17 Liesegang Rings

Introduction

> "*Crystals and Configurations are frequently seen together in the same Drop, and forming at the same Instant. As soon as the Crystals become discernable by the Microscope, they are either Cubes, or Rhomboids, or Columns, or pyramidal, or triangular, or some other certain Figure; and to what Bigness soever they may become inlarged, they shew, from their very first Appearance, the same Sides and Angles that are seen afterwards when at their utmost Size, no Alteration of Figure attending their increase in Bulk.*"
>
> Henry Baker, 1753 [1]

Stones are in fact mineral structures and from mankind's earliest recorded times; minerals have had some degree of interest, even to the Ancients. Gemstones in particular have always been sought and coveted. Babylonian, Greco-Roman, Chinese, and Sanskrit texts all presented studies of minerals. Both Aristotle and Theophrastus discussed minerals and some of their properties. Aristotle did so in his *Meteorologica*. Aristotle theorized that all minerals are combinations of the four basic substances: water, air, earth, and fire. Theophrastus expanded upon this theme in his *De Mineralibus*; he essentially makes two large categories, those affected by heat and those by water [2]. But we must move to Pliny the Elder's 23 CE to 79 CE (current era or AD) work just prior to his volcanic extinction called *Naturalis Historia* for a near modern description of minerals. Pliny spent five entire volumes on minerals, classifying them as "*earths*, *metals*, *stones*, *and gems*." He discussed not only the properties of minerals he also discusses their applications and uses. He also might be the very first investigator to mention crystals. He noted that diamond had a natural "octahedral shape." He also discusses mining in some detail [3].

In the later part of the Renaissance, mining became a substantial industry, especially in what is now Southern Germany and the science of mining became established. Georg Bauer, Latinized to Georgius Agricola, wrote his magnum opus in 1530, *Bermannus*, *sive de re metallica dialogus*. Many believe that this book is the beginning of the science of mineralogy making Georgius the father of mineralogy. He was also the town physician of Joachimsthal, one of the centers of mining. Similar to Paracelsus, Agricola was critical to the knowledge of the Greco-Roman and Middle Eastern ancient writers. He subsequently published *De veteribus et novis metallis* in 1546. And his best-known work followed, *De re metallica*, in 1556. He did praise Pliny for his pioneering discussions about minerals and mining [4]. He began to speculate on the reasons for ore channel and the work of ground waters. He questioned all information and suggested methods of investigation. His work was carried on by others including Anselmus de Boodt (1550–1632) of Bruges who wrote *Gemmarum et Lapidum Historia*. A German mining chemist named J.F. Henckel followed with his *Flora Saturnisans* in 1760 [5].

Crystals are the building blocks of stones as well as snowflakes (Fig. 17.1a). The crystal is the unit that accumulates with known principles of chemistry and physics. That stones grow with

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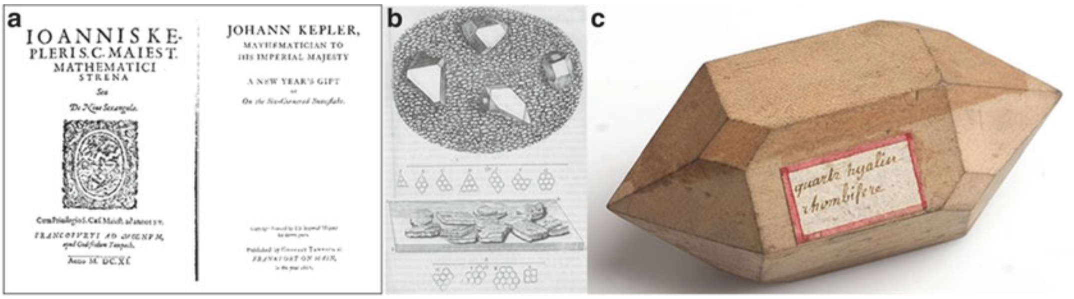


Fig. 17.1 (**a**) Crystals from snowflakes (Kepler, 1611), (**b**) Robert Hooke's *Micrographia* (1664), and (**c**) René Just Haüy's crystals from *Traité de Cristallographie* (1822) (pear wood models)

some degree of regularity is readily apparent by simply slicing stones, which have been done for centuries. A periodic process is apparent in human kidney stones, in tree trunks, in growing corals, in sea shells, and even in ice deposition in the Arctic and Antarctic. All throughout nature, these periodic precipitation patterns were apparent and have been systematically investigated for over 100 years. But the crystals themselves have a quite fascinating history. This includes the father of science itself, who became the leader of a small band of intellectuals who called themselves the "*Philosophical Breakfast Club*" [6]. The story includes the enigmatic scientist who left his fortune to found the Smithsonian Institution, James Smithson. The crystallographers often were mineralogists, chemists, and physicists but most importantly they were also collectors of rocks.

Crystals

In the mid-thirteenth century, the theologian John Duns Scotus believed that crystals lived and grew much like plants. He thought that their structure represented a pure form or an ideal shape that harkened back to Plato [7]. The German astronomer and mathematician Johannes Kepler (1571–1630) wrote a short treatise "The Six-cornered Snowflake" in 1611 and first proposed that these were derived from tiny, spherical elementary particles [8]. Nicolas Steno (1638–1686 or his Danish name, Niels Stensen) was a brilliant physician and polymath who was interested in many scientific subjects. He was briefly a professor of anatomy at Padua in 1666 before coming to the Palazzo Vecchio under the Medicis where he interacted with Francesco Redi and was introduced to Marcello Malpighi [9]. He argued that the growth of minerals was due to the accumulation of particles precipitated from liquids. He believed that an "*outer force*" produced the growth of crystals. He noted that the angles of crystals' regular faces were always the same in his work *Prodromus* in 1669 [10]. Sir William Osler once noted of Steno, "*No one should have a warmer place in our memory than the anatomist, geologist and theologian, whose name is on our lips in connection with the duct of the parotid gland…A strange figure, one of the strangest in our history…*" [11]. Much of Steno's work on minerals, fossils, and geology were introduced to the Royal Society by Martin Lister and William Croone who he met while visiting the medical school at Montpellier [12].

Robert Hooke (1635–1703) has been described as the Leonardo of London because of prolific investigations and writings in so many areas of learning [13]. Hooke in his 1665 book *Micrographia* described the "*fantastical*" (structural, not pigment) colors of the peacock's feathers, "*The parts of the Feathers of this glorious Bird appear, through the Microscope, no less gaudy then do the whole Feathers; for, as to the naked eye 'tis evident that the stem or quill of each Feather in the tail sends out multitudes of Lateral branches, … so each of those threads in the Microscope appears a large long body, consisting of a multitude of bright reflecting parts. … their upper sides seem to me to consist of a* *multitude of thin plated bodies, which are exceeding thin, and lie very close together, and thereby, like mother of Pearl shells, do not only reflect a very brisk light, but tinge that light in a most curious manner; and by means of various positions, in respect of the light, they reflect back now one colour, and then another, and those most vividly. Now, that these colours are onely fantastical ones, that is, such as arise immediately from the refractions of the light, I found by this, that water wetting these colour'd parts, destroy'd their colours, which seem'd to proceed from the alteration of the reflection and refraction*" [14]. He would go on to discuss his concept of crystals forming from spherical particles (Fig. 17.1b).

