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CHAPTER ONE

Theory and Concepts: *The Mythological Foundation of Chemical Theories in Ancient Civilizations*

SYDNEY H. AUFRÈRE, CALE JOHNSON,
MATTEO MARTELLI, AND MARCO BERETTA

EGYPT

Sydney H. Aufrère

Among surviving Egyptian religious texts and culture, no treatise on the spectrum, the origin, the nature, and the uses of precious and raw substances and of other products exists. However, important texts from the New Kingdom (royal panegyrics, funeral reviews, and mythological compositions) as well as from the Ptolemaic and Roman periods give heterogeneous and dispersed information testifying to the permanence and sophistication of these uses as part of the philosophical approach of the hierogrammats (priests specialized in religious texts) of ancient Egypt. In the absence of such a treatise, it is nonetheless possible to draw the outlines and classify a wide range of raw substances and complex products containing ingredients coming from the vegetable, mineral, or animal kingdoms by their origin, their destination, and their use (Aufrère 2016c). In this approach, no substance is considered inert. Even if confined to a minor role, to ancient Egyptians each substance appears endowed with a more or less marked divine potential. Their properties are given by the very essence of the divinities to whom they are closely connected, properties that can be positively or negatively connoted, or presented on a quality scale.

Such a current of thought permeates the priestly circles, even if their expression fluctuates from one religious tradition to another. Far from being watertight, these traditions remain under the control of prestigious Houses of Life – places of intellectual education, of learning and transmission of texts, perhaps even of experimentation (Gardiner 1938) – where "thinking" is the food of life. Priestly libraries, meetings between clergy (synods), and the circulation of scholars and books contributed to the transmission of this line of "thought."

This line of "thought" led the Egyptians to imagine that gods were represented not only by metals, more or less noble, or compounds of metals and minerals, but also by earths, dyes, resins, and plants. These were no longer considered as mere commodities, but as substances with a rich potential. Each substance originated from a distant divine source and had an intrinsic divine signature. Hence the divine statues were made according to a tradition consisting in establishing correspondences between gods and substances, especially since many etiological myths made them divine biological fluids, and even revealed a hierarchy based on their presumed origin.

Indeed, if testimonies initially ascribed this line of thought to the *Texts of the Pyramids*, it in fact asserted itself in the New Kingdom during the economic peak of Egypt, when it imposed its dominance on Asia and on Africa, controlling both remote mining areas and caravan and maritime trade routes. Gold, silver, lapis lazuli, turquoise, carnelian, red and green feldspar, and hematite were then the most valuable materials known in the Egyptian world, since the so-called precious stones (diamond, sapphire, ruby, and emerald) did not become available in the lower Nile Valley until the Ptolemaic period. It is from the latter period onwards that the priestly discourse perpetually emphasized the mythification of the source of noble substances and their close link with the gods. By becoming the elements of a theology that ascribed thought to the divine rather than to a purely poetical or metaphorical approach, precious substances, whatever be their nature, connoted the divine.

Let us take, for example, the enlightening description of the sun god Rēʿ-Atum in the *Book of the Celestial Cow* (Guilhou 1989; Hornung 1997), a myth attested to for the first time in the tomb of Tutankhamun (1345–1327 BCE). The myth explains to us the transformation undergone by the sun, having become extremely old: its bones become silver, its flesh becomes gold, and its hair becomes lapis lazuli. In this process of mineralization of the aging body of the sun, silver prevails over gold – for a long time, in fact, silver – called "white gold" (*hedj*) – was considered more valuable than gold (*nebou*) because of its rarity. This same process applies to deposits of ores and minerals following exposure over a long geological cycle, the "setting" sun corresponding to the start of a paradoxical regeneration, the newborn child representing the start a new life cycle.

The three parts of the divine body (bone, flesh, and hair) then echo an etiological theory, expressed in the Papyrus Jumilhac (XII, 23–XIII, 1; Vandier 1963: 124; Aufrère 1991: 384–6), according to which the flesh and the skin of the newborn child are bequeathed by the mother and his bones by the father. Thus, the golden flesh of this child, delivered by his mother Nut, the celestial vault, is of solar origin, his silver bones are of lunar origin, and his lapis lazuli hair is reminiscent of the darkness in which he was immersed and from which he will spring to life.

Nevertheless, mineral qualities can be observed among the gods. As early as in the *Texts of the Pyramids*, it is said that "metal emanates from Seth," a divinity known for his titanic strength and outstanding fighting abilities. His bones are of "heavenly metal" (*bia-en-pet*; Lalouette 1979; Aufrère 1991: 432–8); that is to say, meteoritic iron, the first known source of iron and from which the dagger of Tutankhamun was made.

This idea prevailed, while it also evolved, because as late as in the second century CE, priestly manuals (Petrie 1889: pl. X, fr. 16; Osing 1998) confirmed a theory by which Manetho of Sebennytos (third century BCE; fr. 79: Waddell 1980: 190–1; see Plutarch, *De Is. et Os.* 62, 376B: Froidefond 1988: 233) associated Seth-Typhon with iron, while Horus, who had defeated him, held his power from magnetite (*beqes-ânkh*). The victory of Horus stemmed from the observation of the properties of attraction of the magnet for iron, transposed in a divine mode. In other words, the essences of Seth and Horus respectively announce their own defeat or victory (Aufrère 1991: 433–4).

Moreover, the Greek transliteration of an Egyptian name Petosorphmus (i.e. "The-One-that-gave-Osiris (*Pet-Osor*)-the-salt (*p-hmus*)") indicates that *natron* (sodium carbonate decahydrate), called "salt" (*hmus* = *hema*) in demotic, was associated with Osiris (Aufrère 1991: 607). The denomination of *natron* was originally represented by the combined sign  (*neter*), a divine mast depicted above the prospector's bag, which indicates that it had for a long time been associated with the idea of the god closely connected to it (i.e. Osiris) and took its name from the god. Indeed, the latter, like Hathor, was believed to supply water to the nitraries, namely those of the Wadi el-Natrun, whose efflorescent alkaline salts were used for the desiccation and preparation of bodies for mummification (Aufrère 1991: 607–9). By contrast, sea salt (sodium chloride), considered to be a toxic and harmful substance, was associated with Seth, a negative deity (Aufrère 1991: 636–7).

Taking into account variations in the interpretation of texts, substances defined, more or less, the essence of the gods who cannot escape the material source of their origin. Here lies the beginning of the doctrine of sympathies, established in the *Treatise of Sympathies* of the Egyptian Bolos of Mendes (second century BCE), for whom the planets of the solar system and the stars exerted an influence on both metals and plants (Bidez and Cumont 1938: 189–90; Halleux and Schamp 1985: xxiv–xxviii).

Such an association is supported by the representations and texts on astronomy found on the ceiling of the pronaos (vestibule) of the temple of Dendara (ancient *Tentyris*), which associate the silhouettes of the thirty-six decans (star groups) with pairs of metals and minerals (Figure 1.1). By disappearing under the ecliptic plane (i.e. under the horizon) for seventy days – the duration of the embalming period for Egyptian nobles – and then rising again, following closely the apparent movements of the sun, moon, and other planets, these stars or groups of stars would deposit their cosmic ferments on terrestrial mines and thus affect the type of minerals they contain.

FIGURE 1.1 Ceiling of the pronaos of the temple of Dendara. Thirty-six decans made of both precious metals and minerals. © Sydney H. Aufrère.

These beliefs led to a balance between texts and objects – such as divine statues, coffins, and even embalmed human and animal bodies. Thus, the composition of the divine statues elaborated by the sacred goldsmiths is in agreement with the tenants of the Egyptian liturgical tradition.

