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SUN AND SALT, 1500-1700

During the Renaissance, the su was regarded primarily as a source of light which gave form to all things*; during the Enlightenment, paradoxically, the sun was regarded primarily as a source of heat. Paracelsian chemistry of the 1500s introduced salt as a third principle which embodied the other two, mercury and sulphur; salt was that universal mediating presence which represented earth. By the late 1700s salt was no longer a metaphysical principle but an acid-base compound, and volatile salts aroused most interest. These changes in scientific perceptions of sun and salt ran parallel to one another: beginning as transcendent sources of form, sun and salt came to be considered manipulable sources of energy. Our modern approach to energy derives from a period during which Europeans gradually lost their belief in the creative agency of two essentials to human life.

Renaissance descriptions of the sun as both a celestial and spiritual object stressed its light rather than its heat. The sun illuminated celestial patterns and human behavior. Sunlight was regarded as a creative agent in nature: light gave things form. For fifteenth-century painters, the sun began to shine in its countryside, no longer an isolated golden ideograph of divine pres-

* The first version of this text was presented to the conference "Helios: From Myth to Solar Energy" held in March, 1978, at the State University of New York at Albany.

https://doi.org/10.1177/039219218203011703 Published online by Cambridge University Press

ence or alchemical rebirth but the integrating force within the painting.[1] For Neoplatonic philosophers like Marsilio Ficino, the sun was a symbol of the operative intellect that not only appreciates but determines forms of the natural world. Sunlight was consequently a physical phenomenon and a metaphysical sign of the "intelligible light" which is God.[2]

Copernican astronomy may or may not have been the offshoot of Neoplatonic light mysticism and hermetic sun-worship, but certainly Copernicus was gratified to find that the sun could be the lamp at the center of the universe, precisely because he did believe the sun to be the true source of form in nature. Although the planets whirled about a sun on which no humans lived, it was appropriate that a universe configured by light be approximately heliocentric.[3]

About the time that Copernicus was working out his heliocentric theory, the physician and chemical philosopher Paracelsus was devoting himself to the elaboration of a salt-centered theory of matter. Previous to Paracelsian chemistry, two basic principles had been recognized by European alchemists: sulphur and mercury. These principles were functionally and morphologically distinct from modern elements or substances; they were, rather, universal presences variously manifested in matter. Paracelsus introduced salt as the third principle, a *Bauprinzip*, "that which holds the body together." Salt was the mediating principle which represented at once solidity and solubility; it was the source of form and color, the ultimate sublimate, fixity. Since it was enduring, since, as Bernard Palissy would write in 1580, "there is nothing without salt," salt was also the universal balsam, a prime medicine.[4]

The weakest part of Copernican theory lay in its Neoplatonic explanation for the circular orbits of planets and in its equally metaphysical explanation for the coherence of the entire system. What *kept* the planets whirling in their orbits?[5] The weakest part of Paracelsian chemistry lay in its explanation for the powers of salt, an explanation compounded of alchemical rhetoric and complicated by Paracelsus' notion that the principles differed in themselves from one substance to another. Wrote Palissy, who had been mapping the Saintonge saltworks for Francis I, "salt is a fixed body, palpable and known in its individuality, preserver and generator of all things," and yet it was also "an unknown and invisible body, like a spirit." How *did* salt hold the body together?[6]

Gradually, European natural philosophers would come to regard sun and salt differently. Gradually, they would abandon the idea that either sunlight or salt was a source of form, a creative agent. When Kepler, benefitting from Galileo's improvements of the telescope, drew up his science of optics in 1611, he proved that light could be acted upon by external forces; light was (in Stephen Straker's words) a patient, not an agent.[7] When Johann Rudolph Glauber, some thirty years later, used his superb furnaces to study the nature of salt, he cut away much of the rhetoric and bombast which accompanied Paracelsian chemical philosophy.[8]

But neither Kepler nor Glauber had entirely abandoned the old beliefs. We can see them struggling toward a new set of constructs about salt and sun. Kepler offered two explanations for the orbiting of the planets. The first was in keeping with earlier ideas about sunlight, the second was not. In the first, the rays of the sun, spreading along the orbital plane of all known planets, and the *anima motrix* of the sun interacting with the planets, were both the motive forces and the form-fixing agents for celestial motion. In the second, magnetic forces were operating between the sun and the planets.[9]

In 1624 or 1625, Glauber had cured himself of an illness by drinking mineral water in which he soon discovered his *sal mirabile* (sodium sulphate). Although he was the first to isolate and identify mineral salts, and although in subsequent years he seems to have recognized that salts are acid-base compounds, he retained salt as a principle, spoke of the universal salt, and claimed that "in the sun and in salt are all things."[10]

Between 1660 and 1770, the new image of sun and of salt took shape. Discussions of the sun became increasingly concerned with the nature of heat; discussions of salt focussed on the problems of effervescence, fermentation and corpuscular motion. When light and salt lost their status as transcendent sources of form, the sun and salts came to be regarded as manipulable sources of energy.[11]

