HYLE Essay

The Plays of Boys

Essay Review of
Oliver W. Sacks: *Uncle Tungsten: Memories of a Chemical Boyhood*, Alfred A. Knopf, New York, 2001, 352 pp.
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by Pierre Laszlo

> *The plays of boys may sometimes deserve to be the study of philosophers.*
> (Robert Boyle, quoted by Oliver Sacks, p. 105)

I have chosen to review for the readership of this journal a book written for the general public. It is fortunate that some authors are capable of writing popular books, and yet that they are also able to convey important ideas, with a light touch, with subtlety and feeling. Oliver Sacks, the neurologist, is one such writer. As another stroke of good luck for us, chemists, his book is a paean to chemistry. Our science, even though it did not remain for Sacks a life-long avocation, nevertheless elicited his passionate interest as a child. *Uncle Tungsten* thus provides us with a unique testimony to the discovery of chemistry by a young mind. In so doing, it raises quite a few interesting philosophical questions.

Appropriation

Oliver Sacks tells us (pp. 75-76) of the aspect of bus tickets in London during his childhood there. They consisted of a colored oblong of cardboard and they were inscribed with letters and numbers. He set about collecting those, such as O 16 or S 32, which to him were symbolical of chemical elements. As he writes,

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> eventually, I had all the known elements, from H 1 to U 92. […] I loved carrying my little collection of chemical bus tickets with me; it gave me the sense that I had, in the space of a single cubic inch, the whole universe, its building blocks, in my pocket.

The naive appropriating gesture of the boy, who has gradually amassed the whole periodic table, is emblematic of an urge of chemistry to both describe exhaustively and analyze matter for its constituent elements.

Matter has many accouterments. Francis Bacon pointed out, with his Proteus metaphor, its awesome multiplicity of diverse forms. Yet, this bewildering diversity of matter submits to an overarching simplicity, that of the constituent chemical elements.

Before proceeding further, let me point out how revealing the word 'constitution' (as in 'constituent elements') is, as well as being coherent with the demiurgic project of Sacks as a child: a constitution, as it refers to the constitution of a country (rather than just that of a body), is a set of statements, drafted by legal experts, which serve as organizing principles, as germinating seed and governing paradigm to establishing a body politic, a nation. Likewise, chemical elements are the sovereign entities from which all subsequent manifestations of matter ultimately will derive.

Such ambition of chemistry at appropriation of the elements is both totalitarian and open-ended. Totalitarian, it strives for nothing less than a complete account of the whole of the material world. Open-ended, it searches constantly for new elements to tack on as new entries.

Metals were especially important to the young Oliver Sacks. He was fond of their weight, of their color, of their brightness, of their sheen and luster. Such visual qualities of the metallic elements were allegoric, to him, by the Uncle Tungsten of the title. This was his Uncle Dave who manufactured light bulbs in his London plant, with filaments made out of tungsten. Sacks goes into the history of artificial lighting, starting with limelight, continuing with Edison's devising of carbon filaments and finding its acme of successful intense illumination, with recourse to metals such as tantalum or tungsten.

But it is quite clear – no fewer than two chapters are devoted to the topic – that there is potent underlying symbolism: chemistry lights up the world and repeals forces of darkness. Chemical knowledge proceeds through elucidation, and may provide one with a sort of a mystical illumination. When the boy Oliver collects these bus tickets, when he grasps at the same time the mind-blowing concept of the whole of matter being made up of these building blocks, the chemical elements represented by the small cardboard stubs in his hand, he is acting-out the three components that the literary critic Northrop Frye, following Aristotle and his *Poetics*, saw in *mimesis*: *mythos*, organization of data into meaningful array; *dianoia*, conceptualization and interpretation, in this case Mendeleev's periodic table; and *anagnôrisis*, the epiphany-like recognition of the adequacy of the general theme and of its admirable self-consistency. The boy Sacks' fascination with the elements and their organization into the periodic table was thus buttressed by the weaving into such an intensely satisfying narrative. To him, science, chemical science, was making sense of the world.