The "Mansion-of-Gold" (*Hout-noub*), commonly called "Workshop-of-the-Goldsmiths" (Traunecker 1989; Aufrère 1991: 374–6), in the temple of Hathor of Dendara is considered as a liturgical space in which a series of eight glosses explain the exact designation of substances used at an earlier time. These glosses were written to avoid losing the thread of tradition and are sometimes interpreted as the origin of an alchemical thought (Daumas 1980; Derchain 1990). One of them mentions the following: "If one says of a god that matter is the true stone, one means that it is magnetite" (*Dendara* VIII: 41, 13–142, 12), a substance referring to the very nature of Horus (cf. above). Quite often, captions relating to representations of the divine statues of temples indicate the size and the nature of the metals and minerals used to make the object. Examples are given in the Crypt no. 1 of the temple of Dendara (cf. *Dendara* VI: 68–71, 74–5, 777–8, 81, 84, 87–90, 93–6, 98, 100; Cauville 2004) (Figure 1.2). It is not

FIGURE 1.2 Crypt South no. 1. Temple of Dendara. Statue of the god Harsomtus as a serpent. Caption indicating the size and the nature of the metals and minerals used (*Dendara* V: 140, 7). © Sydney H. Aufrère.

FIGURE 1.3 Names of the temple of Dendara dedicated to the goddess Hathor. Temple of Dendara, northern passage of the hypostyle hall, Ptolemaic period. © Sydney H. Aufrère.

surprising that one of Dendara's names was "House of Electrum" (*Per-en-Djam*) (Figure 1.3), because "Electrum of the Goddesses" was one of the designations of the goddess Hathor (Figure 1.4).

The *Ritual of Opening the Mouth*, attested since the Old Kingdom for making (divine and royal) statues and coffins (substitutes of the deceased), made use of a variety of natron (Aufrère 1991: 606–37), galena and chrysocolla (Aufrère 1991: 581–8), ointments and fumigations. Their use was meant to vivify, by "catalysis," divine and human effigies, and to simulate the restitution of their vital functions (ritual opening of the mouth, nose, ears, and eyes; Goyon 1972: 85–182).

These beliefs had an impact on the preparation of two liturgical ointments composed of a cocktail of mineral and vegetable ingredients, respectively called

FIGURE 1.4 One of the names of the temple of Dendara dedicated to the goddess Hathor: "Mansion-of-Electrum" (*Per-en-Djam*). © Sydney H. Aufrère.

"divine mineral ointment" and "precious ointment." According to its recipe, the first ointment was obtained after a well-codified series of operations, which associated aromatics, bitumen taken from an oil field near the coast of the Red Sea (Gebel el-Zeit), vegetable tar, metals, and crushed precious minerals. Originally, it was specifically used for the statues of the god Min of Coptos, the god of the Eastern Desert boundary, where important mineral resources were exploited. This mixture of aromatics and minerals of divine essence gave it a specifically long-lasting effect. The recipe of the first ointment was intended for the preparation of a blackish coating that when ritually applied with a spatula on divine statues and coffins gave them a particular efficacy. The second ointment, whose recipe is less elaborated, probably was a variant of the first one. Both were used to give divine meaning to the objects they coated. In his writings, Clement of Alexandria (*Protrepticus* 4–6, 48) mentioned such ointments, saying that in the time of the legendary King Sesostris, a Greek artist named Bryaxis took aromatics from the embalming of Osiris and Apis, mixed them with crushed metal and mineral substances, and spread the mixture on a statue of Sarapis (Sauneron 1962a).

Likewise, the Osiris-Khentymentyu figurine was made following a well-detailed ritual procedure during the festival of Khoiak (fourth month of the Flood season in Egypt; i.e. *Akhet*) and buried in the subterranean crypts of the Osirian mounds. It highlights the use of vegetable substances with a mixture of metals and precious minerals to confer a universal character and announcing the resumption of a new vegetative cycle, called germination (i.e. *Peret*; Chassinat 1966–8, 2: 779–88, 822; cf. 379–477, 814–5). On the basis of the same principle, during the Roman period, all the dead of the Egyptian aristocracy were mummified following special rituals whose purpose was to give them a divine appearance, as if they were Osiris (for men) or Hathor (for women).

According to the *Embalming Ritual* (Papyrus Boulaq 3 and Papyrus Louvre, inv. no. 5158), the ceremonialist calls out the names, as if they were fully-fledged beings, of oils, substances of mineral origin (metals, precious minerals, and bitumen), and even chemicals (natron, orpiment, earths, and dyes), which came from Egypt or foreign countries, all attested to in the liturgical preparations, to regenerate and exalt dead bodies with the example of divine personalities through a *mimesis* (Goyon 1972: 17–84).

In the Greco-Roman period, the funerary use of the *First* and *Second Books of Breathings* spread (Goyon 1972: 183–317). The first book announces characteristics of hermeticism (Quaegebeur 1995). The second, more traditional book reminds one of a characteristic of the *Embalming Ritual* (cf. *supra*): the ceremonialist in charge gathers the necessary products to ensure the deification of the body. According to the *Embalming Ritual of the Apis Bull* (Papyrus Vindobonensis, inv. no. 3873; Vos 1993), the same rituals were used, leading scholars to think that they could also have been used for other sacred animals, such as the Bukhis bull of Hermontis (Grenier 2002; Grenier 2009), the Mnevis bull of Heliopolis (Porcier 2012; Porcier 2014), or the crocodile Petesuchos of Crocodilopolis (Widmer 2003).

These beliefs were greatly influenced by a continuous mythopoeic reflection led by high-ranking priests who explained how to use the substances, which, by their nature and origin, induced specific transformation processes. Such reflection allows us to understand the great Royal orders addressed to miners, stipulating that gold, representing the flesh of Re, could not be diverted from its essential purpose – to serve the gods – such diversion being considered as a sacrilege (*Nauri decree* under the reign of Sethi I; see Edgerton 1947). This idea was still echoed in the work of Chenoute (348–466 CE), an archimandrite (superior of a monastery) who dominated Coptic intellectual life in Panopolis (Akhmîm; Daumas 1956; Aufrère 1991: 381). The exploitation of minerals with a divine status was a royal privilege that could be carried out only by those from within the priestly class. The looting of royal tombs at the end of the New Kingdom shows the fragile character of these beliefs and prescriptions.

These rites highlight an approach that can be characterized as mytho-scientific. The Egyptian priests who had access to the House of Life considered the emergence of substances, processes, and reactions, whether natural or activated by an external agent, through the prism of mythology. This mytho-scientific approach used etiological myths for primary or transformed substances. The recipes for complex liturgical preparations are reproduced on the walls of the so-called "laboratories" (*is*), as if they had been composed there, although these chambers only play a liturgical and not a practical role (see Chapter 7).

One of the best examples of this view, a ritual text (Papyrus BM 100090 + Papyrus Salt 825; Derchain 1964; Fermat 2010; Herbin 2010), explains, under cover of secrecy (see Chapter 2), when (at the beginning of every Egyptian winter, during the month of Khoiak; cf. above), how, and in what context the substances could be used to make the figurine of Khentymentyu. The origin of this rite is reported as resulting from the widespread weakness and affliction of the gods when the murder of Osiris by his brother and rival, Seth, was announced. Raw substances – trees, useful plants, herbs, metals, minerals, honey – or products (*shedeh*, an alcoholic beverage; Tallet 1995; Guasch-Jané et al. 2006; Gabolde 2009), were considered as emanating from biological fluids, including tears (Caron 2014), saliva, blood, sweat, or even the sputum and vomit of gods and goddesses. This was due to the psychological trauma caused by Seth, a god of chaos (Aufrère 2021a: 179–80). In another context, Seth was also considered as the one who had disseminated precious substances on the surface of the earth, just as he had dismembered Osiris and scattered all the parts of his body in the desert, a sacred and metaphorical representation of the extent of productions of terrestrial origin (Aufrère 2007: 160–6; Aufrère 2021a: 192).

