João Paulo André

Sisters of Prometheus

Unmasking Women's Achievements in Chemistry

Translated by
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Preface

O fairest of creation, last and best
Of all Gods works, creature in whom excelled
Whatever can to sight or thought be formed,
Holy, divine, good, amiable, or sweet!
How art thou lost, how on a sudden lost,
Defaced, deflowered, and now to death devote?
Rather how hast thou yielded to transgress
The strict forbiddance, how to violate
The sacred fruit forbidden! Some cursed fraud
Of enemy hath beguiled thee, yet unknown

JOHN MILTON, *Paradise Lost* (1667), verses 896–905 of Book IX

In 1909, a significant milestone for gender equality was achieved when all higher education institutions in Germany opened their doors to women. However, in that same year, Nobel Prize Laureate Wilhelm Ostwald (1853–1932), a German chemist and philosopher, made a categorical statement in his book *Grosse Männer* [*Great Men*], asserting that "women of our time, regardless of race and nationality, are not suited to fundamental scientific work" [1]. Nearly 80 years later, American philosopher Sandra Harding still felt compelled to emphasize that "women have been more systematically excluded from doing serious science than from performing any other social activity except, perhaps, frontline warfare" [2]. This raises a legitimate question: why was the *official* entrance of women into the world of science delayed for so long? This question is linked with another that has recurred throughout history: Were women capable of doing science? From ancient times, the prevailing conviction had been that women's supposed weak nature rendered them unfit for rigorous reasoning.

Predating the opinions expressed by doctors and philosophers of Ancient Greece, literature had already portrayed women as irrational, malevolent, and lacking common sense. For instance, going back to the eighth century BC, Homer's *Iliad* and *Odyssey* conveyed the notion that women were perilous due to their inability to manage impulses and, for this reason, had to be kept on a short leash. Similarly, during that era, in his poem "Works and Days," Hesiod used the myth of Pandora, the first woman, to reinforce the belief that women were solely a source of problems and misfortunes [3].

In both the Hebrew Bible and the Christian New Testament, women were not only confined to the family sphere but also portrayed as being subordinate to men. God first created Adam in His image and likeness and then fashioned Eve from His rib. Furthermore, Eve was burdened with the guilt of original sin (Fig. 1). For centuries, moralists and preachers, from their pulpits,

Fig. 1 *Adam and Eve* (1526), Lucas Cranach. Courtauld Institute of Art, London

addressed women as the *weaker sex*, placing them under the weight of this biblical responsibility [4].

Saint Paul, while proclaiming, "There is neither Jew nor Greek, there is neither slave nor free; there is no man nor woman, for you are all one in Christ Jesus" (Galatians 3:28), also stated, "Let your women keep silence in the churches: for it is not permitted unto them to speak", adding that "if they will learn anything, let them ask their husbands at home" (1 Corinthians 14:34-35). In yet another epistle, he said, "I do not permit a woman to teach or to assume authority over a man" (1 Timothy 2:12). Passages such as these provided the theological and disciplinary foundations for the exclusion of women from the exercise of public functions and teaching, giving material to the Church Fathers, especially Tertullian (*c.*160–*c.*220), Jerome (*c.*347–420), and Augustine (354–430), for the perpetuation of a negative image of the female sex. Isidore of Seville (*c.*560–636) even stated that the word *mulier* (woman) was derived from *mollitia* (softness) [5]. In turn, Thomas Aquinas (1225–1274) merged the biblical concept of women as descendants of Eve, perceived as the origin of all human misfortunes, with Aristotle's belief that women were incomplete beings with the sole purpose of receiving and bearing the offspring of men. This fusion played a role in perpetuating the concept of *infirmitas mulieres* ("woman's weakness") as an unquestionable and evident reality, prompting many women to seek salvation through monastic life [6, 7].