Throughout the seventeenth century, sunlight was steadily divested of its metaphysical properties. Francis Bacon had early on been discomfited by "the manner in which light and its causes are handled in Physics..., as if it were a thing half way between things divine and things natural."[12] Men turning telescopes on the sun observed the cyclic nature of sunspots; the sun itself was not perfect, and it might well be in motion, rotating on an axis.[13] Nor was sunlight simple: it was somehow a congeries of the colors spreading out past Newton's prism, and it might be explained as the motion of particles (or, for Huygens, the motion of waves).[14] The light of the sun could no longer hold the universe together or give it form. Universal gravitation and the interaction of shaped particles now stood as the prime hypotheses.

Men began to investigate the sun and its light in order to determine the nature of heat. Descartes proposed not a brilliant, glamorous sun but a boiling, turbulent sun whose heat was more crucial than its light. Robert Hooke thought the sun a burning body, and Robert Boyle supposed that sunbeams were streams of fiery corpuscles. Pierre Gassendi and others, following a plan of research outlined by Bacon, studied the relationship of light to heat by using burning-mirrors or lenses to focus the sun's rays on various substances.[15] Bacon, like Boyle and Hooke later, had supposed heat to be a form of motion rather than a variety of matter. This theory, not widely accepted until the end of the eighteenth century, would make heat akin to sunlight, and the measurement of heat would be a measurement of light. When the material theory of heat, robust and persistent throughout the 1700's, was finally upset by the discovery of latent and specific heats, what remained was a powerful confusion of light and heat, so powerful that Richard Kirwan's definition of specific heat began, "All bodies require a certain quantity of elementary fire or light to heat them to a certain degree." William Herschel, seeking the best color filter for his astronomical observations of the sun, reported in 1800 that he had found heat beyond the visible red end of the spectrum. He was not prepared for this discovery of heat without visible light, and he stumbled at any sufficient explanation. The problem of thermal radiation and the problem of electricity—which the scientists were substituting for the sun in their study of the problem of light—would provoke major theoretical shifts in nineteenth-century physics and chemistry. And the sun would be analyzed, photographed, pinned like a butterfly to walls.[16]

Salt too had suffered. Boyle had insisted that salt could not be a "principle." In his experiments, he had determined that there were many different salts, none of whose "spirits" (vaporized forms) was necessarily metaphysically potent. Paracelsus had constantly urged forward the alchemical pun that certain procedures for preparing salts were "spiritual." Boyle divested that pun of its mystery. In 1754, after further decades of confusion over the precise nature of the de-mystified salt, Guillaume François Rouelle authoritatively defined salt as an acid-base compound.[17]

Yet, if salt could no longer be admired as the source of form, volatile salts still challenged the imagination of chemists, who had not yet puzzled out the exact relationships between acids, alkalis and salts. The seventeenth century had been a century of mineral salts, first Glauber's salts and then Nehemiah Grew's Epsom salts and other salts trumpeted for their healing, energizing powers. Chemists studied fermentation and effervescence, novelists and playwrights brought in volatile salts to restore the spirits of their heroines, gentlemen and gentlewomen began to take the waters at Bath.[18] And despite failures to decipher the secrets of crystalline structure, Enlightenment scientists were disinclined to attribute to salt the creative form-fixing powers which had so impressed the Paracelsians handling salt crystals. Instead, the new chemists initiated experiments on chemical bonding and close-range particulate forces in salts. Like the sun, salt became a source of energy to be exploited, a substance by means of which one revived the faint or generated heat in chemical solutions.[19]

There is more here than mere parallelism. Sun and salt are intimately related, possibly from the very origin of our word "salt," and certainly by virtue of the antiquity of solar salt pans for producing salt from the sea. Did the shifting perception of sun affect the perception of salt, or vice versa?

Consider first the history of theories of luminescence. With the discovery of many new luminous insects in the Americas, sixteenth-century observers became increasingly interested in the phenomenon of "cold" light, and Conrad Gesner in 1555 was the first to write a book devoted entirely to luminescence. The seventeenth century was (according to E. Newton Harvey) the Age of Phosphor, starting in 1603 with Cascariolo's discovery of the Bolognian (phosphor) stone, ending in triumph in 1669 with Henning Brand's isolation of phosphorus. As knowledge about animal and mineral luminescence accumulated, the problem of light would no longer be tied so closely to theories about the sun.[20]

