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Luminescent substances from ancient history up to the end of the Mamlūk Era (1517 AD): A historical cultural study

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Abstract

This study investigates the history of the discovery of luminescent substances in all their forms Ancient History up to the end of the Mamlūk era (1517 AD). The study then surveys observations from ancient civilizations including the earliest written references to fireflies and myths of luminous gemstones, such as the Buddhist night-shining jewel, Chinese magic painting, and Indian Vedic texts including the Mahabharata, and the Dhammapada that liken the firefly to transience. In Greece, Aristotle provided the first precise description of cold light from dead fish, fungi, and squid, differentiating it from incandescence, while the Roman Pliny the Elder extensively documented luminous mollusks, jellyfish, and gleaming gemstones based on direct observation and collected accounts. The study then shifts to the contributions of Arab and Muslim scholars. It begins with their documentation of the firefly, which they termed al-ḥubāḥib, recording linguistic and poetic descriptions by al-Jāḥiz, Ibn al-Baitār, and al-Damīrī, along with medicinal uses such as drying ear pus. Regarding marine luminescence, Ibn Battūta recorded the milky sea phenomenon in the Maldives, which locals associated with jinn, while Ibn Mājid, in his nautical poem, warned that glowing water hinders stellar altitude measurements. Ibn Wahshiyya and al-Ishbīli also noted trees that emit light at night, attributed to fungi, a phenomenon only recently recreated through genetic modification. In the domain of solid-state luminescence, the study uniquely highlights evidence from Arab heritage demonstrating knowledge of phosphorescence centuries before Brand. Al-Masʿūdi reported that ancient Egyptians coated copper spheres with chemical preparations to illuminate a tomb perpetually and described a ruby-like gemstone shining like a lamp. Al-Birūni, al-Qazwīnī, and al-Bākuwī confirmed the existence of stones that glow in the dark.

Keywords: Bioluminescence, Bioluminescent marine organisms, Fireflies, Luminous stones, Phosphorescence, Phosphorescent inks.

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1. Introduction

The luminescence phenomenon is defined as the non-thermal emission of light from luminescent substances [1]. Unlike incandescence which results from heating a substance to high temperatures, luminescence occurs as a result of the excitation of electrons within a substance, without the need to significantly raise its temperature.

Regarding the term "phosphor" in this context, it should be noted that this does not refer to the chemical element phosphorus (P); rather, it refers to "phosphorescent substances" crystalline solids capable of converting absorbed energy into visible radiation.

The phenomenon of luminescence encompasses two distinct sub-phenomena, which can be differentiated based on the duration of light emission following the cessation of the exciting radiation [2].

Fluorescence is the phenomenon of light emission following the absorption of another form of radiation (such as photons, ions, or particles). Such an emission persists only for the duration during which the radiation is being absorbed, typically around 10 nanoseconds [3]. Consequently, fluorescence involves the emission of light for a very brief period. This phenomenon is practically exemplified in fluorescent lamps and the dye fluorescein.

Phosphorescence, on the other hand is the phenomenon of light emission following the absorption of another form of radiation. However, in this case, the emission continues for minutes or even hours after the absorption of the radiation has ceased [3]. This phenomenon is practically exemplified by the hands of watches that glow in the dark.

While luminescence represents the general act of light emission, fluorescence and phosphorescence define the timing of that act.

Among the chemical substances that exhibit phosphorescence are calcium sulfate, strontium sulfate, barium sulfate, and zinc sulfate. The latter three sulfates emit light for only a short duration after exposure to an external light source; however, calcium sulfate when doped with a small amount of a bismuth salt can continue to glow (emitting a violet light) for up to 40 hours [4].

Perhaps the most renowned of all luminescence phenomena is bioluminescence. This phenomenon occurs in certain terrestrial and marine organisms; unlike other forms of luminescence, however, it does not require an external radiation source such as sunlight to be triggered. Instead, it results from chemical reactions that take place within specialized cells located in specific regions of the organism's body [3].

Bioluminescence serves various purposes for these organisms, including [3].

1. Attracting prey or aiding in the search for food amidst the darkness of the deep sea, caves, vast forests, and dense, towering canopies.
2. Providing protection for the light-emitting animal by directing light toward an adversary to create a distraction, thereby serving as a means of self-defense.
3. Enabling organisms to recognize one another, as males and females exchange light signals during courtship prior to mating.

Among the bioluminescent insects is the firefly, which is an insect that favors humid environments. An old English meteorological adage states: "When the firefly lights its lamp, the air is always damp", an addict that aptly captures the characteristic behavior of these luminous fireflies. Another common saying expressing the same underlying concept notes:

"Seeing many fireflies is a sign of an approaching storm." In fact, such observations were undoubtedly part of the folklore of many ancient peoples before the nature of light or how it is produced by a living insect became a subject of discussion [5].

1.1. Research Significance

The significance of this study emanates from the fact that it is the first scientific study – as far as the researcher knows – that discusses the knowledge of Arab and Muslim scholars about the luminescence during the period from the dawn of history until the end of the Mamlūk era.

1.2. Research Objectives

The main goal of this research is to shed light on the most important scientific achievement of the Arab and Muslim scholars in terms of the manner in which they determined the properties, benefits, and applications of luminescent substances.

1.3. Research Questions

The research will answer a major question, which is: What are the novel scientific and practical additions that Arab and Muslim scholars have added to the science of the luminescent substances during the period from the dawn of history until the end of the Mamlūk era? Three questions branch out from this major question, which are:

1. Have there been any previous studies about the Muslims knowledge of luminescent substances, and what is particularly important about such knowledge?
2. What is the value of the luminescent substances and their applications during the Islamic period subject matter of this study?
3. Where are the locations of luminescent substances as identified by Muslim authors?

1.4. Research Methodology

This research adopted the historical, analytical, critical and descriptive research method in which scientific material is collected from the most reliable sources and then arranged, classified and presented in the form of a descriptive, analytical and critical study, by comparing it with the scientific material contained in the contemporary sources.

2. Luminescent Substances in Ancient Civilizations

The most notable milestones of this period include texts originating from China in the East, as well as from Greece and Rome in the West. The earliest known written observations regarding naturally occurring bioluminescent phenomena were recorded in China, dating back to the period between 1500 and 1000 BC, specifically concerning fireflies and glow-worms.

