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1807: Observations Regarding Chemistry in the Anglo-Saxon World during the Napoleonic Period

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"It may be said of modern chemistry, that its beginning is pleasure, its progress knowledge, and its objects truth and utility."
Sir Humphry Davy[1]

Concerning the Year 1807

"We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness."
Thomas Jefferson, July 4, 1776, The Unanimous Declaration of the Thirteen United States of America.[2]

The still small United States of America, composed entirely of states along the eastern seaboard, saw its western reaches transformed during its first few decades by incorporation of the Louisiana Territory, which in 1800 was ceded by Spain to France. Americans suspected that the European colonial powers Great Britain and France envisioned unifying all the land between Mexico and Canada—a region that at the time was almost completely devoid of white settlers—into a single powerful political entity, posing a serious threat to the very existence of the new United States.[3] But after the fiasco of his failed Egyptian campaign, and a number of defeats at sea, "First Consul" Napoleon Bonaparte thought it unlikely he would succeed against the Royal Navy in establishing a wide-ranging supercolony extending all the way from French Canada to the as yet unconquered Spanish possessions in the south (Figure 1).[4] Furthermore, he was in dire need of money to finance further wars with England, as well as for his anticipated coronation as "Emperor of the French", scheduled for 1804. In December, 1803, representatives of Bonaparte and Thomas Jefferson negotiated a purchase agreement according to which Louisiana would, for 15 million dollars, become the property of the United States. Today this price seems almost ludicrous, but at the time its perceived extravagance triggered a fierce debate in Congress. Virtually nothing was known about the geography of the new territory, and its flora and fauna were almost as much of a mystery as its surface features and boundaries. To address this state of affairs, Jefferson on May 14, 1804, dispatched a "Corps of Discovery", charged with making its way across Louisiana and all the way to the Pacific. After a journey of about 8000(!) miles, marked by countless sacrifices and adventures as well as a host of both geographical and natural-historical discoveries, not to mention numerous encounters with previously unknown Indian tribes, to everyone's surprise the entire party—which had nearly been given up for lost—re-emerged on September 23, 1804, bringing with it a deluge of notes and journals.[5] Patrick Gass, sergeant of the "Corps", published his personal journal in 1807 in Pittsburgh. Three subsequent editions had appeared by 1811, and the work was reprinted in London in 1808 and translated into French in 1811. A two-volume *History of the Expedition under the Command of Captains Lewis and Clark to the Pacific Ocean* [Lewis, by the way, was once Jefferson's secretary] appeared in Philadelphia in 1814—all in all a noteworthy publishing and book-distributing success story. These two works also contributed significantly to the self-assurance of the peoples of the United States. In truth, the political and economic situation of the USA was at the time anything but rosy due to intense ongoing conflict with the mother-country Great Britain, but a clear path was now open to the vast expanses of the West, and a golden future seem-

Figure 1. Napoleon Bonaparte was genuinely *the* dominant figure of the epoch that was later name after him. This oil painting by Joseph Blondel (1781–1853) shows him at the steps of the Palais Royal de Paris.

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ingly awaited everyone in the young nation. It was certainly a propitious moment for establishing a print shop in New York.[6]

The Breathtaking Career of an American Loyalist

> *"I have often wondered that men of fortune and of rank do not apply themselves more to philosophical pursuits, ... but we may in vain search the aristocracy now for philosophers. And there are very few persons who pursue science with true dignity."*
> Sir Humphry Davy[7]

Toward the ends of their lives, many scientists have in fact gained recognition by society. Nevertheless, Humphry Davy, one of many offspring of a woodcarver, was making a valid point. By the standards of the time, most—albeit not all—of Davy's scientific contemporaries would have classed among the nouveau riche. For example, Benjamin Thompson, son of a small farm owner from Massachusetts, and torn from his home in the confusion of the War for American Independence, was destined to become founder of the "Royal Institution", which came to dominate science in the early decades of the 19th Century (Figure 2).[8]

It was not absolutely essential that one be a Jefferson partisan to believe in "the pursuit of happiness" and man's "unalienable rights". Even a loyal American subject of King George III like Benjamin Thompson (1753–1814) of Woburn, Massachusetts, could come under the spell of a yearning for success and "happiness". Starting out as an assistant to a general merchant and haberdasher, Thompson learned mathematics from a clergyman and later studied physics at Harvard College. He displayed even then a certain courage with respect to science, and, "enveloped in a jet of flame", repeated Franklin's famous experiment with lightning, experiencing after the process a "sort of lifelessness". At 19 he married a wealthy 30-year-old widow. Clad in the richest garments, astride a valuable steed, and the very image of a dashing young man, Thompson evolved into a permanent threat to every female virtue crossing his path. In conjunction with a knowledge of secret inks, this helped him become a successful spy for the British. He gradually attracted suspicion, however: in 1774 he was charged with "hostility to the cause of freedom", escaping conviction only because of a lack of evidence. As a result, he was forced to leave America. In London he served George III as "Secretary of the Province of Georgia". In 1788 he published in the *Transactions of the Royal Society* a paper entitled "New Experiments upon Gunpowder", whereupon he was elected a Fellow of the Society, although he was only 27 years old. The British government was then experiencing difficulties with its fleet, so the practiced spy was assigned to shadow several senior civil servants and naval officers with the hope they might be incriminated through his findings.[9]

Figure 2. In 1792 Johann Georg von Dillis (1749–1841) produced this wonderful chalk portrait of "Sir Benjamin Thompson, Lord Rumford", conveying some of the restless energy and willpower of this unusual man.

We pass over the subsequent complicated—indeed, chaotic—phase in British–American history, including Thompson's temporary return to the New World as commander of the King's American Dragoons until what amounted to victory by the Americans in 1782.[10] The same applies to Thompson's oft described (and rather mysterious) summons to Bavaria, and his extremely successful military and organizational efforts in Munich. For a time he served the Bavarian prince-elector as inspector general and minister of war; it seems almost superfluous to mention that, apart from one insignificant skirmish outside New York, he had personally never experienced even the whistle of an enemy bullet! Munich was under threat in 1796 from two different armies simultaneously: both the revolutionary French and the Austrians. "Count Rumford"—the name was taken from the town (later to become Concord, New Hampshire) where Thompson had left his family—succeeded in inducing both of the warring parties to withdraw. It is generally assumed today that Thompson's role as a British agent was at the root of his singular career, in a conspiracy to keep the Bavarian elector on an anti-French course. In all likelihood the abrupt termination of his stay in Bavaria was a consequence of intrigues in the Munich and London courts. In September 1798 he was supposed to become the Bavarian ambassador in London, but the court of St. James refused to agree, on the grounds that it was inappropriate to accept as the representative of a foreign state one of his majesty's own subjects. "Rumford"—as we will hereafter refer to him—needed to find a new occupation.

He had acquired an extraordinary reputation in two areas. From his Munich experiments in caring for the poor and dealing with the problem of beggars, his attempts at reintegrating Bavarian soldiers into society, the laying out of the English Garden, and the development of "Rumford soup", he was perceived as a social reformer (Figure 3).[11] His work on the mechanical theory of heat, especially measuring the frictional heat generated in the course of boring a cannon barrel, together with his determination in 1778 of the mechanical equivalent of heat—which in turn established that heat could not be a "substance"—coupled with investigations into the explosive power of gunpowder, the heat capacities and thermal conductivities of various liquids and solids (including the material used for making Bavarian army uniforms), the development of a shadow photometer, and design of a "Rumford lamp" with parallel wicks—all this contributed to his international standing as a scientist.[12]

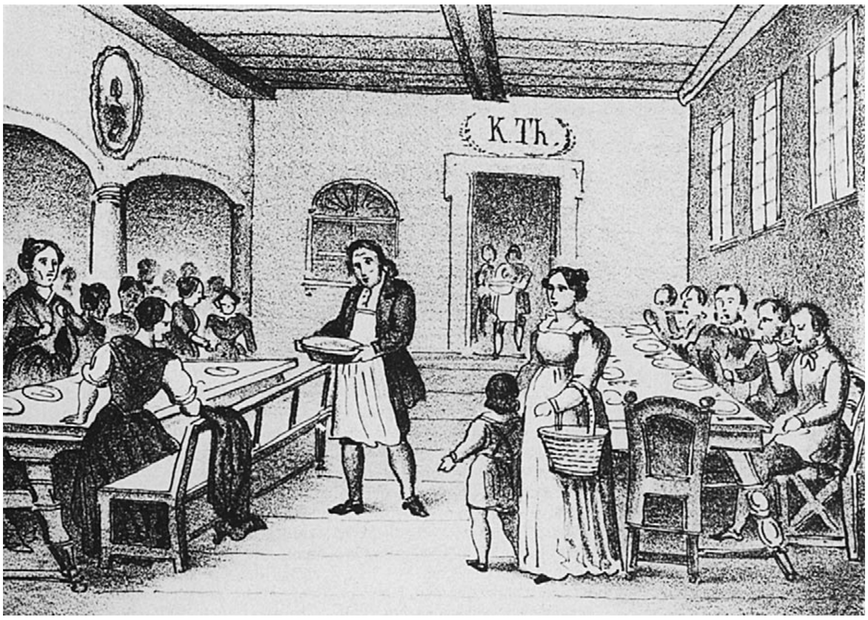

Figure 3. This sketch from 1793 offers a look inside the "Rumford Soup kitchen". Rumford's kitchen for the poor in the Munich suburb of Au together with his general social commitment brought him recognition from Sir Joseph Banks and an invitation to England.

"The Men of England" and the Royal Institution of Great Britain

> *"Men of England, wherefore plough/For the lords who lay ye low?/Wherefore weave with toil and care/The rich robes your tyrants wear?//Wherefore feed, and clothe, and save,/From the cradle to the grave,/Those ungrateful drones who would/Drain your sweat – nay, drink your blood?//Wherefore, Bees of England, forge/Many a weapon, chain, and scourge,/That these stingless drones may spoil/The forced produce of your toil?"*
> P. B. Shelley[13]

The cathedrals of progress often rest on unusual foundations. One especially firm foundation is fear. Always among the most fearful are those who have something to lose, like the "brood of drones" P. B. Shelley (1792–1822) disparages in the name of "the men of England" in his poem. Indeed, the "tyrants" of the developing heavy industries and the "despots" on their estates had every reason to be afraid. The economic bestiality of the upper class, and its brutalization of the working masses, gave rise during the Napoleonic era to dangerous voices. The war with France had driven up taxes and depressed wages, leading to restlessness and famine. The government reacted by imposing restrictions. An attempt was made to suppress all political protest. Freedom of assembly was constrained, and political organizations were banned. Journalists and publishers of "provocative material" found themselves once again behind bars.[14] Although the French Revolution had long since ended, ruling circles in Great Britain worried that, especially in these difficult times, revolutionary sparks from France might blow across the Channel and set an aristocratically dominated England aflame like a haystack. But regardless what the perpetually angry young men of letters might think of the "cowardly flock of drones", stupid they were not!

So far as the landowners' food and drink were concerned, things were actually in rather good shape, although the "despots" had certainly seen better days in the past. The profit to be gained from real estate had shrunk to a few percent of the capital invested. On the other hand, huge sums could be made in the City of London through shady operations conducted by suppliers of the fleet and the army, and through stock speculation fueled by the blockading of commerce.[15] The "brood of drones" sought effective countermeasures. The center of attention was the "Old Lady", the Royal Society, under the leadership of its omnipotent president Sir Joseph Banks (1743–1820). He tried addressing economic problems by establishing, with sponsorship from the Royal Society, new scientific bodies. These came into being in the years around 1800, and focused on botany and agriculture. Thus, a "Board of Agriculture" was set up for the reorganization of "Kew Gardens". Similarly, a "Linnaean Society" and a "Horticultural Society" emerged.[16] A group of conservative landowners, with the sponsorship of Banks, who carried on an extensive correspondence with Rumford in 1796/98 regarding social issues,[17] organized a "Society for Bettering the Conditions and Increasing the Comforts of the Poor". This in turn gave life to the "Royal Institution of Great Britain", with the purpose of invigorating agriculture through the medium of a "sensible chemistry", and "disseminating through society knowledge of useful accomplishments".[18] For the first time in history a political consortium aspired to improve its economic situation with the aid of chemistry!

The motivation behind these events probably came from a group centered around the theologian and chemist Joseph Priestley (1733–1804; Figure 4). In point of fact, the latter had actually never conducted research in agricultural chemistry, although he did add significantly to what was known about plant chemistry.[19] William Pettie, second Earl of Shelburne, later the first Marquis of Lansdowne and, in 1783, Prime Minister, appointed Priestley to a post as lecturer and librarian. Shelburne established his library—which he in fact actually utilized(!)—in one of the most beautiful orangeries in England, in the park associated with Bowood House.[20] Priestley's scientific accomplishments so impressed Shelburne that he installed a chemical laboratory on the shady side of his orangery, behind the gallery designated for rare plants. Surrounded by one of the most beautiful garden complexes in England, Priestley proceeded to discover oxygen and study respiration in plants.[21] There was apparently quite an intense exchange of ideas between Shelburne and his librarian. Priestley claimed always to have been treated by his lordship as a friend. He accompanied Shelburne to Paris in 1774, where he had

Figure 4. Priestley fights Phlogiston, a caricature of the time. Priestley's lifelong support for Phlogiston (the element believed to be responsible for combustion) was then and is now generally laughed at sympathetically. Then, and now, it is usually forgotten, however, that the elegant oxygen theory of Lavoisier though correct could not completely replace Phlogiston in the complex chemical, theological, philosophical, medicinal, and psychological considerations of the spiritual Priestley.

his famous encounter with Antoine de Lavoisier.[22] No complete record exists of the topics discussed on that occasion, but it is documented that Lavoisier, in his fatal role as agent for a private tax-collecting company (the Ferme générale or Farmers-General), was then busy erecting around Paris the "Wall of the Farmers-General", which he himself had proposed in an effort to close loopholes that permitted taxable foodstuffs to be smuggled into the city.[23] Shelburne and Priestley must have been aware that, as a consequence of this "social" measure, Lavoisier was among the most hated men in France. "Love" on the part of his compatriots thundered down so intensely upon his later (on May 8, 1794) all-too-prematurely guillotined head that he was able to travel around only with an escort of several dozen infantry and cavalrymen, accompanied by the din of bitter-witty outcries like "La mur murant Paris rend Paris murmurant!"[24]—a valuable object lesson in failed economic policy. The wall in question, constructed in 1784 by one of the finest French architects (Claude-Nicholas Ledoux), with architecturally superb tollhouses, was gradually undermined by smugglers, who dug countless underground tunnels, some of which still exist today.[25] Political opponents went so far as to claim that Lavoisier, of all people, was trying to block out the wind, thus robbing the city of oxygen. It must have moved Shelburne and Priestley deeply that only five years later, on the very day when, from the steps of the Palais Royal, Camille Desmoulins was calling the people of Paris to arms—"Friends, do we want to die like hares in the hunt?"—the *first* actual attack occurred on the despised regime of Louis XVI. This proved to be plunder of the "Barrier de la Conference", reducing another architectural gem by Ledoux to debris and ashes, to be followed by destruction of the Wall of the Farmers-General,[26] all of this two days *before* the storming of the Bastille on July 14.[27]

Priestley, for his part, was prone to express all too freely in pamphlets his political and religious opinions, causing him to become enmeshed in a host of controversies. Members of the surprisingly conservative poorer class of Birmingham—Priestley had in the meantime left Shelburne's employ—suspected him of having on July 17, 1791, attended a dinner commemorating the storming of the Bastille.[28] An angry mob reacted to this outrage by tearing his domestic furnishings to shreds and destroying his laboratory. The accompanying tumult spread until it engulfed all of Birmingham. It cannot be denied that Priestley harbored antimonarchical views. Friends advised him to take advantage of his fame and seek support from the royal family, but he indignantly declined.[29] Shelburne, following Priestley's departure, had ceded the Bowood House laboratory to the Dutch physician Jan Ingenhousz (1730–1799), who became the first to describe accurately the diurnal and nocturnal respiration of plants.[30] Priestley was an integral part of England's technical and scientific circles. His father-in-law was the distinguished iron manufacturer Isaac Wilkinson.[31] He knew Benjamin Franklin. Josiah Wedgwood, founder of the "Etruria" ceramic works, was a friend who provided him with both monetary support and laboratory equipment. Other benefactors included Matthew Boulton and Erasmus Darwin. Priestley also maintained a correspondence with James Watt, whose own chemical research he significantly influenced.[32] There can be no doubt that his sphere of friends was keenly aware of the kinds of relationships that can exist between politics and science.

The founders of the Royal Institution were clear about the fact that something needed to happen, but what? The Institution's early years were characterized by considerable conflict between Banks, Rumford, their cofounders, and various private sponsors with respect to goals, possibilities for achieving those goals, financing, and also matters related to world view.[33] The complicated back-and-forth of the arguments was exciting to chronicle, but since all the controversy suddenly evaporated upon the fortuitous appointment of Humphry Davy we pass over that particular subject here.

First a sacrifice had to take place, however! In January, 1800, the Institution received the king's seal, and thus the coveted adjective "Royal",[34] and as early as March 11 formal courses of instruction were inaugurated. To be the first "Professor and Lecturer in Experimental Philosophy, Mechanics, and Chemistry" Rumford appointed the physician and physicist Thomas Garnett (1765–1820). Although he presented outstanding lectures, Garnett had recently lost his wife (in the course of the birth of a second daughter), and he soon recognized that his modest income from the Institution would not support him and his children in a manner consistent with his social standing. Rumford refused to let him practice medicine on the side, and apparently philosophical conflicts surfaced as well. At this time Rumford, from his upstairs apartment at the Royal Institution, was monitoring everything that happened, and he discovered that in lectures and publications Garnett was taking controversial positions without first seeking his approval. He therefore decided to sever their relationship. Without first notifying

Garnett, and after briefly considering John Dalton for the post, Rumford designated the 23-year-old Humphry Davy to be Garnett's assistant. Garnett's reaction was to resign and resume the practice of medicine, although shortly thereafter he succumbed to a typhoid epidemic, leaving behind two destitute orphans.[35]

Humphry Davy (1778–1829)

> *"The apparatus essential to the modern chemical philosopher is much less bulky and expensive[36] than that used by the ancients. An air pump, an electrical machine, a voltaic battery (all of which may be upon a small scale),[37] a blow-pipe apparatus, a bellows and forge,[38] a mercurial and water gas apparatus,[39] cups and basins of platinum and glass,[40] and the common reagents of chemistry, are what are required. All the implements absolutely necessary may be carried in a small trunk;[41] and some of the best and most refined researches of modern chemists[42] have been made by means of an apparatus which might with ease be contained in a small traveling carriage,[43] and the expense of which is only a few pounds.[44]"*
> Sir Humphry Davy[45]

To the apparently straightforward question "what might class as the best possible piece of luck?" one plausible response could be: "being at the right place at the right time, surrounded by the right people, with the right idea." But this alone would not suffice! One would need also to truly understand the uniqueness of the right opportunity, and do the only right thing with it! And, once in place, one must in addition—as illustrated by the preceding quote, in a style appropriate to the period—find the proper words of experimental understatement, as would be expected from a gentleman-researcher! Very, very few manage to accomplish this feat, but one who did was Humphry Davy (Figure 5)!