Coming of Age

What a fortunate child! Oliver Sacks, as a young boy, was provided with his own laboratory. He had many physicians and scientists in both his nuclear and his extended families (the latter more than 100-strong). All those adults saw it as their duty to nourish an inquisitive mind, to have young Oliver raise questions, a habit that he saw as being the "family business". "I was encouraged from the start to interrogate, to investigate" (pp. 9-10).

After he had seen his Uncle Dave's laboratory, Sacks longed to have his own laboratory. He was allowed to take over a laundry room for this purpose, was given money for his purchases of chemicals, and was not reprimanded for turning the lawn in the garden outside into a burnt surface, upon which he would dispose of flaming or otherwise noxious contents of flasks.

Boys will be boys: he played with explosives, he played with fire, and he explored the colors of chemicals and evolved an intuitive feeling for a given color as characteristic of an oxidation state of an element. He distilled plants in order to smell their essential oils; and he explored also the converse, the very worst stenches chemistry can offer.

There are two philosophical issues here. Could a feature of chemical science, distinguishing it from say astronomy or genetics, be the uncanny ability of some people, such as Oliver Sacks, for its self-acquisition through observing and experimenting?

The second, related issue is the learning mode. Chemistry is learned language-like: total immersion breeds familiarity, both lexical familiarity *i.e.* intimate knowledge of chemical compounds, each endowed with its characteristic properties; and syntactic familiarity *i.e.* practical know-how of the procedures for turning a given chemical into another. If indeed chemistry is learned in this manner, the question arises of whether such linguistic features are specific to it as a science; or only as a projection of the human mind.

Observation

If indeed chemistry is related to linguistics, it turns into a science whenever careful observation reveals some rule at work. And indeed the reader of *Uncle Tungsten* finds observation to play a key role in young Sacks' joyful learning of chemistry.

So many discoveries, historically, arose from observations. Hence, it is no surprise for this book to emphasize observations by boy Sacks. They belong to a subclass of perceptions – perceptions informed by the meaning they carry; sensory perceptions, each of which induces further measuring and experimenting. Such sensory perceptions, "the look, the feel, the smell of a substance" (p. 44), as this quotation makes clear, follow a hierarchy. Sight is privileged. Colors and their changes are, to the future chemist, the portent of important phenomena. For instance, Oliver is fascinated by the variable aspects of solutions of the alkali metals in ammonia (p. 79):

> when the solutions became more concentrated, they suddenly changed character, turning into lustrous bronze-colored liquids that floated on the blue – and in this state they conducted electricity as well as a liquid metal like mercury.

He cannot help but notice a convergence of approaches between his father's, a medical doctor, examining of patients (p. 93) and his own scrutiny of chemicals and of their transformations. As a rule, each chemical is interesting in its own right and, even if at first sight unrevealing, it may harbor a fascinating hidden property: hydrogen neither smells nor has a taste, but it makes the voice sound funny (p. 114); balloons filled with carbon dioxide or with xenon sink (p. 115).

Sensory perceptions: like most animals, humans gather together their sensors, as near-appendages of the brain, next to one another, in a small and highly specialized region of the anatomy, the face: eyes, ears, nose and mouth. The latter assumes, for young Oliver, an importance second only to the sense of sight: "I loved the smell of fruits and vegetables and would savour everything, sniff at it, before I ate."

The gourmet enjoys, not so much the eating act as mere absorption and incorporation, but the symphony of textures, juiciness, tastes and smells which cuisine endows food with. The experience of the gastronome parallels, in a strong epistemic sense, that of the scientist, making sense of the complexity of reality with just a few rational, organizational principles.

