frame of CDLI, a cooperation between the MPIWG and the Friedrich Schiller University of Jena (FSU) was launched in December 2008 that aims to digitize the cuneiform tablets and the archival materials of the university's Hilprecht Collection and thus provide metadata for classifying the materials and reconstructing the process of the early philological and archaeological work. Pioneering 3D-scanning technology has been acquired that produces virtual images to replicate the original cuneiform tablets. Together with the Hilprecht Collection and the Kunsthistorisches Institut in Florence, in 2009 the project organized an international workshop in Jena on the future perspectives of the use of 3D-technologies in the sciences. This workshop became the starting point for cooperation between several research institutions on new applications dealing with three-dimensional data.

Project 1

Mental Models in the History of Knowledge: The Relation of Practical Experience and Conceptual Structures in the Emergence of Science

General Goals of the Project

The project focuses on mechanics as a part of science that has extraordinary significance for the development of science in general. More than other disciplines, mechanics has a continuous tradition from its origins in antiquity to the elimination of fundamental categories of mechanics by modern physics. The project covers the period from antiquity to the emergence of classical mechanics in early modern times. Key issues are followed up into the 20th century by the research activities of the project on *Reorganizing Knowledge in Developed Science*. Substantial parts of the project have been completed. The results have motivated an extension of the project to cover related areas such as hydromechanics and practical pneumatics. Furthermore, central ideas of the project are being pursued in cooperations with other institutions and with several visiting scholars, enriching the project's findings with complementary investigations, such as the reconstruction of the process of transformation of ancient culture during the early modern period.

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In the case of mechanics, knowledge structures can be reconstructed in terms of a variety of mental models which partly fulfilled functions in specific contexts of application, later covered by abstract concepts such as weight or force. The overarching vision of the project is realized following a series of different phases ranging from the emergence of theoretical mechanics in antiquity, via its elaboration in the scholastic framework, to the further transformations of this knowledge in the Renaissance and the subsequent creation of classical mechanics. This vision includes the investigation of the crucial role that practical knowledge played in all these historical phases as well as the relation between individual and shared knowledge. Taking these dimensions into account, the project has been able to show how social conditions and material culture shaped the large-scale structures of scientific development.

The Ancient Origins of Theoretical Mechanics

The use of mechanical tools predates any theoretical attempt to explain their function. The oldest known of these attempts date to the time of ancient Greece. The early Greek treatises not only changed the conditions for the construction of mechanical

devices but also provided a model case for the structure of scientific theories: experiences of practitioners are traced back to principles from which they can be deduced as necessary implications. Paradigmatically, the work of Archimedes on the equilibrium of planes embodies this notion of a deductive theory.

The investigation of the emergence of this notion of a deductive theory in ancient Greece and the study of its impact on the later development of mechanics is a central activity pursued to understand the emergence of theoretical mechanics (Peter Damerow, Peter McLaughlin, Jürgen Renn). The *Mechanical Problems* of Aristotle (or of one of his disciples) played a crucial role in the early development of theoretical mechanics. Traditionally this treatise has been studied either with philological methods to evaluate the authenticity of attribution to Aristotle as its author, or from the viewpoint of later mechanics as an early application of the law of the lever. In contrast to such investigations, the treatise has been analyzed here against the background of the multilayered knowledge system of mechanics as a transformation of existing knowledge into a new form. In applying this method, it was shown that the treatise is not based on any theoretical explanation of the law of the lever, but rather on a principle that represents a general experience of practitioners and that is best interpreted as a precursor of the law of the lever. This principle can therefore be interpreted as the missing link between the long tradition of mechanical practices and the foundation of theoretical mechanics. On the one hand, it can be traced back to experiences of practitioners. On the other hand, its application is based on the Aristotelian notion of syllogism and not yet on the proof techniques of mathematical deduction as applied to mechanical theorems by Archimedes. In this respect the treatise represents a missing link in yet another sense, namely between the rules of philosophical discourse and the rules of mathematical proofs. It is this crucial position between the first-order knowledge of practitioners and the higher-order knowledge created in Greek philosophy that explains the impact of this treatise in the European Renaissance.

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This is confirmed by a comparative analysis of the first early modern theories of the strength of materials. These theories were presented in the context of early modern commentaries on Aristotle's *Mechanical Problems*. The Aristotelian commentators developed such theories while sharing the practical rules concerning resistance and stability that were embodied in pre-modern building methods established over centuries by architects, shipwrights and machine-makers (Matteo Valleriani). This investigation has shown how novel theorems were formulated on the basis of a process of transformation of ancient theories in view of contemporary practical activities.

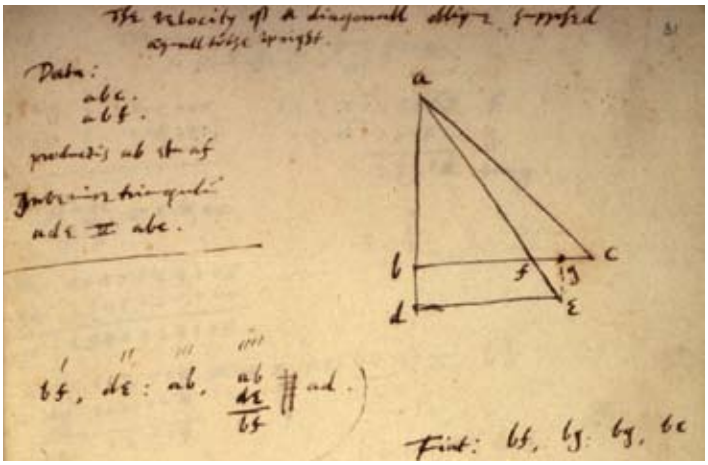
Scholastic Elaborations of Ancient Mechanics

Aristotelian mechanics remained dominant in Medieval times but was enriched in the 14th century by the work of the Oxford *calculatores,* who expanded the ancient theory of proportions, and by the Parisian School, which supplemented the Aristotelian theory of qualities with diagrammatic representations that went beyond the ancient means of representing functional dependencies. To investigate the process of scholastic elaborations of Aristotelian mechanics the *Liber de triplici motu,* published in 1509 by Alvarus Thomas, an early modern Portuguese natural philosopher, is being

translated, analyzed, and interpreted (Stefan Trzeciok). This book about the theory of proportions and the Aristotelean theory of motion represents the culmination of the scholastic dispute about motion before the rise of preclassical mechanics and was directly relevant to Thomas Harriot's studies on mechanics. As a first result, a full-text electronic edition of Thomas Alvarus' book is being published within the ECHO infrastructure.

The Use of Scholastic Tools in Early Modern Mechanics

The mathematical tools that were further developed or originated in the medieval scholastic tradition, such as the theory of proportions or the diagrammatic representation of change usually associated with the name of Nicolàs Oresme, constituted an important precondition for the mathematical treatment of various subjects of early modern science. In the case of early modern treatments of the motion of fall, the combined application of these two tools resulted in new interpretations of the diagrams themselves and eventually in the transformation of fundamental mechanical concepts like that of velocity. The hitherto unpublished working notes of the English mathematician and philosopher Thomas Harriot (1560–1621) contain the most systematic exploration of the implications of the medieval diagrams for the understanding of motion known to us. They clearly reveal the new practical contexts of early modern applications of medieval tools, such as the increasing importance of artillery in early modern warfare, as well as the conceptual difficulties that had to be overcome, such as the interpretation of diagrams in terms of proportions relating space traversed, time elapsed, and velocity. A comprehensive edition and detailed analysis of Harriot's manuscripts on motion has been published as a two-volume set in the Department's series on *The Historical Epistemology of Mechanics: The English Galileo: Thomas Harriot's Work on Motion as an Example of Preclassical Mechanics* (Matthias Schemmel). The book contains facsimile reproductions and transcriptions of the 180 folio pages as well as a thorough interpretation which sets Harriot's work in the context of early modern mechanics.



Thomas Harriot's use of medieval diagrams of change in his notes on the motion of fall, motion along inclined planes, and projectile motion. On this particular folio Harriot determines the ratio of the velocities of two downwards motions, one along a vertical line of given length and one along an inclined plane of the same length (British Library Add MS 6789, f. 31r, excerpt).

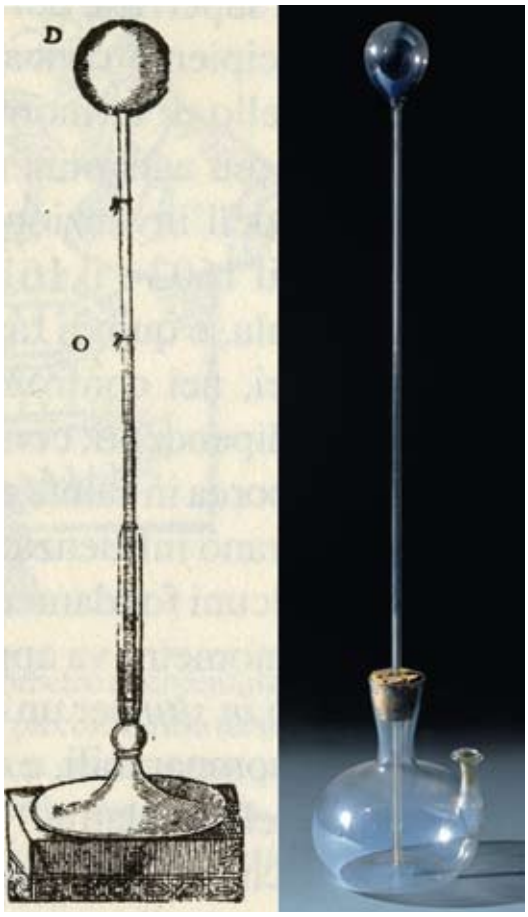
The Impact of Practitioner's Knowledge on Early Modern Mechanics

A series of research activities examined the role of practical knowledge in the development of theoretical mechanics during the early modern period. These activities deal with three questions. What are the relations between practical and theoretical knowledge? What is the structure of practical knowledge as far as it influences the development of theoretical knowledge? What are the socio-economic conditions of the development of practical knowledge?

The work of Galileo Galilei is particularly suited as a model case for addressing the first question. In order to understand the practical background of his theoretical achievements, his apprenticeship as an artist-engineer between 1584 and 1589 and the practical activities performed during his stay in Padua between 1592 and 1610 were analyzed. It was thus shown that his profile was comparable to that of a contemporary military engineer. Practical concerns had an immediate impact on Galileo's theoretical achievements. During his stay in Padua, Venetian authorities led an official enquiry concerning practical issues such as the maneuverability of large galleys. As it turned out, it was in reaction to this enquiry that Galileo developed his theory for analyzing the resistance to fracture of materials, later published in the *Discorsi* in 1638.

During his apprenticeship Galileo also became an expert in pneumatics. In particular he worked on an ancient pneumatic device, mentally re-configured into what is now called thermoscope and used for the first time to determine temperatures. The search for an explanation of the functioning of the thermoscope led Galileo to the formulation of the hypothesis of the discrete nature of heat, published in 1623 in *Il Saggiatore*.

The starting point of such investigations by Galileo was constituted by a set of mental models rooted in Aristotelian natural philosophy, which were transformed in the course of confrontation with practical experiences (Matteo Valleriani). The results of this research are published in a book entitled *Galileo Engineer*, the second volume in the series *The Historical Epistemology of Mechanics*.



