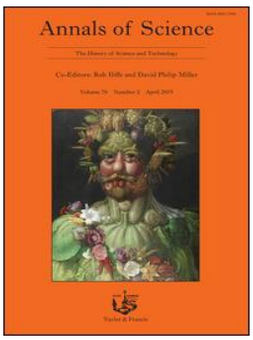

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John Hill (1714?–1775) on 'Plant Sleep': experimental physiology and the limits of comparative analysis

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ABSTRACT

The phenomenon of 'plant sleep' – whereby vegetables rhythmically open and close their leaves or petals in daily cycles – has been a continual source of fascination for those with botanical interests, from the Portuguese physician Cristóbal Acosta and the Italian naturalist Prospero Alpini in the sixteenth century to Percy Bysshe Shelley and Charles Darwin in the nineteenth. But it was in 1757 that the topic received its earliest systemic treatment on English shores with the prodigious author, botanist, actor, and Royal Society critic John Hill's *The Sleep of Plants, and Cause of Motion in the Sensitive Plant*. As the present article aims to illustrate, Hill and his respondents used this remarkable behaviour, exhibited by certain plants, as a lens through which to reassess the nature of vegetables, and to address pressing questions of wider natural philosophical import, particularly the degree of continuity between the structures and functions of plants and animals and whether similar mechanisms necessarily account for related movements in different life forms. These disputes, this paper contends, also had profound methodological implications regarding the proper way to conduct experiments, the extent to which it was acceptable to extrapolate from observations, and the status of causal explanations.

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Royal Society; history of botany; John Hill; experimentation; natural history

'A Sensitive Plant in a garden grew, / And the young winds fed it with silver dew, / And it opened its fan-like leaves to the light. / And closed them beneath the kisses of Night'. Percy Bysshe Shelley, 'The Sensitive Plant'

I. Introduction

The phenomenon of 'plant sleep' – whereby vegetables rhythmically open and close their leaves or petals in daily cycles – has been a continual source of fascination for those with botanical interests, from the Portuguese physician

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Cristóbal Acosta and the Italian naturalist Prospero Alpini in the sixteenth century to Percy Bysshe Shelley and Charles Darwin in the nineteenth. But it was in 1757 that the topic received its earliest systemic treatment on English shores with the prodigious author, botanist, actor, and Royal Society critic John Hill's *The Sleep of Plants, and Cause of Motion in the Sensitive Plant*. As the present article seeks to illustrate, this work was not merely symptomatic of a 'culture of curiosity' around the Royal Society.[1] Rather, Hill and some of his respondents used this remarkable behaviour, exhibited by certain plants, to reassess the nature of vegetables, and to address pressing questions of wider natural philosophical import, particularly the degree of continuity between the structures and functions of plants and animals and whether similar mechanisms necessarily account for related movements in different life forms. These disputes, this paper contends, also had profound methodological implications regarding the proper way to conduct experiments, the extent to which it was acceptable to extrapolate from observations, and the status of causal explanations.

As it stands, studies of the eighteenth-century 'life sciences' have done much to bolster Arthur Lovejoy's claim, put forth in his seminal lectures on the great chain of being, that 'the principle of continuity was reckoned among the first and fundamental truths' for naturalists of this time. James Larson, for instance, eloquently averred that the 'continuity of nature, even in the modified version current in the late eighteenth century, was a necessary trait of the rational order inherent in the relative perfections of natural forms'.[2] According to this historiography, the dominance of the nominalist philosophies of John Locke and Gottfried Wilhelm Leibniz, the burgeoning of comparative anatomy, and the unearthing of species that defied established taxonomical boundaries hastened the displacement of the more rigid categories that had been traditionally summoned to distinguish between natural kingdoms.[3] Pushing back against this discourse, Staffan Müller-Wille has convincingly argued in a recent chapter that the sexual system of the renowned eighteenth-century botanist and taxonomist,

[1]For a focus on 'curiosities' around the Royal Society at this time, see Palmira Fontes da Costa, *The Singular and the Making of Knowledge at the Royal Society of London in the Eighteenth Century* (Newcastle upon Tyne: Cambridge Scholars, 2009).

[2]Arthur Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Harvard: Harvard University Press, 1936), p. 231 and James Larson, *Interpreting Nature: The Science of Living Form from Linnaeus to Kant* (Baltimore: Johns Hopkins University Press, 1994), p. 59. The fullest recent study to make this case for the eighteenth century is Susannah Gibson, *Animal, Vegetable, Mineral? How Eighteenth-Century Science Disrupted the Natural Order* (Oxford: Oxford University Press, 2015). For works that are orientated towards the bearing that eighteenth-century developments had on nineteenth-century taxonomical practices and even evolutionary theories, see Harriet Ritvo, *The Platypus and the Mermaid and Other Figments of the Classifying Imagination* (Harvard: Harvard University Press, 1997) and Peter F. Stevens, *The Development of Biological Systematics: Antoine-Laurent de Jussieu, Nature, and the Natural System* (New York: Columbia University Press, 1994).

[3]For Leibniz's view of natural continuity in particular, see Candice Goad and Susanna Goodin, 'Monadic Hierarchies and the Great Chain of Being', *Studia Leibnitiana*, 29, no. 2 (1997), 129–45; Laurence Carlin, 'Leibniz's Great Chain of Being', *Studia Leibnitiana*, 32, no. 2 (2000), 131–65; and Lea F. Schweitz, 'On the Continuity of Nature and the Uniqueness of Human Life in G.W. Leibniz', in *The Life Sciences in Early Modern Philosophy*, ed. by Ohad Nachtomy and Justin Smith (Oxford: Oxford University Press, 2014), pp. 205–21.

Carl Linnaeus, complicated or even satirized longstanding conceptions of the great chain of being, understood as a scale moving from the least to the most perfect beings.[4] As Müller-Wille demonstrates, the power of Linnaeus's system, with its proliferation of polygamous vegetable unions, stemmed in part from its novel, humorous, and, to some, perverse analogical mapping of a key animal characteristic onto plants.

One aim of the present article is to illustrate that Hill not only challenged the natural continuity hypothesis, but went a step further in rejecting plant-animal analogies in general. He saw the study of 'plant sleep' – a phrase that he could hardly bring himself to use – as an ideal chance to redraw time-honoured distinctions between life forms. In taking this anti-analogical stance, Hill stood on the shoulders of the English clergyman and natural philosopher Stephen Hales, who, embracing an experimental method similar to Hill's own, had established in his groundbreaking 1727 *Vegetable Staticks* that plant sap does not circulate in a manner akin to blood in mammals but rather flows unidirectionally.[5] At the same time, Hill at least implicitly challenged those late seventeenth-century champions of comparative anatomy and physiology such as Thomas Willis, Nehemiah Grew, and Martin Lister who had inspired many of his contemporaries in and around the mid-eighteenth-century Royal Society to uncover missing links and overlaps in an increasingly tightened great chain of being via large-scale and often collective natural historical investigations.[6] As a result, English debates on plant sleep effectively played out as a tussle between Hill, who denied wakefulness and sensitivity to plants based on a schematic division of life forms strongly reminiscent of that in Aristotle's *De anima*, and contemporaries such as the FRS and microscopist Henry Baker, who latched onto the fuzzier picture found in the Stagirite's natural historical writings. Yet, instead of deductively allocating capacities to animals and plants as in *De anima*, Hill attempted to demonstrate that sensitive animals and nutritive plants are fundamentally different on experimental grounds, and, in the process, shored up the 'irritability'/'sensitivity' distinction that the illustrious Swiss physiologist, naturalist, and Göttingen professor, Albrecht von Haller, had introduced.

[4]See Staffan Müller-Wille, 'Linnaeus and the Love Lives of Plants', in *Reproduction: Antiquity to the Present Day*, ed. by Nick Hopwood, Rebecca Flemming, and Lauren Kassell (Cambridge: Cambridge University Press, 2018), pp. 305–18. He pushes back against earlier studies that tended to see Linnaeus as a proponent of natural continuity (see, for example, Philip Ritterbush, *Overtures to Biology: The Speculations of Eighteenth-Century Naturalists* (New Haven: Yale University Press, 1964), pp. 109–21).

[5]This is not to make a judgement as to whether Linnaeus, who cited Hales's view that nutrition comes from the ground, accepted his conclusion regarding the motion of sap, but simply to note that Hales is a likely inspiration for Hill's more general anti-analogical posture (see Carl Linnaeus, *Philosophia Botanica* (Vienna, 1755), p. 88).