Hence, when the apprentice-chemist discovers the Master Rule behind chemical elements and their combinations, the periodic table, only a culinary metaphor can account for such an overwhelming revelation (p. 188):

> In this first, sensuous glance I saw the (periodic) table as a gorgeous banquet, a huge table set with eighty-odd different dishes.

Recapitulation

Uncle Tungsten obeys what might be termed Sacks' Law, in analogy with Haeckel's Law ('ontogenesis recapitulates phylogenesis'): genetic epistemology recapitulates science history. Indeed, the narrative of his personal development as a young chemist is interspersed with half-a-dozen chapters, presenting milestones in chemical history – such as the contributions of Boyle and Lavoisier, of Humphry Davy and John Dalton, of Mendeleev and the Curies. He writes (p. 69): "I would live the history of chemistry in myself."

This gives the impression, of course fallacious, of a linear development of the science; since the innocent mind of a child only needs to retrace the course of history in order to acquire, in logical and orderly manner, the main concepts of the science. Sacks' Law runs counter to the serendipitous nature of many a discovery. Historians chronicle, not a progressive gradual unfolding, but a much more haphazard course. Such a reconstruction as we find here strikes one, at first sight, as somewhat anhistorical and wide of the mark.

The organization of his book, his introducing capsule histories for some of the main chemical discoveries – those of elements by and large – makes me label it, tongue-in-cheek, as Sacks' Law. Furthermore, Sacks has shown in other writings considerable epistemic awareness and originality. Thus I believe that, at least to some extent, we should take the mix of chemical history and self-discovery by the child, as presented here, as an authentic representation of boy Sacks' access to chemical knowledge.

And Sacks was very conscious of this process. He quotes (p. 155) Cannizzaro to this effect ("It often happens that the mind of a person who is learning a new science, has to pass through all the phases which the science itself has exhibited in its historical evolution.") and goes on:

> Cannizzaro's words had a powerful resonance for me, because I, too, in a way, was living through, recapitulating, the history of chemistry in myself, rediscovering all the phases through which it had passed.

But, beyond the apparent paradox inherent in this 'law', I submit that there might be a nugget of truth to be garnered. The *Gedankenexperiment* – which *Uncle Tungsten* rather nicely embodies – installs a smart, precocious, inquisitive child in a chemical laboratory, complete with all necessary glassware, Bunsen burners, crucibles, stills, solvents, and reagents. Will he/she rediscover the principles of chemistry? Will the unaided child, just from handling elements and compounds, plus keen observation of their interconversions, be capable of re-establishing the rules of chemistry-as-a-language, of spelling out what the syntactical structure of chemistry consists of?

The evidence provided in *Uncle Tungsten* does not allow one to answer this question either way. Clearly, boy Sacks was provided by his family with ample reading material, including writings by or about the key characters in the history of the science. Furthermore, it would be natural for the epistemology of the adult to have come, at least to some extent, in-between us and the spontaneous attitude of the child to knowledge.

The key result here is that, when the memory of the adult sieved through all the handlings of chemicals performed by the child, in consonance with the cumulative historical readings, those of the child and those of the adult, this fabric remained of one piece. All these memories became welded and inseparable.

Semiology

To young Sacks, the learning of chemistry identifies with a semiology, with an ability to interpret signs of material transformations, such as changes in the color of a solution, or the colors of flames doped with some salt or oxide. As a rule, Uncle Abe serves as the interpreter. He displays to the boy dramatic transformations, often within the province of solid-state chemistry, such as the near-instantaneous oxidation of aluminum at air, after surface treatment with a smearing of mercury (p. 38); or the relaxation of an activated crystal lattice (p. 262):

> Uncle Abe showed me a piece of fluorspar which he had exposed to radium for a few days. Its original color had been purple, he said, but now it was pale, charged with strange energy. He heated the fluorspar a little, far below red heat, and it suddenly gave off a brilliant flash, as if it were white-hot, and returned to its original purple.

