JOINING KEKULÉ'S DOTS

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"Let us learn to dream, gentlemen, then perhaps we shall find the truth."

– August Kekulé

science, art and myth have chemistry

Science and art are opposites: the one is a dispassionate quest for objective truth, the other deliberately stirs emotions. They differ in the ways they select, organise and use data. And yet they share a vital element: imaginative thinking. In science this is the catalyst behind the formulation of new testable hypotheses. In art it can be an end to itself.

Myth is multivalent in that it operates on multiple levels. In their oldest settings, myths often bore strong sociological and psychological connotations, setting paradigms for law, custom, morality and spirituality. They were artistic in terms of their creative narration and performative aspects. At the same time, though less well known, they were also protohistory and protoscience – the very first attempts to make sense of the past and how nature works. Naïve, inconsistent and selective, they were baby steps on the way towards a disciplined, coherent and open-ended cosmology.

Myth was art at the cradle of science. When the Greek philosophers started building knowledge from scratch with the tool of rational discourse, hoary myths still provided the starting point for some of their cosmological theories. For example, Thales identified water as the first and fundamental element, but in doing so was repurposing the old mythical motif of the primordial ocean. The pre-Socratic theory that the elements of fire and air rose while those of water and earth sank was a precursor to gravitational physics, but also a reinvention of the folktale of the separation of sky and earth. And the wind or winding serpent of creation myths became the philosophers' original vortex, which sorted matter and survives today in the circling of the heavenly bodies around the pole.

This process of myth inspiring scientists arguably continues to the present day, be it in a haphazard and often concealed fashion. The 'Big Bang' theory was the brainchild of Georges Lemaître, a Belgian Catholic priest and scientist. His references to the 'primeval atom' and 'cosmic egg' show that he was no stranger to the old mythical concept of a primeval particle from which the universe arose.

And what about chemistry? From antiquity on, the alchemists persistently represented some stage in the *magnum opus* of gold-making by the emblem of the snake that eats its own tail – the *ouroboros* (οὐροβόρος). This motif occurred in places as far apart as Amazonia and Japan, but the alchemists specifically drew on its Egyptian expression, which originated in solar symbolism and was much used in magic. And the circular serpent did not end its influence there. It also ushered in the birth of structural chemistry. Enter Kekulé.

Kekulé's dreams

In chemistry, the structural theory provides the framework for understanding the positioning and state of atoms within a molecule. Its chief architect was the German scientist Friedrich August Kekulé (von Stradonitz) (1829-1896). At a conference held in his honour in 1890, he gave a speech revealing that the seeds had been sown around 1855 with a daydream:

> During my stay in London I resided for a considerable time in Clapham Road in the neighborhood of Clapham Common. I frequently, however, spent my evenings with my friend Hugo Müller at Islington at the opposite end of the metropolis. We talked of many things but most often of our beloved chemistry. One fine summer evening I was returning by the last bus, 'outside', as usual, through the deserted streets of the city, which are at other times so full of life.
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> I fell into a reverie (*Traümerei* [*sic*]), and lo, the atoms were gamboling before my eyes! Whenever, hitherto, these diminutive beings had appeared to me, they had always been in motion; but up to that time I had never been able to discern the nature of their motion. Now, however, I saw how, frequently, two smaller atoms united to form a pair; how a larger one embraced the two smaller ones; how still larger ones kept hold of three or even four of the smaller; whilst the whole kept whirling in a giddy dance. I saw how the larger ones formed a chain, dragging the smaller ones after them but only at the ends of the chain. … The cry of the conductor: 'Clapham Road', awakened me from by dreaming [*sic*]; but I spent a part of the night in putting on paper at least sketches of these dream forms. This was the origin of the 'Structural Theory'.[1]

One result was Kekulé's discovery that carbon atoms are tetravalent. Soon after, he deduced that they can bond with each other. These first successes, printed in 1857-1858, opened the door for his most remembered contribution to science. Until then, all known types of atomic bonding involved open, linear arrangements. Benzene (C_6H_6), first isolated by Michael Faraday in 1825 from an oily residue of the production of coal gas, presented the enigma that it was highly unsaturated yet slow to react, counter to normal expectations. Chemists struggled to figure out its molecular structure until Kekulé found the answer: a ring of six carbon atoms, with alternating single and double bonds, and a hydrogen atom attached to each carbon atom by a single bond. Published in 1865, this realisation came to him through a second reverie. As he recounted in that same speech:

> Something similar happened with the benzene theory. During my stay in Ghent I resided in elegant bachelor quarters in the main thoroughfare. My study, however, faced a narrow side-alley and no daylight penetrated it. For the chemist who spends the day in the laboratory this

[1] Kekulé 1890: 1306, tr. Benfey 1958: 21.