However, these writings make no mention of any efforts undertaken to understand or apply the knowledge derived from these phenomena. Yet, around 1000 BC, a Chinese emperor reportedly possessed a "magic painting" that revealed the image of a bull at sunset. This painting marked the first known instance of a man-made substance capable of absorbing and subsequently emitting light. Furthermore, in the text of He Ni Shi Zhu Chi, the author describes wondrous marine islands, noting that "if one travels at sea, one may observe fiery sparks when the water is disturbed" a phenomenon most likely attributable to the presence of *dinoflagellates*. The bioluminescence of fireflies and glow-worms is frequently referenced in the texts of this era.

Fireflies and glow-worms are also mentioned in the ancient Indian texts of the *Vedas*, and the epic poem of *The Mahabharata* (c. 200 BC). In the *Dhammapada*, the Buddhist text, the term *Khajjopakana* is employed to denote the firefly. The earliest likely written record of bioluminescence in marine animals is attributed to the Greek philosopher Anaximander of Miletus (585-528 BC). It was the great Aristotle (384-322 BC), however, who penned the first detailed observations regarding light emitted by marine species as well as by insects, describing up to a total of about 180 different animals.

Figure 1.
Fireflies use their light to communicate with their fellow fireflies.
Source: https://kids.nationalgeographic.com/animals/invertebrates/facts/firefly

Aristotle wrote about the luminescence of dead fish; a phenomenon we now know is caused by infection with luminescent bacteria as well as the light that appears when seawater containing *dinoflagellates* is stirred with a stick. In 215 BC, Titus Livy reported that "the shores of Sardinia glowed with frequent fires." A few centuries later, Pliny the Elder (23-79 AD) compiled a more comprehensive record of bioluminescent organisms in his work, *Natural History*.

In this book he provides detailed descriptions of numerous luminous animals, ranging from glowing worms and fireflies to luminescent mollusks (*Pholas-dactylus*: a Roman delicacy). This specific name was coined by the Romans, who were fond of eating them as Pliny attests in *Natural History* saying: "Among the various types of shells are the Dactyli, so named for their resemblance to human fingernails.

By their very nature they glow vividly in the dark and emit light. The more moisture they retain, the brighter they glow in the mouth of the eater, in their hands, and even on the ground and the clothing of the eater as drops fall from them. This demonstrates beyond doubt that the luminous quality we admire resides in the nature of their internal fluids. Pliny also describes the bioluminescent purple jellyfish *Pelagia noctiluca*, which is common in the Bay of Naples, the very place where Pliny perished during the eruption of Mount Vesuvius in 79 AD. The Romans referred to this creature as *Pulmo marinus* (Sea-Lung) due to the mucus it secretes from the outer surface of its bell, which was believed to serve as a remedy for fevers [6].

Figure 2.
The bioluminescent jellyfish Pelagia noctiluca glows when it is disturbed.
Source: https://hakaimagazine.com/features/secret-history-bioluminescence/

2.1. The Phoenicians

Evidence suggesting that the ancients possessed knowledge of true luminescent gems that glow in absolute darkness remains open to doubt, even though numerous writers have alluded to luminous stones, seizing the opportunity to embellish their narratives. Herodotus (d. c. 408 BC), in his Histories (Book II, Chapter 44), wrote of a temple in Tyre (Phoenicia) featuring two pillars: one of gold and the other of *smaragdus* (emerald), which "shone brilliantly at night."

This luminosity may well have been merely a reflection, although false emeralds (a variety of fluorspar) are known to exhibit phosphorescence after exposure to light. It is impossible to verify the veracity of this account; however, the reflection of ambient light remains just as plausible an explanation as the actual emission of light [5].

2.2. The Chinese

The Chinese regarded luminous stones specifically "whale eyes" as objects that naturally emitted a certain degree of light due to their phosphorus content, much like the bioluminescent organs found in many marine organisms. They believed that these spheres were none other than the fabled "Wishing Stone" belonging to the Dragon King, who dwells hidden beneath the ocean depths. Crystal spheres have been known in China since the 4th Calendar century, when the Mohe people of Manchuria sent them to the court of Emperor Xuanzong as tribute on multiple occasions.

Furthermore, during the early years of Emperor Xuanzong's reign, ambassadors from *Mimargh* presented a gift consisting of a gemstone known as *biok*. This name was originally applied to a type of flat ring that, during the Zhou dynasty, symbolized the divine nature of the Emperor. The term was also used interchangeably with another word: *biak*, which denotes a "dark blue-green stone. If this ring was not crafted from jade, it was undoubtedly made of chlorophane, which is a variety of fluorite that emits a glow when exposed to heat. This is the very same mineral family to which the phosphorescent emeralds belong. They were used in the creation of classical artifacts, such as the green eyes of the marble lion discovered in the tomb of King Hermias in Cyprus.

Figure 3.
Luminescent stones are made from luminescent pigments mixed with resin.
Source: https://www.magnific.com/free-photos-vectors/luminescent-stones

This suggests that chemists of the ancient Hellenistic era were well-versed in techniques for creating gemstones that glowed in the dark, specifically by coating certain stones with a phosphorescent substance. The stones most frequently treated with this coating were emeralds and red agates [7].

Fireflies are also mentioned in the Er-ya (circa 400-100 BC), a classified lexicon that elucidates the correct usage of various terms, including the names of animals and plants. In this text, the firefly is referred to as ying-huo or chi-chao: two names that remain in use to this day to designate the insect. This insect was also described as possessing wings, with an abdomen that emits fire.

The insects would typically appear in late summer and take flight during the autumn. Shortly thereafter, the story emerged of the Chinese scholar and government official Chi Yin, or Xian Yin who lived during the Jin Dynasty (264-419 AD) and passed away around 399 AD. His biography, found in the History of the Jin Dynasty (Jin Shu, Chapter 83), describes him as a poor yet diligent student who could not afford lamp oil; consequently, he would gather fireflies and use them to illuminate his studies in the evenings. The Japanese artist Kanō Tan'yū (1602-1650) later depicted this curious scene in a painting [3].

It has been alleged that the Chinese were acquainted with artificial phosphors, although evidence remains much less than convincing. In a letter to the North China Herald, Mr. MacGowan recounted a story concerning a painting of Emperor Taizong (976-998), who belongs to the Song Dynasty, which was subsequently included by H. Robb in her book *Luminous Substances and Their Uses* (Berlin, 1937).