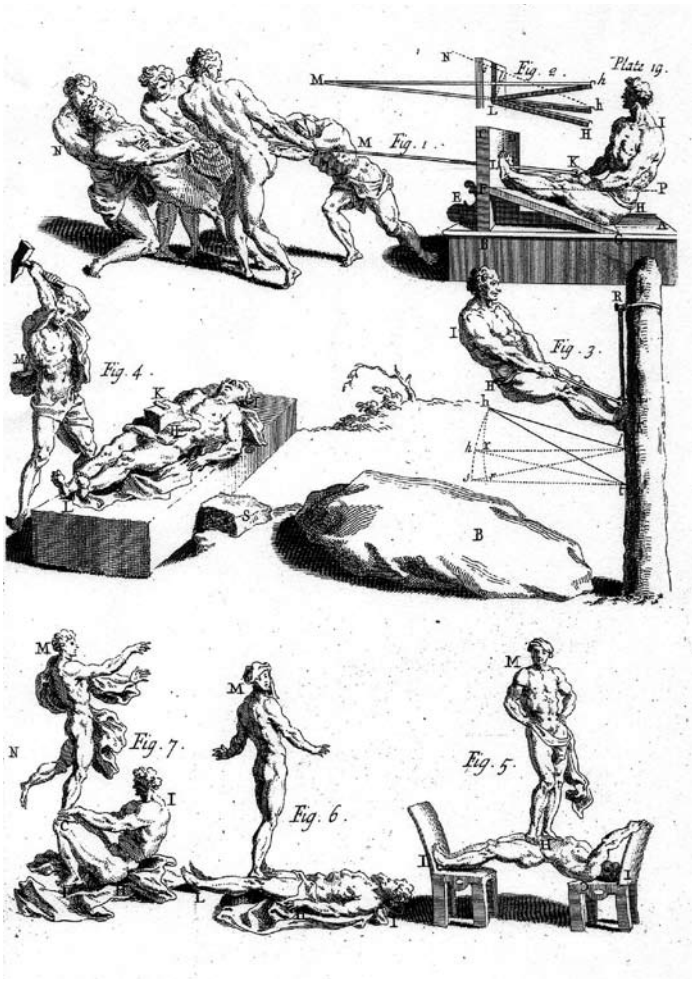
Example of an early thermoscope, from Sanctorius, 1646 (left); Replica of Galileo's thermoscope, IMSS Florence (right), photo by Franca Principe, inv. N° 2444.

In order to address the question of the impact of practical on theoretical knowledge in the context of another, closely related field, the role of early modern hydraulic and pneumatic technology for the development of hydromechanics was examined (Matteo Valleriani). Within the framework of the collaboration with the Research Center—*Transformations of Antiquity*, it could be shown, in particular, that hydraulic engineers, who constructed the Garden of Pratolino near Florence—one of the greatest achievements of early modern technology—relied on ancient sources which they interpreted in the context of Renaissance technology. This research was based on a newly established virtual archive of relevant sources accessible on the ECHO website and via a virtual reconstruction of the garden <pratolino.mpiwg-berlin.mpg.de>. The wider historical background of hydromechanics was studied focusing on the analysis of texts related to clepsydra, water-clocks, the shaduf and Archimedes' screw (Elio Nenci). The relation between practitioners' and scientific knowledge was furthermore examined by investigating the history of the design and construction of complex two- and three-dimensional shapes in architecture and ship geometry. Before 1800, the task of conceiving, documenting and fabricating such shapes constituted an important interface between practical and theoretical knowledge. A volume has been published that comprises comparative results in both naval and civil architecture from classical antiquity to the Renaissance (Wolfgang Lefèvre, Horst Nowacki). Another study has shown that the theoretical reflection of mechanical practices are

not necessarily confined to the realm of mechanics. This becomes particularly evident by the role that anatomy played in the interpretation of the stability of buildings (Antonio Becchi).

Work on the role and structure of practical knowledge was supported by a database of machine drawings. Extending earlier work, these drawings have been systematically analyzed with regard to technical components and pictorial language in social context. They have been made available as part of the Archimedes digital research library, including rare manuscripts from the 15th and 16th centuries (Wolfgang Lefèvre, Marcus Popplow).

The influence of the socio-economic conditions on the development of practical knowledge is revealed by a case study that examines the life and works of the mathematician, architect and engineer Mutio Oddi of Urbino (1569–1639), a contemporary of Galileo and pupil of Guidobaldo del Monte (Alexander Marr). This study has identified the growing overlap between mathematics, instrumental practice, bookish knowledge, and visual culture in the Late Renaissance through close examination of a voluminous archive of manuscript material, comprising some 1000 letters, notebooks, and unpublished treatises.



The 'Mystery of the feats done by Sampsons, or strong men' described by J. T. Desaguliers in *A Course of Experimental Philosophy*, 1734. Courtesy of the library of the Max Planck Institute for the History of Science.

The development of mechanics as the result of an interaction of practical knowledge with other forms of knowledge ranging from antiquity to the early modern period finds its parallels in the evolution of optics and music theory as fields of scientific knowledge similarly dependent on the accumulated experiences of practitioners. Work on a critical edition and translation of Isaac Newton's *Opticks* has continued (Volkmar Schüller). Further work has also been dedicated to the investigation of the process of arithmetization of the theory of proportions in early modern music and its consequences on the contemporary development of theoretical music (Oscar Abdounur).

The analysis of the social contexts of science in the 17th century and the investigations on the origins of "externalism" in science studies has motivated a reconsideration of classical papers (Peter McLaughlin, Gideon Freudenthal). A collection of papers by Boris Hessen and Henryk Grossmann was published with an introduction explicating and analyzing the classical Marxist approach to an explanation of the Scientific Revolution developed in these writings. It was shown that Hessen and Grossmann, far from arguing that science was pursued in order to improve technology, focussed on the role of technology as the precondition and subject matter of theoretical knowledge.

The Impact of Challenging Objects

In the context of the technological development of the early modern period, certain devices, material objects and processes assumed the role of challenging objects for traditional conceptual frameworks of mechanics. Examples are the pendulum, flywheel, and projectile trajectory. The concepts of the extant theoretical frameworks of mechanics were probed by their application in the investigation of these novel challenging objects. The new results thus account for the inherent potential of the challenging objects to trigger and advance conceptual developments. This mechanism contributed decisively to the revolution of the theoretical knowledge of mechanics in the early modern period.

A central case study explores the reorganization of knowledge taking place in the course of Galileo's research process, which is documented by a vast collection of correspondence and research notes. It has revealed the challenging objects that motivated and shaped Galileo's thinking and closely followed the knowledge reorganization that these engendered. The problem of reducing the properties of pendulum motion to the laws governing naturally accelerated motion on inclined planes have thus been shown to have served as the mainspring for the formation of Galileo's comprehensive theory of naturally accelerated motion. These insights have made it possible to rewrite the history of Galileo's theory of motion as a transformation of the shared knowledge of preclassical mechanics, which is comparable to other intellectual trajectories. The focus on challenging objects has thus enabled an understanding of congruent theoretical developments—so characteristic for the period—which cannot be accounted for by oral and textual transmission alone. Another stimulus for the development of the theoretical knowledge of mechanics was the fact that the theoretical accounts given for these challenging objects often sought to mirror and account for the complex relations of these objects in their technological context to other objects and phenomena outside this context. In Galileo's case this led to the integration of established theoretical results that were previously considered to be unrelated. One example is Galileo's integration of knowledge concerning the motion of fall, the pendulum and the inclined plane. This is evidently an important mechanism for the unification of mechanical knowledge. The results of the case study is now being prepared as the third book of the book series *The Historical Epistemology of Mechanics, Galileo's Challenges: The Origin and Early Conceptual Development of Galileo's Theory of Naturally Accelerated Motion on Inclined Planes* (Jochen Büttner).

System of pneumatic automata representing Vulcan's Forge. Drawing by Giulio Parigi, *Gabinetto di Disegni e Stampe*, Uffizi Gallery, Florence.

Further studies pursued in the framework of the Research Center—*Transformations of Antiquity* have deepened the historical understanding of challenging objects in their historical contexts. It has thus turned out, for instance, that the introduction of the fly-wheel as a machine part in the late Middle Ages served as a source for early modern reflections on rotational motion, challenging Aristotelian notions. In the frame of the Network History of Scientific Objects a workshop was organized to explore and elaborate a historiographical approach to the role that a particular type of object played in a particular period for the development of a particular body of knowledge—the challenging objects of early modern mechanics.

→ Conference, p. 214

Archimedes' burning mirror. Fresco by Giulio Parigi, ca. 1600, 'Stanza delle Matematiche' Uffizi Gallery, Florence.

Expansion of Preclassical Mechanics in the Early Modern Period

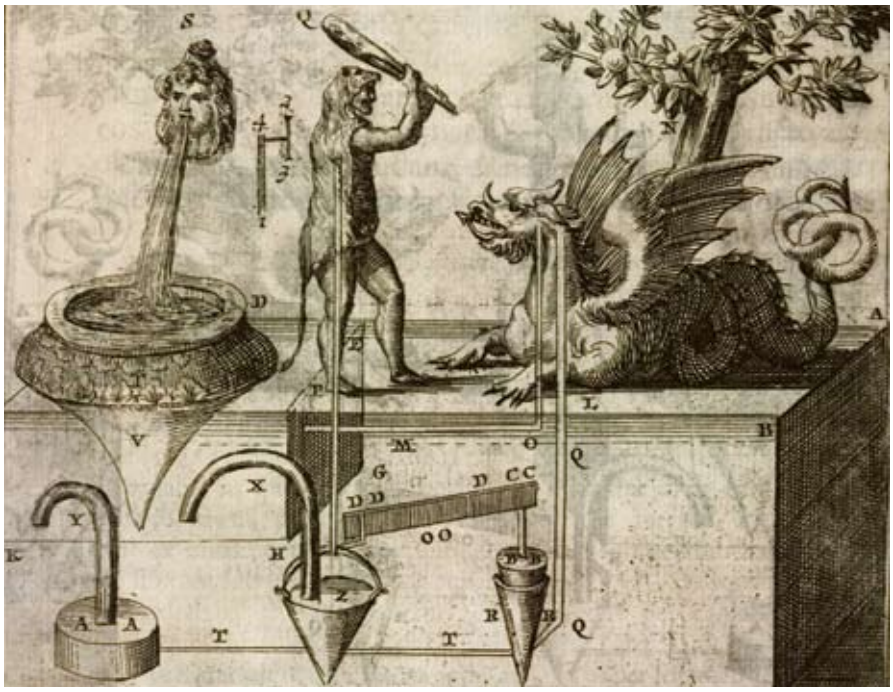
The preclassical mechanics of the 16th and early 17th centuries was characterized by an elaboration of the available mechanical theories in view of challenging objects. Preclassical mechanics, defined in this way as a historical stage in its own right in the development of mechanics, was pursued by engineer-scientists who addressed the technical challenges by drawing on heterogeneous bodies of knowledge—the increasing number of available ancient scientific and technical texts. As a consequence, a multiplicity of pathways developed, sometimes leading to the same insights about a given problem, sometimes to diverging views. At the same time, intrinsic tensions within a given traditional body now emerged in fuller clarity due to the fact that it was no longer, as was typically the case in antiquity, a single author or a string of authors separated by generations who were involved in its elaboration. Alternatively, one and the same problem was now often addressed from distinctive perspectives, thus becoming a borderline problem of different knowledge traditions, catalyzing their conflictual integration. The heterogeneity as well as the fragmentary nature of the shared knowledge of early modern science, in particular with regard to the heritage of

ancient science and its subsequent transformation, has been investigated by analyzing the conflictual integration of Aristotelian and Archimedean knowledge resources on mechanics, as it can be traced in the works of Guidobaldo del Monte, Giovanni Battista Benedetti, Galileo Galilei, Francesco Maurolico, Bernardino Baldi, Henri de Monantheuil, Simon Stevin, and Isaack Beeckman. In particular, an in-depth study was dedicated to a copy of Benedetti's *Diversarum speculationum mathematicarum et physicarum liber* containing hand-written marginal notes by Guidobaldo, the leading expert on mechanics of the generation before Galileo and himself the author of the most influential early modern text on mechanics (Peter Damerow, Jürgen Renn). Guidobaldo's views on mechanics were also compared to those of Maurolico, Baldi, Stevin and others in light of the different roles that mathematics played in physical explanations (Maarten van Dyck).

