

Pioneers of Science Education #11: Justus Liebig (1803-1873): Pioneer of the teaching laboratory

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In this series of Pioneers of Science Education (PoSE) we have been looking at people who have made major contributions to the development of science education, especially in Great Britain and Ireland. This time we look at Justus von Liebig, a German, possibly the most important chemist of the 19th century, who revolutionised the practical teaching of chemistry at university and in so doing affected the way chemistry was and is taught both at university and in schools.

Introduction

Justus von Liebig (Figure 1) was a titan, a giant, of 19th century chemistry, particularly in analytical chemistry, organic chemistry and agricultural chemistry. His laboratory in Giessen, Germany (Figure 2) was the go-to place for aspiring chemists in the 19th century, and they flocked from England, the USA and elsewhere to learn from the master how to conduct chemical research. His main influence was on university chemistry teaching rather than on schools, although his influence percolated down from his disciples into school teaching. It is probably true to say that many chemistry teachers and chemists today have not heard of Justus von Liebig, something that I hope this article will correct. Liebig is best known to students and teachers for the water condenser, which he didn't even invent!

“Most of the present-day chemists seem to be unaware of the great influence Liebig wielded and the fact that he was considered as the authority in chemistry and other areas of knowledge during his time, through his contributions to analytical, organic and inorganic chemistry, chemical education, research methodology, chemical industry, agriculture, physiology, medical field and several other areas.” (Nagendrappa, 2013)

Brock (1979, p. 68) identifies Justus von Liebig as the person who started modern laboratory-based science education:

“My starting date, 1839, is arbitrary. It is the year in which the German chemist Liebig moved into an enlarged laboratory at Giessen, enabling him to expand the output of students. We may take this as a symbolic starting point for the development of modern science education.”

Even in today's world, this model of practical science education is still found in laboratory-based graduate education. Many chemists from the UK and America travelled to Germany in the 19th century for their graduate education and carried home both their doctorate degrees and the model of research-based education. The nature and design of the research laboratories left a lasting impression on the nature and design of university and school teaching laboratories.

We should remember that when Liebig was born and for most of his career, Germany was not a unified nation but was a set of independent states and kingdoms, which were only unified in

1870. Thus during his career, local politics and local rulers were more important and influential than any central government, unlike the situation in France or Great Britain. He started as plain Justus Liebig but was later ennobled to the rank of baron (Freiherr) in 1845 and became Justus von Liebig, the equivalent of a knighthood.

Liebig is described by Brock (1997, p. ix) as the chemical gatekeeper, guarding the borderlands of chemistry with other subjects. Brock says: *“In adopting the gatekeeper image, I have in mind the ways in which Liebig acted as an entrepreneur and propagandist for the extension of chemistry’s boundaries.”* These were the boundaries of chemistry with pharmacy, medicine, agriculture, industry and physiology. Liebig established that chemistry was the central and most useful of sciences. Morrell (1972) described Liebig as a chemist breeder, because of his success in mass producing trained chemists.



Figure 1: The young Liebig: 1843 lithograph after an 1821 painting (Liebighaus)

“In early youth he became familiar with the poet Platen, who noted in his diary “the friendly earnestness in his regular features, great brown eyes, with dark shady eyebrows, which attracted one instantly.

Those brown eyes, shining with earnestness, remain in the portraits which have come down to us, and, as a family feature, reappear in the faces of some of his children. Ardent, eager, enthusiastic in the pursuit of experiment, his remarkable power of exact observation stood him in good stead. Kindly and tender with children, there were times when eagerness in research or controversy led to exhibitions of impatience, but the steadfast character of the man is illustrated by the persistence of his life-long intimacy with Friedrich Wöhler. The intimacy resulted in a correspondence which extended over more than forty years, and had consequences in the lives of both men which were full of importance for the progress of chemical science.” (Tilden, 1921, p. 189)

Table 1: Chronology of Liebig’s life

1803	Born 10 th May, Darmstadt, Hessen
1811-1817	Gymnasium in Darmstadt
1817	10 months in an apothecary’s shop
1817-19	Home – reading and experimenting
1820	University of Bonn under Professor Kastner
1822	Doctorate from University of Erlangen (awarded later)
1822-24	Studies in Paris under Thénard and Gay Lussac
1824-52	Professor of Chemistry, University of Giessen

1826	Married Henriette "Jettchen" Moldenhauer
1837-55	Made six visits to Great Britain
1840	<i>Organic Chemistry in its Applications to Agriculture and Physiology (Agricultural Chemistry)</i>
1840	Made FRS and awarded Copley Medal, Royal Society
1842	<i>Organic Chemistry in its Applications to Physiology and Pathology (Animal Chemistry)</i>
1843	<i>Familiar Letters in Chemistry</i>
1845	Made a baron (Freiherr)
1852-1873	University of Munich
1873	Died 18 th April, aged 69 in Munich

Early life and Education

Justus was born in 1803 to Johann Georg and Maria Karoline Moserin Liebig in Darmstadt, Hessen. His father was a drysalter and hardware merchant, trading in various substances and making chemicals in a home laboratory. In 1811 aged 8 he was sent to the local Gymnasium, which taught a classical curriculum. He was not a distinguished student and when asked what he wanted to be, said 'A chemist'. The class and his teacher erupted in laughter as chemistry was not then seen as a subject to study or a career to pursue. Liebig was to change that perception in his lifetime. He left school aged 14 in 1817 and spent 10 months apprenticed to an apothecary in Heppenheim. He was withdrawn due to shortage of funds to pay his fees and spent 2 years at home. There he busied himself reading all the chemistry books he could lay his hands on and repeating experiments. There he had his first encounter with mercury and silver fulminates, which he made in his home laboratory. They are very sensitive and powerful explosives, and stories about Liebig tell of devastating explosions. Tiny amounts of fulminates are used in Christmas crackers. The fulminates were the topic of Liebig's first paper published when he studied in France, and was a continuing source of research for some years.