The death of his father, a woodcarver, forced Davy early in 1795 after only a meager amount of schooling to enter into an apprenticeship with a physician and apothecary. On the side he taught himself philosophy, theology, mathematics, and literature, accompanied by attempts at writing poetry. Davy began to concern himself with chemistry in 1797/98, reading Lavoisier's *Elements of Chemistry* and Nicholson's *Dictionary of Chemistry*. The young Davy easily established friendships, including with Gregory, the oldest son of James Watt, and then with the pair of private scholars Dr. Edwards and David Gilvert, who loaned him their books. In addition, Gilvert let Davy use his laboratory. It was there that he made the acquaintance of Dr. Thomas Beddoes (1760–1808),[46] to whom he somewhat impetuously presented his own not terribly mature chemical theories. Nonetheless, Beddoes was sufficiently impressed that in 1793 he hired Davy to assist at his "Pneumatic Institute".[47] Conservative Britons took little pleasure in Beddoes' world view: sympathy for the French Revolution cost him in 1792 his lectureship at Oxford. Beddoes was friends with some of the members of the "Lunar Society",[48] including James Watt and Erasmus Darwin. The latter, grandfather of Charles Darwin, was a fascinating character, full of life and surely the last scientist to compose epic didactic poetry in the style of the 18th Century. Erasmus Darwin's physiological experiments were soon to become sources of sinister rumors, ones that inspired Mary Shelley but also aroused considerable interest in Darwin himself.[49] There was Thomas Wedgwood as well, who together with his famous father Josiah conducted research in both ceramics and chemistry.[50]

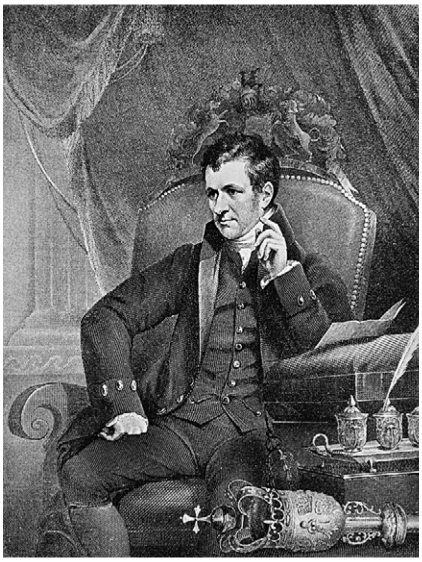

Figure 5. A representative portrait of the older Davy by J. Lonsdale, which shows him as president of The Royal Society along with their insignia.

Circulating in Beddoes' universe were a remarkable number of men of letters, such as the publisher Joseph Cottle. In 1795, Beddoes' sister-in-law, Maria Edgeworth, together with her husband Richard Lovell, wrote a volume on "Practical Education" modeled after Rousseau. John Tobin, an author of light-hearted dramas who seldom attracts mention in literary lexica today, deserves to have note made here of his *Henry Moon*, because Davy wrote the prologue to it. The romantic poets Samuel Taylor Coleridge (1772–1834)[51] and Robert Southey (1774–1843),[52] both heavily influenced by the French Revolution, were in large measure responsible for Davy's political views and literary style. The intimacy of the relationship between Davy and Coleridge in particular is apparent in a letter dated 1801: "Davy calls me the Poet-philosopher. I hope, Philosophy and Poetry will not neutralize each other."[53] This friendship between the two persisted until Davy's marriage to a wealthy society woman, and until he was knighted in 1812 and elevated to the nobility in 1819 as a baronet. In Coleridge's eyes, Davy thereby switched sides, becoming in effect one of society's "drones". In 1795 and 1799 Southey published an *Annual Anthology*, in which he included Davy's poems "The Sons of Genius" and "Ode to St. Michael's Mount in Cornwall", the latter suffused with romantic nostalgia.

Davy had not only located the right people; he had also picked out the right research topics. Beddoes' "Pneumatic Institute", which included a hospital, was dedicated to studying therapeutic effects of gases (Figure 6). "Dephlogisticated nitrous air", today known as nitrous oxide or dinitrogen monoxide, was a gas that had previously been discovered by Priestley. Davy decided to prepare it in pure form using Berthollet's method of heating ammonium nitrate, and he found that, unlike nitrogen, hydrogen, and oxygen, this nitrous air had a direct effect on test subjects, leading upon prolonged inhalation to a markedly animated state. All Beddoes' friends felt compelled to sniff it. The

Figure 6. "Living Made Easy—or Prescription for scolding wives." This anti-feminist cartoon from 1830 by G. Cruikshank shows the relaxing and pacifying effects of laughing gas.

effect was especially intense on the psyche of Coleridge, who began to laugh lustily over Beddoes, Davy, and the others. This is in fact the source of the nickname by which nitrous oxide is still recognized: laughing gas. Davy was the first to use it as an anesthetic, while treating one of his own wisdom teeth, although this self-test was not recognized by the medical world.[54] But as a practical joke for parties, laughing gas, and thus Davy, became quite famous. No less a personage than James Watt devised a special "box" for Davy's inhalation experiments, later fabricated by Boulton & Watt in Soho near Birmingham.

These men of science might be compared to priests affiliated with a strange sect, one whose mission it was to dance in mysterious rituals around the altar of nature's cathedral. As in every religious community, such priests would have belonged to a hierarchy, extending—to draw an impertinent comparison—all the way from lowly vicars in humble rural rectories to scarlet-robed cardinals. Count Rumford was unquestionably one of the cardinals, whereas the young Davy was not yet even a vicar! It is certainly true, as jealous historians of science have pointed out, that Davy's attempt to measure the mechanical equivalent of heat—using a clockwork device in an evacuated bell jar (for better insulation) to rub together two pieces of ice, with subsequent determination of the amount of liquid water that resulted—was complete nonsense due to the (as yet undiscovered) phenomenon that ice also melts under pressure,[55] but so what? After all, Columbus never really journeyed to India! Rumford recognized, albeit only after Davy had been brought to his attention, the parallelism between this experiment and his own studies of the boring of cannon barrels, and so he appointed Davy to a position at the Royal Institution.

It was here that Davy evolved into one of the truly great men of chemistry, as we shall see in the section entitled "An Abundance of Metals" (Figure 7). But the original goal of the Royal Institution, exploring the effects of "sensible chemistry" on agriculture, had by no means been forgotten.

In much of the world, especially Germany, there is a tendency to assume that agricultural chemistry began with the work of Justus Liebig. But this rather stubbornly ignores the fact that Davy lectured for the first time on "Agricultural Chemistry"—albeit not at the Royal Institution, but before the Board of Agriculture—as early as 1802/03, just as Liebig was being born!

Davy, a proponent of the humus theory later so thoroughly despised by Liebig, discussed a great many fertilizing agents, some of plant origin ("green manures, oil seed cakes, sea weed, straw, peat, wood ashes") but others with an animal basis ("fish, bones, hair, blood, horn, tanners refuse, coral, dung, urine, guano etc."). Davy believed incorrectly that many of the organic-chemical substances isolable from plants were actually absorbed from soil, through the roots. He therefore studied plant growth

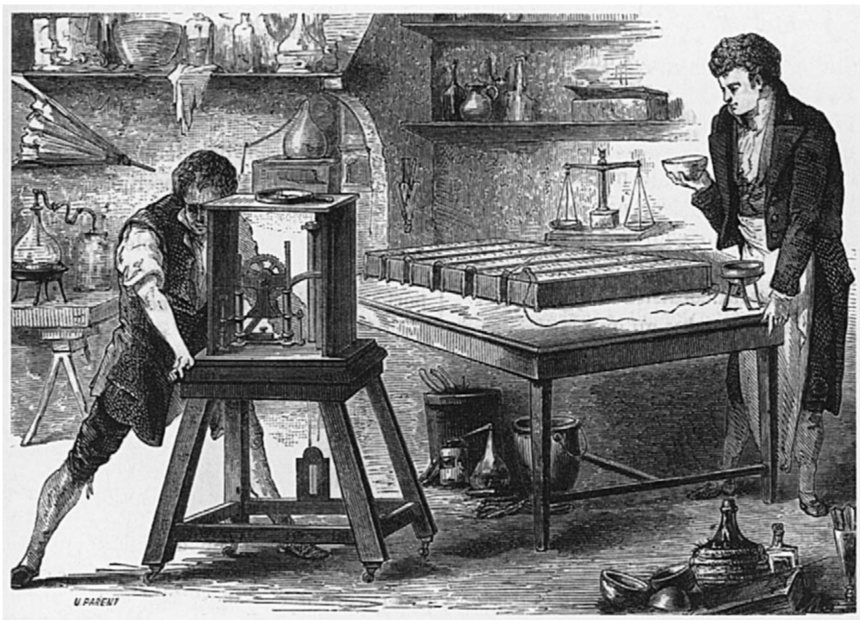

Figure 7. The discovery of aluminum by Davy. The energy source is a "trough battery", a development based on Volta's column. Image: Deutsches Museum.

in sugar solution. In any case, he came to accept Saussure's opinion that at least some of the components found in the ash residue after plant combustion could not have mysteriously formed within the plant itself, but must already have been in the ground. This led him to concentrate especially on inorganic substances like "calcium carbonate, quick lime, slaked lime, dolomite, gypsum, peat ashes, calcium phosphate, and numerous salts of sodium, potassium, and ammonium", the latter three entities incidentally reflecting Davy's own nomenclature, originating in his personal discovery or isolation of elements (although "ammonium" turned out not in fact to be an element!).[56]

The seriousness of the agricultural crisis of the time, and the high regard in which Davy's contemporaries held his agricultural chemistry, can be inferred from the fact that in 1812 the publisher Longwood offered Davy the truly fantastic sum of 1000 guineas as an honorarium for publication rights to a book on the subject, with an additional 50 guineas to be added for every future edition: an unbelievable sum, and one that was probably never again matched in those days.[57]

Davy's book[58] went through five English editions, two American editions, and one edition each in German, French, and Italian, in addition to which it was to appear under alternative titles.

Thomas Young (1773–1839)

> *"... for, whilst in their sublime speculations they reach to the heavens, in their application they belong to the earth."*
> Sir Humphry Davy[59]

In the English-language literature, Thomas Young is sometimes referred to as "the last of the universal natural scientists". J. Carter and P. H. Muir describe him as "the last natural scientist who knew everything one could know".[60] A multifaceted young man, he was active simultaneously as a painter, a musician, a philologist, and a physician. At the early age of 21 he was elected a Fellow of the Royal Society. In 1799 he became the first to attempt to interpret the Rosetta Stone, found during Napoleon's Egyptian campaign.[61] Young recognized not only that its framed hieroglyphics represented personal names, but that they should also be regarded as phonetic symbols. He thus became one of those who paved the way for the work of Jean-François Champollion.[62] Young also investigated the regularity of blood flow, and offered definitions of the modern concepts of "energy" and "power". In addition he developed a reliable theory of the tides, of special importance to Britain as a seafaring nation. In 1800 he settled in London as a physician, but by July of 1801 he was appointed Professor of Physics at the Royal Institution. Unfortunately, it quickly became apparent that Young was *not* an outstanding lecturer, as a result of which, in 1804, he resumed the practice of medicine at a hospital.

Despite his brief tenure at the Royal Institution, Young made a significant contribution to that body's later fame. In 1802 he published in the *Philosophical Transactions* three epoch-making papers—"On the Theory of Light and Colours"—crowning these in November of the following year with a Bakerian Lecture. Contrary to the then-dominant corpuscular theory of light, Young arrived at the conclusion "that light rays consist of periodic wave motions in the luminiferous ether". His decisive experiment was marvelous in its simplicity. In a dark room, he arranged for light from a white source to be passed through two tiny openings (slits), in close proximity to one another, onto a white screen. What appeared on the screen was a luminous colored band. Young interpreted this as the result of interference between light rays with identical wavelengths. At certain points on the screen, rays of the same color were canceling each other out, causing the band at that point to take on the respective complementary color. From the distance between the two slits and the observed angles of the interference phenomena relative to the screen's surface, Young was able with a simple formula to calculate the wavelength of light of a particular color, and this to an accuracy on the order of one two-thousandth of a millimeter! It further permitted him to put forth a plausible theory of Newtonian rings.[63]

Young's ideas initially met with considerable resistance, as illustrated by the following example, drawn from a rather remote source: 1807 witnessed not only the birth of John Wiley & Sons, but other major literary events as well. In 1806, the 19-year-old Lord Byron returned home utterly burned out from over-enjoyment of life, notwithstanding a bout of rage on the part of his mother in her role as "Mrs. Byron the Furious". The resulting enforced spell of quiet led him in 1807 to his first volume of poetry, *Hours of Idleness.* Not everyone was pleased with it! Indeed, there appeared a ghastly anonymous (!) critique in the *Edinburgh Review.* According to André Maurois' 1952 account, "It was in fact … by Henry Brougham, a man of encyclopedic malevolence who was equally capable of unjustifiably criticizing a physicist …, and his article about Young's oscillating wave theory was at least a match for the essay on *Hours of Idleness.*"[64]

This is a remarkable example of the seriousness with which prominent politicians took lectures at the Royal Institution, and the extent to which scientific discoveries were seen to be political in nature, and subject to correspondingly fierce discussion (Figure 8). Although Brougham in fact had not the slightest understanding of the subject, Young's proposal amounted for him to a refutation of Newton's corpuscular theory, and thus an infamous attack on England's most sacred scientific traditions.

Critiques of this sort began slowly to die out only after Dominique F. J. Arago (1786–1853), a physicist and one of the central figures in French scientific research, established contact between Young and the ingenious French physicist and engineer Augustin J. Fresnel (1788–1827), inducing the two of them to develop in common a notation still used in textbooks today for describing the classic wave theory of light. In particular, Fresnel and Arago constructed an interferometer, in which two light rays from a single source were caused to follow different paths, and then with great precision were again superimposed. The final proof of the wave character of light was provided in 1817 by Joseph Fraunhofer (1787–1826) when he succeeded in creating on a piece of glass a grating that consisted of parallel

Figure 8. This caricature from 1801 shows a famous lecture at the Royal Institution. Top right, the hook-nosed Lord Rumford observes how the lecturer, Thomas Young, inflicts a dose of laughing gas on the director of the Royal Institution, Sir Joseph Hippelsley, who, as a result, experiences a greatly reduced level of control over the nerves in his lower body. Young published his lectures under the title "A course of lectures on natural philosophy and mechanical arts" in 1807 in London. The caricaturist ridicules the pompous, smug, though note-taking public.

lines inscribed at the remarkable density of 300 per millimeter. With this grating he was able to diffract carefully defined colors of the spectrum, and thereby also determine their wavelengths. Johann Wolfgang von Goethe, still harboring nebulous alchemistic doubts, formulated somewhat helplessly in a single unrivaled sentence on a scrap of paper his misgivings regarding every (!) theory of light: "The name Fraunhofer impresses me as little as that of Newton." At least he was moved to set the two on a common plane![65]

The long-range implications of Young's and Fresnel's findings are evident in the fact that in 1881 the American physicist Albert A. Michelson (1852–1931) improved upon their interferometer, and then used it (while at sea, on an ocean liner plowing its way through the waters of the Atlantic) to show that the speed of light is constant and also independent of both the direction of motion and the velocity of the light source in the "ether". This apparently "paradoxical" phenomenon, applicable *only* to light, later became the basis for an early proof of the theory of relativity, and earned Michelson in 1907 the first "American" Nobel Prize for Physics.[66]

John Dalton (1766–1844)

> *"It is surely a pure delight ... to produce, as it were, a microcosm in the laboratory of art, and to measure and weigh those invisible atoms which, by their motions and changes according to laws impressed upon them by the Divine Intelligence, constitute the universe of things."*
> Sir Humphry Davy[67]

Davy's text omits mention of the name of the person to whom these sentences apply, although everyone at the time knew who it was. Davy himself, as President of the Royal Society, paid tribute to John Dalton in 1826 in an address on the occasion of his being presented the Royal Medal. Dalton was not actually a member of the faculty of the Royal Institution,[68] but as a Lecturer he offered courses there in 1803/04 and 1809/10. Also no aristocrat, he was "merely" the son of a weaver of wool from Eaglesfield in Cumberland. Dalton was a Quaker, and received the excellent schooling typical for this religious community. This stimulated him to become a teacher himself: of Greek, Latin, French, mathematics, English grammar and literature—in other words, virtually everything, including even chemistry starting in 1794. Despite certain idiosyncrasies that mischievous contemporaries attributed to his being a Quaker, his rather plain wardrobe for example, and despite a "harsh and indistinct voice – 'gruff and mumbling,'" and his "lack of elegance in diction", he was a popular and successful teacher who was frequently called upon. Dalton had a justifiable reputation as an ingenious experimenter with a preference for markedly unostentatious experimental setups (Figure 9). For example, as might seem appropriate for a teacher, he liked to use empty ink bottles for manipulating gas samples. We cite here only some of the most important of his numerous discoveries, including that of color-blindness, from which he found himself to suffer! Meteorology was his hobby. But unlike others who were only curious to find out what weather to expect, he wanted to determine the source of the weather. This provided incentive for him to study the behavior of vapors and gases in liquids.[69] The chief result, among others(!), was Dalton's Law, the theory of partial pressures. Expressed in modern terms: "In a mixture of ideal gases, none of which interact chemically, the overall pressure is the sum of the various partial pressures. With multiple gases in a mixture, each gas exerts the pressure it would have if it were present alone in the same volume." Dalton recognized also that gases become warm when compressed, and that their temperature drops if their pressure is reduced.[70]

Starting in 1803 he developed his famous atomic theory, according to which chemical elements can be distinguished on the basis of their atomic weights, and all atoms of an element are to be regarded as identical in both the chemical and physical sense, while sharing a single common weight. He proposed as a reference point for expressing atomic weights of elements and molecular weights of compounds the value one for hydrogen, and he also presented the first table of atomic (six elements) and molecular weights (13 examples). This in turn led him to his law of multiple proportions. Dalton was also the first to represent atoms graphically as small circles, which he labeled—with inscribed capital letters, dots, or lines—for specificity with respect to element.

Figure 9. This picture by Ford Maddox Brown shows how Dalton isolated marsh gas (methane) for the first time. The technique involves prodding the swampy bottom of a pool of stagnant water and collecting the bubbles that rise to the surface in a "necked vessel", which was simply an upturned water-filled bottle outfitted with a funnel.

With the help of these symbols he also ventured to depict structures for molecules, even going so far as to discuss isomerism (Figure 10).[71]

Dalton permitted Dr. Thomas Thomson to present an outline of his thoughts in Volume III of the third edition of the latter's *System of Chemistry* (1807). His own account, *A New System of Chemical Philosophy*, appeared in three volumes in 1808, 1810, and 1827.[72] Dalton remained true to meteorology until the very end. The last entry in his diary, dated July 27, 1844, reads "little Rain this day"—apparently a day with typical English weather, and thus entirely fitting.