Knowledge and Belief in Early Modern Science

The development of early modern practical and theoretical mechanics was also shaped by religious constraints. In the framework of collaboration supported by the German-Israeli Foundation, it is being investigated how such constraints left their mark on the large-scale structures of scientific development. This will add a further dimension to the understanding of the evolution of mechanics in the 17th century and enrich the account of the Scientific Revolution.

It has been claimed in the past for instance that due to dogmatic constraints the Jesuits did not essentially contribute to the development of the new mechanics in the 17th century. Against this view the study has been able to show that Jesuits did make substantial contributions to the emergence of classical mechanics. The Jesuits, for example, more than anyone else took on the role of providing a growing body of students with new knowledge in astronomy and the science of motion and machines, and some even with a highly advanced level of physico-mathematical knowledge. Although Jesuit physico-mathematicians were constrained by the Society's pro-Aristotelian and anti-novelty programmatic position, their teachings had unintended consequences that contributed to the dissolution of the Aristotelian worldview, as has been shown in a comprehensive survey (Rivka Feldhay).



Description of a new pneumatic device by Giovambattista Aleotti. From Federico Commandino, *Heronis Alexandrini Spiritalium Liber*, 1680. Courtesy of the library of the Max Planck Institute for the History of Science.

In addition, it was shown how Jesuit teaching was interwoven with practices of transmission of scientific knowledge that concerned wider audiences among the urban elites of early modern Europe.

A special case study has addressed the theory of motion of the Jesuit scientist Honoré Fabri and its relation to the Eucharist doctrine (Michael Elazar). The section "Jesuit Sciences" in ECHO currently displays 85 rare books and several manuscripts by Jesuit scholars. Two workshops were held in the report period, one in February 2008, the other in March 2009, the proceedings of which are being prepared for publication.

Frontispiece of Athanasius Kircher's *Romani Collegii Societatus Jesu* showing Jesuit scholars of the Collegium Romanum in the Museum's 'Cabinet of Curiosities'. Courtesy of the library of the Max Planck Institute for the History of Science.

Project 2

Reorganizing Knowledge in Developed Science: The History and Foundations of Quantum Physics

General Goals of the Project

The goal of the project is the study of the emergence and transformation of core groups of concepts that structure the vast knowledge embodied in the mechanical worldview as a result of processes of knowledge integration and disintegration. In the context of the project, the emergence of such a core group of foundational concepts is conceived as a restructuring of the cognitive organization of previously acquired knowledge. Core concepts of the mechanical worldview such as space, time, force, motion, and matter achieved their privileged position in the organization of knowledge only after a long process of knowledge integration in a material, social, and cognitive sense. Such concepts proved to be extremely stable in the face of an enormous growth of knowledge in the course of the further development of science. Nevertheless, physics, like many other scientific disciplines, has witnessed in the past century fundamental changes of precisely such core groups of foundational concepts. These fundamental changes were preceded by more or less extended periods of knowledge disintegration, in which the established cognitive organization of knowledge became problematic. Processes of integration and disintegration of knowledge are studied in close connection to each other within the project, since it has turned out that the essential mechanisms at work in periods of destabilization were of a similar nature as those in the original processes of the emergence of core concepts of a discipline.
The project is focusing on the history of the central mental models which shaped scientific thinking in the transitional period from classical mechanics to modern physics. The results already achieved for the emergence of the new concepts of space and time in the context of the two relativity theories are being complemented by similar research on the emergence of new notions of matter, field and causality established in the context of quantum theory.

The History and Foundations of Quantum Physics

The quantum revolution emerges from a series of crises of the classical mechanical worldview from the late 19th century to the 1920s. These crises were caused in part by conflicts between theoretical expectations and experimental results, but also importantly by the difficulty of integrating recently established physical theories such as electrodynamics and thermodynamics into the mechanical worldview. Similar to the

case of relativity theory, conflicts between theories necessitated a reorganization and re-evaluation of controversial concepts.

Central to this process of re-evaluation was not only a large amount of uncontroversial empirical knowledge accumulated over a long period of time but also the persistence of certain theoretical structures and methods. Theoretical physicists were therefore confronted with critical decisions about which concepts and theoretical structures could be maintained in the emerging theory and could thus serve as a guide for the development of the theory. As in the case of relativity, it turned out that it was often high-level and abstract structures that survived, although frequently with a new physical interpretation.

Differently from the case of relativity, a consensus about the physical reinterpretation of the abstract structures was not easily attained. Famous dissenters, such as Einstein and Schrödinger, while accepting the new theoretical structure, disagreed about its meaning and its connection to the traditional mechanical worldview. Later on, the establishment of quantum field theory, including the unification with the theory of relativity, has turned out to be at odds with the traditional demands on an interpreted physical theory. These disagreements have persisted up to this day, even though quantum mechanics by all counts is a highly successful predictive theory.

The research project on the history and foundations of quantum physics began work in October of 2006 (Christoph Lehner, Jürgen Renn). It is a joint initiative with the Theory Department of the Fritz Haber Institute and has been funded for five years by the Strategic Innovation Fund of the President of the MPG. The project attempts to arrive at a deeper understanding of the genesis and the development of quantum physics, using the tools of historical epistemology that have been developed in Department I over the last years. The project thus focuses on the long-term history of the process of theory change, stressing the continuity of methods and structures. The experience in writing the history of relativity has demonstrated the strength of this method: It leads to results that have been outside the view of approaches limiting themselves to an account of historical developments narrower in a temporal and contextual sense.

X-ray apparatus depicted on the cover of the popular science journal *Koralle*, 1932.

Unlike the relativity revolution, the development of quantum physics was a communal effort whose nature cannot be captured by a biographical approach that focuses upon a few central figures: careful attention must be paid to the broader community of researchers and to the network that allowed them to achieve what no single researcher could do alone. Work in this direction draws upon extensive archival records of correspondence, manuscripts, and notebooks that are investigated and made accessible in an electronic form to other researchers worldwide.

Another important element of the project is the focus on mathematical arguments in the primary source material, a topic not much dealt with in the existing literature. For this aim, the project is conceived as a close collaboration of a large and varied group of historians and philosophers of science with working physicists exchanging ideas and viewpoints through frequent meetings (dedicated conferences, workshops and reading groups).

It is obvious that the history of quantum physics cannot be understood without an appreciation of the radical conceptual changes that it brought. Debates about interpretation played a central role in the development of quantum physics. Therefore, the project investigates the history of the interpretation of quantum mechanics not as a separate "philosophical" subject but as part of a wider debate in physics.

The project aims at fostering the study of the history of quantum physics by facilitating the exchanges between physicists and historians, but also by drawing new scholars into the field through graduate and postdoc fellowships. In addition, one of the main tasks of the project is the maintaining of an electronic infrastructure within the ECHO environment for the publication of primary sources, archival material as well as results of ongoing research by members of the network.

As the central publication of the project, a working group volume in preparation describes the development of quantum mechanics as a long-term process of theory change (Christoph Lehner, Christian Joas, and Jürgen Renn). It emphasizes the continuity of scientific methods and structures through the fundamental changes in the mechanical world picture since the 19th century. This book bundles the individual research programs of the members of the group into a coherent whole, at the same time achieving a legible survey of the development of quantum mechanics, and filling a void between thematically focused technical accounts and popular presentations that do not represent the current historical state of the art. It is being written in close collaboration by all the members of the project, who meet every week for presentations and discussions. In close connection with the working group volume, two edited volumes are also in preparation: One volume (Giuseppe Castagnetti, Michael Eckert, Hubert Goenner, Dieter Hoffmann, Alexei Kojevniknov, Jürgen Renn, Arne Schirrmacher) addresses the role of scientific institutions in the development of quantum theory and comprises, e.g., case studies on the Kaiser Wilhelm Institutes of Physics and Physical Chemistry and the Physikalisch-Technische Reichsanstalt in Berlin, the Sommerfeld school in Munich, Bohr's institute in Copenhagen, and Göttingen University. The second volume (Massimiliano Badino, Jaume Navarro) analyzes early textbooks of quantum theory and their role in establishing and promoting the theory. For both edited volumes, workshops with the external contributors were organized in 2009. Contributions to the textbook volume were presented in two special sessions at the 2009 HSS meeting in Phoenix, U.S.A..

Besides a biweekly reading group for physicists and historians from local institutions, and a colloquium with invited speakers, a series of conferences was launched by the project in 2007 to strengthen the international network of researchers working in the history of quantum physics. The second conference in this series took place in Utrecht in July 2008. Its proceedings were published as a special issue of *Studies in History and Philosophy of Modern Physics* (2008, 40: 4). A satellite meeting of the project took place in May 2008 at the University of Sidney. The project also contributed a session entitled "Quantum Physics at the Crossroads" to the 2008 "Three Societies Meeting" in Oxford, and was featured in a special session "Eighty years of quantum mechanics. A new international project" at the April 2008 meeting of the American Physical Society.

The project contributed the texts for the exhibition "Max Planck: Revolutionär wider Willen" organized by the Max Planck Society at the Deutsches Technik Museum in

honor of the 150th birthday of Max Planck. These texts formed the basis for a special issue of *Spektrum der Wissenschaft* (Biographie). Planck's birthday was also the occasion for a symposium, organized by the project, of the History of Physics Division of the Deutsche Physikalische Gesellschaft in February 2008 in Berlin. The proceedings of this meeting were published in an edited volume entitled "Max Planck und die moderne Physik" (Dieter Hoffmann).

Old Quantum Theory

The old quantum theory was a period of transition between classical and quantum mechanics. Successive crises led to a gradual disintegration of the mechanical worldview. At first, attempts were made to capture quantum phenomena by ad hoc modifications of the description in classical mechanics, such as quantum conditions. The problems of these attempts led to an increasing awareness that a more fundamental revision of mechanical concepts was necessary.

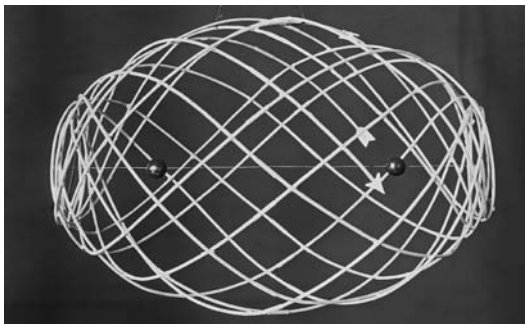
Research on the life and work of Max Planck as a pioneer of quantum physics concentrates on his institutional, social and personal environment (Dieter Hoffmann). It includes a comprehensive scientific biography of Planck and a new edition of his writings on thermodynamics. Further, a study of his role as an editor of the *Annalen der Physik,* the transcription of the correspondence between Planck and his co-editor at the *Annalen,* Wilhelm Wien, as well as an extensive annotated collection of Planck's Annalen papers, were published in 2008.