In 1768, John Canton described a phosphorescent substance derived from oyster shells. Hence, it is conceivable albeit

improbable that the Chinese may have formulated a luminous paint using pearl oysters. Nevertheless, Dr. Hu Shih of the Gest Oriental Library at Princeton University informed me that no record exists of any writings left behind by the explorer Zhang Qian, and that the author of the *Xiangshan Yelu*, Wen Ying, who lived during the 11th Calendar century, was not renowned for his factual accuracy.

In fact he was a poet, a monk, and a man of letters, and his book contains so many fanciful tales that the story of the luminous cow scarcely warrants much attention. Although the extent of Chinese knowledge regarding phosphorus remains open to doubt, because almost all early historical sources make mention of *Ye Guang Bi*, the Night-Shining Jewel that appears to have particularly captured the Chinese imagination, perhaps due to its religious significance.

This sacred Buddhist gem, which is one of the Seven Treasures, known in Japan as *Hōju no Tama*, is alleged to be self-luminous, casting a brilliant glow upon its surroundings as a symbol of the light of Buddha's teachings. W. H. Ridell suggested that Buddhist monks may have derived the concept of this luminous gem from a legend prevalent in Ceylon and India concerning the cobra, subsequently transmitting it to China via Tibet, and thence to Japan.

Reference to this belief specifically, the existence of a luminous "cobra stone" used by the serpent to lure fireflies, may be found in the section dedicated to India. Alternatively, knowledge of such luminous gemstones may have reached China from Asia Minor during the Classical era [3].

2.3. The Japanese

Collecting fireflies has been a popular pastime in Japan since ancient times much like observing the colors of autumn foliage. The Firefly Festival on the *Uji River* was a significant event in the outskirts of Kyoto. Japanese literature abounds with numerous references to fireflies, some of which have Chinese origins such as various tales regarding mysterious lights that originated in China and subsequently found their way into Japanese literature.

For instance, in the *Wa-Kan Sansai Zue*, an encyclopedia covering China and Japan, written in Classical Chinese and published in 1712 by the Japanese scholar Ryoan Terajima, it is stated that the firefly belongs to the *Kasei-rui* category, which are insects believed to spontaneously generate luminescence from decaying vegetation. The encyclopedia describes numerous species of fireflies found in Japan, including the luminous firefly that emerges from bamboo roots and the luminous aquatic firefly, as well as large and small varieties, some of which are said to originate from the decaying roots of *Miscanthus* plants. While no other luminous animals are mentioned, a light-emitting fungus is described.

China and Japan are rich in ancient tales regarding mysterious lights or fires observed over bodies of water, fields, or mountains phenomena often attributed to dragons or ascribed to deities. Sacred trees, too, were frequently said to emit light. Typically, one can only speculate as to the true cause of these phenomena, as they may potentially be attributed to St. Elmo's fire or other forms of electrical discharge, or clusters of bioluminescent fungi, or even phosphorescent decaying timber containing fungal mycelia.

These phenomena are analogous to the *will-o'-the-wisp* (deceptive fires) phenomenon in the European folklore, which is a phenomenon that is also difficult to explain. Accounts of deceptive fires in China and Japan along with a detailed discussion thereof, can be found in Needham’s History of Science in China, as well as in the works of de Groot (1901) and de Visser (1913, 1914). However, there is evidence indicating that ancient Chinese philosophers were acquainted with most forms of luminescence, with the exception of light emitted by synthetic phosphorescent substances.

2.4. The Indians

Scattered references to fireflies and glowworms can be found in the sacred texts of ancient India and within Indian epic poetry. In the Upanishads a component of the Brahmanas (teachings of the Hindu priesthood), likely recorded prior to the 6th century BC we find the following passage:

Mist, smoke, the sun, fire, the wind,
Fireflies, lightning, crystal, the moon
These are the preliminary manifestations,
that herald the manifestation of Brahma in Yoga.

The *Mahabharata*, The Indian famous epic whose precise date of composition and authorship remain unknown (c. 200 BC - c. 200 AD), is perhaps the longest extant poem in the world, comprising 18 books and 220,000 verses. The epic contains numerous tales recounting the history of the great *Bharata* people, descendants of the legendary king and hero, *Bharata*. The Sanskrit term *khadyota* meaning firefly or glowworm appears several times throughout the epic.

In one text, specifically the *Anugita* we find the following: "Just as those with physical sight observe fireflies appearing and vanishing here and there in the darkness, so too do those endowed with the eyes of knowledge. Spiritual masters perceive this soul with a divine vision when it leaves the body, or while entering the womb, or at birth time."

Finally, we find in a later period in the *Sarvadarshan Sangraha*, a treatise examining the various philosophical schools of India authored by the renowned scholar Madhava Acharya in the 14th Calendar century we encounter the phrase: "Many pleasures resemble fireflies." This appears to be a metaphor likening pleasures to fireflies, for both are transient. In Buddhist texts, specifically the *Dhammapada* the *Pali* term *khajjopaka* is employed to denote the firefly. The following passage appears in the *Dhammapada*: "The followers of the Ten Powers multiplied, and countless deities and humans descended upon the sacred earth. As for the heretics, they forfeited both gain and honor, just as the firefly loses its luster before sunrise."

The position of the firefly’s light within a scale of luminosity is noted in the Further Dialogues of the Buddha translated by Lord Chalmers from the *Pali* text *Majjhima Nikaya*. This excerpt features a series of comparisons in which the spiritual perfection of a heretic is likened to a gem. It goes as follows: “… However, it is acknowledged that the gem

shines and sparkles less brightly than a night-firefly; the firefly, in turn, shines less brightly than a lamp; the lamp less brightly than a night-flame; and the flame less brightly than the morning stars at dawn in a clear sky. These stars shine less brightly than the full moon in a clear sky at midnight; the full moon shines less brightly than the sun at its zenith at the end of the rainy season; and this latter shines less brightly than the multitude of deities 'who shine by their own light, drawing no illumination from the sun or the moon.' At the conclusion of this sequence, it is reiterated that the heretic's perfection is "less than, and inferior to, that of a firefly."