[6]On comparative anatomy, see Francis J. Cole, *A History of Comparative Anatomy from Aristotle to the Eighteenth Century* (London: Palgrave Macmillan, 1944), especially pp. 177–254; François Delaporte, *Nature's Second Kingdom: Explorations of Vegetality in the Eighteenth Century* (Cambridge, MA: MIT Press, 1982), especially pp. 9–28; Anna Marie Roos, *Web of Nature: Martin Lister (1639-1712), the First Arachnologist* (Leiden: Brill, 2011), pp. 151–66; and Andrew Cunningham, *The Anatomist Anatomis'd: An Experimental Discipline in Enlightenment Europe* (Farnham: Ashgate, 2010), pp. 295–360.

In their now iconic study, Peter Anstey and Alberto Vanzo argued that a distinction between 'experimental' and 'speculative' natural philosophy remained dominant until the 'first reception of Kant's Critical philosophy'.[7] While this division has proven integral to understanding natural philosophy in 1660s England, the second objective of this article is to point towards a marked shift in conceptions of the 'experimental' and 'speculative' moving into the mid-eighteenth century. To this end, I analyze Hill's experiments and the response that they elicited, not least from Baker who aligned Hill's supposedly 'fanciful' leaps from experimental results to underlying causes with the speculative 'Romances' of René Descartes and *against* his own emphasis on observation as an end in itself. As we will see, by this point, the charge of being unduly speculative could be equally levelled at those who dared to extrapolate from their experimental data and armchair philosophers who refused to get their hands dirty at all. Significantly, the discovery of species such as the fresh-water polyp (a tiny aquatic animal that could reproduce like a plant from cuttings) during the early 1740s was not only thought to prove the continuity hypothesis, but also to legitimize the post-Baconian project of collection and categorization that most Royal Society fellows including Baker had come to favour.[8] I accordingly argue that Hill's potentially disruptive experimental practices were sidelined partially out of a determination to keep this cumulative endeavour intact.

This paper begins by briefly looking at ancient and early modern views on plant sleep, particularly Plato's imputation of sensitivity and desire to vegetables, Aristotle's rejection of this position, and the natural historical observations of Acosta, Alpini, and the great English naturalist and theologian John Ray. Extant historiography – which has been the preserve of practising botanists until recently – frequently posits a sharp break between pre- and post-Linnaean botany. But, turning to how Linnaeus and his student, Peter Bremer from Helsingør, approached plant sleep, I go on to suggest that these eighteenth-century botanists were deeply indebted to their Renaissance predecessors. Following Alpini in particular, they ventured that plants 'slept' in order to protect themselves from cold air. As the next section underscores, however, Hill put no store by such explanations and rather carried out a protracted experiment to prove that light spawned *all* plant motions. While the final section reveals that Hill's contentious hypothesis was violently criticized by Baker and his friend and fellow naturalist John Browning, it also offers fresh manuscript evidence that attests to the remarkable fact that the editorial board of the

[7]Peter Anstey and Alberto Vanzo, 'The Origins of Early Modern Experimental Philosophy', *Intellectual History Review*, 22, no. 4 (2012), 499–518 (p. 499). Also see Peter Anstey, 'Experimental versus Speculative Natural Philosophy', in *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy*, ed. by Peter Anstey and John Schuster (Dordrecht: Springer, 2005), pp. 215–42.

[8]On the efforts to uncover borderline species, see Virginia Dawson, *Nature's Enigma: The Problem of the Polyp in the Letters of Bonnet, Trembley and Réaumur* (Philadelphia: American Philosophical Society, 1987) and Aram Vartanian, 'Trembley's Polyp, La Mettrie, and Eighteenth-Century French Materialism', *Journal of the History of Ideas*, 11, no. 3 (1950), 259–86.

Philosophical Transactions actively suppressed the prized physician, FRS, and botanist Richard Pulteney's praise of Hill's findings. The paper concludes that the common historiographical portrayal of Hill as, in the words of Horace Walpole, an engrosser 'without merit' fails to consider his serious efforts to understand the causal mechanisms of plant functions and is partly an outgrowth of the attempt at erasure among prominent Society members.[9]

II. The backdrop

Although Aristotle never mentioned the daily opening and closing of leaves or petals, the germs of the debate over plant sleep harked back to the Stagirite. In Book I of *De somno et vigilia* (a part of *Parva naturalia*), Aristotle defined sleep as 'the immobilization or fettering of sensation' and maintained 'that the release or relaxation of this is waking'.[10] He proceeded to deny that plants could be said to sleep since this state is opposed to wakefulness, and only beings with sense perception (which plants lack) are truly awake. The latter premise was grounded in the well-known distinction in *De anima* between vegetables as nutritive, animals as sensitive, and humans as rational. In shoring up these theoretical reflections, Aristotle made the further physiological point, with which most ancient and Renaissance authors agreed, that sleep was a paralysis of sorts that arose as hot vapours from food ascended to the brain where they were cooled. According to Aristotle's analysis, this is why meals induce slumber, and digestion is quicker and more complete during sleep. Importantly, the bond between food and sleep was thought to establish that sense perception was not only unnecessary for nutritive functions, but that wakefulness could positively hinder an essentially nutritive being.[11] Despite his explicit assertions, however, Aristotle was apt to connect vegetable life to sleep itself. He contended in *De generatione animalium*, for instance, that a potentially sensitive animal embryo exists in a manner 'resembling sleep – the sort of state that plants also are in; indeed the fact is that at this stage animals are living the life of a plant'.[12] In short, Aristotle held that it was incorrect to ascribe sleep to plants precisely because their permanent condition is akin to sleep.

In denying plants sensitivity, Aristotle was almost certainly reacting to his master Plato who notoriously endowed vegetables with a 'sensing-desiring' soul. As he articulated in *Timaeus*, plants do not share in 'reasoning and mind but in sensation, pleasant and painful, together with desire'.[13] One of

[9]See Horace Walpole to Henry Zouch, 3 January 1761, *The Letters and Papers of Sir John Hill, 1714-1775*, ed. by George Rousseau (New York: AMS Press, 1980), p. 122.
[10]Aristotle, *Parva naturalia*, 454b25-8. On Aristotle and sleep, the best study remains R.K. Sprague, 'Aristotle and the Metaphysics of Sleep', *The Review of Metaphysics*, 31, no. 2 (1977), 230–41.
[11]For a much fuller discussion, see Damian Murphy, 'Aristotle on Why Plants Cannot Perceive', *Oxford Studies in Ancient Philosophy*, 29 (2005), 295–339.
[12]Aristotle, *Generation of Animals*, 778b35-779a2.
[13]Plato, *Timaeus*, 77b. On Plato's rather ambiguous views about plants, see Amber Carpenter, 'Embodied Intelligent (?) Souls: Plants in Plato's *Timaeus*', *Phronesis*, 55, no. 4 (2010), 281–303.

the clearest expressions of opposition to Plato's idea that 'plants should know desire, if they ever have sleep and are aroused by awaking' can indeed be found in a treatise titled 'On Plants', which was included in the Aristotelian corpus, but was probably the handiwork of a first century BC Jewish historian and philosopher, Nicolaus of Damascus.[14] In spite of the general Aristotelian divergence from Plato on the status and attributes of vegetables, however, Aristotle did memorably profess in *Historia animalium* that 'Nature proceeds little by little from things lifeless to animal life in such a way that it is impossible to determine the exact line of demarcation'.[15] The implication in this passage – which sits uncomfortably with some of Aristotle's earlier and more schematic divisions – is that *some* plants might sense. As we will see, a considerable point of disagreement in later disputes was whether sleeping plants were sensitive outliers or non-sensitive species that were simply more ostentatious in how they manifested a universal and innocuous behaviour.

Even as Plato and Aristotle loomed large in subsequent discussions of plant sleep, eighteenth-century botanists most frequently harked back to the more concrete observations of their immediate precursors: Acosta, Alpini, and Ray. The first of these to touch on plant sleep was Acosta, whose incredibly popular 1578 *Tractado de las drogas, y medicinas de las Indias orientales* was swiftly translated into Latin (1582) and Italian (1585), and was widely venerated in the eighteenth century. In this tome, Acosta drew on Androsthenes of Thasos, an admiral of Alexander the Great, and Theophrastus, Aristotle's successor as head of the Lyceum, to make the general observation that the leaves of the tamarind gather and embrace their fruit during the night, but in the morning they greet the sun with open leaves.[16] It was left to Alpini, however, to itemize several genera in Egypt with species that behaved like the tamarind – including the *Acacia*, *Abrus*, *Chamaecrista*, and *Sesbania* – in his 1592 *De plantis Aegypti liber* (which was notably republished in Leiden in 1735). Alpini also hazarded the first explanation for this action when he suggested that God had designed plants to close their leaves as a means to safeguard their tender and essential parts (such as their flowers and fruits) from the dangers of the night.[17] He accordingly put a natural theological spin on Acosta's more utilitarian metaphor of the pod hugging itself for protection.