In his book Micrographia he approaches his section on crystals by first discussing human urine in his *Observation XII. Of Gravel in Urine*. He begins "*I Have often observ'd the Sand or Gravel of Urine…through the Microscope, appear to be a company of small bodies, partly transparent and partly opacious, some White, some Yellow, some Red, others of more brown and duskie colours. The Figure of them is for the most part flat, in the manner of Slats or such like plated Stones…*" [14]. He continues with the now age-old wish "*How great an advantage it would be to such as are troubled with the Stone, to find some menstruum might dissolve them without hurting the Bladder, is easily imagin'd since some injections made of such bodies might likewise dissolve the stone, which seems much of the same nature*" [14]. Now he proceeds with *Observation XIII. Of the Diamants, or Sparks in Flints*. Here he presents his work that so stunned Wollaston, a work on the microscopic structure of "*Crystaline or Adamantine bodies, so curiously shap'd, that it afforded a not unpleasing object*" [14]. He had moved on to investigate a crystalline stone commonly called Cornish diamonds. He begins to question the formation of the crystals and speculates on why they form "*triangular, trapexoidal, rhoboeid, hex-angular, tetrahedron forms*" [14]. He comes to his theory that floored Wollaston, "*I could make probable, that all these regular Figures that are so conspicuously various and curious, and do so adorn and buautifie such multitudes of bodies, as I have above hinted, arise onely from three or four several positions or postures of Globular particles, and those the most plain, obvious, and necessary conjunctions of such figur'd particles that are possible, so that supposing such and such plain and obvious causes concurring the coagulating particles must necessarily compose a body of such a determinate regular Figure, and no other, and this with as much necessity and obviousness as a fluid body encompast with a Heterogeneous fluid must be protruded into a Spherule or Globe*" [14]. Hooke like Boyle, Dalton, Kepler, Huygens, and Wollaston all have developed a picture that is rather modern molecular stoichiometry.

Crystallization

Henry Baker (1698–1774) was predominately a writer but was interested in science, history, and poetry; he translated Molière and was an editor. He became enamored with the microscope based upon Hooke's influential book and the reports from Antonie van Leeuwenhoek [15]. He is mostly remembered today for being one of the early popularizers of microscopy with his 1742 book *The Microscope Made Easy* [16]. This became a best seller and vaulted Baker into a fellowship of the Royal Society. He followed this work with the much more intriguing secondary investigations that focused upon salts and crystals. This was published in 1753 and was entitled *Employment for the Microscope in Two Parts* [17]. The book has 32 chapters on a variety of microscopic investigations, but it is the seven chapters that deal specifically with different crystals that deserve some attention. Baker appears to have been aware of Moritz Anton Cappeler's (1685–1769) 1723 coining of the word "crystallography." Baker also notes on page 7 of his text that discussing crystals is one thing, trying to demonstrate their three-dimensional complexity was quite another. He notes "*Drawings therefore have been made, and Copper Plates engraven, at no small Expense, of the different Configurations hereafter mentioned: which, though greatly deficient in Beauty and Regularity, if compared with* *the Originals, and only pretending to give such a general Resemblance as may distinguish each Kind from other…*" [17]. This problem would be solved using three-dimensional models that were used in Paris.

One of the first great French crystallographers was Jean-Baptiste Louis de Romé de L'Isle (1736–1790) who collected minerals and employed a goniometer to study crystal angles. He was also the first scientist to make models of crystals that were larger and easier to study, some made of porcelain from the Royal Porcelain Manufacture of Sèvres and others made of brass. In 1783 de L'Isle published his *Cristallographie* in Paris that contained hundreds of mineral discriptions [18]. René Just Haüy (1743–1822) was a French priest and scientist who studied crystal growth, crystal geometry, and the concept of unit cell. He may well have known about some studies done on the regular cleavage of calcite by the Swedish mineralogist Torbern Bergman in 1773. In 1784, Haüy presented his work on the constancy of interfacial angles. He suggested that crystals were made up of elementary building blocks which he called "*integral molecules*" which were quite distinct from the ideas of Kepler, Hooke, and Huygens who all believed in the notion of atoms [19]. He called the macroscopic structure as a three-dimensional periodic array of the integral molecules. Haüy concluded that fragments of crystal cleavage resulted from three molecular forms: the tetrahedron, the triangular prism, and the parallelepiped. He also developed a series of wooden crystal models because of the three-dimensional illustration of these complex entities. Haüy also came up with the marketing idea of including a set of the three-dimensional models to help promote the sales of his textbooks, which succeeded (Fig. 17.1c). He also published works in 1801 and 1815 furthering his studies of crystals. Though controversial, no one could argue against these findings until better instruments were developed. This would not take long, as Wollaston followed in 1809 with his instrument that was refined but still used today. Haüy's theories attracted controversy, initially by Romé de L'Isle who called him a "cristalloclast" (crystal smasher) but also a German investigator named Weiss. Haüy simply ignored most of his detractors and continued to work and publish. His magnum opus was published in 1801 called *Traité de Minéralogie* followed by his *Traité de Cristallographie* in 1822 [20, 21].

Louis Pasteur was born in the small town of Dôle late that same year on December 27, 1822, and became one of the truly monumental contributors to medicine though he was not a physician [22]. He attended the famous Ecole normale supérieure in Paris (where Haüy taught) and followed a pathway into science. In 1847 he began to prepare for his doctor's degree at age 24, and he became intrigued with crystallography. He had read some of the work of Mitscherlich in Germany on peculiar characteristics of crystals of tartaric acid. One of his teachers at the Ecole normale, Delafosse, had also noted right- and left-handed facets to quartz crystals when rotated in polarized light. Using tartaric acid Pasteur was able to successfully identify racemic crystals after just 2 years in the laboratory at age 25: "*I have just made a great discovery…I am so happy that I am shaking all over and am unable to set my eyes again to the polarimeter*" [23]! This was just the beginning for this gifted young man [24].