Figure 10. The text book *A New System of Chemical Philosophy* (1808) contains this table in which symbols Dalton invented for chemical elements are presented.

Michael Faraday (1791–1867)—The Greatest "Discovery" of the Royal Institution

> *"Such then are the advantages which result from experiment; nor is the case at all exaggerated, for in Chemistry it may safely be stated that more than nine-tenths of the facts upon which the science is founded are thus evolved by artificial means. Without indeed the great body of truth thus furnished, the science could not have existed; for though it is not exclusively, it is preeminently experimental, being in this respect strikingly distinguished from Astronomy, Botany, Zoology and other sciences, which have regard to appearances and phenomena presented by nature. Hence it derives many of its peculiar charms."*
> Michael Faraday.[73]

In the literature it is occasionally claimed that "Davy's greatest discovery was his successor, Faraday." One might perhaps regard things this way, but a major factor in the discovery was "Mistress" Marcet. The physician and chemist Alexander Marcet (1770–1821), son of a Geneva merchant, in 1799 married Jane Haldimand (1799–1858).[74] Even before her wedding her literary efforts attracted attention, and she had not without some success written several children's books. Today this would hardly be astonishing, but at the time such activities were not necessarily considered acceptable for a young woman from a good family.

After her marriage she turned with unbelievable success to a new genre. She thus wrote a whole series of works about various natural sciences specifically for the edification of adolescents.[75] All the titles in this series began with the word "Conversations". They took the form of closet dramas consisting of assertions and rejoinders involving three parties: one knowledgeable and two uninformed. The emancipation of women was not yet very far advanced, because not until 1837 with the appearance of the 13th edition of her principal work, *Conversations on Chemistry, in which the Elements of the science are familiarly explained and illustrated by Experiments*, first published in 1805, did she risk revealing her name. By 1846 no less than 16 editions (of unknown extent) of these particular "Conversations" had appeared. In the United States alone, 160000 copies were allegedly sold by 1853. Given that the book was also translated into French and German, it is safe to assume that in the first half of the 19th Century this was the most widely circulated chemistry book on the market.[76]

Jane acquired most of her inspiration for the book from public lectures at the Royal Institution, and quite remarkably she made a significant contribution to future development of the ideas, in that she won over to chemistry the man who became their most successful investigator, Michael Faraday (1791–1867).[77] Faraday's professional career began inauspiciously enough in a London bookstore. In those days books were still distributed in unbound form, with larger works issued in multiple parts. The purchaser then arranged to have the sheets trimmed to fit in his bookshelves, after which they could be bound according to his own particular taste and means. Because of the bundles of pages lying everywhere, bookstores looked very different from their counterparts today; only with bound volumes can the works be arranged upright in bookcases. A successful book dealer of the time would operate his own bindery as well, as a way of increasing profits.

In later years Faraday expressed his appreciation for the "chemical" awakening he experienced: "Mrs. Marcet was a good friend to me, as she must have been for many people. At the age of 13, in 1804, I went to work for a book merchant and bookbinder, where I remained for 8 years, during most of which time I bound books. These were the books I read during my working hours, which led me to my science. … Mrs. Martel's conversations about chemistry imparted to me the basic principles of this science."[78]

Faraday began attending official lectures at the Royal Institution on a regular basis, always sitting in the balcony, to the left of the big clock, in a particular seat that is still revered to the present day. Toward the end of his studies he transcribed word-for-word four selected lectures by Humphry Davy. He then polished the copy at home, bound it as a book, and presented it to Davy himself, in the vestibule, next to a specific pillar—which also continues to be a sanctified spot—with the request that Davy assist him in finding a scientific position. First little more than a helpmate, Faraday later accompanied Davy on his great trip. As Davy's successor, director of the laboratory, and professor, it was Faraday more than anyone else before or since who set the tone for lectures at the Royal Institution (Figure 11). Thus, in 1836, a German visitor who heard one of Faraday's lectures about zinc found it fascinating for both laymen and professionals: "Herr Faraday is not only a great chemist and physicist—as everyone in Europe knows—but also an extremely fine teacher … . He speaks freely …, clearly, fluently, precisely, and skillfully."[79]

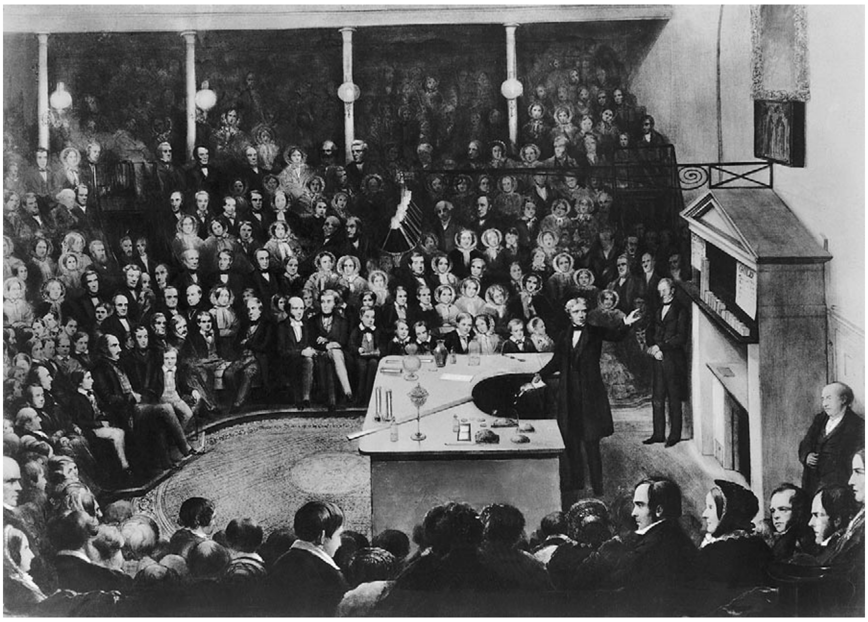

Figure 11. In 1856 the "Prince Consort" Albert, husband of Queen Victoria, together with his sons, the future King Edward VII and his younger brother Alfred, visited one of Faraday's "Christmas lectures" on "Metals". Although these lectures were primarily aimed at children, most were accompanied by their parents, so half the audience shown is adult. This picture from A. Blaikley impressively conveys the charismatic effect Faraday had on his listeners.

An Abundance of Metals

"Consider the varied and diversified applications of platinum, which has owed its existence as a useful metal entirely to the labours of an illustrious chemical philosopher;[80] look at the beautiful yellow afforded by one of the new metals, chrome;[81] consider the medical effects of iodine,[82] in some of the most painful and disgusting maladies belonging to human nature; and, remember how short a time investigations have been made[83] for applying the new substances."

Sir Humphry Davy[84]

The discovery of chemical substances not subject to further decomposition—in other words, new "chemical" elements—began to accumulate in the second half of the 18th Century at an almost frightening rate. Thus, the Berlin apothecary M. H. Klaproth (1743–1817) proved himself a successful seeker of new metals on the strength of mineral analyses, although he was in most cases able to characterize these metals only in the form of their "earths" (oxides).[85] In 1789 he described uranium and zirconium, in 1793 strontium, and in 1795 titanium, to all of which he also assigned the indicated names. There followed in 1797 chromium (independently of N. L. Vauquelin) and in 1798 tellurium, with naming of these two as well. Together with Berzelius,[86] Klaproth in 1803 identified cerium, and later in that year beryllium.

This astonishing plenitude of metal discoveries is actually rather easy to explain: In the history of mankind, peculiar trends from time to time come into vogue. Since the Renaissance, people had displayed a love affair with grottos in various garden and parklike settings—artificial caves, often containing springs and shell work, but elaborated also with real minerals. These were especially popular as places to contemplate the world's philosophical underpinnings. In the course of time, grottos sometimes evolved into monumental constructions, even to veritable "philosopher's towers". Thus, the future King Friedrich II (Frederick the Great) of Prussia, while still crown prince, upgraded one of the round towers of his Rheinberg Castle to become a philosophical refuge. In its subterranean reaches was to be found a grotto with a splashing spring. The levels above contained a laboratory, a print shop for publishing new results, and a library.[87] Within elevated social circles the natural sciences gradually became very much the rage. It was soon considered the "in" thing to do to wander through nature with a geologist's hammer, a butterfly net, and a botanist's collecting box, gathering samples. For example, the court physician F. G. Sulzer crisscrossed Scotland in 1791. Near the village of Strontian he happened upon a new mineral that he christened "stronianite" in honor of its place of origin.[88] Klaproth quickly isolated from this a sample of "earth" corresponding to the hitherto unknown element strontium.

There were critics, too, however. For example, in November of 1796 the Weimar social lion K. A. Böttiger sneered: "One of the most ridiculous periods of genius ever was the mining era in Weimar …. Then man was nothing, and rocks were everything. Goethe perceived a divine trinity in the organization of granite that could only be explained mystically. … Everything mineralogized. Even women discerned a deep significance in stones, and provisioned themselves with cabinets."[89] Finally, the great Goethe laid personal claim to 18000 minerals and rocks![90]

As a result of a general search for new minerals, instances of the discovery of unknown metals accrued rapidly. In 1802 the Swedish chemist and mineralogist A. G. Ekeberg, enthused by the wonderful minerals from Falun and Ytterby, found in Finnish tantalite the metal tantalum.[91] Also in 1802 the English chemist Charles Hatchet discovered columbium in the American mineral columbite, which proved decades later to be identical to the niobium H. Rose found in 1844 in Bavarian tantalite. In 1803, A. M. del Rio, a mineralogy professor in Mexico, studied a "brownish lead ore from Zimepam" and found it to contain a new metal that he called "erythronium." N. G. Sefström, investigating low-temperature brittleness in certain iron samples in 1831, found the cause to be a new oxide that he was also able to isolate from a Mexican lead ore collected by Alexander von Humboldt. Sefström named this metal, which he thereby "discovered" for the second time, "vanadium". Klaproth and Berzelius simultaneously encountered a new "earth" in 1804. Klaproth attached to his sample the name "ochroite", while Berzelius spoke of "cerite earth". This material proved a source in 1839 of a series of "rare earth metals", as did "ytter earth" in 1844.[92]

In 1804/05 a rather unusual metal caused a sensation. It was unclear whether it should actually be classed as a precious metal, a mineralogical troublemaker, or something with technological value. As early as 1700 it got in the way of South American miners as an apparently worthless component of silver ore. The first to recognize "Platina del Rio Tinto" ("silverlet of the black river") as perhaps a new metal appears to have been C. Wood, the mint master of Jamaica. One of his relatives took it along to Europe, and in 1750 gave the first samples to the Royal Society. He also sold pieces of the platinum to wealthy scholars, including the Marquise d'Urfé, in whose laboratory in 1757/58 the versatile adventurer Giacomo Casanova came to know it, later describing its chemical properties in his memoirs.[93] The second time platinum turned up, at the hands of Don Antonio del Ulloa, it was as "merely" a sidelight to a South American geodetic expedition sponsored by the Paris Academy of Science, one assigned the task of measuring the earth's diameter, which was to play a role in definition of the "meter".

Platinum was difficult to purify, and it was even more difficult to work! It thus acquired a reputation as utterly indestructible. In France, shortly before the Revolution, an alloy of platinum and arsenic was developed for jewelry purposes. It proved both castable and moldable, and was employed in 1799 in casting the first standard meter.[94] Chemically this was a very unsatisfactory operation, however, since a platinum–arsenic alloy is clearly *not* the same as pure platinum. Remedying the situation helped bring fame and fortune to the physician and ingenious scientist W. H. Wollaston (1766–1828). Wollaston's student friend, the independent scholar Smithon Tennant (1761–1815), in 1803 dissolved crude platinum ore in aqua regia, and found the insoluble residue to contain a black powder with a metallic sheen. Others assumed this to be graphite, but from the fact that the powder could be alloyed with lead, Tennant concluded it must be a new metal. Then in the spring of 1804 Tennant reported that his powder consisted in fact of *two* new metals, which could be separated by alternate treatment with acid and alkali. Because of the various colors displayed by its salts he gave the name "iridium" to one of the two; the other produced a sharp odor upon oxidation (to the tetroxide, as was later established), so he christened it "osmium" from the Greek word for "smell".[95]

Parallel to these efforts, and working secretly in a remote shed in his big garden, Wollaston between 1801 and 1804 developed a procedure for obtaining "forgeable" (malleable) platinum, one that he kept to himself until shortly before his death. It brought him the (for those times!) fantastic reward of 30000 pounds.[96] In this procedure he dissolved crude platinum in aqua regia and added ammonium chloride to precipitate ammonium chloroplatinate. This he decomposed by heating, after which he washed the finely divided platinum residue, pressed the still-moist powder into a cake, heated the latter until it was white-hot, hammered it into a bar, and then either beat it into a foil similar to gold leaf or drew it into a thin wire. Wollaston had something like a sixth sense for chemical treasures yet undisclosed. Thus, he once again dissolved crude platinum in aqua regia, this time evaporating off the excess acid and introducing dropwise into the mixture a solution of mercury cyanide until a yellow precipitate appeared. After washing and calcining, what remained behind was a white metal that he named "palladium" for the recently discovered Pallas asteroids. In 1803/04 Wollaston undertook to study a particular South American platinum ore. He was not apprised of its precise origin, but it had apparently once contained gold, removed only incompletely by amalgamation with mercury. Yet again he dissolved the crude platinum in aqua regia, this time neutralizing the solution with caustic soda. After addition of ammonium chloride to precipitate the platinum as ammonium chloroplatinate, he introduced mercury cyanide to precipitate any palladium as its cyanide. He then filtered the residue, decomposed excess mercury cyanide through addition of hydrochloric acid, and evaporated the mixture to dryness. The residue, after washing with alcohol, proved to be a marvelous rose-colored salt: a double chloride of sodium and a new metal that Wollaston called "rhodium". This chloride could be reduced to the pure metal by heating in a stream of hydrogen.[97]

Despite his exalted stature as a scientist, Wollaston was not above seeking to make a profit. As a private tutor he was in any case a kind of independent spirit. Numerous discoveries of metals had miscarried at the oxide stage, but it seemed plausible that something might still be earned on the basis of pure metals. Wollaston couldn't resist trying, at first keeping the details of his procedures secret. His "new silver" (palladium) he offered for sale anonymously through an announcement couched in slang reminiscent of the alchemists, and under a half-serious address: "It is sold by Mr. Foster, at No 26, Gerard Street, Soho, London. In Samples of Five Shillings, Half a Guinea & One Guinea each." An unfortunate younger colleague, Richard Chevenix, actually tried to expose the whole thing as a hoax, but palladium turned out indeed to be both new and genuine.[98]

Apparently the eternal gods had in every sense gathered to their breasts Alessandro Count Volta (1745–1827) (Figure 12). In November, 1794, Lichtenberg described how he and Volta set physics aside after a series of rather unsuccessful experiments with Volta's electrometer: "But nothing happened, and he began swearing in French and Italian." Lichtenberg continues: "he is a handsome fellow, and in the course of a few very free hours over dinner at my place, that had us raving until one in the morning, I noticed he is very knowledgeable concerning the electricity of the ladies."[99] With striking features, slender, in an academic gown with silver embroidery, and lecturing fluently in French, this born aristocrat was the very image of a "belle figure", as for example when he delivered his legendary address on July 11, 1801 before First Consul Napolean Bonaparte at the Institut National,[100] during which he introduced his "Voltaic column" (Figure 13). The latter he had already described in a letter in 1800: "the apparatus … is nothing more than an arrangement of a number of good conductors of various sorts, ordered sequentially in a particular way. Thirty … or more pieces of copper—or better, silver—each laid on a piece of tin, or much better zinc, with an equal number of layers of water or some other liquid that is a better conductor than ordinary water, … or pieces of cardboard, leather, etc. which are thoroughly soaked in these liquids, with these pieces connecting each pair … of two different metals; this kind of an alternation of the three different conductors, always in the same order, that is all there is to it …."[101]

Volta's "instrument" was poised to revolutionize completely the worlds of chemistry and physics in the years to follow. As early as 1800 the gentleman scholar Johann W. Ritter discovered that current supplied by Volta's column had the ability to decompose water and aqueous solutions. Moreover, in the same year, W. Cruickshank found that metal from a dissolved metallic salt would collect on a negatively charged wire, this based on Lichtenberg's definitions of positive and negative electricity. Berzelius and Hisinger recognized in 1803 that hidden behind these observation lay not only a new preparative method, but also some completely new theoretical points of departure regarding the structure of materials. Despite the inconspicuous title of their publication, "Experiments into the Effects of the Electrical Column on Salts and Some of Their Bases," the message contained was sensational. They recognized that upon passing a current through a salt solution, the constituents separated, and each accumulated, depending upon its properties, at one of the two poles. From this it followed that the salts must have been broken down into their parent acids and bases. The two also concluded that bases, for their part, can be split into metals and oxygen, where oxygen gas again escapes at one of the poles.[102]

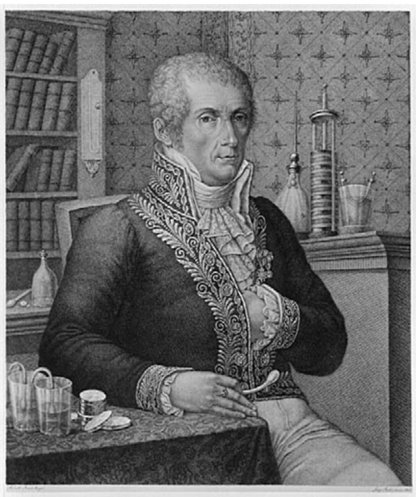

Figure 12. Alessandro Conte di Volta, one apparently favored by the Gods, is shown here in an academic gown with silver embroidery. His epoche-making column is prominent in the background.

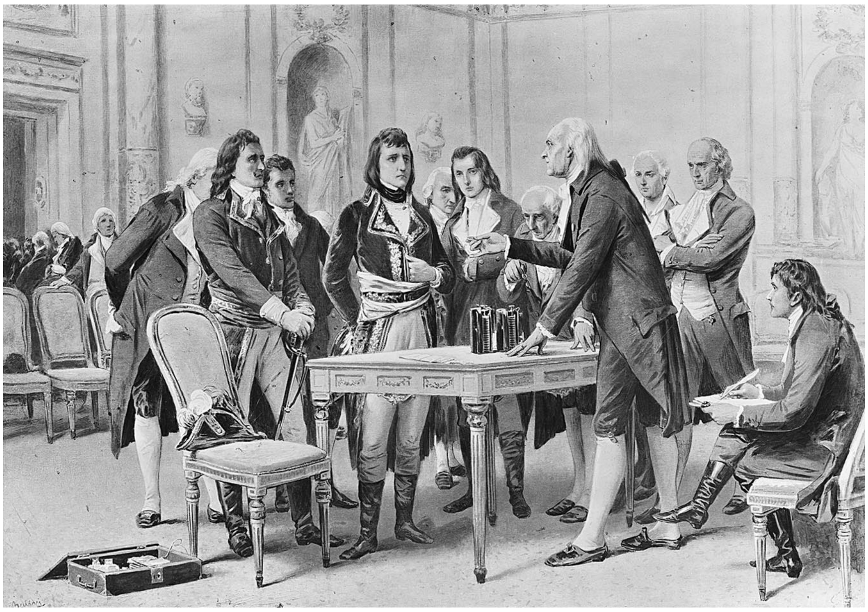

Figure 13. In 1801 Volta explained to Napoleon the principle of his column.

