D esigned to protect and propagate exotic plants collected from around the globe, the nineteenth-century glasshouse was a topos for environmental concerns. As a setting for atmospheric and physiological experimentation, and a site where the natural and mechanical converged, glasshouse culture thrust gardening to the forefront of scientific discourse as horticulturists attempted to renew nature by constructing artificial climates inside glass buildings. While historians have often pointed to the confluence of glasshouse horticulture with the rise of environmental thought in building practices, the question of how and why these transfers took place is not well understood. To address this gap in scholarship, in this article I examine how gardening informed architectural production in nineteenth-century England by helping to transmit Victorian science into building culture. I explore how gardening periodicals and books served as vehicles for environmental and scientific thought spanning numerous disciplines and how, through this popular literature, “artificial climates” made by horticulturists were reinscribed in debates over human health and transformed into “medical climates” in architecture. By helping to bridge these disciplinary boundaries, I argue, the glasshouse played a key role in the emergence of an environmental paradigm in architecture by crossbreeding building practices with scientific knowledge and illustrating how mechanical solutions could be applied to living problems.

Located at the intersection of architecture and landscape design, the glasshouse has been treated extensively by historians of both disciplines. Horticultural glasshouses are often cited as evidence of how technical refinements took place in nineteenth-century architecture through the use of modular construction and the expressive use of glass and iron. Further, they are frequently regarded as a locus for environmental concerns owing to the specific challenges of keeping tropical plants. Similarly, historians of environmental building systems regard the glasshouse as a crucial laboratory where methods of ventilating and heating buildings using steam, water, and air were developed before being adapted for use in buildings to solve issues of human comfort and health. By pursuing the idea that the glasshouse informed architecture through a series of demonstrative building projects, however, historians have overlooked how other, regular points of contact were established at the interface of architecture and horticulture during the first half of the nineteenth century, and how the natural sciences functioned as a key intermediary in exchanges between them. In light of a growing interest in the interpenetration of design history with the history of science and technology, the transdisciplinary character of glasshouse culture makes it an ideal subject for further study. Glasshouses served as sites where nature was subjected to the laws of reason and where foreign bodies and climates were domesticated on English soil, the complexities of which press us to reconsider how cultural and technological transfers were received in architecture as a burgeoning environmental awareness transformed building practices during the Age of Empire.

Scientific Gardening

Horticulture was a modernizing force in early nineteenth-century England as the country sought to improve its agricultural methods and increase domestic production. Stimulated by the Revolutionary and Napoleonic Wars, which resulted in economic warfare with France, the British Parliament enacted enclosures around the turn of the century in an effort to promote innovation in farming by converting common
land into agricultural uses. In the aftermath of these major conflicts, horticulture and botany became a veritable craze among Britain’s middle class, as avid plant collectors accelerated their global search for new specimens, ranging as far as the subtropics and the subarctic to Himalayan peaks (Figure 1). Ornamental and exotic plants proliferated in England over the ensuing decades, revolutionizing the theory and practice of gardening and inspiring many innovative practices.

Beginning in the 1820s and extending into the 1830s, improvements and innovations in printing enabled the proliferation of scientific books and periodicals across Britain. The periodical press soon became the principal vehicle through which scientific knowledge was shared, transforming science into a lucrative publishing venture and a popular pastime among middle- and working-class audiences. At the forefront of this popular press were books and magazines on horticulture, floriculture, and botany that appealed to amateur naturalists and professional scientists alike. Along with journals in other leading fields in the natural sciences, like chemistry and medicine, gardening periodicals helped to satisfy a voracious appetite for reading among Britons who saw the study of plants as both a scientific pursuit and a moralizing force. Gardening and plant collecting were discussed everywhere, from the country estates of British gentry to middle-class homes and working-class pubs. Not only was a scientific knowledge of plants considered proper for educated gentlemen and women, but also gardening was linked by social reformers to moral and physical rectitude and prescribed as a remedy for the idleness and vice that they feared might tempt the working class. In the popular gardening press, gardeners who applied horticultural and botanical knowledge to landscape practices became known as “scientific gardeners.” These scientific sensibilities also influenced new approaches to the creation of productive and pleasurable landscapes. A surge of periodicals and books appeared in which the latest trends and innovations in gardening were discussed and an aesthetic approach to scientific gardening was codified by landscape theorists.

Editor of five periodicals and author of more than thirty books on subjects ranging from the native trees and shrubs of Britain to rural architecture, Scottish-born agriculturalist and landscape gardener John Claudius Loudon (1783–1843) was seminal to the development and interpretation of the Victorian landscape. Having published a treatise on the construction of hothouses in 1805, followed by his enormously popular Encyclopaedia of Gardening in 1822 and the equally voluminous Encyclopaedia of Agriculture in 1825, Loudon founded the first English periodical devoted entirely to horticulture in 1826. As editor of the Gardener’s Magazine from 1826 to 1843, he quickly became one of the most influential scientific gardeners of his time. Eager to condone new horticultural practices and
incorporate them into a unified landscape aesthetic, Loudon called his approach “gartneresque.”16 Unlike followers of the picturesque, who believed that grouping exotics broke with the character of the surrounding British landscape and was a sign of vanity, Loudon prescribed formal arrangements of flowers and shrubs in taxonomic groupings and recast the British landscape as an amalgam of scientific inquiry and nature (Figure 2).17

Loudon openly criticized his predecessors, such as the Reverend William Gilpin and other picturesque theorists who disapproved of exotic displays, for having “lost sight of the beauties of high polish, neatness, cultivation, agriculture, architecture, arboriculture, and other kinds far more important to society, and affording much greater evidence of civilisation, comfort, and the general diffusion of human happiness, than mere picturesque beauty.”18 Rather, Loudon assured his readers, “much of the gardening and botanical interest of all pleasure-grounds consists in the exotic trees and shrubs which they contain.”19 Writing under the pseudonym Scientiae et Justitiae Amator, he promoted the scientific study of gardening and botany, especially by young people and members of the working class. As a popular forum for all matters related to gardening—from horticulture and botany to chemistry, meteorology, and engineering—the Gardener’s Magazine helped link gardening to a wide range of scientific disciplines by announcing new developments in the natural and mechanical sciences and speculating on their relevance to landscape practices.20

Loudon spread his own views on landscape design by publishing reviews of well-known country seats and their gardens. He often reserved his highest praise for the kitchen gardens of estate owners, as these gardens were centers for horticultural experimentation, where exotic fruits and flowers were subjected to the latest advances in scientific research. Loudon described with admiration the kitchen garden at Deepdene, the country estate of famous art collector Thomas Hope, observing that it produced “an excellent crop of grapes . . . and one of peaches in low Dutch pits . . . without artificial heat of any kind,” a plantation of orange trees in pots, a collection of “green-house plants, chiefly from the Cape of Good Hope and New Holland,” and “forty-nine species and varieties of Hibiscus, recently raised from imported seeds.”21 In 1829 he made a lengthy review of the Duke of Northumberland’s 3-acre kitchen garden and “forcing-department” at Syon without any reference whatsoever to the garden proper.22