We've already discussed William Hyde Wollaston (1766–1828, one of the founders of stone chemistry) in several places in this history of urolithiasis, but we shall now concentrate on his contributions to understanding crystals, crystallization, crystal physics, and the chemistry of stone disease in more detail. Wollaston came from a rather incredible background. His grandfather was interested in science and theology and wrote "*Religion of Nature Delineated*" in 1724. His father named Francis Wollaston was a vicar and fellow of the Royal Society. He was interested in astronomy and wrote "*Fasciculus astronomicus*," a star catalogue in 1800. His uncle was perhaps more famous than all of the rest; he was William Heberden (1710–1801), a physician/scientist who is considered a giant in medical history as well as a member of the Royal Society. Another uncle, Charlton Wollaston, was a royal physician to the Queen, a fellow of the Royal Society, and a Harveian orator in 1763. His older brother Francis also attended Caius College, Cambridge, and was a lecturer in mathematics and later became the Jacksonian professor of chemistry. His intimate friends included his pupil and protégé, Alexander Marcet. Sir Humphry Davy was also considered a friend and they died within months of each other. He knew and interacted with possibly the most gifted intellectual of the age, Thomas Young, and they investigated many of the same problems and both served on the Board of Longitude [25]. Wollaston was so highly thought of in his own time that a French mineralogist named wollastonite in his honor. Wollaston Island was named for him by the Arctic explorer Ross.

Wollaston attended Caius College as a medical student and was interested in botany and chemistry graduating in 1787. He moved to London to complete his medical training. He practiced until 1800 when he became a full-time scientist. This might be because he was denied a position at St. George's Hospital [26]. His scientific accomplishments were amazing. He became a fellow of the Royal Society in 1793. He was awarded the Copley Medal in 1802. Between 1800 and 1803 he isolated a secret method to purify platinum which created great scientific controversy amongst those who wanted academic openness. Wollaston greatly added to his wealth with the platinum processing technique; some estimates noted his profits were as much as £15,000 by 1826. He also discovered palladium in 1802 which prompted his French counterpart, Vauquelin, to declare of Wollaston's achievement as "*seams at first incredible*." He also discovered the element rhodium in 1804.

We have previously discussed Wollaston's work in chemistry that prompted his support of Dalton's atomic theory. In 1808 Wollaston had been performing chemical experiments that brought him to urinary calculi. He already discovered that carbonate, sulfate, and oxalates were regulated by the law of multiple proportions. He even anticipated spatial considerations of stereochemistry long before this was a science. On November 26, 1812, he read the Bakerian Lecture "*On the Elementary Particles of Certain Crystals*" [27]. In this truly astonishing work, he boldly stated that the ultimate existence of physical atoms was not established and that virtual special particles, consisting of mathematical points surrounded by forces of attraction and repulsion, would explain the structure of crystals equally well. He is so close to Rutherford's atomic model. He may have been attracted to crystallography via the writings of Haüy who had created a system based upon mathematical idealism that would have appealed to Wollaston.

Wollaston invented the reflective goniometer in 1809 and began a systematic investigation of crystals and crystalline structure. Wollaston's new device gained accuracy to the nearest 5 min of arc, which was almost six times greater than Haüy's measurements. Wollaston proposed in 1812 that alternative spherical units were joined together in space into geometrical arrangements. He was stunned to find his theory in Robert Hooke's *Micrographia* as the thirteenth observation. William Phillips was a printer and bookseller who also became interested in crystallography. Wollaston taught him his methods and how to use his goniometer and he took over much of the work of measuring and recording crystalline angles [28]. He improved upon Wollaston's original measurements to an accuracy of 0.5 min of arc. This information would be useful to allow Mohs and Mitscherlich to discredit much of Haüy's earlier misconceptions. One final comment is necessary on the brilliance of William Hyde Wollaston. He died of a brain tumor and spent his last days trying to communicate his level of awareness to his close friend and fellow crystallographer James Louis Macie who later changed his last name to Smithson (more on him later). It is typical of this great mind "*to convert his death into a grand philosophical experiment, to give data for determining the influence of the body on the mind, and to try whether it was possible for the latter to remain until the very last*" [29].

Finally in the history of crystallography, we have to return to Haüy and the controversy regarding his theories. Eilhard Mitscherlich (1794–1863) was at first a classics scholar who became a physician and then for a scientist discovered chemistry and crystals. He translated much of Haüy's writings into German. In 1819 he discovered the phenomenon of isomorphism where different chemical substances have the same crystalline shape. This was at odds with the observations of Haüy's and the two would battle for the rest of the latter's life [30]. Not only that, but Mitscherlich also discovered that the same molecule called also form into different crystals, called polymorphism using calcite and aragonite ($CaCO_3$). It is Mitscherlich who brought crystallography back into the mainstream of chemistry and supported Dalton's atomic theory with the support of Jöns Jacob Berzelius (1777–1848) [31].

A major advance in crystallography occurred in 1845 when the French physicist August Bravai successfully predicted that 14 possible basic geometric atomic configurations were possible in various crystals (now called Bravais lattices). All of these speculations about structures of crystals were merely hypothetical until Max von Laue and coworkers in Munich irradiated crystals and observed diffraction patterns that correlated with the lattice structures, proving molecular arrangement of the atoms themselves in 1912 [31]. He won the Nobel Prize in physics in 1914 for his work on crystals. In 1914 the physicists William Henry and William Lawrence Bragg published the first detailed atomic arrangement of crystals. They too won the Nobel Prize in 1915 for the physics of crystals. The first textbook on crystallography to include this information was Paul Niggli in 1920 [32].

What's In a Name?

Minerals have been given all types of names, and the development of the nomenclature of these substances has a long history itself. Attempts to codify or come up with rules of naming minerals struggled until after World War II. Also, one might think that new minerals would be getting fairly rare; this too is a falsehood. Modern synthetic chemistry is racing forwards making new mineral species that have unusual properties that are exploited in engineering and manufacturing. In the eighteenth century, none other than our botanizing physician Carl von Linné (Linnaeus) tried to develop a codified method of naming minerals using his binomial Latin names. In his youth, he was actively engaged in the pursuit of geology and geological phenomena. In 1729 he made his first excursion into the mines at Dannemora in northern Uppland. In 1733 he visited the Bergslagen region again to inspect mines and investigate smelting of ores. His most profound works were in paleontology where he named several fossils species which are stilled used today. He also investigated stratigraphic geology much like Steno. Because of his influence in biologic sciences, this binomial method of naming was used for a short period of time but was dropped because of the cumbersome nature and the long antecedent history of naming already existent [33]. A.G. Werner, a German mining geologist, proposed the first chemical classification of minerals in 1774. The Swedish chemist J.J. Berzelius modified and improved upon the nomenclature, and the basis for modern crystal science was utilized in the first textbooks on this subject by Haüy (1801), Dana (1837), Breithaupt (1849), and Groth (1904).

James Smithson was the oldest son of Elizabeth Hungerford Keate Macie and for 35 years he kept his maternal last name. In fact, he was the illegitimate son of the late first Duke of Northumberland, Hugh Smithson, and there is no record of his birth in 1764 or 1765. Smithson was a brilliant student and entered Oxford in early May 1782 to Pembroke College [29]. He was profoundly influenced by the Master of Pembroke, William Adams, who was a radical thinker and much interested in chemistry. It is here that Smithson probably first developed his infatuation with American ideology and the concept of Jeffersonian democracy. Smithson traveled extensively and wrote about minerals and crystals. He published 27 papers on chemistry and mineralogy. He was highly regarded by the small, elite society that he was privy. Smithson's last published paper with the Royal Society was "*A Few Facts relative to the Colouring Matters of Some Vegetables*" published in 1817 [34]. He was interested in the red coloring or organic materials that might be indicators of acid/base interactions. His health had become increasingly a problem, but from 1814 to 1825 he managed to publish 17 of his total scientific publications and he returned to Paris.