Once more the search was on for new metals. Davy noticed that electrolytic phenomena were easier to observe in concentrated solutions. This led him to the idea of trying electolysis directly on fused salts. He also had the clever notion of taking advantage of the recently developed malleable form of platinum for constructing platinum vessels to hold the fused materials. Davy thus succeeded for the first time, on November 6, 1807, in preparing the metal potassium, by electrolysis (using a Voltaic column) of molten potash in a platinum spoon serving simultaneously as the anode and the electrolysis chamber. Potassium collected as tiny, metallic spheres at the cathode. He recognized immediately that a new metal had been born. His cousin Edmund Davy reported that the elated discoverer spent half an hour dancing around for sheer joy. Davy assigned to his find the name "potassium", taken from the starting material, and shortly thereafter in an analogous experiment with soda he produced another metal, "sodium". The neo-Latin (and German) equivalents "Kalium" and "Natrium" were suggested by Berzelius and Gilbert. A mere six weeks later, on November 19, 1807, Davy delivered his second "Bakerian Lecture". In the brief interval between discovery and lecture, working himself to the point of exhaustion, he tried unsuccessfully to apply the new method to salts of other alkaline earths, as well as "argillaceous earth" (aluminum oxide) and quartz, but the strain of it all was too much. After his phenomenally successful lecture Davy collapsed, deathly ill, and it was April, 1808, before he was able to resume his research.[103]

Berzelius, working together with Pontin, refined the process of electrolytic preparation of metals by devising the mercury cathode. Upon evaporating mercury from an amalgam obtained with this innovation, he isolated in 1808 for the first time the alkaline-earth metal calcium. Davy managed by the same method to make "magnium" in 1809, which in 1812 he renamed "magnesium". But this methodology, originally from Berzelius, had its shortcomings. Evaporative removal of mercury from an amalgam was usually not complete, so that the metals isolated were too impure to permit an exact description of their properties. Nevertheless, Davy reclaimed his priority as a discoverer by being the first to see, in his own laboratory, metallic barium and strontium. Two metals proved recalcitrant despite his best efforts, however, and in these two his only claim to fame is having "christened" them with names still used today: aluminium ("aluminum" to Americans), and silicium (or silicon).[104] Just as Columbus erroneously once believed himself to be in India, whereas he had in fact "only" discovered America, Davy prepared through the electrolysis of ammonium hydroxide solutions what he took to be an amalgam of the new metal "ammonium", although its true nature was soon recognized by others.[105] As late as 1818 Davy put the finishing touches on Johann August Arfvedson's discovery of lithium in the mineral petalite with his successful electrolysis of lithium carbonate. The bright red color conferred by lithium upon a flame caught the attention in 1818 of C. G. Gmelin, an observation that, in conjunction with "Fraunhofer lines"—noted in passing by Wollaston in 1804 and described in great detail by von Fraunhofer in 1814—became the basis for the general method of spectral analysis introduced later by R. W. Bunsen and G. R. Kirchhoff. This in turn led, among other things, to the discovery in 1860/61 of rubidium and cesium.[106]

As early as 1808 it was recognized that the metal potassium represented a powerful, innovative reducing agent.[107] With its help, the French chemists J. L. Gay-Lussac and L. J. Thenard[108]—soon thereafter also Davy himself—reduced the well-known substances boric acid and borax to an olive-green powder: the element boron. This meant that, again, a new methodology had been discovered, which A. B. Bussy applied to the reduction of magnesium chloride as a way of collecting larger amounts of magnesium metal. The bright future for potassium as a reducing agent was firmly established in 1827/28 by the experimentally resourceful F. Wöhler in his preparation of metallic aluminum and beryllium.

Now the big question became, was this sudden wealth of metals simply a whim of nature, or might some important principle be hidden behind it? If such a thing as a "system" existed, what might be its significance?

The Search for the Harmony of the World

> *"But, ... there is something in knowing and understanding the operation of nature; some pleasure in contemplating the order and harmony of the arrangements belonging to the terrestrial system of things. There is no absolute utility in poetry; but it gives pleasure, refines and exalts the mind. Philosophic pursuits have, likewise, a noble and independent use of this kind: and there is a double reason offered for pursuing them."*
> Sir Humphry Davy[109]

It is both an effective and age-old trick of scholars to maximize their own renown by deliberately refraining from citing the work of their predecessors. This was how, on the strength of his "rule of triads" (1817/29), J. W. Döbereiner came to be regarded as the originator of the periodic system of elements. But the truth is much more complicated.[110] Even Davy was not really the first to occupy himself with "contemplating the order and harmony of the arrangements belonging to the terrestrial system of things". This problem had vexed people in every cultural context for millennia.

The sudden abundance of new metals in the Napoleonic Era was bound to raise the issue—crudely put—of whether elements had simply tumbled haphazardly out of the cornucopia of a deity gone mad; or might there instead be some sort of order in the seeming chaos of chemical facts—a system of divine origin?![111]

In 1792, Jeremias B. Richter, the "arcanist" (guardian of the mystic chemical art of porcelain-making) at the Royal Prussian Porcelain factory attempted a "mathematization" of chemistry in his "Anfangsgründe der Stöchyometrie oder Meßkunst chemischer Elemente" ("Basic Principles of 'Stoichyometrie' or the Art of Measuring Chemical Elements"). He devised a notion of "equivalence" to express the fact that a defined acidic solution could be neutralized by defined bases. He also tried using this principle to arrange acids and bases in mathematical series. In view of the fact that atomic, molecular, and equivalent weights had by that point not yet been established, and because much time would elapse before the nature of redox reactions and variable valence would be understood, not to mention Richter's lack of access to analytically pure chemicals, his efforts were premature in the extreme. His contemporaries were enthusiastic, however, since Richter—with his motto "God has organized everything by measure, number and weight"—saw himself as belonging to a tradition with roots that went very deep.[112]

The Napoleonic Era was of course more than just "Napoleonic". Great Britain, backed by its mighty fleet, was extending its grasp to the most distant lands, building a colonial empire that would long outlive Napoleon. Through the colonization of India, European intellectuals discovered that a concern with "measure, number, and weight" applied not only to St. Augustine (for example, in his "Commentary on the Wisdom of Solomon") and various of his pious successors: the Indians had been wrestling with such ideas for a long time, too. We therefore have British colonization to thank for an extensive literature on Indian numerology, which exerted an especially powerful influence over the Romantic movement in Germany. An example is seen in the Romanticist Friedrich Schlegel's 1808 volume *Über die Sprache und Weisheit der Indier*[113] ("About the Language and Wisdom of the Indians").

Wollaston as a person was both difficult and withdrawn, so we unfortunately do not know how long he spent assembling numerical material, tinkering with it, and sculpting his epochal publication, "A synoptic scale of chemical aequivalents".[114] The notion of an "equivalent" is presented immediately, in the title. The "Wollaston equivalent scale" consisted of a small, wooden slide rule (Figure 14),[115] on the fixed portion of which 70 compounds (or "equivalents") were displayed, based on a scale equating oxygen to 10. Later models featured 130 compounds. The movable part, or slide, contained nothing but logarithmic numbers. This device made it possible, after appropriate positioning of the slide, to read directly, for instance, how many grams of a specific metal would be required to prepare a given amount of metal sulfide. Alternatively, one might inquire how much sulfur or oxygen was present in a certain quantity of barium sulfate. The average chemist today, who has been brought up with modern ideas, might dismiss this simple tool as at best harmless, indeed ridiculously obvious! But for a scientist in 1814 it was sensational. If one could really make stoichiometric conversions from one element to another, or from one compound to another, and without any limitations, that must mean "equivalents" are representable arithmetically within some closed numeric system, which in turn almost demands a "system" for chemistry itself. The Wollaston scale would not permit one to prepare a true orderly list of equivalent numbers, but a crucial discussion had taken wing; never mind that the "harmony" Davy craved was still a long way off.[116]

Figure 14. A Wollaston equivalent scale from 1820 with German labeling, from the collection of the Deutsches Museums in Munich.

Science has certainly not been immune to the phenomenon of lost opportunities. In 1808 Gay-Lussac and von Humboldt undertook a quantitative study of explosive oxygen–hydrogen mixtures like those Volta had exploited in his noisy and impressive public demonstrations of detonating gas eudiometers, pistols, and cannons. Their results showed hydrogen *always* combined with oxygen in a 2:1 ratio, upon which they formulated a "Law of Chemical Volumes": namely, "volume ratios for gaseous substances participating in a chemical reaction can be expressed in terms of small whole numbers."[117] But why was this true? Starting in 1811, Count Lorenzo Romano Amedeo Carlo Avogadro di Quaregna e di Cerreto—like Volta, an exception to Davy's assertion that aristocrats did not engage in chemistry—also studied volume ratios in gaseous reactions. In an attempt to explain what had until then seemed a contradiction, he put forward the idea that the smallest particles of a gas were not necessarily atoms, but could be *diatomic* entities, which he called "molecules". If one accepted this hypothesis, then the "Law of Chemical Volumes" necessarily became a basis for the simplest, elemental expression of Avogadro's Hypothesis: "Equal volumes of all gases under identical external conditions contain equal numbers of molecules." Unfortunately it was not until 1858 that S. Cannizzaro recognized the true scope of this hypothesis![118]

As a consequence of the imprecision of available analytical results, with data coming in from different authors, in the absence of controls, and often found to be not even reproducible, most of the somewhat ragged proposals for arranging the elements were difficult to interpret. In one sense, however, this made it all the easier to posit new theories. The physician and natural scientist William Prout postulated in 1815 that the atomic weights of all elements were whole-number multiples of the atomic weight of hydrogen. According to Prout, the complete set of elements would turn out to be equally spaced if they were lined up in order of increasing atomic weight.[119]

Another difficulty remained to be confronted, however. Volta, in constructing his column and developing his contact theory—which took into account the relative electrical activities of the various metals—had established his own arrangement of the elements, and this acquired added significance in light of a hypothesis proposed in 1811 by Berzilius. The latter suggested that ordinary chemical substances were made up of components characterized by opposite electric charges. He thereby became the first to define "chemical bonding". In his view, electric forces were what held chemical compounds together—and thus also the world as a whole. He generalized these ideas to a "dualistic theory" of "electrochemical dualism". With experimental perseverance Berzilius rapidly arrived at an ordering for the elements. Because within this order certain aspects of the future "periodic system" lay hidden—in "cryptic form," one might say—the "Berzelius electronegativity scale" showed similarities, but only in a few areas, to Prout's "series".[120]

The contemporaries of these pioneers refused to become discouraged, however. In 1814, J. S. C. Schweigger recalled Richter's conclusion that "the relationships between multiple chemical elements speak against there being a single unique progression". He then added: "But if one looks at the table presented by John Davy [n. b.: Humphry Davy's brother], one does see that the numbers increase, although no mathematical laws are readily apparent, so the term "progression" seems inapplicable. It would be the most ingenious thing imaginable to suggest that Richter uncovered such a law of numerical progression, but also the most audacious."[121]

Immediately after this reminder of Richter's proposal 16 years earlier, Schweigger formulated in an impressive way his own expectations with regard to a future "system": "Since all natural numbers are a consequence of mathematical laws, wherever we perceive so much as a fixed and definite increase in numbers there must surely exist also some sort of progression; this we may boldly assume: for the moment, too many members of the series are clearly missing, however, and those which are known are too vaguely defined to permit us to hope we might already find the true law behind this progression."[122]

Careful reexamination of the chemical properties of the elements led at first to the rather disconcerting and thus unexpected realization that a simple ordering process, along with knowledge of a particular element's position within that order, would *not* lead to an adequate description of the element's properties. In his 1819 paper "Über den stöchiometrischen Wert der Körper, als ein Element ihrer chemischen Anziehung" ["Regarding the Stoichiometric Value of the Body, as an Element in its Chemical Attraction"], J. L. G. Meinecke, chemistry professor at Halle, came directly to the point: "In this correct sense the scientist arranges the bodies [i.e., substances] in families or clans. Chemical attraction is directly opposed to familial relationship: that is, related substances have only the slightest attraction for each other." In Meinecke's opinion it was therefore better to examine "families of related bodies"; in other words: "In order to establish the influence of mass, one must first pick out from this series the similar members, and set them together. Now barium earth and strontium earth, lime and talc, potash and soda are apparently three pairs of similar bodies, which in the order presented here show striking analogies to one another, and their chemical values or masses are as follows:[123]

barium earth	9500	lime	3500	potash	6000
strontium earth	6500	talc	2500	soda	4000"

The obvious weaknesses in this little table need not further disturb us. But it does seem important to recognize that Meinecke here had attempted to set forth a "rule of diads", predating Döbereiner's rule of triads.

Meinecke was convinced that this was only a beginning. His imagination produced a vision of a future system of the elements as a complex three-dimensional pattern: "The fact that in this potash series precisely six principal members appear, and in pairs, cannot be called a coincidence—and who in any case would seriously consider the idea of a coincidence in nature or in the world? … So much is certain: among the chemical substances there are basic principles and intermediate members which in some regions of the system lie far apart, in others degenerate into intermediary links, thus giving rise to a structure that is continuous, but more or less delicate."[124]

War in Saxe-Weimar

> *"A thunderstorm must first move past if a rainbow is to appear."*
> J. W. von Goethe, to his intimate friend Karl Ludwig von Knebel, October 23, 1806[125]

Since Napoleon's militant spirit was the dominant factor in the years around 1807, we present here a description of one of the "Grande Armée's" campaigns. In late September, 1806, Prussian troops joined up with their allies in the Duchy of Saxe-Weimar. On October 2, Duke Carl August sent "his Minister, His Exellency von Goethe, as Commissioner of Rations at the Prussian headquarters".[126] So the latter made one last appearance very much in the style of the *ancien regime*: "He showed up … in court dress and a great deal of show, powdered, and with a bagwig, embroidered coat and vest, black silk hose, white silk stockings, dress sword, and a small silk tricorne under his arm in place of a hat."[127]

But the wheel of history rolled inexorably on! According to an observer on October 12: "The soldiers [n. b.: the *Prussians*, not the enemy!] smashed the windows and furniture in his [Goethe's] garden house."[128] Catastrophe really arrived on October 14. "Early cannonade near Jena." The poet paced nervously back and forth in the "upper" garden. "Cannon balls whistled over the house. … Meanwhile, the Prussian retreat passed behind the garden … in the ghastly confusion. … Perhaps an hour went by before a horrible silence filled the streets and the square in front of Goethe's house. Individual French hussars burst upon the Ladies Gate, … and we hurried, Goethe's son and I,[129] to meet them with bottles of wine and beer." The horsemen were mistrustful and tired. In order to surprise the unsuspecting Prussians, the Emperor had commanded his hussars to undertake a 16-hour ride from Franconia to Jena, which led them to the battlefield and then, immediately following a complete victory, to Weimar.[130] At this point fire broke out. "Meanwhile, there was complete confusion … due to the streaming in of ever more numerous new troops, who bivouacked in the town squares, broke into stores and cellars, and forced their way into houses for the purpose of plundering and abusing the occupants." Provisioning for the Napoleonic army was so bad that the generals had taken into account this sort of behavior on the part of ordinary soldiers. In anticipation of the consequences, Napoleon had issued a letter of safe conduct for Goethe, whose *Leiden des jungen Werther* he had read with much appreciation. Marshall Ney was supposed to have been quartered in Goethe's house on the Frauenplan, protected by his own sentries, but he never arrived, nor did his sentries, and what transpired was the legendary and ominous appearance of two marauders. Goethe's petite housekeeper and intimate companion threw herself resolutely in front of them, thereby protecting the helpless minister.[131]

A few days later, on the morning of October 19, the grateful poet strode with Christiane Vulpius into the sacristy of the palace church—not into the church itself, however, and apparently without members of the public being present—and straight to the marital altar. They were accompanied by their illegitimate son August, who logically enough served as a witness. Goethe arranged for a date to be inscribed in the wedding rings: not that of Sunday the 19th, but rather the 14th, the day of the "visitation" and rescue. Christiane, having formerly worked in a factory that made artificial flowers, would in those days have been utterly unthinkable as the spouse of a member of the government! It was Johanna Schopenhauer, mother of the philosopher, who broke the social ice. "Goethe presented his wife to me; I received her as if I did not know who she had formerly been. It seems to me that if Goethe can give her his name, we can certainly give her a cup of tea."[132] Tea at the Schopenhauer's developed into a standing engagement, in the course of which Goethe often sketched, but also played music. To her son, Johanna wrote on March 20, 1807: "I made tea, and he played the harmonica."[133] The musician in Goethe evidently enjoyed improvising on a Franklin glass harmonica, an American contribution to the European musical culture of the era (Figure 15)!

The year 1807 also witnessed a chemical sensation. As already noted above, Davy succeeded that October in performing the first electrochemical preparations of sodium and potassium. Goethe, whose scientific lectures and demonstrations found an enthusiastic audience in the world of Weimar's women, wrote excitedly to one lady: "However, I may soon be able to let you view with your own eyes those famous experiments of Davy. Fortunately, Dr. Seebeck in Jena[134] has followed up on them … and has subjected the actual earths [oxides] to the action of the column, and when slightly moistened, every one of them exploded."[135] On three successive days Goethe wanted to demonstrate Davy's experiments to Weimar society, in his own house on Frauenplan. Since he himself already owned a few small voltaic columns, he suggested that Seebeck melt down their tiny zinc plates so as to make larger ones as a way of increasing the effect of the large column.

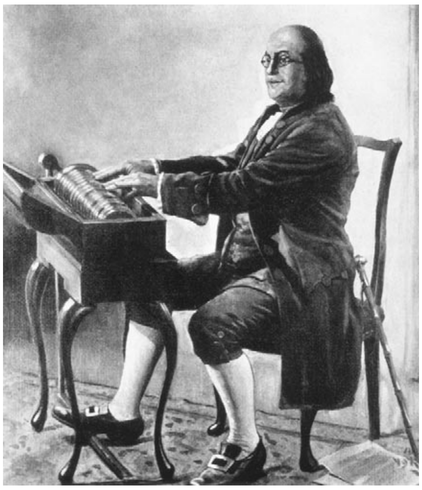

Figure 15. Franklin himself playing on the glass harmonic he invented in 1760.