In reviewing Littlecot Park, owned by General Popham, Loudon described approvingly how, in the kitchen garden, pineapples were grown in hothouses with peaches and nectarines beneath glass frames, praising it as “one of the very few places which we have seen which come entirely up to our ideas of high order and keeping.”23

Like the hothouses and glass frames Loudon observed in kitchen gardens, new structures created to exhibit and force collections of flowers, fruits, and shrubs imported from around the world were central to this new scientific aesthetic. Not only were these structures necessary to produce and preserve the exotic plants so desired by gardeners, but they also epitomized a scientific approach to landscape by requiring gardeners to monitor and simulate southerly climates under glass to force the growth of tropical plants.24 The nineteenth century, Loudon wrote, “has commenced by extraordinary efforts in horticulture”:

The culture of exotic fruits and forcing has been greatly extended, and while in the middle of the eighteenth century scarcely a forcing-house was met with, excepting near the metropolis; there is now hardly a garden in the most remote county, or a citizen’s potagery, without one or more of them. The public markets, especially those of the metropolis, are amply supplied with forced productions, and far better pines [pineapples], grapes, and melons are grown in Britain than in any other part of the world.25

Nor were encounters with these temperate indoor climates the sole privilege of a wealthy and mobile class. Although similar structures had existed in aristocratic gardens since well before the nineteenth century, advances in glass and iron manufacturing allowed even middle-class gardeners to build greenhouses and conservatories, and larger winter gardens and botanical stoves became ubiquitous in public settings.26 As early as 1829, T. R. Rivère praised glass buildings...
in the *Gardener’s Magazine*, writing that “art can do what nature, uncultivated, forbids,” and describing how even in the middle of winter there “are days as fine and agreeable as any in the summer months.”

Well-known glasshouses throughout England became popular social retreats and sites for horticultural tourism. After the English botanist William Jackson Hooker was appointed director of the Royal Botanic Gardens at Kew in 1841, the gardens became among the most prominent horticulture-themed social spaces in London. Hooker opened the gardens to the public every day of the week and permitted people to wander the grounds without being escorted by gardeners. Following completion of the gardens’ famous curvilinear iron-and-glass Palm House under Hooker’s supervision in 1848, attendance at Kew grew from just nine thousand in 1841 to nearly half a million in 1865 (Figure 3).

Other popular horticultural sites included the extensive gardens at several British country seats that were open to the public. At Chatsworth, where the famous horticulturalist and glasshouse designer Joseph Paxton was made head gardener in 1826, visitors to the gardens multiplied after Paxton succeeded in bringing the railway to nearby Rowsley. In 1849, Chatsworth became a renowned site for horticultural tourism when Paxton successfully bloomed the *Victoria regia* water lily in a series of specially built glasshouses and heated water tanks.

By midcentury, horticulture gripped the imagination of Victorians as encounters with glasshouses and their botanical curiosities became commonplace. Atmospheric, light-filled interiors became popular settings in romantic literature, while new glass structures helped breach boundaries between the indoors and outdoors, combining social practices with horticultural settings and invading the domestic interior in the form of conservatories, window boxes, and glass cases (Figure 4).

Encouraged by writers like Loudon who endorsed these displays through new aesthetic theories like the gardenesque, the rise of glasshouse culture epitomized the desire to rule natural processes using artificial means. Not only were glasshouses among the most visible expressions of scientific gardening, but they also granted gardeners the ability to dominate nature for cultural and economic gain by constructing and regulating enclosed artificial atmospheres.

Methods of regulating the atmosphere inside a glasshouse were among the popular subjects discussed in the *Gardener’s Magazine*—from ventilating the air and warming the soil around delicate plants to calculating humidity levels and vaporizing the air with steam. Loudon was renowned for his designs of hothouses that exploited the latest developments in heating, glassmaking, and iron construction. In his view, the desire to force fruits had caused gardeners to notice the “specific influence of light, heat, air, water, and other agents of vegetation.” In one proposal to force pineapples, he illustrated how a shed roof installed against a masonry wall and covered in glass could be heated by the circulation of hot air through a network of brick flues beneath a layer of crushed stones. Gardeners could make precise adjustments to temperature by releasing hot or cold air directly into the building, and they could warm and moisten the soil by pouring water
into a series of vertical pipes that allowed steam to escape beneath the plants. A system of canvas sunscreens operated by pulleys beneath the glass-covered roof was used to shut out excessive sunlight and provide additional insulation at night (Figure 5).  

To refine their methods of heating and ventilating glass structures, gardeners needed to gain a better understanding of the chemical and physical properties of the atmosphere they were creating. They kept meticulous records of the climatic variables inside glasshouses and drew on the work of engineers, chemists, and physicists, whose writings were often discussed in the *Gardener’s Magazine* (Figure 6). In its first issue, civil engineer Thomas Tredgold (1788–1829) authored an article titled “On the Relations of Heat, Moisture, and Evaporation in Natural and Artificial Atmospheres.” Describing the effects of air temperature on the condensation and evaporation of moisture, Tredgold explained how to calculate the quantity of vapor contained in saturated air and its evaporative temperature, stressing to gardeners that “the constitution of the atmosphere has a most important influence on the growth of plants.” Later that same year, Loudon reviewed a paper read at the London Horticultural Society by the English chemist and physicist John Frederic Daniell (1790–1845). Emphasizing how “horticulture differs from agriculture by creating artificial climates . . . effected by an inclosed atmosphere in an artificial structure,” Loudon reiterated Daniell’s belief that “the plants which require this protection are in the most artificial state which it is possible to conceive.” By paying careful attention to humidity levels and the evaporation and absorption of moisture by plants, Daniell promised, gardeners could create an atmosphere “perfectly analogous to the natural processes.” Clearly impressed with Daniell’s insight, Loudon encouraged the transfer of these lessons into practice by basing an entire chapter of his *Suburban Horticulturalist* (1842) on Daniell’s teachings.  

With the rise of the popular gardening press during the first half of the nineteenth century, scientific attitudes and practices were incorporated into British popular culture and aesthetics. At the same time, gardening practices were increasingly premised on the artificial, as gardeners attempted to simulate foreign climates indoors to force the growth of exotic plants. Together with a growing body of horticultural literature, the glasshouse provided an important setting where the triumph of science over nature was put on full display and where new environmental technologies could be developed and tested.  

Climate, however, was only half of the problem. In order to better comprehend and control natural processes, gardeners needed a deeper understanding of plant life and its physiological response to climate. This led them to study the effects of climate and atmosphere on organic life. Their efforts soon attracted the interest of public health reformers who had similar concerns about the effects of climate on living bodies, and who reinscribed horticultural knowledge in debates over human health.  

**Figure 4** Harry E. J. Browne, *Tea in the Conservatory*, ca. 1890 (photograph reproduced with the kind permission of the Russell-Cotes Art Gallery & Museum, Bournemouth).  