This mode of production of minerals associated with bodily fluids was a model used for other substances as well. The turquoise, metaphorically called "stone of festival" (*heb*), is said to have come from emanations of the goddess Bastet-Horit when she appeared on the mountain of Heliopolis (Papyrus of the Delta, IX, 2–3: Meeks 2006: 19). We have here a geographical metaphor used for the Sinai Peninsula, where this cerulean stone, considered as representing dawn and sunrise, was exploited from the mines opening in the flanks of the Sarabit el-Khadim plateau, south of the Sinai. Likewise, sea salt, known to sterilize arable land, was called "the sputum of Seth" (*ishesh en Sutekh*). Plutarch, in his treatise *Isis and Osiris* (32, 363E: Froidefond 1988: 205; Aufrère 1991: 636–7), gave the name of "Typhon scum" (*Tuphōnos aphrón*) to sea salt, because it emanated from places dedicated to Typhon such as Lake Sirbonis, east of the Nile Delta (Aufrère 2017b: 42). However, a more detailed approach would demonstrate that by virtue of a sustainable concept, certain gods and goddesses with close links to substances, valuable or not, would in turn become producers of them. Such is the case of Hathor, goodness of metals and precious minerals (also of gums), who was venerated at the entrances of turquoise mines.

It is debatable whether or not there was a hierarchy of materials on the basis of their presumed origin, going by the lists of aromatics engraved on the walls of the so-called laboratories of the temples of Horus at Edfu and of the goddess Triphis at Athribis (Baum 1994a). These show that there were (a) first-choice gum resins, which were cosmic aromatic entities, including myrrh, oliban, and styrax, considered to be falcons' tears spread across Eritrea and Arabia and dropping from the Eye of Horus or of Osiris, and (b) second-choice gum resins of Sethian origin (Aufrère 2017a). This belief prevailed in Eritrean legends about fragrances (Katz 2009).

To conclude, this mytho-scientific approach of the Egyptians allows us to better understand the manufacturing procedure of drug substances to relieve pain (Aufrère 2021a). The idea of the active principle contained in a product is explained, from an Egyptian point of view, by an efficiency based on a mimetic scheme. The principle is based on an analogy: the disease to be treated is considered equivalent to that of the myth. This equivalence generally affects the healing process when the active principles of the *pharmakon* are presented as emanating from an explanatory etiological myth. Such is the case of the chaste tree according to the Louvre Papyrus, inv. no. E 32847 (Bardinet 2013; Bardinet 2017; Aufrère 2021a: 198–9). The qualities attributed to this tree are closely dependent on an etiological legend in which Osiris plays a role. In the field of Egyptian magic, illustrated by many documents (papyrus, magic stelae), if a product is shown to be effective in the treatment of a snakebite or of a sting in a divine patient, then the same product can be given to a human patient (Jelinková-Reymond 1956).

MESOPOTAMIA

Cale Johnson

Salts, lime, gypsum, and bitumen, not to mention the numerous chemical compounds that could be extracted in one way or another from the plant and animal life that naturally and copiously filled the Mesopotamian alluvium: these were not raw materials, naturally occurring in purified form, but rather materials that had to be extracted from complex natural forms through processes of refinement and purification. More important than any of these other complex materials from the Mesopotamian plain, however, is the ubiquitous material that defines Mesopotamian culture: clay. Carefully chosen from natural deposits, then worked and reworked into a smooth and properly resilient surface, the clay tablet was the primary writing surface throughout Mesopotamian history. It is largely through recipes, prescriptions, and instructions, written in cuneiform script on these clay surfaces, that we have access to the procedures that were used to arrive at chemically complex materials, whether arsenical copper, glass, or cosmetics.

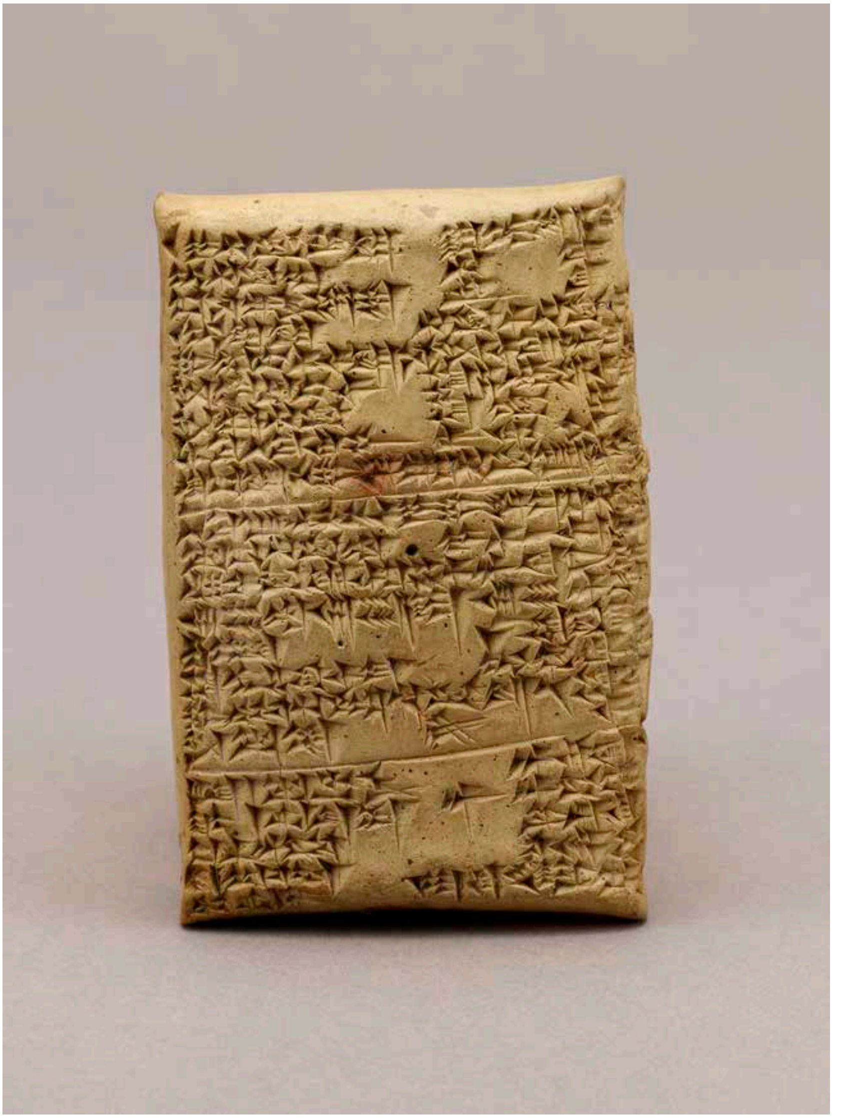

FIGURE 1.5 Cuneiform tablet BM 120960, Middle Babylonian, Tell Umar. © The Trustees of the British Museum.

The alluvial sorting of different sediments throughout southern Mesopotamia meant, above all, that a wide variety of clays – suitable for clay tablets as well as the long history of ceramics and other mineral substances – were always available to Mesopotamian scribes, technicians, and inventors. Just as textile was the privileged medium of the Incas, or divinatory shell or bone in early China, it is perfectly appropriate that clay was the privileged material in ancient Mesopotamia.

Much has been made of the absence of certain kinds of "raw material" from this region, whether stone, precious or base metals, or the lengthy and strong beams of timber needed to span monumental buildings, but we should focus on the manifold procedures known from the Mesopotamian textual record that speak to the extraction or production of useful chemical compounds from materials that were regularly found in the land between two rivers. Standing alongside the local materials of the alluvium, imported raw materials also play a central role in the history of Mesopotamian chemistry. We find a wide variety of semiprecious stones and metals imported from neighboring regions, often via age-old supply chains. In terms of Mesopotamian cultural significance, the most important of these imported materials were semiprecious stones such as lapis lazuli, which were fashioned into the cylinder seals that become a centerpiece of administrative life, particularly with the invention of writing around 3300 BCE. Rolled over the entire exterior surface of a clay bulla, the cylinder seal makes the clay bulla into a tamper-proof legal device. It is little wonder, therefore, that the full technological prowess of the last phases of Late Uruk society (ca. 3500–3000 BCE) was focused on importing semiprecious stones and developing technologies that allow for the carving of increasingly hard stones.