Another founding father of quantum theory was Albert Einstein whose papers on quantum physics are the subject of a study based on correspondence and manuscripts available at the Einstein Papers Project (Tilman Sauer). A Cambridge Companion to Einstein, which studies all facets of Einstein's work and its impact on philosophy, is in preparation (Michel Janssen, Christoph Lehner).

Reproduction from Robert Wood, *Physical Optics*, 1911 showing the optical dispersion by sodium vapour (fig.2).

A previous study of the project had pointed out the central role of optical dispersion in the genesis of matrix mechanics (Anthony Duncan, Michel Janssen). For a better understanding of the historical context, a long-term study is conducted on the history of theories and experiments of optical dispersion from 1870 to 1925, and especially on the challenge of reconciling the classical theories of dispersion with quantum theory (Marta Jordi).

A study of the interactions between statistical mechanics and old quantum theory from 1911 to 1925 (Massimiliano Badino) focuses on the way in which the quantum hypothesis changed the understanding and the application of the conceptual tools of statistical mechanics to the description of matter. Related is a study on Erwin Schrödinger's 1912 work on solid dielectrics, which reflects early signatures of Erwin Schrödinger's approach to physical theory and displays the wide range of possible conceptions about the structure of solids before it became accessible experimentally through X-ray diffraction (Christian Joas, Shaul Katzir). An interesting case of



Model of a hydrogen molecule ion according to the old quantum theory, built for the Deutsches Museum, Munich using calculations by Wolfgang Pauli, ca. 1923.

transfer of knowledge from pure science to technology is the history of piezoelectricity, leading to such applications as the sonar and frequency control in electronic circuits (Shaul Katzir). Research on the history of radioactivity and early nuclear physics is devoted to the investigation of the relationships between persons and institutions in Germany, and their international connections; it also treats the correlations between experiment and theory in this area (Horst Kant). The investigation concentrates on the research groups at the Kaiser Wilhelm Institutes of Chemistry and Physics (Berlin) and Medical Research (Heidelberg).

Early atomic physics and the reception of quantum physics in Britain in the 1920s is the subject of a study on J. J. Thomson and G. P. Thomson (Jaume Navarro). The impact that drawings and three-dimensional models of the atom (originally conceived to make atoms and their structure accessible to a broad public) had on the development of atomic physics and its methods is the subject of a study on the emergence of modern physics in the public sphere (Arne Schirrmacher).

The Genesis of Quantum Mechanics

A second group of studies is concerned with the genesis of modern quantum mechanics, which was established in the mid-1920s as a foundational theory of modern physics involving substantial conceptual modifications compared to classical physics. The research program aims at analyzing how these conceptual changes emerged from a transformation of the knowledge of classical physics.

Research activities on the development of wave mechanics (Christian Joas, Christoph Lehner, Jürgen Renn) are dedicated to the historical roots of wave mechanics and in particular to a study of the research notebooks of Erwin Schrödinger. A detailed account of Schrödinger's formulation of wave mechanics, using the notebooks extensively for the first time, has been published. The study of Schrödinger's research notebooks continues with a focus on the further development of wave mechanics and Schrödinger's debates about the interpretation of quantum mechanics.

Walther Bothe studied the wave-particle dualism of light both from the experimental and from the theoretical side and contributed to the understanding of energy fluctuations of black-body radiation. His little-studied work is analyzed in a collaboration between a physicist and a historian (Dieter Fick, Horst Kant). Another study about the connection between experiment and theory in wave mechanics focuses on Charles G. Darwin's electron diffraction experiments and his work on a wave equation for the electron (Jaume Navarro).

An investigation into the early history of Bose-Einstein condensation and the emergence of quantum statistics has been carried out (Daniela Monaldi). It analyzes the emergence of new concepts related to the new quantum-mechanical formalism, e. g., the concepts of indistinguishable particles and of cooperative phenomena.

Pascual Jordan's 1927 transformation theory, an early unification of wave and matrix mechanics relevant both for the consolidation of quantum mechanics and for the development of quantum field theory is studied in another collaboration between a

physicist and a historian (Anthony Duncan, Michel Janssen). Pascual Jordan was the earliest visionary of the possibilities of quantum field theory as a "theory of everything." His role is examined in a study on the rather unknown early development of quantum field theory from its first appearance in the 1925 Heisenberg-Born-Jordan paper until its crisis in the 1930s because of the problem of infinities and rising skepticism about its fundamental character (Christoph Lehner, Michel Janssen).

The redefinition of traditional mechanical notions, such as angular momentum, and the development of new types of symmetry arguments is the subject of a study on selection rules and symmetry arguments in quantum mechanics (Arianna Borrelli). From late 1926 onward, group-theoretical considerations were employed to interpret spectroscopical selection rules in terms of symmetries, which in turn came to be connected to a new, specifically quantum-theoretical notion of conservation law. Eventually, both in quantum mechanics and in quantum field theory, selection rules—i. e. the failure of specific events to take place—came to be regarded as the observable signature both of symmetries and of conserved quantities.

Erwin Schrödinger and friends at the "baptism of the 'wave packet'," June 21, 1931. Reprinted with permission of Ruth Braunizer

Consolidation, Extension, and Reception

A third group of studies deals with the consolidation, extension, and reception of quantum mechanics from the 1930s onwards, as well as the continuing debates continuing debates the debates about its interpretation. A study investigates how quantum physics developed in China during the 20th century, paying special attention to the relationship between scientists and institutions in China, and their international connections (Xiaodong Yin).

The conceptual and the institutional history of solid-state physics in connection with other emerging fields is the subject of another study (Christian Joas). A special focus is the transfer of quantum-field theoretic concepts and methods between theoretical high-energy physics and theoretical solid-state physics in the postwar era. A study on the history of computation in solid-state physics examines how solid-state theorists' research practices have evolved from the late 1920s to the present (Edward Jurkowitz, Volker Blum). It is particularly interested in the role that changing computational capacities may have played in the different focuses and standards that leading theorists brought to their research on solid-state topics in diverse institutional settings.

A monograph on the history of quantum chemistry was produced in collaboration and with the support of the quantum history project (Kostas Gavroglu, Ana Simões).

The problematic relationship between the two major fundamental theories of physics in the 20th century is the topic of a collaboration on the history of quantum field theory and quantum gravity (Jürgen Renn, Donald Salisbury, Matthias Schemmel, Kurt Sundermeyer). The current focus of this research endeavor is the historical study of efforts to incorporate gauge and coordinate freedom into quantum theory.

One study concentrates on the emergence of the theory of decoherence and is based on numerous interviews with living physicists (Fabio Freitas). It places special emphasis on the local environments and how the work on decoherence and the foundations of physics affected the careers of the physicists involved. Another study on contemporary physics studies visions of nuclear breeder reactors, and inquires how these utopian images of future reactors interplayed with important decisions in the Swedish nuclear program (Maja Fjaestad).

Erwin Schrödinger playing chess with his daughter Ruth Braunizer, who is now the executor of his estate. Reprinted with permission of Ruth Braunizer.

A further study analyzes historically important positions and debates concerning the interpretation of quantum mechanics. As mentioned above, it attempts to understand these debates as negotiations about which elements of the classical theory should be preserved in the new mechanics and which elements need to be jettisoned. Individual topics that have been treated so far are the debates about *Anschaulichkeit* between Heisenberg and Schrödinger (Martin Jähnert), Einstein's critique of quantum mechanics (Christoph Lehner), and the debates about "heterodox" interpretations of quantum mechanics after World War II (Fabio Freitas, Olival Freire). Another study deals with the tension between dialectical materialism and the interpretation of quantum mechanics (Christian Forstner, Olival Freire, Dieter Hoffmann, Anja Skaar Jacobsen, Martin Jähnert, Christian Joas, Christoph Lehner).

Institutions and Quantum Physics

Further studies were dedicated to the reorganization of physical research as a reaction to the emergence of quantum problems in the early 20th century. Of central interest was the extent to which such a reorganization took place as the result of an explicit program to transform the mechanical worldview. The research focused on the effect of contemporary scientists' recognition of quantum problems and how this related to the shifting of their research foci, the reallocation of their resources, and the reorganization of research structures and policies. Several studies were conducted on specific institutions such as the University of Göttingen (Arne Schirrmacher), the Sommerfeld school in Munich (Michael Eckert), and the Berlin physics institutes (Dieter Hoffmann). The results will be presented in the above-mentioned volume on the role of scientific institutions in the development of quantum theory.

In preparation for the 100th anniversary of the KWG/MPG, its history is being studied with the aim of a general overview (Jürgen Renn and Horst Kant). In cooperation with the Fritz Haber Institute (one of the two first Kaiser Wilhelm Institutes to be founded in 1911), a research endeavor on the history of this institute has been started and a colloquium series established with invited speakers addressing various aspects from its history (Dieter Hoffmann, Bretislav Friedrich, Jeremiah James, Thomas Steinhauser). A study of the history of physics at the Humboldt University is being underaken in collaboration with the university for the occasion of its 200th anniversary in 2010 (Dieter Hoffmann).

In reaction to an international public discussion, research was conducted on Peter Debye and his role as a prominent physicist in Nazi Germany. One study concentrated on Peter Debye as director of the Kaiser Wilhelm Institute for physics in Berlin during the Third Reich (Horst Kant). Another study aimed for a more differentiated picture of Debye's role by comparing his situation with that of other foreign researchers in Nazi Germany (Dieter Hoffmann). A conference was held in Göttingen in 2008, "'Fremde' Wissenschaftler unter Hitler. Die Debye-Affäre im Kontext," and a proceedings volume is forthcoming.

Alexander McLean Nicolson in The Western Electric research department (AT&T) c. 1920. Nicolson observes crystal motion on the box in the table with a Fabre Perot interferometer. The white disc just over Nicolson's hands is the paper cone of a piezoelectric crystal driven load-speaker of his design. From AT&T archive.

Digital Infrastructure

To support the individual researchers, a coordinated effort has been made in close cooperation with the IT group to collect, digitize, and make available a wide array of sources for the history of quantum physics in the ECHO environment (Carmen Hammer). Part of this endeavor is the digitization by the MPIWG library of the complete Archives for the History of Quantum Physics, an extensive collection of sources compiled and microfilmed at the American Philosophical Society. This work nears completion and the digitized material is accessible to cooperating researchers on the project's website. Another activity is the cataloging and digitization of Erwin Schrödinger's papers which are in the possession of his daughter, Ruth Braunizer.

Cooperative Venture: The Concept of Scientific Philosophy and the Revolutionary Developments in the Natural Sciences from 1870 to 1950

The Department continued its close cooperation with the Moritz Schlick Research Institute at the University of Rostock. The study investigates the relationship between the works of scientists-philosophers such as Hermann von Helmholtz, Ernst Mach, Alois Riehl, Wilhelm Wundt, Pierre Duhem, Henri Poincaré, Moritz Schlick, and Hans Reichenbach and the revolutionary developments in the natural sciences, especially in modern physics but also in experimental psychology and Gestalt psychology during the period from 1870 to 1950. Ongoing activities include the publication of selected parts of the literary estate of Moritz Schlick through the ECHO platform, and research on the relations between modern physics and scientific philosophy in the early 20th century, focusing on two central figures of scientific philosophy: Moritz Schlick and Hans Reichenbach (Olaf Engler).