He was clearly not cut-out for a classical education or for business and his father sent him in 1820 to study at the University of Bonn under Professor Kastner, who later moved to Erlangen taking Liebig with him. Kastner was not an inspiring chemist and Liebig learned very little. He got involved in student politics and lived a high life, even being imprisoned at one point. He realised that he could not get the chemical education he wanted in Germany and set his heart on going to France to study under the great French chemists of the time. He was given a scholarship by the Grand Duke of Hesse to study in France and went there from 1822-24. Initially he worked with Thénard but a chance meeting with Alexander van Humboldt in 1823, who took a shine to the young chemist, led to an introduction to Gay-Lussac. Liebig worked with Gay-Lussac for over a year and they became lifelong friends. *"In the first place the decision of the young Liebig in 1822 to go to Paris to study the French approach to chemistry was undoubtedly the most important step in his professional life. Liebig himself had harsh things to say later about the spirit of Naturphilosophie so prominent in German science in his youth and to which he had previously been exposed. In Paris he learned the strict experimental approach to the subject, where quantification and precision were emphasized and airy speculation discouraged. Although he learned much from the formal lectures of the professors at the Paris Faculty of Science, Gay-Lussac, Thenard, Biot and Dulong, who all happened to be former members of the Society of Arcueil, even more important was the unique privilege he enjoyed to be taken into Gay-Lussac's laboratory at*

the Arsenal. He collaborated with the master in research on fulminates, resulting in a joint publication in the Annales de chimie. It was from Gay-Lussac that Liebig learned the techniques of organic analysis using copper oxide as the oxidizing agent.”
(Crosland, 2003, p. 354)

Gay-Lussac was impressed by Liebig and recommended his young friend to the Grand Duke of Hesse, who appointed Liebig to an extraordinary professorship at the University of Giessen. This didn't go down too well with the other professors, having a young upstart appointed over their heads. There already was a professor of chemistry in Giessen, who resented the new appointment, but when he died in 1826, Liebig took over as ordinary (full) professor of Chemistry, a job he retained until he left Giessen. His experiences to date, especially in France, had given Liebig the desire to set up a teaching laboratory in Germany, based on the best practice and chemical theory. The way he set about this was to put Giessen firmly on the map of chemistry for all time.

Although devoted to chemistry, Liebig was also a family man, and had a wide circle of friends. In May 1826 he married Henriette "Jettchen" Moldenhauer (1807–1881). They had five children, Georg (1827–1903), Agnes (1828–1862), Hermann (1831–1894), Johanna (1836–1925), and Marie (1845–1920). Although Liebig was a Lutheran and Jettchen a Catholic, they solved the mixed marriage problem, by bringing their sons up in the Lutheran religion and their daughters as Catholics. In Giessen the Liebig family lived 'over the shop.'

He was awarded many honours in his lifetime, and after it.

“The Grand Duke of Hesse conferred on him the Baronetcy in 1845, whence he became von Liebig. He was honoured with Prussian Order of Merit for Science and Art and the French Legion d'Honneur. He was awarded Copley Medal of the Royal Society, London, (then the highest honour for science in the world), Albert Medal of the Society of Art, London. He was made the Freeman (a person who is entitled to full political and civil rights) of the cities of Glasgow, London and Munich. He was an elected member of many learned societies including Royal Society of London, Royal Swedish Academy of Sciences and Foreign Associate of the French Academy of Sciences. He was President of the Academy of Sciences, Munich.” (Nagendrappa, 2013, p. 710)

The Giessen years 1824-1852



His laboratory in Giessen has been preserved as part of the Liebig Museum (<https://de.wikipedia.org/wiki/Liebig-Museum>) at the University of Giessen, now called the Justus Liebig University Giessen (Figure 2.) It is true to say that Liebig put the small, undistinguished University of Giessen on the academic map of Europe, and he made it a centre and a by-word for excellence in chemistry research and teaching. His most productive years were from 1824 to 1852, when over 700 students passed through his hands and on into jobs in industry, businesses and academia in Germany and around the world. His first laboratory was in an old barracks off campus, and it was largely privately funded by Liebig

(Figure 2). Liebig made important advances in the elemental analysis of organic substances using his famous *kaliapparat*, for absorbing carbon dioxide in alkali (Figure 3a and b). His method improved the speed and reliability of earlier methods and his absorption tube, made in his laboratory, became his chemical symbol.