These seal impressions often depict economic activities that supported southern Mesopotamian urbanism such as animal husbandry, the storage of grain, and the domestic forms of production in which many chemical processes first develop (weaving, dyeing, pottery production, and tanning). The need for a broad definition of chemistry in early Mesopotamia is made abundantly clear by a material process that was used to produce the designs on hard, imported semiprecious stones: the use of emery in combination with copper drill bits or lead mounts in abrasive solutions. This is a thoroughly mechanical – rather than chemical – process, but the Mesopotamians may well have thought about it quite differently.

The carving of minute designs like these on hard stones proved to be one of the most difficult technical challenges in Mesopotamian history. In the earliest phases, microliths made of flint were used to drill and bore, but the real leap forward came toward the end of the third millennium BCE, when particles of emery were combined with drill bits made of copper. As Gwinnett and Gorelick (1987) have demonstrated, the copper of the drill bit did not itself serve as the cutting element. Instead, the relatively soft copper of the drill bit served as an excellent holder or mount for microscopic bits of emery. Each speck of emery acted as a separate microscopic drill bit alongside hundreds of others, particularly in an abrasive solution made of emery particles in oil (see Simko 2015 and references therein). And while the production of the copper used to make these drill bits certainly represented a chemical process, the interaction between microscopic particles of emery and the copper of the drill bit is entirely mechanical. Can we really take an entirely mechanical

FIGURE 1.6 Late Uruk cylinder seal, 4000–3100 BCE. Photograph by Ashmolean Museum/Heritage Images/Getty Images.

process like this as an example of chemical practice? If for no other reason than counteracting present-day Whig histories of chemistry, in which we pick and choose ancient practices that happen to line up with modern-day scientific practice, we really must allow for the possibility that mechanical procedures that we might deem nonchemical were, in fact, conceptualized by their inventors and users in Mesopotamia as no different from the smelting of ore or the formulation of a medical prescription.

By far the most important means of classifying different material substances in ancient Mesopotamia was the use of cuneiform semantic determinatives (unpronounced cuneiform signs that indicate the substance from which an object was made), which were largely oriented to distinct types of social, economic, or technical activity rather than to a philosophical paradigm or universal categorization of the natural world. Semantic determinatives in cuneiform are much fewer in number and used for a much narrower range of functions than in Egyptian hieroglyphic. The full repertoire of nearly two dozen determinatives only came into regular use in the middle of the third millennium BCE. As a rule, these determinatives group objects made of the same or similar materials (wood, reed, stone, aromatics, plants, vegetables, and several types of metal), a type of manufactured object (pots and textiles), or human professions and offices, geographical features, and stars (for a traditional account, see Edzard 2003: 9; Selz et al. 2017 combine the traditional set of semantic determinatives with a group of quantificational elements such as Sum. didli that have not traditionally been included in the category, so caution is in order).

One might assume that these semantic determinatives provided the key principle of organization for the earliest lexical lists in the Late Uruk period (ca. 3300–3000 BCE) and consequently the earliest systematic descriptions of the different substances from which specific objects were made (lapis beads as opposed to copper axes, for example), but this is only partially and imperfectly true (see Wagensonner 2010 for an overview). The groundbreaking work of Englund and Nissen on the earliest proto-cuneiform lexical lists still provides the essential starting point for any discussion of classification in ancient Mesopotamia (Englund and Nissen 1993, now contextualized by Veldhuis 2014). Although the proto-cuneiform lists of birds, fish, and domesticated animals often receive the most attention, largely because we have a better grasp of the logograms involved, the lists dedicated to wood, (ceramic) vessels, and metals (including textiles), along with designations of offices and social roles, are more frequently attested and demonstrate the centrality of economic management and craft production rather than the classification of birds, fish, and animals as a purely intellectual pursuit. The early lists that are most relevant to the history of chemistry ("metals," "wood," and "plants") do not use a single recurring logogram in every entry in the list (as we see incipiently in "birds" and "fish"). For the "wood" list, to take up a relatively well-attested example, certain manuscripts (such as W20044,45) only include the "wood" determinative (GIŠ) in certain entries and not in others, whereas other manuscripts (such as W20327,2) add the "wood" determinative to every item in the list.

Where we first see specific and robust material or economic domains, clearly defined in the form of a lexical list, is half a millennium later in the Early Dynastic Practical Vocabularies (EDPV) found in Fara and Abu Salabikh in Mesopotamia and Ebla in present-day Syria. That these vocabularies represent a new moment in the lexical list tradition – the seed of a tradition that culminates in the Old Babylonian ur_5-ra = *hubullu* lists – has been repeatedly emphasized in the work of Miguel Civil (1987; see Veldhuis 2014: 71–139 for an up-to-date overview). In his edition of EDPV A, a decade ago, Civil was able to identify clearly demarcated sections, many of which are relevant to us here (Civil 2008):

- Stones (sect. 1 = entries 1–101 = pp. 51–79)
- Metals (sect. 2 = entries 102–68 = pp. 79–92)
- Textiles (sect. 3 = entries 169–95 = pp. 92–8)
- Oils (sect. 4 = entries 196–204 = pp. 98–9)
- Perfumes (sect. 6 = entries 216–25 = pp. 102–6)
- Skins and leather (sect. 9 = entries 262–83 = pp. 118–25)
- Colored clays and pigments (sect. 16 = entries 344–50 = pp. 137–9)
- Tanning materials (sect. 19 = entries 366–70 = pp. 142–5)

These seemingly "craft" or even "industrial" sections are interspersed with sections devoted to musical instruments, equids and harnesses, weapons, and boats, so we have good reason to suspect that the materials in themselves were less important than the finished products being fashioned. And a closer look at each section confirms this: the "stone" section actually begins with a lengthy section of lapis lazuli collars, necklaces, beads and other luxury goods, and many decorative figurines (stones bowls for offerings and stone tools come later and are few in number). The first items in the "metals" section are, in fact, metal statues and figurines, with metal vessels and tools only at the end of the section. The dozen entries dedicated to pigments and materials for tanning toward the end of the list (lines 344–52 and 366–80) are more promising, but only a few of these items can be readily identified. So even here, in the middle of the third millennium BCE, when we can see clear sectors of artisanal or craft production demarcated in a "practical vocabulary," specifically chemical practices are still entirely in the background and do not enter into the lexical tradition explicitly.

If we want to separate out material substances and the properties, real or imagined, from manufactured or finished objects in early Mesopotamia, the nonexistence of Greco-Roman style treatises in the cuneiform textual record has often led moderns to erroneously suppose that Mesopotamians had no such theories. Postgate (1997) provides us with a particularly useful discussion of how Mesopotamian approaches to substances and properties were actually put into practice in nonmythological texts and the archaeological record. The key evidence that Postgate brings together are small collections of raw materials that are occasionally found in the foundation deposits of temples and, in the particular case that gives rise to his paper, in an intramural burial in Early Dynastic Abu Salabikh containing "a neat arrangement of small items: a black pebble and a white pebble, a flint blade, a piece of bitumen, and nine other pebbles of nondescript colour and three or four cockle shells" (Postgate 1997: 206).