Not long after, Francis Bacon weighed in on the matter in *Sylva sylvarum* (posthumously published in 1626), noting that various species including some marigolds, wartwort, and mallow 'rejoice at the presence of the sun, and mourn at the absence thereof'. Even though he proceeded to offer the first account of this phenomenon based on efficient causation – namely, that plant sleep was brought

[14]Aristotle, *On Plants*, 815a25.
[15]Aristotle, *History of Animals*, 588b1-10.
[16]See Cristóbal Acosta, *Tractado de las drogas, y medicinas de las Indias orientales* (Burgos, 1578), pp. 66–72. For the ancient precedent, see Theophrastus, *Enquiry into Plants* (Cambridge, Mass.: Harvard University Press, 1990), IV.viii.8.
[17]See Prospero Alpini, *De plantis Aegypti liber* (Venice, 1592), p. 15.

about by 'a little loading of the Leaves, and swelling them at the bottom, with the moisture of the Air; whereas the dry Air doth extend them' – later botanists overlooked these passages probably due to their rather obscure, anthropocentric framing.[18] A number of naturalists did, however, begin to provide more comprehensive causal descriptions hard on the heels of Bacon. Shifting discussions from Africa to the Americas, the French physician and botanist Jacques-Philippe Cornut, for example, remarked in his 1635 *Canadensium Plantarum, aliarúmque nondum editarum historia* that the *Pseudoacacia americana* (or *Acacia americana robini*) seemed to sleep because heat activated the expansion and vaporization of its liquid parts while cooling caused their reduction and contraction.[19] In an endeavour to substantiate Cornut's point, Ray reproduced his experiment: he placed a bouquet of flowers in cold water, observed the petals close, and then watched them reopen when subsequently immersed in hot water.[20] Yet Ray was staunchly opposed to the proposition – embraced by contemporaries such as Henry Power and Thomas Browne – that plants were sensitive. In the considerably expanded 1688 edition of *Historia Plantarum*, he accordingly scoffed that Alpini's thesis that the tamarind covered itself for protection, as if in a blanket, 'smelled too strong of the miraculous'.[21] The stumbling block for Ray was that Alpini had failed to specify the added risk to vegetables after sunset. While it was understandable that flowers closed their petals as a barricade against strong winds – which Pliny the Elder had spotted and Linnaeus noted was a commonplace among Swedish farmers – postulating lack of light as the reason why leaves closed could be construed as a projection of the human fear of darkness onto plants.[22] A major dividing line in eighteenth-century debates about plant sleep was between those such as Linnaeus who sided with Alpini in holding that plants fold their leaves or petals for an identifiable purpose, and others like Hill who adopted Ray's scepticism towards such teleological accounts.

Whereas Acosta and Alpini had observed the sleep of plants in African specimens (and Cornut registered an American instance), Linnaeus's 1751 masterpiece *Philosophia Botanica* catalogued no less than forty-six species, many originating from Europe, that exposed and concealed their flowers at fixed intervals throughout the day, and listed the respective times at which this occurred.[23] Linnaeus in fact exhumed such a variety of sleeping species that he designed and hoped to construct in the Uppsala botanical garden a *horologium florae* or

[18]Francis Bacon, *Sylva sylvarum* (London, 1670), 103. On Bacon's views on this topic, see Charles Webster, 'The Recognition of Plant Sensitivity by English Botanists in the Seventeenth Century', *Isis*, 57, no. 1 (1966), 5–23 (pp. 10–11).

[19]See Jacques-Philippe Cornut, *Canadensium Plantarum, aliarúmque nondum editarum historia* (Paris, 1635), pp. 171–4.

[20]See John Ray, *Historia Plantarum* (London, 1686), p. 2.

[21]John Ray, *Historia Plantarum* (London, 1688): 'Folia Sole occidente ut in Acacia aliisque sese contrahere solent, eóque oriente aperire, ut tradit Alpinus. At verò fructum sive siliquam frigoris vitandi causà soliis sese involvere ut Alpinus & Acosta scribunt & miraculi loco habent, mihi cum *D. Syen* fabulam redolere videtur' (p. 1748).

[22]Pliny the Elder, *Natural History*, Book 18.79.365-6 and Carl Linnaeus, *Flora Lapponica* (Amsterdam, 1737), p. 222.

[23]*Philosophia Botanica*, pp. 273–4.

'flower clock' consisting of a circularly arranged sequence of flowers that would allow one to tell the time according to which petals were open.[24] Though Power had speculated as early as 1656, in a letter to the medic Reuben Robinson, that 'possiblely all plants wtever may have a Kind of Sense in them' that is just more easily 'discoverable in these Exotick plants, then in our own Domestick ones', Linnaeus's attention to inconspicuous instances of plant sleep in European gardens that botanists had overlooked owing to habituation directly challenged the association of plant sleep and sensitivity with the strange and foreign.[25] In this, he cleared a path for the sleep and even sensitivity of plants to be conceptualized as pedestrian, mechanical phenomena.

Building upon the research of his doctoral supervisor (Linnaeus), Bremer dedicated his 1755 University of Uppsala M.D thesis to *somnus plantarum*.[26] This text was a source of considerable interest both immediately following its publication and over the next century. Charles Darwin, for one, corresponded with W.T. Thiselton-Dyer and Joseph Dalton Hooker about this work in the 1870s, and even translated it into English when preparing his 1880 *The Movement of Plants*.[27] In the work itself, which notably opens by adumbrating similarities between plants and animals, Bremer described forty types of plants that sleep (chiefly of the 'diadelphia' class) and itemized them according to their particular motions. As he searched for a feature that united them, Bremer noticed that nocturnal changes most notably occur in plant species with pinnated leaves – or foliole on either side of a rachis – because these were flexible enough to assume different positions during the day and night. Outstripping the general proposition that certain plants cover their flowers for protection, Bremer and Linnaeus proceeded to specify that sleep occurs in some species to shield them from cold air, though they were careful to stipulate that, since such an action also transpired during the summer in warm climates, it could not be the only relevant factor.[28] Their more general point was that all creatures require rest, though, again, it was never specified why 'sleep' only appeared to affect certain plants.[29] These conundrums, along with the fact that Bremer and Linnaeus, as the first to explicitly label this long-observed phenomenon '*somnus plantarum*', posited a similar cause of sleep in plants and animals, are what chiefly spurred Hill to compose his treatise.

III. Hill's experiment

Hill's *The Sleep of Plants* is notably framed as a protracted epistle to Linnaeus, with whom he was in regular correspondence throughout his career, and to

[24] *Philosophia Botanica*, pp. 276–7.
[25] British Library, Sloane MS 1326, f. 13v.
[26] See Peter Bremer and Carl Linnaeus, *Somnus Plantarum in Dissertatione Academica* (Uppsala, 1755).
[27] See Cambridge University Library, DAR 209.14.
[28] *Somnus Plantarum*, pp. 10–11.
[29] *Somnus Plantarum*, p. 7.

whom he habitually sent copies of his works.[30] Having been an early English advocate of Linnaeus's binomial nomenclature, however, Hill had come to outspokenly criticize his 'artificial' categorization of plants according to the number and arrangement of their sexual organs, and especially the anthers. He noted in *The Sleep of Plants*, for instance, that if 'our opinions have differed, 'tis upon a single point; your arrangement of plants'.[31] The year earlier, in his 1756 *The British Herbal*, Hill had more fully outlined that 'Linneæus has united the greater part' of plants possessing multiple petals 'with many other plants not properly ally'd to them, under the denomination of *polyandria*; a class altogether artificial, having but a mistaken foundation in nature'.[32] Hill thus rejected Linnaeus's class of *polyandria*, which, culminating with 'twenty or more husbands in the same bed with one woman', had outraged some contemporaries who denied that God would have sanctioned such lascivious arrangements.[33]

In defiance of Linnaeus's scheme, Hill opted for the time-honoured categories of Theophrastus who had classified flowers in terms of their petals, and then further divided vegetables into herbs, shrubs, and trees.[34] He most fully articulated these ideas in his twenty-six-volume *The Vegetable System* (1759–1775), which was completed with the support of his longstanding patron John Stuart, Third Earl of Bute, and illustrates some 4,700 plant species while bestowing English names upon scores of foreign ones for the first time.[35] More generally, Hill had become something of an expert on Theophrastus's thought, having made his name with the first English translation of Theophrastus's *History of Stones* (1746) along with his three-volume *A General Natural History* (1748–52), which relied heavily not only on Theophrastus but also Dioscorides, Pliny, and Galen. In spite of Hill's Theophrastian challenges to Linnaeus, the two remained on friendly terms, and the eminent Swede even interceded with Gustav III to secure Hill the Royal Order of Vasa in 1774. In addressing *The Sleep of Plants* to Linnaeus, then, Hill not only sought to acknowledge his intellectual debts to the great naturalist, but also to endow his reflections on the subject with gravitas by signalling that they were part of an ongoing debate with the foremost botanist of his day.