More surprisingly, between 1680 and 1720, men would link light with salt. Johann Kunckel, who had been working with phosphorus, proposed that "where there is Heat there is Acid, where there is Flame or Light, there is a volatile salt." Paolo Casati in 1688 and Johann Heinrich Cohausen in 1717 would defend the thesis that light comes from swiftly moving salts. At least three different sets of logic were involved in this identification of salt and light. As alchemists knew, salt was what remained after fire—it was ash, "that fixt permanent earth which is in the center of everything that is incorruptible and inalterable;" assuming that luminescence was a sort of nonconsuming firelight, the basis of such light must be salt. As Hooke and Boyle suggested, light was the product of vibratory motion among small particles, and late seventeenth-century corpuscular theory found in volatile salts an inherent motion or a certain shape which could be the source of corpuscular vibrations. As Paracelsian chemists knew, there was an aerial niter, a universal life-giving force, which in the body became a vital saltpeter, a substance that was both salt and fire and therefore the origin of internal light. Jean Baptiste van Helmont, perhaps the most influential chemical philosopher and physician of the seventeenth century, wrote that "the salt Spirits, and Sulphur of the arterial Blood, do by the Pulse, run themselves together in the Sheath of the Heart, and a formal Light together with Heat is kindled in the vital Spirit; from the Light I say, of the most inward, and implanted sunny Spirit, in which is the Tabernacle of the specifical Sun, even unto the World's end."[21]

Salt theories of light did not prevail, and the understanding of luminescence did not much progress until the nineteenth century, but the point of this example may be clear. As sun and salt were translated from sources of form to sources of energy,

https://doi.org/10.1177/039219218203011703 Published online by Cambridge University Press

there was a moment of epistemological contact between the two: to know the energy of salt was to comprehend the light and energy of the sun.

Consider next a change in European salt production techniques. As the sea-level rose in the sixteenth century, Europeans were forced to resort more frequently to the boiling of brine in order to obtain salt supplies. They could not rely as much as they had upon coastal salt pans which were being flooded, or upon the sun itself, which shone less consistently during the "Little Ice Age" in the Northern Hemisphere, whose climatic pessimum occurred in the era 1550-1700. Concern about the sun's heat, then, was prompted in part by the economics of salt trade, and the new salt drilling techniques adapted from the Chinese would turn European workers away from the light of the sun toward the wood and coal flames of the darker earth.[22]

One might place this technological change within a larger context. Between 1600 and 1770, European scientists and theologians began to conceive of a hydrologic cycle that had a significant horizontal, terrestrial component; the sun, previously held responsible for all circulation of waters, became but one element in a continuum of winds, clouds, mountains, rivers, underground springs and streams, layers of earth and rock. The sun still worked to evaporate and draw up the waters, but it shared its task with the winds, and topographical forms had their own special functions within the cycle. The vertical cycle that produced rain was merged with the horizontal cycle that was responsible for rivers. So too in art and literature the mountains began to appear, their hollows and chasms soon to be as sublime as the sun's light had formerly been prepossessing. Mapmakers and surveyors took more care with the delineation of contours. English and then continental gardens meandered according to the "natural" lay of the land. Bourgeois men and women, wanting to know the exact time in a world of stock markets, life insurance, and daily newspapers, began to look around (at clocks and watches) rather than up (at the sun).[23]

This new attentiveness to topography was strangely correlate to the disappearance of both Ptolemaic astronomy and alchemical elements-systems, each of which had been used in the sixteenth century to defend a belief in the tight-knittedness of macrocosm and microcosm. Astrology is not far-fetched when one believes in the actual physical impress of celestial motions and fires upon the terrestrial frame; medicine is but a class of astronomy when one believes in a doctrine of signatures by which one may read in the human body the movements of the planets. As the sun receded into a distant center, as chemical "principles" more slowly lost their macrocosmic origins and fell, as it were, to the earth, topography assumed an independent importance. Land forms had a power of their own, phosphorus (or salt) might give light, and mountains might have majesty.[24]

Christian scientists or natural philosophers in the seventeenth century tended to worry about the consequences of such independence. Did so earthy an appreciation of nature occlude the perception of a Christian universe? Consider—as a final case of the interplay between sun and salt—the answer of one Timothy Byfield.

In the 1690's, Dr. Timothy Byfield (1650-1723) first prepared his universal panacea, *Sal volatile oleosum* (aromatic spirits of ammonia), one of the earliest English patented medicines. He had drawn down from the sun and the air a host of "illuminated Sulphurs," combined them magnetically with volatile salt, and so captured "Spirit of Air, and the best seasoning in the whole World of Animal Bodies in Life." In his disquisition on his *Sal,* Byfield described the sun as illuminator and energizer, salt as mediator and mobilizer.[25] In 1707 Byfield joined a millenarian group known as the French Prophets, and he was not the only follower to stand with some excitement at the crossroads between one image of sun and salt and another. Other followers included Isaac Newton's protegé, Nicolas Fatio, who collected salts, sought alchemical recipes, and wrote a book on fruit-walls which was in part an excuse for a commentary on sunspots; Francis and George Moult, chemists who sought the philosopher's stone, manufactured Epsom salt, and sold pharmaceuticals at the sign of Glauber's Head.[26] These men, and others around them, conceived of prophecy as both an act of perception and a sign of divine activity; that is, as a means of determining the form and pattern of the world, and as a source of spiritual energy. Their prophets described the process of inspiration in physio-

https://doi.org/10.1177/039219218203011703 Published online by Cambridge University Press

logical terms as both a sensation of heat and a flash of light. Byfield's description of the potency of his *Sal* was perfectly congruent; like the process of inspiration, the process of chemical creation and of medical redemption involved both aspects of salt, the volatile and the form-fixing.[27]