The massive troop movements associated with the Battles of Jena and Auerstadt had occurred only a few months earlier, and they had caused serious damage to Weimar's unpaved streets. For this reason, the required pieces of glass apparatus were transported through town not by coach, but rather with a wheelbarrow belonging to the University of Jena. Goethe was deeply impressed by the spark-spewing Davy experiments, which with much noise and spectacle conveyed at least a bit of the research spirit of the distant Royal Institution to the—thanks to Napoleon's departure—now deserted and therefore placid Weimar, and to its citizens, who were still licking their wounds. Indeed, he was so taken by it all that he spent the next few months setting down in writing his "chemical novel", *Die Wahlverwandschaften* ("Elective Affinities").[136]

Torbern O. Bergman, professor of chemistry in Uppsala (Sweden), was one of the great analytical chemists of the 18th Century, and the father of mineralogical chemistry. Bergman was also an important theoretician, whose 1775 book *Disquisitio de atractionibus electives* ("A Dissertation on Elective Attractions"; German edition, 1785) pointed the way toward the force driving chemical reactions. Goethe drew upon the German translation of the book's title for the name and general outline of his novel *Die Wahlverwandschaften*.

"The moral symbols in the natural sciences—for example in elective affinities [in other words, "attractions"], as conjured up and utilized by the great Bergman—are wittier and better suited to association with poetry and indeed society than any others."[137] The plot, corresponding to a chemical reaction of the type

$$AB + CD \rightarrow AC + BD$$

was described by a contemporary as follows: "The title expresses the context of the historical tale; for just as two bound bodies can be chemically separated, with each choosing a new partner, so can a contented and clear-sighted married couple fall in love in middle age with other hearts, and no matter how much the woman wishes with resignation and wisdom to steer things, the man's demands prove irresistible, and the truly loving but later guilt-ridden Ottilie dies before him."[138]

It did not escape Goethe's indignant contemporaries that he was in a sense providing in his novel a scientific basis for adultery. Perhaps for this very reason *Die Wahlverwandschaften* proved a great commercial success. It is true that Austrian authorities forbade the printing of Goethe's works in their country, but in so doing they ruined only an especially potent Viennese producer of pirate editions, in consequence of which Goethe's publisher significantly increased the royalties.[139]

One should not be especially surprised by the influence Bergman's book and Davy's experiments had on a novel by Goethe, since the Royal Institution left its mark elsewhere on the literary landscape as well. Thus, when someone once inquired of Davy's friend, the great Romantic Samuel Coleridge, who regularly attended lectures at the Royal Institution, why he bothered to do so, he replied: "To enrich my stock of metaphors!"[140]

In Jean Paul's 1820 novel *Der Komet oder Nikolaus Marggraf*, the great Davy surfaces as a small but nonetheless important secondary character. This might be considered "a comical story",[143] in the incredibly complicated course of which a crazy apothecary succeeds in using an oven to carry out a secret process whereby calcination of coal leads to diamonds. This brings the protagonist into a dispute with Davy about priority. In Jean Paul's twisted sentence construction (even more striking in the German original!) this comes out: "Davy in England asserted that he had turned coal into diamonds, albeit to gems that emerged petrified as somewhat dark and yellowish, using a voltaic column."[142] The historical Davy never in fact attempted to synthesize diamonds. But in 1813/14, during his great journey to the Continent in company with Faraday, he used sunlight passed through a large burning glass at the Accademia del Cimento in Florence to ignite a diamond in an atmosphere of pure oxygen so as to reproduce quantitatively some earlier experiments by Lavoisier. In the process, he discovered that, once ignited in oxygen, a diamond would continue to burn without any additional energy input. He isolated carbon dioxide as the sole combustion product. Since no water was produced it was clear that diamond, like pure charcoal, contained no hydrogen, but was composed entirely of pure carbon. On the other hand, naturally occurring graphite and many types of charcoal did generate a certain amount of water upon combustion in oxygen.[143] Thus, although exercising considerable "poetic license" in sketching out Davy's research activities in his novel, Jean Paul did not pull the ideas entirely out of thin air.

But now we turn once again to war. Napoleon himself eventually came to Weimar, but did not stay long. He was probably traveling in his soon-to-become-famous bullet-proof coach. He settled in at Berlin as early as October 27, 1806, and on November 21 signed the celebrated decree in which he declared a Continental blockade. The Emperor thereby barred all British goods from the coasts of Europe. This measure should probably have put an end to authentic black tea in Johanna Schopenhauer's kitchen! But, in the event, things were much easier for the upper echelons of society, thanks to daring smugglers and/or good connections. As a result, Weimar society was able to continue meeting over tea at Johanna's for a long time to come.

The Continental Blockade—A Quest for Surrogates

> *"The British Isles are declared to be in a state of blockade."*
> Napoleon I, Berlin, November 21, 1806[144]

Napoleon never succeeded in landing in England, nor could he defeat the British fleet. Though the victor in over 60 bloody battles, in the very last one, at Waterloo, he was vanquished. Nevertheless, even up to the present day no one has had such a marked effect on the appearance of the City of London as the despised Corsican. Beginning with the war of 1801–1804[145] the price of wood in England rose to exorbitant levels. But worse was yet to come. The French occupation of Germany, the Continental Blockade (1806), and the Peace Treaty of Tilsit (1807)—all were intended to drive Great Britain to its knees economically. Napoleon's real goal was probably preventing the British fleet from acquiring more timber for shipbuilding. Great Britain was now paying the price for its near-deforestation of a once heavily wooded countryside in an attempt to meet the industrial revolution's insatiable charcoal demand: for reducing iron ore (Figure 16). Wood had thus become an import commodity, coming primarily from the Baltic countries. It is true that there existed one potential way out of the quandary: greater use of iron, but this expedient was for a long time unpopular with both shipbuilders and the country at large. Effects of the Continental Blockade could be seen in the London cityscape as early as 1807. Buildings lining the streets of the central city began losing their characteristic tall, forward-facing gables, which gave way instead to long, low, flat structures that required less wood, were generally set behind walled balustrades, and featured transverse

Figure 16. The wood shortage resulting from the Continental Blockade had a drastic effect on the London cityscape. Buildings lining the streets of the central city began losing their high steep roofs with characteristic tall, forward-facing gables, to be replaced by low, flat structures that required less wood, generally set behind walled balustrades. Such roofs were in most cases no longer visible from the street. Watercolor from G. Scharf: The Strand, 1824.

roof ridges.[146] More and more frequently, iron did play a role in the framing of roofs. This soon became especially popular with public buildings and townhouses of the nobility since it facilitated incorporation of heavy, horizontal glass skylights for introducing daylight from above, thus brightening to some extent the massive formal dining rooms.[147] The London architectural elite showed no hesitation about combining these novel, modern construction techniques in adventurous ways with the most conservative of stylistic features. An astonishing highpoint was the meeting room of the privy council in Whitehall (1827), with its eclectic column-flanked portals and an imposing hall with freely suspended, bridge-like Renaissance vaults, sporting Gothic style elements. Above it all soared an iron-ribbed glass roof, resting on what at the time were the very latest of iron/concrete joists.[148]

With wood and charcoal having become very costly, Londoners turned to coal or coke for their fireplaces, coke being a by-product of the only recently introduced municipal gas plants. Coal ashes, unlike the clean ashes from wood, contain troublesome mineral impurities, which prevented their easy conversion to potash. The Continental Blockade therefore meant that wood-ash became a scarce commodity, especially since the Blockade meant that nearly all ash import from the Continent was cut off as well, and this in turn led to a shortage of glass. Soda synthesis by the method of Leblanc represented a way around the problem, and this helped make possible the further development of British iron-and-glass construction. The patient reader with considerable time at his or her disposal is encouraged to sample the literature (which would fill several libraries!) from the fields of metallurgy and construction, as well as the history of iron, wrought iron, cast iron, and steel as these were used in the building trades, especially for the greenhouses so popular in Great Britain. At "Carlton House", the London home of the Prince of Wales (later to be King George IV), the architect Thomas Hopper in 1807/09 created a sensational conservatory, with fan-vault tracery inspired by the chapel of Edward VII in Westminster Abbey. But Hopper managed actually to far surpass Edward VII, in that his ribbing was filled in not with masonry but entirely by colored glass.[149]

The principal problem facing Great Britain, however, was not a *shortage*, but rather a *surplus* of goods. Industry and commerce found it almost impossible to ship anything whatsoever to Europe. Unsold colonial and industrial goods piled up on the London docks, not least because the British government reacted with an embargo of its own. Thus, British squadrons cruised off all the major European harbors in the hope of capturing French ships arriving from the colonies. Smugglers were the only ones who really profited. As captain of a small, agile, overcanvassed—and therefore exceptionally swift—sailing vessel with a large crew, one could earn a fortune. It can be reasonably assumed that maritime experience acquired in this way was of great benefit to the rapidly developing upper-class sport of yachting.[150]

On the other hand, the situation on the Continent was also rather dramatic. Suddenly one no longer had access to such classic colonial goods as coffee, tea, sugar, rum, cacao, tobacco, spices, indigo, dyewoods, gum arabic, cotton, and cinchona. Also, British mass-production items, which were cheap relative to their Continental counterparts—scissors, knives, buttons—as well as optical glass and most especially wool and cotton fabrics—calico, muslin, chintz—could no longer reach the mainland. Not all the consequences were negative, however. In the absence of English competition a stoneware industry flourished in the Saar, and a cotton industry in Saxony, Alsatia, and Switzerland. The requisite cotton, originating ultimately in the Near East, came in by way of the free port of Trieste, a sometimes reluctant ally of Austria that did not in fact prove to be a reliable partner for the French. Shortages of optical glass led to establishment of an optical industry in Jena, sponsored by Goethe, with help (not entirely voluntary) from the optical glassworks of Joseph von Utzschneider in Benediktbeuern (Goethe learned some of the secret details of the process from Georg von Reichenbach).[151] A thriving silk industry grew up in Lyon and Krefeld, destined to be permanently associated with the name of J. M. Jacquard, ingenious inventor of a loom that could be programmed with punch cards.[152] Similarly, a hardware industry appeared in Württemberg.[153]

But apart from these highlights, the overall situation was grim, one result being that "surrogates" became important for the first time. For example, hordes of European botany and chemistry professors set off on the search for an "ersatz" (substitute) coffee. W. A. Lampadius, chemistry professor at Freiberg, developed a coffee substitute based on roasted beetroot and chestnuts. All sorts of other things—miscellaneous plant components acting as sources of carbohydrates, sugars, oils, and fats—became subject to a processing that culminated in roasting and brewing, on the chance of producing a brownish aqueous solution with some sort of flavor: an approximation to "coffee". Roasting was tried not only with grains of nearly every imaginable type, but also dandelion roots. Chicory roots produced a better flavor, and this actually evolved into something of a success; even today "la chicorée" can be found almost everywhere in France. But none of the substitutes could take the place of true coffee beans, because none contained even a hint of the stimulant caffeine![154]

Given the vast number of war-wounded suffering from fever, the absence of cinchona-root bark (quinine bark) was especially serious. This powerful remedy was obtained from the cinchona tree, native to and harvested in the northern part of South America. Physicians once believed that all sorts of bitter-tasting plant extracts were capable of reducing fever; even an extract of horse-chestnut shells was recommended for the purpose, despite its having virtually zero fever-reducing potential. Considerably more effective was an extract of willow bark. The latter did in fact possess antipyretic properties, but with the disadvantage that many patients' stomachs found it hard to digest. J. A. Buchner, professor of pharmacy in Munich, was the first to isolate the true active ingredient (in 1828), the vegetable-based drug salicin. In 1837, A. Piria was able to cleave salicin into a sugar and the aromatic compound salicylic acid. While the latter still evoked nausea, it opened the way to the much more digestible ethyl ester, which came to be dubbed "Aspirin".[155]

In those days, one of the most important dye materials was indigo. A local source of indigo in Europe was recognized as early as the 17th Century: leaves of the plant called "woad". By the end of the 18th Century, however, woad cultivation had been virtually abandoned because of the plant's very low indigo content. The Blockade stimulated tremendous efforts, both botanical and chemical, to gain a new grip on woad technology, and as quickly as possible. One valuable contribution to the endeavor came from J. B. Trommsdorff, professor of chemistry and pharmacy in Erfurt. For a time, Trommsdorff was chemical consultant to Carl von Dalberg, not only an important friend of Goethe's but also prince-primate of the Rhine Confederation and political confidant of Napoleon (Figure 17).[156] Trommsdorff significantly improved the processing of woad leaves, and built a factory for this express purpose, but with Napoleon's downfall it met its demise.[157]

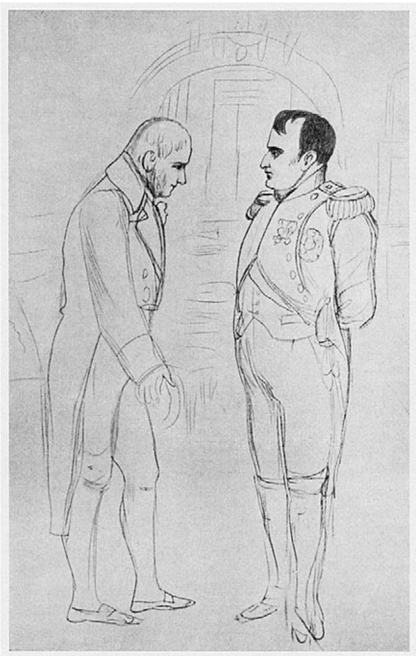

Figure 17. On July 23, 1807, during the "Conference" in Erfurt at which Napoleon and Tsar Alexander I tried, without much success, to set boundaries to their spheres of power, the French Emperor met the Erfurt pharmacist J. B. Trommsdorff. Napoleon allegedly asked Trommsdorff whom he regarded to be the greatest French chemist. He replied curtly that "Chemistry no longer has a head since Lavoisier lost his!" Napoleon loved to regard himself as the great visionary of the French Revolution, so this answer cut him to the core.

The most noteworthy success story to come out of surrogate research was discovery of the sugar potential of beetroot. Selective cultivation soon led to an improved strain called the "sugar beet", with a high saccharose content (Figure 18). Methods were also perfected for isolating from these beets a sugar product identical to cane sugar. Isolation was no simple matter, incidentally, due to the unfortunate presence of various slimy materials. Among the important scientists and technologists involved in this work in Germany were the chemist F. C. Achard and the apothecary S. F. Hermbstädt.[158] The French were represented by A. J. Chaptal, an industrialist who was at one time Napoleon's Interior Minister. Chaptal induced Napoleon to visit the B. Delessert production site in Passy near Paris, and the Emperor was so impressed by the sugar output he witnessed that he spontaneously tore from his breast his own Legion of Honor cross in order to confer it immediately upon Delessert.[159] The presence of grape sugar (glucose) in grape juice ("must") was established by the apothecary and chemist J. L. Proust. Despite the fact that grape sugar was in fact not terribly sweet, Napoleon paid tribute to its discovery with a reward of 100000 francs.[160]

Figure 18. Title page and title engraving from "Der neueste deutsche Stellvertreter des indischen Zuckers oder der Zucker aus Runkelrüben", Berlin 1799 (*The latest German representatives of Indian sugar or sugar from sugar beets*). Even before the Continental Embargo, attempts were being made in Prussia to increase the saccharose content, by cross-cultivation, of what would become known as the sugar beet.

In St. Petersburg the apothecary G. S. C. Kirchhoff embarked upon a search for an alternative to gum arabic, important in the calico-printing process. Among other things, he experimented with a mixture of potato flour and sulfuric acid. In the course of this work he stumbled across acid hydrolysis of starch, and the resulting "starch sugar" (dextrose). Not particularly sweet, we know today that starch sugar as isolated is a mixture of D-glucose and maltose, together with small amounts of higher sugars.[161]

The chemistry professor and pharmacist J. W. Döbereiner was a scientific adviser to Goethe who also bore responsibility in Saxony-Weimar-Eisenach for breweries, distilleries, and other industries (Figure 19). Döbereiner found a way to cleave starch under pressure in a heated digester. Later, in 1812, he supervised construction in Tiefurt of the first "licensed" dextrose factory, shares in which were underwritten by Döbereiner's sovereign, Duke Carl August, as well as the ducal family, and even by Goethe, who was ordinarily an extremely cautious investor. Döbereiner was apparently unsuccessful in completely removing undesirable plant material from the product, leading Carl August to write disappointedly in 1812 that the resulting starch sugar was "very bad, and tasted miserable in coffee."[162] Napoleon's downfall brought an end to this production facility as well. There

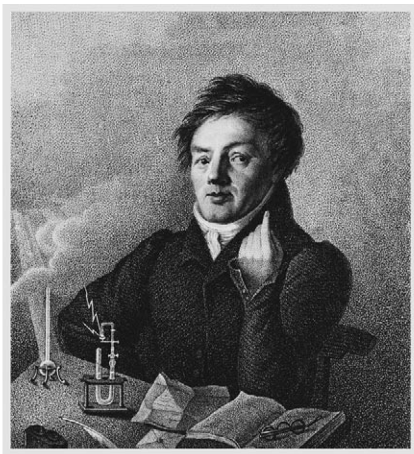

Figure 19. Goethe's chemistry advisor J. W. Döbereiner, who investigated the extraction of starch from potatoes under heat and pressure. In conjunction with Herzog Carl August and Goethe he established a factory for that purpose.

was of course one other way to confront a sugar scarcity: through conservation. Because of its antibacterial properties, sugar and sugar-containing materials like honey had long been employed in the preservation of plant-based foodstuffs, such as jams. The amount of sugar required for preservation purposes could be reduced substantially, however, by keeping air away from the stored food. This insight, which contributed to invention of the canning jar ("Appert's method" of aseptic canning), earned the French confectioner N. F. Appert a reward from Napoleon of 12000 francs.[163]

The Emperor's position with respect to scientific communication between Great Britain and France was, to say the least, inconsistent. Thus, on December 7, 1807, Gay-Lussac issued a report for the Galvanism Commission of the Institut national de France in support of awarding the Galvanism Prize to Humphry Davy.[164] This honor had been endowed by First Consul Bonaparte in June, 1802, as a response to his being so deeply impressed by Volta's experiments.[165] Now as Emperor he apparently viewed it as perfectly appropriate that the Englishman Davy should receive the Prize despite French/English animosities. But it created problems for Davy, who found himself under pressure from official British circles to decline the gold medal. Davy managed to find a way out, though: he waited until 1813 so he could be given the Prize in person.[166]

Somewhat more complicated was the interchange of scientific literature. Despite the blockade, travelers with special permission could occasionally cross the Channel—in both directions—and nothing prevented them from carrying along scientific publications and books. Still, commercial trade in literature was strictly prohibited in France, not only for fiction and the like but also works of a scientific nature. The Swiss scientist M. A. Pictet (1752–1825) helped bridge the gap with his *Bibliotheque Britannique*, a French-language review journal that reported on a monthly basis from 1796 to 1815 on British literature and science—published in Geneva, and thus outside France proper. News collected by Pictet's agents in London was conveyed as quickly as possible to Geneva by an indirect route through the Nordic countries and Germany. As a result, French scientists were informed promptly about Rumford's achievements, as well as Davy's Bakerian Lectures.[167] The peculiarity of the overall situation is underscored by the fact that Davy was simultaneously carrying on direct correspondence with members of the Institut, and Rumford, who now resided in France, was living it up in a complicated relationship with his second wife, the Countess Lavoisier de Rumford.[168]

Throughout history it has unfortunately been the case that, although restrictive economic conditions have serious effects on the masses, the upper echelons of society tend to be spared. If one accepts at face value the studies by Haedley and Meulenkamp in the field of garden history,[169] quite a number of British parks at the turn of the 18th/19th centuries were distinguished by the presence of special "follies" (charming little buildings ostensibly to serve as "eye-catchers") conveniently connected through long tunnels to the seashore—or even to manor houses set farther inland—to facilitate the landing of smuggled goods. The most prominent structure of this sort still extant is Luttrell's Tower near Eaglehurst in Hampshire, built as early as the French Revolution by T. S. Luttrell. Even then there were obstacles to trade between England and France. Historical research has brought to light the astonishing fact that Luttrell and his heirs engaged in smuggling for an especially prominent client: the then Prince of Wales, who in 1811 became Prince Regent and in 1820 was crowned King George IV.[170] Smuggling of this nature is of course perfectly understandable: surely one shouldn't be forced to forego French luxury items just because a war is in progress!

