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DOI: 10.2478/cdem-2023-0003 CHEM DIDACT ECOL METROL. 2023;28(1-2):39-55

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DOES SENDIVOGIUS' ALCHEMY CANCEL THE CELEBRATION OF THE 250TH ANNIVERSARY OF THE DISCOVERY OF OXYGEN?

Abstract: Most chemistry textbooks claim that oxygen was discovered almost simultaneously by Carl Scheele and Joseph Priestley about 250 years ago. Priestley obtained oxygen by heating mercuric oxide (1774), and Scheele - by heating $NaNO_3$, as well as by dissolving pyrolusite in sulfuric acid (1772). The name "oxygen" was given a few years later (1779) by Antoine Lavoisier. This great scientist, often accused of taking advantage of the discoveries of others, conducted experiments related to the decomposition of water vapour over heated iron, as well as the synthesis of water from hydrogen and oxygen. His work was of great importance because it revealed the elemental nature of oxygen and its role in the processes of combustion and respiration. The present article draws attention to the prehistory of the "oxygen theory". It emphasises the natural philosophy of a forgotten alchemist, healer, and diplomat - Michael Sendivogius (1566-1636) - who popularised his belief that the substance ("Water of life that does not wet the hands") obtained by heating the "Central Salt" (nitre, KNO_3) is part of the air. It is the "secret food of life" used invisibly by every living thing.

Keywords: Sendivogius, history of chemistry, alchemy, oxygen

I required again of him, Sir, Doe many know that Water, and hath it any proper name? He cryed out saying, Few know it, but all have seen it, and doe see it, and love it: it hath many and various names, but its proper name is the Water of our Sea, the Water of life not wetting the hands. I asked yet further, Doe any use it to any other things? Every creature (saith he) doth use it, but invisibly. Then I asked, Doth anything grow in it? But he said, of it are made all things in the world, and in it they live: but in it nothing properly is, but it is that thing which mixeth it self to everything.

M. Sendivogius, 1604
(Translated by John French, 1650)

Introduction

The modern chemist, who tries to understand the period of alchemy, meets with considerable difficulties, connected not only with the remoteness of time, but also with the peculiarities of the problems posed, and with the strange, misty, and symbolic language, intended only for the adept. Early chemistry, and particularly its alchemical period, may be compared to a tree whose roots are buried deep, and many of its branches are blown away

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by the winds of time. Its history can hardly be seen as a chain of sequential events, although this may prove a useful approach to its study.

The primary goal of the alchemists was to obtain the Philosopher's Stone, a mysterious tool that could turn base metals into gold - the perfect metal that does not tarnish and corrode. Another role of the same tool was to serve as a remedy, infusing health and perfection into the human soul [1, 2].

"Alchemy is the art of producing magisteria [Philosopher's stone] and of extracting pure essences by separating bodies from mixtures" wrote Livabius in his textbook "Alchemia" (1597) [3, p. 21], which claims to summarise all discoveries made by alchemists up to that point.

One of the alchemical aspects related to the role of the Philosopher's Stone in the processes of transmutation was the idea of living metals and minerals [2, 4, 5]. Like plants and animals, they were born from seeds, grew, decayed, and died. These simple creatures lived long and changed slowly. After their birth in the depths of the earth they rose to the surface, ripening in motion. Depending on the path taken and the speed of ascent, they "surfaced" in different forms. If the ascent was rapid, the mineral would be impure, immature, and corrupt. On the other hand, if the ascent was slow, the mineral would "ripen" into the form of gold [2]. In this regard, the Philosopher's Stone could be seen as a "purification plant" or "catalyst" accelerating the natural processes of maturation of imperfect metals.

From a modern perspective, the idea of living metals is absurd, and the search for the Philosopher's Stone is a hopeless endeavour. The search for an instrument of perfection, however, was not the only characteristic of the alchemical period. An illustration of this is Roger Bacon's (1220-1292) definition of "speculative alchemy" [6, p. 185], in which he deservedly used the word "science":

Sed alia est scientia, quae est de rerum generatione ex elementis et de omnibus rebus inanimatis: ut de elementis et de humoribus simplicibus et compositis; de lapidibus communibus, gemmis, marmoribus; de auro et caeteris metallis; de sulphuribus et salibus et atramentis; de azurio et minio et caeteris coloribus; de oleis et bituminibus ardentibus et aliis infinitis, de quibus nihil habemus in libris Aristotelis. ("But there is another science [speculative Alchemy] of making things out of elements and inanimate objects, as well as a science of the elements and of simple and complex fluids; for common and precious stones and marbles; for gold and other metals; for sulphur and salts; for azure, minium, and other dyes; of oils and burning resins, and an infinite number of other things, which are not mentioned in the books of Aristotle.")

This article is devoted to the alchemy of a forgotten and maligned alchemist, healer, Rosicrucian, and diplomat - Michael Sendivogius (1566-1636) - who popularised his belief that the substance ("Water that does not wet the hands") obtained by heating the "Central Salt" (nitre, KNO_3) is part of the air. He knew that this "secret food of life", which we now call oxygen, was used invisibly by every living thing, but he realised that only the wise would understand this.