[30]For an overview of Hill's relationship to Linnaeus, including a discussion of Linnaeus's apparently frosty reception of *The Sleep of Plants*, see George Rousseau, *The Notorious Sir John Hill: The Man Destroyed by Ambition in the Era of Celebrity* (Bethlehem, Pa.: Lehigh University Press, 2012), pp. 215–30.

[31]John Hill, *The Sleep of Plants, and the Cause of Motion in the Sensitive Plant* (London, 1757), p. 2.

[32]John Hill, *The British Herbal* (London, 1756), p. 1.

[33]On how Linnaeus used erotic language to promote his taxonomical system, see Müller-Wille, 'Linnaeus and the Love Lives of Plants'.

[34]For a fuller discussion of Hill's taxonomical contributions, see the chapters in *Fame & Fortune: Sir John Hill and London Life in the 1750s*, ed. by Clare Brant and George Rousseau (London: Palgrave Macmillan, 2018): Brent Elliott, 'Sir John Hill as Botanist: *The Vegetable System*', 267–90 and Sarah Easterby-Smith, 'John Hill, *Exotic Botany* and the Competitive World of Eighteenth-Century Horticulture', 291–314.

[35]For the background to this dispute between the 'natural' and 'artificial', the seminal paper is P.R. Sloan, 'John Locke, John Ray, and the Problem of Natural System', *Journal of the History of Biology*, 5, no. 1 (1972), 1–53, but also see Staffan Müller-Wille, 'Systems and How Linnaeus Looked at Them in Retrospect', *Annals of Science*, 70, no. 3 (2013), 305–17.

Whatever the rhetorical and commercial strategies at play in *The Sleep of Plants*, Hill rejected out of hand Linnaeus's suggestion (adapted from Alpini) that plants close their leaves or petals for protection. Indeed, he denied that Linnaeus had offered a mechanism for plant sleep at all, stating that the Swedish botanist's contribution was in tracing 'nature's steps, and recording those observations'. Outlining his own objective, he proceeded to state that to 'relate these facts is to give the history of nature: but there is something more within our reach. The human mind, daring, tho' weak, and inquisitive under all its limitations, seeks, (and sometimes not unhappily,) their causes'.[36] Hill, in other words, desired to go beyond what he considered to be the natural historical and develop a *causal* explanation for the observed phenomenon.

On an equally fundamental level, Hill worried that even Linnaeus's phrase 'plant sleep', which appropriated a term that had historically been applied exclusively to animals, would strike the 'judicious British eye' as highly 'affected, as well as improper'.[37] Reflecting Immanuel Kant's response to Johann Gottfried Herder in the 1770s, he contended that such attempts to analogically relate plant and animal behaviour would inevitably paper over substantial differences between them, and ultimately lead to a skewed understanding of both life forms.[38] To give some further context for Hill's position, he not only derided the euphemisms 'Animal Flower' or 'Flower Animal' as contradictory in his 1751 *Review of the Works of the Royal Society*, but he also sarcastically noted that if one were to lend 'Mr. *Baker*'

> a Microscope, and inform him of the Manner of using it, when he examined the Seed of the *Bidens*, we doubt not but he will be able to discover the Circulation of the Blood in the *Indian* Fig, and the tubular Cavities in the Filaments of the Muscles, and thus convince the Society of the perfect Analogy between these several Parts of the Creation.[39]

With this parody, Hill scoffed at Baker's fanciful use of optical devices to justify his projection of animal attributes onto vegetable life, as documented in works such as his best-selling 1742 *The Microscope Made Easy*. A similar disdain towards natural continuity and plant-animal analogies underpinned Hill's repudiation of the idea that certain plants found in the Caribbean gradually turn into insects – which naturalists including Emanuel Mendez da Costa and George Edwards had affirmed – and his refusal to admit that the Venus flytrap sustained

[36] *Sleep of Plants*, p. 6.
[37] *Sleep of Plants,* p. A7v.
[38] For an overview of the literature on the well-covered debate between Kant and Herder, see Dalia Nassar, 'Analogy, Natural History and the Philosophy of Nature: Kant, Herder and the Problem of Empirical Science', *Journal of the Philosophy of History*, 9, no. 2 (2015), 240–57. For the prominence of 'biological' analogies during the seventeenth and eighteenth centuries, see Ritterbush, *Overtures to Biology*, 61–70 and 109–57 along with comments throughout Delaporte, *Nature's Second Kingdom*.
[39] John Hill, *A Review of the Works of the Royal Society of London* (London, 1751), pp. 85–6. On Hill's *Review* more generally, see George Potter, 'The Significance to the History of English Natural Science of John Hill's *Review of the Works of the Royal Society*', *University of California Publications in English*, 14 (1943), 157–80.

itself on flies, which he maintained closed its leaves mechanically when triggered by an insect.[40]

While Hill's focus on differences between life forms barred him from summoning a universal principle akin to Bremer's and Linnaeus's proposal that all beings require rest, he went on to clarify that the only potential causes of plant sleep are the four 'natural agents' that 'come within contact of plants': namely, air, heat, light, and moisture. Having noted that 'experiments are the true test of reasoning', Hill specified that an experiment of the sort that he set out to conduct would be successful only when a single (or 'proper and particular') cause could be isolated, which, under artificial conditions, consistently instigated a deviation from typically observed behaviour.[41] He delineated from the outset of his book the criterion necessary to reach such a benchmark in the case of plant sleep, announcing that if he could incite the *Abrus precatorius* (or jequirity bean) to close its leaves 'at noon day, and open them again at pleasure, you will own, I know the principle of their change of position'.[42]

In setting up what was in fact a series of interconnected experiments, Hill initially sought to narrow the set of possible causes of plant sleep. To this end, he placed his *Abrus* in a stove, insulated from temperature variations and other external forces.[43] Since the plant opened and closed its leaves in normal cycles under these conditions, he inferred (contra Ray) that heat could not be the cause of plant sleep. He then watered one specimen heavily while leaving the other dry, and noted that both plants behaved as expected, which emboldened him to reject rain as the cause (contra Bacon). Having eliminated 'Two of the four natural agents' (fire and water) from his catalogue of potential causes, Hill ventured that air could be set aside as well because 'it is too universal and its changes too much'.[44] With that being said, he did not gainsay the conclusion of Bremer and Linnaeus outright, but rather allowed that since air is in 'a continual state of variation, its alterations are to be considered as possible subordinate causes'.[45] If there were occasional irregularities in the time that a plant opened or closed its leaves, Hill therefore conceded that air, and especially strong winds, could be partly to blame.

Proceeding to make a positive case, Hill isolated light (rather than mere heat) as the cause of plant sleep. To substantiate this hypothesis, he commenced a seven-day experimental cycle, which he allegedly ran on multiple occasions. On the first day, he exposed an *Abrus* in his study to moderate light, and observed that its leaves fell perpendicularly in the evening and remained close to their undersides throughout the night. Yet half an hour after dawn they

[40]See *Review of the Works of the Royal Society*, pp. 89–91 and John Hill, *A Decade of Curious and Elegant Trees and Plants* (London, 1773), pp. 19–20.
[41]*Sleep of Plants*, pp. 8 and 10–11.
[42]*Sleep of Plants*, p. 8.
[43]See *Sleep of Plants*, p. 13.
[44]*Sleep of Plants*, p. 14.
[45]*Sleep of Plants*, p. 10.

began to separate, and by a quarter of an hour they were horizontal, flat, and expanded.[46] All of this was consistent with Linnaeus's timetable for the *Abrus*. The next day, Hill relocated the plant to a less illuminated location, and the lobes did not rise as high and drooped earlier, while, on the third day, when he put the specimen in a sunlit room, the leaves attained their horizontal position earlier and closed later. He controlled the amount of light that the plant received for six consecutive days, and noted that the elevation of the lobes and the times of their opening and closing fluctuated accordingly. On the seventh day, Hill ran a more sophisticated test: he placed the *Abrus* on a sunlit bookshelf in the morning until it opened its lobes, but then closed the shelf doors and cut off its light. He returned a few hours later (in the early afternoon) to find the leaves drooping, as if it were midnight, but, upon reopening the doors, the lobes rapidly returned to an elevated position. These findings, then, not only cast doubt on the causes of plant sleep that his precursors had posited, but, at least implicitly, also seemed to call into question Linnaeus's observations of great regularity in the times that plants opened and closed their leaves throughout the year, since in Uppsala the hours and amount of sunlight varied tremendously according to the season.

