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# Germs and Ornaments:

# The Johns Hopkins Hospital (1873-1891)

A dissertation submitted in partial satisfaction of the

requirement for the degree of Doctor of Philosophy

in Architecture

by

Iman Ansari

2021

# ABSTRACT OF THE DISSERTATION

Germs and Ornaments:

The Johns Hopkins Hospital (1873-1891)

by


Iman Ansari

Doctor of Philosophy in Architecture

University of California, Los Angeles, 2021

Professor Sylvia Lavin, Co-Chair

Professor Michael Osman, Co-Chair



This dissertation examines the design, construction, and early operation of the Johns Hopkins Hospital in Baltimore as an instance where the disciplinary techniques for medical observation, experimentation, and education became deeply entangled with architecture. The design and construction of the Hospital—led by a physician and assisted by an architect—reveals the professional dynamics and rivalry between medicine and architecture at a time when both were in the early stages of their professionalization, and in a subject in which both professions claimed expertise and authority. Influenced by the rise of the laboratory medicine, the project reflects the application of the scientific method to architecture that ultimately conceived the built hospital as a full-scale architectural experiment: "a sort of laboratory for heating and ventilation." The process began with a survey of current practices on the basis of literature review and visits to

existing hospitals, leading to the development of a hypothesis that manifested itself in the plans, followed by the construction of the experiment, and finally the evaluation and analysis of the building performance during the operation of the hospital. Using building forms and heating and ventilation systems as independent variables, the goal of the experiment was to correlate environmental condition with disease incidence in order to arrive at the best architectural configuration. The result was the isolation and abstraction of specific components of architecture that allowed them to become objects of scientific study and analysis. In a period when American architects were embracing the revival of classicism and the aesthetic principles of the École des Beaux-Arts, the hygienic and antiseptic principles in the Hospital resulted in bright, sterile interiors with rounded corners, smooth and impermeable surfaces, and no cornices or ornaments to hold germs or foul air. Meanwhile, seeing the building as a didactic demonstration of the experiment, all the pipes, ducts, traps and mechanical apparatus were exposed to view so that the Hospital would function as "a laboratory for teaching the practical application of the laws of hygiene to heating, ventilation, house drainage, and other sanitary matters." The project represents a salient moment when the disciplinary entanglement of medicine with architecture, in the pursuit to increase and diffuse knowledge, became at once phenomenological and discursive. By the time the Hospital was constructed, these architectural propositions conformed to, but at times contradicted, the therapeutic, educational, and experimental mandates of the institution.

The dissertation of Iman Ansari is approved.

Soraya de Chadarevian

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2021

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# INTRODUCTION

*The first hospitals were established to give shelter and food to the sick poor, especially those who gathered in cities. Gradually physicians found that they could learn much in theses aggregations of suffering and that they afforded the means of teaching others; but this last use of them is only about two hundred years old. Gradually, also, it came to be known that the knowledge thus obtained in the care of the sick poor was of use in treating the diseases of the well-to-do; and finally, within the last twenty-five years or so, people are beginning to find out that when they are afflicted with certain forms of disease or injury they can be better treated in a properly appointed hospital than they can be in their own homes, no matter how costly or luxurious these may be. […] This hospital, then, is to provide for the rich as well as for the poor; for those who can, and ought to, pay for the help given, as well as for those who can not.*[1]

*—John Shaw Billings, 1889.*

On March 10, 1873, Baltimore businessman and self-made millionaire Johns Hopkins wrote a letter to his trustees instructing them to build a hospital in connection with the medical school of his university that would "compare favorably with any other institution of like character in this country or in Europe," and would admit without charge "the indigent sick of this city and its

[1] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 3-4.

environs, without regard to sex, age or color."[2] Hopkin's letter of instruction formed the blueprint of the twin institutions that bore his name. He split his unprecedented fortune, amounting to over seven million dollars, between the Hospital and the University, making it the largest philanthropic gift in the history of the United States at that time, and leaving the two institutions with the largest endowment than any other in the country. Through this prescribed alliance, the Hospital became the first institution in the United States to combine higher medical education with practice, laying the groundwork of what has been regarded as a revolution in American medicine.[3] The Johns Hopkins Hospital occupies a pivotal position in the history of medical practice, research and education, but also, as I argue, in that of architecture.