Byfield's Christian *Sal* is the clue to the significance of the shift in images of sun and salt. Between 1500 and 1770, sun and salt were divested of sacramental power. In Leonardo's *Last Supper*, Judas has overturned the salt cellar, and sixteenth-century clerics could recognize witches by their hunger for salt, absent from the demonic, exhausting witches' sabbaths; in the late eighteenth century, the salt cellar had been demoted to an ordinary piece of tableware that no longer signalled the authority of the lord's table, and in the place of exorcism, Voltaire intended to spread salt on his agricultural land in order to *increase* its fertility.[28] In the 1500's, the sacramental wafer, round and white, had been identified with the sun, and Ignatius Loyola had as his device a cross implanted on a flaming sun; the poet Ronsard described the French king Charles IX dressed for a ballet in the costume of the solar god. In the 1700's, regardless of another Sun King, the sun's light was but a set of colors for poets and painters, the sun's heat manipulable by mirrors, and Franz Anton Mesmer could claim to have mesmerized the sun itself.[29]

It has become traditional within the last decade to associate the "rise of the modern world" with the primacy of sight, visualization and the spread of the printed word.[30] Vasco Ronchi in particular has argued admirably that the invention and perfection of the telescope had to await a cultural milieu in which one could trust one's eyes to see the truth of things, and it was not until the seventeenth century that Galileo could persuade men like Kepler that what lay beyond the lenses was other than optical illusion. As scientists learned to trust their sight, they abandoned the long-standing double definition of light as either psychic (*lux*, that light in Genesis which precedes the creation of the sun) or sensational (*lumen*, the physical aspect of light). Indeed, argues Ronchi, scientists after Kepler so favored *lumen,* the physical light, that they neglected the valid medieval concern for the subjectivity of perception. For to trust sight, one had to assume the objectivity of the eye.[31]

Obviously, this paper is a brief argument against the notion that the "modern world" or its "scientific revolution" can be easily associated with the primacy of sight. If the sun's heat rather than its light was most important to Europeans in the seventeenth and eighteenth centuries, if salt's energy was more intriguing than its capacity to sustain forms, then what we have in front of us is a movement away from sight toward touch and kinaesthesia. Ronchi's thesis need only be rewritten to prove the point: scientists did not so much learn to trust their sight as they did push to develop theories of light which made the physical (analogically tactile) aspect of light more presentable. Bacon, encouraging his contemporaries in the early seventeenth century to experiment more and contemplate less, was still dubious about the prospect of observing very minute or very short reactions. What was new to the "modern world" and its "scientific revolution" was not methodical observation but methodical manipulation. This was as true for the furnaces of Glauber as for the burning mirrors of Gassendi and later Lavoisier.

The self-generated propaganda for an eighteenth-century Enlightenment created by a coalition of scientists and *philosophes* has too often and too successfully obscured an eighteenth century of manipulation, manufacture and European expansion. It was a tactile, earth-moving, ungenerous conquest of sun-burned land and salt sea that underlay the marvelous delicate faience and the Wedgwood china of the Enlightenment. The sentimentalism of the romantic response to "cold reason" and "clear language" may be taken to have been only another version of conquest by touch and sensation.

Robert Boyle, tentative, wrote in 1688, "I see no Absurdity in supposing that, among other Uses of the Sun, and of the Stars, the Service of Man might be intended." By the nineteenth century, William Herschel could write, "The Sun... appears to be nothing else than a very eminent, large, and lucid planet." By 1951 our own modern astronomer, Harlow Shapley, could write or, rather, proclaim, "In partial balance of the servile parasitism of man on the light of the sun, we seek to turn the tables and make the sun the servant of man." And in 1978 we can find

Joseph W. Little of the University of Florida proposing that we agree for our own good to sell the sun to utility companies.[32]

Our modern approach to energy seems to derive from a period during which Europeans stopped believing in the transcendent agency of salt and sun, two essentials to human life. We inherit as well a persuasive faith in our ability to manipulate, and a suspicion of the visual which has been strengthened by our sophisticated manipulation of lights, cameras, and news. Ironically, ecological activists are the ones who now believe what they see. The rest of us believe in hidden resources, the power of invention, human ingenuity, manipulation. To what degree may the present ecological concerns with solar energy be prompted by desires to reinvest life-promoting forces or substances with in-forming sacramental powers?