Despite Hill's self-proclaimed impartiality, judicious relation of his methods, and detailed reporting of his observations, it is notable that a handful of botanists on the continent had made observations that did not straightforwardly tally with his own. The first and most remarkable of these came from the French astronomer Jean-Jacques d'Ortous de Mairan in 1729, but he was followed by the German botanist Johann Gottfried Zinn in 1758, and another Frenchman, Henri-Louis Duhamel du Monceau in 1759.[47] In complete opposition to Hill, Mairan had noted in his 1729 'Observation botanique', which Jean Marchant published in the 1731 volume of the *Histoire de l'Académie Royale des Sciences*, that the *Mimosa pudica* opened and closed its leaves even when shrouded in darkness for days on end. Given the discrepancies between Mairan's and Hill's results, we can only assume that either one of them performed a flawed experiment or that Hill's observations did not, as he confidently maintained, extend from the *Abrus* to all other plants that manifested similar behaviour. Whatever the case, clinging to causal precepts similar to Hill's led Mairan to contend that his plant must have been able to 'sense the sun without seeing it'.[48]

With his desire to locate a single cause that extended across plant species, Hill hypothesized even before he presented his findings that 'the position of the

[46] See *Sleep of Plants*, pp. 24–30.

[47] Johann Gottfried Zinn, *Von dem Schlaf der Pflanzen* (Hamburg, 1759), pp. 40–50 and Henri-Louis Duhamel du Monceau, *La physique des arbres: où il est traité de l'anatomie des plantes et de l'économie végétale* (Paris, 1759), p. 159.

[48] Jean Marchant, 'Observation botanique', in *Histoire de l'Académie royale des sciences avec les mémoires de mathématique et de physique* (Paris, 1731), p. 35. Contemporary botanists have taken significant interest in Mairan, though they have consistently misconstrued the conclusion of his experiments: see, for example, William J. Schwartz and Serge Daan, 'Origins: A Brief Account of the Ancestry of Circadian Biology', in *Biological Timekeeping: Clocks, Rhythms and Behaviour*, ed. by Vinod Kumar (New Delhi: Springer, 2017), pp. 3–22.

leaves of plants by light, is the result of a motion occasioned by its rays among their fibres'.[49] Outstripping his immediate observations, he thus ascribed the opening and closing of leaves to the interconnection between the structure of plant fibres and the force of sunrays, while holding (*à la* Bremer and Linnaeus) that this movement was most remarkable in species with supple, pinnated leaves. On Hill's account, daily sunlight could only stimulate leaf vibrations for so long, and, after these were 'extinguished, and lost', the leaves closed once again. Of a piece with his emphasis on experimentation as a means to uncover the immediate causes of observable effects, he accordingly explained his results by appealing to the elements, rather than more fundamental matter like atoms or spirits, and even characterized light in broadly Aristotelian terms as 'subtile, active, and penetrating: by the smallness of its constituent parts'.[50] While the strength of sunrays of course depends on factors such as proximity to the equator and altitude, it is notable that Hill did not so much foreground environmental considerations as physiological ones (like the density of fibre clusters) when making sense of why sleeping plants opened and closed their leaves at disparate times, sometimes well before sunset.

In developing his conception of the mechanism for plant sleep, Hill's inspiration was almost certainly Haller, his friend and long-time correspondent. Far from a one-sided relationship, this renowned professor expressed immense admiration for Hill's output (especially his early publications) and religiously acquired his botanical books, which he was 'by no means able to be without'.[51] Although Haller was more concerned with zoology than botany, his physiological (rather than natural historical) orientation prompted Hill, in turn, to style him 'the first Botanist of the world'.[52] In commending Haller as a botanical pioneer, Hill no doubt had at the forefront of his mind his concept of irritability, which was articulated most fully in his celebrated 1752 *De partibus sensilibus et irritabilibus*.[53] Earlier theorists of irritability such as the august English physician Francis Glisson, who penned the remarkable 1678 *Tractatus de natura substantiae energetica*, sought to establish a material principle of natural perception or vital reactivity that energized matter as such and could accordingly apply across life forms. By contrast, Haller rigorously distinguished the irritability that affected all living beings from the perceptivity and sensitivity that he deemed to be a function of animal nerves and responsible for sense impressions. This physiological point allowed him to prize mechanical plants apart from sentient animals without taking recourse in the language of

[49] *Sleep of Plants*, p. 18.
[50] *Sleep of Plants*, p. 18.
[51] Especially see Haller's letters to Johannes Gessner during the early 1750s: *The Letters and Papers of Sir John Hill*, pp. 36–9.
[52] *The Letters and Papers of Sir John Hill*, p. 138.
[53] On Haller and irritability, see Dominique Boury, 'Irritability and Sensibility: Key Concepts in Assessing the Medical Doctrines of Haller and Bordeu', *Science in Context* 21, no. 4 (2008), 521–35 and especially Hubert Steinke, *Irritating Experiments: Haller's Concept and the European Controversy on Irritability and Sensibility, 1750–90* (Amsterdam: Brill, 2005).

'souls'.[54] Since Haller mostly developed his theory through animal experimentation, Hill probably conceived of himself as building upon his findings by pinpointing a definite manifestation of irritability (as opposed to sensitivity) in vegetables.[55] With that said, Hill (even more than Haller) steered clear of the speculative questions that had fascinated Glisson and his generation, such as whether irritability is an immaterial force, a quality inherent in matter, or an energetic principle that God superadded to matter. While a good deal of scholarship on eighteenth-century natural philosophy prioritizes discussions of mechanical and vital matter, Hill and the preponderance of his fellow English botanists emphasized the dynamic between observed elements, their qualities, and anatomical parts.[56] For Hill, 'irritability' had explanatory power irrespective of its metaphysical status.

Hill's desire to avoid metaphysical speculations did not, however, extend to a rejection of generalizations as such. In seeking to corroborate Haller's conclusions, one of his main aims was in fact to show that *all* plants, including the famously responsive *Mimosa pudica*, were wholly bereft of sensitivity.[57] Earlier natural philosophers had periodically extolled sleeping plants for betraying that at least some vegetables possess basic sensitivity, as would Romantic poets such as Shelley in his 1820 'The Sensitive Plant'. But Hill concluded, on the contrary, that 'the sleeping and the sensitive plants are naturally allied' insofar as 'their motions, tho' differently brought on, are dependent on the same principle' (light inciting non-sensitive irritability).[58] Shoring up this point, he confirmed that during 'the night the sensitive plant is not capable of the common motion on the touch', which means that light rather than touch had to be the principal cause of its motion.[59] He concluded *The Sleep of Plants* with the further abstraction that 'on a strict and close examination, I have not found any plant or tree wholly unaffected' by 'sleep'.[60] During the

[54]For how Haller adapted and eventually displaced Glisson's ideas, see Guido Giglioni, 'What Ever Happened to Francis Glisson? Albrecht Haller and the Fate of Eighteenth-Century Irritability', *Science in Context*, 21, no. 4 (2008), 465–93.

[55]But on Haller's interest in botany, see Luc Lienhard, '"La machine botanique": Zur Entstehung von Hallers Flora der Schweiz', in *Hallers Netz. Ein Europäischer Gelehrtenbriefwechsel zur Zeit der Aufklärung*, ed. by Martin Stuber, Stefan Hächler, and Luc Lienhard (Basel: Schwabe, 2005), pp. 371–410 and Jean-Marc Drouin and Luc Lienhard, 'Botanik', in *Albrecht von Haller. Leben—Werk—Epoche*, ed. by Hubert Steinke and Urs Boschung (Göttingen: Wallstein, 2008), ,pp. 292–324. For wider discussions of plant irritability from around this time, see Delaporte, *Nature's Second Kingdom*, pp. 149–86.

