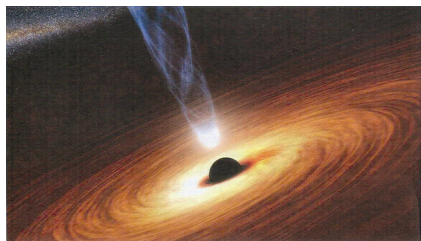


million-year-old *Sivapithecus* fossil from Late Miocene Siwalik Formation of an extinct ape as the possible ancestor of humans. But what made the rift valleys of Africa a fertile ground for the rapid rise of Homo species rather than other parts of the globe is an exciting story to be told separately.

The book chronicles the natural history of India and the milestones in the evolution of Indian landmass (which mostly remained unchronicled for the purpose of public education, despite the existence of professional geological societies in the country; also geology still remains off the limits in school syllabi). For example, many in India would not know that a major part of the evolutionary history of dinosaurs is pieced together by the fossils collected from India's Mesozoic rift valley regions (e.g. Pranhita–Godavary valley and Kutch). These 'Jurassic Parks' were veritable breeding, hunting and playing grounds of a wide variety of dinosaurs, including the flying types until nature conspired to trigger the Deccan volcanism at the end of the Cretaceous (~66 million years ago). The complete skeleton of *Barapasaurus*, the gigantic herbivorous dinosaur measuring about 18 m and weighing about 7 tonnes is exhibited at the Indian Statistical Institute, Kolkatta. Many would have heard about Lucy, the skeleton of a female of the hominin species obtained from the Ethiopian rift valley region, but may not have heard about a 236,000-year old female of Homo species called 'Narmada Man' – discovered from our backyards – Hathmora, MP. Calling it initially as 'man' was a mistake; it was actually a woman of 27–32 years old. Maybe we should have given



An artist's representation of the Big Bang nucleosynthesis and the formation of the Sun and the planets. On 11 February 2016, an international team of physicists and astronomers announced that they had heard and recorded, for the first time ever, a faint murmur or chirp which they believe was the sound of two black holes colliding a billion light years away!

her a beautiful name like Lucy, which could have been etched in public memory. Lal enchantingly attracts our attention to such mostly forgotten or little-known facts outside the academic circles with great flair and panache.

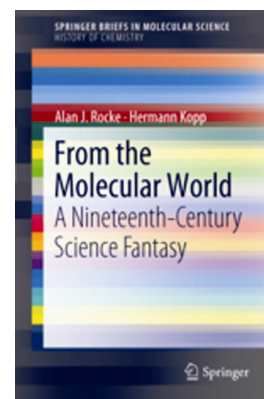
The book demonstrates how India as a unique geological entity showcases a diverse and informative natural history museum, and how this ancient land has been trampled over by spectacular creatures over millions of years in the backdrop of forests of strange-looking plants and trees, watered and washed by primitive rivers and oceans – all undergoing cycles of destruction and rebirth. The book also functions as an exposition of geo-diversity representing a variety of geological features, including rocks, minerals, fossils and landscapes that evolved over billions of years which tell us the spectacular cosmic tale of our origins. India's tumultuous geological past is recorded in its rocks and landscapes, and should be considered as our non-cultural heritage. Geological conservation seeks to ensure the survival of the best representative example of India's geological features and events, so that present and future generations can better appreciate one of the world's best natural laboratories. Unfortunately, geological conservation is an ignored subject in the country. The book cautions us about the disappearance of such treasures by the ever-expanding built environment. I have seen it happening in Kutch, Gujarat, where Mesozoic formations containing valuable geological information and fossils are being mindlessly scooped up to level the ground for construction. You may see the same mindlessness in the fast-disappearing Karewa Formation in Kashmir and Nepal, a treasure trove of 3.0 to 0.4 million old vertebrate fossils. Those who cry hoarse on vanishing cultural heritage and national pride should also worry about the disappearing geological heritage. The Geological Survey of India is the lead agency, but is it doing a good job in this regard?