Hospitals during the nineteenth century were in a process of transformation from a charitable to a medical institution. Michel Foucault has traced the origin of "medical hospital" to the disciplinary and epistemological transformations during the Enlightenment that resulted in the convergence of two fundamentally distinct domains that, while existed before, never overlapped: medicine and the hospital. The reformulation of disease as a natural phenomenon along with the introduction of a political technology or *discipline* to the space of the hospital allowed the medical institution to become the place for the formation and transmission of knowledge. Foucault, and later Sven-Olov Wallenstein, have argued that through that medicalized power structure, the hospital of the nineteenth and early twentieth centuries functioned as a bio-political instrument for experimenting on individuals in the service of advancing medical knowledge and

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[2] *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873).

[3] Erwin H. Acherknecht, *A short History of Medicine,* 2nd ed. (Baltimore: Johns Hopkins University Press, 2016), 203-205.

practice.[4] This dissertation examines the planning, design, construction, and early operation of the Johns Hopkins Hospital as an instance where the disciplinary methods and techniques of medical observation, research, and education became deeply entangled with architecture. Through this process, it was no longer only the patients' bodies or their diseases, but the very components of the Hospital's architecture and its environment that constituted the primary object of scientific study. In this way, more than an instrument for disciplinary control over human populations, architecture itself was subjected to discipline, at times turning the living patients into the means and measures of research and experimentation in the pursuit to increase and diffuse knowledge of architecture.

The project represents a salient moment when the disciplinary entanglement of medicine with architecture became at once phenomenological and discursive—phenomenological, because it required architecture, and discursive, because it demanded new forms of documentation and representation. This disciplinary convergence occurred in a unique historical moment marked by new socio-economic, epistemological, technological, and professional transformations: the rapid economic and industrial growth in the post-Civil War era, the rise of philanthropy and private enterprises, the advent of new organizational and managerial systems, advances in medical knowledge and practice brought about by the emergence of germ theory of disease and antiseptic

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[4] For Foucault, the reformulation of disease as a natural phenomenon subjected the very environmental conditions of the hospital to medical observation, study and education, while the application of discipline to the space of the hospital instituted the the inquiry, surveillance, and ordering of the disorderly world of both patients and diseases by transforming and regulating the very conditions that constituted their environment. The convergence of the two resulted in the birth of the "medical hospital." See: Michel Foucault, "The Incorporation of the Hospital into Modern Technology" (1976), Edgar Knowlton Jr., et al. (trans.), *Space, Knowledge and Power: Foucault and Geography*, Stuart Elden and Jeremy W. Crampton (eds.) (Burlington, VT: Ashgate, 2007), 141-152; Sven-Olov Wallenstein, *Biopolitics and the Emergence of Modern Architecture* (New York: Princeton Architectural Press, 2009).

practices, the rise of experimental medicine and laboratory science, professionalization of doctors, engineers and architects, the introduction of new methods of higher education and research, advances in building technologies such as mechanical heating and ventilation, innovations in construction materials and techniques, as well as public health movements and sanitary reforms. These unique historical circumstances had a profound impact on the planning, design and construction of the Hospital that spanned nearly two decades, leaving a visible imprint on the plans and the final buildings that opened to public in 1889.

Baltimore at the time was uniquely positioned to benefit from these circumstances. The city's economy revived after the Civil War with the expansion of the railroads and the growth of the manufacturing industry, leading to an exponential growth in population that turned it into the second largest city in the United States.[5] The booming economy also resulted in growth of individual wealth, allowing Baltimore to produce more millionaires than any other city in America. Hopkins himself made most of his wealth through investments in the Baltimore & Ohio Railroad Company (B&O), the first commercial railroad to be chartered and built in the United States, where he was the largest stockholder and was appointed as the director in 1847. These wealthy individuals, who made their money primarily through liquor, railroads and banking business, soon discovered that "it was pleasanter to give money away than it was to make it."[6] George Peabody founded the Peabody Institute (1857), Johns Hopkins established the Johns Hopkins Hospital and University (1867), Enoch Pratt founded the City's Library system

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[5] "The History of Baltimore," *The City of Baltimore Comprehensive Master Plan* (July 9, 2006)*,* 33-34.

[6] John W. Garrett, the President of the B&O at the time, recalls George Peabody telling Johns Hopkins at a dinner: "I began to find out it was pleasanter to give money away than it was to make it." Virgil McClure Harris, *Ancient, Curious and Famous Wills* (London: Stanley Paul & Co., 1912), 410.