Living in times when the discovery of elements in the "element of air" was "impossible" from both a theoretical and a practical point of view, he showed observation and flair. Stepping on the Emerald Table of Hermes, Aristotle's doctrine of the elements, and Paracelsus' conception of the three principles, he developed a two-part theory. The first part was called "geological theory" by Bugaj [7], and "theory of matter" by Porto [8]. In it, based on analogies and symmetry, he described his ideas about the structure of the

universe. In the second "chemical" part, called "Central nitre theory" by Szydlo [9-12], truths about the properties of nitre and its thermal decomposition products shine through.

Sendivogius' ideas were developed and presented to the reader in several books, before van Helmont's conception of the gas [13, p. 17] and before the invention of the air pump and pneumatic trough, important tools in the hands of pneumatic chemists of subsequent generations.

On Paracelsus, salt, gunpowder, and thunder

Before we dwell on the philosophy of Sendivogius let's look at one of the greatest philosophers of the 16th century - Philippus Aureolus Theophrastus Bombastus von Hohenheim, known as Paracelsus (1493-1541) - who was deservedly called by medieval and modern authors "the Zenith, and rising Sun of all the Alchymists" [14, p. 184].

Paracelsus pioneered the reformation of medicine using chemicals and minerals. He is considered "the father" of iatrochemistry and toxicology and his thought that "the dose makes the poison" features in the introductions of many modern pharmacy and toxicology textbooks.

Paracelsus viewed the functioning of the living organism as a set of chemical processes governed by Archeus (life force, soul). He assumed that anatomical organs act alchemically, in the sense that they separate the pure from the impure. Accepting the four ancient Greek elements (air, fire, water and earth), he believed that they manifested in every body as three alchemical principles: sulphur, mercury and salt [3]. Mercury was the principle of volatility and fusibility, sulphur of flammability, and salt of incombustibility and incorruptibility. To illustrate this theory, he set fire to a piece of wood, associating the fire with sulphur, the smoke with mercury, and the residual ash with salt [15].

For Paracelsus, salt was the "universal natural balsam" that protects man from decay [3, p. 20]. He distinguished three types of salt, namely sea, spring, and mineral:

"There is sea salt, which is salt of itself, not salted by others. As wine differs from water, so the sea in its nature differs from other waters. Other waters are sweet; this is salt. Secondly, there are some springs which are sweet yet salt at the same time. These have a special nature, insomuch as they have that nature not in common with the sea, but of themselves contain a different kind of salt. Thirdly, there are also mineral salts, with the appearance of a stone, of a different kind from other metals or minerals" [16, p. 259].

Paracelsus also mentioned the salt nitre (KNO_3) that is formed in stables and pens. For him it was the "perfect salt":

"It is composed naturally of the natural salt of animals' bodies, and the salt of nutriment in those bodies combined… The two constituents are more and more closely united, so that from them results one single and perfect salt ..." [16, p. 100].

Paracelsus saw an analogy between gunpowder ("blasting powder" or "earthly thunder") containing sulphur and nitre (saltpetre) and thunderbolts that resembled the gunpowder explosion [9, 11, 17]. Gunpowder was a human work and thunder was a divine work resulting from the action of Aerial nitre and Aerial sulphur.

The analogy mentioned above is directly related to the *Tabula Smaragdina* (The Emerald Table), a compact enigmatic text attributed to Hermes himself:

"*Quod est superius est sicut quod inferius, et quod inferius est sicut quod est superius. Ad preparanda miracula rei unius.*" ("That which is above is like to that which is below,

and that which is below is like to that which is above, to accomplish the miracles of one thing.") [18].

Who is Michael Sendivogius?

In his book *History of Chemistry*, Michele Giua made an unexpected connection between Paracelsus and Antoine Lavoisier (1743-1794). He argued that the gap between "these two great and passionate designers of our science, creating fruitful theories about it" was not so wide [1, p. 59]. The idea of such a connection also appears in Debus's article on the Aerial Niter [17]. Today it can be safely said that the main link in the chain connecting Paracelsus's "perfect salt" with Lavoisier's oxygen was Michael Sendivogius. This great Polish thinker was the most widely published alchemist. According to Prinke [19], who compares his impact with that of Nicolaus Copernicus and Marie Skłodowska-Curie, Sendivogius's treatises underwent at least 80 editions in several languages (Latin, German, French, English, Russian and Dutch [20]) by the beginning of the 19th century. Obviously, interest in his works continues to be high, with around 50 more editions and new translations in other languages published since the beginning of the 20th century [19].

Fig. 1. Fragment of the title page of Michael Meyer's *Symbola Aureae Mensae Duodecim Nationum* (Symbols of the Golden Table of the Twelve Nations, 1617) [21]

Sendivogius tried to keep his name hidden from his contemporaries (see below). As a result, he was depicted on the title page of Michael Meyer's Symbols of the Golden Table of the Twelve Nations (1617) [21] as one of the twelve great adepts (Fig. 1) under the name "Anonymous the Sarmatian" (which can be translated as The Anonymous Nobleman from Poland). On this page he is in the company of such authorities as Hermes Trismegistus, Democritus, Thomas Aquinas, and Roger Bacon.