These excerpts serve to illustrate the status accorded to one of the most common and captivating bioluminescent creatures in ancient Indian literature. Two points of interest are worth noting here. The first is the emphasis placed on the ephemeral nature of the firefly; a creature that appears during specific seasons for a mere few weeks before vanishing, completing the remainder of its life cycle as a wingless larva on the earth.

The second point concerns the disparagement of the firefly's light. Rather than eliciting admiration for this tiny creature's ability to generate light without heat, the firefly was relegated within Buddhist texts to a lowly rank among luminous entities. In this regard, this attitude mirrors that of the Arabs, who derived the name for the firefly from the name of a miserly man known for kindling only a small, insignificant fire.

No discussion of the phenomenon of luminescence in ancient India would be complete without mentioning the luminous cobra stone found in India and Ceylon. Although the origins of the legend remain unknown, and the story itself appears highly improbable, it is nonetheless very captivating. The most compelling account of this legend was provided by Professor H. Hensoldt, who actually acquired one of these stones known as a *Naga Kalu* during his stay in Point de Galle, Ceylon.

It is said that one in every twenty cobras carries within its mouth a small, luminous stone, which it places in the grass at night to attract fireflies, only to devour them thereafter. Hensoldt hunted fifty cobras without ever finding such a stone; however, one night, while out in the fields with a Tamil laborer, he spotted a cobra resting beside what appeared to be a luminous patch of ground. Hensoldt intended to kill the snake immediately, but the Tamil man implored him not to do so, warning that the cobra is allegedly at its most dangerous bout when guarding its *Naga Kalu*. The following night, however, the Tamil man spotted the cobra at the very same location; he managed to retrieve the stone by climbing a tree and scattering ash over it. The ash was subsequently collected and sifted once the snake had departed.

The stone itself was described as "a semi-transparent, water-worn pebble of a yellowish hue, approximately the size of a small pea which, in the dark (and particularly after being warmed), emitted a green, phosphorescent glow." Chemically speaking, the pebble was composed of fluorite; and as is known, certain varieties of this mineral, specifically chlorophane, possess phosphorescence that enables the stone to glow throughout the night after having been exposed to sunlight. There is no doubt regarding the presence of the pebble; however, the role of the cobra calls to mind another, more recent story concerning the *Ploceus baya* (Indian Baya weaver), also known as the bottle *birdwhich*, which is said to embed fireflies within pellets of clay inside its bottle-shaped nest to frighten off predators and keep them away from its eggs and hatchlings [5].

2.5. The Greeks

Among the ancient Greek philosophers ranging from Thales of Miletus (c. 640-546 BC) and his pupil Anaximander (c. 611-547 BC) to Plato (428-347 BC), the surviving literary fragments and quotations contain no definitive references to luminous objects.

Homer (c. 1000 BC) mentioned certain invertebrates in the *Iliad* and the *Odyssey*, yet he made no mention of any luminous species. There is, however, inconclusive evidence suggesting that the Greeks possessed knowledge of inorganic luminescence. In his tragedy *The Bacchae*, Euripides (d. 406 BC) described how the Maenads "carried fire in their hair without suffering harm." J. B. Jurissen (1948) interpreted this "fire" as a phosphorescent substance, though the supporting evidence remains unconvincing [3].

2.5.1. Theophrastus (3rd Century BC)

In his treatise *On Stones*, Theophrastus (d. c. 286 BC) noted that the *semi-precious carbuncle* a term literally meaning "small piece of charcoal" derived its name from the fact that it appears to glow only when viewed in the light, rather than from any inherent self-luminescence, as many later writers erroneously believed [3].

Theophrastus (374-286 BC) is credited with clarifying, in his *History of Stones*, that the name *carbunculus* (little charcoal) was applied to this stone because it resembles a glowing ember (perhaps a garnet stone) when exposed to sunlight. Nevertheless, most subsequent historians posited the existence of a stone that glowed at night, which is an idea that became associated with the carbuncle. In addition to fluorspar, certain types of diamonds exhibit phosphorescence when heated after exposure to light; however, the verification of this property dates to a later period. The carbuncle, for its part, does not display such a characteristic [3].

Theophrastus quotes Alcmaeon (6th century BC) as saying that: "It is evident that there is fire inside the eye; for when struck, this fire is extinguished." As previously noted, Aristotle wrote: "However, the researchers believe that the sense of sight consists of fire; a view to which they are led by a specific sensation whose true cause they don't know. For example, when the eye is pressed or moved, fire appears to flash forth from it. This naturally occurs in darkness, or when the eyelids are closed, for in this instance, too, darkness prevails [3].

2.5.2. Strabo (1st Calendar Century)

Strabo (d. 24 AD), the Greek geographer, mentioned in the last of his seventeen books a fish he called *Deilexnos* (literally meaning "double light"), identifying it as a fish of the Nile. According to the Swiss naturalist Conrad Gessner

(1516-1565), the name refers to a glow emanating from the eyes or gills of the fish. During a visit to Dongola on the Nile River in northern Sudan far from saltwater environments, Ehrenberg (1834: 532-533) observed a glow within the nearly fleshless skeleton of the armored fish *Heterotis nilotica*, and he wondered whether this was the very Deilexnos mentioned by Strabo. It is believed that the luminescence observed in Ehrenberg's fish was caused by bioluminescent bacteria, which are occasionally found on freshwater fish, in addition to saltwater species. However, some manuscripts of Strabo's work employ the term *Lexnos* instead, and the text contains no indication whatsoever of luminescence. *The Lexnos* is mentioned merely alongside a number of other fish species inhabiting the Nile. The most that can be said is that it was indeed possible to observe a luminous fish; yet, surprisingly, Strabo provided no indisputable references to bioluminescence [3].

2.6. The Romans

It is difficult to understand why references to fireflies are so scarce in classical Roman literature, given that later travelers emphasized the spectacular nature of these insects' appearance in Italy. There is no mention of bioluminescence in the writings of the epic poet Virgil (70-19 BC), despite the maritime adventures described in the *Aeneid*, wherein he had numerous opportunities to witness the glow in the sea. It appears that Virgil was instead captivated by the sparks generated when flint is struck, which is a phenomenon that can hardly be described as glow, although he mentioned it twice in the *Aeneid* and once in the *Georgics*. Nevertheless, numerous authors have observed and described in great detail the phenomena of bioluminescence and the aurora borealis.