Project 3

TOPOI—Historical Epistemology of Space: Experience and Theoretical Reflection in the Historical Development of Spatial Knowledge

General Goals of the Project

The project on *Historical Epistemology of Space: Experience and Theoretical Reflection in the Historical Development of Spatial Knowledge* is conducted by a TOPOI Junior Research Group jointly organized by the TOPOI Cluster and the MPI. The group is headed by Matthias Schemmel and integrated into the work of Department I.

The project aims at a long-term history of basic structures of spatial thinking, ranging from prehistory to the most recent and ongoing scientific revolutions. It focuses on the question of how the emergence and the development of spatial concepts is shaped by experience and how, in turn, these concepts influence the acquisition of further experiential knowledge. In this project, experience is understood in a broad sense, ranging from the interaction of biological organisms with their environment to the systematic acquisition of knowledge by means of the complex experimental systems of modern science. The experiential spaces that one may thus distinguish have traditionally been investigated by different disciplines, such as developmental psychology, anthropology, ethnology and psycholinguistics, archeology, and the history of science and technology. In the framework of the project, these are set in relation to each other with respect to their research potentials and results concerning the historical development of spatial knowledge. In order to achieve an integration of research results from different disciplines pertinent to the understanding of the long-term development of spatial knowledge, the group has worked on a shared theoretical framework which shapes and correlates the concrete research activities. In this endeavor the project group built upon results of the project on *Mental Models in the History of Knowledge*.

One of the basic results of the group was that the development of spatial knowledge is closely linked to external knowledge representations such as coordinated actions, landmarks for orientation, lexical and grammatical properties of spoken and written language used to express spatial relations, instruments for measurement, navigation, and surveying, geographical maps, and geometrical formalisms from Euclid's *Elements* to the field equations of general relativity and quantum field theory. The investigation of the role of external representations allows for an understanding of the development of knowledge structures as a result of manipulating them and reflecting upon the outcome. This model of explanation pertains not only to individual human cognition. External representations also serve the communication of knowledge and its transmission from one generation to the next and also from one culture to another.

Thus, in the project, the analysis of representations became the central method for reconstructing the social reproduction of knowledge. For understanding the long-term development of spatial knowledge from antiquity to the present this social dimension of external knowledge representation turned out to be of crucial importance. Results of the group's research will be integrated and published in a volume which is in preparation under the title *Spatial Thinking and External Representation*.

→ p. XXX

Spatial Concepts in Non-Literate Societies: Language and Practices in Eipo and Dene Chipewyan

The most basic forms of spatial knowledge that are studied in the project are those represented by spatial concepts in non-literate societies. Obviously, certain aspects of spatial cognition are universal owing to the shared biological constitution of the human body and mind and to universally shared experiences. Other aspects of spatial cognition are culturally specific, being shaped, for instance, by particular practices of spatial orientation and organization. The question of how to empirically verify this distinction is a matter of controversial debate. Taking into account the results of research pursued by the Max Planck Institute for Psycholinguistics at Nijmegen and based on discussions with the *Language and Cognition Group* at this institute the question has been taken up again by the present project under the specific perspective described above.

On the basis of the study of spatial practices in two non-literate cultures and (utterances in) their languages, certain aspects of spatial cognition that are candidates for universals (although they may find different expressions in different languages), and aspects that are truly culture specific in the sense that different cultures develop different cognitive structures have been identified (Wulf Schiefenhövel, Martin Thiering). The two cultures that have been thoroughly studied are the Eipo living in the highlands of Indonesian New Guinea and the Dene living in the North American plains. It has turned out that, while the peculiarities of the two cultures' environments did shape their spatial language and practices (importance of mountains vs. lakes; practices of gardening vs. hunting), similar practices of spatial orientation such as the use of landmarks can be discerned in both cultures. Although the semantic and grammatical resources provided by the two languages differ substantially, no differences in spatial abilities have been identified that could be attributed to language peculiarities. In the context of the long-term historical perspective of the project, the results will be evaluated with respect to what can be inferred from them concerning the spatial knowledge of prehistoric humans in order to complement what can be known through archeological finds.

Seemingly chaotic construction (left) and finishing (right) of a sacral men's hut by the Eipo tribe in West New Guinea. From Gerd Koch, *Malingdam,* 1984.

The Impact of Notation Systems: From the Practical Knowledge of Surveyors to Babylonian Geometry

Mesopotamian proto-cuneiform and cuneiform clay tablets written in the time period from the invention of writing (around 3200 B. C.) to the development of Babylonian mathematics in the Old Babylonian period (around 1900 – 1600 B. C.) document the development from elementary spatial knowledge to an esoteric art of formulating complex geometrical problems and solving them using sophisticated arithmetical tools applied to geometrical intuition. It is evident that the spatial cognition under these circumstances differs considerably from what has been identified in non-literate cultures. The representation of this new form in the documents of surveyors, school texts, and the problem-texts of Babylonian mathematics have been studied (Peter Damerow). It turned out that the emergence of the new kind of spatial cognition documented in these sources was primarily based on the growing knowledge of surveyors and the scholarly reflection on their means and practices. The resulting mental constructions remained implicit but can be partly reconstructed from the arithmetical operations of Babylonian mathematics. They turn out to show "non-Euclidian" peculiarities such as the neglect of the role of angles, resulting from the practices of surveyors which they reflect.

Pre-Euclidean geometry in Mesopotamia. Calculation of the area of a field in a surveyor's document, 21st cent. B. C. (left), and of the area of a trapezoid in a geometrical school text, ca. 17th cent. B. C. (right). Courtesy of the Schøyen Collection.

Writing and Reflection on Elementary Actions and Professional Practices: The Chinese Mohist Canon and Its Counterparts in Greek Science

A new kind of spatial knowledge is characterized by explicit definitions and inferences in written form. This knowledge is documented, in particular, in philosophical and mathematical texts in ancient China and Greece. The work on these texts has focused on the analysis of a unique source of ancient Chinese thinking, the so-called *Mohist Canon*, written around 300 B. C. In a series of working meetings continuing earlier work in the context of the project on *Mental Models in the History of Knowledge* it was attempted to reinterpret the *Mohist Canon* from a comparative and contextual perspective (William G. Boltz, Matthias Schemmel). It turned out that the text can be understood as documenting the reflection on elementary and practical forms of knowledge, such as intuitive knowledge on spatial arrangements and natural processes, and knowledge obtained in the handling of mechanical and optical devices or instruments for measurement and astronomical observation. Theoretical reflection is documented in the text through the definition of general terms, the consistent use of terminology, and the resolution of apparent paradoxes or explanation of unexpected phenomena.

Texts handed down from Greek antiquity, such as Aristotle's *Physics* or Euclid's *Elements* equally document a reflection on elementary and practical spatial knowledge. The comparison of the Chinese and the Greek cases suggests that the existence of a culture of disputation and the related emergence of argumentative text traditions is a general precondition for this kind of theoretical reflection. While the Mohist tradition ceased with the rise of the Qin Empire at the end of the third century B. C., the later tradition of the Greek texts reveals the different potential of theoretical reflections on elementary experiences, as exemplified by Aristotle, on one hand, and on the use of drawing instruments (compass and ruler), as exemplified by Euclid, on the other.

The Impact of Geographical Knowledge on the Generalization of Spatial Concepts: From Ancient to Modern Maps

A further step in the development of spatial knowledge was initiated by the growth of geographical knowledge due to the expansion of the spaces certain societies inhabited, controlled or explored. As a consequence, a new kind of representation of spatial knowledge occurred, i. e., the representation by geographical maps. The development of this new kind of representation was at the center of a further study (Peter Damerow, Jacqueline Jugl, Matthias Schemmel, Irina Tupikova). It turned out that the great variety of maps show a common developmental pattern. Maps of a basic type represent primarily the relation between landmarks such as major paths between named locations, rivers, mountains, coastal lines, lakes, etc. However, ancient sources such as Ptolemy's *Geography* show that there were early attempts to embed landmarks into context-independent frameworks such as coordinates constructed by projecting celestial coordinates to the spherical earth. The results of the analysis of such attempts suggests that this kind of representation is one of the roots of the Newtonian concept of space as a container.

The Ebstorf World Map, 13th century, shows a flat round world surrounded by water, representing a Medieval worldview. Knowledge about the edge of the world was poor; it was believed that the people who lived there had strange afflictions, such as sealed mouths (top), huge body sizes, no ears, four eyes, or extremely prominent lips to give shelter from the sun (bottom).

Ongoing work aims at developing an elaborate classification system for all kinds of plots, plans, and maps. In particular, in order to classify the great variety of geographical maps within the developmental scheme from the representation of relations between landmarks to coordinate systems, preliminary categories of their properties have been defined and applied to a representative selection of maps which reflect the change of the concepts of space involved.

Another particular focus of the research activities has been the relation of astronomical knowledge, cosmological theories and geographical knowledge in ancient times (Matthias Schemmel, Irina Tupikova). From the study of the prehistory of Ptolemy's *Geography*, the close connectedness between the cosmological hypotheses of a spherical earth and the transfer of celestial to terrestrial coordinates became obvious. The comparison with Chinese cosmology and cartography suggests that the absence of a concept of spherical earth explains, at least in part, the absence of similar uses of coordinates in ancient Chinese cartography in favor of plane coordinates.

The Transformation of Ancient Spatial Knowledge in its Intercultural Transfer: The Early Modern Translation of Euclid's *Elements* into Chinese.

A further research activity analyzed the intercultural transmission of geometrical knowledge and its impact on culturally-specific notions of space (Jens Braarvig, Peter Damerow, Matthias Schemmel, Tian Miao). This transversal study of knowledge transformation, which is closely related to the project on the *Globalization of Knowledge,* complements the more numerous longitudinal studies that exist on the transformation of ancient geometrical knowledge within the Western tradition. In 1607 the Jesuit Matteo Ricci and the Chinese scholar-official Xu Guangqi translated the first six books of Euclid's *Elements* into Chinese. Their endeavor demanded the transfer of ancient Western knowledge on geometry into a different mathematical tradition which inevitably implied the transformation of that knowledge. As a first step, a detailed comparative analysis of parts of the Chinese version of the *Elements* and its European source, Christopher Clavius' edition of the *Elements*, has been launched. Furthermore, different versions of the Chinese *Elements* have been compared and the reception of Euclid's *Elements* in 17th and 18th-century China has been studied (Tian Miao).


EVCLID. GEOM.

PROBLEMA I.
PROPOSITIO I.

SVPER data recta linea terminata triangulum æquilaterum constituere.

SCHOLIVM.


古今算學叢書

賜同進士出身 記名總理各國事務衙門章京內閣中書舍人加三級 劉錫鴻校

幾何原本第一卷 本篇論三角形 計四十八題

泰西利瑪竇口譯

吳淞徐光啓筆受

第一題

于有界直線上求立平邊三角形

First proposition of the first book of Euclid in the influential Christopher Clavius' edition (1607, first published in 1574) and the Chinese adaption and translation by the Jesuit Matteo Ricci and his Chinese collaborator Xu Guangqi (1865, first published in 1607).

The Impenetrability of Matter: Space and Matter in Early Modern Science

Besides the introduction of geographical coordinate systems, the epistemological problem of the relation between the concepts of matter and space had an impact on the Newtonian concept of space as a container. This problem had been intensively studied in the context of the project on *Mental Models in the History of Knowledge*. It has been taken up again here with a focus on alternative conceptualizations of the relation of space and matter in early modern science and philosophy (Peter Damerow, Jürgen Renn, Matthias Schemmel).