Contemporary with the EDPV that we were just looking at, this mortuary assortment is paralleled by archaeologically recovered foundation deposits: Ellis identifies a number of these assortments in excavated temple foundations, such as the "small rectangular pieces of gold, copper, lapis lazuli and slate … in each corner" of the Oval Temple at Khafajah, with additional materials salted into specific corners (Delougaz 1940: 85–6 and figs 78–9; Ellis 1968: 132). Likewise, in the corners of the main ziggurat at Assur:

> two sets were found, one directly on the bedrock, and the other six courses higher … The lower deposit consisted of round masses … of small shells and of glass, frit and stone beads … The upper deposits were similar; each one consisted of about 1,000 beads, laid on and covered with reeds. Small fragments of iron and lead were included (as were) a pair of small disks of gold and silver, each one bearing an inscription of Shalmaneser III (reigned 859–824 BCE), dedicating the ziggurat to Aššur.
>
> (Ellis 1968: 132)

The second of these foundation deposits, the one found in the ziggurat of Assur, is quite similar to descriptions of assemblages of substances in royal inscriptions running from Šamši-Adad (reigned 1809–1776 BCE) down to the famous statement of Sargon II (reigned 722–705 BCE) that "I aligned its masonry on gold, silver, copper, precious stones, cuttings (of fragrant resins) from Amanus; I laid its foundation and made its brickwork firm" (App. A, No. 15; Ellis 1968: 134).

Postgate's query to this rare instance of parallel bodies of evidence from the textual and archaeological record is clear enough: "What was the thinking behind this age-old practice? … The texts tell us that these deposits were made, but refrain from explaining why" (Postgate 1997: 211).

These parallel assemblages in the textual and archaeological record point to a self-conscious effort to assemble a group of substances (and thereby their respective properties) *rather than* the finished objects made from these substances. Postgate cites a Hittite text in which it is said that "just as copper is secured, (as) moreover it is firm, even so let this temple be secure!" Postgate goes on to say:

> The point here is that copper is attributed properties, security and firmness or safeness and solidity, which are to stand for the properties the royal builder wishes to impart to the building itself. It is recognised as partaking of a *substance* and is put into the foundation for the *properties* which its substance confers, not for its appearance or its function.
>
> (1997: 211)

In the latter phases of the first millennium BCE, we see this type of systematic concern with substances and properties only in the Late Babylonian effort, in the second half of the first millennium BCE, to align medicinal substances with astrological configurations. This type of astrological medicine first becomes visible in the so-called "stone, plant, tree" lists in which four classes of material (stones, plants, trees, and a fourth category including things like scorpion carapace and dust from various locales) are crossed with three manners of preparation (phylactery, fumigation, and anointment) to arrive at twelve combinations (Heeßel 2005; Heeßel 2008). These twelve combinatorial possibilities could then be aligned with the twelve months of the year or, after its invention in 500 BCE or so, the zodiac (on the microzodiac algorithms deciphered in the last couple of decades, see Brack-Bernsen and Steele 2004; Wee 2016; Schreiber 2018). Unmoored from its astrological roots (where "blood of a ram" is a straightforward cover term for a plant associated with Aries; Steele 2011), this kind of schematic approach to substances and properties led ingredient names like "mongoose tail" (Akk. *zibbat šikkê*), which actually stands for the plant/drug "liquorice" (Akk. *šūšu*), to be systematically misunderstood, especially in later translations, as actually referring to mongoose meat. And this may well have had a significant impact on the "properties" literature that culminates in both Pliny the Elder's collection of exotic recipes (Rumor 2015: 87–95) and in Pseudo-Democritus's four alchemical books (Martelli 2013; Martelli and Rumor 2014).

The most famous and comprehensive of the cuneiform lexical lists, known as (Sum.) ur_5.ra = (Akk.) *hubullu*, was compiled in the heyday of the Old Babylonian period (ca. 1800–1600 BCE). In it we see the dynamic variation in the use of semantic determinatives and the gathering of different terms within a specific domain rooted out and replaced by relatively frozen sequences of Sumerian lexical items. Here instead we have extended lists of items, frequenting running for hundreds of entries without interruption, in which each entry begins with the same semantic determinative. These lists have been admirably summarized and the subsequent history described at length in Niek Veldhuis's *History of the Cuneiform Lexical Tradition*, from which I will only highlight a few key points here. The standard list of objects in Old Babylonian ur$_5$.ra = *hubullu* consisted of six large tablets or chapters (Veldhuis 2014: 150):

1. Wood
2. Crafts, including raw materials and manufactured items
3. Animals and cuts of meat
4. Natural entities and objects made from them
5. Geographical names
6. Food

Starting in the Middle Babylonian period (ca. 1400–1000 BCE), the same overall structure is renumbered (though not reconfigured in a substantial way) into a larger number of tablets so that the standard edition in the first millennium BCE ultimately consists of twenty-four chapters, usually designated as "Hh" followed by the tablet number (Veldhuis 2014: 156). The standard editions of these texts are published in the series *Materials for the Sumerian Lexicon* (MSL). Of these, the most relevant for our purposes here are as follows:

- Hh 3–7 ("Wood"), edited by Benno Landsberger in MSL 5 and 6 (1957 and 1958)
- Hh 8–9 ("Reed"), Hh 10 ("Vessels"), Hh 11 ("Leather"), and Hh 12 ("Metals"), edited by Benno Landsberger in MSL 7 (1959)
- Hh 16 ("Stones"), Hh 17 ("Plants"), and Hh 19 ("Textiles"), edited by B. Landsberger, E. Reiner, and M. Civil in MSL 10 (1970)

These editions are now subsumed and expanded online in Veldhuis's *Digital Corpus of Cuneiform Lexical Texts* (DCCLT) website, containing individual editions of each manuscript rather than the mixture of synthetic and "forerunner" editions found in the MSL series.

In each of these tablets or chapters we now find the stereotypical picture of hundreds of entries, each beginning with the same semantic determinative, a pattern that never appears so plainly in the earlier phases of the lexical list tradition. To give some scale to the enterprise, there are nearly 2,000 entries beginning with Sum. giš "wood" in Hh 3–7, ca. 350 entries beginning with Sum. gi "reed" in Hh 8, ca. 335 beginning with Sum. dug "pot," as well as a smaller group of ovens, kilns and related equipment, and ca. 125 entries beginning with Sum. im "clay and minerals" in Hh 10. In Hh 11 there are ca. 280 entries beginning with Sum. kuš "leather" and ca. 140 entries beginning with Sum. an.na "tin" or Sum. uruda "copper," and in Hh 12 there are ca.

350 entries beginning with several types of metal, including statues and tools. Hh 16 includes ca. 450 entries beginning with the general determinative for "stone" (Sum. na_4), Hh 17 consists of ca. 250 entries beginning with Sum. u_2 "plant/drug" and another 150 or so that end with the determinative sar or nisi(g) "vegetable," and Hh 19 comprises ca. 100 entries beginning with Sum. sig_2 "wool," ca. 200 entries beginning with Sum. tug_2 "textile," and a largely destroyed final section on threads and linen. It is really only in the Old Babylonian thematic lists like ur_5-ra = *hubullu* that a normative classification of entire fields of material composition is applied to the lexical list tradition. And yet, even in the Old Babylonian thematic lists there are numerous classificatory outliers such as a variety of manufactured minerals and pastes determined with Sum. im "clay" or the humble "spiderweb" (Sum. $aš_5$ = Akk *ettūtu*) classified as a type of Sum. u_2 "plant" because of its use in Babylonian pharmacology (Scurlock 1995; Postgate 1997).