This beautifully crafted book with colour figures, diagrams and photographs ends with this summation: 'There is no guarantee that the replay of the time sequence of all the chance events and accidents, starting from what happened one afternoon in a shallow stranded pool nearly 3.5 billion years ago, will again give rise to life as we know it.' This statement vaguely reminds me of what

Stephen Jay Gould, a proponent of contingency, wrote in his book, *Wonderful Life*, an old copiously annotated copy that I carry around which I bought while I was researching in University of South Carolina back in early 90s. Gould says that a replay of life's tape could 'yield an entirely different but equally sensible outcome'. He uses the analogy from a 1946 movie, a fantasy drama, called 'Wonderful Life' as an illustration for the basic principle of contingency – 'small but apparently insignificant changes lead to cascades of accumulating difference'. The hero of the movie, a frustrated businessman, who saw no meaning in his life was finally convinced by a neophyte angel who was sent from heaven to show him what life would have been like (for others around him), if he had never existed. Pranay Lal's book actually is a tutorial showing how everything in nature is related to each other and how each entity, big or small, counts in the overall scheme of things.

C. P. RAJENDRAN

*Geodynamics Unit,
Jawaharlal Nehru Centre for Advanced
Scientific Research,
Jakkur,
Bengaluru 560 064, India
e-mail: cprajendran@gmail.com*



From the Molecular World: A Nineteenth-Century Science Fantasy. Hermann Kopp. Translated, Annotated and Introduced by Alan J. Rocke. Springer-Verlag, Berlin. Series: Springer-Briefs in History of Chemistry. 2012, vii + 105 pages. Price: £44.99 (PB).

Picture this: You and a friend are visiting a newly constructed aquarium. You both walk through it, looking at the huge, gleaming compartments, each

meticulously labelled. But here's the thing: there are no animals in this aquarium. The first compartment that you look at is labelled – 'Hydrogen'. Peering inside through the glass body of the compartment, you see a 'scramble of incredibly tiny bodies swarming around in pairs'. What's more, you see that each of these creatures has one hand and that 'this one hand of the first is entwined fast in the one hand of his partner, to form a pair swimming around'. Realization dawns: you are watching hydrogen molecules in motion in the compartment in front of you. You look around in the aquarium, and see compartments labelled 'Chlor', 'Oxygen', 'Nitrogen', and so forth. In each of these compartments you see atoms with different number of hands, joining to form molecules. You take notes on their mobility, ruminate on their weights, and exult in your romp through the molecular world's aquarium. Only, you decide to call it the 'aerarium'. All of this would be true if you were born Hermann Kopp, and the friend accompanying you on this trip were Robert Bunsen.

It is this aerarium and its curator – Hermann Kopp that form the central tenets of Alan Rocke's book. It is a translation of Kopp's 1882 classic *Aus Der Molecular-Welt*. Rocke prefaces his translation with Kopp's biography, and a detailed account of how this book came to be. It is essentially a celebration of scientific imagination and a tribute to the creative genius of the chemist-turned-historian-of-chemistry, who was born Hermann Franz Moritz Kopp.

Born in 1817 in Hannau, Germany, Kopp studied at the universities of Heidelberg and Marburg, and received his doctorate in 1838 for his thesis on the links between the physical and chemical properties of elements and compounds. In 1839, he shifted to Giessen to work with Liebig. Here, he did the bulk of the experimental work of his career, and simultaneously found his interests veering towards the history of chemistry. It was at Giessen that Kopp gave his first lectures in the history of chemistry, which were published as *Geschichte der Chemie* in four volumes between 1841 and 1847. They dealt with the history of science, special branches of chemistry, the history of elements and the history of compounds. Kopp shifted to Heidelberg in 1863. This move was engineered by Robert Bunsen, already at the University of Heidelberg. Kopp had become ac-

quainted with Bunsen while at Marburg, and with time developed a deep friendship with him owing not just to their similar scientific interests. Kopp continued to serve at Heidelberg until 1890, despite financial hardships and lucrative job offers from many of the German universities. 'Bunsen alone', he once said, 'holds me fast in Heidelberg'.

Kopp's major contribution to chemistry involved his work with the calculation of specific gravity of organic compounds. His métier also extended to crystallography. However, more striking was Kopp's envisaging of the genesis of the field of physical chemistry based on the interplay of chemical and physical properties of compounds in his research.