[56]The seminal texts are Lester S. King, 'Stahl and Hoffmann: A Study in Eighteenth-Century Animism', *Journal of the History of Medicine*, 19, no. 2 (1964), 118–30; Theodore M. Brown, 'From Mechanism to Vitalism in Eighteenth-Century English Physiology', *Journal of the History of Biology*, 7, no. 2 (1974), 179–216; and John Yolton, *Thinking Matter: Materialism in Eighteenth-Century Britain* (Minneapolis: University of Minnesota Press, 1983). More recently, Charles Wolfe has written essays such as 'Vitalism and the Resistance to Experimentation on Life in the Eighteenth Century', *Journal of the History of Biology*, 46, no. 2 (2013), 255–82 and 'Sensibility as Vital Force or as Property of Matter in Mid-Eighteenth-Century Debates', in *The Discourse of Sensibility: The Knowing Body in the Enlightenment*, ed. by Henry Martyn Lloyd (New York: Springer, 2013), pp. 147–70.

[57]On the relationship between 'sleeping' and 'sensitive' plants, along with broader attitudes towards the *Mimosa pudica* at this time, the best study is now Guido Giglioni, 'Touch Me Not: Sense and Sensibility in Early Modern Botany', *Early Science and Medicine*, 23, no. 5–6 (2018), 420–43. Also see Robert Maniquis, 'The Puzzling "Mimosa": Sensitivity and Plant Symbols in Romanticism', *Studies in Romanticism*, 8, no. 3 (1969), 129–55.

[58]*Sleep of Plants*, p. 7.

[59]*Sleep of Plants*, p. 37.

latter half of the seventeenth century – following the discovery of the *Mimosa* and with the proliferation of vital matter theories – unprecedented attention was paid to sensitive plants, and physicians and natural philosophers of all stripes openly speculated that vegetables in general might enjoy a primordial sensitivity.[61] Power, for example, reiterated in a 1659 letter to Browne 'that all plants may not only have a transpiration of particles, but a sensation like animals', which was a point to which the latter could easily acquiesce.[62] Under the sway of William Harvey, Margaret Cavendish went so far as to ask in 1655 why 'may not *Vegetables* have *Light, Sound, Taste, Touch,* as well as *Animals,* if the same *kinde* of *motion* moves the same kinde of *matter* in them?'.[63] In accordance with his ultimate aim to strictly distinguish between life forms, Hill put these bold claims about plant sensitivity to the test, and found them wanting, even if he was similarly unable to resist making generalizations about vegetable life.

IV. Responses to Hill

In the succeeding years, Hill's publication ignited a fierce debate around the Royal Society not only about plant sleep and how to explain it, but also about what characterized a valid experiment.[64] Hill's most vehement antagonists in these skirmishes were Baker and Browning. While these two had corresponded on topics ranging from the effects of electricity on vegetables to dwarfs, the most relevant epistle is a lengthy, unpublished one from 10 July 1758, now located in the Osborn Collection at Yale University, in which Baker directly responded to Browning's description of his unsuccessful attempt to replicate Hill's experiment.[65] The backdrop to this exchange is a long and rocky personal history between Baker and Hill. During the 1740s, Baker recognized Hill's acumen as a naturalist and invited him to speak at the Royal Society's weekly meeting on numerous occasions while vigorously promoting his nomination as a fellow. But, when this failed, Hill's frustration with the Society mounted, and he

[60] *Sleep of Plants*, p. 48.
[61] For a fuller discussion, see Webster, 'The Recognition of Plant Sensitivity'.
[62] Henry Power to Thomas Brown, *Works of Sir Thomas Browne*, ed. by Geoffrey Keynes (London, 1928-31), Vol. 6, p. 291.
[63] *Philosophical and Physical Opinions*, 23. See Justin Begley, '"The minde is matter moved": Nehemiah Grew on Margaret Cavendish', *Intellectual History Review*, 27, no. 4 (2017), 493–514.
[64] While this article focusses on the responses of fellow naturalists, his paper was also reviewed in literary journals, which emphasized the sometimes-overblown tone of his piece: see George Tobias Smollett (ed.), 'Art. IX. The Sleep of Plants Explained, by Dr. Hill', *The Critical Review, or, Annals of Literature*, 4 (1757), 227–30 and Ralph Griffiths (ed.), 'Hill on the Sleep of Plants', *Monthly Review, or, Literary Journal*, 17 (1757), 330–6.
[65] See 'Part of a Letter from Mr. John Browning, of Bristol, to Mr. Henry Baker, Concerning the Effect of Electricity on Vegetables', *Philosophical Transactions*, 44 (1746), 373–5 and 'Extract of a Letter from John Browning; Of Barton-Hill Near Bristol, to Mr. Henry Baker, Concerning a Dwarf', *Philosophical Transactions*, 47 (1751), 278–81. Evidence for Browning's activities is rather sparse, but see his correspondence with Emanuel Mendez da Costa on the nature of fossils found in Dudley, Staffordshire in British Library, Add MS 28535, ff. 193r-95r. While Baker's epistle to Browning on Hill is absent from Rousseau's *The Letters and Papers of Sir John Hill*, it is a powerful source for understanding the way in which Hill's contemporaries engaged with his ideas; Rousseau has more recently mentioned these letters in *The Notorious Sir John Hill*, pp. 210–11.

eventually accused Baker of pilfering his ideas in his 1750 *Dissertation on Royal Societies*. He also scornfully labelled him the 'Prince of Societarians' and (as noted) condemned him in his *Review*, not least for depicting 'Matters of no Consequence' with 'amazing Nicety' at the expense of weightier subjects.[66] In the wake of these charges, Baker cut all ties with Hill, as he proudly remarked in the epistle to Browning.[67] Although Browning does not appear to have had any personal dealings with Hill, he was Baker's long-time friend.

It is impossible to say whether Hill anticipated that others would actually replicate his experiment, but he boldly asserted in *The Sleep of Plants* that 'the Curious who shall chuse to repeat the experiments mention'd in the preceding pages, may find no difficulty in that respect', and proceeded to provide 'the particulars of the plants, and apparatus' that he employed, going so far as to convey where he purchased his exact specimens.[68] Despite the far-reaching conclusions that he drew from his results, these details suggest his awareness that any deviation from the specificities of his trial might yield competing outcomes. It is therefore unsurprising that when Browning tried to replicate the experiment with various sleeping plants including the *Abrus* he discovered, contrary to Hill, 'that the same Plants open or awake again tho' kept in Darkness, and consequently that Light is not the only Cause, or indeed at such Times at all the Cause of such their opening'.[69] While Browning's observations chimed with Mairan's rather than Hill's, Mairan had supposed that flaws in his experimental setup enabled the plants to sense sunlight, whereas Browning insinuated that Hill had gone out of his way to shore up his hypothesis and perhaps even fabricated his results. Predisposed to prefer Browning's testimony, Baker gleefully declared that Hill 'must have been a very careless Observer not to have seen these Plants open themselves in Darkness, or a very unfair One not to have acknowledged it'.[70] As this episode indicates, debates over experimental findings could easily to tailspin into battles over testimony.

Beyond any personal disdain for Hill, it has already been intimated that Baker was inclined to resist his broader point about the fundamental differences between life forms, and he thus preferred to think that the same mechanism might induce sleep in plants and animals.[71] As he wittily remarked, if one were to transfer

[66] *Review of the Works of the Royal Society*, p. 89. For a broader look at Hill's criticism of the Society, see Kevin Fraser, 'John Hill and the Royal Society in the Eighteenth Century', *Notes and Records of the Royal Society of London*, 48, no. 1 (1994), 43–67 and Clark Emery, '"Sir" John Hill Versus the Royal Society', *Isis*, 34, no. 1 (1942), 16–20. For Baker's expressions of contempt for Hill after 1750, see *The Letters and Papers of Sir John Hill*, pp. 40–4, pp. 46–7, and p. 49.
[67] See Yale University, Beinecke Rare Book and Manuscript Library, Osborn fc109 ½, f. 6.
[68] *Sleep of Plants*, pp. 48–9.
[69] Osborn fc109 ½, f. 3.
[70] Osborn fc109 ½, f. 3.
[71] See Henry Baker, *An Attempt Towards a Natural History of the Polype* (London, 1743) and 'An Account of the Sea Polypus', *Philosophical Transactions*, 50, no. 2 (1757-8), 777–86.