(1882), and William and Henry Walters founded the Walters Art Gallery (1931). While these philanthropic enterprises were intended to provide opportunities for all, regardless of their race, gender, or economic status, most depended on and profited from Southern economies based in slavery.[7]

Hospitals during this period largely operated outside the domain of architecture. The prevalent scientific theories of disease, the growing rate of hospital diseases or "hospitalism," and therapeutic assumption about the environment had enabled doctors and medical professionals to extend their expertise and authority beyond hospital organization towards its design and construction. Already established as a therapeutic instrument since the eighteenth century, "máchine à guérir" or *a healing machine,* the perceived correlation between environment and disease incidence had enabled nineteenth-century physicians to assume the role of architects.[8] In the United States, for instance, the majority of hospitals during the eighteenth and the nineteenth century were designed by doctors and hospital administrators with little or no input from architects.[9] From the "pavilion plan" to the "Kirkbride plan" and the "barrack plan," doctors saw the architecture of the hospital as an instrument for cure, regularly prescribing their own designs,

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[7] Hopkins' own abolitionist biography has been recently challenged in light of new findings. See for instance: Martha S. Jones, "Johns Hopkins and Slaveholding, Preliminary Findings, December 8, 2020," Hard Histories at Hopkins (December 8, 2020); "Johns Hopkins's Feet of Clay," *The New York Times* (December 10, 2020); Since the the news of Johns Hopkins having enslaved people in his household broke in December of 2020, the Peabody Institute has started a historical inquiry into George Peabody: "Regarding Johns Hopkins" (December 9, 2020); "William and Henry Walters and the Confederacy" (accessed on March 30, 2021).

[8] In 1773, Jean-Baptiste Le Roy famously called his proposed hospital "máchine à guérir," *a healing machine.* "A ward," he wrote, "is, as it were, a machine for treating the sick." Quoted from L. Klasen, *Grundriss-Vorbilder in Gebäuden aller Art,* 15 pts., (Leipzig, 1884-1896), pt. IV, 315, in Nikolaus Pevsner, *A History of Building Types* (Princeton: Princeton University Press, 1979), 146-147, 150-151.

[9] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 78-79.

even drawing their own plans. Meanwhile, the introduction of mechanical heating and ventilation during this period allowed doctors and engineers to further cement their professional authority through production of various articles, papers and books, and regular discussions and debates in scientific journals.[10] More than an architectural problem, the design and construction of hospitals during this period came to be viewed as a medical and engineering one.

Meanwhile, architecture in the United States during this period was in the process of a transformation from a craft-oriented vocation to a professionalized occupation. Before the 1860s, American architects could only seek specialized education through apprenticeships, enrollment in the few existing engineering programs, or by enrolling educational institutions in Europe like the *École des Beaux-Arts*. The first professional architects and engineers in the United States, like Maximilian Godefroy and Benjamin Henry Latrobe, were immigrants, and the remaining majority either did not have a professional education or were educated abroad. And while the American Institute of Architects (AIA) was formed in 1857, the first school of architecture in the United States was not established until nearly a decade later in 1865 at Massachusetts Institute of

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[10] Most notable American examples include: William J. Baldwin's *Steam Heating for Buildings* (1881), and *Hot Water Heating and Fitting* (1889), as well as Billings' *Ventilation and Heating* (1893), and his *Principles of Ventilation and Heating and their Practical Application* (1884). Engineers from other countries, including France and Germany, also produced major treatises on ventilation but with less influence than their American counterparts.

Technology.[11] In that environment, John Rudolph Niernsée, the architect selected by the Trustees of the Hospital, was well qualified for the job. He was trained as an architect and an engineer at Prague Polytechnic, was among the early members of the AIA, and had established the first professional architectural practice in Baltimore.[12]

These professional qualifications, however, proved to be inadequate for the Trustees who considered the design and construction of the Hospital a "technical scientific question." After consulting with five physicians with hospital expertise, the Trustees hired one of them, John Shaw Billings, as the Medical Advisor to oversee the design and construction of the project, and asked Niernsée "to prepare his plans in consultation with and under the supervision of a surgeon who is a recognized authority in hospital construction."[13] Billings, the de-facto architect of the project, was an Assistant Surgeon in the U.S. Army whose experience in managing the Marine Hospital Service had established him as an expert in hospital construction and hygiene. He was

