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THE FIRE/HEAT CONCEPT AND ITS JOURNEY FROM PREHISTORIC TIME INTO THE THIRD MILLENNIUM*

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Abstract

The notion of fire/light/heat/energy is recognized as an integrating element in the pathway of ordering matter and society, and its historical aspects are thoroughly reviewed. Fire is argued to be a philosophical archetype and its role in the early concept of four elements is discussed. The Indian, Arabic and Greek historical bases are mentioned. Alchemy is briefly reviewed as a source of the wider adoption of fire. The era of renaissance and the new age are also included. The message of fire/heat is nowadays focused on the progress of civilization, with the assumption of engines as information transducers based on the conscious exploitation of fire. The role of chaos is emphasized. Overall, a condensed but consistent view is given of the various concepts that emerged during the historical progress of the understanding of heat (noting 61 references).

Keywords: alchemy, caloricum, chaos, elements, engines as information transducers, entropy, fire, heat, history, information, living cells, philosophy, thermodynamics

Fire as a philosophical archetype

Motto: 'Fire shall try every man's work' [Corinth. III:13]

The integrative notion of fire/light/heat (and more recently energy) is generally recognized as an integrating element rudimentary in the pathway of ordering matter and society. Its first rendition, called fire, has had an extremely long history, passing through several unequal stages in the progress of civilization. Within the chronicle of the interactions of society with fire, we can distinguish roughly four periods. Perhaps the longest age can be named the period without fire, as the first human beings were afraid of fire (like wild animals), but gradually associated with it a sensation of warmth and cold. Another long era was accompanied by the growth of the continuous

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experience of using fire, which helped distinguish human beings from animals (the use of fire as a weapon, as a conscious source of warmth, or as a substantial aid in cooking meat, making it more easily digestible). A definite advance came with the recent, but short period of making fire, up to the present brief exploitation of fire, including the domestication of fire and its use as energy.

Fire is believed to have both heavenly and earthly origins: it is brought from the sky by lightning, and it lives in the underworld of volcanoes, so that the worship of fire is widespread, particularly in areas where the older earthly fire is believed to be the image of heavenly fire. For various psychological reasons, fire is considered to be a personified, animated or living power: it is red like human blood, and warm like the human body, it shines brightly in the night and may have a form of 'eternal life', or by constant rekindling can be made into a 'perceptual fire'. Masculine fire (the principle Jang – light) is thought to fight from the center and to have the power to decompose what nature has joined together, while feminine fire (the principle Jin – shadow) attacks from the surface, is difficult to restrain and often disappears as smoke. Fire was believed to extend throughout the celestial spheres, and even time was thought to move in cycles (ekpyrosis, 'conflagratio'), involving a period of its destruction by fire during the cycle's involution and/or end. Fire has for all intents and purposes accompanied mankind's thoughts, beliefs and doings from the very beginning [1–38] until today's serious scientific treatises [39–57], including the theory of chaos applied, for example, in the transfer and/or distribution of heat (weather).

The generation of fire, which would have been unachievable without the aid of fire bores or saws, was sometimes also perceived as a sexual act, with the imaginative

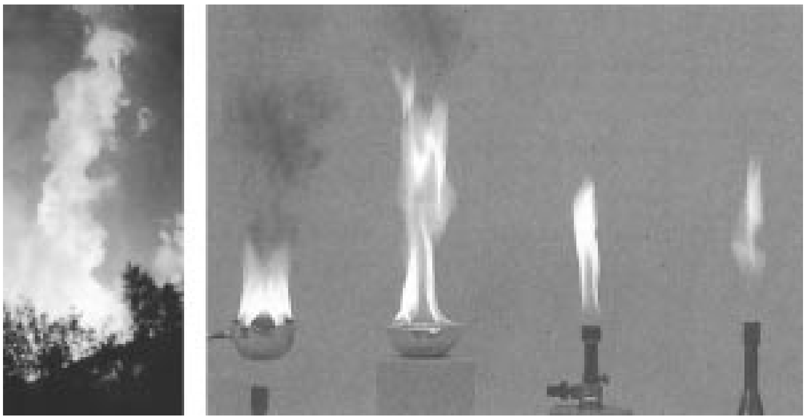

Fig. 1 Fire has created a landscape diversity through regular lightning and burns. Thanks to the fire, the landscape mosaic has been maintained and, on the other hand, thanks to the mosaic structure, the extent of the fire damage has been kept local. This natural course, however, has been disturbed by man-made woods – monotonous cultivation (agriculture) (left).
The shape of flame is similar for the substrates of natural and artificial fires. Burning natural oil has a similar character to the natural burning of woods. The lower the content of carbon, the lighter the flame (throughout the sequence from oil, to gasoline, butane and methane) (right)

concept of male and female firewood. Corresponding views were probably most pronounced among Aborigines, and such a conceptual framework consequently influenced the ideas on fire in the body of humans, especially of women, as a center of sexual life. In archaic civilizations with sacral kings, the sacred perpetual fire (state fire) of the residence and temples of the royal ancestors was believed to have a phallic element. It was sacred for virgins, who were viewed as wives of the fire. The extinguished and rekindling of fire at the inauguration of a prince points to the idea of a spirit of the princes within the state fire and also to the cyclical renewal of the state in the purifying act of fire, which signifies the beginning of a new era. According to some Hermetic and Gnostic doctrines, it was believed in the mysteries that the soul emanated from the Lord, fell into the body, casting its internal fire, and then had to return to its former home. Thus, it was believed that during cremation the soul is helped to separate from the body though the effect of external fire. Fire has therefore become a mandatory part of almost all holy places.