Figure 2: Liebig's restored laboratory at the Liebig Museum. Compare with the drawing in Figure 4. (Source: Von Eberhard Theophel, CC BY-SA 3.0 de, <https://commons.wikimedia.org/w/index.php?curid=40187663>)



Figure 3a: Liebig's apparatus for organic analysis in the Liebig museum ([https://de.wikipedia.org/wiki/Liebig-Museum#/media/Datei:Liebigmuseum Elementaranalyse.jpg](https://de.wikipedia.org/wiki/Liebig-Museum#/media/Datei:Liebigmuseum_Elementaranalyse.jpg))

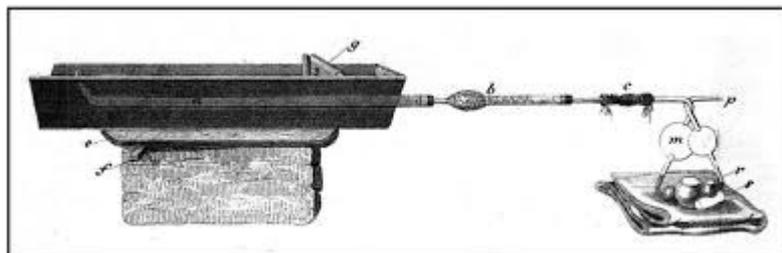


Figure 3b: Drawing of Liebig's apparatus for organic analysis

Students were put through a rigorous training programme of chemical analysis, which involved making their own apparatus, before they were let loose on original projects. Initially

Liebig concentrated on analysis but then moved into the synthesis of new compounds and their properties and the elucidation of the principles behind organic compounds. When Liebig started, organic chemistry (the chemistry of carbon compounds) was still a tangled thicket of facts, still influenced by vitalism, but when he finished it had become a science, based on firm principles. He discovered chloroform and chloral (a sedative), as well as the aldehydes (which he named) and developed the radical theory (with Wöhler) based on their study of benzoyl compounds – a radical or group which remains unchanged in different compounds. They also did work on uric acid and other biomolecules. Liebig invented a safe way of silvering mirrors, a familiar reaction from LC chemistry. His scientific approach and amount of work he produced have led him to be called the Father of Organic Chemistry.

“To speak of Liebig only: were we to consider merely the vast number and incalculable importance of the chemical facts which he established, we should have to proclaim him one of the greatest contributors to chemistry at large, that ever has appeared; while of organic chemistry we could not hesitate to consider him the very source and fountainhead.”

(Von Hofmann, A.W. (1876), p. 7)

The teaching laboratory

In Giessen as a young professor, Liebig’s main achievement was to set up a teaching laboratory for chemists and pharmacists, which became a mecca for chemists from all over Germany and the world. By the time he moved to Munich, exhausted by teaching and research, over 700 people (all men) had passed through his hands and on into employment in education, industry and business, in Germany and many other countries, especially Great Britain and the USA.

He started in makeshift premises in a laboratory off campus in an old army barracks, but in 1839 his successful lobbying led to a custom-built and larger laboratory complex. Figure 4 is the classic picture of his laboratory in action. Notice the laboratory wear – top hats and tails! No PPE in sight but an impression of intense activity and concentration.

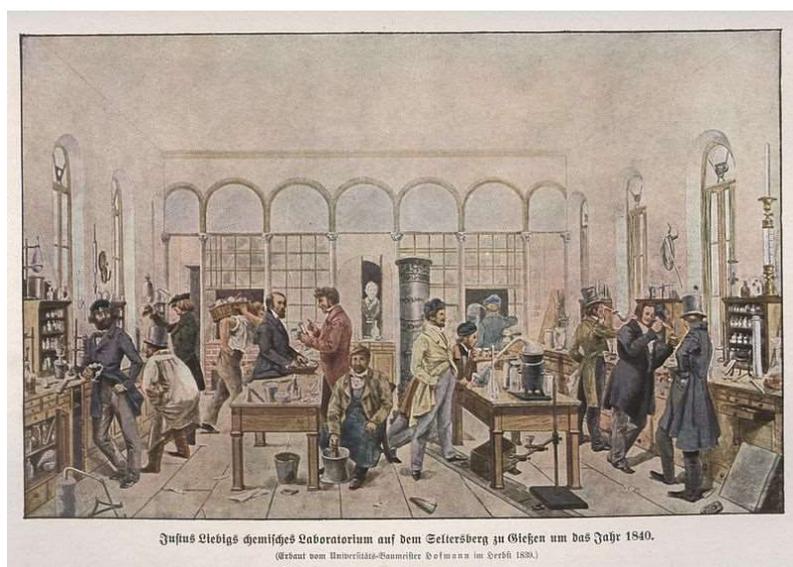


Figure 4: Liebig’s laboratory 1842

https://en.wikipedia.org/wiki/Justus_von_Liebig#/media/File:Justus_von_Liebigs_Labor,_1840.jpg

We have several descriptions of life in the laboratory, including Liebig's own rose-tinted version in his autobiography, written about 1863 but only published in 1890 after being discovered in his papers.

“Actual instruction in the laboratory, with experienced assistants in charge, applied only to the beginners; my special students learned only in proportion to what they brought. I gave them assignments and supervised the execution; like the radii of a circle, everybody had a common centre. There was no actual guidance; every morning I received from each one a report on what he had done the day before as well as his views on what he intended to do; I either agreed or made my objections, everyone was obliged to seek his own way, In companionship and constant intercourse, and in which each one participated in the work of all, everyone learned from the others ... We worked from daybreak until nightfall, distractions and diversions were not available in Giessen ... The memory of their stay in Giessen awakens in most of my pupils, as I have often heard, the pleasant sense of satisfaction for a well-spent time.”

(Justus von Liebig *Autobiography* (1863) quoted in Brock, 1997, p. 46.)