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NOTES

[1] Francesco Negri Arnoldi, "L'iconographie du soleil dans la Renaissance italienne," in *Le soleil à la Renaissance. Science et mythes. Colloque international tenu en avril 1963.* Travaux de l'Institut pour l'Etude de la Renaissance et de l'Humanisme, 11, Brussels and Paris, Presses Universitaires de Bruxelles, 1965, pp. 519-538; Kenneth Clark, *Landscape into Art*, new ed., New York: Harper and Row, 1976, p. 29; G.F. Hartlaub, "The Sun in the Sign-Language of Alchemy," *Graphis*, 18 (March, 1962), 138-45, 264.

[2] Marsilio Ficino, *Letters*, trans. Language Department, School of Economic Science, London, 2 vols. (London: Shepheard-Walwyn, 1975), I, 81; Michel Mollat, "Soleil et navigation au temps des découvertes," in *Le soleil à la Renaissance*, pp. 93-94; Vassili P. Zoubov, "Le soleil dans l'oeuvre scientifique de Léonard de Vinci," in *ibid.*, pp. 181-82.

[3] Contrast Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (New York: Random House, 1964), pp. 153-55; Edward Rosen, "Was Copernicus a Hermetist?" *Minnesota Studies in the Philosophy of Science*, 5 (1970), 161-71; idem, "Was Copernicus' *Revolutions* Approved by the Pope?" *Journal of the History of Ideas*, 36 (1975), 531-41; S.K. Heninger, Jr., "Pythagorean Cosmology and the Triumph of Helicocentrism," in *Le soleil à la Renaissance*, pp. 33-54.

[4] Arthur Edward Waite, ed. and trans., *The Hermetic and Alchemical Writings of Aureolus Philippus Theophrastus Bombast, of Hohenheim, called Paracelsus the Great,* 2 vols. (Berkeley: Shambhala, 1976), I, 89-100; Joachim Schroter, "Die Stellung der Paracelsus in der Mineralogie des 16. Jahrhunderts," *Schweizerische Mineralogische und Petrographishe Mitteilungen*, 21 (1941),

313-331; Bernard Palissy, *Les Oeuvres*, (Paris: Charavay, 1880), p. 294; Allen G. Debus, *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries*, 2 vols. (New York: Science History Publications, 1977), I, 56-57, 80; J.R. Partington, *A History of Chemistry*, 4 vols. in 5 (London: Macmillan, 1961) II, 143-44; Marie Boas, "Structure of Matter and Chemical Theory in the Seventeenth and Eighteenth Centuries," in *Critical Problems in the History of Science*, ed. Marshall Clagett (Madison, Milwaukee and London: University of Wisconsin Press, 1969) pp. 499-514; Robert P. Multhauf, *The Origins of Chemistry* (London: Oldbourne, 1966) 234. For detailed information on salt and salt production, see *idem*, *Neptune's Gift: A History of Common Salt* (Baltimore and London: Johns Hopkins University Press, 1978).

[5] See I. Bernard Cohen, *The Birth of a New Physics* (Garden City: Doubleday and Company, 1960) esp. pp. 125-28; Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (New York: Random House, 1959), pp. 147-55.

[6] Palissy, *Oeuvres,* p. 305; Debus, *The Chemical Philosophy,* I, 57, and II, 412.

[7] Stephen Straker, "The Eye Made 'Other': Dürer, Kepler and the Mechanisation of Light and Vision," in *Science, Technology and Culture in Historical Perspective*, eds. Louis A. Knafla, Martin S. Staum and T.H.E. Travers, University of Calgary Studies in History, 1 (Calgary: University of Calgary, 1976) p. 19.

[8] Robert P. Multhauf, "Sal Ammoniac: A Case History in Industrialization," *Technology and Culture*, 6 (1965), 569-70, and see note 10 below.

[9] Kuhn, *The Copernican Revolution*, pp. 245-46; Debus, *The Chemical Philosophy,* I, 258-60 and cf. 103-04 on the Paracelsian attraction to magnetism as further evidence for action at a distance.

[10] Partington, *A History of Chemistry*, II, 34-53.

[11] In the English language, one used a feminine pronoun in reference to the sun until the end of the sixteenth century; after that the sun was masculine. In alchemy and in Glauber's chemistry, salt was feminine, representing the *anima mundi* (world soul); later, salt was neuter. This transformation in the sexuality of sun and salt comes just as the two are losing metaphysical potency; one might suggest, *à la* Jung, that the splitting away of the feminine from both sun and salt was either the cause or the sign of their loss of transcendent status. See "Sun," *Oxford English Dictionary*, X, 151; C.G. Jung, *Mysterium Coniunctionis: An Inquiry into the eparation and Synthesis of Psychic Opposites in Alchemy*, trans. R.F.C. Hull, Bollingen eries, XX (New York: Pantheon, 1963), pp. 188-92, 221n., 239-57. Cf. Gaston Bachelard, *La psychanalyse du feu* (Paris: Gallimard, 1965).