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**The Medicalization of Horticulture**  
Like gardening, the medical sciences experienced a surge in popularity during the second and third decades of the nineteenth century; medical treatises, atlases, and periodicals were widely published and read by medical professionals and other scientific-minded audiences. At the same time, a systematic
reordering of the natural world that had begun in the seventeenth century came to fruition in print media, where natural scientists delved into the inner workings of organic life. Natural scientists saw plants, animals, and humankind as linked by their organic unity, pointing to their shared susceptibility to the physical environment and to the seemingly analogous processes of nutrition, expiration, and acclimatization across animals and plants. While English natural scientists concentrated on revealing this underlying unity, others—including health reformers, botanists, and engineers—drew on these popular analogies to explain what they saw as an increasingly interrelated world.40

There were many reasons for medical professionals to take an interest in the activities of gardeners and horticulturalists. In addition to their cultural and aesthetic value in gardens, exotic plants retrieved by plant collectors could lead to the discovery and refinement of new medicines. The search for medically, and economically, valuable plants accelerated during the nineteenth century as plant transfers grew with colonial expansion.41 One result of this expanded search
was the Apothecaries Act, passed by the British Parliament in 1815, which required all medical practitioners to obtain a working knowledge of medicinal herbs and led to the establishment of botany as a subject in schools of medicine. Named professor of botany at Glasgow University in 1820, William Hooker became a key figure in the dissemination and popularization of botanical knowledge. Hooker supplemented his lectures with colorful botanical illustrations of the structure and anatomy of plants in an effort to attract more people to his classes and to sway the interest of medical students, for whom the course had only recently become compulsory. This botanical imagery was designed to assert the seriousness of botany as a field of study by demonstrating a systematic approach to the study of plant physiology and reflecting the new methods of classifying plants developed by the eminent English botanist John Lindley (1799–1865), who stressed the physiological structure of plants rather than other empirical characteristics. Produced using new lithographic printing techniques, colorful and detailed images showing floral dissections and vegetable amputations helped fuel a scientific interest in plants and spread botanical knowledge to other scientific fields. The new imagery entered the popular press, beginning with Lindley’s own Botanical Register, which he founded in 1815, and later in the Botanical Magazine, for which Hooker served as editor from 1826. Even before Paxton succeeded in blooming the first *Victoria regia* in England—a specimen of which Hooker supplied to him from the Royal Gardens at Kew—Hooker’s magazine had helped to elevate the plant to fame by dismembering its royal flower across several colorful pages (Figure 7).

Although sparing in its use of imagery as a result of being restricted to woodblock prints, the Gardener’s Magazine soon provided descriptions and illustrations that reflected the growing interest in plant physiology and botanical experimentation. In a three-part essay titled “On the Anatomy of the Vine,” one author proclaimed that only through the study of vegetable anatomy could gardeners “convince themselves how sublimely Nature carries on her grand operations.” Together with a detailed description of how the specimen was meticulously dissected and examined, the essay included a series of illustrations enumerating the parts of the vine and revealing its anatomy to be a multiform of different layers and interrelated parts, from its outward-facing skin to the tiny cellular texture visible only under a magnifying glass after the sample had been treated with special chemicals. Even the botanist’s scalpel was carefully recorded and etched in the first of a series of images (Figures 8 and 9).

The inclusion of the dissector’s tool in this case was not a benign point. If imagery developed by botanists drew on medical conventions to explain the anatomical disposition of plants, the practices developed to probe and dissect these specimens were equally important in asserting a scientifically rigorous approach to the study of plants. Grafting was one such operation in which the use of medical terminology and metaphors was prevalent. Grafting allowed gardeners to shorten the growing time of plants, maximize the production of fruits and flowers, and propagate the most successful specimens in a garden by embedding cuttings onto new hosts. When a gardener mechanically inserted a new cutting (scion) or bud (budding) into the stock of an established plant and covered the wound with a sticky compound, the host plant would heal around the new graft and begin to nourish this new prosthesis (Figure 10). Articles in the Gardener’s Magazine on grafting and other plant manipulations often evoked medical practices and were sometimes even authored by medical practitioners. In 1835 the surgeon William Thom contributed an essay describing in detail how he operated on his plants using special knives with hooked ends and the delicate procedure of making “an incision of the form of the

![Figure 7 Dissection of a *Victoria regia* water lily, 1847 (Curtis’s Botanical Magazine 73 [1847], plate 4278; © Dumbarton Oaks Research Library and Collection, Rare Book Collection, Washington, D.C.).](image-url)
inverted capital L” for grafting new cuttings onto a plant’s stem.46 Gardeners’ attempts to graft plants into unusual shapes or combinations were not always met with enthusiasm. In 1839 P. B. Webb described a “monstrous ‘inoculation’ ” made by combining a cypress, Catalonian jasmine, and olive, all “growing sociably together” on the stock of a lemon. “How this unnatural union was accomplished,” Webb wrote, “I could only have learnt by purchasing the tree at an exorbitant price, and dissecting its trunk.”47

Abetted by similar practices and imagery, analogies between the science of plants and the science of human beings were often insinuated by gardeners and medical
practitioners alike. Speaking at the University of London in 1834, John Lindley stressed the importance of botany to medical studies, citing its economic benefit for agricultural purposes and its application in the discovery and refinement of medicines. And although he warned his audience that “lively imaginations” were the cause of some analogies between plants and animals “where no analogies really exist,” Lindley argued that the application of botany to medical studies was also indirectly beneficial by teaching a comparative approach to anatomical studies, supposing—he averred—that “the two kingdoms of animals and plants start from one common point.”

By 1838, the extent of this bond was confirmed by an article in the Gardener’s Magazine titled “Of the Analogy between Plants and Animals,” whose author argued that both plants and animals are nourished by “warmth, air, and light.” The article went on to compare the absorption and circulation of nutrients by a plant’s roots to the function of an animal’s stomach and blood, the delicacy of a plant’s stem to that of an animal’s vertebrae, and a plant’s leaves to an animal’s lungs. Explaining that the well-being of plants is linked to an ideal, geographically determined temperature, the author explained how, in horticulture, this ideal temperature “must be maintained by art; either by a suitable situation in the open air, or by its culture under a structure which admits the light, and is capable of having its atmosphere heated to any required degree.” The inference that, like plants, animals and humans were acclimatized to an ideal, geographically determined temperature was not lost on other scientific professionals. Beginning in the late 1840s, the relocation of animals throughout the British Empire spurred different theories about how these and other living organisms were acclimatized to specific environmental conditions through their physiological makeup.

Lindley, too, had hinted at this mutual interest in his address to medical students at the University of London, pointing out how “a science which explains the organic laws under which plants are permitted to live and grow, which teaches the manner in which they are influenced by the elements, or how they themselves act upon the earth and atmosphere that surround them, stands in the same relation to the vegetable as physiology to the animal kingdom.