2.6.1. Claudius Aelianus

Claudius Aelianus, Roman orator from the 2nd Calendar century, and author of *On the Nature of Animals*, described luminous stones as well as two types of luminous plants, namely: *Aglaophotis terrestris* and *Aglaophotis marina*. He preferred to write in Greek, and his seventeen books of *On the Nature of Animals* were subsequently translated into Latin and edited by Conrad Gessner in the 16th Calendar century, and no English translation of the books exists.

Both *Aglaophotis terrestris* and *Aglaophotis marina* must have greatly impressed Gessner, as he described them in detail in his work *De Lunariis* (1555) on luminous plants. Regarding the legend of *Aglaophotis terrestris* also known as *Cynosbastus* Gesner wrote: "During the day, it is difficult to distinguish it from other plants (for it does not differ from them at all), and it cannot be easily identified. However, at night, it shines like a star and radiates a fiery glow, making it easily visible. Hence, people used to mark its roots, for they can neither identify it during the day by its color nor by its shape. Then, once night has passed, they approach the plant and identify it by means of the mark, taking care, however, neither to uproot it nor to dig around it."

For they say that the first person to touch it, unaware of its true nature, will surely die. Consequently, they procure a small dog that has been left unfed for a full day, and they securely fasten a sturdy rope between the plant and the animal. They then retreat as far back as possible and toss pieces of roasted meat toward the dog. Awakened by the overwhelming scent, the dog lunges at the meat, uprooting the plant completely. However, should the sunlight strike the exposed roots, the dog perishes instantly; it is then buried according to specific, secret rites, honored as one who died in their service. Only then do they dare to touch the plant and carry it away. The plant is renowned for its numerous benefits, including its use as a remedy for epilepsy. It is also employed to treat a specific eye ailment that impairs vision by causing an excessive accumulation of aqueous humor within the eye.

As for the other plant described by Aelian, which is the *Aglaophotis marina*, Gesner wrote the following: "When the summer heat reaches its zenith, a certain species of seaweed algae or *Fucus* grows upon the deep-seated rocks. In size, it resembles the tamarisk tree, and in its fruit it resembles the poppy. The outer portion of the fruit is a shell-like casing or covering of vivid yellow color, which encases and shields the inner core like a protective wall. The inner core is dark blue in color, soft to the touch, and as translucent as an inflated bladder. A noxious poison drips from this inner core, and at night, it emits a fiery glow much like shimmering scintillating radiance."

The story of the alga *Aglaophotes terrestris* seems more akin to a myth. However, the account regarding *Aglaophotes marina* may well have been based on the apparent luminescence of marine algae covered by colonies of bioluminescent hydroids. These growths are common and create a spectacular sight on late-summer nights, glowing brightly when disturbed by the touch of a hand [3].

Figure 4.
The crustacean ostracod can create a light bright enough to light maps.
Source: https://hakaimagazine.com/features/secret-history-bioluminescence/

3. The Inhabitants of South American Nations

The inhabitants of certain South American nations, specifically the Dominican Republic, Jamaica, and Cuba, utilized a particular species of firefly as a source of illumination prior to the advent of electric lighting. They gave these insects various names such as *lamp-flies*, *fire beetles*, or *Cucujos* depending on their local dialects. This practice was corroborated by the Spanish historian Gonzalo Fernandez de Oviedo (d. 1557) [8]. The rationale behind this nomenclature lies in the presence of two luminous organs located at the insect's head, which light up as needed to help it navigate in darkness. The male possesses two such organs, which remain illuminated during the mating period serving as a signal to other individuals to be at a distance [9].

4. Arab and Muslim Scholars

Arab and Muslim scholars, for their part, observed the phenomenon of bioluminescence in terrestrial, marine, and plant organisms. They provided us with detailed descriptions of these occurrences in both prose and poetry, and even identified certain geographical indicators associated with specific bioluminescent species.

4.1. Bioluminescence in Insects

The only species in which Arab scholars documented their observations is the luminous firefly or the lightning bugs. They referred to these insects by a variety of names, including luminous beetles, *al-Hubāḥib*, *Abū Ḥubāḥib*, and lightning insects. Al-Antāki mentioned two additional names, namely: *al-Taybūth*, a term, according to him, used in the Levant, and *Sirāj al-Quttāb* [10].

The descriptions of the firefly provided by linguists and zoologists are in agreement. As stated in *Al-Qamūs al-Muhīt*: "*Al-Habhāb* is a fly that flies by night and emits a glow resembling that of a lamp, hence it is called Nar *al-Hubāhib* (the firefly's light)." It further notes that: "*Al-Hubāhib* refers to the small ones, the singular form being *Habhāb* [11].

Abu Uthmān Amr Ibn Bahr al-Jāhiz (d. 255 AH / 869 AD) was among the earliest Arab zoologists to discuss the luminous firefly. However, he did not classify it as an insect, but rather as a bird.

Ibn Fadl Allah al-Umari (d. 749 AH / 1349 CE) recounted, based on reports from trustworthy sources, that luminous masses would appear before travelers journeying through the region of Kanem, a territory then part of the Sudan [12].

Fireflies control the timing of their flashes by regulating the flow of oxygen to their light-producing organs. In the absence of nitric oxide gas, the mitochondria sequester the oxygen, preventing it from reaching the reactants necessary for light production. However, when nitric oxide is released, it inhibits the mitochondria from consuming oxygen, which allows the oxygen to flow freely and trigger the flash. Due to the rapid breakdown of this gas, the flashing ceases immediately once its secretion stops, which is a mechanism that explains the rapid frequency of the firefly's light pulses [13].

4.2. Bioluminescence in Marine Organisms

There exists a rare and spectacular marine phenomenon in which vast expanses of ocean water turn a glowing white at night, resembling milk or snow, to such an extent that they become visible from space. Scientifically known as *Milky Seas*, this phenomenon can cover an area of up to 100,000 square kilometers, an area equivalent to the size of entire nations, such as Iceland.