The so-called *šiknu* lists are a distinct literary form that expands the basic pattern of the lexical list with a fixed formula consisting of (a) the characteristic name of the overall semantic class and the word *šikinšu* "its feature(s)," as in, for example, *šammu šikinšu* "the plant, its feature(s)," (b) a description or illustrative comparison, (c) the name of the specific entity in question, and (d) the expression *šumšu* "(is) its name" (see Schuster-Brandis 2008: 17–47; Stadhouder 2011; Stadhouder 2012; Mirelman 2015 for recent editions and discussion). This pattern was applied to a limited number of lexical fields: "stone" (Sum. na_4 = Akk. *abnu*), "plants" (Sum. u_2 = Akk. *šammu*), "snakes" (Sum. muš = Akk. *ṣēru*), and what is most likely a cryptographic writing for birds or their calls (BALAG, perhaps equivalent to Sum. mušen). More elaborate forms of this pattern, particularly for *šammu šikinšu* (the descriptions of plants), are known as well, and there may even be one manuscript of this descriptive pattern that dates back to the last centuries of the second millennium BCE (Schuster-Brandis 2008: 18, text E = VAT 9587). The schema outlined above is similar to a few other types of text, notably the so-called *Göttertypentext* (Mirelman 2015: 174), which are descriptions of the different parts of divine statues, a descriptive paradigm that has affinities with so-called Body Description texts and other similar forms (Reynolds 2002; Reynolds 2010; Pongratz-Leisten 2015). These descriptive lists of the properties of plants, minerals, and so on were not the idle speculations of a lone scholar, but rather a regular part of the first-millennium BCE scientific tradition, cited or alluded to in royal inscriptions and wedged into sequences of other compendia through the use of incipits and catch lines (Reiner 1995: 119–32; Robson 2001: 52–3). It is telling that the descriptive lists of plants (*šammu šikinšu*) almost always use other plants as their comparanda, including occasional *Decknamen* (cover names) such as "sailor's feces" (Akk. *zê malāhi*) or "dog's tongue" (Akk. *lišān kalbi*), but these were clearly recognized as plants (Rumor [2018] argues that the textual structure of Theophrastus' *Historia plantarum* IX is based on the *šammu šikinšu* tradition). As we move into the other descriptive lists, the comparanda become far more diverse, vivid, and nonpharmacological: in the stone list *abnu šikinšu* we find items of comparison ranging from "a swirl of red wool" (Haupttext line 10) or "uncooked bull blood" (line 33) through "dragonfly wing" (line 84) and "sulfur flame" (line 46).

GRECO-ROMAN WORLD

Matteo Martelli

Expressions like "chemical element" or "chemical reaction," at least in their modern meanings and formalizations, are alien to ancient classical philosophy and science. However, Greek and Latin authors certainly made various attempts to describe, conceptualize, and explain the material transformations that they experienced in the natural world. In the framework of different systems, all classical philosophers dealt with natural substances, investigating their properties, compositions, and mutual interactions. Modern scholarship on this subject is vast, and one can potentially find relevant information in every piece of a massive literature dealing with ancient "physics" (i.e. *ta physika*, "natural phenomena") and ancient explanations of what, in Aristotelian terms, may be identified with the sublunary world. J.R. Partington's first volume of his monumental *History of Chemistry* (published posthumously in 1970) is devoted to the "theoretical background" of ancient alchemy: this volume, in fact, is a monograph-length survey of ancient philosophy, from early pre-Socratics to late Neoplatonic schools. Partington also described Plato's *Timaeus* as "the first treatise on theoretical chemistry" (1970: xi), whereas similar definitions were applied by other scholars to certain Aristotelian treatises, such as the fourth book of *Meteorology*, explicitly referred to as Aristotle's chemical treatise (Düring 1944; Viano 2002), or *On Generation and Corruption*, defined as the manifesto of Aristotle's physical chemistry (Giardina 2008; see already Joachim 1903).

Scholars have also addressed the question of the possible influence that classical philosophers, Plato and Aristotle in particular, had on the writings of Greco-Egyptian and late antique alchemists, such as the works by Zosimos of Panopolis (third to fourth centuries CE), Synesius (fourth century CE), and Olympiodorus (sixth century CE; Viano 1996; Viano 2005; Dufault 2015). Byzantine alchemical collections do include the names of Plato and Aristotle in the lists of the fathers of alchemy, which are handed down in Greek manuscripts (*CAAG* II 25–6). In his commentary on Zosimos' (lost) work *On the Action*, Olympiodorus – perhaps to be identified with the writer of that name who was a Neoplatonic commentator of Aristotelian works (Viano 2006: 199–206) – draws a close comparison between early Greek philosophers and the fathers of alchemy, namely Hermes, Chymes, Agathodaimon, and Zosimos (*CAAG* II

80–5; Viano 1995). In this doxographical section, Olympiodorus discusses the different "first principles" (*archai*) proposed by nine pre-Socratics, such as Thales' water, Heraclitus' fire, or the air of Diogenes of Apollonia. Then, he compares these principles with those of the alchemical art. He writes, for instance:

> Anaximander referred to "the intermediaries" [as first principle], namely smoke (*kapnos*) and vapor (*atmos*). Indeed, Agathodaimon's [words are]: "in short, it is the sublimate (*aithalē*)," as Zosimos says. Most of those who philosophically treated this (alchemical) art have mainly followed these (men). Hermes spoke about smoke as well; indeed, speaking about *magnēsia*, he says: "let it be burnt against a furnace with flakes of purple *kōbathia* [arsenic ores?]." For, being white, the smoke of *kōbathia* whitens the (metallic) bodies. Smoke, in fact, is between hot and dry; the same is the sublimate and all the substances made of it; vapor is between hot and wet (substances), and he means wet sublimates, such as those produced with alembics and the like.
>
> (*CAAG* II 84–5)

With Olympiodorus, we are at the end of the chronological period under review in this volume. The alchemist discusses ideas inherited from the earlier philosophical tradition, such as the distinction between dry smoke and wet vapor, which recalls the Aristotelian theory on the composition of minerals (see below). However, rather than being purely philosophical principles, these elements coincide with operative objects, namely wet and dry sublimates that ancient alchemists produced and manipulated in their operations. Indeed, the alchemical art is a combination of theory and practice, as already pointed out by Festugière, who defined Greco-Egyptian alchemy as a *mélange* of Egyptian traditional goldsmithing and Greek philosophy, mainly Platonic and Aristotelian ideas (Festugière 1944: 218–19). This relationship cannot be simply conceived as the application of theories made up beforehand to the explanation of alchemical operations. Since the classical period, in fact, "chemical" arts (e.g. dyeing procedures, metallurgy, perfume-making; see Chapters 2 and 3 on these arts) provided empirical observations that fostered the formulation of various theories on natural phenomena. Relevant examples will be discussed below, with a particular focus on those elements that had an impact on the later development of Greco-Egyptian alchemy.

In Olympiodorus' doxographical section (see above), the name of Democritus is missing. On the other hand, Democritus is mentioned throughout Olympiodorus' commentary (as well as in almost every Greek and Byzantine alchemical work), not as the founder of atomism, but as the author of four pseudo-epigraphical books on alchemical dyeing that date back to the first century CE (Martelli 2013). The later history of the concept of the atom does not need to be emphasized here, let alone the impact that the discovery of Lucretius' *De rerum natura* in the Renaissance had on the works of early modern scientists such as Pierre Gassendi or Robert Boyle (Luthy 2000; Beretta 2015: 219–64). In the same period, other ancient texts providing discussions of ancient atomism were rediscovered, edited, and translated into Latin, such as Diogenes Laertius' *Lives of Eminent Philosophers* and Galen's *On the Elements According to Hippocrates*. Atoms, on the contrary, do not play any role in Greco-Egyptian alchemical writings, where the historical figure of Democritus the atomist is overshadowed by "Democritus" the alchemist, the pseudonym used by a first-century CE alchemical author whose historical identity cannot be reconstructed. Democritus' name seems to have been used by this writer because of the atomist's expertise across several arts or *technai* (Martelli 2013: 34–6), as emerges, for instance, from the portrait given by Petronius (*Sat.* 88): "Democritus extracted the juice of every plant on earth, and spent his whole life in experiments to discover the virtues of stones and twigs" (Democritus, fr. B300,6 DK; transl. by Heseltine 1913: 173).

