Science in Industry and War in the Early 20\textsuperscript{th} Century

International Trends and National Rivalries
Technological Systems

• 20\textsuperscript{th} century technology is characterized by the development of large scale systems of production.
  – Exploitation of resources
  – Production of parts
  – Distribution
  – Production of goods
  – Consumption

• Every aspect of the system requires elaborate distribution of resources and energy, etc.

• The real presence of these systems was first felt in war times when they were disturbed by blockades, sanctions, etc.
Physics in Industry

• At the turn of the century, physics began to enter industrial labs in the same way that chemistry had decades earlier.

• Warburg, 1891: “As far as physics is concerned, the so-called rise of the natural sciences, which characterizes modern times, lies not in the number and discoveries of principles of research. It is due much more to greatly increased effect which this science exerts on civil life and on branches of technology dependent on it. And, as we must add, to the counter effects which result thereby.”
National Labs

• Siemens to the Prussian government, 1887: “In the competition between nations, presently waged so actively, that country which first sets foot on new paths and first develops them into established branches of industry has a decisive upper hand.”

• Physikalisch-Technische Reichsanstalt (1887), the National Physics Laboratory (1898, England), the National Bureau of Standards (1901, US), the Institute of Physical and Chemical Research (1917, Japan).
Industrial Labs

- The development of private labs was most advanced in the US, then Germany.
- In 1910, 2% of the research papers in physics were from industry; in 1915 it was 14%; by 1920, 22%.
- The leaders were General Electric (GE) and the American Telephone and Telegraph Company (AT&T).
War-Time Production Surge

• During WWI, production in the private labs skyrocketed.

• In 1917, the total production of vacuum tubes in the US was 400/week; by the end of the war it was 80,000/week (200 fold increase).

• This did not entirely abate in the post-war period.

• As an example, in 1925, papers in Physical Review were distributed as follows: 27 from GE, 29 Bell Labs (AT&T), 25 Columbia, 21 Yale, 75 Caltech.

• Between the wars, Bell Labs was the biggest and wealthiest institution for research physics: 3,400 technical staff, 600 PhD scientists.
Science in War

• When WWI broke out, chemists and physicists offered suggestions to the military about ways they could contribute to the war effort.

• At first, they were ignored or treated with skepticism. Military officers were reluctant to acknowledge any role for civilian scientists.
  – In Germany and Austria, young scientists were simply sent to the front to die in the trenches.

• Gradually a number of wartime scientific offices were established.
Military Technologies (examples)

- The Artillerie-Prüfungs-Kommission (Germany) organized physicists to study ranging techniques for artillery: optical, acoustic, seismometric and electromagnetic.
- The Department for Scientific and Industrial Research (England) promoted, funded and coordinated scientific research for military applications.
- The Germans developed the U-boats (submarines). Rutherford developed new techniques for tracking them. Curie developed radiology units. De Broglie worked on radio transmission from the Eiffel tower.
“The Chemists’ War”

- Chemists developed:
  - High-explosive shells that detonated on impact
  - Production technologies that would secure production without the trade relations of their enemies
  - Production of drugs for medicine and combat was reorganized on a purely national basis
  - Chemical weapons

- The stalemate of long-term trench warfare may help account for the resort to poison gases.
Gas Warfare

• Fritz Harber (1868-1934) established connections between the war ministry and the Kaiser Wilhelm Institute for Physical Chemistry. They developed a series of poison gases that could be used in explosives. [Tear gas (1914), chlorine poison “Disinfection” (1915), mustard gas (1917)]

• The French responded with their own gasses.

• There were over a million gas casualties.

• Gattefossé: “The war of tomorrow will surpass the horror that preceded it; without any doubt, the perfection of aviation and chemical warfare will allow entire regions to be rendered uninhabitable.”
Fritz Harber (1868-1934)
The Outbreak of War WWI

- Rutherford and Moseley were at the BAAS meeting in Brisbane. Rutherford proceeded home via Montreal and New York. Moseley joined the army.
- Bohr was at a conference in Germany. He took the last train back to Denmark.
- In the early weeks of the war, otherwise rational men degenerated into nationalistic polemic.
- When Brittan declared war on Germany, a number of German scientists renounced their honorary degrees from English institutions.
Mixed Reaction

• While most German scientists supported this gesture, there were some who did not.