In recent decades, several scholars have undertaken an in-depth study of Sendivogius' life and work. Despite their efforts, much of his early career remains a mystery. It is known that he was born on February 2, 1566, either in Skorsko, in Lukawica, or in Krakow (Poland) [19, 22, 23]. At first, he entered the Jagiellonian University in Krakow (then the capital of Poland) [20]. It was probably there that he first met alchemy and the teachings of Paracelsus [20, 24, 25]. Here he befriended Mikołaj Wolski, an influential nobleman, art devotee and alchemist who, along with the Holy Roman Emperor Rudolph II, was considered his patron. It is likely that both helped him to travel abroad to get a comprehensive education and Hermetic knowledge [11, 25, 26]. It is known that he studied in at least three foreign universities - Leipzig, Vienna, and Altdorf [11, 19]. Early sources also listed some other universities that he attended, such as Cambridge, Ingolstadt, Frankfurt, Rostock, and Wittenberg. Other places he visited were Russia (Moscow), Sweden, Italy (Vatican Library), the Ottoman Empire (Constantinople), Spain, Portugal, and Switzerland [22, 25].

Fig. 2. Alchemist Sendivogius. Painting by Jan Matejko from 1867 [30]

In 1591 he received a diploma from the University of Vienna. Three years later, he officially became a courtier of Rudolph II [27] in Prague, the "European capital of alchemy". From 1595 he was the secretary of the Polish king Sigismund III Vasa, and from 1598 - an imperial counsellor at the Diet of Regensburg [26]. Between 1600 and 1604 Sendivogius was mostly in Poland participating in important diplomatic missions [11, 20].

A notable episode in his alchemical career was a demonstrative transmutation of base metal into gold (1604) before Rudolph II and many witnesses [11, 28]. In honour of this event, the Emperor ordered a marble tablet to be displayed in the room where the transmutation took place with the following inscription [11, p. 23; 20; 29, p. 134]:

"*Faciat hoc quispiam alius, / quod fecit Sendivogius Polonus*!"

("Let anyone else do what Sendivogius the Pole has done!")

None of the contemporary researchers of Sendivogius dared to interpret from a chemical point of view this "transmutation" [11] immortalised by the famous painting of Jan Matejko (Fig. 2). The fire of January 1595, which burned part of the north wing of the Royal Castle in Kraków, was easier to interpret - it could be attributed to the alchemical experiments of Sendivogius and Wolski.

The corpus of Sendivogius' works

Sendivogius strove to write short books and encouraged his readers to familiarise themselves with the writings of other authors as well [31, p. 79]. Like the Curies, this "lover of truth" believed that science should benefit humanity, not specific individuals. His main motives for concealing his identity were altruism and modesty.

"It seemed good to me for some Reasons to conceal my name, whilst I doe not seek praise to my selfe, but endeavour to be assisting to my lovers of Wisdome. Therefore I leave that vain desire of honour to those that had rather seem to bee, then to bee indeed" [31] (A2).

"I seek neither profit, nor vain glory by them [my books]; therefore I doe not publish who I am" [31, p. 75].

Sendivogius maintained his anonymity with anagrams and pseudonyms. He used several anagrammatic forms of his name: *Divi Leschi Genus Amo* [I love the divine race of the Lechites (i.e. Poles)], *Angelus Doce Mihi Ius*, [Angel, teach me justice] and *Ioachimus d'Estinguel*. The first two anagrams can be easily obtained by rearranging the letters of his name (Michael Sendivogius). The third anagram contains the redundant letter "t".

His primary pseudonym *Cosmopolite* (i.e. citizen of the world) caused great confusion after the mid-17th century [24, 32, 33]. Still, some modern books based on 17th- and 18th-century texts erroneously claim that *Cosmopolite* was a pseudonym for the Scottish alchemist Alexander Seton, which was posthumously appropriated by Sendivogius (1604). In his paper "Michael Sendivogius - Adept or Impostor?" [25] Prinke retold a false story according to which, in addition to Seton's pseudonym, Sendivogius appropriated his widow, a remnant of the transmutation powder, and his best book *Novum Lumen Chymicum* - a real hit, republished many times under different names (see below). In fact, Sendivogius had already used this pseudonym at least six years before Seton's death [33].

Roman Bugaj was the first to undertake the difficult task of a comprehensive summary of the works and editions of Sendivogian corpus. His list of Sendivogius's works included the following items [11, 34]:

- *Operatie elixiris Philosophici* [Operations on the Philosophical Elixir] (written in 1586-1590 in Polish/Latin, discovered in manuscript form by Bugaj and translated in 1965 into modern Polish).
- *Processus super centrum universi, Seu Sal centrale* [Process on the centre of the Universe, or the central Salt] (1598); published posthumously in 1651.
- *Tractatus de Lapide Philosophorum* (1604).

- *Parabola, seu aenigma philosophicum* (1604).
- *Dialogus Mercurii, alchymistae et Naturae* (1607).
- *Tractatus de sulphure* (1613).
- *55 Lettres Philosophiques* (1616?; full text published in 1702).