Burning, as a source of fire, is invisible, perceptible in its product only, i.e. flame, which exhibits a surprising similarity for different substrates (fuels) and is scientifically reasoned to be a universal portrayal of conglomerated chemical reactions resulting in energy production in the form of heat and light (Fig. 1). At the beginning of science, however, flame was acclaimed as an optical illusion and only a spectre, as fire was felt not to have a substantial carrier: it illuminates and animates its surroundings, making the illusion of liveliness. Fire also calls for a vision of a living organism ('agile' sive/i.e. 'ignis') exhibiting growth and change, digesting and shining, or a need for food and air. Fire is composed of very sophisticated internal structures of flames, and shows continual instability, self-structuring and self-reproduction. It is often exemplified by a burning candle: the more the wick flames, the more it is extinguished, being buried in the melted wax, thereby feeding back the actual fuel supply. Flame is the visible pattern of fire and has been treated in many scientific, poetical and mystical essays [23–28]. There is a Latin proverb 'Ignis mutat res' (fire changes things), stating that through fire all matter changes its properties, metals become ductile, or raw food-stuffs change into a meal. Fire furnishes heat and light, which are symbols of the intimate asylum of safety guarded homes, but at the same time is a source of perpetual danger: the domestic fireplace ('focus') can become a focus of complete destruction. Fire is part of 'apeira' – limitless, sacred and self-referenced 'apeiron' (primordial beginning – subsistence). Fire ('pyr' – flamma) delivers light (~eyesight), which is transmitted (~heating) by air ('aer' – flatus), reflected (~appetite) by water ('hydro' – fluctus) and absorbed (~tactility) by earth ('ge' – moles). Fire is the source of both expansion and contraction, annihilation and purification: the light of ideas reveals the truth, while the glow of fire proves its genuineness. Everything that flares up ends in ashes. Fire is self-destructing, factually turning itself into a worthless thing. Fire is a fundamental beginning, with its final effect being the entire end. Fire is often assumed to be a mirror of chaos.

Mission of fire – creative imaginations

It is a part of mythology that Prometheus stole fire from Zeus (thought by platonians to have actually happened to the blacksmith Hephaestus). It is of interest that the word 'promethean' is derived from the Sanskrit name for a drill, and can thus be understood as a personification of the act of making fire. Oastanes (about 500 BC), teacher of Democritos, was aware that there existed a natural power (possibly fire in the sense of energy) that can overcome all other powers, and is therefore capable of creating unification, but is also ready repeatedly to diminish it. However, this was not specified until speculations by some early Greek philosophers, notably Empedocles (500 BC), who was apparently the first to name the four basic elements (Fig. 2) that signified the substantially from which all subsistence/being was composed. In Greek, however, the elements are termed 'stoicheia' (today's chemical stoichiometry) and the overall name 'elementa' (beginning) was authentically derived from LMN, the first letters of the Etruscan (Phoenician alphabet). Empedocle's concept of four such patterns/roots ('rhizómata') was made were widely known by Aristotle 70 years later, but this came together with the fifth platonian subsistence/being 'quinta essencia', which was thought to interject a certain qualitative principle ('arche'). It was correspondingly conceived as ether ('aither') – something celestial and indestructible (derived from 'aitho', meaning glowing, flickering), possibly related to the Aristotelian 'primeval matter' ('prote hyle') and interpreted as the presence of subjects/things. Four elements had gradually been proposed through the ideas of Anaximenes (air), Xenophanes and Parmenides (earth) and Heracleitos (fire) and the latter also emphasized that fire most completely reveals the 'heavenly' reality of our universe, i.e. its order ('kosmos'). Sanctified fire gave the basis of the 'Empedocles complex', where the love of fire is linked with its respect and the instinct of life with the perception of death.

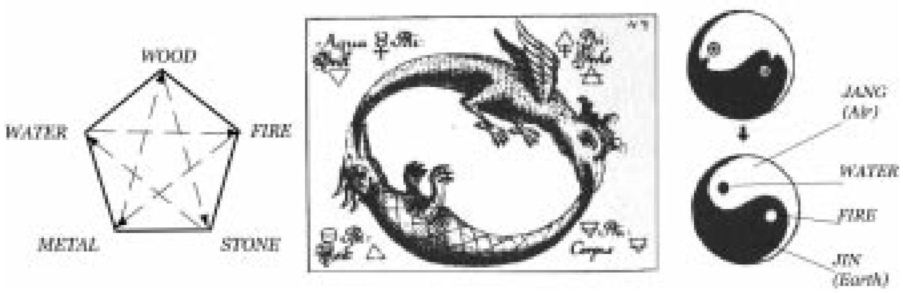

Fig. 2 Early concept of material elements (left). The clockwise solid line denotes creation, while the dashed lines with arrows symbolize destruction. It is noteworthy that this scheme already accounted for creation (water-wood) and destruction (fire-wood) of life. In the middle, a loop consisting of two dragons is revealed, together with the symbols of four elements in the corners. The upper dragon has wings, to symbolize volatility, while the lower dragon has only legs, to denote a solid. The dragon and fish are exchangeable (right) and from two fishes biting each other's tails the symbol of jin-jang is created, which has had an important role in Chinese alchemy and philosophy

In such a Greek interpretation, it was supposed that all material things were different combinations of elementary fire, air, water and earth with the integrative and structural essence ether, which was a heavenly natural and imperishable matter, thought to make up the universe of the fixed stars and the firmament. The four elements were not only plain mixtures (quantities), but also the bases of newly unified matter, whose balance was retained by four qualities: hotness, coldness, humidity and dryness, each element being defined by pairs of opposites (dry/hot, dry/wet, wet/cold and dry/cold). Hotness and coldness were active, whereas the remaining two were passive qualities. Properties associated with dominant (active) qualities have a tendency to grow if the object is surrounded by either a hot or a cold environment. In fact, this was the first definition of a thermal process. The source of hotness was anticipated (underworld hell), but the source of coldness (primum frigidum/colidum) was never identified.