Smithson was eagerly investigating and collecting during his final illness. After writing his last will and testament, some 200 non-published manuscripts were sent to the United States and the Smithsonian Institute, but the fire of 1865 destroyed much of James Smithson's notes and observations. His last paper was not on minerals but on refuting the claims of the theory of the universal deluge (Noah's Flood) supported by recent work of William Buckland on his findings at the Kirkdale Cave. He is at his writing best in this treatise entitled "*Some observations on Mr. Penn's Theory Concerning the Formation of the Kirkdale Cave*" [35]. "*It is in his knowledge that man has found his greatness and his happiness, the high superiority which he holds over the other animals who inhabit the earth with him.*" Smithson returned to London in the spring of 1825 to prepare for his death. He had his will drawn with the following codicil, "*I then bequeath the whole of my property, subject to the Annuity of One hundred pounds to John Fitall, & for the security & payment of which I mean Stock to remain in this Country, to the United States of America, to found at Washington, under the name of the Smithsonian Institution, an Establishment for the increase & diffusion of knowledge among men*" [29]. Richard Rush, son of the Revolutionary physician, Benjamin Rush, was sent to England to make the necessary transfers. John Quincy Adams became the leading proponent to make an institution and museum, but Congress took until August 10, 1846, to approve of the plan. In December of 1846, Joseph Henry was appointed by the regents to be the first secretary of the Smithsonian. Charles Doolittle Walcott, his fourth and perhaps most famous successor and known kidney stone sufferer, took the reins from 1907 to 1927. Kidney stones at the Smithsonian are not currently referenced in their rather significant stone and mineral collection but the National Museum of Medicine (formerly the Army Museum has an extensive collection as does the William P. Didusch Center for Urologic History). Three years following Smithson's death, in 1832, Francois Beudant named a new mineral originally described by Smithson, zinc carbonate in his honor, smithsonite [29].

William Whewell (1794–1866) has become iconically linked with science and the term scientist. This really is limiting to both his life and his legacy [36]. In his lifetime, Whewell was a towering intellect and widely recognized for his contributions to science. Whewell was born on May 24, 1794, in Lancaster. He was quite athletic and pugilistically inclined though gregarious; he made friends easily and these often lasted lifetimes. He received a fellowship at Trinity College of Cambridge in 1811. Trinity had a powerful tradition of scholarship including the giants Francis Bacon, Isaac Newton, and Lord Byron. We've already mentioned his role in the "Philosophical Breakfast Club" that included his friends from Cambridge: Charles Babbage (inventor of the first mechanical computer amongst other innovative devices), Sir John Herschel (son of Frederick William Herschel who discovered Uranus) who became a famous astronomer in his own right and became a major influence upon Charles Darwin, and much less-known Richard Jones (clergyman and economist) [6]. Whewell was strongly influenced by one of his professors, E.D. Clarke, who was a popular lecturer of mineralogy. Also Francis Wollaston was the Jacksonian Professor of Natural Philosophy (older brother of his friend William Wollaston). Whewell won the Chancellor's medal for poetry in 1814. Sitting for this Tripos examinations, Whewell took a second wrangler and he joined the Cambridge Union Society. William Whewell practiced science and was a historian and philosopher of science for over 51 years as well as becoming the Master of Trinity College on November 16, 1841. But his primary title for much of his career was professor of mineralogy at Cambridge [37].

Whewellite is the mineral named after William Whewell and is commonly referred to as calcium oxalate monohydrate (CaC_2O_4 *H_2O). Henry James Brooks (1771–1857) first described this mineral in 1840, and another mineral is named in his honor, brookite. Whewellite is uncommon or rare in natural minerals but more common in biologic processes. These are the dumbbell crystals which are small, smooth, botryoidal to globular, and yellow-green (olive green) to brown in color [38]. Papillary concretions tend to predominate with whewellite, but they often have an apatite nucleus. Jackstones of the bladder also tends to be composed of whewellite. This crystalline form represents a difficult type of calcium oxalate stones to fragment with extracorporeal shock waves.

Weddellite is named after James Weddell (1787–184) who was the great Antarctic explorer and discoverer of the sea that bears his name. He also has a species of seals named after him, *Leptonychotes weddellii*. This mineral was found in sediments from the bottom of Weddell Sea by naturalists in 1942. Weddellite is calcium oxalate dehydrate (CaC_2O_4 *$2H_2O$). These are the Maltese crossed crystals (tetragonal dipyramidal) that commonly make up the calcium oxalate stones. These yellowish crystals tend to form sharp spicules on stones. It should come as no surprise that weddellite can dehydrate to form whewellite and are commonly found together in calcium oxalate stones. More commonly however weddellite follows whewellite in depositional sequence. They tend to make up stones that break up or comminute easily by extracorporeal shock wave lithotripsy [39].

Apatite is one of the oldest named minerals, derived from the Greek "I am misleading," referring to the many instances it is confused with other minerals such as beryl, quartz, nepheline, and calcite. It can form with either the hydroxyl group or the carbonate group substituting for a phosphate. The hydroxyl form is most commonly associated with calcium oxalate stones, whereas the carbonate form is more common in struvite stones [40]. Apatite is essential for the body because it is found in bones and teeth. It is often just called calcium phosphate but chemically it is $Ca_5\ (PO_4)_3OH$. Apatite can form the nucleus of stones and is soft, often a white powdery consistency though it can be transparent. A second form of apatite is massive, glassy, yellow-brown, or even blackish. This substance commonly accompanies other types of mineral substances of stones, and Prien and Frondel have hypothesized that waves of saturation alternate the glassy and powdery laminae in stones [41].

Struvite is named in honor or despairingly after Heinrich Christian Gottfried von Struve (1772–1851). He was a Prussian naturalist from a large family of scientists. Struvite was first discovered in bat guano or feces in 1845 by Georg Ludwig Ulex of Sweden and has a classic coffin-lid appearance (orthorhombic pyramidal). This mineral was initially and erroneously referred to as "triple phosphate" and was also referred to as guanite [42]. It is in human urine, a complex crystalline substance that occurs secondary to urea-splitting bacterial infections, particularly from the organism *Proteus mirabilis*. These infections too are linked to periodic precipitation patterns that we will discuss later [43]. Its chemical formula is $MgNH_4PO_4$ *$6H_2O$.

