Building with light
Primo Levi, science and writing

by Nick Lane

This story begins with a gentle criticism that I made of Primo Levi, in my book *Life Ascending*. I did not make the criticism lightly, as Levi's books had made a searing impression on me in my formative years. But in the circumstances I felt obliged to point out that Levi had been wrong about a simple (I hesitate to say trivial) point of chemistry.

The context was an open meeting at the Royal Institution of Great Britain, that famous crucible in which Humphrey Davy, Michael Faraday and others forged their great reputations in Friday Evening Discourses. This particular evening was a bit different, but for a scientist and writer living in London, unmissable: a series of short presentations followed by a vote on the best popular science book ever written.

Who were the contenders? Names like Richard Dawkins, Steven Jay Gould, Peter Medawar and Jared Diamond sprang to mind. Rather unexpectedly, the names that featured most prominently turned out to be Konrad Lorenz, Tom Stoppard, Bertolt Brecht – and Primo Levi. The Periodic Table was named the best science book ever written, its final chapter on carbon singled out as the finest sustained piece of scientific writing.

Now I had read *The Periodic Table* twenty years earlier. At that time I knew nothing of Levi, but who could not be entranced by those tales, and by the horrors of the backdrop? I didn't remember it as a book about science, and of course Levi says as much himself; but plainly it was more ambitious than the 'microhistory' that he claimed it to be. I suspect that his protestations to the contrary should be taken in the same spirit as that antiquated device, the author's apology to the reader.

I had gone on to read other books by Levi. I remember *If Not Now, When?* as one of the finest novels I have ever read, uplifting through bleakness in the manner of Solzhenitsyn and few others. Even his lighter works, like that breezy collection of essays, *Other People's Trades*, made a lasting impression. A true writer, I recall him saying there, should be able to bring any subject to life, however dull. I still take that as a challenge. I suppose that means I aspire to be a true writer. Like Levi.

And that, I think, was the elephant in the room that evening at the Royal Institution. We all aspired to be true writers, we all aspired to literature. We held up as our ideals not the science books that challenged our world view – Dawkins et al – but the most poetic. I went away and read several of them, enjoying them greatly; but none were really science books. Then I reread Levi's chapter on carbon.

It is indeed a fine piece of writing, if perhaps to my eyes now a touch overwritten. But what really struck me on reading it again was the following passage, describing, in heightened prose, the mechanism of photosynthesis: how plants build their structures using no more than water, carbon dioxide, and the power of light.

> Our atom of carbon enters the leaf, colliding with other innumerable (but here useless) molecules of nitrogen and oxygen. It adheres to a large and complicated molecule that activates it, and simultaneously receives the decisive message from the sky, in the flashing form of a packet of solar light: in an instant, like an insect caught by a spider, it is separated from its oxygen, combined with hydrogen and (one thinks) phosphorus, and finally inserted in a chain, whether long or short does not matter, but it is the chain of life.

As I wrote in *Life Ascending*, this statement is revealingly wrong about two points, and conforms to a common misconception about photosynthesis. First, it implies that a ray of light splits carbon dioxide into carbon (which is incorporated into an organic molecule, a sugar, Levi's chain of life) and oxygen, flushed out into the world as mere waste. In other words, Levi assumed that the oxygen released by photosynthesis – without which animals could not exist – comes from carbon dioxide. And second, it implies that the conversion of carbon dioxide into a sugar is driven directly by light, and takes place in an instant. Neither is true. The actual mechanism was discovered as long ago as the 1930s, so Levi ought to have known better. There are several ironies about this; I shall come to them in a moment.

At the time, though, my reaction was to worry about the nature of science writing. Should we hold Primo Levi as the paragon of science writers, when he apparently never aspired to the title himself, and when he was plain wrong about some salient facts? Science writing should, first and foremost, be accurate. But then in science even facts change and evolve. We are all wrong, all too often. Being accurate can hardly be the measure of good science writing. That tantalising quality is more bound up in the ability to explain and inspire. Levi certainly did that. How many youthful dreams turned to chemistry after reading *The Periodic Table*? I imagine many. In that sense, Primo Levi achieved all that could be wished for.