[12] Francis Bacon, "Of the Dignity and Advancement of Learning," in *The Works of Francis Bacon*, 17 vols. (London: Longman, 1850-1874) IV, 403.

[13] On sunspots and solar observations, see Robert Burton, *The Anatomy of Melancholy,* 6th ed. (London: W. Tegg, 1854 [1st ed. 1621, 6th ed. 1652]) 328-29; John A. Eddy, "The Maunder Minimum," *Science*, 192 (1976), 1189-1202; idem, "The Case of the Missing Sunspots," *Scientific American*, 236 (May, 1977), 80-88, 92; John A. Eddy, Peter A. Gilman and Dorothy E. Trotter, "Anomalous Solar Rotation in the Early 17th Century," *Science*, 198 (1977) 824-29; Richard A. Proctor, *The Sun: Ruler, Fire, Light and Life of the Planetary System*, 3rd ed. (London: Longmans, Green and Company, 1876) pp. 156-77.

[14] See esp. A.I. Sabra's discussion in his *Theories of Light from Descartes to Newton* (London: Oldbourne, 1967) ch. 9. Cf. Jean Bernhardt, "Hobbes et le mouvement de la lumière," *Revue d'histoire des sciences,* 30 (1977), 3-24; Henry John Steffens, *The Development of Newtonian Optics in England* (New

York: Science History Publications, 1977); Paul-Henri Michel, "Le soleil, le temps et l'espace: Intuitions cosmologiques et images poétiques de Giordano Bruno," in *Le soleil à la Renaissance*, pp. 402, 412.

[15] Bacon, "Novum Organum," in *The Works*, IV, 131; Partington, *A History of Chemistry*, II, 463-64, 561; "An Account of a not ordinary Burning Concave, lately made at Lyons, and compared with several others made formerly," *Philosophical Transactions of the Royal Society of London,* 1 (1665), 95-98; "An Account from Paris Concerning a great Metallin Burning Concave, and some of the most considerable Effects of it," *ibid.*, 4 (1669), 986-87; John Harris and J.T. Desagulier, "An Account of some Experiments tried with Mons. Villette's Burning Concave, in June 1718," *ibid.,* 30 (1719), 976-77; W.E. Knowles Middleton, "Archimedes, Kircher, Buffon and the Burning Mirror," *Isis*, 52 (1961), 533-43; Douglas McKie, *Antoine Lavoisier: Scientist, Economist, Social Reformer* (London and New York: H. Schuman, 1952), pp. 98-100. On mirror manufacture in cultural context, see Martha Fischer, "My Friend, the Connoisseur, Reflects on Mirrors," *House Beautiful*, 52 (November, 1927), 538-39, 589-90, 592, 594.

[16] Douglas McKie and Niels H. de V. Heathcote, *The Discovery of Specific and Latent Heats* (New York: Arno Press, 1975) p. 130 (Kirwan quote) and throughout; D.J. Lovell, "Herschel's Dilemma in the Interpretation of Thermal Radiation," *Isis*, 59 (1968), 46-60; Stephen J. Goldfarb, "Rumford's Theory of Heat: A Reassessment," *British Journal for the History of Science*, 10 (1977), 25-36. Several papers presented at the Helios Conference tempt me to exclude colonial New England from my generalization about the declining importance of sunlight vis-à-vis the sun's heat. Helen H. Naugle and Peter J. McGuire show that American Puritans had need of a bright and nourishing sun in their response to the New England wilderness, itself a New Jerusalem apart from the scorching sun of English Puritanism. Keith R. Burich shows the high value placed on sunlight by Jonathan Edwards. See Naugle and McGuire, "A Light for Eden: The Sun in American Literary Symbolism 1650-1850," and Burich, "Images of the Sun in Jonathan Edwards' Theology," in *Proceedings of Helios: From Myth to Solar Energy*, comp. M.E. Grenander (Albany: SUNY Albany, 1978) pp. 365-72, 92-99.

[17] Robert P. Multhauf, "Geology, Chemistry, and the Production of Common Salt," *Technology and Culture*, 17 (1976), 634-45; Marie Boas, *Robert Boyle and Seventeenth-century Chemistry* (Cambridge: Cambridge University Press, 1958), pp. 117-31. Contrast Debus, *The Chemical Philosophy*, II, 484, 502. For the relevant passages in Boyle's writings, see especially his "Sceptical Chymist" in *The Works*, ed. Thomas Birch, 6 vols. (Hildesheim: Georg Olms, 1966-1967) I, 468-71, 485, 532, 548.