Aus Der Molecular-Welt began life in the autumn of 1876 when Kopp was investigating certain salt solutions to determine whether they existed as hydrates or in the anhydrous state in solution. He conjectured that anhydrous salts could form hydrates only when they crystallized out of solution. Kopp imagined the salt and water molecules knocking about in solution, when his train of thought led him to gaseous bodies. Finding the latter state of matter more interesting and productive, he abandoned his work on salt solutions and forgot all about his draft on the work until early 1882.

Molecular-Welt got a second lease of life as a birthday gift for Bunsen. The latter was vacationing in Naples, Italy during his birthday, when Kopp decided that he needed to present something special to Bunsen to commemorate their 'long and close friendship'. Hard-pressed for time, rummaging through his desk, Kopp found his first draft of *Molecular-Welt*, and decided he could modify it a little to be presented to Bunsen. In his words, he 'adapted it to the present purpose, which necessitated some additions'. C. Friedrich Winter Book-Press, Darmstadt's services were sought, and *Molecular-Welt* went into print for a limited number of copies. One of these printed copies (105 pages) made its way into Italy to be delivered to Bunsen as his birthday present.

Molecular-Welt draws heavily from the founts of Kopp's creative genius. The manuscript enthalls with its author's laconic humour and his penchant for analogies. It is a picturization of what might possibly be happening in the sub-microscopic world and delivers a treatise

on atomic valence, molecular structure, solution theory and the kinetic theory of gases. The atoms, molecules, compounds and radicals that we meet here on our walk through the aerarium have personalities. They have dialogues, they dance, and they enjoy music. Here's a sample: Organic molecules like methanol and ethanol are enclosed in distinct hot-air balloons, which in turn are encased in their labelled-compartments. The molecules in these balloons do a sort of 'chain dance'. The chain part depicts the arrangement of atoms along the carbon backbone/around the central carbon atom. And the dance part depicts how the molecules race along in a straight line, until they experience a collision, and then move straight again.

Kopp definitely liked what he saw through his mind's eye, and averred that his construction of the aerarium – and his fantasy world, in general – was a reflection of what went on in his mind as a scientist. What's interesting here is that in stark contrast to this tendency to revel in imagination, as a young man, Kopp's scientific research was pursued purely inductively. Of those days, he had once said: 'The imagination has nothing to do with scientific research, which must proceed "soberly" and "without the assistance of other powers of mind".'

This was the 1850s, and by the time *Molecular-Welt* came out in 1882, a lot had changed. The most prominent change perhaps was the growing predominance of organic chemistry in Germany. What is noteworthy in this is the hypothetico-deductive underpinning of organic chemistry as opposed to the inductive method in which Kopp was involved. He realized this change around him, and Rocke suggests that *Molecular-Welt* might well be his attempt at coming to terms with this transformation. This however was not easy for Kopp, and he once said: 'But in the evening of my life, I often find it a bitter thought that I came to this world with the unfortunate characteristic of constantly seeking my place between two stools.'

Speaking at the Karlsruhe Congress in 1890 about his dream of snakes swallowing their tails and his discovery of the structure of the benzene molecule, Kekulé remarked: 'I saw what the venerable Kopp, my honoured teacher and friend, so charmingly depicted for us in his "*Molecular-Welt*" but I saw it long before him.'

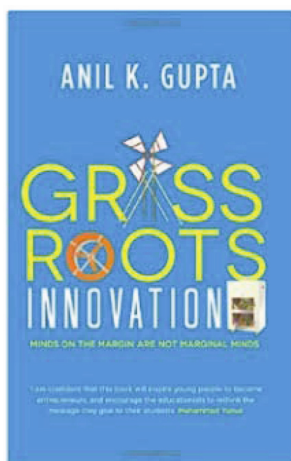
Kopp was not the first to indulge in imagination to explain his science, and the history of science is a testament to the fact that he was not the last. Think Max Planck, Niels Bohr and Albert Einstein.

Science and imagination. Seemingly unlikely bedfellows at first thought, but a closer look reveals otherwise. How does one explain the role of imagination in science, given that the hallmark of science as we know it is empiricism? In essence, this is the question that Rocke, and ultimately Kopp seem to be grappling with. Do we have answers? Yes and no.