Thus, chemistry is replete with astounding phenomena to wonder at. Such episodes convey the sense of wonder of the child, invited to witness strange and marvelous manifestations of some of the strange powers animating matter.

Besides this notion of the magic and of the wonderful in chemistry, presented as part of a natural history, a second reading of such episodes, admittedly from the *a posteriori* knowledge of Sacks' later elected profession as a physician, is the introduction to the duality of the normal and of the pathological – not from examination of human patients, but from that of samples of seemingly inert matter.

Indeed, the return to normalcy of the sample of fluorspar, which the exposure to a radioactive source has lifted into a metastable higher energy state, suggests to the future M.D. that medical treatment may likewise effect a quite dramatic reversal of symptoms, especially for the whole category of neurological and mental disorders Oliver Sacks made his reputation treating (and writing about).

Notice also how thermal energy is used as a yardstick, in the episode quoted, for other forms of energy, such as radioactivity. The activation of the sample has been performed with invisible rays, with a “cold fire” (this is the title of one of the chapters), nevertheless intrinsically more energetic than the hottest of fires.

And the analogy with the treatment of sick people imposes itself to the mind: if energy is what animates matter, likewise (p. 25) “violence is the principle of life”.

Popularization

There were other intercessors, equally influential on the young mind, besides Uncle Abe. These were the books young Sacks relied heavily on for his initiation into science. As a rule, they were popularizations from another, Victorian age, found in antiquarian rather than in ordinary bookshops. One of those was J.F.W. Johnston’s *The Chemistry of Common Life*, about which Sacks indeed comments (p. 73) that it introduced him “not only to chemistry, but to a panorama of exotic human behaviors and cultures”. Would not his career, and the books of popularization he himself wrote, be devoted to exploration of this very panorama?

Another precious little manual was J.J. Griffin’s *Chemical Recreations*. Young Sacks owned the 10^{th} edition of this book, published originally in the 1830s. It had (p. 71) “an easy, practical, and above all playful style; *chemistry was clearly fun*” (my emphasis).

There were a few other such books in Sacks’ obviously well-stocked child library: Valentin’s *Practical Chemistry*; A.J. Bernay’s *The Science of Home Life*; and, last but not least, James Parkinson’s *Chemical Pocket-Book or Memoranda Chemica*, written in 1803. Sacks was eleven when he read it. He was then little aware that this was the Parkinson who gave his name to a disease, whom he would encounter again during medical study as the author of the *Essay on the Shaking Palsy*.

An aunt had given Oliver for his tenth birthday a copy of James Jeans’ *The Stars in their Courses*, a little introduction to astronomy. Accordingly, his ‘physics’ uncle (Abe) presented him soon thereafter with a copy of J. Norman Lockyer’s *The Spectroscope* (1873). Henceforth, Oliver would go around armed with a pocket spectroscope, which let him analyze all sorts of emitted lights, in the streets and in the sky, and ascertain which particular element was the cause.

To a great extent, all these books served as a shield. They protected Oliver from the contents of other, threatening books whose lurking omnipresence in the household made the boy uneasy and turned him into a young hypochondriac. Those were the medical books, such as Bland-Sutton's *Tumours Innocent and Malignant*, French's *Differential Diagnosis,* or an *Atlas of Dermachromes*, depicting horrifying skin conditions.

As Sacks writes, on p. 235,

> The special dangers of chemistry were sought out, to some degree, I suspect, as a means of playing with such fears, persuading myself that by care and vigilance, prudence, forethought, one could learn to control, or find a way through, this hazardous world.

Aesthetics

"Chemistry is beautiful" is one of the main messages of *Uncle Tungsten*. Starting with its elements, its lexicon of chemicals displays luscious appearances and is thus made very attractive. The pure metal cesium for instance (p. 188)

> was golden – it gave at first just a glint, a flash of gold, seeming to iridesce with a golden luster; then, from a lower angle, it was purely gold, and looked like a gilded sea, or golden mercury.