Aristotelian physics and the Peripatetic tradition negated the possibility of empty space and instead concentrated on the concept of place. In opposition to this tradition ancient atomism was based on the idea of atoms moving through empty space. In the Renaissance, a transformative development of spatial concepts was triggered by cosmological concerns, namely attempts to replace the Aristotelian world system by alternative systems which were often based on ancient atomistic ideas including the concept of empty space, which implicitly involves the notion of space as a container. The growing corpus of empirical knowledge on mechanics and astronomy eventually stabilized Newton's concept of a universal space. In Newton's conception, gravitation is decoupled from the structure of space, which allows for space to be homogeneous and isotropic. Nevertheless this conception was not altogether convincing, so that the debate about space and matter continued. An advanced version of the attempts to distinguish between space and matter resulted from Kant's criticism which tried to remove metaphysical presuppositions. As a consequence, Kant's solution to the problem departed from atomism altogether, proposing an early version of matter as an appearance of repulsive and attractive forces.

The Transformation of Cosmological Space in the Course of the 18th Century

A particular aspect of the development of the concept of space in early modern science is the influence of cosmological models, which is the subject of a dissertation project focusing on the change of the cosmological worldview between 1550 and 1800 in the context of the Copernican Revolution (Anna Holterhoff). Contrary to what the term "revolution" might imply, the change from a geocentric to a heliocentric worldview was not achieved in a short period of time. The establishment of Copernicanism reflects a complex interaction between different forms of knowledge within the contradictory epistemological contexts of science and religion. The ongoing investigation shows how and by which processes of knowledge transformation the heliocentric theory became more and more accepted and finally canonical.

Beyond the Myth of Universal Space and Impenetrable Matter: The Overlapping Worlds of General Relativity and Quantum Theory

A further research activity following-up on a specific aspect of research pursued in the context of the project *Reorganizing Knowledge in Developed Science* concerns the transformation of the Newtonian concept of space in the relativity and quantum revolutions of the early 20th century (Jürgen Renn, Donald Salisbury, Matthias Schemmel, Kurt Sundermeyer).

Space warped by a galaxy cluster producing a mess of distorted inages of astronomical objects illustrating the falsification of the Newtonian concept of invariable, absolute space by modern cosmology. (Source: NASA, *http://apod.nasa.gov/apod/ap040627.html)*.

A first survey of the current epistemological situation in physics has revealed the crucial role of the concept of space in the ongoing attempts to unify relativity theory and quantum mechanics. Many decades following Einstein's representation of gravity as geometry, and then the introduction of the counterintuitive notion of quantum superposition by Heisenberg and Schrödinger, we still do not possess a fully coherent notion either of space, or of the matter that we traditionally hold to occupy it. The concepts of space and of matter have co-evolved through the relativity and quantum revolutions. A dynamical spacetime is conventionally considered the centerpiece of general relativity, while matter is commonly understood to be the principal actor in quantum mechanics. Each area has developed its own highly successful experimental procedures and analytical tools, building on ostensibly contradictory understandings of the nature of space and matter. But a closer look within each theory reveals that the pretensions of both are not fully justified. The ongoing work on the modern concept of space aims at outlining the fundamental changes in the concepts of space and matter that the two fundamental theories of 20th-century physics brought about, and at determining the overlapping realms of their applicability that hint at future developments.

Infrastructure: A Bibliographical Database on Sources and Literature on Spatial Knowledge and a Digital Collection of Sources on Spatial Knowledge

A database collecting references to sources and literature pertinent to spatial language and cognition and the history of spatial concepts has been set up and is continuously expanded (Sascha Freyberg, Matthias Schemmel, Martin Thiering, Irina Tupikova). The database, currently contains 800 items and is openly accessible on the internet under <http://echo.mpiwg-berlin.mpg.de/content/space>.

A digital collection of scanned images and transcriptions of sources pertinent to the history of spatial concepts has been prepared in the framework of the ECHO environment and will be further expanded (Sascha Freyberg, Simone Rieger, Matthias Schemmel). Presently, it contains around 250 texts. It is also openly accessible via the ECHO website at <http://echo.mpiwg-berlin.mpg.de/content/space>.

Project 4

The Globalization of Knowledge and its Consequences: The Transfer and Transformation Processes of Knowledge across Different Cultures

General Goals: Globalization Processes and the Role of Knowledge

The aim of this project is to focus on a hitherto neglected dimension of globalization processes, the globalization of knowledge. The much discussed globalization process of the present mainly refers to the economic processes of the globalization of the markets for goods, capital, and labor, whereas the global diffusion of technical innovations and bodies of knowledge is often merely considered as either a presupposition or a consequence of economic, political, and cultural processes. But globalization is not only a phenomenon of the present and it involves knowledge in more significant ways. In this project, the globalization of knowledge is being analyzed by integrating diverse studies of the conditions, pathways, and consequences of historical processes of the production, the transmission and the transformation of knowledge, relating them to present processes of globalization.

The main goal of the research project is to explain this geographic diffusion of knowledge throughout history in terms of historical-epistemological concepts. The project aims at a unified and systematic account of the globalization of knowledge by means of large-scale comparative research grounded in empirical detail. Individual investigations contribute the breadth of empirical detail that the research initiative requires. In order to gain the critical breadth, the project draws necessarily on contributions from visiting-scholars.

The theoretical framework developed in the course of the project comprises a core set of concepts which will necessarily be extended and revised in the course of further research. The basic concepts include a typology of knowledge forms, knowledge representation structures, and knowledge transfer processes.

The network established at a Dahlem Conference in 2007 has since been expanded. The participating scholars have collaborated in a variety of meetings and exchanges on producing a series of volumes dedicated to an integrated and coherent history of the globalization of knowledge.

Bactrian camel being presented as a gift to the Achamenid king, as depicted on the Apadana staircase reliefs, Persepolis (Iran).

The four research foci of the project are chosen such that theoretical claims can be validated with reference to outstanding historical phases in which knowledge production, transmission and transformation was critical for advancing processes of intercultural transmission.

Focus 1: From Technology Transfer to the Origin of Science

The first focus explores a series of processes in the very early phases of globalization from the transmission of practical knowledge to the emergence of science. These processes are layered, in the sense that the introduction of a new process does not lead to the eclipse of earlier processes. The first process considered is the transfer of technology in prehistory such as metallurgy, ceramics, agriculture, and animal husbandry. Processes of technology transfer are also necessarily processes of knowledge transfer. With the rise in Mesopotamia of the technologies of writing and arithmetic, which have a shared origin, new means for the globalization of knowledge were created. Although writing was initially tied to local contexts, there was a general trend in the evolution of writing towards decreased context dependence. Ancient Near Eastern and Greek science produced a corpus of written texts documenting systematic higher-order knowledge in such domains as cosmology, astronomy, mathematics, and medicine. Since this knowledge was explicitly written down, it was in later phases able to travel and eventually exerted a worldwide influence that continues to the present day.

Assyrian celestial planisphere found in the library of the Assyrian king Ashurbanipal at Nineveh. Kuyunjik Collection K.8538, © Trustees of the British Museum.

One research venture pursued in this context studied technological transfer and innovation in ancient Eurasia (Daniel T. Potts), and analyzed numerous instances—particularly in the realm of metallurgy, agriculture and technologies like wheeled transport—where knowledge probably did spread through human agency. The case of Near Eastern metallurgy in the Bronze Age and its possible influence on China has been examined in some detail. A second area of research on the development from technology transfer to the origin of science concerned the preconditions and the consequences of the invention and spread of writing (Peter Damerow, Manfred Krebernik). The invention of writing not only changed the conditions of the geographical transfer and historical transmission of knowledge, but in addition to these basic functions extended the human cognitive facilities by stimulating reflection processes and the creation and articulation of previously unknown mental constructions.

The relation of scientific activities and magic was investigated in two different fields. Recently accomplished work on Babylonian medicine in theory and practice (Mark Geller) challenges the usual notion that Babylonian medicine completely lacked theory. This can most clearly be seen in the close (but still distinct) relation between Babylonian medicine and magic, since magical texts often provided the theoretical assumptions upon which medicine operated. In a similar way it has been shown that the prominent distinction between scientific activities and speculative or mystical activities like divination, magic or meteorology is not tenable for the development of early astronomy in Mesopotamia (Gerd Grasshoff).

The importance of political and social developments in creating the preconditions for the diffusion of knowledge was analyzed in a survey of the emergence of Greek and Hellenistic science as a result of transformation processes of earlier knowledge traditions within the Near East, the Mediterranean and neighboring regions (Mark Schiefsky).

Focus 2: Knowledge as a Fellow Traveller

The second focus deals with the dissemination of knowledge in the sequel of that of power and belief structures on the Eurasian continent. The focus here is on processes in which knowledge spreads across long distances or over vast areas as an incidental effect of other diffusion processes such as the expansion of empires or the spread of religions. These processes may be of transregional and cross-cultural character, but they may also be corridor-like, connecting distant regions by a thin and fragile chain of transmission, for instance, a trade route like the Silk Road or the Jesuit mission to China. As knowledge is but a fellow traveller in these processes, the results of transmission are often only of a transitory nature but have the possibility of the long-lasting sedimentation of at least some achievements, such as practices of writing and calculating that later became relevant to the appropriation of scientific knowledge. This kind of knowledge globalization began with the emergence of institutions bundling cultural activities such as centers of trade and production, states, and world religions. As a consequence, also transmission processes themselves became institutionalized. Commercial, military, and missionary activities provided new stimuli for knowledge transmission.

Within this focus the kinds of knowledge are communicated during the spread of Buddhism in the first millennium A. D. were investigated as well as the transformative processes involved (Jens Braarvig). An outcome is that the adoption of Buddhism had a great impact on some of the receiving societies. It created not only new knowledge and religious activities, but also important institutions, such as the monastic community, and stimulated further intellectual and educational activities in fields such as grammar, lexicography, logic, philosophy and psychology.

One investigation addressed the transmission by Jesuit missionaries of European scientific knowledge to China in the early modern period (Matthias Schemmel). It was confirmed that this transmission led to a partial integration of European knowledge into the Chinese tradition without however bringing about the revolutionary developmental dynamics European scientific knowledge experienced at the same time in its culture of origin.

→ Independent Research Group, p. 46

A complementary research endeavor deals with educational journeys in Europe and Asia in early modern times taking the example of the travel diaries of the polyhistor Martinus Fogelius Hamburgensis (1634–1675), a correspondence partner of Gottfried Wilhelm Leibniz (Simone Rieger). In preparation for the reconstruction of a worldwide network in the early modern period, 1500 pages of Fogel's travel diaries have been digitized in cooperation with the Gottfried Wilhelm Leibniz-Bibliothek Hannover and the Niedersächische Landesbibliothek and made available via the ECHO environment.

The Mongols cross the River Tigris and conquer Bagdad. From the Saray-Alben, 1258. © bpk-images.

Research concerned with the spread of early modern science in Europe has shown that the spread of advanced knowledge from the centers to less-developed scholarly traditions at the European periphery was not a simple transfer (Kostas Gavroglu, Manolis Patiniotis). By exploring the case of the establishment of Newtonian science in the Greek-speaking regions of the Ottoman Empire it has been shown that new ideas introduced to the so-called periphery were not placed in a void; they rather interacted with and displaced other, usually strongly entrenched systems of knowledge closely associated with religion. Research on folk religion in South-Eastern Europe provided further insights into the socio-cultural background of knowledge diffusion at the turn of the 20th century (Florentina Geller). A further study of transmission from the center to the so-called periphery concerns the spread of French models of textbooks on mathematics to Spain in the 19th century (José M. Pacheco).