According to the *Book of Enoch*, a set of apocryphal Old Testament texts written roughly between the third and second centuries BC, two hundred angels, led by Azazel, descended to Earth, driven by the desire for carnal pleasures. In return, they taught women the alchemical arts of metallurgy, dyeing, and the production of cosmetics and precious stones. This change brought lust, impiety, and corruption, resulting in divine wrath, and Azazel was severely punished. However, something had now become irreversible: women had acquired knowledge of alchemy [8]! Setting aside legends, the truth is that women, despite their recurrent illiteracy, played an essential role in chemical crafts, encompassing the manufacture of medicines, perfumes, cosmetics, paints, and more [9]. This aspect has garnered increasing attention from science historians in recent decades. Patricia Fara, in her work *Pandora's Breeches*, observes that today's conceptions of the evolution of science include participants whose motivations may be as trivial as improving food, health, or physical comfort for human beings, or even the mere search for wealth or recognition. This notion sharply contrasts with more traditional views that scientific development results from sporadic leaps made by isolated geniuses in a selfless search for truth [10]. Therefore, instead of focusing exclusively on great figures and their scientific discoveries, historians have also sought to investigate the work of those not belonging to universities or academies, yet contributing to the advancement of science. These were the ones who, instead of intellectual knowledge, possessed practical knowledge, meaning that they knew how to do. These were artisans such as potters, dyers, tanners, hatters, goldsmiths, etc., as well as professionals like miners, navigators, and herbalists, among others. It is under this understanding that the contribution of women to the evolution of chemistry as practitioners of the chemical crafts has created an increasing interest among historians [10, 11].

When discussing new historiographies, it is essential to mention Hélène Metzger (1889–1944), a French philosopher and historian of science who particularly focused on the history of chemistry. Her background in crystallography certainly played a role in shaping her contributions. Of Jewish origin, she fell victim to the Holocaust, dying at the age of 54 in the gas chambers of Auschwitz [12]. Thomas Kuhn, the author of *The Structure of Scientific Revolutions* (1962), a work considered a landmark in the history and philosophy of science, included Metzger in the select group of intellectuals who influenced him [13].

While keeping these considerations in mind, this book sheds light on women's historical involvement in chemical crafts, alchemy, and chemistry in general through Antiquity, the Middle Ages, the Early Modern Period, and the Age of Revolution. In Chap. 1, readers will find the first women who dedicated themselves to practices involving physicochemical processes, such as the handling and preservation of food, and the art of perfumery in the first civilizations. This chapter also delves into ancient Greek thinking and Alexandrian alchemy. Chapter 2 focuses on women's participation in European alchemy during the monastic era, addressing as well the *querelle des femmes*, a debate on women's alleged inferiority initiated by Christine de Pisan in the early fifteenth century. Dedicated to women's "books of secrets", Chap. 3 reveals the popularity of homemade medicine, cosmetics, and alchemy recipes from the Renaissance onwards. Chapter 4 explores the scientific environment in seventeenth-century England, with influences from Paracelsian iatrochemistry, mechanical philosophy, and atomism. Chapter 5 unfolds in the Age of Enlightenment, mainly in France, witnessing the dawn of modern chemistry. Lastly, Chap. 6 primarily features significant written works by or for women when formal education for them was not yet common.

Some explanations are still warranted, with the first one concerning chronology. Chapters are arranged in a sequence that, to some extent, follows chronological order. However, there might be partial overlaps in terms of their time frames with others. For instance, in Chap. 6, which focuses on chemical literature written for and by women, the narrative extends into the twentieth century. The second clarification pertains to the term "science," which is used flexibly in this book. Although its modern usage, with a strict definition, has emerged only in the nineteenth century, the term "science" has a long story, stemming from the Latin word *scientia*. It meant knowledge or understanding that was not exclusively limited to the realm of Nature and encompassed a wide range of subjects, including history, grammar, rhetoric, and even the arts.

Finally, an explanation concerning the excerpts of texts presented in the following pages (correspondence, literary works, etc.) is due. As the book was initially published in Portuguese, special care has been taken in this edition to present the excerpts of texts originally written in English in their authentic form.

Braga, Portugal　　João Paulo André

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Contents

1

Perfumers and Hermetists

> Devoted to her companion, who loves her in return, she grows old by his side, giving birth to beautiful and illustrious offspring. Distinguished among all women, adorned with divine grace, she has no inclination to join those who engage in discussions about Aphrodite's affairs. These are the best and most sensible women that Zeus has granted to men. However, the others, by the invention of the same god, are an eternal scourge to them.
>
> SEMONIDES OF AMORGOS, *Types of Women*, seventh century BC

The history of women's involvement in activities related to chemical processes can be traced back to ancient times, primarily in the domains of food preparation and preservation. Women likely played roles in early pottery—and in the conversion of ores into metals. They were also responsible for preparing remedies, and with the development of the earliest civilizations, they became creators of perfumes.

In the fourth century BC, Aristotle held the belief that women were physically and intellectually inferior to men—a notion that persisted through the ages. Another lasting contribution by this Greek philosopher was his theory of the four elements, which served as the foundation for the concept of transmutation. In the early Christian era, the alchemists of Alexandria embarked on extensive exploration of this concept, ultimately seeking to transform base metals into gold.