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[11] On the history of architectural education and professionalization in the United States see: Mary N. Wood, *From Craft to Profession: The Practice of Architecture in Nineteenth-Century America* (Berkley: University of California Press, 1999); Bernard Michael Boyle, "Architectural Practice in America, 1865-1965—Ideal and Reality" in Spiro Kostof (ed.), *The Architect: Chapters in the History of the Profession* (New York: Oxford University Press, 1977); Sibel B. Dostoglu, "Towards Professional Legitimacy and Power: An Inquiry into the Struggle, Achievements and Dilemmas of the Architectural Profession through an Analysis of Chicago 1871-1909" (Dissertation: University of Pennsylvania, 1982); Burton J. Bledstein, *The Culture of Professionalism: The Middle Class and the Development of Higher Education in America* (New York: W. W. Norton and Company, Inc., 1976); Elyse Gundersen McBride, "The Changing Role of the Architect in the United States Construction Industry, 1870-1913," *Construction History*, Vol. 28, No. 1 (2013), 121-140; Ulrich Pfammatter, *The Making of the Modern Architect and Engineer: The Origins and Development of a Scientific and Industrially Oriented Occupation,* M. Ferretti-Theilig (trans.) (Basel: Birkhäuser—Publishers for Architecture, 2000); Andrew Saint, *Architect and Engineer: A Study in Sibling Rivalry* (New Haven: Yale University Press, 2007).

[12] In his 1875 essay proposal, Niernsée introduced himself in the following way: "John R. Niernsée, F.A.I.A., Architect to the Board of Trustees of the Johns Hopkins Hospital, Corresponding member of the Austrian Institute of Architects and Civil Engineers, Member of the U.S. Commission of Science and Art, and Member of the Jury of the Exposition of Vienna in 1873."

[13] *The American Architect and Building News,* (October 6, 1877), 318.

also a leading figure in the sanitary reform, serving as the Vice-President of both the American Public Health Association (APHA) and later the National Board of Health (NBH).[14]

The planning and construction of the Johns Hopkins Hospital therefore reveals the professional dynamics and rivalry between medicine and architecture, at a time when both were in the early stages of their professionalization in the United States, and in a subject in which both professions claimed authority and expertise. The rapid development of heating and ventilation systems, the growing knowledge and expertise in building technology and hygiene, and the undefined roles of architects, doctors and engineers resulted in regular disputes between these professionals.[15] And these conflicts were increasingly pronounced in the design and construction of hospitals where both sanitary and engineering requirements were paramount. Architects saw their authority in design challenged by scientific theories and technical knowledge in medicine and engineering, while doctors and engineers continually charged architects with being merely concerned with decoration and ornamentation. The dispute between Billings and Niernsée stemmed from similar assumptions, which ultimately led to the architect's resignation in 1877, just over a year after the two began their professional relationship.

The confusion of these professional roles and responsibilities had a direct impact on the design and construction process. Influenced by the rise of the laboratory and experimental medicine,

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[14] For a biography of Billings see: Fielding Hudson Garrison, *John Shaw Billings: A Memoir* (New York: G. P. Putnam's Sons, 1915).

[15] The dispute between physician David Boswell Reid, who was appointed as the heating and ventilating engineer of the New Houses of Parliament, and architect Charles Barry is a well-known example of that. See: Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 152-153.

Billings' approach towards the project reflects the application of the *scientific method* to architecture that ultimately conceived the built hospital as a full-scale architectural experiment: "a sort of laboratory for heating and ventilation." The process began with a survey of current practices on the basis of literature review and visits to existing hospitals, leading to the development of a hypothesis that manifested itself in the plans, followed by the full-scale construction of the experiment, and finally the evaluation and analysis of the building performance during the operation of the hospital. Using building designs and heating and ventilation systems as independent variables, the goal of the experiment was to correlate environmental condition with disease incidence in order to arrive at the best architectural solution. Billings justified this experimental approach as an epistemological, pedagogical, economic, and even moral imperative—one that less-endowed institutions could not afford to carry out.

Architectural experimentation was not unprecedented during this period. Experiments and demonstrations were especially fundamental to the environmental design of major nineteenth-century buildings. These experiments, however—such as those of David Boswell Reid on the heating and ventilation of the House of Commons—were usually conducted in temporary structures, models or mock-ups.[16] Billings' intended experiments considered not just systems of heating and ventilation, but also building form which, unlike earlier experiments, was not predetermined. The sheer number of architectural variables and possibilities would have made a laboratory setting impractical. As a set of isolated and independent objects within a larger assembly, the "pavilion plan" hospital typology offered an ideal sampling for an architectural

[16] David Boswell Reid, Illustrations of the Theory and Practice of Ventilation (London: Longman, 1844), 273–309.

laboratory where these variations could be manifested not only independently but also simultaneously, allowing multiple experiments to be conducted at once. In this way, beyond the use of architecture to test or validate a pre-conceived scientific hypothesis, architecture therefore became the requisite premise for the development of a scientific hypothesis and eventually the production of an experiment.