For this reason, horticultural glasshouses and the artificial climates they contained garnered considerable interest among English sanitary reformers. In addition to providing laboratories where the effects of climate on organic life could be studied at first hand, glasshouses showed how technology and science could be used to triumph over geography and weather.

The idea that climate and health were related was renewed with considerable force in the nineteenth century as urban pollution and crowding led sanitarians to view poor environmental conditions as a leading public health concern. Consequently, the provision of fresh air and sunlight became a cornerstone of preventive medicine in nineteenth-century England. Warm and temperate climates were also believed to possess powerful healing properties. The work of Scottish-born physician and phrenologist Andrew Combe (1797–1847) is exemplary in this regard. In his widely read Principles of Physiology Applied to the Preservation of Health (1834), he argued that sudden changes in climate could be fatal to human health and that climate was directly related to the growth and spread of disease. Basing his observations on the diaries and testimonials of sailors and other global travelers, Combe concluded that climates with excessive humidity, temperature, or variability posed the greatest risk to human health. For those afflicted by an impure atmosphere (such as London’s), Combe—like most medical practitioners of his day—recommended removal “to a milder and less variable climate.” Similar views were widely disseminated in popular medical books and journals. Founded in 1823 by the English surgeon Thomas Wakley, the British medical journal The Lancet was one such leading venue where the effects of atmosphere and climate on human health were frequently debated and where advances in botanical medicine were often announced. Among the numerous diseases that physicians associated with poor environmental conditions were ailments of the lung such as pulmonary consumption, for which, owing to unsatisfactory methods of treatment, doctors believed that “more is to be expected perhaps from change of climate towards curing the disease, than from the use of medicine.”

In medical discourse, patients who became sensitive to environmental changes were sometimes compared to hothouse plants. Physicians like Combe believed that exposure to the elements was necessary to fortify individuals against environmental sensitivities and prevent those suffering from such sensitivities from being reduced “to the level of a hot-house plant.” In 1835, the surgeon Henry Searle repeated this advice, cautioning his fellow doctors that a tubercular convalescent risked becoming “a perfect hot-house plant, liable to be influenced by every slight change of weather, clothing, or diet.” Medical writers also drew on analogies with plants and vegetables to explain physiological responses to climate in humans. Combe opened his book with a discourse on vegetable physiology and stressed the importance of light for human health by remarking how “even vegetables become pale, watery, and feeble in the dark.”

Of particular interest to medical authorities was the way in which artificial climates made by horticulturalists allowed glasshouses and their occupants to communicate with distant places. Like nineteenth-century gardens, which provided a key index of imperial expansion through their physical and imaginative association with foreign plants and cultures, horticultural glasshouses reaffirmed Britain’s triumph over geographical forces by relocating foreign climates from across
the British Empire. Unlike gardens, however, glasshouse interiors demonstrated their foreignness through total and abrupt environmental change. Changes in light, temperature, humidity, flora, and even fauna allowed Britons stepping into a glasshouse to experience being transported to a different part of the world, where even the air one breathed was felt to be foreign. The fact that these artificial indoor environments were modeled on and even interpreted as foreign climates was well understood by horticulturists. By grouping collections of plants from specific regions inside purpose-built structures, glasshouse interiors were encoded with geographical meaning. In 1840 the Royal Gardens at Kew had ten different glass structures acclimatized to different parts of the world, from the Cape of Good Hope to Botany Bay in Australia. In his Cyclopaedia of London, published in 1851, Charles Knight described how upon entering the conservatory at Kew “England is left behind you for Australia” and remarked how visitors were refreshed upon leaving the great palm-stove “after so long breathing an atmosphere, which, however pure, was not certainly intended for our comfort and well-being.” In a proposal for the Birmingham Horticultural Society, Loudon explained how four different climatic zones could be created inside one circular structure; his plan called for organizing the plantings in concentric rings and using radiating partitions to divide a three-story, conical greenhouse measuring 200 feet in diameter and 100 feet high. Loudon’s design would even simulate rain indoors by circulating water through a series of pierced pipes.

By showing how different climates could be reconstructed in England to preserve delicate plant life, glasshouses provided critical illustrations of how artificial climates could be put to use for the preservation of human health as well. In London especially, where miasmas, pollution, and coal smoke were constant menaces to inhabitants’ well-being, horticultural developments resonated with sanitary reformers, who warned about the dangers of vitiating atmospheres and cold climates while championing the curative powers of warm retreats. Like gardeners, medical professionals valued artificial climates for their ability to erase geographical differences, and they sought to transfer this knowledge into medical practice. In this they were helped by engineers who sought to develop a practical and theoretical corpus for heating and ventilating buildings, and who drew on popular analogies in medicine and horticulture to justify the need to construct healthy, artificial climates for human habitation.

As early as 1826, civil engineer Tredgold noted in the Gardener’s Magazine how “men, as well as plants, feel the exhausting influence of dry air, or perish under the effect of a cold and saturated atmosphere.” Two years prior, Tredgold had published his pioneering Principles of Warming and Ventilating Public Buildings, in which he announced that even “a little attention to the effect of air on plants will be sufficient to prove that a small degree of ventilation is at all times necessary.” Considered a landmark in the development of heating and ventilation that consolidated many earlier experiments in heating industrial and public buildings, Tredgold’s treatise drew extensively on current practices in glasshouse design and made frequent references to the effects of climate on plant life as evidence of the need to build artificial climates for human habitation. Alongside his recommendations for heating and ventilating dwellings, mills, churches, prisons, and hospitals, Tredgold dedicated an entire chapter to houses for forcing plants, urged his readers to study the atmospheric conditions inside hot-houses, and asserted boldly that “a gardener’s researches should embrace other, and not less important objects.” He also posited that the expense and disadvantages of traveling to foreign countries might be saved through the production of the “effect of a milder climate” inside buildings. Tredgold’s views were repeated in many subsequent treatises, including physician Neill Arnott’s On Warming and Ventilating, produced in 1838.

The impact of this discourse on building culture was immediate and profound. By the 1840s, efforts were being made to combine the healthy benefits of a southerly climate with English buildings. Across London, so-called Madeira houses were created to treat people suffering from pulmonary disorders: the interiors of these houses were kept at a uniform high temperature intended to resemble that of the small Portuguese island of Madeira, renowned for its health-inducing sun, sea, and hot sands. In 1843, the humor magazine Punch ridiculed one such establishment, calling it a “social hot-house” for “sick servants . . . consumptive cooks, bilious butlers, paralytic pages, hysterical housemaids, and feverish footmen.” In On the History and Art of Warming and Ventilating Rooms, published in two volumes in 1845, Walter Bernan echoed these developments by offering an entire essay on “medical climates,” stating that “where a change of country is not expedient, a warm artificial climate is considered the next best alternative.” Arguing that the use of artificial heat and ventilation should be employed on a great scale to ameliorate the climate and health of British towns, Bernan conjectured that even a northerner could “breathe air as pure as that blowing over his ice-fields, and as bland and balmy as if it were wafted from the bay of Naples,” assimilating, he boldly claimed, “to the godlike standards of his species in the incense-breathing south.”