[18] Debus, *The Chemical Philosophy,* II, 357, 530; John Brown, "Observations and Experiments on the Sal Catharticum Amarum, commonly called the Epsom Salt," *Philosophical Transactions of the Royal Society of London,* 32 (1723), 348-54, 372-81; Warwick E. Wroth and Arthur L. Wroth, *The London Pleasure Gardens of the Eighteenth Century* (London: Macmillan, 1896), on mineral springs and spas; R.S. Neale, "Bath: Ideology and Utopia, 1700-1760," *Studies in the Eighteenth Century*, 3 (1976), 38-54; "Sel," *Dictionnaire de la langue française*, ed. Emile Littré, 4 vols. (Paris: Hachette, 1875) IV, 1880-1881, on salt as liveliness and on smelling salts.

[19] Cyril Stanley Smith, "The Development of Ideas on the Structure of Metals," in *Critical Problems in the History of Science,* pp. 467-98; Stephen Toulmin and June Goodfield, *The Architecture of Matter* (New York: Harper and Row, 1962), pp. 186-98.

[20] E. Newton Harvey, *A History of Luminescence From the Earliest Times*

https://doi.org/10.1177/039219218203011703 Published online by Cambridge University Press

Until 1900, Memoirs of the American Philosophical Society, 44 (Philadelphia: American Philosophical Society, 1957). Robert Hooke, seeking to explain the mechanism of memory, would postulate the existence in the brain of a substance similar to phosphorus, which seemed to be able to receive and retain light in much the same manner that humans retain impressions. Hooke also used an analogy to the sun, but it was to the sun's radiation, which is felt more powerfully the closer the sun is. See the fine article by B.R. Singer, "Robert Hooke on Memory, Association and Time Perception," *Notes and Records of the Royal Society of London*, 31 (July, 1976), 115-31.

[21] Boas, *Robert Boyle*, p. 153; Harvey, *A. History of Luminescence,* pp. 136-37, 154-55; "Salt," *Oxford English Dictionary,* IX, 59 (definition 4); Allen G. Debus, "The Paracelsian Aerial Niter," *Isis*, 55 (1964), 43-61; *idem, The Chemical Philosophy*, II, 367. Cf. also Everett Mendelsohn, *Heat and Life: The Development of the Theory of Animal Heat* (Cambridge, Mass.: Harvard University Press, 1964) on the gradual rejection of the analogy between solar heat and innate body heat.

[22] M.R. Bloch, "The Social Influence of Salt," *Scientific American*, 209 (July, 1963), 98; *idem*, "Salt in Human History," *Interdisciplinary Science Review*, 1 (1976) 345; Edward Hughes, "The English Monopoly of Salt, 1563-1571," *English Historical Review,* 40 (1925), 334-50; Multhauf, "Geology, Chemistry, and the Production of Common Salt," 640; H.H. Lamb, *The Changing Climate: Selected Papers* (London: Methuen, 1966), pp. 65-66, 99-104, 212-13, some of which is graphically summarized in Samuel W. Matthews, "What's Happening to Our Climate?" *National Geographic*, 150 (November, 1976), 586, 614-15.

[23] This paragraph relies heavily on Yi-Fu Tuan, *The Hydrologic Cycle and the Wisdom of God: A Theme in Geoteleology*, University of Toronto Deprtment of Geography Research Publications, 1 (Toronto: University of Toronto Press, 1968), and *idem*, *Topophilia: A Study of Environmental Perception, Attitudes, and Values* (Englewood Cliffs: Prentice-Hall, 1974), pp. 129-36, for which references I must thank Lucy K. Ludwig. See also S.K. Heninger, Jr., *A Handbook of Renaissance Meteorology* (New York: Greenwood Press, 1968); Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (New York: W.W. Norton, 1963); H.F. Clark, *The English Landscape Garden* (London: Pleiades, 1948); Hillel Schwartz, "Games, Timepieces and Businesspeople," *Diogenes*, 99 (Fall, 1978) 66-70.

[24] Cf. Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Random House, 1970) pp. 46-77, 125-65; W.R. Albury and D.R. Oldroyd, "From Renaissance Mineral Studies to Historical Geology, in the Light of Michel Foucault's *The Order of Things,*" *British Journal for the History of Science*, 10 (1977), 187-215. Note also Aaron J. Ihde, "Commentary on the Papers of Cyril Stanley Smith and Marie Boas," in *Critical Problems in the History of Science,* p. 523: "the collapse of the Ptolemaic system may have been a factor in the decline of the alchemical concept of the elements."

[25] Timothy Byfield, *Horae Subsecivae: Or, Some Long-Vacation Hours Redeemed, For the Discovery of the True* Sal volatile oleosum *of the Ancient Philosophers* (London: J. Whitlock, 1965), pp. 18-23.

[26] Nicolas Facio, *Fruit-Walls Improved By Inclining them To the Horizon* (London: R. Everingham, 1699) 113; Oxford, Bodleian Library, Rawlinson Letters 109, f. 28; London, British Museum, Add. MSS 28,536, f. 238; Frank E. Manuel, *A Portrait of Isaac Newton* (Cambridge, Mass.: Belknap Press of Harvard University Press, 1968) ch. 9; Nehemiah Grew, *A Treatise of the Nature and Use of the Bitter Purging Salt... With Animadversions on a late corrupt*

Translation publish'd by Francis Moult, Chymist (London, 1697), p. vii; John Brown, "Observations and Experiments on the *Sal Catharticum amarum,*" pp. 350-52.