There are surprising tidbits to cite from the other side of the Channel as well. An Emperor of the French was of course in a position to order the blockade of islands, or even continents, but certainly not a blockade of his own wife! It happens that Josephine was quite probably the most important patroness ever of botany, and the most successful amateur botanist as well. In the greenhouses of her chateau Malmaison, as well as at Navarre (another chateau given to her by Napoleon in 1809 after their divorce), she cultivated a not-to-be-duplicated collection of the rarest of plants. In calling to mind this remarkable personage one should actually pause to recite her complete name—Marie-Joseph Rose Tacher de la Pagerie—because, thanks to Napoleonic botanists, the sundry components of that name now occupy unique places in the nomenclature of plant species: Josephinea, Lapageria, etc.[171] In carrying out their mission to enhance Josephine's gardens, her gardeners took advantage of diplomatic passes to visit seed dealers in London, and even Kew Gardens itself. At the same time, English seed merchants journeyed under diplomatic protection to Malmaison. There is good reason to suspect that in their "serres portatives" (portable greenhouses) these travelers transported not only peonies but also diplomatic correspondence.[172]

Mankind's Little Pleasures: Kitchen Ranges, Coffee Filters, and Watercolors

> *"In our own times, it would be easy to point out numerous instances in which great improvements and beneficial results connected with the comforts, the happiness and even life of our fellow creatures have been the results of scientific combinations."*
> Sir Humphry Davy[173]

If Rumford's fireplace led to only gradual improvements (Figure 20), his development of the modern kitchen range set off a culinary revolution. When the 19th Century began one could still find in kitchens everywhere, situated beneath gigantic "aprons", what amounted to "campfires". Pots and pans rested there, perched over the coals on special three-legged wrought-iron stands, or they hung in the flames from soot-blackened iron chains like oversized paunches.[174]

From our vantage point, Rumford's ideas seem not all that complicated.[175] One might even harbor the suspicion that he was struck during his lengthy sojourn in Bavaria by the obvious potential in ceramic-tile stoves he encountered there. Perhaps at the Ammerland villa on Lake Starnberg he merely observed his beloved little illegitimate

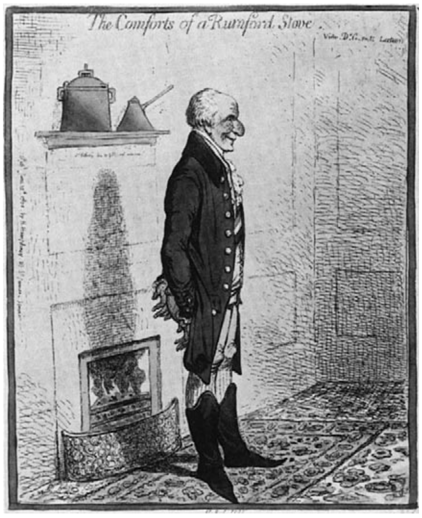

Figure 20. Rumford improved the air flow of the British chimney by making it smaller and flatter. In fog-plagued London (the fog was really brown smoke!) it became commonplace to install a small "Rumford Chimney" into the huge old fire place. However, the emitted warmth was dispersed very irregularly throughout the room, which the anonymous caricaturist from 1800 indicated by the burnt rear of the Rumford figure.

daughter Sophie, or her mother Josepha Countess Baumgarten, baking an apple in the oven compartment of their Bavarian stove.[176] In any event, Rumford lost patience with the open kitchen fire, choosing to enclose it instead with masonry and cast-iron plates and then equipping the range so obtained with a top surface of cast iron. There were openings in this cover into which various pots could be set, and these could in turn be partially or fully masked, as required, with the aid of concentric iron rings.

We learn of the significant amounts of coal saved by a Rumford range, and the accompanying economic impact, from a delightful letter written by the President of the Royal Society, Sir Joseph Banks, to Sir William Hamilton[177] on November 17, 1795 (in which every rule of capitalization has been systematically ignored!): "We have Count Rumford here who is to Reduce the value of Newcastle coals to half its Present Price by enabling us to Cook our Kettles with 1/4 of the fire we now use." But Rumford's innovation did not meet with Sir Joseph's whole-hearted approval. Soot in his soup apparently did not bother him all that much, because the letter continues: "I am submissive but I Seriously hope he will find some one better used than mine."[178] Rumford was a sharp businessman, and he became rather prosperous on the strength of his ranges. Meanwhile, he developed other kitchen equipment as well, including special pressure cookers for English pasties and a little porcelain pot with a porous filter base that could be set atop a coffeepot. Indeed, "filter coffee" was perhaps Rumford's greatest gift to ever-weary mankind!

One indirect accomplishment of the Royal Institution was the way it stimulated the birth of other scientific societies, such as the "Surrey Institution". For a time, the latter was quite a success. The young Faraday attended chemistry lectures there, for example, but the Surrey, in contrast to the Royal Institution, also offered literary courses. Thus, Davy's sometime companion and greatest admirer, S. T. Coleridge, expounded there on Shakespeare. Friedrich Accum (1769–1835), a German who was for a while librarian at the Royal Institution, delivered chemistry lectures at the Surrey starting in 1808.[179] The spirit of the recently deceased Count Rumford shows itself in a book Accum wrote that became extraordinarily well-known despite its complex and convoluted title: "Culinary Chemistry, Exhibiting The Scientific Principles of Cookery, With Concise Instructions For Preparing Good and Wholesome Pickles, Vinegar, Conserves, Fruit Jellies, Marmelades, And Various Other Alimentary Substances Employed in Domestic Economy, With Observations On The Chemical Constitution And Nutritive Qualities of Different Kinds of Food".[180] Accum attracted attention especially with his attack on insufficiently (or non-) tin-plated copper kitchenware, as leveled in a chapter entitled "Poison in the Pot".

This book offered a host of refined recipes, which—in contrast to past practice—a cook could prepare *on* the hot stove top, conveniently at table height, protected from showers of soot and sparks. Accum also supplied propaganda for a perfected and in fact standardized commercial version of the Rumford range, complete with built-in ovens for baking and roasting as well as basin-like depressions from which one could ladle warm water. These Rumford ranges, made entirely of cast iron, turned up in large numbers in the mansions of British nobility. An especially beautiful example is to be seen in the kitchen of Tredegar House,[181] in Gwent (the southeastern-most part of Wales). Here, next to the primary built-in Rumford range, with its massive, ponderous top formed from cast iron, stands another, somewhat more modern version clad in enamel and set into a former fireplace opening. These are complemented by a set of true gems: polished-copper pressure cookers, also developed by Rumford, mounted in wall niches and equipped with their own heat sources, and with safety valves of a very picturesque design, featuring polished-brass levers.[182] In an aristocratic kitchen one could hardly forego the possibility of roasting an entire ox, so an immense open fireplace was also at hand, the spit for which was driven by a clockwork-like mechanism mounted on the fireplace canopy and connected to the spit itself by chains rather like today's bicycle chains.[183] Rumford's early behemoths presently gave way to more graceful ranges, clad in sheet enamel, which came to dominate kitchens everywhere for well over a century until eventually being displaced by gas and electric ranges.

In 1799, Accum's publisher, Rudolph Ackermann (1764–1834), came to recognize the enormous significance watercolor painting was likely to achieve, specifically in Great Britain, thanks to scores of wealthy amateur painters. In fact, wooden watercolor cases, from the Reeve brothers, had already been available to the public since 1780. Ackermann, prototype of the disconcertingly bustling Saxon entrepreneur,[184] commanded in his own right considerable chemical knowledge. Working together with "Frederick" Accum, he had by 1802 managed to develop and put up for sale 69(!) different watercolor paints, derived from both vegetable sources and inorganic pigments. He never succeeded in fully cornering the market for watercolors, but his legendary outlet ("Repository of Arts, Literature, Commerce, Manufactures, Fashions, and Politics", dedicated to supplying the upper classes with objects of good taste), as well as a subtle strategy of endowing art awards specifically targeted to watercolor painters, assured that Ackermann would enjoy a significant market share while securing for himself a solid spot in British art history.[185] From then on, astonished locals all over continental Europe would register amazement at the way dedicated, "splenetic" English watercolorists (they were nearly always English)[186] turned up in the most unlikely places, often exploiting a "camera lucida" to better "capture" the distant landscape. This device (introduced by the brilliant Wollaston, who was also a physicist) functioned on the basis of a prism with specially mirrored surfaces, set in a small frame, which could be held such that with one eye it became possible to observe simultaneously a drawing pad and, superimposed over it, an image of the landscape ahead—an extremely clever tool that greatly facilitated accurate drawing (Figure 21).[187]

Figure 21. A Wollaston camera lucida, from the collection of the Deutches Museum, Munich

The "Last Veil" Masking the "Luster of the Divine Light"—Sir Humphry's Dream of the Moral Refinement of Chemists

> *"The true chemical philosopher sees good in all the diversified forms of the external world. Whilst he investigates the operations of infinite power, guided by infinite wisdom, all low prejudices, all mean superstitions, disappear from his mind. He sees man, an atom amidst atoms, fixed upon a point in space; and yet modifying the laws that are around him by understanding them; and gaining, as it were, a kind of dominion over time, and an empire in material space, and exerting on a scale infinitely small a power, seeming a sort of shadow or reflection of a creative energy, and which entitles him to the distinction of being made in the image of God and animated by a spark of the Divine Mind."*
>
> Sir Humphry Davy[188]

Pious words, but also proud ones! In order to render such contemplations intelligible in our own generation we must keep in mind that the brutal, atheistic French Revolution had touched off a mass exodus of religiously oriented people to Great Britain. Despite a long-standing anti-Catholic attitude on the part of the Anglican state church, and many other sects as well, the new arrivals were able to contribute to a flourishing of religious tolerance, culminating in the Catholic Emancipation of 1829, and to a distinct reinforcement of Christian cultural life in general.[189] This was not to be staved off even by Napoleon's half-hearted concordat with the Catholic church in 1801, or by his coronation as emperor, with the pope's blessing, in 1804. The subsequent incarceration of the pope in 1809 spoke altogether too eloquently. Thus, especially in Great Britain, the early decades of the 19th Century brought to the natural sciences a renewed consciousness of the centuries-old "physicotheological" mindset—once such fertile ground for the development of science in Europe—with its lesson that there are two books the true Christian absolutely must read: the Bible and the "book of nature."[190] As works of God, orderliness and beauty in nature were to be regarded as reflections of the Creator himself. Throughout Davy's writings one finds numerous passages documenting his physicotheological turn of mind. Physicotheology in fact developed a rather substantial following. Thus, the aristocratic entrepreneurial family Egerton/Bridgewater (the Bridgewater Canal) created a forum specifically suited to physicotheological writings with their "Bridgewater Treatises on the Power, Wisdom and Goodness of God, as Manifested in the Creation."[191]

Until the mid-19th Century, every halfway comprehensive periodic system of the elements was considered to be a proof of God. Attitudes in this regard soon shifted rather abruptly, however. Thus, Mendeleev categorically rejected any philosophical—let alone religious—interpretation of his system! The alchemists of old were of the unshakable opinion that observing alchemical/chemical reactions would ennoble the souls of the "adept". It therefore should come as no surprise to find similar notions in the later formulations of Humphry Davy. Our problem today is deciding whether such ideas might still have relevance. It is tempting to wonder if the prolonged battles currently playing out between university chemistry departments in Germany in the context of the so-called "Initiative for Excellence" and the related quest for official recognition as an "Elite University", if these are in some sense parallel to Davy's lofty vision of the morally refined chemist. At least for the authors of this essay, Davy's reflections on the moral refinement of chemists by chemistry itself seem euphemistic in the extreme: "*And, in becoming wiser, he will become better; he will rise at once in the scale of intellectual and moral existence, his increased sagacity will be subservient to a more exalted faith, and in proportion as the veil becomes thinner through which he sees the causes of things, he will admire more and more the brightness of the divine light by which they were rendered visible.*"[192] How lovely that would be! Truly lovely!!

Conjecture Regarding the Establishment in New York of a Print Shop

> *"But the English being equally tyrannical at sea as he [Napoleon] is on land, and that tyranny bearing on us in every point of either honor or interest, I say: 'down with England'!"*
>
> Thomas Jefferson, August 21, 1807[193]

The Continental Blockade had its effects on the young United States as well. Altogether too many American merchants saw in it an opportunity to carry on trade between the adversaries under protection of the "neutral" flag of the USA. American ships were easily prevented from shuttling back and forth directly between the English and French coasts, but triangular trade involving ports on the American east coast was more difficult to regulate. The situation did not sit at all well with the British government, and the Royal Navy treated American merchant vessels in a decidedly rude fashion. Ships were ransacked, and their cargoes confiscated. In June 1807 the English warship "HMS Leopard" attacked the American frigate "Chesapeake," and several crew members were killed. Yankee pride boiled over, and Jefferson declared a general embargo applicable to all harbors in the United States. He, too, was determined to bring British trade to its knees, which was why he decreed that no American ships would be allowed to leave US ports.[194] The orders were enforced only until 1809, but they dealt a serious blow to the American public. Manufacturing and shipping came to a standstill; 30000 seamen found themselves unemployed, and numerous businesses went bankrupt.[195]

This situation must have placed a substantial burden on the Wiley family as well, given their rum, molasses, and slave trade with the Caribbean, so it would certainly have been tempting for the young Charles Wiley to leave behind the mercantile tradition of his kin and take up something different. Since his wife's family plied the printing trade it probably seemed sensible to him to open a print shop of his own.[196]

In Germany in the 1930s there was a famous film with the title "Napoleon Is to Blame for Everything!" ("Napoleon ist an allem schuld!"). So why wouldn't he have played a role in the founding of Wiley?

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[1] Sir Humphry Davy, *Consolations in Travel or The Last Days of a Philosopher*, Adamant Media, Boston, **2005**, p. 120.

[2] a) P. Nicolaisen, *Thomas Jefferson*, Rowohlt, Reinbek, **1995**, p. 40; original text: b) J. Dunlap (Ed.): "In Congress, 4. July 1776, A Declaration", Philadelphia, **1776**; c) discussion: *Bücher, die die Welt verändern* (Eds.: J. Carter, P. H. Muir), Prestel, Munich, **1968**, p. 407; d) J. Crafton, *The Declaration of Independence and other great Documents of American History, 1775–1865*, Dover, New York, **2000**.

[3] a) See reference [2a], p. 109; b) H. Haan, G. Niedhart, *Geschichte Englands vom 16. bis zum 18. Jahrhundert, 2nd ed.*, Beck, Munich, **2002**, therein the map "Das britische Weltreich 1793" (p. 228); c) H. Wasser, *Die große Vision: Thomas Jefferson und der amerikanische Westen*, VS Verlag, Wiesbaden, **2004**, therein the maps "North America in 1700" (p. 15), "North America after the Treaty of 1763" (p. 17) and "Gebietswachstum der Vereinigten Staaten 1776–1858" (p. 18); d) historical background: D. J. Weber, *The Spanish Frontier in North America*, Yale University Press, New Haven, **1992**; e) for subsequent developments, see, for example: K. J. Bauer, *The Mexican War 1846–1848*, University of Nebraska Press, Lincoln, **1993**; f) H. Dippel, *Geschichte der USA, 7th ed.*, Beck, Munich, **2005**, therein: "Die junge Republik (1789–1825)" (pp. 33–43).

[4] a) R. Dufraisse, *Napoleon. Revolutionär und Monarch, 4th ed.*, Beck, Munich, **2005**, p. 74, pp. 86–87; b) J. Tulard, J. F. Fayard, A. Fierro, *Histoire et dictionnaire de la Révolution Française 1789–1799*, Robert Laffont, Paris, **1989**, pp. 472–478; under the keyword "Louisiane" (p. 858) appears the following classic observation: "*Mais, le jugeant indefendable contre les appetits britanniques, Bonaparte la vendit aux Etats-Unis, le 30 avril 1803, contre 80 millions de Francs.*"

[5] See reference [2a], pp. 110–112, as well as reference [2b], pp. 180–183.

[6] Elaboration on the background: "Über Land zum Pazifik", in reference [2c], pp. 499–500; primary reference: *History of the Expedition under the Command of Captains Lewis and Clark to the Pacific Ocean, 2 vols.*, Bradford & Inskeep, Philadelphia, **1814**. This was the era of huge and grandiose research reports and travel accounts. For this reason one should note the parallelism with the following works: A. von Humboldt (in collaboration with Cuvier, Latreille, Gay-Lussac, et al.), *Voyages aux régions équinoxiales du Nouveau Continent fait en 1799–1804, 30 vols.*, 1425 copperplate engravings (!), Paris, **1805–1834**; *Description de l'Egypte ou Recueil des Observations et des Recherches qui ont ete faites en Egypte pendant l'Expeditions de L'Armée Francaise, publie par les Ordres de sa Majesté l'Empereur Napolen Le Grand(!!)*, 1006 plates, De l'Imprimerie Imperiale, Paris, **1809**; reprint of the plates: *Description de l'Egypte. Publiée par les ordres de Napoleon Bonaparte*, Benedikt, Cologne, **1994**; regarding the history of Bonaparte's Egyptian expedition: *Muséum National D'Histoire Naturelle: Il y a 200 ans, les Savants en Egypte*, Nathan, Paris, **1998**.

[7] H. Davy, *Consolations*, p. 108.

[8] G. I. Brown, *Graf Rumford. Das abenteuerliche Leben des Benjamin Thompson*, dtv, München, **2002**, p. 11.

[9] See reference [8], "Sir Benjamin, Oberst in englischen Diensten" (p. 27).

[10] Described especially amusingly in G. Grass, *Der Butt, 4th ed.*, dtv, München, **1999**, therein: "Der verrückte Graf Rumford, der es nirgendwo lange aushielt und immer was Nützliches erfinden mußte." (pp. 371, 397, 410, 416).

[11] See reference [8], "Graf Rumford als Staatsmann in Bayern" (p. 43) and "Rumfords Reformen" (p. 65).