The production and dissemination of scientific knowledge as a fellow traveller of colonization, can, by active accommodation to new circumstances, become a powerful motor of decolonization, as the example of 20th-century India illustrates (Dhruv Raina). The transmission of new technological and scientific knowledge under the conditions of external pressure often provoked an immune response mobilizing or newly inventing local knowledge traditions. In India such a mobilization led, for instance, to attempts to revive and reinterpret traditional Ayurvedic medicine in terms of Western medical and pharmaceutical knowledge.

Focus 3: The Place of Local Knowledge in the Global Community

Focus three concentrates on the encounters between culturally specific knowledge and globalized knowledge. All knowledge traditions are local traditions in the sense of depending, at least at their origin, on specific contexts, specific groups, specific ranges of knowledge, as well as on a specific history determining its architecture in an ultimately contingent way. The globalization of local knowledge traditions involves intrinsic as well as extrinsic developments, potentially enhancing their social dominance, their range of application, and their degree of reflexivity or, alternatively, destroying their autonomy and reducing their complexity. The globalization of local knowledge has thus to be conceptualized as a cross-over phenomenon, resulting from the integration of local knowledge traditions whose initial encounter primarily depends on a specific constellation of dominance, resources, and knowledge potentials, that is, on

an extrinsic dynamics, while their subsequent co-development is also shaped by an intrinsic dynamics. The globalization of local knowledge is typically accompanied by a localization of globalized knowledge in the sense of the recontextualization of an alleged universal system of knowledge that may trigger its restructuration.
First explorations of the fate of local knowledge under the influence of intruding globalized knowledge have made evident that such an encounter can have quite different consequences. In some cases, local knowledge systems have been irrecoverably extinguished in a rather short time. Alternatively there are cases in which local knowledge has been synthesized with or at least partly defended against the influences of the global community. A more detailed study has been pursued in order to clarify the mutual influences of local and global knowledge among two indigenous cultures in the state of Espírito Santo of Brazil, the Tupinikim and the Guarani. Due to the influence of the Brazilian constitution, a set of political and educational activities have been launched to investigate the changes that certain traditional knowledge of Tupinikim and Guarani cultures, as well as non-indigenous peoples, have undergone and what measures can make it possible to reconcile local and external knowledge and to compensate the social deprivation of indigenous people caused by the clash of local and global knowledge systems (Circe Silva da Silva, Ligia Sad).

Rare books collected by L. Damdinsuren, held at the Mongolian Academy of Science in Ulaanbatar, with detail photos (left) showing the spine titles (above) and the contents (below).

A further case of confrontation of local knowledge with external influences is the situation of Mongolian culture and science at the crossroads between East and West. Several research trips were made to develop the cooperation between German and Mongolian researchers and to establish the working conditions for an extended research network (Jürgen Renn, Simone Rieger, Urs Schoepflin, Gerhard Wolf, Rüdiger Wolfrum).

Focus 4: The Globalization of Knowledge and Modern Science

To assess the relevance of an investigation of historical processes of globalization for the present situation, a fourth focus of the globalization network is dedicated to the great challenges that humanity faces today when dealing with knowledge. These challenges are partly consequences of socio-cultural evolution, such as the climate and energy challenges, and in particular of the powerful knowledge that has accumulated during this evolution, such as the exploitation of fossil fuels. Dealing with the consequences of such unplanned, global experiments with our planetary system requires more knowledge than can be produced by the dominat modes of knowledge production of socio-economic evolution, such as state-supported basic research or market-driven applied research. We thus face an emergent process in which the global production of ever more and increasingly diversified knowledge about humanity's interaction with nature becomes crucial for human survival. Within the framework of the globalization project, this emergent process is analyzed as an epistemic evolution. In this process, political developments do not merely shape the conditions of knowledge diffusion, but policy-making regarding these global challenges critically depends on the generation of new knowledge and knowledge-based assessments. In this focus, a variety of modes of epistemic evolution are analyzed with regard to the coupling of social and political developments and the diffusion of knowledge.

A special investigation has been dedicated to the knowledge that is transmitted with the establishment of nuclear programs both at the national and international level. The associated transmission processes have been analyzed in relation to their transnational elements, their characteristics in various national contexts and the intervention of individual actors. A central outcome of this research has been that standard models for knowledge diffusion can hardly be applied in this case. The proliferation of nuclear programs often followed local patterns and was shaped by the interaction of specific political, economic and technical conditions which require case-specific adaptions of diffusion models (Angelo Baracca, Albert Presas i Puig).

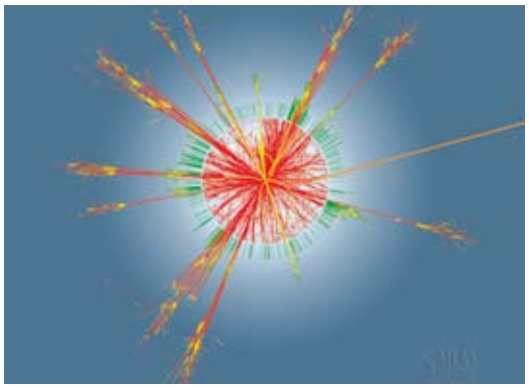


Photo taken from an ATLAS collision event in which a microscopic-black-hole was produced in the collision of two protons. Reproduced by kind permission of CERN.

A further research endeavor dealt with CERN as an example for a particular mode of epistemic evolution by means of an unbiased international large-scale research organization (Hans Falk Hoffmann). CERN demonstrates the possibility of knowledge production under the boundary conditions of an absence of immediate political, military or economic implications. The results of the investigation have raised the question of whether the CERN model can be transferred to other areas, for instance, to the domain of energy supply and climate change, where—in contrast to high-energy physics—strong political and economic interests may condition or even constrain the necessary knowledge production.

Another area of research focused on current developments towards a global information infrastructure based on the new information technologies. In principle, for the first time in history, the Web enables a global, dynamic representation of human knowledge with a strong, self-organizing potential. The ways in which the Web can provide a completely new way of representing and disseminating knowledge have been investigated (Malcolm Hyman, Jürgen Renn).

Additional research related to this focus ventured into the collaboration and transfer of knowledge on industrial management and the interface between humans and their technical environments. The investigation was centered on knowledge transmission within the USSR, between the USSR and other COMECON countries, and between the USSR and the West (Margareta Tillberg). Another study has investigated the transfer of economic knowledge to developing countries during the 20th century analyzing the reception, localization and appropriation of economic knowledge within the local context (Arie Krampf). A research endeavor undertaken in cooperation with the University of Havana focused on the history of the development of physics in Cuba from its origins until the present day. The study has investigated not only the influence of the USSR and the European Socialist countries on the development of physics, but also traced the active participation of several Western physicists and technicians during the 1960s (Angelo Baracca). A dissertation project is focusing on the role of linguae francae in experimental psychology (Anna Perlina).

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Workshops and Conferences

A number of workshops and conferences were organized within the project's framework. The first follow-up conference to the Dahlem conference was devoted to a specific aspect of the globalization of knowledge: multilingualism and lingua francae. It was co-organized by the MPIWG and the Norwegian Research Council, and held in 2009 in Athens under the title "Multilingualism, Linguae Francae, and the Global History of Concepts." Contributions ranged from an investigation of Sumerian as a lingua franca in the ancient Near East to a study of contemporary multilingualism in the former Soviet republics of Central Asia. A second meeting was held at the beginning of 2009 in Einsiedeln, Switzerland on the writing and the transmission of knowledge. In 2010, a third conference on multilingualism, linguae francae and the globalization of knowledge will be held in Berlin.

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Perspectives

Two directions of the globalization project will be strengthened in the future: the globalization of knowledge in the ancient world and in recent times. It is planned to establish a cross-sectional group within the Excellence Cluster TOPOI that should combine research results from various areas of the TOPOI project under the perspective of their contribution to understanding processes of knowledge migration in antiquity. The investigation of the globalization of knowledge in recent times will address the epistemic and political dimensions of scientific uncertainty and decision-making in regard to global challenges such as climate change and the energy crisis (Milena Wazeck).

History of Science in Action: Alternative Forms of Dissemination

General Goals

Based on the insights that scientific knowledge evolves as part of a comprehensive system of knowledge and that external and cognitive representations of knowledge are closely intertwined in this evolution, the Department explores alternative forms of dissemination in order to probe the potential of research-driven technology development for opening up new horizons for the humanities and their place in society, and in order to investigate the potential of the history of science as a mediator between science and society.

The Epistemic Web

New technologies and the Internet offer innovative forms of publications of scholarly data and results. Against this background, the idea of an Epistemic Web has emerged. Such a Web will enable the creation of dynamic representations of knowledge, integrate research and dissemination, accommodate recursive processes in knowledge formation, integrate both conceptual models and data, and build "intelligence" into scholars' working environments.

Department I in cooperation with the MPIWG library and the IT group initiated the creation of a research-driven infrastructure for the humanities, which is now the basic infrastructure for all Internet-based working environments and presentations of the research projects. Together with the IT group and the library researchers make digitized cultural heritage—the primary sources for the projects—publicly accessible and sustainable on the Internet and develop tools for an Internet-based scholarly analysis of the sources.

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Traditional and Virtual Working Environments: working with sources in cooperation with the Stiftung Bibliothek Werner Oechslin, Einsiedeln

The Werner Oechslin Library in Einsiedeln/Switzerland chiefly assembles source texts on architectural theory and related areas in original editions extending from the 15th to the 20th century. Over 50,000 volumes document related developments in the context of humanities and science. The Department hosted three workshops at this location which offered a unique opportunity to access this wealth of rare books. Complemented by a digitization program, the workshops made a selection of these sources accessible to the scholarly community. More than 70 different volumes representing the major editions of Vitruvius' "Ten Books of Architecture" were digitized and made publicly available on the ECHO website. Furthermore, a database was developed to facilitate access to the holdings of the library.

→ Library, p. 224

The first workshop centered on case studies that elucidated the impact of practitioners' knowledge on the development of scientific theories. The second workshop was dedicated to "Writing and the Transmission of Knowledge". The third workshop investigated the interactions of the various editions of Vitruvius' "Ten Books of Architecture" with the specific social and scientific contexts of their publication.

→ Globalization of Knowledge, p. 53

Digital Edition of the Sources on Florence Cathedral: The Years of the Cupola

The work on *The Years of the Cupola,* a digital edition of the surviving administrative documentation in the historic archive of the Opera of Santa Maria del Fiore for the period 1417–36, has been completed. The inauguration of the digital edition, established in cooperation with a group of scholars at the Opera, was celebrated in June 2009 in Florence.

The edition now contains over 21,000 transcribed and analyzed documents and incorporates a modulated system of indices and guided research functions that facilitate navigation in the *mare magnum* of data with clear and scientific criteria. It offers various consultation tools: document summaries that provide convenient syntheses of the content of the acts, active links between records, reference to the 'shadow' archive whose composition is evoked by citations of other original sources, bibliography for the publication history of the known documents. Finally, it is possible to search the transcribed documentary texts directly, a function available in the online representation of the data through word indices for vernacular and Latin texts. *The Years of the Cupola* is therefore a proper edition in the classic sense, yet it exploits the capacity of digital systems to facilitate retrieval and comprehension of its contents (Jochen Büttner). It thus represents a powerful tool for a new approach to the study of a great construction site and the world of its contexts as it has been pursued in the project *The Epistemic History of Architecture* <http://www.operaduomo.firenze.it/cupola/home_eng.html>.