> mattered little. I was sitting writing at my textbook but the work did not progress; my thoughts were elsewhere. I turned my chair to the fire and dozed.
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> Again the atoms were gamboling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by repeated visions of the kind, could now distinguish larger structures of manifold conformation: long rows, sometimes more closely fitted together all twining and twisting in snake-like motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I awoke; and this time also I spent the rest of the night in working out the consequences of the hypothesis.[2]

how did it happen?

Over time, Kekulé's dreams have elicited a wealth of diverse opinions – enough to fill a book. Had he been truly asleep or not? And what was the tail-biting snake he saw? Cognitive scientist Margaret Boden was at a loss: "Maybe Kekulé, taking a country walk before his fireside nap, had encountered a snake (dead or alive) with its tail in its mouth. Or his intuition might have been triggered by his dozing dream-memory of a snake in a painting by Hieronymus Bosch. Conceivably, the snake-image might have arisen from physiological causes, thanks to some foodstuff or hallucinatory drug which upset Kekulé's mental processes. The possibilities are endless. … We shall never know just how Kekulé's idea arose in his mind."[3]

'Skeptic' Michael Shermer reckoned that Kekulé had been "lost in thought" and was just speaking figuratively, similar to saying that "the solar system is like a giant clock; memory is like a hologram."[4] However, the idea of an autophagous snake is hardly intuitive and informative enough to have been consciously devised as a rational metaphor for molecular structure. Consuming its rear end is not something a snake does routinely, though there have been cases.

The *ouroboros* of myth and alchemy didn't rate a mention with these writers, but the connection is obvious to symbologists. Kekulé hinted:

> It was said that the benzene theory appeared like a meteor in the sky, absolutely new and unheralded. Gentlemen! The human intellect does not operate in that way. Something absolutely new has never been thought, certainly not in chemistry. Anyone who has studied the historical development of his science from his student days on, as I have, first as a hobby and then later, as befits old age, by immersing himself anew in thorough studies of the pioneers, can certify that no science has developed as steadily as has chemistry.[5]

He must have been alluding to the alchemical tradition, in which the *ouroboros* takes pride of place. This much was noted long ago by John Read in a history of alchemy.[6]

Had Kekulé been fully awake, the image could have been a returning memory from past reading without him recognising it as such – cryptomnesia for short. In the context of sleep, the creature's spontaneous appearance looks more like an archetypal manifestation from the collective unconscious, as Jung claimed in his final book.[7] Or was Kekulé's

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[2] Kekulé 1890: 1306, tr. Benfey 1958: 21.
[3] Boden 2004: 67.
[4] Shermer 2001: 273.
[5] Kekulé 1890: 1304, tr. Benfey 1958: 21.
[6] Read 1937: 241.
[7] Jung 1964: 38.

subconscious recycling something it had absorbed much more recently? So organic chemist Arthur Greenberg:

> Did August Kekulé actually dream about the ouroboros when he postulated that benzene was a cyclic compound? … What was Kekulé reading before he dozed off? Perhaps Libavius' Alchymia … inspired his serpent dreams. Perhaps Porta's tortoise … was the clue he needed for benzene's structure.[8]

Half awake with eyes shut, the pioneer surely entered the *alpha-thēta* (α-ϑ) range of brainwave frequencies. Trance-like, this corresponds to the hypnagogic state or transition into sleep.[9] Carl Alfred Meier, who was a Jungian psychologist, felt that the round snake, far from biological, was the archetype surfacing in that mental stage.[10]

Apophenia might be a piece of the puzzle. This is the false tendency to see apparent patterns in random things. When these are visual, it is called pareidolia. Walter Hehl, a physicist, credited Kekulé's revelation to this type of cognitive bias, but gave no details.[11] To avoid a circular argument, Kekulé would have to have seen something that he already knew in the random 'atoms', such as snakes or the alchemical *ouroboros*. He would not have hallucinated these directly, but observed something else that somehow *resembled* snakes. What could have set these wheels in motion?

in the eye of the beholder

Biological psychologist Heinrich Klüver regarded the cavorting 'atoms' as entoptic phenomena.[12] These are visual effects produced within the eye, best known from 'floaters'. If Kekulé had had his eyes closed, he may in particular have seen phosphenes – light forms perceived while no light actually enters the eye. Only one writer – the obscure Joseph Aloysius Mast (1914-1993) – seems to have made that exact suggestion,[13] but it rings true. Phosphenes often make up the hallucinations people have in the early stages of trance, whether induced by means of psychotropic drugs or sensory deprivation. They are also a well-known hypnagogic effect.