> a Man awake, on a Dowry Couch, into a Place of Darkness and leave him there some Hours, 'tis then probable he will be found with his Eyes closed, his Arms hanging, and his Head reclined. After some Hours more, tis no less probable he will awake, whether he remains in Darkness or be carried into [^the] Light Is not this the very Case of your sleeping Plants?[72]

Baker's point was that even if Hill had obtained the experimental findings that he recorded, they did not prove that plants lacked sentience, for a similar result (and Browning's exact one) would be expected with sentient beings as sophisticated as humans. In this sense, Baker concurred with Hill's general notion that sleep was brought about by an external force, but he was happy to extend this from plants to all life forms in a manner that resonates with Aristotle's representation of sleep as an impulse that overtakes animal bodies like a seizure. Along with 'moisture' and 'silence', Aristotle had indeed considered absence of light to account for why humans and the vast majority of large animals sleep at night.[73] In line with a longstanding tradition that couched sleep *tout court* as involuntary, Baker and Browning nonchalantly affirmed that this naturally applied to plants, rendering Hill's conclusions unremarkable and certainly insufficient to sever plants from more overtly sensitive beings.

For his part, Baker repeated over the course of the letter that one should carefully observe diverse specimens without making universal proclamations or positing causal explanations. Regarding the mechanisms behind sleep as exceptionally complex, he insisted that even the most talented natural philosopher or physician was incapable of determining 'by what Arrangement of Fibres or Muscles, by what motion of the Blood or nervous Spirits, or by what other Cause' sleep is induced in humans. More generally, Baker was sceptical about the possibility of reaching causal knowledge, having written in his 1753 *Employment of the Microscope*, for instance, that we 'are able to see Effects, though their Causes are beyond our Knowledge'. Because he supposed that understanding the causes of 'the mechanical Operations' of natural bodies was usually outside the ken of human intelligence, he concluded on the theological note that 'we should raise our Contemplations and Adoration to that Eternal, Omnipotent, Supreme First Cause' and marvel in the mysteries of creation.[74] Aware that physiologically-attuned botanists typically viewed plants in light of the more easily observable structures and functions of larger beings, Baker went on to note in his letter that 'surely we know more of the Human Body and of what passes within ourselves than we can possibly do of Plants'.[75] If one *were*, then, to pursue causal knowledge, Baker held that it was better to at least begin with the simpler task of seeking to comprehend the cause of sleep in humans before turning to less

[72]Osborn fc109 ½, f. 4.
[73]See Karl H. Dannenfeldt, 'Sleep: Theory and Practice in the Late Renaissance', *Journal of the History of Medicine and Allied Sciences*, 41, no. 4 (1986), 415-41 (p. 418 and p. 424).
[74]Henry Baker, *Employment for the Microscope in Two Parts* (London, 1753), pp. 48–9.
[75]Osborn fc109 ½, ff. 5-6.

well-known beings further down the scale of nature. By contrast, Hill aimed to establish that anatomical and physiological discrepancies rendered comparative approaches in the round of minimal utility. When it came to questions about both the possibility of causal knowledge and the utility of comparative approaches, Baker and Hill were talking past one another once again.

The other major Royal Society member to engage with Hill on the topic of plant sleep was Pulteney, who had long been a champion of regional and national botany, and later penned the first *Historical and Biographical Sketches of the Progress of Botany in England* (1790). The occasion for his correspondence with Hill was a paper that William Watson read before the Society in January 1758 on Pulteney's behalf, which was published soon after in the *Philosophical Transactions* as 'Some Observations Upon the Sleep of Plants'. Gripped by Linnaeus's taxonomical spirit while embracing aspects of Hill's explanation and critiquing others, Pulteney's main contribution to the discussion of plant sleep was to catalogue additional English species that 'remarkably displayed' this behaviour including two that Linnaeus had overlooked: the 'common kidney-bean' (*Phaseolus vulgaris*) and 'clover-grass' (*Trifolium repens*). While Linnaeus was the first to itemize sleeping plants systematically, Pulteney noted that English commoners had long been acquainted with this phenomenon and that even the vernacular name of one species (the *Tragopogon luteum*) reflected its sleeping patterns: 'John-go-to-bed-at-noon'.[76] Not only did the very existence of this plant seem to undercut Hill's hypothesis, but it also allowed Pulteney to intimate that even a farmer could disprove his causal account. More generally, Pulteney's paper suggests that even if natural historians refused to hypothesize, they could easily complicate the conclusions derived from experiments simply by gathering fresh data.

As one might expect from Pulteney's natural historical rather than experimental orientation, he did not actively seek a general, causal explanation for the actions of sleeping or sensitive plants. Instead, he catalogued differences between species, observing that some never seem to close their leaves, others shut them in the evening or during the night and open them in the morning (such as the *Abrus*), while a last set (which includes the *Tragopogon*) open and close their leaves at hours that are unrelated to normal human sleep patterns.[77] Though Hill's experiments with the *Abrus* bolstered his premise, Linnaeus had already pointed out (and Pulteney confirmed) that numerous species beyond the *Tragopogon* – including certain flowers in the *Primulaceae* family, the *Convolvulus sabatius*, and the *Lessingia arachnoidea* – likewise closed their leaves in the early afternoon.[78] Being diplomatic, Pulteney proposed

[76]Richard Pulteney, 'Some Observations Upon the Sleep of Plants; And an Account of That Faculty, Which Linnaeus Calls Vigiliae Florum', *Philosophical Transactions*, 50 (1757), 506–17 (p. 508).
[77]Pulteney, 'Some Observations', p. 508.
[78]Pulteney, 'Some Observations', pp. 509–10.

in his epistle that the cause and duration of sleep might differ across plant species, just as Hill had supposed that it varied across kingdoms. Yet Hill's desire to uncover one cause and to slot as many vegetables as possible into a bounded kingdom led him to overlook this suggestion in his response. Pulteney further noted that because Linnaeus recorded the 'bedtimes' of relevant specimens 'in the academical garden at Upsal', those who repeated 'them in this country will never probably find' the same results, since 'the difference of climate will occasion a variation in point of time'.[79] Similar to Baker, Pulteney intimated that Hill's neglect of natural historical surveys in *The Sleep of Plants* and his desire to pin down a single cause rather than various secondary ones drove him to unjustifiably extrapolate from experiments with an individual species to all sleeping plants. Along with doubting that sunlight alone induced sleep, Pulteney made the point that climate-related factors might, taken together, considerably impact the times at which a plant sleeps and awakes, which was an implicit explanation for why Hill's experiment could not account for the regularity that Linnaeus had observed in the sleeping specimens that he studied throughout the year in Sweden. With his emphasis on controlled experiments, however, it was only natural for Hill to downplay the potential for regional variations.

Despite quibbling with some of his conclusions and promoting a different approach to the study of plants, Pulteney was far more sympathetic towards Hill than Baker or Browning, and announced in a 1758 epistle to Hill that he had 'long been the object of my Admiration'.[80] When it came to Hill's particular conclusion that all plants slept, Pulteney generously forecasted that 'future observation will very probably confirm Dr. Hill's sentiment, that no "plant or tree is wholly unaffected"' by the phenomenon.[81] Hence the renowned physician, antiquarian, and clergyman, William Stukeley, noted a few days after hearing Pulteney's paper that it 'commends Dr Hill very much'.[82] Pulteney's praise of Hill is also apparent from the manuscript copy of his speech in the British Library, which states that.

> The Revival of the Subject [of plant sleep] has led the way to an Explanation of its cause: This Linnæus had left untouched. The Honour of this discovery is due to our own Countryman D^r. Hill, and his ingenious and elegant Explanation of it demands applause. Every acquisition of knowledge in this way should be steadily pursued. The Oeconomy of nature is ever worth of our regard, and every step gained in the Investigation of her principles may lead the way to great, though at present latent, usefullness.[83]

[79]Pulteney, 'Some Observations', p. 509.
[80]*The Letters and Papers of Sir John Hill*, p. 80.
[81]Pulteney, 'Some Observations', p. 507.
[82]See Bodleian, MS Eng. misc. e 137, ff. 66-67.
[83]See British Library, Add MS 4440, ff. 33v-37v (f. 34v).

In contrast to Browning and Baker, Pulteney recognized that Hill's boldness was likely to spur on future investigations and Hill, in his turn, thanked Pulteney 'for the mention you have made of me in a Paper on the Sleep of Plants, which was read at the Royal Society with great applause'.[84] The manuscript of the speech is virtually identical to the paper published in the *Transactions*. But Pulteney's commendation of Hill – which immediately follows his eulogy to Linnaeus, and should appear on page 57 of the volume – has been bracketed in the manuscript and dropped from the published piece. While this could have been an authorial decision, the fact that Pulteney's presentation openly lauded Hill strongly suggests that the young naturalist was under institutional pressure to bowdlerize his acclamations for this now derided figure.

