

How Does Science Change?
and
Overview of the Social Role of
Scientists and Knowledge Workers:
1700–1950

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How Does Science Change?

- When we talk about change in science are we primarily interested in changes in *ideas, practices, institutions, etc*?
- What does this change look like, and how does it affect the unity or diversity of the scientific disciplines?
- Are there specific **mechanisms** for scientific change? If so, what are they?

Karl Popper, Simplified

- A model, or theory, is put forward.
- This theory is developed and criticized. This process subjects the theory to attempts to falsify it through reasoning or experimentation.
- Eventually, the theory is falsified, and a new theory replaces it.
- Scientific change is *gradual but progressive*.
- An exclusive definition of science based on the concept of *falsification*.

Thomas Kuhn, Simplified

- *Normal science* works to explain the world based on current theories.
- In this process, anomalies are noticed and accumulate. Eventually, there is a critical mass and the old theory will no longer suffice.
- The science enters a period of *revolutionary science*.
- Eventually, a new theory becomes dominant. This causes a *paradigm shift*.
- Normal science resumes in developing the new paradigm.
- Scientific change is split between being *gradual but progressive* most of the time, and then *episodic and discontinuous* at crucial junctures.
- Inclusive definition of science based on the historical circumstances.

Approaches to the History of Science

Three historiographic¹ approaches to the history of science, of which **we should be cautious**.

Wig history: Looking at the past *through our categories* in an attempt to explain how the past leads to us. (*We are the framework and the goal.*)

Triumphalism: Looking at the history of science as *naturally revealing* what is true. (*What has come to be is the natural goal. There can only be one goal.*)

Social constructivism: Science is entirely constructed by human and social actors. (*All goals are entirely subjective.*)

¹ Historiography is the study of the history and methodology of the **discipline of history**.

Other conceptual practices **we should avoid** when thinking about history.

- Avoid explanatory shifts from historical episodes to the present. Ex., Ancient atomism, Newton's particles of light, Faraday's electro-chemistry.
- Avoid assuming that the motivations and concerns of historical practitioners can be judged on the basis of those of our contemporaries.
- Avoid using contemporary categories and disciplines to categorize historical activities.
- These are some examples of *anachronism*.

- Entirely new modes of conceptualizing the physical world. (Examples: organic chemistry, nuclear physics, evolutionary biology, etc.)
- These involved a new organization of knowledge constructed with new models and mathematical tools.
- These sciences were so successful that they produced powerful new ways of controlling the physical world that are at once highly beneficial and extremely harmful.

- At the beginning of this period, science was produced by a very small group of privileged individuals – mostly *men*.
 - Rather, in this period, the social role of people who dedicate themselves to the study of the physical world expanded, both in Europe, as well as the rest of the world.
- This period saw the creation of the *scientific career* (**educator, researcher, engineer, science administrator, technical manager**, etc.).
- This was accompanied by the solidification of the *role of science in society*.
- Currently, modern science is practiced by men and women of every religious, national and ethnic background.

- The role of science in society is instantiated in a wide range of different institutions.
- The first of these were general **societies** created for the practice and promotion of the sciences and arts. These were followed by specialized societies devoted to specific disciplines.
- The rise of specialist institutions: **research laboratories, botanical gardens, agricultural stations, observatories, various technical ministries and national labs, the research university**, etc.
- Currently, we have institutions for the production, transmission and preservation of the sciences, and institutions to administer and fund these, etc.

Exploration, Exploitation and New Wealth

- During this period, European nations, and later Japan and others, were involved in exploring and colonizing.
- This made the development of technological systems of navigation and mapping projects of “national importance.”
- Engineers, industrialists and imperialists began to work together to develop systems for measuring and codifying the natural and technological world.

New Technologies and Industries

- During this period (and largely for the first time), the results of theoretical science began to drive technological development.
 - Steam, coal, steel, rail, electricity(*), atomic power(*), computers(*), etc. Some of these technologies were interdependent with developments in the sciences.
- These technologies came to be deployed by companies that hired knowledge workers, who were highly trained experts in the sciences.
- Engineering and industry became essential to “national wealth” and security.

17th Century – England

- 17th century England was characterized by a number of revolutions and shifts of power and religious authority.
 - 1642: Struggle between Charles I and Parliament.
 - 1649: Commonwealth established.
 - 1660: Restoration.
 - 1685: James II (Catholic).
 - 1688: Glorious Revolution (William and Mary, Protestants).
- On the international stage, England became a major European colonial power, through crown corporations and naval power.

17th Century – England

- By 1700 in England, science had been institutionalized to some extent and was widely accepted as contributing to the common good.
- The implications of *institutionalization*: (1) instantiation of a society's acceptance of a science, (2) existence of norms that regulate and grant autonomy to that science, (3) transmission of social norms from other fields (such as law and medicine, the guilds, etc.) to the sciences.
- A limited number of scientists were able to obtain high social status and it was considered that their work was for the benefit of the commonwealth.