In his dissertation [11], Szydlo proposed four more works to be added to Sendivogius's corpus: *Harmonia* (also known as Treatise on the true salt); Treatise on Salt, 1656; Philosophical Letters, 1659; and Statutes of the Unknown Philosophers, 1691.

Goodall [20] wrote that Sendivogius "produced at least ten works". This statement is consistent both with the information given by Daniel Stoltius (1600-1660), who noted in his *Viridarium Chymicum* (1624) that Sendivogius was the author of twelve books [9, 35], and with Prinke's work [33], who disputed Sendivogius' authorship of two of the books included in Szydło's list (Treatise on Salt and Harmony).

The best-known Sendivogius' works were *Tractatus de Lapide Philosophorum* (1604), *Dialogus Mercurii, Alchymistae et naturae* (1607) and *Tractatus de sulphure* (1613). They were often published together under the general title *Novum Lumen Chymicum*, first translated into English by J. French as New Light of Alchymie (1650) [31]. Great scientists such as Isaac Newton and Antoine Lavoisier are known to have owned and read copies of this book [10, 12, 28, 36-39]. A contemporary advertisement for the same book states that it "has been selected by scholars as being culturally important and is part of the knowledge base of civilisation as we know it" [40].

Sendivogius on Elements, Principles, Hell, and Paradise

For Sendivogius, the nature was "plain and simple" [31, p. 78]. There were four elements: earth, water, air, and fire. "[T]wo are heavy and two are light, two dry, and two moist, but one which is most dry, and another which is most moist" [31, p. 8]. They were created by "the great and good God out of the confused Chaos".

Creation and separation were a single process, and God's first task was to set the "utmost bound of all things" exalting the "quintessence of the Elements" [31, p. 88].

Each of the elements had its own sphere (Fig. 3) in which it was "most apt to produce things". The four elements were never at rest. They always acted on each other; and each by itself sent forth its thinness and subtlety, and they all met in the centre [31, p. 8].

The centre of the earth was particularly important in Sendivogius' system, and he used different words to describe it:

- "Centrall Fire" (or "Centrall Sun" analogous to the "Celestiall Sun" [31, pp. 33, 43, 89, 90, 93]
- An "empty place, where nothing can rest" [31, p. 6]
- "Archeus, the servant of nature" [31, p. 8], which, however, was different from the Archeus described by Paracelsus [8].
- "[F]ire of hell" govern by the Archeus [31, p. 88], or simply Hell [31, p. 100].

The "Centrall Fire" was like the fire of the heavenly Sun because, although separated, "[t]he fire of Nature is one and the same" [31, p. 33]. It purified "all things that are fixed" and made them perfect [31, p. 33]. In addition, fire had a protective role, because its "heat or beams" kept the earth from drowning or dissolving, as the latter formed "one globe" with the water [31, pp. 93, 94].

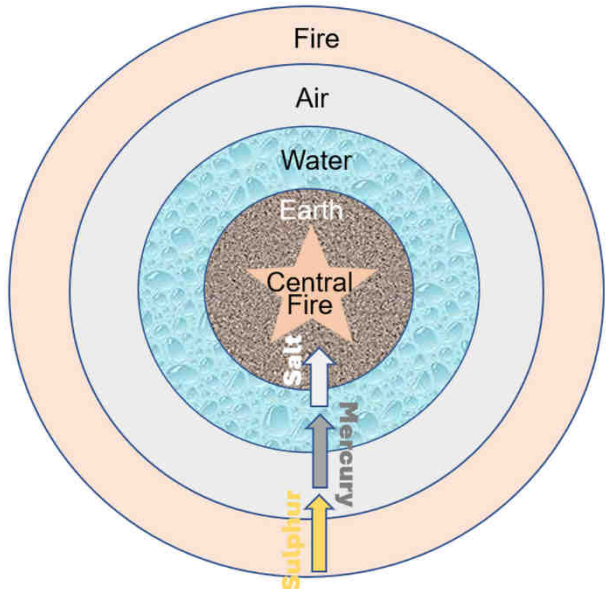

Fig. 3. Schematic presentation of Sendivogius' views on the four elements and three principles. Fire acting on air produces sulphur, air acting on water produces mercury, and water acting on earth produces salt

In Sendivogius' system, water was the heaviest element, probably because the earth was full of pores and cavities "as a spunge" [31, p. 83]. He described it as both "the menstruum of the world" and "the sperm of the world", in which the seed of all things was kept [31, pp. 85, 86]. There were three sorts of water: "pure, purer, and most pure":

"Of the most pure substance of it the Heavens are created, the purer is resolved into Aire, but the pure, plaine, and grosse remains in its sphere, and by divine appointment, and operation of Nature doth preserve and keep every thing that is subtile" [31, p. 87].

Sendivogius believed that the three Principles were derived from the four elements (see Fig. 3):

"The Fire [...] began to act upon the Aire, and produced Sulphur, the Air also began to act upon the Water, & brought forth Mercury, the Water also began to act upon the Earth, and brought forth Salt" [31, p. 111].

His further reasoning was based on diminution (Fig. 4):

"For as these three Principles were produced of four, so also by diminution must these three produce two, Male, and Female; and two produce one incorruptible thing, in which those foure shall being equally perfect" [31, p. 112].