An English student Frank Buckland left an account of his experience there in 1845 (quoted in Brock, 1997, p. 45-46). He didn't stay long and eventually took up natural history not chemistry. His account shows how challenging life in Liebig's laboratory was.

“When a young man begins here, he generally goes through the course of analysing a set of one hundred bottles, which takes him sometimes a year. These bottles are various compounds, which he must find out – viz., in the first ten he had only to find one metal, etc; in the second two metals or substances, etc; till at last the highest bottles contain six or seven substances, all of which he must find out. Liebig thought I had better not begin there, as I had to learn German, and to stay only a short time there. However, I think I know more chemistry than when I came. About 3 o'clock Liebig comes into the laboratory, and he seems to be able to tell everybody, whatever they may be doing, what to expect, and how to proceed.”

Liebig had fulltime assistants who gradually took over Liebig's role, as well as using older students to help new ones. This resembles life in a modern research laboratory, where postdocs and older students help the beginners.

“There developed in the laboratory an esprit de corps, which was factor in spreading its fame. Liebig lived in the building [above the laboratory] and the students spent their entire day there; Aubel, the caretaker, complained about not being able to get them to leave. Liebig, a highly energetic man, had numerous projects under way at the same time. He gave the younger students little instruction in the laboratory, relying instead on his older students to act as his assistants in guiding the beginners in their work. The older students worked on original problems, turning in a report each morning on their progress the day before. Liebig discussed these reports with the various students in planning their future work. Thus there was a great deal of activity of different kinds, and the students educated one another.”

(Ihde, 1964, p.262-263)

Several commentators have identified how Liebig helped his students to think for themselves so that they became independent researchers in their right, not mere technicians.

“Liebig was not a teacher in the ordinary sense of the word. Scientifically productive himself in an unusual degree, and rich in chemical ideas, he imparted the latter to his advanced pupils, to be put by them to experimental proof; he thus brought his pupils gradually to think

for themselves, besides showing and explaining to them the methods by which chemical problems might be solved experimentally.” Hermann Kolbe

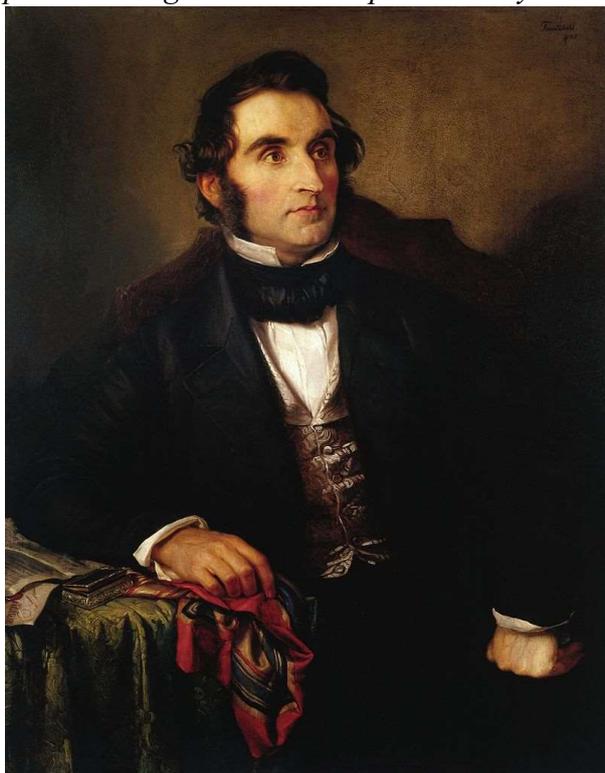


Figure 5: Painting of Justus von Liebig, by Wilhelm Trautschold, circa 1846

https://en.wikipedia.org/wiki/Justus_von_Liebig#/media/File:Justus_von_Liebig_by_Trautschold.jpg

The final years in Munich 1852-1873

After turning down offers of professorships, together with attractive packages, from several German and overseas universities, Liebig at last accepted an offer to move to the University of Munich in 1852. By then he was exhausted and tired of teaching after nearly thirty strenuous years in Giessen. He wanted to move to a quieter life where he could do research and give lectures, concentrate on his writing, but no longer direct a demanding research laboratory. Thus after 1852, chemists from overseas ended up studying with other German chemists like Bunsen and Kolbe, rather than with Liebig.

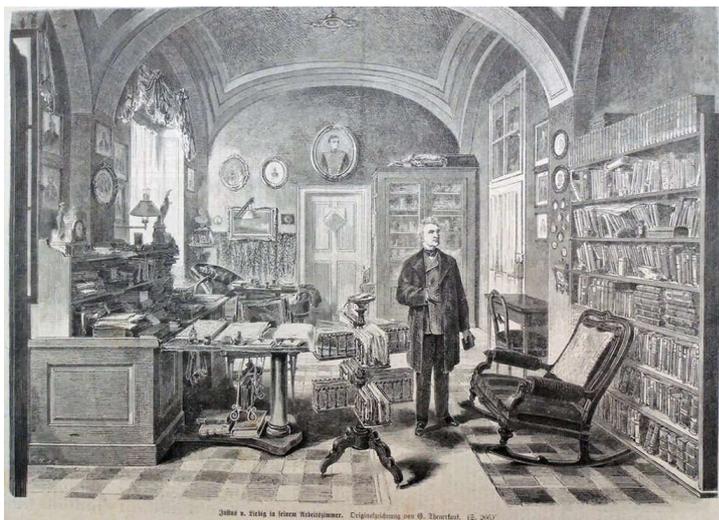


Figure 6: Liebig in his study in Munich

<https://graphicarts.princeton.edu/2019/01/09/justus-freiherr-von-liebig-1803-1873/>

Influence on chemistry teaching

Liebig's example in Giessen had a worldwide effect on the teaching of chemistry at university level, which in turn spilled over into chemical education in schools.