Such beauty extends to metallic alloys, to chemical compounds in general. Boy Sacks gets a kick when his Uncle Dave (Tungsten) shows him (p. 36) a sample of "osmiridium", a natural alloy of osmium and iridium, "the two densest substances in the world".

Equally important as the external appearances, perceptible to the senses, is the internal beauty of the science. Nowhere is it as obvious as in the periodic table, with its inner harmonies and its succession of echoing melodies (p. 190). Sacks is very explicit as to the reasons for his seduction by chemistry (p. 276): he has

> a passion for order, for formal beauty […] the beauty of the periodic table, the beauty of Dalton's atoms. […] At times I felt a sort of ecstasy at the formal intellectual beauty of the universe.

A sort of ecstasy? One cannot help but evoke the sexual orgasm which, just a few pages earlier (270-271), Sacks had recalled.

His admiration focuses on the periodic table especially, which he sees as (pp. 190-191)

> a sort of cosmic staircase or a Jacob's ladder, going up, coming down from, a Pythagorean heaven. […] a great nebula, going from the first element to the last, and whirling beyond uranium, out to infinity.

An agnostic, but imbued with Jewish culture and religion, Sacks might be termed nevertheless a pantheist. He sees the Divine in this feat of human intelligence and imagination, the periodic table. His notion of beauty is Kantian; it is a universal, even though the aesthetic feeling is in the realm of the subjective.

For Sacks, emotions are on a par with his natural historical bend. He is very much an 18^{th} century natural philosopher. Reminiscent of a Diderot in his strong emotions, in his empathy for people in all walks of life, for the downtrodden especially, he also evokes Rousseau in his openness about himself.

Uncles

The issue here, which merges anthropology and psychology, is also rooted in history. Together with operations such as distillation or calcination, it is a lingering trace of the alchemical past of chemistry. A distinctive trait of chemistry is the intervention of a father figure during the learning process. The master-apprentice relationship – the master-adept relationship one might say – is still an integral part of the learning of chemistry, which amounts to an initiation.

Uncle Tungsten, in its very title, illustrates this important factor. The psychological issue is that of the role model. The young chemist forgoes his own, biological parents, and indeed in this memoir and elsewhere, in interviews, Oliver Sacks hints at a mutual (if muted) rejection. Young Oliver gave himself role models in his two uncles, Abe and Dave, who became for him emblematic figures of chemistry and physics, respectively. The intellectual parents partly replaced and pushed aside the biological parents.

The tension was very much apparent in Oliver's career choice. Would he become a physician, as was the tradition within the (nuclear) family, or would he embrace chemistry, the avocation his two uncles had seduced him into pursuing, single-mindedly, as a boy at least until his teens? The author does not elaborate, but this tug-of-war between his parents and his uncles, even if it never came out into the open, was a determining force during his formative years. They were mentors, beloved guides into the attractive pastures of science – whereas the father and the mother were a little rough with their son at times.

One should not exaggerate the extent of the divergence between young Oliver and his parents. His father and his mother, besides being outstanding physicians, nevertheless had other interests as well; and they keenly followed the advancement of science in various fields. In an endearing chapter, the author presents a portrait of his mother. She was fond of anatomy, at which she excelled, and she strongly encouraged young Oliver into dissecting fetuses and corpses at an early age (fourteen). More generally, she had a gift for ascertaining spatial relationships of various parts to one another. And she clearly was an instinctive mechanical genius, very good at fixing any clock, or an out-of-order mechanical contraption.

Sacks portrays a huge, about 100-strong, closely-knit extended family. He was the youngest of four sons. His mother was the sixteenth of eighteen children in her own family. He had two uncles, on his father's side. Abe and Dave were both brothers of his mother. It is perhaps no accident that they were maternal uncles; we have been made aware by anthropologists such as Claude Levi-Strauss of the importance of the maternal uncle in many cultures – and indeed Oliver Sacks refers (p. 10) to his extended family as a "tribe".