By midcentury, environmental medicine and its horticultural connotations were at the forefront of Victorian thought. In 1848, Punch mocked these efforts in a parody of what it called “the Cold-Earth Cure.” Together with a series of burlesque illustrations showing how patients—tended by “medical gardeners”—were submerged in soil, fertilized, and watered before being transplanted to a conservatory for
several hours, the magazine reported that “by these means you are restored to the flower of your youth, and live to a green old age.” “Flesh may be grass,” the article went on, “but still we cannot imagine that a kitchen-garden was ever intended as the hospital to cure all the ‘ills that flesh is heir to’ ” (Figure 11).71

Environmentality in Building Practices

As concern for the effects of climate on human health cast new importance on experiments by scientific gardeners to create artificial climates indoors, the adaptation of glasshouse technologies to solve urban and architectural problems followed. As early as 1817, Loudon developed a fireproof multifamily housing scheme lit by gas and heated by steam—leading one critic to speculate that, in such an “equable artificial climate,” children might be raised “as easily as grapes and pineapples” (Figure 12).74 By midcentury the production of healthy indoor environments was advocated in building treatises written by physicians and engineers, and in publications where gardening and medicine converged under the rubric of warming and ventilating. These works continued to draw on knowledge developed in the natural sciences and in horticulture to articulate a theoretical and technical approach to new building practices.

Engineers recognized the suitability of glasshouse technologies for solving other practical problems in building and helped standardize these technologies for use in architectural settings.75 Gardening periodicals were an important and popular forum where the application of scientific and mechanical knowledge was discussed and where many engineering principles and problems were articulated and solved. In 1822 the Gardener’s Magazine unleashed a torrent of innovation after revealing an experiment by the English architect William Atkinson (with Tredgold acting as his principal assistant) to heat the interior of a forcing-house by circulating hot water through a series of metal pipes (Figure 13).76 Other experiments soon followed, including a fireplace insert developed by Scottish horticulturalist William Anderson that combined a large metal water tank with any domestic fireplace to convert it into a multipurpose boiler and reclaim “waste heat” for floricultural and horticultural uses.77 These efforts quickly culminated in an invention by the civil engineer Angier Perkins, who in 1832 patented a method of warming buildings by circulating hot water in small-diameter sealed tubes, leading to the first applications of radiant heating by hot water in architecture. Perkins’s invention was announced in the pages of the Gardener’s Magazine that same year. In a letter to Loudon, the inventor described how he had developed this new method of heating to warm the printer’s plates at the Bank of England before he tested it at a larger scale to heat the interior of a hothouse owned by one of the bank’s directors. Printing Perkins’s letter alongside the full text and plates from his patent application, Loudon remarked approvingly that “however favourable this plan may be for heating hot-houses, the advantages for that class of structures are as nothing compared to those which it offers for heating dwelling-houses, and all kinds of manufactories.”78 Nearly fifteen years after experiments to heat hot-houses using water were first described in the Gardener’s
Magazine, Loudon reviewed a copy of Charles Hood’s *A Practical Treatise on Warming Buildings by Hot Water* (1837), calling it the “only book, that we are aware of, exclusively devoted to the subject of heating by hot water.”

Treatises like Hood’s continued to evoke comparisons between plants and animals to justify a scientific approach to building. In 1837, Hood argued in favor of warming by hot water by explaining how both animals and vegetables could be harmed by improper methods of warming. Stating unequivocally that “we cannot violate the one class of laws with impunity, any more than we can the other,” he reassured his readers that “practical gardeners have almost universally acknowledged the superior healthiness and productiveness of plants cultivated in houses which are warmed by the circulation of hot water.”

Seven years later, when Scottish physician David Boswell Reid produced his *Illustrations of the Theory and Practice of Ventilation* (1844), in a chapter on heating by hot water he, too, referred readers to the fact that “conservatories, hot-houses, and hot-beds, have been heated upon this principle with the greatest success” and even supplemented his treatise with illustrations taken directly from the *Gardener’s Magazine.* In his preface, Reid cited the works of a host of leading health reformers, including a lecture by the British physician Sir James Clarke on the “sanative influence of climate” and Thomas Tredgold’s *Principles of Warming and Ventilating Public Buildings.* Reiterating that the greatest scourge to human health was “exposure to alterations of air and temperature,” Reid emphasized the recuperative power of artificial climates and asserted that “the great and primary object of architecture is to afford the power of sustaining an artificial atmosphere....It is, in reality, to every building what the breath of life is to the human frame.”

Loudon’s writing also reflected this trend. In a new edition of his *Encyclopaedia of Cottage, Farm, and Villa Architecture* published posthumously in 1846, he stressed how proper methods of warming and ventilating were critical considerations in building for human habitation, citing Dr. Combe’s theory of climate and reiterating the doctor’s belief that environmental factors were key to the preservation of human health.

Despite the conviction of engineers and others who believed that new scientific findings could be readily applied to improve public and private buildings, architects—for whom questions of style and beauty were paramount during the nineteenth century—were unimpressed with the prospect of environmental concerns encroaching on other aesthetic considerations. In a laudatory review of Reid’s treatise that anticipated this brewing conflict, *The Lancet* praised the book as “the most interesting and valuable work on the subject that has yet been published,” then chided architects for remaining “perfectly ignorant” of the science of ventilation and of the dangerous effects of a “vitiated atmosphere.”

Glass, a material indissociable from horticulture and key to the maintenance of indoor climates, posed another substantial challenge to architects. In 1845 the cost of crown and plate glass was dramatically reduced in Britain when Parliament abolished the Glass Excise Tax. Reporting on this event, the trade journal *The Builder* predicted that glass would soon be “applied in numerous ways at present unthought of,” listing glass chronometers, pipes, bells, and transparent pavement as possible uses, but the publication remained conservative in its estimation that horticulture and gardening stood to benefit most from this
tax exemption. On the subject of glass in architecture, The Builder ventured more cautiously. It cited the benefits of window glass in solving a “want of ventilation, deficiency of light, and a corrupt atmosphere” but withheld making any final, architectural judgment by quoting instead from a similar announcement that had appeared in The Lancet:

The fact of the multiplicity of windows being an immense advantage for health, is most important, and should be strongly impressed on the public mind whenever the opportunity offers. It must not, either, be forgotten, that in this respect we have not only the window-tax to contend with, but architectural prejudices.

These “prejudices,” The Lancet continued, were the result of the popular idea among architects that beauty could be derived through the imitation of antique buildings whose proper climate was southern Europe, “where the intensity of light is so great, that it has rather to be avoided than courted.”

The result is, that among architects a multiplicity of windows is considered a defect instead of a beauty, and studiously avoided. We trust, however, that no such doctrine will be allowed to exercise a permanent sway in a climate to which it so little applies. It must not, either, be forgotten, that in this respect we have not only the window-tax to contend with, but architectural prejudices.