Certainly, matter ('materia' – potentia pura) was not distinguished from energy ('energeia' – actus), so that heating a metal involved simply adding more 'fire' to it. Theophrastus [11] (287 BC) proposed three stages of fire: glow, flame and light, while Galenos (129–199 AD) introduced the idea of four degrees for becoming warm or cold with the 'neutral point' of equal parts of ice and boiling water. These four degrees were still accepted by medieval alchemists, and Mylius (1622) [6] proposed classification according to the Sun passing through Aries (signifying calcination), Cancer (solution), Libra (sublimation) and Capricornus (fermentation). The highest degree of fire was burning as vehement as fusion and each degree was twice as great as the preceding degree. The Bohemian educational reformer and Czech thinker Comenius (1592–1670) progressed to distinguish three degrees of heat (calor, fervor and ardour) and cold (frigus, algor and an unnamed degree) with a reference to a normal temperature (tepor). The highest thermal stage 'ardor' meant an internal degradation into 'atoms'. He stated [19] an almost modern definition of thermal analysis (skillfully interpreted by Mackenzie in [33]) '…to observe clearly the effects of heat and cold, let us take a visible subject and let us observe the changes that occur while it is heated or cooled, so that the effects of heat and cold are apparent to our senses…'. Comenius was also the first to observe the 'non-equilibrium character' of such thermal treatment and analysis '…with a well burning fire we can melt ice to water and heat it quickly to very hot water, but there is no means of converting hot water to ice quickly enough, even when it is exposed to very intense frost…', intuitively thereby noting the phenomena of latent heat and also undercooling.

Alchemy as the basis for adopting fire

The history of fire cannot be complete without mention of the spheres of alchemy [17–22, 27]. The origin of the word involves several associations: from the Arabic 'Al chama' (treated by fire) through the Hebrew 'Ki mijah' (given by God) to the Greek word 'chemeia', found in the writing of Diocletian as the art of making metal ingots, or 'chumeia' as the art of extracting juices or herbal tinctures. Even the abbreviation INRI 'Jesus Nazarenus Rex Judaeorum') was once interpreted as 'Igne Natura

Renovatur Integra', i.e. through fire Nature is restored to its wholeness. Alchemy, however, was subdivided into spagyrii, the art of producing medicaments (Table 1), dyes, ceramics, etc. (often in attempts to transform matter into algebraic combinations), archemii, focused on the development of metallurgy and the transmutation of metals, and Hermetic philosophy (often synonymous with alchemy overall, Fig. 3), i.e. sanctuary learning ('prisca theologia'), built up on performance ('traductio'), explanation ('exegesis') and interpretation ('hermeneusis' – nowadays giving a substructure for a modern interpretative hermeneutic description).

Table 1 Scheme of spagyric treatment of herbs (possible early roots of homeopathy)

Harvesting plants under given conditions (at full moon – polarized light, etc.)			
	Distillation ('separatio')		
Separation of etheric oils ('sulfur')			Fermentation ('purificatio')
	Separation, filtration		
Distillation		Calcination of plant residue	
Alcohol dissolution	Calcination of sediment ('calcinatio')	Plant ash ('sal')	
Distillation	Residual ash		
Absolute alcohol	Agglomeration ('cohobatio')		
	Filtration		
	Spagyric tincture		

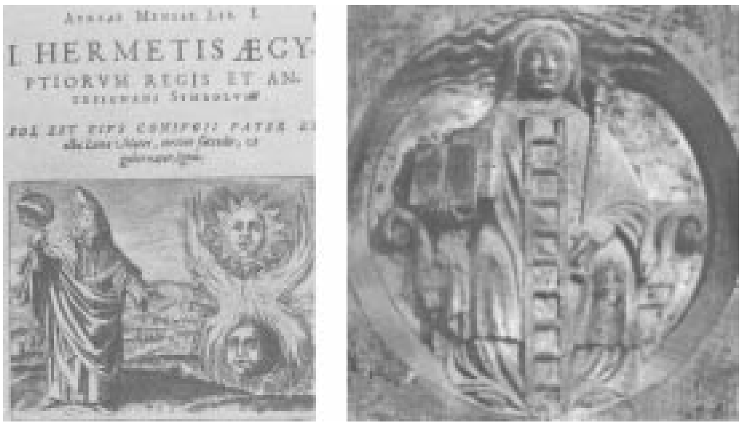

Fig. 3 Allegoric pictures associated with edition of books relating to Hermetic philosophy and alchemy. The latter discloses the position of alchemy as a figure sitting on royalty, whose head touches the sky, while the left hand holds a scepter as a symbol of power, and the right hand one open and one closed book, representing the open and secret sides of science. The ladder symbolizes the patience necessary to achieve all steps of a great masterpiece