In Rocke's translation, Kopp at places appears somewhat obscure as he moves easily from a Mozart reference to a sonnet of Shakespeare as his molecules go about enjoying these finer things in life. (Kopp initially trained to be a philologist, but turned to chemistry, inspired by Leopold Gmelin.) Rocke on his part makes these analogies understandable for the reader with his extensive footnotes. This fantasy world of Kopp is ultimately not for the general reader, but will make an interesting read for someone with interest in the history of chemistry in general, and the workings of scientific imagination in particular. In looking up certain biographical sketches of Kopp on-line, I found that some authors consider him the first historian of chemistry. Though there were other histories of chemistry before Kopp's, none was as accurate and comprehensive as the *Geschichte der Chemie*. For this reason, and for Kopp's seminal contributions to chemistry, his anthropomorphic molecules will find takers. In the final analysis, this stroll through Kopp's aerarium is an invitation to dream.

SANGEETHA BALAKRISHNAN

PG Department of Chemistry,
Women's Christian College,
Chennai 600 006, India
e-mail: balakrishnan.sangeetha@gmail.com



Grassroots Innovation: Minds on the Margin are not Marginal Minds. Anil K. Gupta. Penguin Books India Pvt Ltd, 7th Floor, Infinity Tower C, DLF Cyber City, Gurgaon 122 002. 2016. 381 pages. Price: Rs 599.

Innovation, a buzzword in the globalized world economy, predominantly refers to technological changes within the formal sector, although the genealogy of the word shows its use in ancient and medieval times with a negative connotation. This was not an important concept until the 'Schumpeter Mark I&II' that has changed its understanding and revolutionized the field of innovation studies. Also, the agents of change in Mark I, i.e. individual innovators were replaced by firms in Mark II. However, at the turn of the 21st century, scholars and policymakers once again focused on individual innovators, especially in the informal sector in India. This book is a timely intervention in terms of highlighting the contribution of these 'unsung heroes' or the 'grassroots innovators', as termed by the author Anil Gupta.

The author, a renowned name in the field of grassroots innovation, describes such innovators as a rich source of knowledge and inspiration for millions in the country. He has been the brain behind institutions and networks like Honey Bee Network (HBN), Society for Research and Initiatives for Sustainable Technologies and Institutions, Grassroots Innovation Augmentation Network, National Innovation Foundation and many more such initiatives to support the grassroots innovations movement. This book is an elaborate narrative of the author's journey, and the associated experiences and experiments with the

grassroots innovations over two and half decades in and outside India.

The book contains eight chapters; the introductory chapter rightly sets the tone by introducing the philosophy behind the grassroots innovations movement in India. It also unlocks many hidden tales and anecdotes from the author's college days, tracing the genesis of this movement. The author attributes his ideas to this fairy-tale journey and how it fed into his thought process to help him reach the present position in his life. The second chapter, in continuation with the first, explains in detail the context of setting up HBN in India. However, one has to note that the Network's roots can be traced in the philosophies of Gandhi and Tagore, and their discussion on *Charkha* and *Shantiniketan* respectively¹. The author too has acknowledged Gandhi as the source of ideas on several occasions. Further, the author has provided a detailed account of individuals, institutions and organizations engaged in the process and problems faced by the movement. Such an experiment of creating networks of organizations in itself was an excellent example of organizational innovation in the context of informal sector innovations. The narratives are relevant and useful, especially for the young generation when it is looking for start-ups in the formal sector, and this experience may encourage youngsters to think about informal sectors too.

The third chapter discusses *Shodhyatra*, one of the important institutions related to grassroots innovations, organized twice a year by HBN mostly in remote locations of the country. The idea is to seek, recognize and reward the knowledge of grassroots communities at their doorsteps. So far, HBN has organized 38 such yatras, which have proved instrumental in building trust with the local communities across India. The chapter is further enriched by many experiences from the field that are shared by the author to highlight the institutional innovation by the network.

The fourth and fifth chapters are dedicated to knowledge of grassroots communities. The author argues that we are largely ignorant of the developments happening at the grassroots level. However, he strongly puts forth the need to pay special attention to such innovations happening at the grassroots level; also people can be trained to cater to the specific needs of their local settings. The