[27] For further details about Byfield, Facio, Moult and the other French Prophets, see Hillel Schwartz, *Knaves, Fools, Madmen, and that Subtile Effluvium: A Study of the Opposition to the French Prophets in England, 1706-1710*, University of Florida Social Sciences Monograph, 62 (Gainesville: University Presses of Florida, 1978); *idem*, *The French Prophets: The History of a Millenarian Group in Eighteenth-Century England* (Berkeley and Los Angeles: University of California Press, 1980).

[28] A.E. Crawley, "Metals and Minerals," *Encyclopedia of Religion and Ethics,* ed. James Hastings, 13 vols. (New York: C. Scribner's Sons, 1961), VIII, 591; Jean Palou, "Le sel et la sorcellerie," in *Le rôle du sel dans l'histoire*, ed. Michel Mollat (Paris: Presses Universitaires de France, 1968) pp. 277-85; Edward Wenham, "The Significance of the Salt," *House Beautiful*, 52 (November, 1927), 517, 570, 572-73; "Sel," *Dictionnaire de la langue française,* IV, 1880, citing Voltaire; E.P. Deatrick, "Salt, Soil, Savior," *Biblical Archaeologist,* 25 (May, 1962), 41-48.

[29] Arnoldi, "L'iconographie du soleil dans la Renaissance italienne," *Le Soleil à la Renaissance,* p. 536; Jacques Toussaert, "Le sel dans la liturgie," in *Le rôle du sel dans l'histoire*, pp. 287-303; William B. McDonald, "Christian Sun Symbols," *Graphis,* 18 (March, 1962), 132-37, 258; Gilbert Gadoffre, "Ronsard et le thème solaire," in *Le soleil à la Renaissance,* p. 510; Marjorie Hope Nicolson, *Newton Demands the Muse: Newton's Opticks and the Eighteenth Century Poets* (Princeton: Princeton University Press, 1946); Robert Darnton, *Mesmerism and the End of the Enlightenment in France* (Cambridge, Mass.: Harvard University Press, 1968) p. 119. Contrast Cesar Rouben, "Louis XIV: The Sun King," in *Proceedings of Helios*, pp. 355-64.

[30] For an extensive recent summary of this issue, see Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change,* 2 vols. (Cambridge: Cambridge University Press, 1979) I, 129-36, 151-59, and throughout.

[31] Vasco Ronchi, *The Nature of Light: An Historical Survey*, trans. V. Barocas (Cambridge, Mass.: Harvard University Press, 1970); disputed by David C. Lindberg and Nicholas H. Steneck, "The Sense of Vision and the Origins of Modern Science," in *Science, Medicine and Society in the Renaissance. Essays to honor Walter Pagel*, ed. Allen G. Debus, 2 vols. (New York: Science History Publications, 1972) I, 29-45; rebutted by Ronchi, "A Fascinating Outline of the History of Science. Two Thousand Years of Conflict Between 'Reason' and 'Sense,'" *Atti della Fondazione Giorgio Ronchi*, 30 (1975), 525-55; analyzed by Vincent Ilardi, "Eyeglasses and Concave Lenses in Fifteenth-Century Florence and Milan: New Documents," *Renaissance Quarterly*, 29 (1976) 341-60. For a fine example of a seventeenth-century distinction between *lux* and *lumen*, see Antoine LeGrand, *An Entire Body of Philosophy according to Principles of the Famous Renata Des Cartes* (New York and London: Johnson Reprint Corp., 1972 [original ed. 1964]) Part V, xv, p. 160: "The Propension to *motion,* or pression, which is in the *Lucid Body*, as the *Fountain*, is properly called *Lux*: But when considered in its progress, that is, in the *Heaven*, or the *matter* of the second *Element*, then it is called *Lumen*, tho' *Authors* commonly confound both these *words*, using them *promiscuously.*" See also Antonio Ferraz, "'Lux' et 'lumen' aux XVIe et XVIIe siècles," *Proceedings XIVth International Congress on the History of Science*, 4 vols. (Tokyo, 1975) IV, 245-48; David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler* (Chicago and London: University of Chicago, 1976), pp. 122-35 *et passim.*

[32] Robert Boyle, *A Disquisition about the Final Causes of Natural Things*

(1688), cited in Tuan, *The Hydrologic Cycle*, p. 75; Proctor, *The Sun*, citing Herschel, p. 184; Harlow Shapley, "Prefatory Note," *Conference on the Sun in the Service of Man, Proceedings of the American Academy of Arts and Sciences,* 79 (July, 1951), 184; Joseph W. Little, "Capitalization of the Sun," in *Proceedings of Helios*, pp. 274-82.