Brushite is the mineral named after George Jarvis Brush (1831–1912) who was a mineralogist from Yale University. He was a ravenous collector of minerals for the museum and at his death he left over 15,000 specimens to the Peabody Museum. The mineral was named in 1864 by G.E. Moore [42]. The chemical composition is $CaHPO_4$ *$2H_2O$. Monetite is a triclinic variation of brushite that is rarely identified in human kidney stones but has been seen in carnivorous animals [44].

Whitlockite is the mineral named after Herbert Percy Whitlock (1868–1948), another American mineralogist. Whitlock was a curator for the American Museum of Natural History. This mineral is most commonly found in prostatic calculi and rarely associated with kidney stones because zinc helps to stabilize this molecular structure. This mineral has been described as resinous with a brownish color [42]. Occasionally, small amounts of whitlockite has been deposited on struvite calculi and rarely in thick layers [45]. The chemical formula is $Ca_3(PO_4)_2$.

Newberyite was named after an Australian chemist James Cosmo Newbery (1843–1895). Newbery also served as curator for the Melbourne Museum. This mineral is very close structurally and usually found in association with struvite in guano deposits [46]. The chemical structure is $MgHPO_4$ *$3H_2O$.

One further rare mineral composition of stones is hannayite. This is named for James Ballantyne Hannay (1855–1931) who was a Scottish chemist at the University of Manchester.

It was originally discovered in the Skipton Lava caves in Australia. This has been found in association with struvite, newberyite, apatite, and the calcium oxalates. This has been described in only five stones [47]. The chemical composition is $2Mg_3(NH_4)_2(PO_4)_4 * 8H_2O$. Other minerals may or may not be scarcely present in stones either, because they are arbitrarily added or contaminates include aragonite ($CaCO_3$), calcite ($CaCO_3$), gypsum ($CaSO_4 * 2H_2O$), halite (NaCl), and vaterite ($CaCO_3$) [48].

Every Picture Tells a Story

Photography is the ability to record an image using chemical properties. The name was coined by one of the "Philosophical Breakfast Club" members, John Herschel, in 1839. Herschel had done the critical experiments necessary for the advancement of the chemistry of photography, but he stayed out of the fray of arguing who conceived and published first [6]. Herschel developed and published about the chemical reactions with silver solutions and the ability to stop or fix the reaction in 1819 using hyposulphites. He followed this paper with a presentation of using light to develop simple images using platinum salts in 1831. In 1826 the French investigator Joseph Nicéphore Niépce produced an image on polished pewter plates [49]. On January 7, 1839, Niépce's partner was Louis Daguerre who refined the silver nitrate process to produce higher-quality images with the silver deposited upon copper plates announced his daguerreotype. Since May of 1834, a fellow chemist and friend of Herschel's was also working on silver salt-impregnated paper that could be fixed using Herschel's hyposulphites, called a calotype. He demonstrated his technique on January 25, 1839, with Michael Faraday at the Royal Institute.

John Herschel graduated from Cambridge after taking top honors in his Tripos examination in 1813. He was named the youngest fellow ever of the Royal Society that same year. Though pursuing the law, he began investigations in chemistry and reported to his friend Babbage a new acid which he called "*hyposulfurous acid*" (sodium thiosulfate). He could now dissolve silver salts; this would come to his advantage when he became interested in photography [6]. He also began to investigate the optical properties of chrystals, reporting "*This salt has the most remarkable optical structure of any chrystal I have yet examined, and presents phenomena of quite a unique kind*" [6]. This property was pyroelectricity. Herschel eventually joined his aging father in astronomy in the summer of 1,816, but he continued his chemical investigations and the development of photography for studying the universe.

Photography has had a substantial impact on the diagnosis and management of urolithiasis. As early as 1893, Albert Musehold described an apparatus to photograph the endoscopic appearance of the pharynx [50]. Nitze who was pioneer in developing the first clinically usable scope to visualize the bladder (cystoscope) published the first photographic atlas of the pathology of the urinary bladder in 1893 which included the first photograph of a bladder stone in situ (Fig. 17.2) [51]. On December 30, 1926, Clarence Weston Hansell, an RCA engineer, wanted to view images from a distance using fiber optic bundles [52]. Henning and Keihack published the first color photographic pictures of the stomach in 1938 [53]. Rudolf Schindler developed a rigid and then a semirigid gastroscope, and Heinrich Lamm tried to reproduce Hansell's findings with fiber optics as a third-year medical student using commercially available materials. These findings pale in significance to the use of photography to document the location and presence of stones in the urinary tract using X-rays. The first X-ray to demonstrate a human kidney stone was Professor John Macintyre's film after first experimenting upon stones in vitro. Macintyre presented the case of a patient previously explored at the Glasgow Royal Infirmary in *The Lancet* on July 11, 1896 [54].

Liesegang

Raphael Eduard Liesegang (1869–1947) was a colloid chemist. He was the scientist who discovered the periodic precipitation reactions in gels that bear his name, Liesegang rings. Raphael was

ELEKTRO-ENDOSKOPISCHE INSTRUMENTE.

BESCHREIBUNG UND INSTRUCTION

Dr. M. NITZE und J. LEITER

INSTRUMENTE UND APPARATE

ZUR DIREKTEN BELEUCHTUNG MENSCHLICHER
KÖRPERHÖHLEN DURCH ELEKTRISCHES GLÜHLICHT

JOSEF LEITER

WILHELM BRAUMÜLLER & SOHN

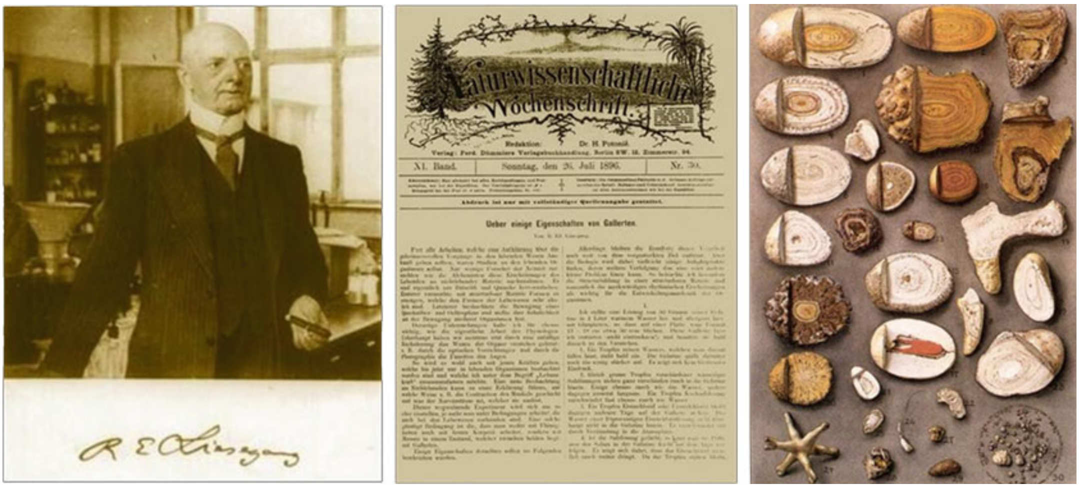
Fig. 17.2 Nietze's work and the first published photographs of bladder stones