Gardeners also criticized architects for prioritizing aesthetics over environmental considerations in designing glasshouses. In 1838, the hothouse designer and nurseryman J. W. Thompson cautioned gardeners that while “an architect may make a very interesting external drawing, which to the eye, appears perfection,” the provision of heating, ventilation, water, “and innumerable other little requisites and necessaries for a stove, greenhouse, or conservatory, may be overlooked in a design by one not intimately acquainted with the subject.” Architects were no less eager to dismiss these men of science who, they feared, sought to interfere with their own art. In 1840, the English architect Alfred Bartholomew stated plainly in his Specifications for Practical Architecture that architects are not “scientific men,” and that scientific men are not architects, and then delivered this diatribe:

There is at present such a gulf between architecture and science, that architecture instead of improving and blending more and more with science, degenerates and becomes every day more and more detached from it. . . . The natural philosopher in applying his knowledge to architecture, forgets that it is one of the fixed laws of nature to clothe its deep science in external beauty . . . now the architect is outraged at the uncouthness produced by the man of science, when he dabbles in architecture, while the man of science views with contempt the broken and irrational nature of modern architecture.

Bartholomew’s comments seem to have been formulated in response to the highly publicized quarrel between science and architecture that erupted after 1840 when the English architect Charles Barry and ventilation engineer David Boswell Reid were both appointed to oversee the reconstruction of the English Houses of Parliament, which had been destroyed by fire in October 1834. Far from having a cordial working relationship, the architect and the engineer engaged in recurring and contemptuous debates that were widely discussed in the popular press, with each man accusing the other of sabotaging his respective mandate. The conflict came to a head when rival groups of workers arrived on-site and were forced to resolve the two seemingly incongruous positions as construction progressed.

Immediately prior to these events, Loudon had founded the Architectural Magazine with the express purpose of reconciling differences between architects and the scientific community. Appearing monthly from 1834 to 1839, the Architectural Magazine called on “young architects to read, write, and think, as well as to see and draw,” and created a forum for all topics related to building—from garden architecture to ironmongery, bridge building, road making, and engineering—combining essays on the philosophy and elements of classical and Gothic architecture with essays on methods of warming and ventilating buildings. Like the Gardener’s Magazine and other popular literature, the Architectural Magazine allowed Loudon to foster a conversation.
between scientific-minded individuals and building experts by curating the journal’s content. In this way, Loudon attempted to intervene in the future of architectural practice by advancing scientific and medical views. In one issue he drew readers’ attention to Combe’s Principles of Physiology, calling it “a work which ought to be in the hands of every individual, but more especially those of every architect.”92 For Loudon, the decision to invite a physician in 1835 to advise the Select Committee on Ventilation for the new Houses of Parliament was a milestone event. Subsequent experiments to regulate the atmosphere inside the temporary House of Commons designed by Robert Smirke were discussed in the Architectural Magazine as Reid, who was tasked with Remediation the poor interior climate under which members of Parliament had previously suffered, attempted to regulate the interior climate in the temporary House of Commons using experimental methodologies he had developed for studies of human physiology he conducted while professor of chemistry at the University of Edinburgh.93 For Reid, chemistry was a science that revealed the underlying unity of the organic and inorganic worlds and was a key consideration in increasing the duration of human life.94 Although Reid’s efforts to ventilate the Houses of Parliament were ultimately unsuccessful (he was dismissed in 1852), his and Loudon’s influential plea soon reappeared in other technical treatises. For example, in his Useful Hints on Ventilation (1850), engineer William Walker appealed to the sentiments of Gothic revivalists by remarking on the utility of turrets, spires, and towers for ventilating vitiated air, arguing that “if the external forms adopted for churches in by-gone ages cannot be adapted to the artificial necessities of the present day, more suitable forms should be chosen or invented.”95 Reid had employed a similar strategy in his plan to ventilate the Houses of Parliament by drawing vitiated air out of the building through a centrally located tower, which Barry disguised as a Gothic spire.

With the Reid–Barry fiasco still fresh in the public’s mind, scientific gardeners scored a significant victory in 1851 when Joseph Paxton’s design for the Great Exhibition building in Hyde Park was selected over 245 other schemes, many of which had been produced by leading English architects.96 Architects, including the Gothic revivalist George Gilbert Scott, were quick to condemn Paxton’s design as an aberration of their art. Scott called Paxton’s Crystal Palace a “miserable travesty” and asked rhetorically whether the building was more like a Grecian temple or a Gothic cathedral. Scott’s position is not surprising given that he also decried the “exotic, hot-house look” of modern English villas, which he found “portentous.”97

Although Paxton’s building did not immediately repair the schism between science and architecture, criticism of the building overshadows the important role that large, public glasshouses played in uniting architects with other scientific-minded individuals. Constructing large glass buildings required developing and testing many innovative building practices and necessitated a high degree of collaboration and cross-disciplinary exchange among diverse actors, including horticulturalists, engineers, architects, scientists, and builders. Two of the earliest glasshouses completed in London that were open to the public were the conservatory of the Royal Horticultural Society at Chiswick (1840), executed by the construction firm of D. and E. Bailey in collaboration with Loudon, and the winter garden of the Royal Botanic Society in Regent’s Park (1842–46), designed by architect Decimus Burton and built by the iron contractor Richard Turner (Figures 14 and 15).98 Burton and Turner would later collaborate on the design and construction of the Palm House at Kew (1840–48), where the physicist Robert Hunt was invited to develop an experimental glazing system to optimize the transmission of light without damaging the foliage of tropical plants. In consultation with John Lindley, William Hooker, and a Birmingham glass manufacturer, Hunt developed a formula for copper-tinted glass that was used throughout the Palm House. The use of colored glazing to prevent overexposure and the results of Hunt’s experiments at Kew were often discussed in the horticultural press.99

Similarly, Paxton developed his design for the 1851 Great Exhibition in close cooperation with civil engineer Charles Fox, an expert in structural ironwork and partner in the construction firm of Fox and Henderson. In addition to Paxton’s well-known innovations in the design and construction of glasshouses, including a flat-roofed, ridge-and-furrow design and a sash bar glazing system, his achievements in scientific gardening and horticulture invested his practice with a high degree of environmental thought. Although much has been written about Paxton’s skill as a designer of greenhouses, he is seldom recognized for his contributions to horticulture and gardening more generally. Paxton began his career as a horticulturalist in 1823, when—at the age of twenty—he started working at the gardens of the Royal Horticultural Society in Chiswick, where the first successful germination of an orchid from seed was reported.100 Shortly thereafter, he became head gardener at Chatsworth, where he carried out further experiments on tropical orchids, accomplishing the unprecedented feat of growing seven flowers on a single stem. Paxton also won numerous medals from the Horticultural Society for the many fruits he grew, and he achieved fame after he nurtured the Victoria regia in a specially built glasshouse and heated pool with such skill that in just one year the plant outgrew its tank on two occasions and produced 122 flowers and 140 leaves.101
Paxton was interested in the popular gardening press as well as the scientific press, and in 1831 he founded the *Horticultural Register*, followed by his *Magazine of Botany* three years later. In 1841, together with botanist John Lindley, Paxton created the *Gardener’s Chronicle*, a publication that effectively succeeded the *Gardner’s Magazine* after Loudon’s death in 1843.