- The institutionalization of science was the successful result of a *scientific movement*.
- A group of people who believed in science as a way of obtaining truth, mastery over nature, and solutions to personal and social problems. Mostly, they were *not* expert scientists.
- In this view, the empirical and mathematical sciences were taken as paradigms and symbols for all knowledge and progress.

17th Century – England

- The *Royal Society* founded in 1660.
- A few expert scientists and a large number of enthusiastic gentlemen who wished to use science to improve society.
- The *Royal Society* was meant to give science *social autonomy*.
- At this time, high level science produced few social benefits.
- People turned more to philosophy and technology as means to shape a new social order.

- *l'Académie des sciences* founded 1666.
- The membership was almost entirely *elite scientists*, whose aim was to control science and put it to work for the French crown.
- *l'Académie* was meant to submit science to royal control and to separate it from other social institutions. It was a part of the *civil bureaucracy*.
- The scientific movement continued outside official channels and reached its apex with the 18th century *Enlightenment*.

18th Century – France

- Toward the end of the 18th century, France went through a number of major political and institutional changes.
 - 1789: The Revolution.
 - 1793: Louis XVIII, and then Marie Antoinette, guillotined.
 - 1799: Coup d'état by Napoleon Bonaparte.
- Major military conflicts with the other European powers.
 - 1792: War with Austria.
 - 1793: War with Great Britain.
- Centralization of government, military, industry, education and science.

18th Century – France

- The whole century was characterized by competition between England and France (and to a lesser extent other European states): military, industrial, economic, colonial and scientific.
- During the late 18th century, France became the scientific center of Europe. French methods in science dominated the continental scene, while the English tradition, dominated by an archaic Newtonianism, became increasingly isolated.
- The Scottish, on the other hand, followed the continental model. (Known as the Scottish Enlightenment.) Some of the major British scientists worked in the Scottish university system.

- The institutional changes effected by the Revolution and the Napoleonic Reforms strengthened the role of science in the central bureaucratic structures of the highly centralized state.
- There were special institutions for research (*Institut de sciences, Musée d'histoire naturelle, l'Observatoire*), while *grandes écoles* were established for teaching (*École polytechnique, École normale*, and so on), in which every faculty was a separate institution. This institutionalized a division between research and training.
- Research was at the discretion of the researcher, whereas education was tightly controlled by the state.

18th Century – France

- At the beginning of the century the majority of French scientists were “traditionally” employed (priests, lawyers, physicians, industrialists, engineers, proprietors, military officers, civil servants, and so on).
- By the end of the century the majority were employed in modern scientific professions (educators, researchers, civil servants in educational or scientific institutions, and so on).
- Throughout the course of the century, science became institutionalized, but research was still sharply divided from education.
- The centralization in Paris began to cause problems in the next century.

19th Century – France

- After the Napoleonic period, during the 1830s and 40s, the progress of French science began to stagnate.
- It was now institutionalized and centralized and French scientists had little motivation to change the educational systems or the scientific institutions.
- Each institution had a special and rigorously delimited function.
- This situation avoided competition between the French schools, and fostered a culture of individualism and intellectual conservatism. In France, each field was often dominated by a few individuals.
- At the end of the century, France finally began a system of reforms based on the German and American models.

19th Century – Europe

- This century saw the proliferation of the modern nation-states and, with this idea, the quantitative study of the citizenry (statistics).
- The beginning of the century was dominated by the Napoleonic wars of conquest.
- There were a number of major political and military shifts:
 - 1848: Rebellions in France, Italy, Ireland and the some of the German States. (The *Communist Manifesto* was published. The first declaration of the rights of women, Seneca Falls Declaration, US.)
 - 1850–60s: The suffragette movement began.
 - 1870: The Franco-Prussian War.
 - 1871: The unification of the German states (Kaiser Wilhelm I and Chancellor Otto von Bismarck).

19th Century – German States

- The German states transformed science from a marginalized career into a bureaucratic, organized activity.
- The German states were absolute monarchies and intellectuals could have no pretense to political leadership – they were part of a modest middle class.
- German philosophy was concerned with the aesthetic expression of individuals and nations through culture (*Kultur*), systematic metaphysical knowledge, and moral systems based on intuition and speculation.
- The natural sciences and humanities were both part of a broad conception of scientific knowledge (*Wissenschaft*).

19th Century – German States

- Starting around the time of the foundation of the Prussian University of Berlin, in 1806, the German States began a complete reformation of the university system.
- Scholars from every field worked together to increase their *social capital*.
- Because natural science had not been successfully institutionalized outside the university system, the universities became one of the primary locations of the sciences.
- Both the sciences and the humanities were situated in the faculty of Philosophy.