• Ehrenfest to Lorentz, 1914: “The typical newspaper report that Haeckel... has rejected his English academic honorary degrees has left me very depressed. Whatever one may think of Haeckel as a scientist... he is at all events a man who is really true to his own conscience, or so it seems to me. Then how could he do such a thing? Now he should also throw away Darwin’s books... as another gesture... I don’t doubt for an instant that a large fraction of the scientists in all these countries know that the distinctive element of Haeckel’s action (treating an honorary degree from Cambridge as if it were a military decoration) is completely irrational and perverse...”
English Reaction

• Ramsey, *Nature* 1914: “German ideals are infinitely removed from the conception of the true man of science... The greatest advances in scientific thought have not been made by members of the German race... So far as we can see at present, the restriction of the Teutons will relieve the world from a deluge of mediocrity... The motto of the Allies must be ‘Never again.’ Not merely must the dangerous and insufferable despotism which has eaten like a cancer into the morals of the German nation be annihilated, but all possibility of its resuscitation must be made hopeless. The nation, in the elegant words of one of its distinguished representatives, must be ‘bled white.’”

• But, Ramsey had been educated in Germany.
English Reaction (con’t)

• He was conflicted in his outright denunciation of the “Teutonic” race.

• Ramsey, letter to Remen: “Our friends, the Germans, are very different from what we knew then. I have found out why. Before the war, our Govt. appointed a commission of which the president is one of my old medical colleagues… to investigate syphilis… He told me that in Britain less than 1/2% of the population is syphilitic, in France, about 1-1/2%; in Germany 8.5%! … While syphilitics often keep going, & retain energy, they appear almost always to have a mental twist; they become abnormal in one way or another. So it comes to this: this is a war against syphilis.”
Krieg der Geister
(War of the Learned)

• Most British scientists were more restrained than Ramsey and maintained their German connections. They were all the more hurt by what followed.

• The Allied press was alarmed that Germany attacked neutral Belgium and there were reports that the troops were destroying treasures of art and science.

• 93 prominent German intellectuals responded to this with the “Appeal to the Cultured People of the world.” (Only 4 abstained and signed a dissenting manifesto. One of these was Einstein.)

• It was distributed in 10 languages in all the major German papers. It was followed a few weeks later by a shorter manifesto signed by 3,016 German professors.
An die Kulturwelt!

- They declared themselves, the German leaders of art and science, to be at one with the Prussian army.
- They repudiated the claims of atrocities as malicious lies, and anyway impossible for good, well-educated German boys to commit.
- They ended, ridiculously, by claiming that they were waging a “civilized war” because after all they were the country which had produced “a Goethe,” “a Beethoven” and “a Kant.”
The Shorter Manifesto: “We instructors at Germany’s universities and institutes of higher learning serve scholarship and carry forth a work of peace. But it fills us with dismay that the enemies of Germany, England at the head, wishes—ostensibly for our benefit—to polarize the spirit of German scholarship from what they call Prussian militarism. In the German army, there is no other spirit than in the German people, for both are one, and we are also a part of it. Our army also nurtures scholarship and can attribute its accomplishments in no small part to it. Service in the army also makes our youth effective for all the works of peace including scholarship.
• For the army educates them to sacrificial faithfulness to duty and lends them the self confidence and sense of honor of the truly free man who submits himself willingly to the whole. This spirit does not only exist in Prussia, but it is the same in all the lands of the German Reich. It is the same in war or peace. Now our army stands in battle for Germany’s freedom and thereby for all the assets of peace and morality—not just in Germany alone. Our belief is that salvation for the very culture of Europe depends on the victory that German ‘militarism’ will gain: manly virtue, faithfulness, the will to sacrifice found in the united, free German people.”
The French Response

• The Academy, in Paris, revoked the foreign memberships of all who had signed.

• The French scholars claimed that although the Germans were good organizers, they appropriated all their ideas from elsewhere.

• According to Duhem, a French physicist and historian of science, *la science allemande* (German science) was distinctly marked by the German races’ deplorable moral and mental characteristics.

• An example of this, which he mentioned, was the theory of relativity with its “absurd” postulate of the velocity of light as the upper limit of all velocity.
The French Response (con’t)

• A French Newspaper Editorial, 1916: “The principle of relativity is the basis of a scientific evolution which can best be compared with futurism and cubism in the arts… We find a good example of this mathematical-metaphysical delirium in the theory of quanta of Max Planck, a professor of physics in Berlin and one of the 93 intellectuals on the other side of the Rhine. Planck… introduces… atoms of heat, light, mechanical energy [!], indeed of energy in general; as a result of the theory of relativity these atoms even posses a mass endowed with inertia [!].”
Post-War Tension

• With the Treaty of Versailles signed, the Swedish Academy announced the Nobel Prize recipients for 1918 and 1919: Planck, Stark and Harber (All Germans). The French refused to go.

• No Germans or Austrians were invited to attend a major international conference in chemistry, Solvay, 1922.