devoted to science throughout his life. His first book was called *Die Organologie* published in 1892 [55]. In this treatise we gain a glimpse in his ideas of chemistry: "*The trend toward a unified physical appreciation of nature can already be found over two thousand years ago as the basis of natural science of the ionic philosophers. It culminates in an attempt to find a law which is valid for all branches of science and can alone explain all facts. First I shall attempt to find this axiom for the organology. In the next volume I shall attempt the same for inorganology, and finally I shall attempt to eliminate the dualism between organic and inorganic*" [56]. Like the alchemists of old, he had crossed over to a belief in experiment and observation, the ability to measure and distill. In effect what he was proposing was nothing short of the bridge between life represented by organic molecules and the nonlife via inorganic molecules. He was dedicating his life and his work to break down the barrier between organic and inorganic chemistry using his colloidal investigations. He studied colloidal silver solutions and their use in photography. Liesegang thought that compared to the electron released from the Br^- ion by a light quantum from the masculine sperm, Ag^+ behaved like the feminine egg. The photographic process was likened to embryonic development [56].

Liesegang patterning is a special type of chemical pattern formation in which spatial order follows density fluctuations in weakly soluble salt solutions. Liesegang was a chemist interested in photography and experimental gelatin layers impregnated with potassium dichromate in 1896 (Fig. 17.3). When a drop of silver nitrate was added, a precipitate formed concentric bands radiating outwards. The distances between each ring always increased with the distance from the center. Liesegang systematically pursued this phenomenon of spatiotemporal precipitate patterns, which he referred to as "*quasiperiodic precipitation*." Wilhelm Ostwald popularized Liesegang's findings in his book of general chemistry in 1897, calling the phenomenon an extension of supersaturation theory. It was Jablczinsky who described the mathematics of the periodic banding as a geometric series in 1923. Now sophisticated computer modeling schemes generate many of the aspects of Liesegang rings [57].

Liesegang Rings

Periodic precipitation patterns had attracted interest at least since 1855 by Friedlieb Ferdinand Runge (1794–1867) who noted periodic banding on filter paper which he called "*self-painting pictures*." Runge is today a relatively unknown physician whose works are lost in the labyrinth of specialized scientific history. He was born on February 8, 1794, in Billwerder, a small town



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Ueber einige Eigenschaften von Gallerten.

Fig. 17.3 (**a**) Liesegang, (**b**) his famous paper on periodic precipitation, and (**c**) Liesegang rings in stone disease as famously depicted in Howard A. Kelly and Curtis F. Burnam's *Diseases of the Kidneys*, *Ureters and Bladder* by Max Brödel [82]

near Hamburg. He was apprenticed to his uncle, a pharmacist, at the age of 16 but went on to medical school at the new University of Berlin but graduated from Jena in 1819, writing a thesis on his investigations of atropine, derived from the plant belladonna [58]. He published a two-volume book on biologically active plant chemicals in 1820 and 1821 and obtained a Ph.D. in chemistry from Berlin in 1822. He wrote many books and papers on chemistry through the years, but he became interested in the chemistry of colors while a professor at Breslau in 1826. In 1834, 1842, and 1850 he published a three-volume work on *The Chemistry of Coloring* (*Farbenchemie*) [58]. It is in this third volume on the preparation of dyes when he noted using filter paper for testing dyes, "*due to its capillary force it separates a drop spotted on it into its components and…creates a picture with a dark colored center part and lightly colored or even colorless rings on areas*." Runge was interested in his colored filter paper's patterns and privately printed his *Musterbilder* which in English is "*To Color Chemistry*. *Pattern Pictures for the Friends of Beauty and for Use by Draftsmen*, *Painters*, *Decorators and Textile Printers*, *Prepared by Chemical Reactions*" and was dedicated to King Frederick William IV. Though these chromatographs represented the first use of paper chromatography (honor was given to M.S. Tswett in 1903), he was becoming more artistic and philosophical regarding his images. He published 5 years later an expanded new book of his filter paper images called "*The Driving Force of Formation of Substances Visualized by Self-Grown Pictures*" (often called *Bildungstrieb*) [58]. Each color illustration of both books were individually created by Runge and glued into the books (though he used children to actually place the chemicals on all of the filter papers for the books). Runge received a special medal for this work at the 1855 World Exhibition in Paris and later at the 1862 World Industrial Exhibition of London [58].

It is fascinating that Runge came to believe that his patterns were created secondary to a mysterious "driving force" that he incorporated from his former professor, J.F. Blumenbach (1752–1849), at Göttingen. This is also similar to Liebig's "vital force" in organic chemistry and perhaps Mesmer's animal magnetism that was debunked by a scientific investigation that involved Benjamin Franklin in 1784. But another clear influence upon Runge came from Johann Wolfgang von Goethe (1749–1869) who he met while a student in Jena between 1818 and 1819. Goethe published his own Farbenlehre (The Science of Colors) in 1810 where he sought a transcendent meaning to coloring as well [59]. This was also picked up by Karl von Reichenbach (1788–1869), another chemist who introduced the idea of "*the Od*," a hypothetical force that pervades all of nature [60]. Since we are discussing patterns, it is fitting to curcle back to the final self-published edition of Runge's, a single copy of his *Bildungstrieb* where he inserts "*The Od as the driving force of formation…*" [61].

Tree rings have fascinated investigators for centuries and the links of these rings to dating go back for many years. The actual science of tree ring dating has been attributed to the growth of science following World War II [62]. The growth of these tree rings provides impressive abilities to date archeometrically, and newer strategies allow investigation of fossilized trees as well extending the dating strategies to over 12,460-year-old oaks [63]. Saturn's rings represent another periodic precipitation pattern that consists of ice and dust particles that encircle the sixth planet from our sun. The rings were first sited by Galileo in 1610 but he was uncertain as to what they were. They were identified by Christian Huygens in 1655 and again later by Hooke. But it was Giovanni Cassini that determined that there were multiple rings and began to note a pattern to them in 1675 [64]. Each planet in our solar system is also arrayed in a rather regular precipitant pattern, and each have a right-handed spin. Biologically, corals grow with annual ring formation patterns that also seem to be from periodic precipitation [65]. Not surprisingly sedimentary rocks themselves were first studied by Nicolas Steno for their periodic banding stratification. Finally, in pathologic processes that result in sporadic inflammations such as xanthogranulomatous pyelonephritis, inflammatory breast disease and other sites that laminated structures can result [66].

So Liesegang rings are simply a naturally occurring series of either circular (one dimension) or banded geometric, nonuniform spatial distributions of materials. Though attributed to Liesegang, others certainly noted these occurring and have commented upon them over the years. Research into Liesegang phenomenon is extraordinary and now involves complex computerized modeling and mathematical probability equations. Ostwald was a chemist who first proposed that supersaturation represented the driving force to the creation of Liesegang ring formation and distribution. Nowadays, complex laboratory methods can keep supersaturated urine solutions constantly mixing to measure and investigate the kinetics of crystal precipitation and aggregation [67]. Growth models can be formulated [68].