As a writer, these issues continue to play at the back of my mind. How much fact checking can one reasonably do? Some points taken on trust, or memory, turn out to be wrong, and years later leer back at you in black and white. How much detail should a writer include, given that simplification is another form of misrepresentation? Succeed in being accurate and representative, but bore, then what? If no-one reads you, nothing is gained. I'm grateful to Levi for sharpening these questions in my mind, and I like to think that he has mulled over them too.

And there it would have rested, were it not for an email from the Primo Levi Foundation, asking if I would consider expanding a little on that passage in *Life Ascending*, in this essay, here.

So I have just reread *The Periodic Table*, and with a more mature eye noticed some ironies I had not spotted in my youth. From the point of view of science writing, and of Levi's motivation, the story of carbon dates back to what we might call his idealistic pre-war period; its execution to his post-war acceptance of (and gratitude to) a trade. The young Levi was bursting with the untold possibilities of philosophy and science; chemistry was the key to understanding the universe, to the mysteries of life.

> For me chemistry represented an indefinite cloud of future potentialities... I would watch the buds swell in spring, the mica glint in the granite, my own hands, and I would say to myself: "I will understand this too, I will understand everything, but not the way they want me to. I will find a shortcut, I will make a lock-pick, I will push open the doors."

After the unimaginable horrors of the *Lager*, Levi wound up seeing chemistry as a living, befitting the humble and ignorant human condition, but the key to little more than the ways of men. He seems to have lost his sense that chemistry is the path to understanding life.

> If to comprehend is the same as forming an image, we will never form an image of a happening whose scale is a millionth of a millimetre, whose rhythm is a millionth of a second, and whose protagonists are in their essence invisible. Every verbal description must be inadequate, and one will be as good as the next, so let us settle for the following description.

That 'following description', ironically, is precisely the passage I cite as being wrong. One description, however poetic, is not as good as the next. If it were, science, even knowledge, would be pointless.

Another irony is that he was right, in the flush of youth, that chemistry is the key to understanding life; and he was right, in the end, to be preoccupied with trades. Living things, too, ply their trades. The key to understanding life, our planet and its geology, is the trade of chemistry as practised by living cells. They carry out the kind of chemistry that Levi would have celebrated; yet by the time he was writing *The Periodic Table*, he appears to have given up trying to connect the two. I hesitate to be critical – how could it have been otherwise? – but I am sure that the dreams of the young Primo Levi would have been delighted by what we now do know about biochemistry. And for that matter, did then.

Take photosynthesis. Yes, cells use carbon dioxide to forge organic molecules. To do so, they require hydrogen, and that's why they need water. We know, because some bacteria ply a slightly different trade. They too use the energy of the sun to build their substance from carbon dioxide, but they get their hydrogen from a different source: sewer gas, or hydrogen sulphide, responsible for the stench of rotten eggs and the foul smell of flatulence. That comes from bacteria too.

Strip hydrogen from hydrogen sulphide, as Levi knew well, and you will deposit sulphur itself, biblical brimstone. That's exactly what these bacteria do. Just look at the equations:

$$2H_2S + CO_2 \rightarrow [CH_2O] + H_2O + 2S$$
$$2H_2O + CO_2 \rightarrow [CH_2O] + H_2O + O_2$$

Where $[CH_2O]$ is the general formula for a sugar, Levi's 'chain of life'. The resemblance of these two equations was first noted by the Dutch-American microbiologist Cornelis van Niel in the 1930s. He immediately realised that the H_2 is stripped from H_2S and forced onto CO_2 to form a sugar, leaving behind a mounting pile of brimstone. By exact analogy, in plants, H_2 is stripped from water, but in this case the waste product is a gas, oxygen, which bubbles away into the air. That's what the light does: it provides the energy needed to strip out the hydrogen. Light has nothing to do with carbon dioxide.

The proof that oxygen is released from water and not CO_2 came from experiments by Sam Ruben and Martin Kamen in 1940, when Levi was still studying chemistry at the University of Turin. Ruben later died tragically after inhaling phosphene gas in the lab, but not before he and Kamen had worked wonders. They made the invisible visible by using 'heavy' forms of water or carbon dioxide, which incorporate a heavier isotope of oxygen, O^{18}, in place of normal oxygen. Then they measured the weight of the gas emitted (using a mass spectrometer) to show that the heavy oxygen all came from water, not CO_2. They worked at the 'Rad Lab', the radiation laboratory in Berkeley where the first cyclotrons were built, and the story of their exploration of radioactive isotopes intertwines with the Manhattan Project, the story of the atomic bomb, a tale memorably told in Oliver Morton's fine book *Eating the Sun*.