"The first real advance in laboratory teaching is due to Liebig, who, after working for some years in Paris under Gay-Lussac, was appointed in 1824 to be Professor of Chemistry in Giessen. Liebig was strongly impressed with the necessity for public institutions where any student could study chemistry, and to him fell the honour of founding the world-famed Giessen Laboratory, the first public institution in Germany which brought practical chemistry within the reach of all students.

Giessen rapidly became the centre of chemical interest in Germany, and students flocked to his laboratory in such numbers as to necessitate the development of a systematic course of practical chemistry, and in this way a scheme of teaching was devised which, as we shall see later, has served as the foundation for the system of practical chemistry in use at the present day.

When the success of this laboratory has been clearly established many other towns discovered the necessity for similar institutions, and in a comparatively short time every university in Germany possessed a chemical laboratory."

(Perkin, 1900, 638-639)

Following Liebig's successful example in Giessen, other teaching laboratories were opened in Germany by, *inter alia*, Wöhler (Göttingen), Bunsen (Heidelberg), Hofmann (Berlin), and Kolbe (Marburg and Leipzig).

"It is fair to say that all modern teaching of chemistry starts in Liebig's laboratory and classroom. He pioneered the concept that the study of chemistry had to be done using an experimental approach. Every student (and they came from all over the world, Great Britain, the United States and all of Europe sent their best and brightest), worked in bleak conditions, but received the highest degree of training that was possible.

Everyone learnt how to carry out quantitative and qualitative analysis, and were even given grounding in the new science of "synthesis", i.e. making new chemical compounds. They also did their own, supervised miniature research projects, a rarity in any teaching laboratory. It

is generally reckoned that Liebig's greatest contribution to the future of chemistry and science was in the classroom." (Blamire, 2002)

Perkin identifies 1845 as the date when the first such laboratory was opened in England by A. W. Hofmann in The Royal College of Chemistry, London, to be followed by Frankland in Manchester and Williamson in University College, London, all of them former students of Liebig. Chemists who had gone through the German system, either with Liebig or with other German chemists, or under the influence of Liebig's students like Hoffmann, brought this idea of laboratory teaching back to Great Britain. Henry Armstrong was one of these – he had worked with Hofmann and later Frankland, and had been to work with Kolbé in Germany. He became convinced that chemistry (and other sciences) should be taught through inquiry-based practical work, in a laboratory (or workshop as he preferred to call it), not only in colleges and universities, but also in secondary schools (see Childs, 2019).

"Indeed, Liebig's greatest influence on the development of British academic chemistry may be said to have been exerted through the presence in London during 1845-1865 of his German pupil August Wilhelm Hofmann." (Fruton, 1988, p. 34)

"Liebig, who had studied in Paris with Gay-Lussac and Thénard, went back to the University of Giessen and opened a teaching laboratory. He attracted students from various countries to Giessen, and his teaching became a model for others in Germany and overseas.

Liebig's pedagogical model was particularly influential in the United States, where university chemistry education was organised by professors who had studied with Liebig or Friedrich Wöhler (1800-1882). While Scotland had its own research tradition .. London followed the German model. The Royal College of Chemistry, founded in 1845, was directed by August Wilhelm Hofmann (1818-1892), a former assistant to Liebig, who had left Bonn for London." (Bensaude-Vincent, B. & Stengers, I., 1996, p. 98)

Liebig had been asked to suggest someone to fill this post. Hofmann stayed in London for 20 years and helped plant the seed of Liebig's pedagogy in English higher education, along with other ex-students of Liebig like Edward Frankland, Alexander Williamson and Robert Kane. One of the chemists influenced was Henry Armstrong (PoSE #7), who pioneered inquiry-based teaching in English schools and higher institutions. Several of Liebig's students ended up teaching chemistry in Irish universities: Robert Kane (Dublin and Cork), John Hodges (Belfast), Edmund Ronalds (Galway), Thomas Rowney (Galway), and William Sullivan (Cork).

In the United States something similar happened. Students went back from Giessen to American universities to start chemistry laboratories, combining teaching and research. Liebig's second American pupil was Eben Norton Horsford (Van Klooster, 1956), who was already teaching science but was urged by friends to take further study under Liebig (1844-1846). He returned without completing a doctorate to take up a professorship in Science at Harvard University in 1847. He raised funds to start a scientific school modelled on Liebig's laboratory. He got involved in chemical manufacturing (again following Liebig's example) and resigned in 1863 to concentrate on his business interests. Horsford was succeeded by Oliver Wolcott Gibbs, another of Liebig's students. Charles W. Eliot, who studied at Harvard, imbibed the laboratory method teaching, and took over Horsford's teaching in 1861. He had hoped to replace Horsford as professor, but the more experienced Walcott Gibbs was appointed instead. Eliot was committed to the laboratory teaching method as he explained himself:

“I was in charge of the Chemical Laboratories of the Lawrence Scientific School [at Harvard] .. my teaching was given wholly by the laboratory method without formal lectures or recitations from books.” (quoted in Sheppard & Horowitz, 2006, p. 567)

Eliot travelled abroad for two years and then returned to establish chemical laboratories at MIT. However, in 1869 he was appointed as President of Harvard, the first scientist and non-clergyman in the post. He raised the profile of science at Harvard and helped draw up a list of physics and chemistry experiments for high schools, completion of which would expedite a student’s admission to Harvard. This led to local high schools setting up laboratories and encouraging individual practical work, a movement which spread countrywide. At the time there was considerable variation in high school qualifications and entry qualifications to college. Eliot instigated the setting up of the Committee of Ten (CoT) in 1892, charged with restructuring high school education. The Committee’s recommendations for practical work (Table 2) show the influence of Liebig, and they created lists of experiments and encouraged the writing of new textbooks.