Supersaturation Theory

As urine becomes supersaturated with mineral components, usually cations and anions which are filtered by the kidneys, then the risk for precipitation increases. The physics of this process is now well known, and the physical chemistry that drives this process is also well described.

George Rainey (1801–1884) is principally known as an anatomist and was born at Spilsby, Lincolnshire, in 1801. He was apprenticed to a doctor and self-educated in Latin, Greek, and mathematics. He served as assistant to Mr. Barker, a local surgeon in Spilsby, prior to becoming a student at St. Thomas's Hospital in 1824. Not wealthy, he supported himself by tutoring others and developed keen skills as a teacher. He especially was good at anatomy and for the next 10 years was a private teacher at the medical school until he developed tuberculosis. He went to Italy in 1827 to recover and returned to become the curator of the museum and demonstrator of anatomy at St. Thomas's Hospital. George Rainey was another surgeon and anatomist who developed an interest in chemistry and influenced many others including Henry Vandyke Carter, William Ord (who we will meet later), and Lionel Beale [69]. Rainey early experimented upon plant life. "*An Experimental Enquiry into the Cause of the Ascent and Descent of the Sap, with observations on Endosmose and Exosmose*" was published in 1847 [69]. He became interested in microscopic pathology publishing in *Proceedings of the Royal Society* in 1846, the *Philosophical Transactions* in 1850 and 1857, and the *Medico-Chirurgical Transactions*. He became very interested in the organic/inorganic processes

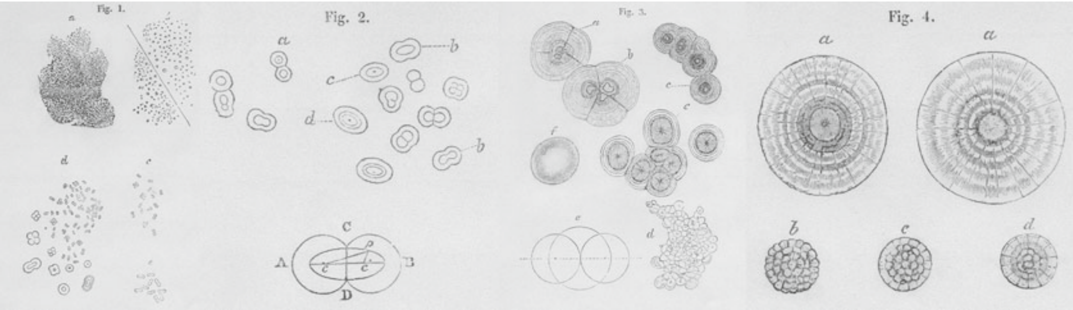

Fig. 17.4 The first four illustrations of George Rainey's model of actual stone formation

of animal shell production and the formation of bones. In 1858 Rainey produced a substantial work on the formation of animal shells and bone. The treatise was entitled "*On the mode of formation of shells of animals, of bone, and several other structures, by a process of molecular coalescence, demonstrable in certain artificially formed products*" [70]. Even negative reviews of his theories praised Rainey's minute observations.

He began his book by pointing out methods for those who question his findings to pursue themselves, and he opens up his collection of specimens to those who wished to observe for themselves. This was quite in keeping with the motto of the Royal Society, "*Nullius in Verba*" or don't take anyone's word for it [71]. He began with his observations on the formation of shells of animals. He would use his methods of microscopic examination, chemical identification, and experimental artificial models to formulate his theory of coalescence. This is prior to the actual biochemistry and intracellular physiology, but his methods were truly amazing. His first four figures show how in an ex vivo supersaturated solution stones actually form (Fig. 17.4) [70]. He called the formation of globules of crystalline substance, in this instance carbonate of lime coalescence, and believes that it naturally forms into spheroidal patterns by mutual attraction and gravity. It was the method of concentric lamination from which he made his bold observations. On page 18 of this work he states, "*Hence, prior to the complete coalescence of any number of spherical particles into one sphere, each particle or spherule must undergo a process of disintegration (or be taken to pieces), an after that, the molecules of the disintegrated spherules must be put back together again under the same static conditions as they were before*" [70]. He continues by stating "*Hence the careful inspection of specimens exhibiting these different stages of coalescence brings to view numerous examples of calculi with concentric lamiae (as shown in Figs.* 17.2 *and* 17.3*)*" [70]. So now we can proceed to his model of stone formation: "*The first stage in the formation of such calculi is a spherical conglomeration of those globules producing a mulberry-like appearance, (See Fig.* 17.4*b–d) and form closely resembling that of the corpuscle called by pathologists a glomerulus, although that is composed of particles of oil. The next is the disintegration of these spherical particles which takes place first in the peripheral ones. In this process every vestige of their original form and structure is destroyed, and they become reduced to amorphous granular mass. Next, the molecules nearest the surface coalescing, form a clear ring completely surrounding the amorphous matter occupying the interior. (See Fig.* 17.4*b) The further progress of the process of disintegration and subsequent coalescence is marked by the increase in width of the circumferential bright ring, just as the central amorphous part diminishes, showing that the one is formed at the expense of the other, (See Fig.* 17.4*d) until all the latter has disappeared, and is replaced by a succession of bright concentric laminae*" [70].

Modern Science and Phases of Precipitation

We have discussed throughout this chapter on crystals, stone formation with crystal aggregation, stone growth, and the role of periodic precipitation patterns common to all stone formation. But stone formation occurs in the urine of humans and it is time to look at the urine itself [72]. Since prehistoric times man was first able to only look at the color of the urine and perhaps any gross materials that might occur. The ancient Babylonians and Egyptians added taste, color, odor, and sedimentation to the urinary evaluation. Hippocrates in his aphorisms stated, "*When the urine of a man with fever is thick, full of clots and of small quantity, an increase in quantity and clarity is advantageous. Such a change is especially likely to occur if, from the beginning or very shortly afterward, the urine has a sediment*" [73]. The Middle Ages added the macula to the science of urinary evaluation but also led to the rise of the "Pisse Prophets" [74]. The French microscopist Fabricius Nicolaus De Peiresc (1580–1637) first turned a high-powered look into urine sediments in 1630. He is reported to have stated that the urine looked like "*a heap of rhomboical bricks*" [75]. Robert Hooke again looked at urine as well and drew some of the first urinary crystals in his 1665 *Micrographia*. Hermann Boerhaave carried out studies of urine to investigate if crystals in the urine were normal, common, or caused by certain types of food and drink in early eighteenth century. James Tyson (1841–1919) published one of the first practical guides to urinary examination in 1870 [76].