This phenomenon is attributed to the presence of vast numbers of marine organisms, including invertebrates, marine

worms, plankton, and bacteria. One potential source is the blue squid, which is a marine creature found in Toyama, Japan, where it exists in millions. These squids measure no more than 7 centimeters in length. They typically inhabit the deep ocean, but ascend toward the surface during the spring to mate. Alternatively, the phenomenon may be caused by the crystal jellyfish, a delicate, gelatinous marine organism found along the coast extending from British Columbia down to California. This creature emits light to startle predators when it senses danger, utilizing a specific type of protein in its body that enables it to glow [14].

Figure 5.
Plankton light up the ocean adding a fascinating picturesque view
Source: https://www.deevanahotels.com/blog/biolumninescent-plankton-krabi/

The renowned Arab navigator Ahmad Ibn Mājid (d. 906 AH / 1500 AD) also observed the phenomenon of bioluminescence in luminous marine organisms. He documented this observation in his *urjuza*, a form of rhymed verse he titled *Hāwiyat al-Ikhtisār fi Usūl Ilm al-Bihār* (The Compendium of Essentials in the Principles of Maritime Science). This extensive poem consists of 1,080 verses, divided into eleven chapters, which address the signs and navigational aids available to sailors as they approach the shore, among which are luminous marine organisms [10].

4.3. The Phenomenon of Bioluminescence in Plants

Ibn Wahshiyyah al-Nabaṭi [15] described a specific type of tree that emits light of its own accord at night. Researchers were unable to replicate this type of tree until the 21st Calendar century, utilizing genetic engineering technology.

Ibn Wahshiyyah al-Nabaṭi [15] stated that: "In the land of Bakiyān, there exists a tree that glows at night just as a lamp does. If people travel in its vicinity, they require no lantern. So abundant is the light radiating from this tree that its intensity and reach correspond to its size. When the tree is large, its light extends far, while a small tree emits confined light." He named it the *Moon Tree* Ibn Wahshiyyah al-Nabaṭi [15]. Abu al-Khayr al-Ishbīli [16] also alluded to this specific variety, dubbing it *Ūd al-Barq* (The Lightning Wood). He noted that: "*Ūd al-Barq* is a tree that glows at night [16]. It is highly probable that the trees described by both Ibn Wahshiyya and Abu al-Khayr al-Ishbīli were host to a species of bioluminescent fungi similar to those found in the forests of the Western Ghats in India.

Additionally, Ahmad Hasan al-Rashīdi of the 19th Calendar century described a tree known as *al-Yabrūh al-Waqqād* (The Glowing Mandrake) or *Sirāj al-Qutrub* (The Goblin's Lamp), which belongs to the category of trees that emit light at night. However, he clarified that the source of its illumination is insects, not fungi [17].

4.4. The Phenomenon of Luminescence in Solid Substances

Aristotle had previously alluded to solid phosphorescent substances, though without offering a philosophical or scientific explanation for them. He said that: "Not everything visible is visible in the light; this holds true only for the specific color inherent in every object. Some objects (for which there is no single collective name), are not visible in the light; rather, they produce a sensation only in the dark. Objects such as truffles, horns, fish heads, shells, and their eyes, appear fiery and luminous. Yet, we do not perceive the specific color of any of these objects. As for why these things are visible in the dark, that is a separate matter [18].

In reality, knowledge of phosphorescent mineral substances dates back to the era of the Ancient Egyptians long before the time of Aristotle. Indeed, we find that Abu al-Hasan Ali Ibn al-Husain Ibn Ali al-Mas'ūdi (d. 346 AH / 957 AD)

recounts how those responsible for the burial rites of King Qibtīn son of Misrāyim, son of Baysar, son of Hām, son of Noah (one of the first kings to rule Egypt after the Great Flood) crafted for him copper spheres coated with chemically treated substances, which he termed *medicaments*. These spheres subsequently functioned like lamps that never ceased to glow.

Al-Mas'ūdi indicated that: "Qibtīn reigned over them for eighty years. Upon his death, his sons and kin were overcome with grief. He was interred in a subterranean passage beneath the Great Inner Mountain in a chamber lined with variegated marble and pierced with vents for the wind, through which the air rushed with a mighty, awe-inspiring roar. Therein, they placed copper heads treated with special compounds that glowed eternally, resembling lamps that could never be extinguished. They embalmed his body with marble dust, camphor, and mummy resin, and laid him in a golden sarcophagus draped in garments woven with coral and pearls. His face remained uncovered in his sarcophagus, which was situated beneath a dome supported by columns of variegated marble; suspended from the center of the dome, hung a gemstone that radiated light like a lamp Al-Mas‘ūdi [19].

Al-Mas‘ūdi [19] further recounts that Ashmūni, who is said to be Hermes I, erected a lighthouse in a city known as *Tahratis*. It stood eighty cubits high and was surmounted by a dome that changed color daily, over the course of seven days, and cycled through seven distinct hues, after which it reverted to the original color, and the entire city would appear to take on that same shade Al-Mas'ūdi [20].

Al-Mas‘ūdi [19] also notes that King Misrām son of Baqrāwus constructed a temple dedicated to the Sun, built of marble, with the structure overlaid with gold. At the center of the temple, he placed a statue resembling a horse, fashioned from blue gemstone and bearing an image of the Sun crafted from red gold. He draped both the horse and the solar image in robes of multicolored silk and decreed that they are incensed with burned fragrant rayhān herb. Within the temple, he installed a lamp made of crystal-clear glass, housing a specially treated stone that radiated a light far more brilliant than that of any ordinary lamp [20].

Furthermore, Al-Mas‘ūdi [19] relates that King Afrāwus son of Manāwus constructed a lighthouse featuring a dome made of gilded brass. He treated the dome with special compounds so that, at sunset, it would burst forth with light illuminating a vast portion of the city with a radiance resembling fire. The flame could be extinguished neither by the wind nor by the rain; yet, by day, its glow would recede, overshadowed by the brilliance of the sun Al-Mas'ūdi [20].