These two maternal uncles, Abe (mineralogy and chemistry) and Dave (physics), embodied to the boy the modern age, the 20th century. They worked in the family firm, which produced light bulbs. It was a business thriving upon technological wizardry, itself based upon scientific knowledge. One may wish to contrast the two uncles with that in Jacques Tati's *Mon Oncle*: the hero of this French comedy film of several decades ago, a protest against change and the Americanization of French society, personified the past, a fondly recalled time of old-fashioned values, of convivial relationships between people, as contrasted to the mechanical, aseptic, and automatized world of today.

Another indication of the importance to young Oliver of his two uncles Abe and Dave, in his growing-up process, is that they provided him with a pattern for his future friendships, these two male figures structured his mental world. One feels that there is a parallel between those two uncles, on the one hand, and the two male friends, on the other, whom Oliver met as a teenager and who have remained his best friends to this day: Jonathan Miller, the polymath and theater director, and Eric Korn, who has become a well-known antiquarian book-dealer and literary critic. To young Sacks, Korn and Miller embodied literature. And for a while the three friends, still in secondary school, published jointly a literary review.

Pythagoreanism

In his awareness of chemical history, in his obvious sympathy for epistemic issues, Sacks is at his most endearing, to my taste, when linking his personal fascination with numbers with the numerology that is such an integral part of chemical thinking.

One of the first chapters tells of his initial fascination with arithmetic. The wording is quasi-mystical:

> The association of plants, of gardens, with numbers [this alludes to the Fibonacci series describing various botanical patterns along a logarithmic spiral] assumed a curiously intense, symbolic form for me. I started to think in terms of a kingdom or realm of numbers, with its own geography, languages, and laws; but, even more, of a garden of numbers, a magical, secret, wonderful garden. It was a garden hidden from, inaccessible to, the bullies and the headmaster [...].

Some years later, young Sacks, who has just mastered the concepts of atomic structure according to Niels Bohr, feels transported by the notion of those magic numbers (Elsasser's) which connect the shell structure of the quantum atom to the inner architecture of the periodic table (p. 301):

> I repeated this series – 2, 8, 8, 18, 18, 32 – over and over to myself.

and he reproduces statements by physicists of the first rank regarding the harmony of the physical world, which as it were, also inhabits a garden of numbers; Einstein thus commenting on Bohr's atom (p. 298):

> This is the highest form of musicality in the sphere of thought.

Or Sommerfeld who likewise wrote (also on p. 298):

> The language of spectra has been revealed as an atomic music of the spheres.

I should like to remind the reader, at this point, of the impact of Pythagorean ideas on chemistry. It suffices to consider a panorama, centered on geometrical shape. Pythagorean beliefs in numerology became projected on the sky when the Neo-Platonic mystique induced Kepler to inscribe the orbits of the planets in the regular solids of Plato. This idea of 1595 gave him in 1618 his third or harmonic law for description of the solar system.

The second stage in the gradual, step-by-step *mise en abyme* of the material world came about at the end of the 18th century with Haüy's representation of crystal shapes, also with a small number of regular polyhedra as building units. The Platonic idea inherited from the Renaissance then came to encompass the whole of mineralogy.

Step 3 was Ampère's 1814 open letter to Berthollet in *Annales de chimie*: henceforth molecules could also be described by regular geometries, with their component atoms located at the corners of polyhedra, in arrangements obeying very simple mathematical relationships. Ampère pioneered the notions of molecular structure and architecture as goals for chemistry to establish and understand, and as tools for chemists to apply to the unraveling of the laws of chemical combination.