Inauguration brochure of The Years of the Cupola.

Bringing Together Virtually Distributed Collections: The Cuneiform Digital Library Initiative (CDLI)

The CDLI is a common initiative of the Department of Near Eastern Languages and Cultures of the University of California at Los Angeles (UCLA) and the MPIWG (Jacob Dahl, Peter Damerow, Robert Englund, Jörg Kantel, Sarah Köhler, Manfred Krebernik, Imad Samir, Marcel Sigrist, Christina Tsouparopoulou). On the websites of these institutions, more than 230,000 of the estimated more than 500,000 excavated tablets distributed over museums and archives of the whole world have currently been cataloged. For most of them standardized transliterations are provided, complemented by about 75,000 images (scans, scanned copies, or photos). Considerable efforts are presently being made to improve the searching facilities for retrieving the data. In the period of the report the work of the project was influenced by some major organizational and personal changes. The CDLI acquired a major grant from the Andrew Mellon Foundation in the United States to fund the digitization of major collections in Europe and the US: University of Pennsylvania Museum, British Museum, as well as Syrian collections, and smaller collections in the US and Europe (i. e. Leiden).

The Electronic Text Corpus of Sumerian Literature (ETCLS) provides an online searchable corpus of about 400 compositions of 'classical' Sumerian literature, with

bibliographies and English translations. The data is now being integrated into the CDLI dataset. In the report period, a database to complement the CDLI datasets with data about physical seals, seal impressions, and composite reconstructions of the complete seal motifs has been created. Work has also been undertaken on the Liagre Böhl collection, housed at The Netherlands Institute for the Near East (NINO) in Leiden. Furthermore, work in Syria in the context of the Syrian Digital Library of Cuneiform project (SDLC) has been carried out (Christina Tsouparopoulou).

In cooperation with the SCLC, an interactive Arabic/English/French presentation of a rich and indigenous cuneiform tradition dating back five millennia is in preparation.

Members of the working group of CDLI inspecting cuneiform tablets to be scanned together with the curator of the collection of the Vorderasiatischen Museum Joachim Marzahn. Photo by Ernst Fesseler.

The cuneiform tablet collections kept in the museums of Damascus, Aleppo, Deir ez-Zor, Raqqa, Lattakia, Idlib and Homs, originate from close to 30 different archaeological sites. In the summer of 2009, about 800 cuneiform tablets were digitized and catalogued from the archaeological sites of Tuttul (Tell Bi, Äôa) and Tell Beydar, housed in the archaeological museums of Raqqa and Deir ez Zor respectively. These digitized images will shortly be freely available online.

In the frame of the CDLI project, research was carried out on year names in the period of the third dynasty of Ur (Marcel Sigrist) and on administrative documents of the excavated archive of the city of Ebla (Imad Samir).

Open Access Research Infrastructure: "European Cultural Heritage Online" (ECHO)

In 2002 the initiative "European Cultural Heritage Online" (ECHO) was established to create a research driven infrastructure for the humanities. It is coordinated by Simone Rieger. In cooperation with the MPIWG library, part of the ECHO infrastructure is dedicated to the installation and documentation of workflows for the digitization of cultural heritage.

In cooperation with the IT group developments of research driven tools and workflows for analysis and publication of scholarly data linked to primary sources were supervised and integrated in the common and expanding open access working environment. In addition, work focused on the development and documentation of XML-full text production and its possibilities for linguistic analysis and comparison of large text corpora.

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In the report period, the content of the ECHO environment has been greatly expanded and its technical infrastructure and accessibility improved. ECHO now features more than 150 collections from more than 20 countries worldwide. Its basic infrastructure has been adopted for all internet-based projects of the MPIWG and has also provided a model for the development of a common research infrastructure by the MPDL (Scholarly Workbench).

The ECHO initiative is characterized by its strict open access policy. It has been presented at many international forums, such as UNESCO, various Open Access conferences, advisory boards for funding organizations (DFG, Gerda-Henkel-Stiftung, NSF, Getty Foundation), as well as advisory boards for national and international initiatives for creating research infrastructures (DDB, Europeana, DFG, DARIAH) as a best

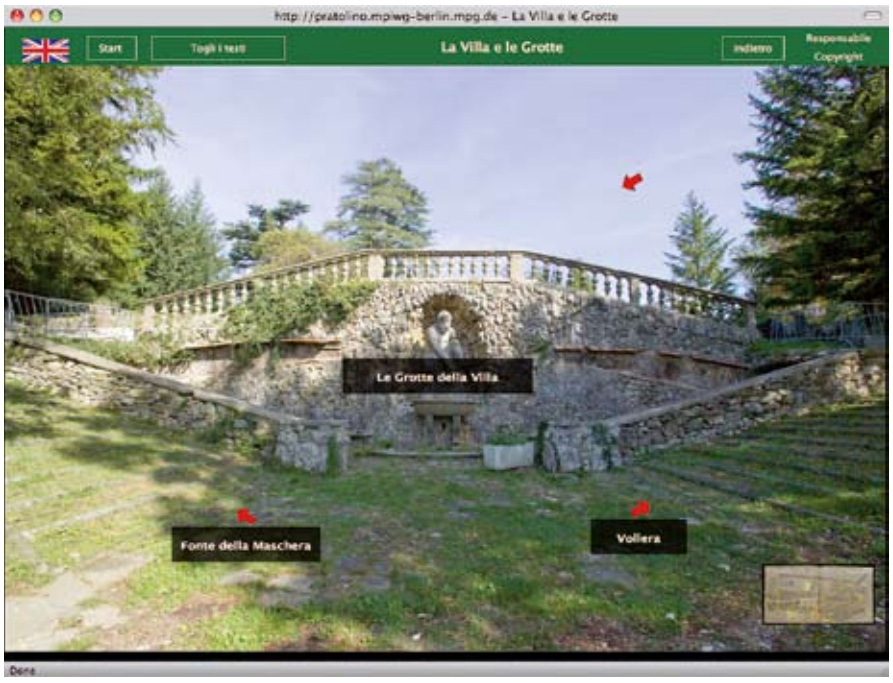
practice example of an open access environment. It now includes more than 600,000 digitized images of historical source material in high-quality resolution, about 240 video sequences, and 57,000 full-texts in several languages, 70 seed collections in several disciplines and thematic fields, in particular in the history of science.

Working with Full-Texts in the History of Science: Development of XML-Workflow and Content-based Web Access

During the report period work has been undertaken on the implementation of some of the key Epistemic Web concepts. A group has been established on the basis of a cooperation with the MPDL in order to complement the generic infrastructure of the MPDL with an application layer and interface to serve the specific purposes of scholars working with sources in the humanities (Jochen Büttner, Falk Knauft, Malcolm Hyman, Wolfgang Schmidle, Klaus Thoden, Josef Willenborg). This application layer consists of a content-based access mechanism for texts that incorporates language technology and thus enables semantic access to their content. In order to prepare historical sources for ingestion into this infrastructure, a workflow is being developed to structure texts in an XML-format, a presupposition for the integration of texts with various tools. As a testbed for this development, sources from a variety of the Department's projects written in different languages—such as Chinese, Greek, Italian and Latin—have been used, opening up new approaches for computer-assisted analysis of their content. Upon completion of the project, the application layer will be freely accessible. It is conceived as a prototype that can be further generalized within the MPDL and made available to a broad scholarly community.

Virtual Spaces

In 2005, the MPIWG created the virtual Albert Einstein exhibition. This virtual exhibition made the content of the "real" 2005 Albert Einstein exhibition available



Virtual walk through the Garden of Pratolino comparing the historical garden with the modern park.

online. The software used to create the virtual Albert Einstein exhibition was redesigned in the context of a diploma thesis written in 2008 in cooperation with the MPIWG (Julia Damerow). Released as "Virtual Spaces 2008," this redesigned software has a broader range of possible applications. It is open source software implemented in Java and has an easy-to-use graphical user interface for creating 2D graphs that represent real, fictive or knowledge spaces. From 2D graphs, virtual tours through such virtual spaces can be generated. The current version of Virtual Spaces 2008 creates HTML pages, a PDF or RTF file of a virtual tour. Its modular architecture facilitates the export functionality by implementing new components that create other file formats. The technology used for the Internet representation of a Virtual Space can therefore kept up-to-date with modern Web standards. Virtual Spaces 2008 is freely available at <http://virtualspaces.sourceforge.net/>.

Public Dialogue about Science and its Historical Roots

Department I adopted various forms of disseminating insights from the history of science, often combining scholarly communication with public outreach. For example, in order to foster interest in the history of science in schools, lectures have been given, as well as guided tours of the Institute and scholarly discussions involving classes and teachers on a variety of research topics, ranging from Renaissance studies to the history of quantum mechanics. Another example is the cooperation of the Institute with the 2008 exhibition "Max Planck: Revolutionär wider Willen" organized by the Max Planck Society in cooperation with the Deutsches Technikmuseum in Berlin. In addition to such outreach activities, the investigation of historical approaches and themes of the public understanding of science forms part of the research of Department I. The epistemological role of science communication is investigated in detail by looking at fundamental innovations in science and technology from the 20th century (Arne Schirrmacher). Specifically, the public presentation and discussion of the scientific understanding of the structure of matter (atomic structure, chemical bonding, crystals, quantum models ...) around the beginning of the 20th century has been analyzed, complementing insights of the project on the *History of Quantum Physics*. In this way it could be shown, for example, that the conception of the Rutherford-Bohr nuclear atom built on widely discussed public knowledge claims.

Entrance to the 2008 exhibition at the Deutsches Technikmuseum in Berlin "Max Planck:Revolutionär wider Willen".
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International Year of Astronomy 2009

In the International Year of Astronomy 2009, Department I joined forces with the Max Planck Institute for Astronomy in Heidelberg to explore how the invention of the telescope recast our view of the universe; the results were published in a special issue of the German astronomy journal *Sterne und Weltraum,* directed at both profes-

sional scientists and amateurs (circulation 14,500 copies). The research investigated astronomical knowledge existing before the invention of the telescope (Giorgio Strano, Matthias Schemmel) and the relation between the numerous antecedents of the telescope (Sven Dupré) to the available observational data and ancient sources, such as the works of Plutarch and the medieval reports on sunspots (Horst Bredekamp). The conflict between science and the dogmas of the Catholic Church (Rivka Feldhay, Elio Nenci) and the figure of Galileo as an engineer-scientist (Matteo Valleriani) were contextualized in the process of the transformation of ancient knowledge and the reorganization of its internal structure (Jürgen Renn). The work concluded with the analysis of how Galileo's physical ideas nevertheless remained anchored in Aristotelian natural philosophy, constituting the starting point from which classical Newtonian mechanics emerged (Jochen Büttner).

Children as Researchers: "Wunderforschung" and the "Werkstatt des Wissens"
Ongoing scholarly cooperations since 2003 between the Comenius Garden Berlin-Neukölln and Department I are reflected in common endeavors with the "Werkstatt des Wissens" set up by the Comenius Garden. In collaboration with the Museum für Naturkunde in Berlin and the Monash University in Melbourne, children's perceptions of wondrous everyday phenomena were confronted with historical forms of scientific knowledge about these phenomena (Carmen Hammer, Katja Bödecker, Henning Vierck). An exhibition displayed in 2008 at the Museum für Naturkunde in Berlin and an accompanying book have concluded the initiative.

Young researcher at work in the Comenius Garden, Berlin.