Indeed, in the framework of his atomistic theory, this pre-Socratic philosopher did focus his attention on arts or *technai*, and he emphasized their pivotal role for the advance of human civilization (Cole 1967). According to Democritus, infinite and eternal atoms, which differ in shape and size and move and combine in an empty space (the void), are the ultimate constituents of the natural world. Atoms of the same kind tend to congregate, thus forming various materials, from the sea to earthy substances, such as salt, soda, alum, and bitumen (fr. A99a DK). Moreover, the philosopher speculates on the atomic composition of metals. Iron is lighter than lead because it contains more void, while its atoms are densely packed in specific areas; lead, on the contrary, is formed of atoms more regularly arranged (Theophr. *Sens.* 62 = fr. A135 DK; see Halleux 1974: 74–6). When discussing the nature of the four primary colors (white, black, red, and yellow), Democritus refers to the shapes of the atoms and their disposition: white, for instance, depends on atoms whose shape is similar to the inner surface of shells (Theophr. *Sens.* 73 = fr. A135 DK). Likewise, the color of metals depends on the mixture of different primary colors: gold and copper, for instance, are bright because they are a combination of white and red – that is, the result of the combination of atoms with particular shapes (Theophr. *Sens.* 76 = fr. A135 DK).

A complete system of four elements – earth, water, air, and fire – recognized as the fundamental constituents of the natural world was fully developed by Empedocles (fifth century BCE), who used the term "roots" (or, sometimes, the names of Olympian gods) to refer to these elements. If early Ionian philosophers identified a single dynamic substance with the cosmic principle (*archē*) undergoing cyclic transformations, Empedocles "posits a plurality of substances of fixed natures that interact in different proportions to produce mixed substances" (Graham 1999: 165). These substances (i.e. the elements), eternal and unalterable, are mixed together and separated by two opposite cosmic forces, Love and Strife, whose work is often assimilated by Empedocles to the work of craftsmen (Wright 1981: 39). For instance, the combination of the four elements is explained in Galen's *Commentary on (Hippocrates') Nature of Man* (I 3 in XV 32 Kühn = Mewaldt 1914: 19) as follows:

> Empedocles maintained that the nature of compound bodies derives from the four unchangeable bodies: these are the first (elements) that mix one with the other, as if someone finely ground verdigris, copper ore (*chalkitēs*), cadmia (zinc oxide) and *misy*, and produced a fine powder by mixing them together, so that none (of its components) can be handled without the others.
> (Empedocles, fr. A34 DK)

The comparison with pharmacology might not belong to Empedocles' original writings (Halleux 1974: 68), although we must observe that the philosopher referred to how painters mix pigments of various colors (*polychroa pharmaka*) when he tried to explain how things come to be from the combination of the four elements (fr. B23 DK; text fully quoted in M. Beretta's introduction, pp. 9–10). Scholars usually agree that, rather than referring to the blending of pigments, Empedocles meant that colors were put side by side to depict a picture (Ierodiakonou 2005: 5–8). Colors (like elements) touch one another rather than fusing one into the other: they may be compared to bricks and stones that are placed side by side to build a wall, as Aristotle explains in *On Generation and Corruption* (II 7, 334a). On the other hand, if the four elements do not change in Empedocles' theory, they are conceived as capable of being broken into very small parts (Wright 1981: 37–8); thus miniaturized, they can intermingle with one another in compositions like the medicinal powder mentioned by Galen. The nature of these compositions seems to depend on the structure of their components. In *On the Generation of Animals* (II 8, 747a–b), Aristotle discusses Empedocles' explanation of the sterility of mules (in contrast to the fact that horses and donkeys are fertile). In Empedocles' opinion, the soft seeds of both parents, when mixed together, become hard, because the hollows in each fit into the densities of the other. The hardness of tin-copper alloys was explained in the same way: while the two metals are soft, their "mixture" is hard, presumably because the structures of copper and tin allow them to fit one into the other in tight juxtaposition (Halleux 1974: 69–70).

While Empedocles referred to the four elements as "roots," one of the earliest occurrences of the term *stoicheion* (στοιχεῖον, lit. "letter") as "element" appears in Plato's *Timaeus*. In this cosmological account – a "likely account" (*eikos mythos/logos*), as the philosopher defines his argument in the dialogue (29d; 30b) – each of the four elements has the shape of a geometric figure (or solid) whose main components are right-angled triangles: fire-tetrahedron; air-octahedron; water-icosahedron; earth-cube. If the *Timaeus* is one of the first attempts to bring mathematics (geometry in particular) into a cosmological discourse, this geometric explanation is often colored by images and terminology taken from the world of ancient arts, which Plato used to explain the work of the demiurge, a craftsman god (Brisson 1998: 35–50). For instance, in order to explain the nature of *chōra* (traditionally translated as "receptacle"), one of the central entities in the dialogue, Plato writes:

> That is why, if it is to be the receptacle of all kinds, it must be altogether characterless. Think, for instance, of perfumery, where artisans do exactly the same, as the first stage of the manufacturing process: they make the liquids which are to receive the scents as odourless as possible. Or think of those whose work involves taking impressions of shapes in soft materials: they allow no shape at all to remain noticeable, and they begin their work only once they've made their base stuff as uniform and smooth as possible.
> (*Tim*. 50e; transl. by Waterfield 2008: 43)

The ambiguity of Plato's *chōra* was already stressed and criticized by Aristotle (*Ph*. IV 2, 209b–210a), and it is also mirrored in the different explanations proposed by modern scholars (Miller 2003), who interpreted it either as "space" or as "prime matter" – a meaning that was fully encapsulated in Aristotle's concept of *hylē*. In the quoted passage, Plato insists on the fact that the *chōra* must be completely formless, a feature that he describes on the basis of two examples taken from the "arts": (a) wax must be formless, in order to receive the impression of a seal; and (b) the liquid basis for a perfume must be as odorless as possible in order to receive the scent or fragrance from the aromatic substances that are added to it. The reference to perfume-making (similar to what we read in the technical section of Theophrastus' *On Odors*, 18) is particularly interesting, since it implies liquid mixtures. The blending of liquids, in fact, is evoked in key passages of the *Timaeus*, when Plato describes how the demiurge blended (a) the world-soul (35a1–b1), (b) the human soul (41d4–7), and (c) the vegetative soul (77a3–5). In cases (a) and (b), moreover, Plato specifies that the "ingredients" of these souls were mixed in a *kratēr* (κρατήρ, lit. "bowl"), which usually refers to a large vessel used to mix wine with water. However, we cannot exclude that Plato had a metallurgical model in mind, according to which metals were melted and mixed in a crucible (namely the *kratēr*; see Brisson 1998: 36–8).

In the *Timaeus*, metals are considered as a kind of water: next to "liquid water" (*hygron hydōr*), in fact, one must also consider "fusible water" (*chyton hydōr*; i.e., solidified water that can be melted). Copper, for instance, is gold-like, but lighter, because its particles of water are mixed with earth: sometimes, in fact, the earthy part appears on the surface and is called "verdigris." As for gold, Plato writes:

> To take a few of all the varieties of what we've called liquefiable water, there's one that is extremely dense (because it consists of the most subtle and uniform parts) and unique of its kind (*monoeidos*), and has been endowed with a shiny, yellow colour: this is our most highly prized possession, gold, the solidity of which is due to its having been filtered through rocks.
>
> (*Tim.* 59b–c; transl. by Waterfield 2008: 54)

Plato's definition of gold as *monoeidos* ("unique of its kind," "unique species") seems to have influenced Zosimos of Panopolis, who describes a method for the making of gold as follows (*Authentic Memoires*, X 8 in Mertens 1995: 41–2): after treating copper with several ingredients (salt, sulfur, and vitriol) and exposing it to the three sublimates, the alchemist will be able "to subdue the matter (*hylē*) and get the unique species (*to monoeidon*, i.e. of gold) out of many species" (Viano 2005: 99–102). Even though he manipulates, mixes, and treats complex species rather than elemental constituents (as the Platonic demiurge does), Zosimos attributes to the product of these manipulations the same qualities of natural gold. This claim was firmly criticized by the Neoplatonic philosopher Proclus (fifth century CE). In his commentary on Plato's *Republic* (Kroll 1899–1901: vol. 2, 234), in fact, he denies the possibility of *chrysopoeia*: by echoing Plato's words, he defines gold as a "unique species" produced by a demiurgic act, which cannot be imitated by the alchemists who simply mix other species (Viano 1996: 202–3; Viano 2005: 105–6).