Crystalluria is a condition in which urinary crystals occur in human urine. In most cases, this condition is transient and apparently completely normal. Crystals can be those that make of pathologic stones such as calcium oxalate, uric acid, and amorphous phosphates. Struvite and cystine crystals are almost always pathologic. Since crystals are the building blocks of stone disease, it is little wonder that they have been studied extensively as a condition that progresses to disease. In 1969, Robertson and colleagues reported that stone formers though having about the same quantity of crystals in their respective urines had larger crystals (10–12 μm vs. 3–4 μm), and they noted crystal aggregation or clumps [77]. Numerous other authors have sought to redefine these risks using sophisticated methods but there still appears to be great controversy. The amount and size of crystals has likewise been utilized to monitor therapeutic effects of medications such as orthophosphates, thiazides, citrate, and pyridoxine. So, there are many variables that affect the supersaturation of urine including the presence or absence of other illnesses (such as gout or leukemias), the state of hydration, the ambient temperature and humidity, the diet, bone health, and bowel function. Even this simplifies things a bit but more on this later. A recent music video from Western University highlights the chemistry, the suffering, and the social interactions associated with stone disease [78] (http://www.mineralogynetwork.com/brainbios/video/145246).

Conclusions

> "*What is man, the son of man, asks the biochemist, but a container of salt solution in a state of more or less saturation? Ever so slowly he settles out, clouding milkily up, depositing within himself silt, a silt whipped by the slowest of currents and inner winds into serrated banks and whorls. Who knows at what point the balance between solution and precipitation will have been tipped, and the first speck of mineral will appear like the \birth of a planet in the void, realizing out of tissues overcharged calcium, uric acid or others of the stone-forming elements, a mote, a jot, unbeknownst, uncelebrated? No tocsin is sounded, no alarum. Yet toxin and alarm are its business credentials. When is it that the acidity or alkalinity of the urine is so mysteriously altered, and with such a misdirected hospitality, as to encourage the persistence of the wicked speck? Too small by many months, even years, to be seen or felt, it is most importantly THERE, either lodged in some damp cul-de-sac, or carried by hidden currents, crashing against secret membranes, all the while gathering unto itself from the high urinary waters, full as briny as the Dead Sea, more and more of the bitterest crystals, grow slow as a diamond, and as cursed, worn only at the greatest peril*" [79].
>
> —Seltzer, Richard: Mortal Lessons. 1974.

Minerals are naturally occurring substances that form solids at room temperatures and are distinct from rocks that can be aggregates of minerals. Human urolithiasis can therefore be both minerals and rocks. But the substantial building blocks of all urolithiasis are the minerals. These make up as much as 90 % of most stones, although there are those rare human stones that are mostly proteins. Hematin is one such stone that forms very rarely; also indigo stones and other chemically or drug-induced stones fall into this category [80]. Mineralogy is one of those ancient sciences that literally exploded from the sixteenth to the seventeenth centuries and gave rise to the studies of crystals themselves. Crystal science is intimately tied up with physics and mathematics because of the geometry of crystal lattices and the peculiar effects that crystals have upon light and color. The early scientists in these fields also crossed over to the study of light itself and the development of modern photography. All of these peculiar sciences are quietly linked to urolithiasis but as shown in the preceding sections, at times loosely. This brings us to the very basics of science itself that ties this story of sorts together, the "Philosophical Breakfast Club" of Trinity College [6].

During the times essentially covered during the bulk of this chapter, the scientific community was undergoing significant upheaval. The British Association for the Advancement of Science (also shortened to the BA) was proposed and held its first meeting on Tuesday, September 27, 1831, in York. The prime movers were all somewhat disenfranchised with the Royal Society and were seeking alternative venues to advance the cause of scientific investigation. On June 24, 1833, the British Association for the Advancement of Science met for the third time. William Whewell who was one of the guiding lights in the formation of this organization rose in response to Samuel Taylor Coleridge's remarks that members should no longer be called "*natural philosophers*" which created an uproar. Whewell rose and suggested that if "philosophers" was too lofty a term, "*by analogy with artist*, *we may form* '*scientist*'" [6]. Curiously the BA also recommended against the most significant instrument created by one of the "Breakfast Club," Charles Babbage's analytical engine which would have been the world's first computer in 1878. Also the venue for the BA also launched the famous debate created by Darwin's Origin of Species when Thomas Henry Huxley and Bishop Samuel Wilberforce clashed at Oxford in 1860 at the thirteenth annual meeting.

Liesegang initially described the process of the periodic precipitation reactions in gels; others would continue to describe this same process in other biologic and natural systems, such that the literature on this subject is absolutely massive. Examples include the pigmentation in animal's irises, the Haversian canalicular system of bones follow this pattern, as does Rainey's beloved clam and oyster shells amongst a wide array of naturally occurring structures.

The Crystal Palace was an iron and plate glass building constructed in Hyde Park, London, for the Great Exposition of 1851. There were more than 14,000 exhibitions including the "*crystal fountain*" which was a light-guided illumination taking advantage of total internal reflection of light that would later be able to illuminate fiber optic endoscopes in the modern treatment of urolithiasis and lasers that would evolve into the devices used to destroy stones [81]. In addition, Persian cats were shown for the first time at the Crystal Palace, and they notoriously develop calcium oxalate bladder stones. Dinosaurs were demonstrated for the first time with gigantic renditions created by Benjamin Waterhouse Hawkins and the physician/anatomist and sometimes nemesis of Charles Darwin but great friend of Wollaston, Richard Owen. The Crystal Palace came to represent progress as did crystallographers in the science of mineralogy.

Niels Stensen (aka Nicolas Steno) investigated crystals, mineralization, and the ideas of stratification of sedimentary rocks as well as being a gifted anatomist. In addition, he had a crisis of faith, having been born and raised in the Protestant stronghold of Denmark. After so much academic effort, this truly gifted individual gave it all up to become a Roman Catholic priest. His rise was also quick in this new profession and he became the Bishop of Titiopolis or the north in order to attempt to return Catholicism to Germany. He resigned as bishop in 1685 when he became ill. Some say he suffered from stone disease, some from gallstones, and others from colon cancer. He died on December 6, 1686, living and writing in poverty and suffering colic as only stone patients can imagine. He was initially buried inconspicuously but was moved at the request of the Medicis to their tomb in San Lorenzo. The grave was again opened in 1953 to a new chapel called Capella Stenoniana with a Latin epitaph:

Here rest the remains of Niels Stensen, Bishop of Titiopolis, a God-fearing man.
Denmark gave him a life of heresy, Tuscany gave him a rebirth in a true faith.
Rome in bravery honored him by a bishop degree.
Germany had a heroic announcer of the gospel.
Schwerin lost him completely crushed and suffering for Christ.
The Church has mourned him. Florence wanted to won at least his ashes.
Anno Domini 1687.

Steno was consecrated by the Vatican in 1938 the occasion of his 300th birthday. On October 23, 1988, Pope Pius Jan Pavol the Second proclaimed this quiet physician/anatomist and scientist a saint.

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