It was aimed at providing trust in the existence of the 'first mover', God, as it reflected the evident order of the world. This argument, first formulated by the Persian prophet Zoroaster, was expressed in the form of questions: Who could have created the heavens and starts? Who could have made the four elements, except God? Hermetic learning was primarily ascribed to astrology by the Hermes Trismegistos, but later extended to medicine and alchemy, where the Byzantine 'Tabula Smaragdina' became a favorite source even for medieval alchemists. It contained seven principles, and scholars achieved knowledge of the laws of sympathy and antipathy, by which the parts of the universe were related. Hermetism was extensively cultivated by the Arabs, and through them it later reached and consequently greatly influenced Western culture, though it was often misinterpreted. Hermes' stick 'rhabdos' was ornamented with two twisted snakes showing 'waving water and blazing fire' as a unity of contradictions, thus becoming a symbol of life. In present times, it may also resemble the double helix of the DNA structure.

Alchemy most probably originated in China (known as early as 600 BC) in connection with an enterprise older than metallurgy, medicine, and in the belief that physical immortality could be achieved through drugs. Alchemy probably vanished when the Chinese adopted Buddhism, which offered other, less dangerous avenues to immortality, via meditation. In India too, alchemy came to be associated with the rise of Tantric religious mysticism, leaving a record in the writings 'Rasarnava' (AD 1100 – Treatise on Metallic Preparations). The earliest records, from 500–300 BC, already pointed out that the theory of nature was based on the conception of material elements (fire, wind, water, wood, metal, earth and space, cf. Fig. 2), vitalism ('animated atoms') and the dualism of love and hate or action and reaction. In the Theravada view, there was a plurality of the universe, surrounded by water and mountains, having three planes of material form (physical body) and of immateriality and/or formlessness (body of law).

The Indians exploited metal reactions more widely and knew as many as seven metals (and already subdivided five sorts of gold). They supposed that metals could be 'killed' (corroded) often to provide medicine bases, but not 'resurrected', as was customary in later European alchemy. However, the known alchemy tradition points to Egypt as its birthplace, and the Greek God Hermes (identified with the Egyptian god Thoth) is represented as the father of alchemy, first noted in 150 BC, in the Emerald Tablet (part of a larger book of the secrets of creation), which existed in both Latin and Arabic manuscripts. The history of Western alchemy may go back to the beginnings of the Hellenistic period, starting around 300 BC, and represented by Zosimos of Panopolis, who expressed alchemical theory and focused on the idea of a substance 'tincture' that was capable of bringing about an instantaneous and magical transformation. The earliest notable author was designated by scholars as Bolos of Mende, a Hellenized Egyptian, author of a treatise called Physica et mystica (Natural and Mystical Things), containing obscurely written recipes for dyeing and coloring, as well as gold an silver making.

Inherited concept of fire within the idea of four elements

As mentioned above, the Greek philosophers played the most important role. The Greek word philosophy, meaning love ‘philein’ and wisdom ‘sophia’, first appeared in the 5th century BC and was primarily concerned with the problem of ‘the One and the Many’. Simply stated, it involved the explanation of the infinity of things in the universe (the Many) and the early Greeks believed that the single unifying thing (the One) was some material substance, such as water or stone. They were concerned with finding the unchanging principle of substances that lay behind all changes, and the stable unchanging component of the universe the Greeks called ‘arche’ and living nature ‘physis’.

Plato (427–347 BC) seemed to distinguish between fire and heat, while Aristotle (383–322 BC) apparently differentiated temperature from a quantity similar to heat, even though the same word (‘thermon’) was used for both. Aristotle and later philosophers paid attention to the notions ‘spirit’ and ‘breath’, which by some were identified with ether, and by others with entire fire, which was always regarded as a basic composition element. Democritos (460–370 BC) and his teacher Leucippos already assumed its dependence on the shape and arrangements of elementary particles (atoms). Democritos also supposed that the soul had a fire nature. The Pythagoreans distinguished notions for matter and form, linked through a process of development. In contrast with Plato, Aristotle believed that form had no separate existence, but was immanent in matter – their philosophy and science ideas dominated Western thoughts for two thousand years until a radical change was brought about by the new discoveries in physics, astronomy and mathematics (Copernicus, Bruno, Galilee, Descartes, Bacon and Newton), with the world assumed to be a perfect machine governed by exact mathematics.

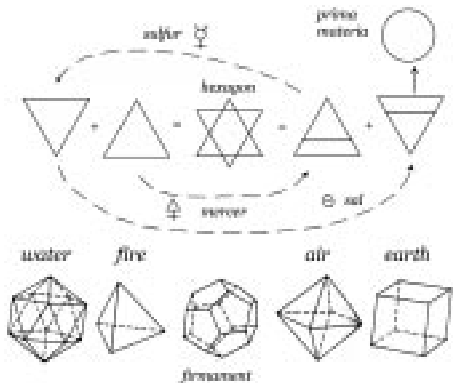

Fig. 4 Symbols used for depiction in the concept of four elements

The oldest book on chemistry was known as the ‘summit of perfection’ [2], where the terms alcohol, alkali, borax and elixir were already used, but it also held that metals were compound bodies made up of mixtures of mercury and sulfur only. ‘Prima materia’ (first matter) was recognized as being fixative (visible solid-earth, represented by sulphur), quintessential (personification – sal) and evanescentive (implicit, hidden – air, represented by mercury). It was characterized by triangles pointing up (escaping) or down (falling) (Fig. 4). It was close to the platonian geometrization, representing fire as a tetrahedron, air as an octahedron, water as an icosahedron and earth as a hexahedron (cf. the illustrations in the lower line of Fig. 4). By analogy, it showed spheres of Mars, Earth, Venus and Mercury, with the Sun in the center. Reciprocation of the elements with the geometrical bodies, however, led to the mechanization and geometrization [29] of learning, and the dodecahedron was assumed to act as the fundamental structure of the firmament. Mere abstraction of four elements was not thought to be enough for the needs of the teaching, of alchemy, so that three other imaginary principles were also included, Table 2.