Al-Mas‘ūdi [19] also recounts the story of a ruby gemstone known as *Al-Jabali*, which glowed at night as if it were a lamp. He states that: "In the year 248 AH/ 862 AD, Al-Musta'īn brought forth from the Caliph’s treasury a red ruby gemstone known as *Al-Jabali*. Kings had long treasured and preserved it. Al-Rashīd, for instance, had purchased it for forty thousand dinars, had his name, Ahmad, engraved upon it, and wore the stone on his finger; an event that became the talk of the people. It is said that this gemstone had been passed down through the ages among the Persian Emperors (*the Akasira*) and their names have been engraved on it since ancient times. It was further said that any king who had his name engraved on it met a violent end; consequently, whenever a king died and his successor ascended the throne, the new monarch would have the engraving effaced. Thus, the stone circulated among kings void of engraving, until on rare occasions a particular king would acquire it and choose to have it engraved once more. It was a red ruby that glowed at night with the brilliance of a lamp, and if placed in a room devoid of any light source, it would illuminate the space, and at night, one could discern within it phantom-like images shimmering [21].

The *Al-Jabali* gemstone mentioned by Al-Mas'ūdi was not the only one to exhibit this phenomenon of luminescence, in fact there was another one by Abu Rayhān al-Birūni (d. 440 AH / 1047 AD). This second stone appears to have also served as a reading lens, shaped as a hemisphere that is convex on one side and flat on the other.

Al-Birūni states that: "Al-Sallāmi related, on the authority of Al-Lahām, that Abu al-Bashar al-Sirāfi was visiting his maternal uncle in Sarandīb (Sri Lanka) one night. His uncle produced a red ruby gemstone, which he placed over the characters of a book he was reading. The narrator Al-Lahām was astonished by this, assuming that the stone was emitting light of its own accord amidst the darkness of the night, without any external light source falling upon it. In reality, the ruby was shaped like a hemisphere, with its flat surface facing the book; consequently much like a crystal lens it rendered the fine lines of the text legible, as the characters appeared magnified and the lines of text seemed to expand. The scientific explanation for this phenomenon, however, falls within the domain of the science of optics [22].

Yaqūt al-Hamawi (d. 626 AH / 1229 AD), citing the traveler Shams al-Dīn al-Maqdisi al-Bashāri (d. 380 AH / 990 AD), noted that the substance known as *Badakhshān* (or *Balkhshān*) is a type of stone that emits light of its own accord albeit faintly. He stated that: "There is a stone found there which, when placed in a dark room, illuminates it to a slight degree [23]. Muhammad Ibn Abi Bakr al-Zuhri al-Gharnāti (d. after 541 AH / 1154 AD) corroborated this account while discussing the *Balkhashi* stone (known as spinel), describing it as a stone that "shines more brightly at night than it does during the day [24]. It should be noted, however, that self-luminescence is not an inherent physical property of this gemstone; thus, it is possible that the specimens in question were imbued with phosphorescent substance.

Furthermore, the historian and geographer Zakariya Ibn Muhammad al-Qazwīni (d. 682 AH / 1283 AD) cited the existence of rocks that glow spontaneously at night, citing them within the context of his discussion regarding the mountains situated near the city of Ashbūna (Lisbon) [25]. He added that: "Near the city lies a mountain containing the al-*Barrād* stone a stone that glows at night. It is said according to those who have ascended this mountain by night that it is also of onyx mineral [26].

Abdul Rashīd Ibn Sālih Ibn Nūri al-Bākuwi (d. 806 AH / 1403 AD) presented a different account regarding this stone, in which he distinguished between the luminous stone itself and the onyx, which appears to be more precise. He stated: "Near Lisbon is there is a mountain containing the *al-Barrad* stone that glows at night like a lamp. This same mountain is also a source of onyx [27]. Onyx is a gemstone and a variety of cryptocrystalline quartz [28].

Thus, the aforementioned texts point specifically to the knowledge and discovery of raw white phosphorus by the

Arabs, which is a discovery made before the German merchant Hennig Brand (d. 1710) isolated the element phosphorus in 1669 from urine residues [29]. In nature, two forms of phosphorus exist [30].

- The first is white: This is a crystalline substance that dissolves in carbon disulfide, melts at 44°C, and glows in the dark. It is considered a toxic substance.
- The second is red: This form does not dissolve in carbon disulfide, does not glow in the dark, and unlike the white form is non-toxic; while its reactivity with other elements is weak.

Regarding the references made by Al-Birūni and Al-Qazwīni to the existence of a "radiant stone" which Al-Birūni regarded as an elixir the researcher Muhammad Yahya Al-Hāshimi does not rule out the possibility that they may have actually discovered a radioactive substance rather than a phosphorescent one, which could potentially be radium. This hypothesis is supported by their description of its properties: namely, that it emits light only while it remains within its ore, but ceases to glow once it has been extracted from its matrix [31].

4.5. The Production and Application of Phosphorescent Substances

As the phenomenon of luminescence is chemical in structure yet physical in effect, it follows that its artificial production can be achieved with relative ease. Some researchers have noted that Jābir Ibn Hayyān (d. 200 AH / 813 AD) succeeded in formulating a type of ink that glows in the dark. He achieved this by utilizing a substance known as *Golden Marcasite*, a form of iron pyrite which was considerably less expensive than gold. He would use this specialized ink to inscribe valuable manuscripts, thereby enabling their owners to read them even in total darkness [32]. However, we believe they were mistaken in this assertion, for gilded ink cannot glow in the dark like phosphorescent substances, rather, it requires light to fall upon it in order to shine.

Figure 6.
Chemical luminescence: Luminol with a blue glow when mixed with an oxidizing agent.
Source: https://www.hamamatsu.com/jp/en/applications/evaluation-of-luminescent-materials.html.

Abu Bakr al-Rāzi (d. 313 AH / 925 AD) mentioned a recipe for creating an ink that appears only at night and vanishes during the day, utilizing nothing more than turtle gall [33]. Abu Bakr Muhammad Ibn Muhammad al-Qallūsi (d. 707 AH / 1308 AD) corroborated this recipe, adding further details, stating that: "If you wish to have your writing appear to you at night but remain invisible during the day, write using turtle gall; it will then become visible at night [34]. Al-Rāzi further added noting: "Likewise, if you write using the gall of a fish known as *al-Nattāf*, the writing will appear at night, gleaming like gold [35].

This may well be the very same fish to which Al-Mas'ūdi alluded when discussing the fish of the Black Sea [20]. Furthermore, Muhammad Ibn Muhammad Ibn Abdullah Ibn Idris al-Idrīsi (d. 560 AH / 1165 AD) described a flying fish called *al-Natīq* inhabiting the Sea of Oman or Bahr Harkand as it is known to the people of India. He noted that when its gall is used in writing, and the writing is allowed to dry, it "can be read in the dark just as it is read during the day under the light of the sun [36].