The heroes of this chapter include the prehistoric women, as well as figures such as Tapputi, a perfumer from Babylon, and Maria the Jewess, an alchemist likely from Alexandria.

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1.1 Origins

Before the advent of hunting, humans were primarily engaged in food gathering as their main subsistence activity. Women played a crucial role in performing tasks related to this endeavor, leading them to design tools and methods for collecting, preparing, and preserving food. Among the earliest instruments were sticks, levers, and hand axes, as well as simple stones for extracting roots, scraping, and grinding plant products. Over time, these primitive tools evolved into more advanced equipment, including mortars and pestles, along with rudimentary systems for milling grains and seeds. As hunting activities became more prominent, women acquired skills in carving meat, processing animal products, tanning hides, and using leather for various purposes. These skills were likely followed by the invention of the needle and the discovery of natural pigments (not necessarily in this order).

It is highly plausible that our female ancestors may have been involved in the discovery and development of pottery. If this were the case, transitioning from using their kilns for firing clay to using them for extracting metals from ores might have been a small step. Additionally, they assumed roles as midwives, healers, and surgeons, applying their knowledge of the medicinal properties of plants acquired through food collection. It is not far from the truth to say that therapeutic practices made limited progress from the time when these prehistoric women relied on herbs and roots until the discovery of sulfonamides and penicillin in the twentieth century [1].

From the third millennium BC onward, the civilizations inhabiting the region extending from the Nile to the Euphrates raised metalworking techniques to truly admirable levels. They were also skilled in glazing ceramic pieces and in the production of glass, a material that Egyptians began producing on a large scale in the fourteenth century BC. By then, the process of obtaining indigo blue from plants of the *Indigofera* genus and the use of mordants [2] in dyeing fabrics were also common in Egypt. The production of beer, medicines, and perfumes was equally important in the land of the pharaohs, with the particularity of usually being done by women (Fig. 1.1) [3]. Perfumery reached a high level of development in Babylon, the great Mesopotamian city founded in 2300 BC on the banks of the Euphrates. It was in Babylon that some of the classic techniques for extracting essential oils emerged, namely, pressing and maceration. The essential oils were necessary for scented waters and lotions, as well as ointments and other preparations for medicinal, magical, and religious purposes [4].

Fig. 1.1 Preparation of lily perfume by women; fragment from a Fourth Dynasty Egyptian tomb; *c*. 2700–2200 B.C. Louvre Museum, Paris

The cuneiform writing found on clay tablets dating back to the thirteenth century BC has yielded valuable insights into the techniques employed in Babylonian perfumery. These ancient texts not only disclose the solvents used but also outline the necessary equipment for this craft. This equipment included an array of items such as pots in various shapes and sizes made from clay, glass, or metal, measuring cups, basins, sieves, flasks, furnaces, and possibly sublimation devices. Among the technical information gleaned from these tablets, we also find the name of one of the perfumers, Tapputi-Belatekallim, where "Belatekallim" indicates her role as a supervisor in the royal palace. Furthermore, from another woman, likely an assistant to Tapputi, we learned the latter part of her name, "ninu." In her perfumery, Tapputi used not only myrrh and balms but also botanical species from the *Cyperus* genus and *Acorus calamus* [5–7].

A significant part of Western civilization came from Egypt and Mesopotamia, but it was the ancient Greeks who endowed it with an intellectual splendor that still surprises us today. They were the true creators of philosophy, science, and mathematics (arithmetic and geometry already existed in Egypt and Babylon but only with practical rules). Based on rationality and logic, Greek philosophers crafted theories to explain the origins of the universe, the composition of material bodies, and their transformations. According to the pre-Socratic philosophers, everything had its origin in a primordial matter. Thales of Miletus (*c.*625–*c.*545 BC) believed this matter to be water, while his disciple Anaximander (*c.*610–*c.*546 BC), also from Miletus, posited that the material basis of all things was something formless and indeterminate, which he called *apeiron*. For Anaximenes, also from Miletus (*c.*585–*c.*528 BC), the origin of everything was air. In the view of Heraclitus of Ephesus (*c.*540–*c.*480 BC), it was fire, and for Xenophanes of Colophon (*c.*570–*c.*475 BC), it was earth. In an attempt at unification, Empedocles of Agrigento (*c.*490–*c.*435 BC) considered water, air, fire, and earth to be the "roots of all things."