Many of the innovative technologies that Paxton deployed in the Crystal Palace were based on earlier experiments he had conducted, and refined, in the design of horticultural glasshouses at Chatsworth. These included ventilation and solar control as well as glazing technologies and methods of regulating condensation (Figure 16). Although no heating system was provided in the Crystal Palace because the building was not expected to operate in cold weather, an innovative iron-and-wood glazing system with ventilators was employed to circulate the air, and canvas shades were used to block out the sun. A nearby boiler house provided a constant supply of steam to drive the industrial machines on display, and an elaborate network of buried pipes supplied water to fountains and firefighting apparatus. Descriptions of the Crystal Palace by its designer, contemporary critics, and the public suggest how the building’s likeness to an immense, garden-variety glasshouse was central to its design and interpretation. Inside the Crystal Palace, the building’s interior climate was a constant source of interest and concern to exhibition organizers and the public. Temperatures inside the building were judiciously measured at two-hour intervals throughout the exhibition, and constant adjustments were made to the building’s envelope in an effort to improve visitors’ comfort over the course of the summer. In addition to the Crystal Palace’s displays of people and goods from across the British Empire (the building’s transept was nicknamed “the equator”),
exotic shrubs, flowers, trees, fountains, and a fragrant atmosphere added to the near-total effect of this climatic simulation (Figure 17).

The popularity of public glasshouses was reflected in medical discourse. Conservatories and winter gardens attracted the interest of health seekers who sought out warm artificial climates in which to convalesce. In 1852, one writer for the *Cottage Gardener* recommended that such seekers visit the winter garden in Regent’s Park, where no heating system was installed, complaining that the tropical climate reproduced inside the Palm House was too hot for convalescents:

> Indeed, we have been hitherto too far in the wrong direction with all our large glass houses; instead of endeavours to imitate the warm, healthy climate of Pau or Madeira, where the invalid could enjoy a walk or ride, we have all along been putting up houses, as if on purpose to make invalids of the strongest constitutions in the country.106

Paxton’s Crystal Palace also attracted the interest of medical professionals, who heralded the building and its indoor climate as a signpost for a new, sanitary architecture. Under the title “The Crystal Palace: A Hint for Hospital Authorities,” an article in the March 1851 issue of...
The Lancet described how “the sanitarian sees at a glance the countless developments to which the great Palace of Glass will give rise” and pointed to the suitability of its “crystal shield” to protect patients from “the rude assaults of weather.” By regulating indoor temperatures and giving access to fresh air and light, the article continued, “such enclosed spaces might form winter gardens and conservatories for the sick, as we already have them for the hale and strong.” Unlike at the Palm House, where rules were introduced requiring all wheelchair users to obtain special permission from the director before visiting, Saturday mornings at the Crystal Palace were reserved for invalids and the infirm. Later that year, Paxton was invited to design a building for the London Chest Hospital. Nicknamed the Crystal Sanatorium, the building incorporated a conservatory roof that was 200 feet long and 72 feet wide to provide patients with a healthy, temperate climate, simulated through the use of an elaborate heating, cooling, and ventilation system (Figure 18).

As debate swelled around the future of the Crystal Palace beyond the Great Exhibition’s closing, medical writers were joined by horticulturalists in their plea that the building be preserved for sanitary purposes. Paxton proposed transforming the Crystal Palace into a permanent winter garden, where “climate would be the principal thing studied” and where Londoners “could be supplied the southern Italy.” This idea was quickly seconded by one medical writer who predicted that such a building would “supply all the benefits of a southern climate without the expense and discomfort of journeying to it.” Physician Stephen Ward went one step further. In discussing the Crystal Palace as it was rebuilt at Sydenham (1852–54) for use as a winter garden, Ward claimed that for all intents and purposes the new building, “being devoted to the maintenance of health,” was a sanatorium.

Even prior to 1851, horticultural and environmental thought had begun to permeate the practice of architects, artists, and critics. For the English architect John Soane, the pioneering use of interconnected interior spaces was the direct result of horticultural developments. After several failed attempts to heat the interior of his museum by compartmentalizing its spaces, Soane installed a system using hot water under high pressure to warm the space uniformly; its success allowed him to preserve the museum’s complex, interlocking spaces, which Soane had created by removing several partitions during the 1820s. Early in his professional career, Soane designed some thirty-eight greenhouses and garden structures, and in his eighth lecture on architecture given at the Royal Academy in 1815, he drew attention to the fact that heating systems using hot water could be effective in public buildings, dwellings, and greenhouses alike. In 1837, civil engineer Charles Richardson (a former pupil of Soane) described in his Popular Treatise on the Warming and Ventilation of Buildings how some 1,200 feet of small-diameter pipe heated by hot water had been successfully installed throughout Soane’s museum. Richardson cited Dr. Combe’s personal endorsement of the “Perkins” hot-water system as a healthy and fireproof method of warming and presented a long list of public and private buildings that had been heated in this manner since 1832. Decimus Burton was another architect whose work, like Soane’s, often transgressed the disciplinary boundaries separating architecture and gardening. In addition to assisting Paxton on the design of the Great Conservatory at Chatsworth (1837–40) and collaborating with several others in the design of the Kew Palm House, Burton was renowned for designing several buildings in London, including the Grecian-styled Athenaeum Club (1829–30) on Regent Street. In 1840, the Royal Botanical Society selected him to lay out the society’s gardens following the Linnaean taxonomic system.
However, the extent to which environmental thought transformed building practices was not determined by technology alone. As William Taylor has shown, transformations inside and outside the Victorian home were also instrumental in writing science into the British domestic economy and raising Victorians’ awareness of the need to construct suitable environments for comfort and well-being, illustrated through a plethora of self-contained, exterior worlds in the form of conservatories, fern cases, aquariums, and other natural history curios. For others, including painter Joseph Turner and critic John Ruskin, the pervasiveness of environmental thought inspired innovative practices of a different kind that resisted the ability to control climate and collapse geographical distinctions. In lieu of a well-lit and warmed interior, Turner preferred to paint in a ruinous and leaky open-air studio. Ruskin deployed climate as a critical tool to nationalize (and thus resist) foreign architectural styles as part of his mission to moralize the English Gothic.

Located at the intersection of horticulture, medicine, and technology, the glasshouse was a critical medium through which architecture and the sciences communicated. Despite some architects’ resistance to technical and material innovations, horticulture and medicine played a crucial role by mediating between architecture and environmental practices as engineers looked to these scientific fields to elaborate a theory of warming and ventilating—imbricating architecture with efforts to reconstruct foreign climates across England. By helping to popularize scientific and environmental thought across disciplinary boundaries, gardening literature was central to this exchange, introducing science into aesthetic discourse and providing a set of design practices that incorporated scientific thinking.