Table 2 Initiative of 'Tria Principia', derived from the scheme of four elements and their consequent performance: fire acting upon air created 'sulfur', air against water released 'mercer' and water against earth gave rise to 'sal'

combustibility	fusibility, ductility	durability
sulfur	mercury	salt
soul, psyche ('mens')	mind, brain ('anima')	body, figure ('soma')
Egyptian tradition	Greek philosophy	Metallurgy spirit
	Emphasizing priciple of	
– flammability	– shining and volatility	– solubility/incombustibility
	Taste of	
– smearingness, oil	– alcohol	– salt, earthiness
hidden air, water	air, fire	earth

In the Middle Ages, European alchemy was chiefly practised by Spanish and English monks (R. Bacon, who seemingly invented fire powder, and Lullus) seeking to discover a substance more perfect than gold (philosopher's stone) and a potable gold (elixir of life). It is noteworthy that the Swiss/German Paracelsus (1493–1541) held that the elements of compound bodies were salt, mercury and sulfur, representing earth, water and air, respectively. Fire was regarded as imponderable or non-material, and alchemists used heat lavishly; most of their illustrations include some indication of fire, a furnace or a symbol of sulfur. Despite the crudity of the above-mentioned degrees of heat, alchemists laid more emphasis on an accurate temperature control of furnaces (Norton [4]), necessary in early metallurgy (Agricola [5]). The adjustment of temperature was purely manual, however, including oil lamps with adjustable wicks, water and sand baths for lower temperatures and variation of fuels for higher temperatures. In various forms of processing, such as the firing of ceramics or the melting of glass, it was vital to keep certain temperatures constant. This required the introduction of early scales for experimental practice. Moreover, fuels giving moist and dry heats were distinguished, with an awareness of how to produce high temperatures (also by using burning glasses and mirrors). A vast store of knowledge was accumulated of the effects of heat on various substances, even if it was not possible to interpret the results and satisfactorily measure the temperature. An undiscovered element, termed alkahest ('alkali est') in the sense of a universal solvent (resembling today's action of catalysts), was believed to exist common to all (of which the four basic elements of ancients were merely derivative forms), to prove to be a universal medicine. Alchemy flourished markedly in the territory of the Bohemian emperor Rudolf the Second (1552–1612) and Prague became home to many famous alchemists, among others Hajek or Rodovsky of Czech origin, and the noteworthy Stolcius (1600–1660), who wrote an advanced book [3], noting the laws of light refraction and the nature of the laws of conservation. He was to introduce at the Bohemian Charles University (founded in Prague in 1348) the first specialization called 'chimiatrie' a novelty as concerns the traditional university disciplines 'artes liberales' and 'artes mechanicae'.

The Renaissance and the New Age

In the 'Sceptical Chymist' (1661), Boyle (1627–1691) attacked the theory of four elements, and his explanation of an element in the sense of its apparent 'non-existence' provided the modern roots for the natural sciences and the definition of a modern concept of the chemical elements. It is worth noting that Plato possessed a similar view, based on the 'chóra' (analogous to the Indian 'amah', understood to become fire or water containing 'proté hylé'), i.e., the continuous dynamic transformation of elements within themselves (resembling the quantum vacuum in the framework of bootstrap and/or particle democracy). The four elements were then identified with macroscopic phases of a gas (from the Dutch contortion of the Greek word 'chaos') and the Latin-derived liquid and solid. Fire became heat and was recently related to plasma; accentuation of this and further thoughts of yet other forms of energy (e.g. nuclear) lie outside the scope of this article. Although the 17th century was a time of notable scientific progress [30–38] (notwithstanding the reminiscence of Greek philosophy) scientists themselves were then still far from the respected scientists of the current era (Fig. 5). Some of them, held to be responsible for the introduction of modern theories, such as Newton (1645–1727) and Leibniz (1646–1748), were still devoted alchemists. The idea of 'fire fluid' (globular particles which attach easily only to combustible objects) persisted for another two hundred years, with the assumption that, when a substance was burnt, the non-substantial phlogiston ('terra pinguis') escaped. The definitions of the laws of conservation needed more precision on account of the action of elderly traditional vital and mortal forces, conservation being assumed to be something general between and within the system, probably first discovered by the non-cited Czech Marcus Marci (1596–1667) [8]. An important role was played by Descartes (1596–1650) [7], though he first believed that the Universe was filled with matter in three forms: fire (the Sun), transparent matter (the Heavens) and dark matter (the Earth).