Shortly thereafter, Leucippus and his disciple Democritus of Abdera (*c.*460–*c.*370 BC) argued that everything was made up of atoms. In Greek, the word *atomos* meant "indivisible." These were corpuscular entities that, in an infinite number and variety and in constant vortices, filled the void, which was a prerequisite for movement. In their permanent whirlwind—beyond any external cause, as it was the ultimate cause of everything—atoms could unite among themselves, giving rise to all forms of matter. The properties of matter would be determined by the sizes and shapes of their constituting atoms.

Epicurus of Samos (341–270 BC), the founder of the Epicurean School, shared an atomist view of the world. One of his followers, the Roman poet and philosopher Titus Lucretius Caro (*c.*99–*c.*55 BC), made significant contributions to the dissemination of atomism in the Latin-speaking world with his remarkable poem *De rerum natura* [*On the Nature of Things*]. The Epicureans, who believed that the soul was also composed of atoms, introduced new dimensions to atomism. They proposed that atoms did not move in vortices but followed parallel rectilinear trajectories, similar to bodies in free fall. Occasionally, they could undergo a small and unpredictable swerve, known as the *clinamen*, leading to collisions with other atoms, allowing for the formation of matter. Atomism was a doctrine that later also acquired a moral and ethical dimension, particularly linking human free will—liberated from the constraints imposed by religions, superstitions, or ignorance—to the concept of the *clinamen*. Although it eventually faded into obscurity, atomism experienced a revival starting in the fifteenth century, as will be explored in Chap. 4.

In the fifth century BC, the Athenian Socrates (*c.*470–399 BC) left an indelible mark on philosophy. He advocated deductive reasoning, always commencing with an irrefutable premise, and held disdain for experimentation, believing that reflection alone was sufficient to comprehend the world. His interests, however, focused more on the nature of the human being than that of the universe, advising individuals to "know thyself." Socrates considered natural philosophy too speculative (a tendency from which mathematics was exempt), but the significance he placed on aspects such as the need for clarity in definitions and classifications, logical argumentation, respect for order, and rational skepticism had a lasting impact on the future of science. Despite being sentenced to death for allegedly corrupting the ideas of Athenian youth, his influence continued to flourish in fertile ground, particularly through another Athenian, Plato (*c.*427–*c.*347 BC), his most brilliant disciple.

Considering that atheism was incompatible with understanding the universe and that natural laws were believed to be subject to divine principles, Plato's natural philosophy marked a departure from that of his predecessors. Nevertheless, he, like them, argued that everything was formed by the four material principles of Empedocles, combined in varying proportions. He was also the first to refer to them as "elements" (*stoicheia*).

In his theory of ideas (or forms), which posited that an observed object was merely an imperfect copy or reflection of an idea, with the idea being the only true reality, Plato argued that the senses were not reliable. For this reason, he contended that knowledge could only be achieved through deductive reasoning and not through direct observation, which explains the little importance he placed on experimentation. Influenced by the mathematical spirit of the Pythagorean School, founded by Pythagoras in the sixth century BC and which held that the cosmos could be explained through arithmetic and geometric relationships, Plato associated ideas with numbers.

In *Timaeus* (*c.*360 BC), a dialogue that can be considered one of the earliest treatises on chemistry, as it includes a discussion on the composition of organic and inorganic bodies, Plato expounded his vision of cosmogony. He associated each one of the primordial elements with a regular geometric solid: fire to the tetrahedron, air to the octahedron, water to the icosahedron, and the earth to the cube. He further suggested the existence of a fifth element, the ether or quintessence, present in celestial space, which he associated with the dodecahedron. These polyhedral, known as Platonic solids, were believed by Plato to be convertible elements. According to him, it was possible to convert elements into each other by resolving the respective polyhedra into right-angled triangles and reassociating them. However, due to the impossibility of solving the pentagonal faces of the dodecahedron, this polyhedron was considered a separate case with a divine connotation.

The concept of the soul was of central importance in Plato's thought. Recognizing that the soul was devoid of gender, he advocated social equity for women and promoted similar education for both boys and girls, although this was typically restricted to those from the ruling class. For this reason, despite his sexism, he is sometimes considered one of the first Western intellectuals who championed the female gender [8].