Table 2: CoT’s recommendations for practical work (quoted in Sheppard & Horowitz, 2006, p. 570)

- *That in secondary schools, physics and chemistry be taught by a combination of laboratory work, textbook, and thorough didactic instruction carried on conjointly, and that at least one-half of the time devoted to these subjects be given to laboratory work.*
- *That the laboratory work in physics should be largely of a quantitative nature.*
- *That careful notebook records of the laboratory work in both physics and chemistry should be kept by the student at the time of the experiment.*
- *That the laboratory work should have the personal supervision of the teacher at the laboratory desk.*
- *That the laboratory record should form part of the test for admission to college, and that the examination for admission should be both experimental and either oral or written.*
- *That a committee to consist of Mr. Fay and Mr. Krall have charge of making a list of 50 experiments in physics, and 100 experiments in chemistry, to be subject to the approval of the Conference.*

Sheppard & Horowitz (2006, p. 570) summarise the effect of Liebig on American science education.

“In 1844, Horsford studied chemistry in Liebig’s laboratory in Germany. On returning, he set up a laboratory at the Lawrence Scientific School, which would strongly influence Charles W. Eliot. When Eliot became president of Harvard, he modified Harvard’s admission policies to allow science and science laboratory courses to be admission options. Further, as chair of the Committee of Ten and as instigator of the College Entrance Examination Board, Eliot made sure that laboratory work became integral in high school curricula.

Eliot brought about changes that would leave a lasting impression upon science education in the United States. A pattern of teaching science as a combination of lecture and laboratory developed and became formalized and ingrained. This method, primarily unchanged, has remained in use to the present. Thus, the laboratory method promoted by Liebig, imported by Horsford, and championed by Eliot became an established teaching method in science education in the United States.”

Justus von Liebig’s arms were indeed long.



Figure 7: Justus von Liebig in later life

The popularisation of science

From 1839 Liebig turned his attention to topics outside pure chemistry and became known as a populariser of science with a series of influential books and newspaper articles, which made his name a household word inside and outside Germany.

“Liebig also used simple words and clear sentences that anyone could understand, and thus contributed not only to the formation of the chemical language, but also to the broader public education. In addition, he frequently used simple images and analogies drawn from ordinary life, particularly in his Letters on Agriculture and in the last editions of the Agricultural Chemistry.” (Blondel-Megrelis, 2014)

The main popular works were:

- *Organic Chemistry in its Applications to Agriculture and Physiology (Agricultural Chemistry)* 1840
- *Organic Chemistry in its Applications to Physiology and Pathology (Animal Chemistry)* 1842
- *Familiar Letters in Chemistry* 1843

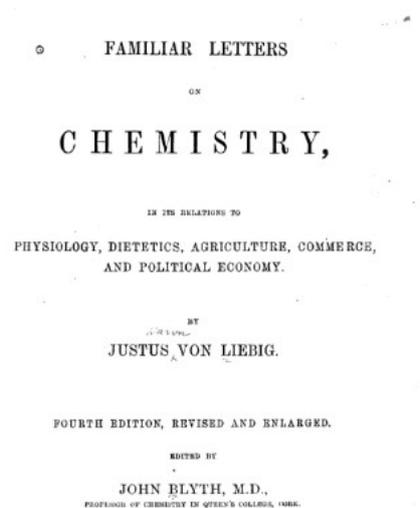


Figure 8: Title page of Liebig's *Familiar Letters on Chemistry* (4th edition)

The latter work was originally published as a series of articles in a German newspaper and in book form went through many editions. It was republished in instalments in *Chemistry in Action!* and is available to read online, although it is now considerably outdated (see <https://archive.org/details/in.ernet.dli.2015.216589>). These works cemented Liebig's reputation as Europe's best-known chemist and gave him unrivalled influence in the corridors of power. It is hard to see any chemist in the 21st century having such influence or popular impact. Interestingly Liebig saw Chemistry as learning the language of nature in understanding its phenomena, as this extract on p.10 of the 3rd *Familiar Letters in Chemistry* shows.

“But to enable us to read the book of nature, to understand its language, to perceive the truth of the theories of the philosopher, to subject to our will, and examine at our pleasure, the phenomena upon which a theory is based, and the powers producing them, we must necessarily learn the alphabet of the language, we must become familiar with the use of the signs or symbols employed, and by practice acquire skill in their management, and a knowledge of the laws which regulate their combinations. As in the higher branches of physics it is indispensable that the philosopher should have attained considerable practical skill in mathematical analysis so the chemist, before he can investigate natural truths successfully, must have the most perfect knowledge of chemical analysis — he must be able to express all his conclusions—all his results—in the form of phenomena. Every experiment is a thought thus rendered perceptible to the senses. In order to prove or disprove our conclusions we have recourse to experiments, to the interpretation of phenomena at will.”