Principles were important to Sendivogius as a "medium betwixt the Elements and Metals" [31, p. 144]. Without them nothing could be perfected neither in Nature nor through Art.

The perfect place was Paradise intended "for men only". It was composed of elements in their purest form:

"Paradise was, and is such a place, which was created by the great Maker of all things, of true Elements, not elementated, but most pure, temperate, equally proportioned in the

highest perfection, and all things that were in Paradise were created of the same Elements, and incorrupt" [31, p. 107].

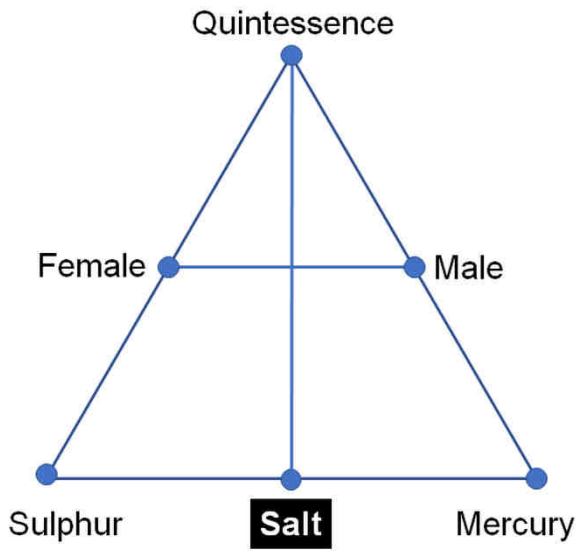

Fig. 4. A 3-to-1 diminution leading to the quintessence

On the motion, heat, and the water cycle

Sendivogius knew about the relationship between motion and heat [31, p. 38]. For him, the "heat of motion" was the tool that purified, multiplied, and separated the pure from the impure in the earth [31, p. 83].

God was the cause of motion and motion was the key to explaining natural processes:

"But when the Lord himself moves, there is an universall stirre, and motion, then all that attend on him, move with him" [31, p. 101].

"Nature causeth Motion, Motion stirs up Aire, the Aire the Fire; Now Fire separates, cleanseth, digesteth, coloureth, and maketh all seed to ripen, and being ripe expells it by the sperm into places, and matrixes, into places pure or impure, more or lesse hot, dry or moist, and acccording to the disposition of the matrix, or places, divers things are brought forth in the earth" [31, p. 106].

What we today call the water cycle was explained in detail by Sendivogius, who, based on analogy and symmetry, compared the "Center of the Earth" with the "Center of the Sea":

"To conclude therefore, know that Springs, or breakings forth of Water are not generated of Stars, but that they come from the Center of the Sea, whither they return, and that thus they observe a continuall motion" [31, p. 92].

Sendivogius described different types of water (salty, sweet, hot, and mineral) and explained the mechanisms of their production in nature: purification through the pores of the earth or in the sands, heating "in the bowels of the earth" and mineralisation when passing through certain mineral zones:

"But left it may bee objected, that in the Sea all Waters are salt, and that the Waters of Springs are sweet: Know, that this is the reason, because that Water distills through the pores of the Earth, and passing many miles through narrow places, and through sands, the saltness being lost, is made sweet […] There are also in some places greater and larger pores, and passages, through which salt Water breaks through, where afterwards are made salt pits, and fountains, as at *Halla* in *Germany*. Also in some places the Waters are constringed with heat, and the salt is left in the sands, but the Water sweats through other pores, as in *Polonia* at *Wielicia*, and *Bochia*: So also when Waters passe through places, that are hot, sulphureous, and continually burning, they are made hot, from whence Bathes arise: for there are in the bowells of the Earth places, in which Nature distills, and separates a sulphureous Mine, where by the Centrall Fire it is kindled. The Water running through these burning places, according to the nearnesse or remotencsse are more or lesse hot, and so breaks forth into the superficies of the Earth, and retains the tast of Sulphur, as all broth doth of the flesh, that is boiled in it. After the same manner it is, when Water passing through places where are Mineralls, as Copper, Allum, doth acquire the favour of them" [31, pp. 92, 93].

The Central Nitre Theory

Sendivogius criticised the ancient philosophers for not paying attention to the third principle - salt, which was "the key and the beginning of this sacred Science" [31, p. 113]. To protect the "the searcher of the Art" from error and avoid further slips, he turned his attention to salt as a tool for making the Philosopher's Stone. His ideas, presented in several works, are known as the "Central Nitre Theory" or "Central Salt Theory" (Fig. 5) [9-12]. The main points of this theory are summarised by Szydło in three sentences:

"1. Nature produces the Central Salt which plays a vital role in the life cycle of plants and animals.
2. Man uses the Central Salt to produce the universal solvent, from which the universal seed of metals can be formed, which enables the transmutation of base metals to gold to be accomplished.
3. The Central Salt provides a link between 'what is up there' and 'what is down below'" [9].