Until the work of the Scot Black (1728–1799), the notions of heat and temperature (temper/temperament, first used by Avicena in the 11th century) were not distinguished. He and Magellan (1722–1799) made known the quantity that caused the change of temperature, but itself is not temperature (the concepts of latent heat and heat capacity, explaining how heat is absorbed without changing temperature and what heat is needed to increase a body's temperature by one unit). A noteworthy feature is the original proposal of a heat unit expressed in therm (to warm 1 g of water), which was proposed by Groffith to be named after the physicist Rowland (1848–1901). Yet, at the beginning of 18th century, Boerhaave (1668–1738) [10] warned that '…if we make a mistake in the interpretation of what fire is, this deficiency can afflict all disciplines of physics and chemistry, because in all natural creations fire is involved, in gold as well as in emptiness…'. Rumford (1753–1814) still presented qualitative arguments for the fluid theory of heat, but succeeded in evaluating the mechanical equivalent of heat; this was not accepted until approved by Mayer (1814–1878) and particularly by Joule (1818–1889) for the transformation of electrical work.

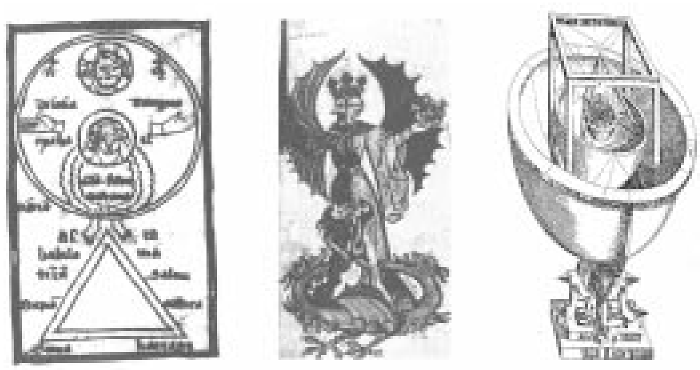

Fig. 5 Examples of illustrations from old writings: Left – The triangle symbolizes both earth and fire (with its corner pointing up). It may be read in such a way that water and earth would be freed by fire form prima materia and transformed to 'kvintesency' symbolized by a circle (about 14th century). Middle – Demonic hermaphroid standing on a dragon (symbolizing 'prima materia'). The masculine part holds a sword (justice), and the feminine part a crown (boast), about 15th century. (It is interesting that this was supposed to be part of a gift of the Franciscans to the emperor Zikmund on the occasion of the Constancy council that condemned the Bohemian priest and Czech reformatory speaker Hus to the stake). Right – the geometrical model of the universe, with the outermost sphere of Saturn and with Mercury and the Sun at the center (according to Keppler's Mysterium Cosmographicum, about 17th century)

However, it took two centuries to replace the fluid theory of heat (caloricum, thermogen) by the vibrational view (the state of inherent particles) that was substantiated by Cavendish's discovery of 'inflammable air' (hydrogen) and the theory of combustion by Lavoisier (1743–1794), though he first associated oxygen with phlogiston. Sadi Carnot (1796–1832) provided the theory of a four-cycle device [13] to run an idealized heat engine, proposed on the confused basis of heat transport taking place in the form of a fluid discharging from a state of higher to one of lower tension (conservation of materialistic caloricum) and supported by Clapeyron (1799–1864). It was notable that Carnot excluded the existence of a thermal perpetuum mobile, formulating an important efficiency theorem: '…the moving force of fire does not depend on the medium used for its outgrowth; its magnitude depends only on the temperatures of the bodies between which the transfer of heat is conveyed…'.

Following the textbook by Pencelet (1826), in 1853 Rankine introduced the term energy – actuality ('ergon' – actus and 'energeia' – activity, in the opposite sense to the possibility 'dynamis' – potentia). Simultaneously with the development of the separated fields of electricity and magnetism, another important field of thermal sciences was introduced, named thermodynamics ('thermos' heat, and 'dynamis' – force). This was first made known by William Thompson (1824–1904), but was preceded by Maxwell's concept of thermal equilibrium [15]. During the 19th century, Helmholtz and Laplace [14–17] described both theories of heat as equally suitable for complying with a theory of temperature measurements, because this was determined only by the state of the system under investigation. A similar understanding was anticipated for the internal motion of particles because heat was also a measure of the transfer of motion from one system to another (kinetic and potential energies being qualitatively different forms of motion, particularly in the scaling variance in the degree of self-organization). Heat transfer is nowadays associated with a modern description in terms of non-integral dimensions called fractals [52–54].

The current message of fire/heat

Motto: 'Ordered by number and by weight of every one' [Ezra 8:34]

The modern scientific world is far from using mystic concepts and nature research is a public property. Early mystical philosophy did not really need exact science. It did not look for mere measurable quantities and scholarly knowledge was therefore deliberately kept a secret, often for moral reasons. The human mind, however, needs a little of both. Hermetic philosophy admitted that the universe is calculable, separating quality and quantity at the same time, i.e. harmony is best perceptible sensually, but also expressible by numbers. Measurement was thought to be associated with the consciousness of the person who actually makes it, but has nowadays come close to the ideas of quantum mechanics. Bohr stated that 'There does not exist a quantitative world. There exists an abstract description of quantum physics. The task of physics is a search not for what nature is, but for what we can say about nature'.