In reality, there is no contemporary scientific research confirming the validity of the claims made by Al-Rāzi, Al-Qallūsi, Al-Masūdi, or Al-Idrīsi. Nevertheless, Al-Rāzi's recipe for a phosphorescent ink, i.e. one that glows at night, eventually reached Europe and appeared in the writings of the German saint Albertus Magnus (d. 1230 AD) also known as Albert the Great, albeit with certain modifications. He formulated it as a mixture of turtle bile and glowworms [37]. The likely objective behind adding the turtle bile was to create a compound that would enhance the luminescence of the phosphorescent substances naturally present in the glowworms, thereby yielding an ink that glows even more brightly in the dark. It is possible that Albert the Great derived this information from *Liber Ignium ad Comburendos Hostes* (the Book of Fires for Burning Enemies), a work first compiled in the 8th Calendar century and attributed to Marcus Graecus,

describing various substances, including incendiary agents and phosphorescent substances. This book may, in fact, have been authored by a Jewish or Spanish scholar during the 12th or 13th Calendar century [3].

Among the earliest known recipes for producing a phosphorescent ink, one designed to assist a reader in reading at night, is the formula provided by Al-Mu'izz Ibn Badīs al-Sanhāji (d. 454 AH / 1062 AD). The composition of this ink incorporates ammonium chloride (NH_4Cl), a substance well known for its ready solubility in water. Al-Sanhāji described the formula as follows: "Take half a mithqāl of sal ammoniac and dissolve it into a consistency suitable for writing. Then, add to it one dirham's weight of *Khawlān* (also known as *Hadhad),* and set it aside for twenty days, keeping it completely shielded from sunlight. Next, bring it to a vigorous boil, and then mix it with two dirhams' weight of mercury and let the mixture rest for forty days. Finally, add ten dirhams' weight of sour milk, and let the mixture settle. Use this mixture as ink and you will find that the writing produced can be deciphered only at night, in total darkness." *Hadhad*, mentioned in the preceding text, is the extracted sap of the *Khawlan* tree, a thorny plant bearing fruit that resembles peppercorns in appearance but possesses a bitter taste, and has leaves that resemble those of the boxwood tree [38].

Al-Hasan Ibn Muhammad al-Iskandari (d. c. 640 AH / 1243 AD) also mentioned another recipe, stating as follows:

"Take one part of plumbum (lead), file it down and pound it into a fine powder. Then take an equal part of intensely white Yemeni alum and pound it together with the lead. Moisten the mixture; the resulting script will remain invisible except in total darkness. It is also recounted that Aristotle, in his book *On the Nature of Animals*, mentioned that if one takes the gallbladder of a crane, places it in a small dish, and uses it as ink, the writing will remain invisible except in the dark; a truly remarkable phenomenon [39].

Ibn Ma'n al-Lakhmi (d. 759 AH / 1358 AD) likewise succeeded in creating such phosphorescent ink, and used it to transcribe a copy of the Qur'an that could be read by a reader even at night [40].

We may be surprised to learn that the solution that shredded bioluminescence in a mystery and perplexed the ancients that long; was not finally unveiled until our modern era. Researchers have since discovered that nitric oxide gas plays a significant role in regulating light emission in insects, acting in conjunction with oxygen and other substances.

From the foregoing, it becomes evident that Arab and Muslim scholars maintained an active presence in investigating the phenomenon of luminescence in all its various forms, going so far as to harness it for practical application. Scholars from other global civilizations likewise made their own distinct contributions to this field.

5. Conclusion

1. The research established that the discovery of luminescence phenomena was not a sudden event, but rather the result of a cumulative body of knowledge spanning across the ages. The ancient Chinese observed fireflies and luminous stones; the Greek philosopher Aristotle was the first to distinguish the phenomenon of luminescence from thermal incandescence; and the Roman scholar Pliny documented dozens of luminous organisms. This knowledge subsequently passed to the Arab-Islamic civilization, which did not stop at mere observation but advanced beyond it to encompass synthesis and practical application.
2. The research reveals a significant scientific precedence: Arab and Muslim scholars successfully synthesized phosphorescent inks, readable at night, centuries before the German chemist Hennig Brand discovered the element phosphorus. The study documents various recipes attributed to several figures, including: Al-Rāzi (using turtle gallbladders), Al-Sanhāji (using sal ammoniac and mercury), Al-Iskandari (using lead and alum), and Ibn Ma'n al-Lakhmi, who utilized such ink to transcribe an entire copy of the Qur'an.
3. One of the most notable findings of the research is the confirmation, as recounted by Al-Mas'udi, that the ancient Egyptians coated copper spheres with chemical compounds designed to glow perpetually within tombs. This serves as a clear indication of intentional chemical processing undertaken to produce sustainable light. Furthermore, Al-Birūni, Al-Qazwīni, and Al-Bākuwi attested to the existence of natural stones that glow in the dark; a phenomenon that can be scientifically explained by the presence of either phosphorescent impurities or naturally occurring radioactive materials.
4. Arab scholars did not stop at the stage of merely theoretically describing the phenomenon of bioluminescence; rather, they linked it to practical, real-world applications. Ibn al-Baitār, for instance, incorporated fireflies into medical prescriptions for treating ear ailments; Ibn Majid alerted navigators to the danger that the glowing of the sea posed to the accuracy of astronomical measurements; and Ibn Battūta documented the relationship between this phenomenon and local beliefs in the Maldives.
5. The research reveals that the enigma which preoccupied Aristotle, Al-Damīri, and Ibn Wahshiyya, namely how living organisms produce light without generating heat, was not fully resolved until the twentieth Calendar century, with the discovery of the roles played by nitric oxide gas and the enzyme luciferase. This underscores the fact that major scientific questions may persist for two millennia before finally finding answers.
6. The research implicitly calls for a re-evaluation of the Eurocentric narrative regarding the history of the discovery of phosphorus. It presents multiple textual evidences demonstrating that the Arab-Islamic civilization possessed advanced applied knowledge of luminescent substances, knowledge that integrated chemistry, physics, and pharmacy, a subject that merits further study and documentation within the literature of the global history of science.

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