Sendivogius called the Salt-nitre (KNO_3) by various names, such as Central salt (*Sal Centrale*), Salt of the Earth (*Sal terrae*, *Sal mundi*), and Load-stone (synonymous with magnet). Like Paracelsus, he believed that it was a complex body. However, unlike his famous predecessor, Sendivogius "recognised" three constituent parts:

1) Volatile salt.
2) Alkaline (or solid) salt.
3) The spirit of the Earth.

"Our salt is therefore three-in-one" - Sendivogius wrote - "and in this respect it resembles our Creator" (see [11, p. 117, 319]).

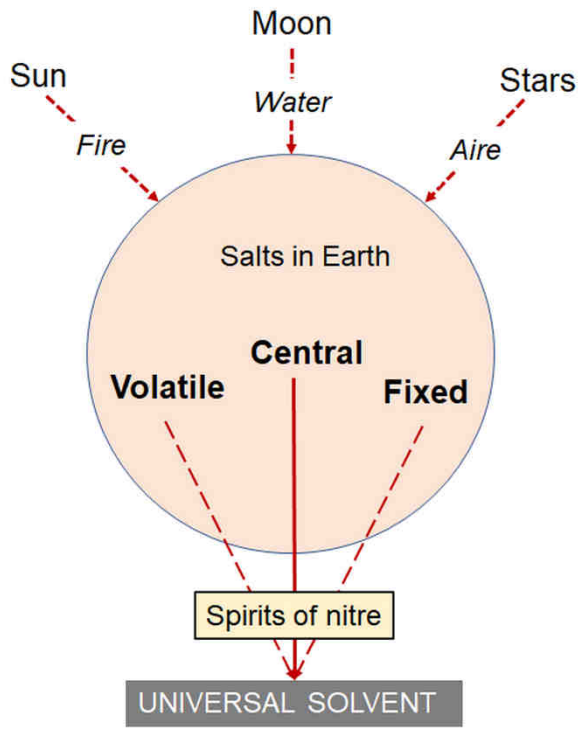

Fig. 5. A visualisation of Sendivogius' Central Nitre theory (see Refs. [9-12]). There are three types of salt: Volatile, Fixed, and Central. The universal solvent required for the preparation of the Philosopher's Stone can be obtained by dissolving a finely powdered mixture of Volatile and Fixed salts (NH_4Cl + K_2CO_3) in Spirits of nitre (HNO_3) obtained from the Central salt (KNO_3) according to Scheme 1

Scheme 1. A simplified representation of the chemistry of the Sendivogius method for making a strong solution of nitric acid (see Refs. [9, 11]):

1) $4\ KNO_3 \rightarrow 2\ K_2O + 4\ NO_2 + O_2$
2) $2\ NO_2 + H_2O \rightarrow HNO_3 + HNO_2$
3) $2\ HNO_2 + O_2 \rightarrow 2\ HNO_3$
4) Additional concentration of the resulting diluted acid

For Sendivogius, the third component (the "spirit of the Earth") was essential to all life-related phenomena, but difficult to describe. He specified that it was "not solid but of an intermediate nature" and likened it to "[w]ater of life not wetting the hands", emphasising that without this "water" no one could live, and nothing could grow and be generated in the world [31, pp. 44, 55].

Are we to believe that Sendivogius was giving a description of oxygen? Many modern scholars consider this to be an indisputable fact.

Sendivogius' views on the relation between the Central salt and air

Sendivogius realised that there was a connection between the salt-nitre and air, or more precisely a part of the air, which he called "power of life":

"[W]hen there is raine made, it receives from the aire that power of life, and joins it with the salt-nitre of the earth (because the salt-nitre of the earth is like calcined Tartar, drawing to it self by reason of its drynesse the aire, which in it is resolved into water)" [31, p. 43].

He described what today we would call an equilibrium process or regeneration opportunity:

"The Aire generates this Load-stone, and the Loadstone generates, or makes our Air to appear" [31, p. 41].

From a modern perspective, the second part of this sentence corresponds to Equation (1), which is valid for temperatures on the order of 400 °C.

$$2\ KNO_3 \rightarrow 2\ KNO_2 + O_2 \quad (1)$$

The first part of the same sentence, in turn, may be an expression of the well-known ability of potassium nitrite to be oxidised slowly by the air oxygen:

$$2\ KNO_2 + O_2 \rightarrow 2\ KNO_3 \quad (2)$$

Today we can figuratively say that KNO_2 attracts oxygen like a "magnet" (Load-stone), producing nitrate. The "attractive power" or magnetism was explained by Sendivogius as a sympathy between the salt-nitre and the air arising from their similar nature. For him, salt-nitre was air "joined to the fatnesse of the earth" [31, p. 43].

The idea of air being associated with the "fatnesse of the earth" is not devoid of meaning. It directs us to a comparison with the modern view (Scheme 2) of the medieval method of producing saltpetre (from urine, dung, and other decaying substances) [41, 42]. Of course, Sendivogius could not "see" the soil bacteria that add oxygen to the N^{3-}. Like Antoine de Saint-Exupéry's Little Prince, however, he realised that "the essential is invisible to the eye".