Conclusion

Stripped of their complex meaning by modern historians who see the glasshouse as a forerunner to structural rationalism, the generative principles of glass architecture and their relationship to nineteenth-century science are often overlooked or mystified. While a burgeoning environmental awareness led architects and engineers to reconceptualize buildings in terms of the atmospheres they contained, technological transfers alone cannot explain the emergence of an environmental paradigm or its materialization in nineteenth-century glass architecture. With the reinscription of architecture in the history of science and its popular literature, a more complex portrait emerges that reveals architecture’s interpenetration with broader social and cultural themes. Gardening literature was one such venue in which an environmental approach to building was elaborated through a theoretical corpus that celebrated scientific achievement over natural processes. Moreover, by engaging in productive dialogue with other scientific and mechanical disciplines, gardening literature provided a forum where numerous fields—including architecture—converged under the banner of popular science and taste. Among these, medicine provided a crucial link between gardening and architecture by drawing on environmental knowledge and the natural sciences to articulate ideas about human health and pressing architects to adopt these principles in building practices. Stimulated by the work of scientific gardeners who sustained exotic living plants by constructing artificial climates inside glass buildings, the medicalization of horticulture and its convergence in engineering and building treatises under the rubric of warming and ventilating announced how healthy climates could be relocated inside buildings through the coupling of architecture with mechanical systems. Crucially, transfers between building and landscape practices in the nineteenth century highlight the important role played by the natural sciences in easing technology into architecture. As experiments by gardeners seeking to conquer the natural world stimulated thought across multiple disciplines, the glasshouse exerted a decisive influence over the emergence of environmentalism as a dominant paradigm in Western architecture.

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Notes

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I use the term glasshouse to refer to a variety of horticultural structures designed to force the growth of plants by creating an enclosed, artificial climate, including greenhouses, conservatories, hothouses, botanical stoves, and winter gardens.

2. William Taylor has argued that the desire to “accommodate nature” in nineteenth-century architecture and landscape reflected developments in the natural sciences whereby plants, animals, and humans were seen as linked by their “organic unity” and shared sensitivity to such “vital” forces as earth, water, and air. For Taylor, the glasshouse illustrates how Victorian science granted control over nature, climate, and geography, and how notions of environmental unity manifested in building practices as imprecise boundaries separated the natural and built environment. See William M. Taylor, The Vital Landscape: Nature and the Built Environment in Nineteenth-Century Britain (Aldershot, England: Ashgate, 2004). For Henrik Schoenefeldt, the Crystal Palaces of 1851 and 1854 signal the emergence of an environmental paradigm in architecture, as attention focused on the technical performance of these two glasshouses and their adaptability for human comfort. See Henrik Schoenefeldt, Palaces of 1851 and 1854 signal the emergence of an environmental paradigm in architecture, as attention focused on the technical performance of these two glasshouses and their adaptability for human comfort.


6. Exemplary in this regard is the architect and historian John Hix, who dedicates two full chapters of his influential book The Glasshouse (Cambridge, Mass.: MIT Press, 1974) to the construction and maintenance of artificial climates in horticultural settings, then sketches a teleology of glass buildings, from industrial exhibition halls to the controlled indoor environments of the modern movement and beyond.


16. Loudon’s first use of the term gardencensu was in the Gardener’s Magazine in 1832. John C. Loudon, “Preface,” Gardener’s Magazine 8 (1832), iv.


20. Sarah Dewis has called the Gardener’s Magazine “the first in Britain to combine the science and the design of gardens,” pointing to its collaborative nature and the diversity of its themes: from politics and gender to science, literature, and education. Sarah Dewis, The Loudon and the Gardening Press: A Victorian Cultural Industry (Aldershot, England: Ashgate, 2014). Published concurrently with the Gardener’s Magazine from 1828 to 1849, Loudon’s Magazine of Natural History provided him another, complementary forum for the discussion of topics as far-reaching as zoology, botany, mineralogy, and meteorology.


24. Used to prolong the development of plants so that fruits, vegetables, and flowers could be enjoyed for longer periods throughout the year, methods of forcing employed structures ranging from simple pits and glass frames for cucumbers and melons to heated walls for climbing plants and elaborate glass structures heated by steam and water.


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31. Mark Laird notes similarly how it was Loudon who came to make the effects of the 'artificial' possible through glasshouse technology. Laird, "Plantings," 70.
44. Anne Secord has argued that the use of didactic illustrations was central to the participatory pursuit of Victorian science. See Anne Secord, "Botany on a Plate: Pleasure and the Power of Pictures in Promoting Early Nineteenth-Century Scientific Knowledge," *Isis* 93, no. 1 (2002), 28-57.
50. Ibid., 414.
52. Lindley, "University of London: Address," 89.
54. Andrew Combe, *The Principles of Physiology Applied to the Preservation of Human Health* (New York: Harper & Brothers, 1834), 180-90. Not all warm climates were regarded as healthy, however. Medical authorities believed that tropical climates were damaging to the temperate bodies of Europeans and a breeding ground for fever and disease. See Rod Edmund, "Returning Fears: Tropical Disease and the Metropolis," in *Tropical Visions in an Age of Empire*, ed. Felix Driver and Luciana Martins (Chicago: University of Chicago Press, 2005), 175-94.
64. John C. Loudon, "Description of a Design Made for the Birmingham Horticultural Society . . .," *Gardener's Magazine* 8, no. 9 (1832), 422-23.
67. Ibid., 194.
68. Ibid., 187.
71. Walter Bernan, *On the History and Art of Warming and Ventilating Rooms and Buildings* (London: George Bell, 1845), 2:289-90. Walter Bernan was the pen name of civil engineer Robert Meikleham.
72. Ibid., 1:21–22.


82. Ibid., 9, 71.


86. Quoted in ibid., 146.

87. Quoted in ibid.


100. The exact date of this event is uncertain, but it is thought to be either 1822 or 1832. See Joseph Arditti, “An History of Orchid Hybridization, Seed Germination and Tissue Culture,” *Botanical Journal of the Linnean Society* 89, no. 4 (1984), 359–81.


120. Antoine Picon’s claim that “since the beginning of the nineteenth century, architecture and science have seemed to belong to two different worlds” suggests that a closer study of the transdisciplinary nature of Victorian science is needed if we are to gain a better understanding of how exchanges with the natural sciences manifested in architectural production and discourse. Antoine Picon, “Architecture, Science, and Technology,” in *The Architecture of Science*, ed. Peter Galison and Emily Thompson (Cambridge, Mass.: MIT Press, 1999), 314. A more recent volume has begun to address this gap; see Antoine Picon and Alessandra Ponte, eds., *Architecture and the Sciences: Exchanging Metaphors* (New York: Princeton Architectural Press, 2003).