• At the Solvay physics conferences, Schrödinger (Austrian) was the only German to attend until 1927. Einstein was invited but declined in solidarity with his German colleagues. Einstein, 1924: “In my opinion it is not right to bring politics into scientific matters, nor should individuals be held responsible for the government of the country to which they happen to belong.”
Rising Anti-Semitism

- In 1920, Weyland gave a public lecture slandering Einstein’s theories because he was a Jew, a pacifist, a publicity-seeker and a “scientific Dadaist.”
- When Einstein received the Nobel Prize in 1921, Lenard complained to the Swedish academy that it “had not been able to bring to bear a sufficiently Germanic spirit to the avoid perpetrating such a fraud.”
- When Einstein was invited to give a talk to the Society of German Physicists and Physicians in 1922, he received death threats.
- Stark began a campaign against “Jewish theoretical physics.”
Anti-Semitic Laws

• In 1933, Hitler gave his acceptance speech as the new leader of Germany.

• Lise Meitner described the speech in letter to Otto Hahn as moderate and tactful. She said, “hopefully things will continue in this vein… Everything now depends on rational moderation.”

• The Nazi party soon declared the country a dictatorship and began to issue a series of progressively more severe anti-Semitic laws.
  – 1933, Civil Service Law.
  – 1935, Nuremberg Laws.
1933 Civil Service Laws

• “Section 1: To restore a national professional civil service and to simplify administration, civil servants may be dismissed from office in accordance with the following regulations, even where there would be no grounds for such action under the prevailing Law.

• Civil servants who are not of Aryan descent are to be retired; if they are honorary officials, they are to be dismissed from their official status.

• Section 1 does not apply to civil servants in office from August 1, 1914, who fought at the Front for the German Reich or its Allies in the World War, or whose fathers or sons fell in the World War.”
1935 Nuremburg Laws

• German Blood and German Honor:
  – “Marriages between Jews and citizens of German or kindred blood are forbidden.
  – Extramarital intercourse between Jews and subjects of the state of German or related blood is forbidden.”

• Citizenship:
  – “A citizen of the Reich is that subject only who is of German or kindred blood and who, through his conduct, shows that he is both desirous and fit to serve the German people and Reich faithfully.
  – Only the citizen of the Reich enjoys full political rights in accordance with the provision of the laws.”
Intellectual Emigration

• The dismissals of 1933 included over 1,000 university teachers and over 300 full professors. (Some German professors resigned in protest.)

• An American reporter, by letter: “Most people don’t give a darn; a large proportion is rather glad it happened. Those extremely few who are upset by it are disinclined to say anything publicly or even privately.”

• Although the majority of emigrants were Jews, among intellectuals and artists a much smaller number of other Germans and central Europeans also left.
The Example of Physics

- In the early 1930s, Germany lost about 25% of its physicists.
- But this was a critical mass of talent, experience and originality that could not be replaced.
- In general, the more theoretical the institute, the more dismissals.
- Göttingen was the hardest hit. John von Neumann: “We have been three days in Göttingen and the rest in Berlin, and had time to see and appreciate the effects of the present German madness. It is simply horrible. In Göttingen, in the first place, it is quite obvious that if these boys continue for only two more years, they will ruin German science for a generation - at least.”
The Example of Physics (con’t)

• The international physics community began to respond to this by isolating Germany; canceling subscriptions and memberships and not traveling to Germany.

• German physicists and science administrators tried to convince their government that the policies were bad for Germany.

• Ramsauer, 1942, gov. report on German physics: American citations in Annalen der Physik were rising, while German citations in Physical Review, “the internationally acknowledged leading physics journal,” were declining.
• Ramsauer, 1942, gov. report on German physics, nuclear physics: “The number of German papers in this most modern and promising field has thus risen 3.5-fold, whereas the number of papers written in English has risen 13.5-fold. Yet, as every nuclear physicist will confirm, the quality of American papers is at the very least equivalent to that of the German papers.”
The Destinations

• Many of the emigrants initially moved to nearby countries; Denmark, Switzerland, the Netherlands, and France. They mostly settled, however, in Brittan and especially the US.

• The US was still dealing with the effects of the depression and a strong, but disorganized, anti-science movement.

• Nevertheless, the US science infrastructure was now the largest in the world and the country was best able to absorb the emigrants.
The International Community

• The German dismissals gave the scientific community the chance to test the ideals of its international commitment.
• Scientists reacted swiftly and efficiently.
• They established private foundations, funded by individual donations and gifts. Many pledged 1-3% of their salary.
  – Emergency Society for German Scientists Abroad
  – Academic Assistance Council [England]
  – Emergency Committee in Aid of Displaced German Scholars [US]
• Corporations and private funding agencies also established short-term positions to help the emigrants.
Integration

• The integration of emigrant scientists in the US was as varied as the individuals.
• Jewish scientists had to cope with American anti-Semitism, especially in the South.
• They had to cope with large cultural differences. Some returned to Europe after the war, but many stayed.
• Those who stayed had a lasting impact on the intellectual history of North America.
Nationalistic Science

• Stark, 1934: “The slogan has been coined, and has been spread particularly by the Jews, that science is international.”