Scheme 2. A simplified representation of the biochemistry of the production of KNO_3 in the Middle Ages according to the Medieval Gunpowder Research Group (HO Medieval Gunpowder Research Group | School of History | University of Leeds):

1) Urea + bacteria (using the enzyme urease) → NH_3.
2) NH_3 + Nitrosomonas → NO_2^- + H_2O + H^+.
3) NO_2^- + Nitrobacter → NO_3^-.

More about air, life, and other elements

The above comparison between Sendivogius and Exupéry was not accidental. Here is what Sendivogius thought about the wonders of nature and the difference in how they were perceived by different observers:

"O wonderfull Nature, which knows how to produce wonderfull fruits out of water in the earth, and from the aire to give them life. All these are done, and the eyes of the vulgar doe not see them; but the eyes of the understanding, and imagination perceive them, and that with a true sight" [31, p. 32].

In other words, "[t]he eyes of the wise look upon Nature otherwise, then the eyes of the common man" [31, p. 32].

Sendivogius claimed that air gave "the life of all living things" [31, p. 38] because he "saw" a special ingredient in it:

"Man was created of the Earth, and lives by vertue of the Aire for there is in the Aire a secret food of life, which in the night we call dew; and in the day rarified water, whose invisible, congealed spirit is better than the whole Earth" [31, p. 40].

This special ingredient, called in the above text "a secret food of life", can today be unmistakably recognised as oxygen. "It is volatil, but may be fixed" [31, p. 95], for example in saltpetre. Without it nothing can live and grow:

"Man dies if you take Aire from him &c. Nothing would grow in the world, if it were not a power of the Aire, penetrating, and altering, bringing with itself nutriment that multiples" [31, p. 96].

Sendivogius summarised that in the air "is the vitall spirit of every Creature" [31, p. 96]. In agreement with pan-vitalistic ideas, he believed that this "spirit" lived in Minerals, Animals, or Vegetables. What's more - thanks to everyday experience he found it in the other elements (water, fire, and earth) as well:

"For wee see that all Waters become putrefied, and filthy if they have not fresh Aire: The Fire is also extinguished, if the Aire be taken from it. The pores also of the Earth are preserved by Aire: In briefe, the whole structure of the world is preserved by Aire" [31, p. 96].

Did Sendivogius know that elements were not elements in the modern sense of the word? Did he know that Water (H_2O) and Earth (SiO_2, Al_2O_3, etc.) contain chemically bound oxygen? Did he know that there is oxygen "in the purest blood", as Bugaj wrote in one of his works [7, p. 763]? He most likely did not.

Rather, he knew that the Elements contained dissolved oxygen - the vital spirit and quintessence that God had originally set aside to create the Paradise of perfect elements. For as Water was divided into "pure, purer and most pure" [31, p. 87], so the other elements, by logic of analogy and symmetry, had to be divided into the same "sorts". And what could be cleaner and more "penetrative" in this sense than the real element - oxygen - the "food of life", the Water of our Philosophical Sea "not wetting the hands" [31, p. 55], located "in the belly of the wind" (p. 77). And as the *Tabula Smaragdina* says:

"The wind carried it in its womb, the earth is the nurse thereof.

It is the father of all works of wonder throughout the whole world.

The power thereof is perfect […]

This thing is the strong fortitude of all strength, for it overcometh every subtle thing and doth penetrate every solid substance" [18].

The next links in the chain of events led to the formal discovery of oxygen

The post-Sendivogius "oxygen story" has been discussed extensively. It is primarily associated with the names of Carl Scheele (1742-1786), Joseph Priestley (1733-1804), and Antoine Lavoisier (1743-1794) [1, 43] (Fig. 6). The names of other researchers and practitioners such as Cornelis Drebbell (1572-1633), Robert Hooke (1635-1703), Robert Boyle (1627-1691), John Mayow (1641-1679), Stephen Hales (1677-1761),

and Pierre Bayen (1725-1797) are sometimes added to this constellation of scientists [7, 12, 38, 39, 43, 44].

Cornelis Drebbel was a talented scientist and engineer who created the first navigated submarines powered by oars (1620-1624). They were built for James I of England and tested repeatedly in the Thames. The largest of his submarines could carry up to 16 passengers and remain submerged for at least three hours. This was possible thanks to a specific chemical regeneration of the air. Since Drebbel knew Sendivogius personally, some scholars believe that he may have learned from him a recipe for producing oxygen from saltpetre.

Robert Hooke was a respected experimenter, assistant to Robert Boyle, and designer of his air pump, which became an important tool for pneumatic chemists. He developed a theory of combustion (1665) according to which the air contained a substance similar (or even identical) to that solidified in saltpetre.

John Mayow, another contemporary of Boyle who felt his influence, defended a thesis on the problem of combustion and respiration. He carried out an experiment important for the further development of science involving a mouse and a lit candle in a closed glass container: when the candle went out, the mouse died. His experimental idea was subsequently extended by Joseph Priestley, who found that the air spoiled by the candle could be repaired if a green plant was placed in the closed vessel.