Later in the 1940s, Melvin Calvin and Andrew Benson conducted a series of similar experiments with radioactive CO_2, to show that the biochemical steps which fix hydrogen onto CO_2 are independent of light, and can take place perfectly well in the dark. Indeed they are now called the 'dark reactions' of photosynthesis. These tales of ingenious research into the molecular mechanisms of photosynthesis unfold against the background of America's descent into the war, a pale and distorted reflection of the horrors endured in Europe.

Such experiments are how we know what little we do know; and that knowledge, that insight into mechanism, is the glory of biochemistry. It is also our surest guide back into the depths of geology and time. A final irony relating to Primo Levi lies buried there.

Rocks and life may seem diametrically opposed: the inanimate versus the animate, the unyielding against the yielding. Yet many rocks are formed by life itself, often on a fantastic scale, and not just limestones and chalks formed from the shells of sea creatures. Take iron. Great mountains, indeed whole ranges like the Hammersley Range in Australia, are composed of 'banded iron formations', the most abundant low-grade iron ore deposits in the world. Levi could not have known this, as the culprits were not discovered until the 1990s, but these mountains are in all likelihood deposited by another type of photosynthetic bacteria plying their trade.

Back then, three billion years ago, bacteria were only just beginning to split water: that is a difficult and dangerous trade. Most bacteria chose easier targets, notably hydrogen sulphide – and iron. Before the rise of oxygen, ferrous iron dissolved freely in the oceans of an anoxic world. There were (in time) literally mountains of it. These bacteria stripped this ferrous iron of electrons, and stripped protons from water itself, and combined them into hydrogen. The waste was rusty rock – ferric iron hydroxides and oxides. These settled to the bottom of the oceans on a colossal scale, heavy enough, I am told, to plunge deep into the mantle of the Earth. A small proportion was thrust back up to the surface by tectonic forces, there to be mined by others plying their trade. It is a story, I imagine, that Levi would have cherished.

There is one other: a story of rock giving birth to life. On re-reading *The Periodic Table*, this must be the deepest irony of them all. Primo Levi's first job, on graduating in Chemistry in 1941, *cum Laude*, but as a member of the Jewish race losing his entitlement to work, was in a mine in the serpentine foothills of the Alps. His task was to isolate and enrich the small quantity of nickel from the iron and (one thinks) magnesium. Despite some joy in this ancient human trade, he at times grew frustrated with the lifeless obduracy of the rock:

> At moments of weariness I perceived the rock that encircled me, the green serpentine of the Alpine foothills, in all its sidereal, hostile, extraneous hardness: in comparison, the trees of the valley, by now already dressed for spring, were like us, also people who do not speak but feel the heat and the frost, enjoy and suffer, are born and die, fling out the pollen with the wind, obscurely follow the sun in its travels. Not the rock: it does not house any energy, it is extinguished since primordial times, pure hostile passivity…

I know a geologist: a brilliant, argumentative, erudite scientific prophet, once a rough boy from East London, who started out on his career as an industrial chemist, working on nickel too. He became a distinguished mineral geologist, famed for his work on the same mineral lodes, rich in nickel or gold or pyrites, that entranced Primo Levi. Some were formed, he said, in the deep ocean hydrothermal vents. And then he metamorphosed into something else. He became obsessed with the origin of life, for he saw that life, too, began with the geochemistry of submarine vents.

Not just any geochemistry, but the reaction of water with rock: with the mother of serpentine, the mineral olivine. The rocks of the ocean floor, thrust up from the mantle below, fizz and crack with the embrace of water. They give up hydrogen gas, the mother of life itself, now free to react with carbon dioxide, no need for the energy of the sun. This rock is full of catalysts, found today in the very cells that dwell within the crevices. Among them, tightly bound up to iron, is nickel, the 'little demon' that is also the catalyst of life.

If Mike Russell is right – I say why I think he is in *Life Ascending* – then this hostile rock did indeed give up its energy in primordial times, with the release of hydrogen. How pleasing that Primo Levi tried to tease the nickel out by pumping hydrogen back in. It's hardly surprising it didn't work. His hostile rock was dead because it had already given birth to life.