The orderly employment of fire provides warmth and pleasant conditions to think, e.g. about how to order things or how to gain energy with ease. Wild fire destroys everything, creating chaos in both aspects: the material possessions of society and the useful thinking of the mind. Fire leaves a fingerprint in all types of evolution. We may mention alchemy, as an old endeavor for fire/heat. Within the modern world of science, alchemy, as a rather extraordinary field of learning, would surely be subjected to ironical comments. However, we should recall that alchemical philosophy was close to the science of causation, trying to perfect matter while being aware of nature as the model itself, respecting the order of nature, somehow resembling present-day thoughts about liveable nature (ecology). Alchemy was related with the process of self-recognition, and success in the laboratory led to individualization and *vice versa* (individuality guided the laboratory mastery). Alchemy was a universal art of vital chemistry, which, by fermenting the human spirit, purifies and finally dissolves itself so as to become a kind of philosophy. On the other hand, chemistry as a consequently derived true science of facts, is primarily oriented to the utilization of nature, freely processing and exploiting basic/raw materials and trying to dominate nature – it is shamelessly enforcing order on nature and is neglecting its consequences.

Heat/fire has always played a significant role as an explicit tool, either in the form of industrialized power (applied by men long ago for working materials in the process of manufacturing goods) or as an instrumental reagent (for the modern analysis of the properties of materials). The consequences of a better understanding of heat led to the formulation of a consistent science of thermal physics, and the development of the field of thermodynamics [13–16, 40–42, 55, 56] (and the related domain of thermal analysis, touching on any adjacent field of science where temperature is taken into account). As mentioned above, it was originally developed on the erroneous premises of caloricum, although we should rather say that it was the application of different premises as regards the manner of the individual approach. The fluid hypothesis was common to the way of thinking of Archimedes and the Epicureans, and even to the present-day theories of Prigogine. Our everyday use of the heat flow equations applied in thermal analysis bears the 'caloricum' philosophy. The thermodynamic story is further complicated by the introduction of an artificial quantity called entropy, which eliminates heat from its mathematical framework. The first law of thermodynamics actually gives a quotation of the law of energy conservation, but only under specific conditions for heat that are not fully equivalent with other kinds of energy [35]. Heat cannot be converted back to mechanical energy without changes necessarily affiliating heat with entropy via the second law of thermodynamics, intuitively stating that heat cannot be annihilated in any real physical process. It may somehow be felt that thermodynamics was originally situated on a level of esoteric ('those within') doctrine [35]. (This article purposefully ignores modern aspects of the equivalency of matter and energy and associated spheres of heat/energy exploitation.)

Let us look at the term entropy, after Greek 'tropos' ('trepó' – turn), meaning transformation (proposed by Clausius on analogy with the term energy). Entropy is a measure of the order of chaos, both in physics and in everyday life (e.g. how effortlessly a laboratory can become a mess, and how difficult it is to force everything back to order, humorously illustrating the irreversibility of entropy). In fact, we can never know where an electron is positioned in the atom and the sub-particles quarks are still just 'strange'. Religions, on the other hand, seems to manage ideally to emanate desirable order, with the Bible and moral rules, with everything in its right place. Similarly, we can elucidate symmetry by looking at the thoughts of the Eastern religions (of the Buddhists, Taoists and Hindus) and their philosophical views of the Universe, comparing these views with the actual scientific facts of crystallography or quantum mechanics, for instance.

The general meaning of chaos is empty space or matter not yet formed (Theogony, about 700 BC). It was derived from the Greek words 'chaskó' (drifting apart, opening) and 'chasma' (abyss, chasm, gap) and was associated with the primeval state of the Universe (also associated with 'apeiron'). In the Chinese tradition, chaos was apprehended as homogenous space preceding the constitution of directions/orientation (i.e. the separation of four horizons) in the sense of a great creation. In Egyptian cosmology, chaos ('nun') represented not only the state preceding the great creation, but also the present state of a coexistence with the world of forms/structure, which also serves as a limitless reservoir of field forces where forms dissolve during infinitesimal time. In alchemy, chaos was associated with primeval matter ('nigreden') capable of creating a 'great masterpiece'. Chaos was a symbolic representation of the internal state of alchemists, who first needed to overcome their unconsciousness to become ready for transmutation study. In Genesis, chaos is understood as a symbol of paltriness and non-distinctiveness, but also a source of feasibility. The word chaos is sometimes taken to mean the opposite of 'kosmos', this latter term having the connotation of order, and the Arabic meaning of 'chajot1 is also closely associated with life. In the Epicurean conception, chaos was a source of progressive transformation. Chaos thus became a definite domain of present-day science, showing by law that disorder can disclose windows of order (order through fluctuations) and that, *vice versa,* order bears inherent minutiae of disorder (disorder as information noise). The theory of chaos provided the bases for various progressive specialties of numerous branches of knowledge [46–51], seemingly important for any further advancement of science in the coming century.

Let us emphasize the first conscious exploitation of fire as proposed by Newcomen (1705), Watt (1800) and Stephenson (1813), while constructing a steam heat engine and later a functional locomotive that actually interconnected the three forms of the above-discussed early elements: heating water by fire to obtain a thick air (steam) capable of providing useful work (moving a piston and turning a wheel). Lenoir (1868, the gas engine) and particularly Otto (1878) and Diesel (1892), who imprisoned fire in a cylinder itself, thereby introducing four-stroke combustion engines, were later again restricted by the laws of thermodynamics and controlled by the four-cycle sequence essential to start and end at the same point. The encircled loop for the given pair of associated intensive and extensive parameters then provides a convenient estimate of the net gain (energy, goods [36, 37, 56, 57]). This idea was subsequently developed for a wide variety of engines, turbines, pulse-jets and other power cycles [55, 56], all still governed by the same principles of thermodynamic efficiency for the external and/or internal utilization of heat/fire.