If this is the case, the incident in question presents a direct challenge to some recent claims that the 1752 editorial reform of the *Philosophical Transactions* precipitated a transition from 'censorship' to 'peer-review'.[85] Indeed, it is a cruel irony that Hill's forceful attacks on the *Transactions* in his *Review* were a proximate cause for introducing committee voting into the editorial process, which in turn seems to have guaranteed that some of his natural philosophical contributions were blotted out of the public record.[86] Whatever Hill's intellectual and social missteps, the manuscript of Pulteney's paper, along with Browning's replication of his experiment, offer further evidence that his contemporaries took him seriously, and indicate that the still prevailing image of Hill as a zealous amateur rather than a serious natural philosopher is partially the consequence of coordinated erasure.

V. Conclusion

In the late seventeenth-century, many Royal Society affiliates found inspiration in Bacon's famous dictum from his 1620 *Instauratio Magna* that 'natural and experimental history' was the only 'thing needful for laying the foundations of a true and active philosophy'.[87] Upholding this principle as an end in itself, Joseph Glanvill exclaimed in a 1667 letter to Cavendish that 'to make *Hypotheses*' must 'be the happy priviledge of succeeding Ages; when they shall have gained a larger account of the *Phoenomena*' through dutiful natural historical spadework.[88] But, in practice, Glanvill and most active Society associates of his day willingly formulated hypotheses before carrying out experiments,

[84]See *The Letters and Papers of Sir John Hill*, pp. 79–80.
[85]For such a narrative, see Mario Biagioli, 'From Book Censorship to Academic Peer Review', *Emergences: Journal for the Study of Media & Composite Cultures*, 12, no. 1 (2002), 11–45 and Noah Moxham, 'Fit for Print: Developing an Institutional Model of Scientific Periodical Publishing in England, 1665-ca. 1714', *Notes and Records of the Royal Society*, 69, no. 3 (2015), 241–60.
[86]See Noah Moxham and Aileen Fyfe, 'The Royal Society and the Prehistory of Peer Review, 1665–1965', *The Historical Journal*, 61, no. 4 (2018), 863–89 (especially pp. 870-1).
[87]Francis Bacon, *The Instauratio Magna Part II: Novum Organum and Associated Texts*, ed. by Graham Rees and Maria Wakely (Oxford: Oxford University Press, 2004), p. 453.
[88]William Cavendish and Margaret Cavendish, *A Collection of Letters and Poems* (London, 1678), pp. 124–5.

which they then extrapolated from in their efforts to understand the functions of natural bodies.[89] While Hill operated from this latter orientation, Baker, by contrast, was far more apt to take the rhetoric of early Royal Society propagandists at face value. In keeping with his general scepticism towards causal explanations, Baker advised Browning to be 'content with the Honour of discovering a real Fact, without perplexing yourself with Steams or vibrating Fibres' such as those that Hill posited to explain plant sleep. He went on to proudly announce that

> What we collect from the Information of our Senses may be called Knowledge, what from Matters our senses cannot examine, however we may flatter [^ourselves] is merely the Work of Fancy, which presents a more or less ingenious Fancy or Romance according to the strength of the Inventive Faculties and this wants no Proof so long as the Epicurean, the Cartesian, and many other Systems of Philosophy shall be remembered. For my own Part, Nullius in Verba is the Motto of the Royal Society.[90]

Whereas Hill had mocked Baker for his fixation with natural particulars and his emphasis on plant-animal analogies, Baker branded Hill as a speculative thinker who outstripped his immediate observations and posited causes that bolstered his preconceived hypotheses and his broader understanding of the relationship between life forms. Baker's words resound with Robert Boyle's assertion almost a century earlier in his 1661 *Certain Physiological Essays* that Gresham College had already 'produc'd Inventions of greater use to Mankind, than were ever made by *Leucippus,* or *Epicurus,* or *Aristotle,* or *Telesius,* or *Campanella,* or perhaps any of the speculative Devisers of new Hypotheses'.[91] But whereas Boyle's work offers a robust defence of experimentation (despite noting problems associated with replication) and uses experiments on colour and nitre to defend causal accounts and the atomic hypothesis, Baker aligned experiments that sought knowledge of underlying causes, which could only ever be inferred, with the 'romances' of ancient philosophers and their modern advocates and critics, even in cases such as Hill's where no speculative systems or imperceptible substances were summoned at all. As Baker saw it, extrapolations to causes were unnecessary because observations, devoid of interpretation, amounted to knowledge.

Unlike during the prior epoch, Baker's ideal largely reflected the reality of the mid-eighteenth-century Royal Society. The shift in the character of the institution after Isaac Newton's death in 1727 is encapsulated in the preoccupations of the successive presidents: Hans Sloane prioritized collecting and natural history, while Martin Folkes dropped his early concern with mixed mathematics

[89]For a tempered take on the role of experimentation around the Royal Society in the late seventeenth century, see Mordechai Feingold, '"Experimental Philosophy": Invention and Rebirth of a Seventeenth-Century Concept', *Early Science and Medicine*, 21, no. 1 (2016), 1–28.
[90]Osborn fc109 ½, f. 4.
[91]Robert Boyle, *Certain Physiological Essays and Other Tracts Written at Distant Times* (London, 1661), p. 25.

in favour of antiquities. As Richard Sorrenson established in a quantitative study of the *Philosophical Transactions* over a fifty-year period, the journal's natural historical output peaked in the 1750s (with 268 papers deploying this approach, up from 86 in the 1720s), whereas experimental pursuits, and especially those related to anatomy and physiology, plummeted as a proportion of total articles (with 51 experimental papers and 24 anatomical ones).[92] Hill even noted in the preface to his *Review* that because Society meetings revolved around natural historical 'trifles', 'the Opportunities of Experimenting have long brought a select Set of the Members once a Week' to his own house.[93] Under these circumstances, it is no wonder that talks of a merger with the Society of Antiquaries were incessant from the 1730s to the 1750s.[94] While Hill came closest to Hales in deploying an experimental approach to draw conclusions about the discontinuity between plants and animals, by the time that Hill came onto the scene even Hales was principally focussing his energies on parish duties and practical exploits such as finding more efficient modes of food preservation.[95] Far from defining mid-eighteenth-century philosophical inquiries, the speculative/experimental split became virtually non-existent as these approaches, insofar as they sought causal knowledge, became associated and then sidelined.

As George Rousseau has established, social issues including Hill's irascibility, ineptitude at networking, and readiness to lampoon the *Transactions* and prominent Society members undeniably contributed to his failure to integrate himself into the institution or have his results accepted among powerful affiliates.[96] But this article has suggested that there is another germane, more intellectual, and hitherto less appreciated reason for Hill's exclusion: his methods were out of step with the move towards observation and collection as ends in themselves. It is notable on this score that Browning refrained from publishing the results of his experiments on plant sleep in the *Transactions* or elsewhere – which would undoubtedly have been interpreted as taking Hill overly seriously – and even Pulteney was satisfied with building upon Linnaeus's catalogue despite his admiration for Hill's work. As the episode in question underscores, experiments were far more likely than natural descriptions to erode consensus thanks to the difficulty of replication and the tricky nature of the causal questions that they raised. While socially disadvantageous, Hill's intransigence ultimately drove him to remain more in step with the Royal

[92]Richard Sorrenson, 'Towards a History of the Royal Society in the Eighteenth Century', *Notes and Records of the Royal Society of London*, 50, no. 1 (1996), 29–46 (p. 36).
[93]*Review of the Works of the Royal Society*, p. v.
[94]On the proposed merger of Royal Society with the Society of Antiquaries, see George Rousseau and David Haycock, 'Voices Calling for Reform: The Royal Society in The Mid-Eighteenth Century – Martin Folkes, John Hill, and William Stukeley', *History of Science*, 37, no. 4 (1999), 377–406. The best study of the antiquarian interests around the Royal Society at this time remains Joseph Levine, *Dr. Woodward's Shield: History, Science, and Satire in Augustan England* (Berkeley: University of California Press, 1977).
[95]While Hales is unfortunately understudied, the most significant studies are Anna Marie Roos, *The Salt of the Earth: Natural Philosophy, Medicine, and Chymistry in England, 1650–1750* (Leiden: Brill, 2007), pp. 195–206 and Gibson, *Animal, Vegetable, Mineral?*, pp. 154–50.
[96]See Rousseau, *The Notorious Sir John Hill*, especially pp. 31–64.

Society's stated objective to disseminate 'experimental learning' than many active members of his day.[97]

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[97]See Thomas Birch, *History of the Royal Society* (London, 1756), Vol. 1, p. 3.