Spiralling filaments are a common entoptic form and could strike one as snakes, but who can make heads or tails of the circular pose? Was that a pure hallucination, separate from any phosphenes? Or did entoptics produce that, too? Klüver believed so:

> This hexagonal pattern was seen entoptically by Purkinje, Konig, and many other observers. I have seen it on several occasions, not with closed eyes, but on the ceiling after awakening. It is highly probable that Kekule, who was used to watching repeated visions and configurations gamboling before his eyes, also saw hexagonal patterns either entoptically or in hypnagogic hallucinations.

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[8] Greenberg 2007: 79 figure 55, 441, *cf.* 78; similarly Schütt 2000: 572 note 39.
[9] *e.g.*, Mavromatis 1991: 289-292 and pp. 193, 199, 212-214, 217 for Kekulé, without a link to the *ouroboros* (see p. 252); Lewin 1969: 118 (he misunderstood the vision as a ring of multiple snakes); Cvetkovic & Cosic 2011; Foulkes & Vogel 1965.
[10] Meier 1984: 21-23.
[11] Hehl 2021: 234.
[12] Klüver, in von Foerster 1950: 233 (*non vidi*), in Doyle 2011: 132; also Polland 1996: 57-64, 150, 161.
[13] Mast 1991: 66.

Neither Klüver nor Mast factored in the classic *ouroboros*, but if that familiar image was involved, was it by pareidolia that Kekulé's brain read it into a phosphene circle? Or did the age-old symbol pop into his awareness as an associative afterthought, as soon as watching one 'snake' bend opened his eyes to the solution of the benzene problem? One way or another, the *ouroboros* through this timely 'brainwave' consolidated the shift from alchemical pseudoscience to the pure science of structural chemistry. And thereby hangs another 'tail'.

Crick and Watson

James Watson and Francis Crick worked out the double helix structure of the DNA molecule in the early 1950s. They cannot have missed the symbolic resemblance to the two serpents twined around the winged staff of the classical god Hermes – the so-called *caduceus*. Was this another case of mythical serpents popping up at a pivotal moment in chemistry, this time in biochemistry? Watson, in his autobiography, recalled an episode of fruitless 'musing' in front of the hearth fire:

> Back in my rooms I lit the coal fire, knowing there was no chance that the sight of my breath would disappear before I was ready for bed. With my fingers too cold to write legibly I huddled next to the fireplace, daydreaming about how several DNA chains could fold together in a pretty and hopefully scientific way. Soon, however, I abandoned thinking at the molecular level and turned to the much easier job of reading biochemical papers on the interrelations of DNA, RNA, and protein synthesis.[14]

This reads like a humorous nod to Kekulé, telling those with eyes to see that Watson's problem required more than some quiet reflection by the fire. In similar vein he told of a flash of insight he had on the bus to Oxford.[15] Not picking up on that, science writer Nancy Tiley helped a myth into the world: "He awoke with the first acceptable formula for the structure and the function of DNA. … Watson's dream concerning the double helix, described in his book, *The Double Helix*, is an example of how the creative realm has assisted genetics."[16]

Other canards doing the rounds are that Watson had a crucial dream of a spiral staircase[17] and that Crick had benefitted from a small dose of LSD.[18] Thus, science in the end begets its own 'myths' and this brings one full circle.

psychedelicious food for thought:

nominative determinism: Kekulé's surname is Czech. It is etymologically related to the Greek and Latin words for 'circle' (*kýklos* and *circulus*) as well as the English *wheel*. All come from the Proto-Indo-European stem $^{*}k^{w}ek^{w}lo$-, 'round, wheel'.

simultaneous discovery: Archibald Scott Couper (1831-1892) independently discovered the tetravalence and self-linking of carbon and proposed two ring compounds in 1858,

[14] Watson 1968: 152-153.
[15] Watson 1968: 114.
[16] Tiley 1983: 52, 60.
[17] *e.g.*, Fagan & Durrani 2019: 34; Bleakley 2024: no page number yet.
[18] Rees 2004, repudiated in Ridley 2006: 156-157.

but was delayed in his publishing and did not provide evidence. There were some French influences, too.

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