19th Century – German Universities

- Although they were state controlled, the bureaucratic structures of the university granted academic freedom and self-government. This gave freedoms to intellectuals that were not given to the people in general.
- Each field had one Professorship (later also Extraordinary Professors) and a number of Privatdozenten. The primary role of a Professor (Chair) was research, while that of a Privatdozent was teaching. They all has a fair measure of intellectual autonomy.
- The PhD was instituted as a specialized degree based on training in research skills – a four-year research degree, following *gymnasium*.

19th Century – German Universities

- The large numbers of Privatedozenten had to compete amongst themselves for students and for the limited number of professorships. They were paid directly by their students.
- There were a large number of similarly structured universities and students were free to transfer between them seeking the best teachers.
- Hence there was a great deal of competition and opportunities for innovation, which lead to the emergence of regular training for careers in science.
- The greater funds, which were available to the most successful researchers, were used to establish university research laboratories. These were individual institutes attached to directly to the Chair.

19th Century – German Universities

- The success of the sciences created a new hierarchical structure of research – institutes run by the Chair, sub-disciplines practiced by research assistants.
- It also gave rise to institutes of applied science and technical schools that only taught applied science, but did not grant PhD degrees before 1899.
- The universities expanded rapidly during the century, but did not change their structure to take full advantage of the new changes.
- The limited number of professors, whose incorporation was the *university*, would not share power.
- This strain was most felt in applied fields in which large laboratories were required.

Expanding Horizons

- In the 19th and 20th centuries, the people who practiced modern science began to come from a broader set of backgrounds in terms of gender, class, religion, ethnicity, etc.
- New institutions devoted to the production, preservation, and dissemination of science were established in many non-European nations.
- American, Asian, Middle Eastern and African nations began active programs of assimilating the modern sciences into their societies and adopted many of the European-style institutions that supported the sciences. Sometimes this was done in colonial settings, and sometimes independently.

20th Century – Overview

- The century was characterized by military and economic wars between the more industrialized nations.
 - 1914–18: WWI
 - 1939–45: WWII
 - 1950s–89: The Cold War
- New forms of social and political structure: totalitarianism, socialism, communism, etc. The rise of the corporation as the dominant economic and social institution.
- Science and scientific technology became a cornerstone of military and economic power.
 - The rise of “big science.”
- Throughout the course of 20th century the US went from being a political and economic backwater to being a dominant superpower. Science and scientific technology played a key role in this.

- Originally, the American university and college system was based on the British schools – a well-rounded BA could be followed by law, medicine or theology.
- In 1876, Johns Hopkins was founded with an emphasis on research and graduate training.
- In general, however, during the 19th century, Americans who wanted to pursue a career in science went to Europe (mostly Germany) after their BA for a German PhD.

20th Century – United States Universities

- The German model of research training was imported into the *graduate schools* of the American universities.
- The departmental structure of the American schools eliminated many of the problems of the German system.
- It could easily accommodate the development of new disciplines, because there were a large number of professors working on many different specialties.
- Graduate students who had already obtained a general BA trained under these professors for a career in research.

20th Century – United States Universities

- The US universities incorporated the professional schools (law, medicine, engineering, theology, later business, and many other fields) as analogous to the graduate schools.
- There were three sections (undergraduate, graduate and professional) each of which had *different goals*.
- This meant the universities saw themselves as pursuing various goals: teaching, training and research.
- Hence the universities pioneered research that went far beyond the needs of training students.

20th Century – United States Universities

- The American university system is decentralized and competitive.
- Universities had to continuously demonstrate their usefulness by developing new courses of study and bringing more professional training within their purview. (ex., architecture, nursing, business, management, etc.)
- Their internal structure was more successful than their European models.
 - They were flexible enough to accommodate new functions.
 - They were autonomous and could act more quickly.
 - They were large enough to teach and research in a large number of fields.
- The institutes and labs were not attached to a single department or professorship.

20th Century – United States

- An American PhD was considered equivalent to an MD, its recipient was considered to be eligible for a career in research.
- The US established the social role of the professional researcher. Employers accepted an implicit obligation to provide the PhD with facilities, time and freedom necessary for further research.
- This created the world's largest market for researchers in the academy, industry and government.
- Many foreign scientists and scholars came to work in the US university system.
 - This was especially driven by the emigrations caused by the National Socialists (Nazis) in Germany, and the military-industrial-academic complex during the Cold War.
- This model was then adapted in varying degrees by other nations.

- We have looked at various changes in the institutionalization and professionalization of science.
- In particular, we have focused on the role of the university and the university system as a locus of scientific activity.
- What is the importance of institutionalization for the production of a clear social role?