Centuries before this debate, the concept of mixture was discussed in Aristotle's *On Generation and Corruption* (I 10). Here, as Cristina Viano recently pointed out (2015), Aristotle introduced the new idea of *mixis* as "chemical mixture"

> … to explain the constitution of those homogeneous substances from which all complex beings in the sublunary world, both natural and artificial, are comprised. In such a mixture, the ingredients "react" together to give rise to a new substance that is qualitatively different and possesses its own form. At the same time, the original ingredients remain present in power (*in potentia*) so that they can be separated again.
>
> (Viano 2015: 204)

Even though the elements of a *mixis* react to give rise to a new homogeneous substance, they remain present *in potentia*; that is, they can be still detected if the substance is properly analyzed. This analysis is the central object of the fourth book of *Metereology*, in which Aristotle discusses the composition of homogeneous bodies by describing eighteen pairs of opposite transformations (or affections) that they can or cannot undergo. These affections depend on the elemental constitution of the bodies, in particular on the different ways their two passive qualities (i.e. dryness and moistness, which are to an extent identified by Aristotle with earth and water) are affected by the action of heat and cold. For instance, bodies that melt when heated, such as metals or fusible stones, are mainly composed of water. More complex analysis, moreover, involves forms of experimentation, where the *technai*, especially the chemical arts, appear "as an instrument for generating knowledge" (Viano 2015: 211). A telling example is provided by the passage in which Aristotle discusses the composition of must (*Met.* IV 7, 384a3–7); its main components (water and earth), in fact, become evident to the experimenter when must is distilled:

> There is a kind of wine, for instance, which both solidifies by cold and may be dried up by boiling – I mean, must. In drying up all substances of this kind the watery part is separated off. That it is their water may be seen from the fact that the vapour from them condenses into water when collected. So wherever some sediment is left this is of the nature of earth.
>
> (Düring 1944: 45)

If we go back to Aristotle's concept of "chemical mixture," this *mixis* differs from a simple "combination" or "juxtaposition" (*synthesis*), where the elements are put side by side without underdoing any transformation. Aristotle specifies that liquids are particularly prone to "chemically" combine (*Gen. corr.* I 10, 328b3), thus anticipating a fruitful idea in the history of chemistry. As Düring (1944: 10) points out, "one of the chemical principles laid down by Aristotle was undisputed until some twenty years ago, namely the theory formulated in the words *corpora non agunt nisi liquida*. Only in 1925 did Arvid Hedvall succeed in proving that solid bodies also were capable of chemical reactions." The reactivity of liquids was also stressed by various Greco-Egyptian alchemists: natural substances, when dissolved, produce wonderful transformations, as Pseudo-Democritus claims (Martelli 2013: 94–5). In Aristotle's account, examples of liquid mixtures are metallic alloys produced by combining melted metals. In particular, he speculates on a copper-tin alloy: when tin and copper are mixed, "the tin almost vanishes, behaving as if it were an immaterial property of the copper: having been combined, it disappears, leaving no trace except the color it has imparted to the copper" (*Gen. corr.* I 10, 328b). Again, we find here a seminal idea that will be further developed by the alchemists, who tried to transfer the color form of the dyeing ingredients to the metal (often copper) to be dyed, as Synesius (Martelli 2013: 134–7) and Olympiodorus (*CAAG* II 91–2) explain (see already Lippmann 1919: 324; Viano 1996: 199–200; Dufault 2015: 221–5, 237–8).

Aristotle deals with metals and minerals at the end of his third book of *Meteorology* (III 6, 378a–b), where he provides a sketchy account on metallogenesis. Here, in order to explain the blending of the elemental constituents of minerals, Aristotle refers to the mixture of two kinds of exhalations: (a) smoky–dry exhalations and (b) vaporous–moist exhalations (Eichholz 1949; Halleux 1974: 98–105; Wilson 2013: 271–7). Vaporous–moist exhalations are trapped inside dry rocks and solidify (probably because of the cold), thus condensing into substances called *ta metalleuta*, that is, "metals" in this context (Aristotle lists iron, gold, and copper as examples of *metalleuta*; see Halleux 1974: 35–44). These substances, in fact, are fusible and malleable – properties that were clearly exploited by ancient smiths and metalworkers. The different amounts of earth mixed with the solidified moist exhalations determines the variety of metals. On the other hand, smoky–dry exhalations burn the earth in which they are trapped and thus produce a second type of minerals, which Aristotle refers to as *ta orykta*, lit. "fossils." He lists among these substances realgar, ochre, minium, sulfur, and cinnabar. Most of these "fossils," Aristotle continues, are colored dust, thus making reference to the production of pigments in antiquity (see Chapter 2).

The exhalations theory was later inherited and reshaped by the Stoic philosopher Posidonius (ca. 135–51 BCE; see Sen. *QNat*. II 54,1), who explained the composition of gemstones as well. In fact, as Halleux pointed out (1981: 50–1), we can assume that Diodorus Siculus (first century BCE), when discussing the origins of Arabian gemstones (*Bibliotheca historica*, II 52), had Posidonius' work in mind, even if the name of the philosopher is not mentioned in the passage (text fully quoted in Chapter 4, p. 134). Diodorus explains that rock crystals are made of water that solidified underground: here, specific kinds of rock crystals, namely emerald and beryl, take their colors from a bath of sulfur (*baphē theiōn*), as well as from the smoky exhalations produced by the sun heating the earth. Various elements of the theoretical explanation derive from empirical observations based on artisanal practices: in fact, the similarity with ancient dyeing techniques, which either used dyeing baths to dye crystals (as explained in the third-century CE Leiden and Stockholm papyri) or exposed metals to dyeing fumes (especially in the Greco-Egyptian alchemical tradition), is evident (see, for instance, the description of the *kērotakis* in Chapter 3, pp. 110–112).

CONCLUSIONS

Marco Beretta

Chemical arts played a central role in the development of ancient civilizations. Many important discoveries and technological breakthroughs remained unsurpassed until early modern times. However, such achievements were rarely the objects of autonomous reflection on the composition of matter and on the nature of its changes. Chemistry as a science simply did not exist. This does not mean that the effects of the manipulation of matter did not generate an effort to embody them in a theoretical frame. In the Egyptian civilization, precious stones and minerals were not just valuable commodities, but were believed to be material manifestations of the presence of gods. For this reason, their treatment was included in religious rites that were carried out under strict control of the clergy. The Egyptian classification of stones and metals depended on the nature of the gods from which they stemmed. The mythological origins of these materials exalted their value well beyond the world of the living. The funerary adornment of the pharaohs, the rite of embalming, and other complex religious rites endowed these precious materials with the properties of regenerating the dead.

The classification of chemicals, minerals, and metals in the Mesopotamian civilization was approached through quite different criteria. The transmission of knowledge by the cuneiform texts favored the systematic use of semantic determinatives, which attested to the centrality of economic management and craft production rather than a theoretical classification of chemical products and operations. In fact, chemical practices were not recognizable in one specific lexical classification, and they were often associated with medical and astrological texts.

The natural philosophies conceived by the Greek and Roman authors created a theoretical framework that was partially independent of the mythological and metaphysical assumptions of previous civilizations. Some of the most successful concepts, however, embodied earlier ideas. Empedocles' theory of the four elements and Pseudo-Democritus' view on the sympathies existing among substances echoed ideas and concepts that had been circulating in Egypt for a long time. On the other hand, by exploring the ideas that matter could be constituted of atoms (Democritus), of solid geometric forms (Plato), or of ever-changing combinations (Aristotle), the Greek philosophers presented new chemical theories that were at the basis of a classification of metals and stones destined to be absorbed, discussed, and developed by the Byzantine alchemists.