Step 4, definitely influenced by a sound knowledge of crystallography and by his being steeped in René-Just Haüy's writings, perhaps also echoing Ampère's 1814 paper, was Auguste Laurent's conjectural account in his doctoral dissertation (1837) of the reactivity of organic molecules, additions and substitutions, with a schematic diagram in the shape of a parallelepiped for a hydrocarbon 'nucleus' of 12 hydrogen and 8 carbon atoms. In so doing, Laurent was experimenting with the notion of a three-dimensional regular solid or polyhedron in order to recapitulate (and abstract) the whole series of metamorphoses a molecule was capable of undergoing. This was one of the seeds for the molecular formula as Kekulé would conceive it 20 years later (1858 and step 5).

Step 6 in the *mise en abyme* that unfolded with slow and inevitable deliberation across the ages was Le Bel's and van't Hoff's discovery that the tetrahedron (the simplest of the Platonic solids) proved to be an adequate descriptor of carbon asymmetry and of tetravalent bonding (1874).

Step 7 is, of course, Alfred Werner's parallel establishment in the 1890s of a similar role for the octahedron, another Platonic solid, as an organizing template for a whole class of coordination complexes, of "higher-order compounds" as he termed them, and for their isomerism.

Then, in the early 1900s, Gilbert N. Lewis became puzzled by the coexistence of two types of bonding interactions, normal covalent in organic molecules and dative coordinative as present in the Werner complexes. This led him, as early as March 28, 1902 to draw on the back of an envelope the electronic configuration as yet another Platonic solid, the cube: the electrons making up a shell occupied gradually and symmetrically, in his scheme, the eight corners of a cube. Recognition in Lewis' words "that the pair of electrons forms the stable group, [and that] in general the pair rather than the group of eight should […] be regarded as the fundamental unit" gave him both the notion of the two-electron bond and the tetrahedral carbon atom. Thus, Lewis was led to the conclusion, anticipating the discovery of electronic spin and of Pauli Principle, of the electron pair being held together in like manner as coupled little magnets. This would be step 8 in the gradual Platonization of matter. It would also be a major step in the reopening of a creative dialog between chemistry and physics, during the first three decades of the 20th century, which would end with Linus Pauling importing into chemistry the key ideas of the new quantum mechanics and with the physicists (Hans Bethe, Fritz London, Julius R. Oppenheimer, Edward R. Teller, and very few others) beating a hasty retreat from the complexities of chemistry, after some magnificent forays of lasting benefit.

Jingling Bells

That physicists have contributed, *en masse*, to the march of chemistry is a little trite. One of the virtues of Sacks' lovely memoir is when he pays homage, also, to the contributions of mathematicians to the advancement of chemical science. An illustrative case is that of the prescient recognition by Leonhard Euler of light being absorbed by matter through the exciting of resonant vibrations amongst the particles of matter (p. 81n):

> The nature of the radiation by which we see an opaque object does not depend on the source of light but on the vibratory motion of the very small particles of the object's surface. These little particles are like stretched strings, tuned to a certain frequency, which vibrate in response to a similar vibration of the air even if no one plucks them. Just as the stretched string is excited by the same sound that it emits, the particles of the surface begin to vibrate in tune with the incident radiation and to emit their own waves in every direction.

It is prescient in that such resonant attuning of a set of vibrators (not unlike the little bell carillon, Papageno's *glockenspiel* in *The Magic Flute*) to an outside exciting radiation causes the blue color of water, which indeed absorbs (and subtracts) red wavelengths from visible light by this very mechanism, in which individual water molecules serve as the vibrators.

Conclusion

The autobiographic memoir has an unhappy ending, especially for chemists. Young Sacks feels expelled from chemical Paradise, for two reasons. His parents browbeat him into going into medicine, following their example and the family tradition both. And Sacks realizes, at the same time, that the chemistry he had become so fond of, the descriptive macroscopic chemistry of the 19th century, has been replaced by a new, unfamiliar science, of molecular objects describable by the laws of quantum mechanics.

To sum up: a most enjoyable book, replete with fascinating material for the philosopher of chemistry.

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