A variety of useful machinery has been developed through the human cognition (mind), but within a relatively short history of merely a few thousand years. The evolution of life, in contrast, exhibits a history several orders longer, involving billions of years, and even a living cell can be understood as a precisionally fine-tuned machine gradually constructed through the ages as an extraordinarily sophisticated set of interrelated parts (molecules) that act together harmoniously in predictable ways, thus ensuring the progressive development, variability and selective survival of more of its kind and the efficient use of energy. Its 'know-how' experience record is coded in the DNA memory, which possesses a capacity of creative incorporation within its structure changes (internal development of a certain 'cognition'), which permits further evolution of its machinery cell into forms needed to prosper successfully upon the Earth's continuously changing face. It is clear that the space-time structures do not remain stable and some of the above-mentioned principles, such as chaos/entropy, order/information and the generalized course of cycling (making a process in such a reliable way as to exhibit co-equality of the initial and final points necessary to retain the capacity for continuous periodicity), have penetrated to other fields, such as the humanities, sociology, economics, etc. [57]. Although thermodynamics cannot provide a general law for all 'open' (highly non-equilibrium) systems, it has helped unlock important scientific insight for a better understanding of chaos as a curious, but entire source for systems evolution. All such progress, however, would not be possible without taking into account the fourth element – material (earth), too, which is acting in the form of an assembled mechanism (engine) that can be understood factually as an information transducer. It virtually contains the aspects of the early comprehension of 'ether' (and its role of an internal structure), thereby binding mind and perception ('nus') with thinking and distinction ('dianoia') and reasonableness, sanity and ability to collect known facts ('logos'). Ether can thus be associated with in-formation ('in-formare') in the sense of the evoking, formation and transmission of 'internal shape'. Within a period of generations, it gradually became evident that, to obtain useful work, one needs to apply not only energy, but also cognition [43–45] and attached information. The applied energy must either include information within itself or act on some organized subject and/or device (an engine, machinery, clockwork or even a cell) which then ultimately serves as the above-mentioned energy transducer, usually developed and invented through the self-possessed skill of generations (and hence of necessity bearing a definite value of order/information). In this way, the originally information-vacant heat/fire can be transformed to other forms of energy containing certain information within themselves. The present-day advancing exploitation of fire, on the other hand, means its effective enrichment by a certain degree of order through the inserted information provided by our manufacturing know-how, the only way to tame primarily frightening fire.

The short history of civilization is beyond comparison with the much longer history of life. The recently constructed mechanical engines can not be matched on a sophisticated level with the mechanism of living cells, which has undergone very long-lasting development. Thus, the present propensity of the fabrication of macroscopic human tools necessarily tends to avoid the undesirable aspects of self-destruction by introducing: 1. pure technologies, producing ecologically harmless by-products, 2. clean engines, producing safe wastes (their fabrication, however, usually involves higher costs of energy consumption, e.g. solar cells, which can repay their higher production costs after a long period of functioning) and 3. miniaturization, whereby attempts are made to simulate a more efficient level of molecular tools of living cells. The so far conventional approach of 'top-down' technology starts with a large clump of material and forms it by cutting into a desirably useful shape, yet carried out mostly within the capability of our hands. Energy-saving nanotechnology would, by contrast, comprise the 'bottom-up' stacking of individual molecules directly into a useful shape, controlled by the 'power of our minds' in a similar way as proteins are assembled from individual molecules. We can contemplate the vision of a 'nanobots' age with the effective manipulation of individually small species to form miniature engines (or more imminent computers). Similarly to processing instructions on how to operate macroscopic machines (either by an experienced engineer, with the help of a printed manual or fully automatic, as controlled by a programmable computer) achieved at the one-dimensional level of a written message, we must additionally look for the analogy to microscopic instructions within the models of the three-dimensional level of the DNA structure. Such an approach is also related to the present message passed by the human cognition on the basis of the early initiated need to understand fire from its visible wholeness down to its imaginable composition of internal vibrations. This is a very important sphere of communication and of a specific message reading (necessarily to take place between people as well as individual parts of a machine), but unfortunately it lies beyond the scope of this article.

Even in the modern world with its many progressive technologies, philosophy has retained its important role in the challenge of striving to maintain a sustainable world (on the both levels of matter and mind) for the coming generations. Popper recently recalled the 'Tria Principa' of cosmic evolution grades, pointing out three appearances of the universe : 1. a world of physical contradictions ('sal'), 2. a world of significance (subjective experience 'sulfur') and 3. a world of energy (the creation of the human mind and ingenuity 'mercer'). It is somehow close to Hermetic philosophy, with prophecy (God) having the highest, and matter (earth) the lowest state of eternal vibration, everything there undergoing processes of dissolution ('solve') and integration ('coagule') within three levels : the digesting of raw materials or food on a physical level (life), breathing, based on a spiritual level (love), and meditation, based on a heavenly level (wisdom).

'We are not just observers, we are participants in the play (universe)', Bohr once said, which applies to the above story of fire, too. The struggle by mankind for a better life, while striving to survive in the universe/nature and while hunting for eternal fire, should therefore be understood as a fight for lower chaos (entropy) and maximum order (information), and no mere seeking for sufficient energy, which seems to be more or less plentiful. We should therefore not underestimate certain self-organization tendencies perceivable not only on the micro, but also on the macro level of nature [58–61] noting that 'even biospheres can maximize their average secular construction of the diversity of autonomous agents and the ways those agents can make a living to propagate further. Biospheres and the Universe itself create novelty and diversity as fast as they can manage to absorb them without destroying the accumulated propagation organization which is the basis of further novelty' [59].

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