[12] a) See reference [8], "Rumford als Wegbereiter der Thermodynamik" (p. 103); b) J. R. Partington, *A History of Chemistry*, MacMillan, London, St. Martin's, New York, **1964**, therein: "Rumford" (p. 30); c) "Napoleon und die Naturwissenschaften": J. Fischer, appearing in *Boethius, Texte und Abhandlungen zur Geschichte der exakten Wissenschaften, Vol. 16*, Franz Steiner Verlag, Wiesbaden, **1988**.

[13] S. Schmid, *Byron. Shelley. Keats. Ein biographisches Lesebuch*, dtv, München, **1999**, therein: "Shelley—Anarchie und Freiheit", "An Englands Männer" (p. 85). This poem is anachronistic in the sense that it first appeared around 1810. However, it depicts in masterly fashion the state of revolutionary ferment in England during the entire Napoleonic period—and even afterward! Shelley succeeded in achieving comparable revolutionary tones on only one other occasion: in a poem directed against the 1819 Peterloo Massacre, promulgated by the British military at a demonstration of 60000 workers near Manchester, where numerous demonstrators were wounded and a few killed: see reference [13], p. 123: "The Mask of Anarchy./ I met Murder on the way/ He had a mask like Castlereagh—/ Very smooth he looked, yet grim;/ Seven blood-hounds followed him; …"; Robert Stewart Viscount Castlereagh (1769–1822), Foreign Secretary after 1812, was especial-

ly despised as an extremely conservative member of the government, and is portrayed here by Shelley as one of the "horsemen of the apocalypse". Berthold Brecht was a great admirer of this poem.
[14] G. T. di Lampedusa, *"… Ich sucht' ein Glück, das es nicht gibt …"*, Wagenbach, Berlin, **1999**, therein: "Das Gesellschaftliche Miljeu" (p. 12) and "Shelley, 1792–1822" (p. 63).
[15] *Metropole London. Macht und Glanz einer Weltstadt* (Ed.: Kulturstiftung Ruhr Essen), Bongers, Recklinghausen, **1992**, therein: "Martin Daunton: London und die Welt" (p. 21).
[16] a) H. B. Carter, *Sir Joseph Banks. 1743–1820, 2nd ed.*, British Museum (National History), London, **1988**, pp. 240–241; b) P. O'Brian, *Joseph Banks. A Life*, Collins Harvill, London, **1987**; c) *Sir Joseph Banks. A Global Perspective* (Eds.: R. E. R. Banks, B. Elliott, J. G. Hawkes, D. King-Hele, G. Ll. Lucas), The Royal Botanic Gardens, Kew, **1994**; d) see reference [15], p. 429.
[17] See reference [16a], p. 378.
[18] See reference [16a], pp. 384–385 and F. R. Kreißl, O. Krätz, *Feuer und Flamme, Schall und Rauch, Schauexperimente und Chemiehistorisches*, Wiley-VCH, Weinheim, **2003**, therein: "Öffentliche Experimentalvorlesungen für Chemie im London des 18. und 19. Jahrhunderts" (pp. 21–31).
[19] J. R. Partington, *A History of Chemistry*, *Vol. 3*, MacMillan, London, **1962**, p. 273.
[20] S. Saudan-Skira, M. Saudan, *Orangerien. Paläste aus Glas vom 17. bis zum 19. Jahrhundert*, therein: "Das Kuriositäten Kabinett" (pp. 94–95). The designation "House" is a typical British euphemism. The reference is to a massive palace, unfortunately demolished in 1955, and built in 1769 based on a description by the architect Robert Adam: "Ruins of the Palace of the Emperor Diocletian at Spalato" (1764); the still-existing wonderful orangerie, known by architects as the "Diocletian Wing", was built at the same time. This also housed Lord Shelburne's collections of antiques and miscellany, hence the name "Curiosity Cabinet". The current planting of the terraces unfortunately falls far short of the historic prototype.
[21] See reference [19], p. 277.
[22] C. Djerassi, R. Hoffmann, *Oxygen*, Wiley-VCH, Weinheim, **2001**.
[23] R. Toman, *Klassizismus und Romantik. Architektur, Skulptur, Malerei, Zeichnung. 1750–1848*, Könemann, Cologne, **2000**. The nature of the "Barrières", tollhouses built by Ledoux, makes it likely that their building material also came from underground Parisian limestone quarries, the "Carrières souterraines". This means that some of the holes under the "Wall of the Farmer's-General" used by smugglers originated in this way. Ledoux's second major construction project for the "Ferme General" was the salt works at Chaux, built in 1775–79.
[24] "The wall walling in Paris causes Paris to mumble;" better: "grumble!"
[25] A. Clement, G. Thomas, *Atlas du Paris souterrain. La doublure sombre de la Ville lumière*, Parigramme, Paris, **2001**, therein: "Octroi et Contrebande" (pp. 88–89). In consequence of the many underground quarries, catacombs, and fresh-water channels for palaces of the nobility and for certain hospitals—ordinary citizens had to buy their water (scooped out of the Seine) from peddlers—subterranean Paris was permeated by a tangle of tunnels and shafts that was difficult to guard, requiring the erection of underground walls and provision of an elite and valiant customs force.
[26] *Freiheit, Gleichheit, Brüderlichkeit. Bilder von der Französischen Revolution* (Ed.: I. Groth), Harenberg, Dortmund, **1982** (a highly condensed, partial reprint of the *Tableaux historiques de la Révolution Française*, Paris, 1802), pp. 40–41.
[27] See reference [26], pp. 46–47.
[28] English-language works on the history of chemistry unanimously take the position that Priestley was not a participant at the dinner in question, and that the mob thus punished him unjustifiably. On the other hand, J. Tulard, J.-F. Fayard and A. Fierro in their *Histoire et dictionnaire de la Révolution Française* (Paris, **1987**, pp. 1044–1045) devote an entry specifically to Priestley because he met with "ses amis dans sa maison" for dinner, whereupon "la foule" set fire to his library and his church.
[29] See reference [19], p. 242.
[30] See reference [19], pp. 278–279.
[31] The Wilkinson company is still synonymous today with superb razor blades for anyone who shaves in the old-fashioned way.
[32] See reference [16a], pp. 382–83.
[33] See reference [16a], pp. 284–85.
[34] And indeed *only* this adjective. To this day the Royal Institution receives no official allowance from the state.
[35] See reference [8], p. 150.
[36] A veiled reference to Lavoisier, who was famous—indeed notorious—for his extremely expensive instruments, intricately assembled by first-rate technicians.
[37] Here Davy glosses over the fact that in the winter of 1807/08 he engaged in a sort of race with the French scientists Guyton de Morveau und Gay-Lussac to see who might succeed in obtaining even more impressive results using a voltaic column of larger diameter and with still more pairs of plates.
[38] This passage suggests that Davys' collection of apparatus was perhaps not really all that small, but he actually is referring to a miniature anvil, like that employed by a watchmaker.
[39] This refers to two Hales-type pneumatic troughs.
[40] With respect to the malleability of platinum, see the section entitled "An Abundance of Metals".
[41] When he traveled (especially in 1827, through Continental Europe), Davy himself packed his laboratory gear into *two* trunks, occasionally carrying out very small-scale researches in his hotel room. There is no apparent record of how the hotel management reacted!
[42] This passage presumably refers especially to Wollaston, who when asked about his "laboratory" always presented only a cigar box filled with puzzling odds and ends. No one other than him apparently ever penetrated his secret garden house, in which he discovered the malleability of platinum. Wollaston was indeed famous for experiments on a tiny scale, as when he built the smallest electrical device of his day: an iron nail, dipped into a silver thimble filled with acid. He connected the nail and thimble with an extremely fine platinum wire, one he drew out himself, and this glowed as a result of the voltage difference. He demonstrated the phenomenon in the streets of London to astonished acquaintances who by chance happened by, and were thereby permitted (in the dark) to view his partially unbuttoned overcoat.
[43] He means an especially light carriage hitched to only one or two horses.
[44] Another sarcastic remark aimed at Lavoisier!
[45] H. Davy, *Consolations*, p. 119.
[46] L. Dunsch, *Humphry Davy. Biographien hervorragender Naturwissenschaftler, Techniker und Mediziner*, Teubner, Leipzig, **1982**, therein: "Assistent in Dr. Beddoes Pneumatic Institution" (pp. 15–20).
[47] "Die Chemie im Spiegel der schöngeistigen Literatur zur Zeit Leopold Gmelins": O. Krätz in *Der 200. Geburtstag von Leopold Gmelin. Eine Dokumentation der Festveranstaltungen* (Ed.: Gmelin-Institut für Anorganische Chemie und Grenzgebiete der Max-Planck-Gesellschaft), Frankfurt, **1990**, therein: "Mary Shelley" (pp. 93–94).

[48] W. Durant, A. Durant, *Am Vorabend der französischen Revolution. Kulturgeschichte der Menschheit*, *Vol. 16*, Ullstein, Frankfurt, **1982**, p. 290; this contains the following (translated) description: "In the 'Lunar-Society' of Birmingham entrepreneurs like Matthew Boulton, James Watt, and Josiah Wedgwood, listened without being horrified to the heresies of Joseph Priestley und Erasmus Darwin." Members of the Lunar-Society met at the full moon, hence the name.
[49] W. Durant, A. Durant, *Die Napoleonische Ära. Kulturgeschichte der Menschheit*, *Vol. 18*, Ullstein, Frankfurt, **1952**, therein: "Biologie. Erasmus Darwin" (pp. 78–79).
[50] Davy paid the following tribute to Wedgwood's accomplishments: " … by multiplication of his chemical studies Wedgwood discovered how these beautiful vessels could be made at such low cost, rivaling older vases in elegance, variety, and taste in the arrangement of the forms, while at the same time surpassing them with respect to solidity and perfection of the materials. (Davy, *Consolations in Travel*, p. 258). The passage refers to the "Etruria" style, created by Wedgwood as an imitation of an Etruscan vase, and based on prototypes from the collection acquired in Naples by Sir William Hamilton. The originals are today in the British Museum in London. J. Wedgwood was prepared to pay British painters the (for those days!) outrageous honorarium of 50 pounds for every Etruria vase smuggled into a portrait of a high-ranking personage. A remarkable example of an early marketing ploy!
[51] H. W. Breunig, *Verstand und Einbildungskraft in der englischen Romantik. S. T. Coleridge als Kulminationspunkt seiner Zeit*, LIT, Münster, **2002**.
[52] See reference [49], pp. 148–150.
[53] See reference [51], p. 17.
[54] M. Amberger-Lahrmann, D. Schmähl, *Gifte. Geschichte der Toxikologie*, Fourier, Wiesbaden, **1993** therein: "Narkotika. Lachgas" (pp. 14–18).
[55] See reference [8], p. 111.
[56] C. A. Browne, *A Source Book of Agricultural Chemistry*, *Vol. 4*, Chronica Botanica 8, Waltham, **1944**, pp. 204–211.
[57] "Sir Humphry Davie [sic!], The Prince of Agricultural Chemists": M. D. Wyndham, *Chymia* **1961**, *7*, 126–134.
[58] H. Davy, *Elements of Agricultural Chemistry* in *A Course of Lectures for the Board of Agriculture*, Eastburn, Kirk & Co., New York, **1815**.
[59] H. Davy, *Consolations*, p. 116.
[60] See reference [2c], p. 478.
[61] F. Beaucour, Y. Laissus, C. Orgogozo, *La découverte de l'Egypte*, Flammarion, Paris, **1989**, pp. 174, 198, 237–238; The Rosetta Stone was discovered by the French Captain Pierre-François Bouchard in July 1799 during the construction of Fort Julien, designed to protect the port city of Rosetta (now Rashid) in Lower Egypt from the English, who had landed near Abukir. After the capture of the Napoleonic expeditionary force—Bonaparte himself had escaped in timely fashion after the defeat—the black granite stone (originally thought to be basalt), inscribed in three scripts, was turned over to the British, and now resides in the British Museum in London; *Il y a 200 ans, les savants en Egypte* (Ed.: Museum Nationale D'Histoire Naturelle), Nathan, Paris, **1898**, pp. 116–118. After the capitulation of Alexandria in September, 1801, the victorious English demanded the surrender not only of all antiquities found by French troops in Egypt, but also certain documents. The French researchers threatened to destroy their records, so they were allowed to keep them after all. In 1821 J.-F. Champollion succeeded in fully revealing the secret of the hieroglyphics.
[62] A. Maurois, *Don Juan oder Das Leben Byrons*, Wegner, Hamburg, **1969**, pp. 75–76.
[63] K. Simonyi, *Kulturgeschichte der Physik*, Harri Deutsch, Thun, **1990**, pp. 352, 354.
[64] Henry Peter Baron of Brougham and Vaux (1778–1868) was an important writer and politician (Lord Chancellor, 1830–34). In the House of Commons and later in the House of Lords he fought for the abolition of slavery, emancipation of Catholics, and improvements in the educational sector. He was also a great utilitarian and warrior in the reform debate of 1830–32.
[65] With respect to the wave nature of sound and light, and the debate concerning it—which is to say *lack* of debate—between Goethe, von Humboldt, Arago, Fresnel, and Young: O. Krätz, *Alexander von Humboldt. Wissenschaftler, Weltbürger, Revolutionär*, *2nd ed.*, Callwey, Munich, **2000**, epilogue to the *2nd ed.*, pp. 190—191; footnote to the footnote: O.K., the author of this brief study, subsequent to the folly of his having written the book *Goethe und die Naturwissenschaften* (Callwey, *2nd ed.*, Munich, **1998**), became embroiled in numerous discussions concerning Goethe's "capricious" (an adjective Goethe employed regularly to characterize opinions different from his own) assertions that in the 19th Century only *he* had done battle with the evil Newton(!), and only *he* was in possession of the eternal truth concerning the nature of light. See also: Johann Wolfgang Goethe, *Farbenlehre*, *5 vols., with introduction and commentary by Rudolf Steiner* (Eds.: G. Ott, H, O. Proskauer), *7th ed.*, Freies Geistesleben, Stuttgart, **2003**. In the meantime, O.K. has become a passionate admirer of Young and Fresnel.
[66] Michelson perfected his experimental setup, and eventually replaced the steamer chugging across the Atlantic with the earth itself as it moved through space; see: *Nobelpreise. Chronik herausragender Leistungen*, Brockhaus, Leipzig/Mannheim, **2001**, therein: "1907. Nobelpreis für Physik: Albert Abraham Michelson" (pp. 102–103).
[67] H. Davy, *Consolations*, pp. 116–117.
[68] Initially there was even some talk of appointing Dalton rather than Davy; see reference [16a], p. 385.
[69] See reference [19], pp. 755–826(!).
[70] This formulation was taken from: *Lexikon der Naturwissenschaftler* (Eds.: D. Freudig, S. Ganter, R. Sauermost), Spektrum, Heidelberg, **2000**, keyword: "Dalton" (p. 103).
[71] See reference [63], pp. 363, 377.
[72] See reference [2c], pp. 481–483.
[73] a) M. Faraday, *Chemical Manipulation*, Applied Science Publishers, London, **1974**, reprint of the 1842 edition, p. 2; see also: "Jane Marcet and her Conversations on Chemistry": E. V. Armstrong, *J. Chem. Educ.* **1938**, *15*, 53; b) Jane (Mistress) Marcet, *Unterhaltungen über die Chemie in welchen die Anfangsgründe dieser nützlichen Wissenschaft allgemein verständlich erläutert werden*. Based on the the 13th English edition, edited by F. F. Runge, Sauder'sche Buchhandlung, Berlin, 1839; see also: H. Rossotti, *Chemistry in the Schoolroom 1806: Selections from Mrs. Marcet's Conversations on Chemistry*, Authorhouse, 2006.
[74] J. Marcet, *Unterhaltungen* (Ed.: E. H. Berninger, G. Giesler, O. Krätz) (see reference [73a]). Reprint in the series: "Dokumente zur Geschichte der Naturwissenschaft, Medizin und Technik", *Vol. 3*, Verlag Chemie, Weinheim, **1982**, therein: O. P. Krätz: epilogue, pp. 471–520; regarding Alexandre Marcet: pp. 471–475.
[75] With respect to the problem of popularizing the natural sciences: A. Q. Morton, J. A. Wess, *Public & Private Science. The King George III Collection*, Oxford University Press, New York, **1993** (this work extends significantly beyond the time—and the collection—of George III !) B. M. Staf-