Liebig was also heavily involved in scientific publishing. In 1832 Liebig joined Philipp Geiger (a pharmacist) in editing the journal *Annalen der Pharmacie*. Later its title was changed to *Annalen der Chimie und Pharmacie*, to reflect its change in focus. Later others helped Liebig and Geiger in the editing - Wöhler, Kopp, Erlenmeyer and Volhard. After Liebig's death it became *Justus Liebig's Annalen der Chimie*, and became one of the premier chemistry journals. It was published continuously from 1832 to 1997 and in 1998 became the *European Journal of Organic Chemistry*.

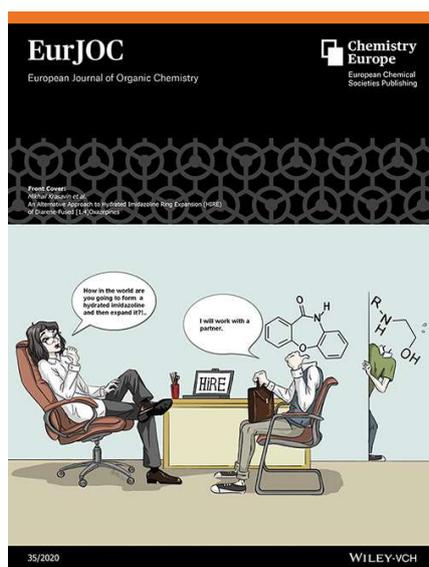


Figure 9: Cover of a recent issue of *EurJOC*, successor to the *Annalen*.

Liebig's influence on chemistry is the main reason why until the 1960s, when I went to university, intending chemists had to pass an exam in German so they could read the German

literature. Liebig was also involved in the publication of other influential reference works in chemistry (see https://en.wikipedia.org/wiki/Justus_von_Liebig). Liebig can fairly be described as the chemical colossus in his time.

Some Liebig quotes

"Alles ist Chemie." ("Everything is chemistry.")

"If you want to become a chemist, you will have to ruin your health. If you don't ruin your health studying, you won't accomplish anything these days in chemistry."

"The finest imagination in the world could not have conceived of a better idea than the philosophers' stone to inspire the minds and faculties of men. Without it, chemistry would not be what it is today. In order to discover that no such thing as the philosopher's stone existed, it was necessary to ransack and analyse every substance known on earth. And in precisely this lay its miraculous influence."

"I have spent some months in England, have seen an awful lot and learned little. England is not a land of science, there is only a widely practised dilettantism, the chemists are ashamed to call themselves chemists because the pharmacists, who are despised, have assumed this name."

"We may fairly judge of the commercial prosperity of a country from the amount of sulphuric acid it consumes."

"By the deficiency or absence of one necessary constituent, all the others being present, the soil is rendered barren for all those crops to the life of which that one constituent is indispensable."

"I would... establish the conviction that Chemistry, as an independent science, offers one of the most powerful means towards the attainment of a higher mental cultivation; that the study of Chemistry is profitable, not only inasmuch as it promotes the material interests of mankind, but also because it furnishes us with insight into those wonders of creation which immediately surround us, and with which our existence, life, and development, are most closely connected."

"Nature speaks to us in a peculiar language, in the language of phenomena; she answers at all times the questions which are put to her; and such questions are experiments."

"For all great discoveries chemists are indebted to the 'balance' – the incomparable instrument which gives permanence to every observation, dispels all ambiguity, establishes truth, detects error and guides us in the true path of inductive science."

"Never to give up anything taken in hand, and immediately put to the proof any new idea."

The Irish connection

In his six trips to Great Britain, Liebig visited Ireland several times. In his first visit to England in 1837 he met James Muspratt in Liverpool, the Irish-born alkali manufacturer and they became firm friends. Muspratt sent four sons to study in Giessen with Liebig and they remained friends throughout Liebig's life. During this first visit in 1837 to address the British Association (BA) in Liverpool, he visited Dublin and Belfast and met two former pupils – Robert Kane and William Gregory. He attended the BA meeting in York in 1844 where he was feted for his work on agriculture. In 1851 he visited the Great Exhibition in London and

he visited post-famine Ireland to see the conditions. In Galway he met Edmund Ronalds, professor chemistry at the University College.

Several chemists who were educated in Giessen ended up working in Irish universities and these are listed here: John F. Hodges (Belfast), Robert J. Kane (Dublin and Cork), James S. Muspratt (Dublin), Edmund Ronalds (Galway), Thomas H. Rowney (Galway), William K. Sullivan (Dublin and Cork). This is how Thomas Dillion (1943, p. 52) described this influence of Liebig on Irish chemistry.

“Outside the Museum of Irish Industry [which involved Robert Kane as Director and W.K. Sullivan as chief chemist] there were other influences working, against fearful odds, to establish a spirit of scientific inquiry in the country. Sullivan brought the Liebig tradition to the Catholic University, where he became professor of Chemistry on its foundation in 1851. ..the first professors of Chemistry at the [Queen’s Colleges] at Cork and Galway were pupils of Hofmann at the College of Chemistry [in London].”

In 2018 John Ryan from Tipperary won the prestigious Justus von Liebig Award, the Nobel Prize of soil science.