Plato, who founded the School of Athens around 387 BC, paved the way for his disciple Aristotle (384–322 BC). In turn, Aristotle established the famous Lyceum in 335 BC, where the Peripatetic School flourished. Although he followed in the footsteps of his master, Aristotle was more favorable to the observation of natural phenomena, as he did not conceive that only ideas could form reality. Nevertheless, in his systematic approach to understanding the world, Aristotle prioritized the use of syllogism, a form of deductive reasoning based on a priori premises considered to be true, leading to deduced conclusions. Consequently, there was no room for experimentation in his methodology. Aristotle's physics (*physis* was the Greek term for the final cause of something, or its purpose, although it is often translated as "nature") is essentially a metaphysical exploration of the nature of things rather than an inquiry into their laws. By rejecting the notion that everything was composed of atoms and empty space, Aristotle supported the concept of a fundamental substance called *hyle*. Similar to clay shaped by a potter, *hyle* possessed the capacity to assume diverse forms. However, these forms would develop from within, akin to an organic growth. In his treatise *On Generation and Corruption*, he argued that it was from the union of form with pairs of sensible qualities (hot, cold, dry, and wet) that the four elements of cosmogony resulted, as illustrated in the diagram in Fig. 1.2. All bodies were generated from the elements combined in varying proportions, except for celestial bodies, which, considered perfect, contained the ether or quintessence in their constitution. Aristotle observed that any two adjacent elements in the diagram shared a common sensible quality, leading him to view them as interconvertible, thus perpetuating the concept of transubstantiation introduced by his master.

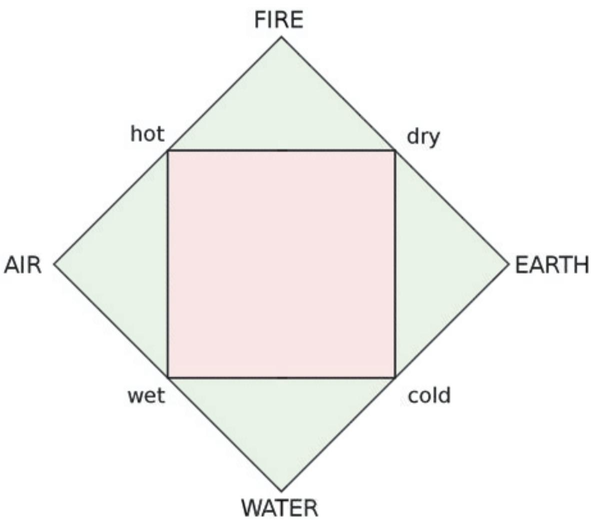

Fig. 1.2 The four Aristotelian elements and their shared properties

Hellenistic medicine also reflected Aristotelian doctrine. In the *Corpus Hippocraticum*, a collection of writings attributed to Hippocrates (*c.*460–*c.*370 BC) and his followers, the notion of assigning a natural cause to each specific illness emerged for the first time, thereby separating medical practice from religion and magic. Diseases were considered as the body's natural reactions rather than punishments from the gods. The *Corpus Hippocraticum* expounds the theory of the four humors (fluids) of the body—blood, yellow bile, phlegm, and black bile—originating, respectively, from the heart, liver, respiratory system, and spleen. These humors were associated with the fundamental qualities of the four Aristotelian elements: blood, hot and moist like air; phlegm, cold and wet as water; yellow bile, hot and dry as fire; and black bile, cold and dry as the earth. According to Hippocrates, often referred to as the "father of Medicine," a healthy body relied on the close balance between the four humors. Any excess or shortage of these humors resulted in specific symptoms and disorders. Furthermore, the humoral theory suggested that the predominance of a particular humor in a person's constitution was also responsible for their temperamental characteristics. Galen of Pergamum (129–*c.*216 AD), the physician responsible for the perpetuation of this theory for many centuries, classified four fundamental temperaments (Fig. 1.3)—phlegmatic (associated with phlegm), sanguine (blood), choleric (yellow bile), and melancholic (black bile). As a result, men and women were believed to have different temperaments. Men, being hot and dry, were considered choleric, which accounted for their strength and intelligence, while women, being cold and wet, were labeled phlegmatic and thus considered weak and irrational.

Aristotelian doctrine made its way into Jewish, Christian, and Islamic thought. Some authors attribute the enduring influence of his ideas on European culture for almost two thousand years to the fact that he was the tutor of Alexander the Great (356–323 BC). Aristotle's views on the role and status of women in the society were shaped by biological considerations, leaving a lasting impact. He held the belief that women were inferior to men—physically, intellectually, and socially. In his work *Rhetoric*, he asserted the importance of women's happiness being identical to that of men, as a society could not be happy if they were not. However, in *Politics*, he regarded women as subaltern and incomplete beings. Even in matters of reproduction, Aristotle underestimated the role of women, considering their reproductive contribution to be inferior to that of men due to a lower degree of heating and cooking of their blood, which he attributed to their colder nature. In his view, women merely provided the raw material for the development of new beings, while it was men's semen that possessed the principle of movement necessary for generating the form [8–10].