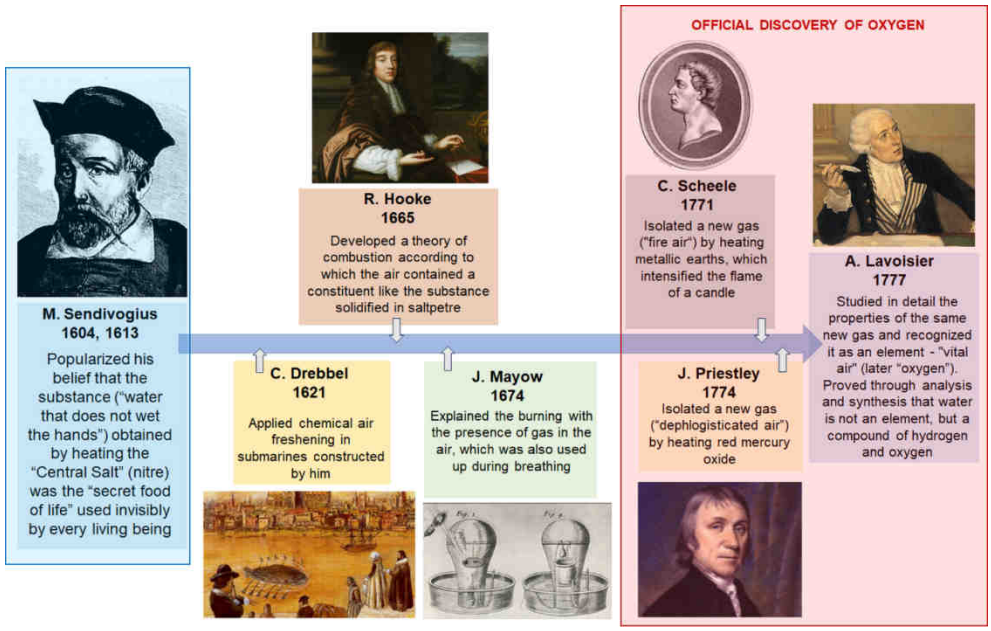

Fig. 6. Short history of the discovery of oxygen

In 1774 Pierre Bayen published a paper in which he explained the reasons for the increase in mass of mercury during calcination, not by loss of phlogiston, but by combination with a gas that is heavier than ordinary air. A few months later in the same year, Priestley repeated Bayen's experiments on the thermal decomposition of red mercuric

oxide. In his work, Priestley took advantage of the pneumatic trough invented by Stephen Hales, which was an important technical achievement and made it possible to collect gases under water or mercury. Priestley tested the properties of the obtained new gas and, as a supporter of the phlogiston theory, decided to call it "dephlogisticated air".

Another part of the story relates to the name of Carl Scheele. He received oxygen about 2 years before Priestley, but his book *Chemische Abhandlung von der Luft und dem Feuer* (*Chemical Treatise on Air and Fire*) was printed with great delay (1777) "for publishing reasons". This gave him second place. In fact, Scheele's descriptions were much more detailed and accurate than those of Bayen and Priestley. He reported the production of the new gas from six different inorganic compounds: mercuric oxide, mercuric carbonate, silver carbonate, magnesium nitrate, potassium nitrate and pyrolusite. Scheele assumed that atmospheric air has two components: "phlogistic air" - nitrogen and "fiery air" - oxygen. Like Priestley, he believed in the phlogiston theory and had no way of correctly explaining the role of oxygen in the processes of combustion and respiration.

The story of the discovery of oxygen was brilliantly completed by Antoine Lavoisier. He worked on many interrelated fronts, and his conclusions, shortly summarised below, raised chemistry to a new level [1, 45].

1) The phlogiston theory does not fit the experimental data and should be abandoned.
2) Water is not an element, as the ancient Greek philosophers taught, but a compound of two "real" elements - oxygen and hydrogen.
3) Oxygen is the substance that gives rise to the combustion of burning bodies, and in the process of breathing of animals it performs a similar function.

Concluding remarks

In his paper entitled "Who Discovered Oxygen?" [38], Szydło quotes a short text from a modern textbook describing the discovery of oxygen by Joseph Priestley. Seeing the limitations of the traditional textbook approach, in which everything is presented as straight-forward, obvious and very easy to accomplish, he resourcefully and wryly describes what a modern reader might imagine about the process of discovering oxygen [38]. Indeed, it is necessary to give more information about the background of a given discovery, as well as an account of the intellectual processes behind it.

An important question is what is meant by the "discovery" of a new element or substance - physical isolation and description of properties or a comprehensive concept that truly reflects the general picture. If we consider the creation of the overall concept, the closest to the "discovery of oxygen" were not Scheele and Priestley, but the chemist Lavoisier, who debunked the phlogiston theory, and the philosopher Sendivogius, who felt in his heart the "secret food of life" that is part of both - air and saltpetre. The latter knew that the processes involving this "food of life" were constantly happening before our eyes, but almost no one understood them. This lack of understanding over an extended period of time was not the fault of Sendivogius.

In the column titled "tough question for your teacher" in Nick Arnold's hilarious children's book Chemical Chaos [46], the author asks: "Who discovered oxygen: Priestley or Lavoisier?" The provided answer is: "None of them. Scheele did".

We hope that in one of the next revised editions of this wonderful work, or in another more academic book, the correct answer to the question of the discoverer of oxygen will include the name of Sendivogius.

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