ford, *Kunstvolle Wissenschaft. Aufklärung, Unterhaltung und der Niedergang der visuellen Bildung*, Verlag der Kunst, Amsterdam, **1998**; regarding the availability of scientific demonstration materials and experimental setups: *The amazing Catalog of the esteemed firm of George Hieronimus Bestelmeier* (Ed.: D. S. Jacoby), Merrimack, New York, **1971**; Georg Hieronimus Bestelmeier, *Magazin von verschiedenen Kunst- und anderen nützlichen Sachen, zur lehrreichen und angenehmen Unterhaltung der Jugend, als auch für Liebhaber der Künste und Wissenschaften*, … (1803), reprint, Edition Olms, Zurich, **1979**.
[76] See reference [74b], p. 478.
[77] See reference [12b], pp. 99–139.
[78] See reference [73a], p. 192.
[79] See reference [15], p. 131.
[80] H. Davy, *Consolations*, p. 115.
[81] See reference [19], p. 699. The reference here is to W. H. Wollaston, who demonstrated the malleability of platinum in 1804. As is often the case with such assertions, this is not entirely accurate! Wollaston's predecessors, Count von Sickingen, E. Swartz, A. N. Tunborg, and Guyton de Morveau, are here ignored.
[82] L. N. Vauquelin, Professor at the Ecole des Mines of the Ecole Polytechnique in Paris prepared metallic chromium in 1792. A mixture of lead chromate and lead sulfate soon became a cherished source of a new, lustrous yellow pigment (cf. the post coaches in Germany). Even today, yellow remains *the* distinctive color for the German postal service.
[83] B. Courtois, who operated a facility for producing soda from kelp, noticed in 1812 that, upon heating with sulfuric acid a lye solution from kelp ashes, there arose a violet vapor, the chemical nature of which was investigated by Gay-Lussac. Davy postulated the elemental nature of iodine, and described its healing powers in his *Consolations*, p. 263: "Consider the pharmaceutical effect of iodine against two of the most terrible and hated diseases to which the human race is subject, cancer and goiter." Iodine can disinfect open and bleeding malignant tumors!
[84] H. Davy, *Consolations*, p. 116.
[85] See reference [81], pp. 654–658.
[86] See reference [12b], therein: "Berzelius" (pp. 142–177).
[87] O. Krätz, H. Merlin, *Casanova, Liebhaber der Wissenschaften*, Callwey, Munich, **1995**, therein: "Mit Friedrich II. im Park von Sanssouci" (pp. 105–108); *Aus dem Briefwechsel Voltaire–Friedrich der Große* (Ed.: H. Pleschinski), Haffmanns, Zurich, **1992**, pp. 119, 125.
[88] O. Krätz, *Goethe und die Naturwissenschaften*, 2nd ed., Callwey, Munich, **1998**, p. 258.
[89] K. A. Böttiger, *Literarische Zustände und Zeitgenossen. Begegnungen und Gespräche im klassischen Weimar*, Aufbau Verlag, Berlin, **1998**, p. 41.
[90] See reference [88], p. 207.
[91] Dates for first discoveries of the elements and their first processing have been taken from: S. Neufeldt, *Chronologie Chemie. 1800–1980, 2nd ed.*, VCH, Weinheim, **1987**, pp. 1–13.
[92] "Niobium (columbium), tantalum, vanadium": M. E. Weeks, H. M. Leicester, *Discovery of the Elements, 7th ed.*, Journal of Chemical Education, Easton, **1967**, pp. 323–384.
[93] See reference [87], therein: "'Egeria Semiramis' oder die 'Hypostase' einer leichtgläubigen Alchemistin" (pp. 70–84).
[94] K. Alder, *Das Maß der Welt. Die Suche nach dem Urmeter*, Goldmann, Munich, **2005**, pp. 328–329.
[95] See reference [92], therein: "The platinum metals. Platinum, rhodium, osmium, iridium, palladium, ruthenium" (pp. 323–432).
[96] In terms of buying power today, this was equivalent to tens of millions of euros (or dollars).
[97] See reference [81], p. 700.
[98] See reference [81], p. 712.
[99] G. C. Lichtenberg, *Schriften und Briefe*, *Vol. 4*, Briefe. To Franz Ferdinand Wolff. October 10, **1784**, p. 586. Includes a caricature by Lichtenberg: Volta as a straw electrometer!.
[100] See reference [12c], pp. 204–206.
[101] See reference [63], p. 334.
[102] See reference [91], p. 3.
[103] See reference [92], therein: "Three alkali metals. Potassium, sodium, lithium" (pp. 433–478).
[104] See reference [92], therein: "Elements isolated with the aid of potassium and sodium" (pp. 517–590).
[105] See reference [46], S. 37.
[106] See reference [92], p. 258.
[107] See reference [92], p. 310.
[108] See reference [92], p. 356.
[109] H. Davy, *Consolations*, p. 116.
[110] This section represents a revised and condensed version of: "Zur Frühgeschichte des Periodensystems der Elemente" ["On the Early History of the Periodic System of the Elements"]: O. Krätz, *RETE* **1972**, *2*, 45–166; see also: "Versuch einer Gruppierung der elementaren Stoffe nach der Analogie": J. W. Döbereiner, *Poggendorffs Annalen der Physik und Chemie* **1829**, *15*, 301.
[111] It was especially protestant—and more specifically pietistic—theologians who were interested in chemical–mathematical–theological systems with a numerical base; see, for example: D. Clüver, *Disquisitiones Philosophicae oder historische Anmerkungen über die nützlichsten Sachen der Welt*, Hamburg, **1707**.
[112] A rich source of document: U. Eco, *History of Beauty*, Rizzoli, **2004**, chap. III. See also: Leonardo da Vinci's drafts on "Ycocedron abscisus solidus" in Luca Pacioli's "De devina proportione", Venice, 1509.
[113] Of comparable significance: Johann Arnold Kanne, *Systhem der indischen Mythe, oder Chronos und die Geschichte des Gottmenschen in der Periode des Vorrückens der Nachtgleiche*, Leipzig, **1813**; derived from this: "Über die Umdrehungsgesetze der magnetischen Erdpole den berühmten indischen Zahlen gemäß, und ein davon abgeleitetes Gesetz des Trabanten und Planetenumschwungs": J. S. C. Schweigger, *Journal für Chemie und Physik* **1814**, *10*, 90. Here the notion is clearly expressed that relationships must exist between the equivalent numbers that are roughly comparable to those found in the Indian "divine numbers" and Kepler's harmonies.
[114] "A Synoptic Scale of Chemical Equivalents": W. H. Wollaston, *Philos. Trans. R. Soc. London* **1814**, *103*, 1.
[115] The Verlag Chemie in Weinheim (now Wiley–VCH) was still marketing a chemical slide rule in the 1970s—150 years after Wollaston introduced his. It should be noted, however, that the VCH device was considerably more versatile, allowing one, for example, to solve problems in thermodynamics.
[116] The analyses upon which Wollaston relied were far too inexact to permit one to discern an underlying set of rules! On the other hand, the problem presented by the diversity of substances within a given unit of material implied the existence of some sort of similarity in the way different materials are assembled, hence a "system". For chemists even then, enormous variety was displayed by substances with very different chemical behaviors, but a number of physical laws were also known that applied to material in general. In a vacuum, for example, spheres of iron, sulfur, wood, or anything else were known to fall at precisely the same rate! Why?
[117] S. Neufeldt, *Chronologie Chemie. 1800–1990*, VCH, Weinheim, **1987**, p. 7.
[118] See reference [117], p. 9.
[119] William Prout thought that all elements were assembled from hydrogen, hence their "atomic weights" were necessarily whole-number multiples of the atomic weight of hydrogen. At the

beginning of the 19th Century, science was almost always regarded in the context of religion. A typical example is the "Bridgewater Book": W. Prout, *Chemie, Meteorologie und verwandte Gegenstände als Zeugnisse für die Herrlichkeit des Schöpfers* (German translation), Stuttgart, **1836**. The English clergyman and philologist Francis Henry Egerton, Earl of Bridgewater (1756–1829), left a significant fraction of his estate to support publication of the "Bridgewater-Books," all of which present nature as a reflection of God. They represent the end of the heyday of physicotheological literature.

[120] J. R. Partington, *A History of Chemistry*, MacMillan, London, **1964**, pp. 142–176; similarly: see reference [117], p. 9.
[121] "Über Daltons Messkunst chemischer Elemente": J. C. S. Schweigger, *Journal für Chemie und Physik* **1914**, *10*, 380.
[122] Schweiggers footnote to reference [121].
[123] As suggestive as this grouping appears, its significance is somewhat vague. One cannot clearly ascertain here, for example, whether the "pairs" are meant to reflect elements or their compounds.
[124] "Ueber den stöchiometrischen Werth der Körper als ein Element ihrer chemischen Anziehung": J. L. G. Meinecke, *Journal für Chemie und Physik* **1819**, *27*, 39–47. A modern version of the periodic system (table) of the elements, taking into account IUPAC recommendations up to 2002: E. Fluck, K. G. Heumann, *Periodensystem der Elemente*, *3rd ed.*, Wiley-VCH, Weinheim, **2002**.
[125] R. Steiger, *Goethes Leben von Tag zu Tag. Eine dokumentarische Chronik*, *Vol. IV*, *1799–1806*, Artemis, Zurich, **1986**, p. 761.
[126] See reference [125], p. 748.
[127] See reference [125], p. 748.
[128] See reference [125], p. 753.
[129] Friedrich Wilhelm Riemer (1774–1845), for a short time private tutor to Goethe's son August, acted as Goethe's "housemate" and editorial colleague in conjunction with the 1806 major edition of his works, as well as with his color theory and the *Wahlverwandtschaften* ("Elective Affinities").
[130] O. Connelly, *The Wars of the French Revolution and Napoleon, 1792–1815, Warfare and History*, Routledge, New York, **2006**, pp. 131–133.
[131] See reference [125], p. 755.
[132] See reference [125], pp. 761, 773.
[133] See reference [125], *Vol. V*, 1807–1813, p. 37.
[134] Thomas Johann Seebeck (1770–1831), physician. At this time he lived as an independent scholar in Jena.
[135] Goethe in December, 1807, to Caroline von Wolzogen.
[136] Seebeck's three demonstrations took place in late March/early April, 1808.
[137] See reference [125], *Vol. V*, p. 328.
[138] Friedrich Gottlieb Welcker to Caroline von Humboldt, included in: *Die Wahlverwandtschaften. Eine Dokumentation der Wirkung von Goethes Roman. 1808–1832* (Ed.: H. Härtel), Akademie Verlag, Berlin, **1983**, p. 88.
[139] See reference [138], p. 101.
[140] H. M. Enzensberger, *Die Elixiere der Wissenschaft. Seitenblicke in Poesie und Prosa*, Suhrkamp, Frankfurt, **2004**, p. 271.
[141] J. Paul (pseudonym for Johann Paul Friedrich Richter), *Der Komet oder Nikolaus Marggraf. Eine komische Geschichte*, Reclam, Leipzig.
[142] Jean Paul, "Nachschrift des guten Recepts für ächte Diamanten", included in reference [141], p. 232.
[143] J. R. Partington, *A History of Chemistry*, *Vol. IV*, MacMillan, London, **1964**, "Davy", p. 61.
[144] J. Wilms, *Napoleon. Eine Biographie*, *2nd ed.*, Beck, Munich, **2005**, pp. 451–460.
[145] *Metropole London. Macht und Glanz einer Weltstadt. 1800–1840* (Ed.: Kulturstiftung Ruhr Essen), Aurel Bongers, Recklinghausen, **1992**, therein: "Andrew Saint: Die Baukunst in der ersten Industrie Metropole", pp. 51–76; also cat. no. 41, p. 255, through cat. no. 58, p. 268.
[146] See reference [145], p. 56.
[147] See reference [145], p. 57.
[148] See reference [145], cat. no. 58, pp. 259, 268–269.
[149] G. Kohlmaier, B. von Sartory, *Das Glashaus, ein Bautypus des 19. Jahrhunderts*, *2nd ed.*, Prestel, Munich, **1988**, pp. 79–89, 126–27; S. Koppelkamm, *Künstliche Paradiese. Gewächshäuser und Wintergärten des 19. Jahrhunderts*, Ernst & Sohn, Berlin, **1988**, pp. 16–26; M. Woods, A. S. Warren, *Glass Houses. A History of Greenhouses, Orangeries and Conservatories*, *4th ed.*, Aurum, London, **1999**, pp. 88–141.
[150] This marked the point at which more streamlined ships began to be built, with convex curvature to the ribs and to the waterline at the bow and the stern.
[151] O. Krätz, *Goethe und die Naturwissenschaften*, *2nd ed.*, Callwey, Munich, **1998**, therein: "Die Anfänge der Glasindustrie in Jena", pp. 198–203.
[152] W. Durand, A. Durand, *Die Französische Revolution und der Aufstieg Napoleons. Kulturgeschichte der Menschheit*, *Vol. 17*, Ullstein, Frankfurt, **1982**, p. 148; Joseph Marie Jacquard (1752–1834); his mechanical loom (1801) was purchased in 1806 by the French government, and it allowed the French textile industry to become competitive with that of England. In 1808 there were 10720 Jacquard looms operating in Lyon.
[153] See reference [151], "Die Wirtschaft", pp. 311–321.
[154] Not until 1819/20 did F. F. Runge discover the "coffee base", which is why the absence of caffeine went previously unrecognized. See reference [150], therein: "Friedlieb Ferdinand Runge in Jena", pp. 152–157.
[155] J. R. Partington, *A History of Chemistry*, *Vol. IV*, MacMillan, London, **1964**, p. 489.
[156] M. K. Färber, *Kaiser und Erzkanzler. Carl von Dalberg und Napoleon am Ende des Alten Reichs*, Mittelbayerische Druckerei- und Verlagsgesellschaft, Regensburg, **1988**, p. 22.
[157] J. R. Partington, *A History of Chemistry*, *Vol. III*, MacMillan, London, **1962**, p. 587.
[158] See reference [157], pp. 592, 577.
[159] E. Vaupel, *Chem. Unserer Zeit* **2006**, *40*, 306–315.
[160] See reference [157], pp. 640–651.
[161] See reference [159].
[162] See reference [159].
[163] See reference [159].
[164] L. Dunsch, *Humphry Davy. Biographien hervorragender Naturwissenschafler, Techniker und Mediziner*, *Vol. 62*, Teubner, Leipzig, **1982**, p. 35.
[165] J. Fischer, *Napoleon und die Naturwissenschaften. Boethius. Texte und Abhandlungen zur Geschichte der exakten Wissenschaften*, *Vol. XVI*, Franz Steiner, Wiesbaden, **1988**, pp. 142–151, 209.
[166] See reference [164], p. 35.
[167] H. B. Carter, *Sir Joseph Banks. 1743–1820*, *2nd ed.*, British Museum (Natural History), London, **1991**, pp. 376, 520.
[168] G. I. Brown, *Graf Rumford. Das Abenteuerliche Leben des Benjamin Thompson*, Deutscher Taschenbuch Verlag, Munich, **2002**, pp. 159–176.
[169] G. Headley, W. Meulenkamp, *Follies, Grottoes and Garden Buildings*, *5th ed.*, Aurum, London, **2003**; a unique work, highly recommended to friends of absurd literature, in which not only smugglers have their garden-architectural fling, but also rural clergy lie in wait for academic body snatchers in "watchtowers" in out-of-the-way cemeteries, and eccentric lords enliven the English summer with artificial volcanoes, not to mention the presence of a catalog of "observatories" in peculiar buildings serving virtually every imaginable scientific purpose.
[170] See reference [167], p. 253.

[171] H. W. Lack, *Ein Garten Eden. Meisterwerke botanischer Illustration*, Taschen, Cologne, **2001**, therein: "Etienne Pierre Ventenat: Jardin de la Malmaison", pp. 254–263.
[172] See reference [169], therein: "Aime Bonpland: Description des plantes rares cultivees a Malmaison et a Navarre, Paris 1812–1817", pp. 342–351.
[173] H. Davy, *Consolations*, p. 114.
[174] In especially backward parts of Europe, like rural Bavaria, chimneys were quite rare, and as late as the beginning of the 19th Century one would still find houses where an open fire burned on the stone floor, the smoke having to find its way out through the rafters, and through chinks between the wooden shingles.
[175] If one examines illustrations connected with the various crafts, as for example in: *Diderots Enzyklopädie. Die Bildtafeln. 1762–1777.* (greatly reduced reprints of the 3115 originals) Weltbild, Augsburg, **1995**, it is striking how many of the stoves depicted (for example, Fig. III on Pl. II "Chymie", *Vol. 1*, p. 544) rather closely resemble the later Rumford ranges. These were not to be found in households, however, but apparently only in workshops.
[176] Regarding Rumford's relationship with Countess Baumgarten and to Lady Palmerston at Schloss Ammerland on Lake Starnberg: *Johann Georg von Dillis. 1759–1841. Landschaft und Menschenbild* (Ed.: C. Heilmann), therein "Graf Rumford und Gräfin Baumgarten im Wald. 1791", p. 57. Portrait of Rumford: p. 127, with associated text on p. 126. Stepchildren and children of Lady Palmerston, pp. 128–129, with associated text on p. 130. Presumed picture of the young Sophie von Baumgarten: "Mädchen als Flora vor Schloß Ammerland 1798," with associated text, p. 132.
[177] Reference [16a], p. 381.
[178] Reference [16a], p. 192.
[179] Reference [15], p. 343.
[180] Reference [15], p. 302.
[181] H. Montgomery-Massingberd, C. S. Sykes, *Schlösser und Adelssitze in England und Wales*, Könemann, Cologne, **1998**, pp. 204 – 217.
[182] Reference [181], p. 214.
[183] Reference [181], p. 215.
[184] Reference [15], therein Simon Jervis: "Rudolph Ackermann", pp. 97–110, as well as "Ackermann's Repository of Arts", pp. 328–342.
[185] Reference [15], p. 337. Ackermann was a master at psychologically clever marketing: "The best artists of our times are indebted for encouragement to enthusiastic cultivation of watercolor painting on the part of the enlightened women of our day; and the patronage of the fair sex has ushered in an epoch in art which will do permanent credit to the country."
[186] The tiny cases used by traveling watercolorists were easy to transport, and thus especially cherished by the English, who are rightly credited with being the originators of tourism. Watercolor painting was perceived even in Great Britain as "quintessentially British", and there was serious discussion of the question whether the country had a special affinity to water. Regarding the history of the Water Colour Society, see reference [15], p. 171. J. M. W. Turner (1775–1851), apart from J. Ruskin "the most skilled landscape painter that ever lived", painted thousands of watercolors, and apparently carried with him in his jacket pocket a conveniently portable homemade contrivance. This consisted of the leather binding of an old almanac, from which he had removed the paper pages, sewing in their place a double leather sheet to which his paint pots were attached. This singular curiosity is today preserved in the Tate Gallery in London. For a delightful description of Turner's highly original watercolor techniques entailing the use of spittle, blotting paper, bread crumbs, and thumbnail scratches for highlights: M. Clarke, *Aquarell. Bild Erlebnis Kunst*, Belser, Stuttgart, **1996**, pp. 36 – 37.
[187] Modern versions of the camera lucida can still be purchased—200 years after its invention in 1807 by W. H. Wollaston: D. Hockney, *Geheimes Wissen. Verlorene Techniken der Alten Meister wieder entdeckt*, Knesebeck, Munich, **2001**. therein: "Photographien und Kontruktionszeichnungen", p. 204; as well as "William Hyde Wollaston 1807. Eine Beschreibung der Camera lucida von ihrem Erfinder", pp. 215–216; and M. Kemp, "Der klare Blick des Zeichners: David Hockney und seine Experimente mit der Camera lucida", pp. 228–229.
[188] H. Davy, *Consolations*, p. 117.
[189] D. Schwanitz, *Englische Kulturgeschichte von 1500 bis 1914*, Eichborn, Frankfurt, **1996**, pp. 283 – 284.
[190] The physicotheologians of the 18th Century—often pietistic clergymen—identified the foundation stone of their world view in the Old Testament: in The Book of Job, chapter 37, in which the chapter title from Martin Luther's German translation (retranslated into English) reads "God's Majesty is Recognizable in the Book of Nature". Further, from the Apocrypha: "The Song of the Three Jews". Regarding Daniel 3, for example verse 38: "Bless the Lord, all the Lord's creation: praise and glorify him forever!" (as rendered by *The New Jerusalem Bible*). See also the hymn, set to music by Beethoven: "Die Himmel rühmen des ewigen Ehre …." ["The Heavens sing the praises of the eternal glory …]".
[191] Francis Henry Egerton, VIII. Earl of Bridgewater (1756–1829), Anglican clergyman; as heir to his brother and builder of the Bridgewater Canal he was very rich, and lived his life to the fullest: a life that even for an English aristocrat was unusually eccentric, but also showed outstanding cultural tendencies. His passion for collecting autographs was the basis for the "Egerton Papers" in the British Library. His will bequeathed funding for publication of the "Bridgewater Books", which blossomed during the years 1833–1840. Davy's *Consolations* also appeared in 1833, fitting very well into the general tone of that year.
[192] H. Davy, *Consolations*, p. 277.
[193] P. Nicolaisen, *Thomas Jefferson*, Rowohlt, Reinbek, **1995**, p. 116.
[194] In order not to annoy the British to excess, Jefferson extended the trade embargo to cover France as well. H. Dippel, *Geschichte der USA*, *6th ed.*, Beck, Munich, **2003**, pp. 36 – 37.
[195] See reference [173], pp. 116–117.
[196] J. H. Moore, *Wiley. One Hundred and Seventy Five Years of Publishing*, Wiley, New York, **1982**, pp. 2–5.