• “No, science is not international; it is just as national as art. This can be shown by the example of Germans and Jews in the natural sciences.”

• “… Natural science is overwhelmingly a creation of the Nordic-Germanic blood component of the Aryan peoples.”
“It is true, however, that the Jewish spirit, thanks to the flexibility of its intellect, is capable, through imitation of Germanic examples, of producing noteworthy accomplishments, but it is not able to rise to authentic creative work, to great discoveries in the natural sciences. In recent times the Jews have frequently invoked the name of Heinrich Hertz as a counter-argument to this thesis. True, Heinrich Hertz made the great discovery of electromagnetic waves, but he was not a full-blooded Jew. He had a German mother, from whose side his spiritual endowment may well have been conditioned.”
Aryan Science

• Thüring, 1936: “The ancient magnanimity of soul of the Germanic man, directed away from the world and all external appearance, posed the first world-encompassing question about nature and thus became the mother of natural science.”

• According to Thüring, Kepler, Newton, Galileo, Guericke, Faraday, Gauss, Maxwell, and Robert Mayer all had the proper “German spirit” to do real science.

• “It is altogether different with the Jew Einstein.”
“There have been repeated attempts in lectures and books to present the theory of relativity as the grand capstone of centuries of progressive scientific development, which began with Copernicus and Galileo and led, via Kepler and Newton, to Einstein. No! Copernicus, Galileo, Kepler, and Newton are not Einstein’s predecessors and pathfinders, but his antipodes. Einstein is not the pupil of these men, but their determined opponent; his theory is not the keystone of a development, but a declaration of total war, waged with the purpose of destroying what lies at the basis of this development, namely, the worldview of Germanic man.”
The Mainstream Reaction

• The Nazi scientists were actually a small minority of the German scientists but they had a strong power base in the 1930s.

• The clear danger that this sort of thinking posed to intellectual life became a rallying point for the mainstream German scientists, even those who politically supported the Nazis.

• Prominent physicists, such as Planck and Heisenberg, took it as their imperative to fight this threat.

• By the early 1940s, the racist scientists lost much of their following and the movement began to fall apart.
Einstein’s Reaction

• In 1933, when Nazi Germany passed the anti-Semitic civil service laws, Einstein was at Caltech, Pasadena, and stated that he would not return to Germany since the country no longer enjoyed “civil liberty, tolerance, and equality.”

• The Berlin Academy of Science issued a statement that this was an insult to the fatherland.

• Einstein resigned his membership in the Academy and his German citizenship (for the second time).
Break with Pacifism

- Einstein renounced his previous pacifism and internationalism in 1933.
- He was asked to speak out on behalf of two conscientious objectors in Belgium.
- Einstein, 1933: “What I shall tell you will greatly surprise you… Imagine Belgium occupied by present day Germany. Things would be far worse than in 1914… Hence I must tell you candidly: Were I a Belgian, I would not, in the present circumstances, refuse military service.”
Big Science

- WWII gave rise to major projects in developing scientific technologies using a model of development that has been called big science.
- Major projects were: radar, jet fuel, penicillin production, code breaking, computers, the atomic bomb.
The Manhattan Project

• This was the codename for the allied project to build an atomic bomb.

• The leaders were General Leslie Groves and Robert Oppenheimer.

• There were three sites: Hanford, Washington (plutonium production); Oak Ridge, Tennessee (uranium enrichment); Los Alamos, New Mexico (research and design).
Political Will

• The motivation for starting the project was the fear that Nazi Germany would start work on a similar vein.

• During the war, Germany, Russia and Japan also had programs for developing atomic weapons. (With no success.)

• The Manhattan Project is one of the most conspicuous examples of “Big Science,” in which a huge quantity of natural and human resources are coordinated under a single budget using mechanisms of organization on a military scale.
Deployment

• Although, the project was begun with the Germans in mind, by the time the bombs were complete the Germans had surrendered.

• The US military intentionally left certain Japanese cities alone so that they would have “virgin targets” upon which to “test” the effects of the new weapons.
  – Hiroshima, Aug. 6, 1945 (uranium, 90-160K casualties).
  – Nagasaki, Aug. 9, 1945 (plutonium, 60-80K casualties).
Overview

- In the 20th century, science and technology moved into a central role in the political, military and economic arenas.
- Scientists and technocrats became entangled with politicians.
- It became clear that science and technology were a necessary component of military and economic strength.
- It became clear that science and technology made it possible to commit atrocities on a massive scale.
- The public’s image of scientists changed.