Other interests – from farm to physiology to nutrition

From 1839 onwards Liebig became interested in applications of chemistry rather than pure chemistry. His application of chemical ideas to agriculture and physiology was revolutionary, and although he got many things wrong, he was the first to try and approach farming scientifically. He identified the importance of minerals in plant growth and although he made a mistake in thinking fertilisers should be insoluble, to stop wastage, he is rightly considered as the father of the artificial fertiliser industry. He persuaded James Muspratt, the Irish-born chemical manufacturer, to set up a plant in England to make Liebig’s patent fertiliser, which turned out to be a failure. Liebig established the law of the minimum in fertilisers growth of plants is determined by the least available nutrient. He was also the first to identify the importance of biochar in storing and releasing plant nutrients. (Wilson, 2014)

Liebig the entrepreneur

Liebig’s extract of beef is well-known in Europe, less so in England and Ireland, but we are all familiar with the OXO cube and marmite. All of these resulted from Liebig’s work to provide nutritious food by concentrating the essence of meat or yeast. In the mid-19th century cows were killed in South America for their skins and the carcasses were thrown away. Liebig developed a way of boiling down beef to extract its essence and this was successfully commercialised in Uruguay from 1865 at a town later called Fray Bentos, familiar now as a corned beef brand. Liebig’s extract was marketed initially in a liquid form but a dried form became the familiar OXO cube. It made Liebig a household name. The company produced a series of trading cards highlighting aspects of Liebig’s life and work (Figure 10).

https://en.wikipedia.org/wiki/Liebig%27s_Extract_of_Meat_Company

Liebig also developed first a liquid, then a dried milk (with wheat and malt flour and potassium bicarbonate) for use as an infant formula in 1865.

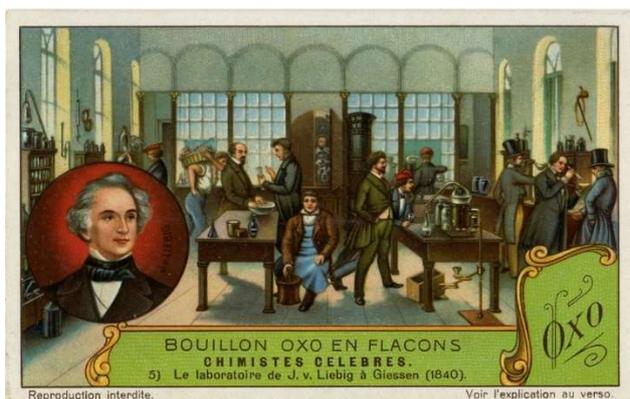


Figure 10: Liebig's laboratory, Chimistes Celebres, Liebig's Extract of Meat Company (LEMCO) Trading Card, 1929

https://en.wikipedia.org/wiki/Justus_von_Liebig#/media/File:Liebig_Company_Trading_Card_Ad_01.12.006_front.tif

Liebig also invented a safe way to silver mirrors using silver without using mercury, and later patented the idea.

Conclusion

When Liebig started his formal education in chemistry in 1822, he had to go to France to study with the French master-chemists, Gay-Lussac and Thénard. In the early 19th century France and England were the main centres of chemical expertise and chemical industry. By the time Liebig died in 1873, the balance had shifted in favour of Germany, both in chemical education, chemistry research and chemical industry.

“At the beginning of the nineteenth century, France was in the forefront of chemical industry; then Great Britain took the lead; in the last quarter of the century, Germany achieved supremacy, and after the First World War the United States made a spectacular ascent.”
(Bensaude-Vincent and Stengers, 1996, p. 102)



Figure 11: A stamp issued in 1978 by the GDR to celebrate Liebig's contributions to agriculture

This was due in large part to Liebig's laboratory-school in Giessen (1824-1852) and its influence on other German universities and on the chemical industry. He started the idea of the modern research school, and the research group with a group of researchers working with a master, a distinguished chemist. Liebig emphasised practical skills, to underpin chemical theory, but also encouraged his students to think for themselves and solve problems. His students went away from Giessen, imbued with their master's philosophy, equipped to think

for themselves, and proficient in laboratory skills, to found similar research schools in universities in England, Ireland and America. The emphasis on students doing practical work themselves, developing practical skills but also finding out new knowledge, was to spill over into school science through the efforts of Henry Armstrong and other German-trained chemists like Edward Frankland and William H. Perkin (of mauve fame), and in the United States through Eben Horsford and Charles Eliot.

“Liebig taught the world two great lessons. The first was that in order to teach chemistry it was necessary that students should be taken into a laboratory. The second lesson was that he who is to apply scientific thought and method to industrial problems must have a thorough knowledge of the sciences. The world learned the first lesson more readily than it learned the second.” (Ira Remsen, American chemist)

Liebig was also a populariser of science, through his writings (*Familiar Letters on Chemistry* and *Chemistry in its Application to Agriculture and Physiology*) as well the dissemination of research through publication (in what became Liebig’s *Annalen der Chemie* after his death). He laid the foundation of modern organic chemistry and organic analysis, and the application of chemistry in agriculture and physiology. He discovered chloroform, chloral and chloral hydrate, popularised the Liebig condenser (though he didn’t invent it), and played a part in the development of the fertiliser industry and the application of science to agriculture. He seems to have a finger in almost every chemical pie in the 19th century.

“..his ideas on chemical education – ideas that continue to be practiced in universities today – mark perhaps his most lasting contribution, for most chemists trace their educational heritage to a small laboratory in Giessen and to its master, Justus von Liebig.”
(Heitmann, 1989)

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