The desire for experimentation at that time was fueled by the rise of the laboratory and experimental medicine in Europe.[17] The laboratory, in words of Claude Bernard, became the sanctuary of medicine. Unlike the *library medicine* of the Middle Ages, the *bedside medicine* of the seventeenth and eighteenth centuries, or the *hospital medicine* of the first half of the nineteenth century that relied on empirical observation and immediate sense impressions, the *laboratory medicine* of the second half of the nineteenth century was an "abstract medicine," concerned primarily with numbers.[18] The construction of an experiment was therefore only a component that needed to be supplemented by a thorough scientific analysis. Building on his administrative and managerial experience in the barrack hospitals of the Civil War, Billings established "a perfect system of records" that documented "not only the history of each patient, but of each ward and each bed" in order to correlate the information collected from patients, classified and grouped in the wards, with temperature and environmental conditions both inside and outside the wards. The performance of the heating and ventilation systems was evaluated with "scientific precision," using thermometers and glass tubes to measure temperature or

[17] For the impact of the laboratory on medicine see: Andrew Cunningham and Perry Williams (eds.), *Laboratory Revolution in Medicine* (Cambridge & New York: Cambridge University Press, 1992).

[18] Erwin H. Acherknecht, *A short History of Medicine,* 2nd ed. (Baltimore: Johns Hopkins University Press, 2016), 160.

velocity of water in the pipes, a "telemeter system" to measure the amount and temperature of air passing through the wards, and pneumatic clocks to ensure uniform time-keeping throughout the buildings. The result was the isolation and abstraction of specific components and conditions of architecture that allowed them to become objects of scientific study and analysis.

By the time the Hospital was constructed, the research and experimental ambitions of the institution came into conflict with the therapeutic mandates of the Hospital. With the building design and the heating and ventilation system as *independent variables* of the experiment, the living patients in the wards assumed the role of the *control group*—a laboratory material or a measure against which architecture's performance could be evaluated. The intricate heating and ventilation system also required regular manipulation and adjustment by the nurses who were trained to attend both "the apparatus and the patients" and keep an hourly record of temperatures, humidity, and air pressure. The Hospital nurses began their training with courses on the properties of air, atmosphere, and study of ventilation systems before reaching human anatomy, digestion or nervous system. This emphasis on the architecture of the Hospital also impacted the record-keeping practices of the institution. From construction diaries to inspection forms and environmental statistics, the architectural records of buildings and their performance far surpassed the medical records of the patients and their treatments.

The Johns Hopkins Hospital represents the convergence of various institutional mandates—medical treatment, education, and research—within architecture. The alliance between the Hospital and the University instigated new approaches to wards medical education and practice. The introduction of "ward-work," "clinical clerkships" and "ground rounds" into the curriculum along with the establishment of the residency, internship, and fellowship programs within the Hospital moved medical education away from large lecture halls and textbooks and towards the hospital wards and the bedside. But more than the objects of an architectural experiment, the buildings were also to play an "instructional" role, as a tool for didactic demonstration of that experiment. To that end, all internal pipes, ducts, traps and apparatus as well as external exhaust stacks and chimneys were exposed to view, and visitors were advised to "note mixing valves in walls at head of beds for regulating temperature." Beyond a conventional hospital or a medical school, the Hospital was intended to function as "a laboratory for teaching the practical application of the laws of hygiene to heating, ventilation, house drainage, and other sanitary matters." The fixation on the architecture of the Hospital as a laboratory was to an extent that the need to include actual clinical laboratory spaces in the buildings was entirely overlooked.

These medical, sanitary and hygienic provisions also had an impact on the choice of materials and finishes throughout the Hospital. At a time when American architects were embracing the revival of classicism and the aesthetic principles of the École des Beaux-Arts, the hygienic and antiseptic principles in the Hospital resulted in bright, sterile interiors with rounded corners, polished surfaces, impermeable materials, and no cornices or ornaments to hold germs or foul air. More that formal or aesthetic theory, these strategies were predicated on architecture's interaction with new and uniquely modern assumptions about social class and institutional structure, industrialization and labor economy, scientific methods and its applications, professionalization and modes of practice, building technology and construction techniques, sanitation and hygienic standards, and advances in methods of higher education and research.

The period between the American Civil War and the turn of the twentieth century witnessed a dramatic transformation in medical education and practice, the rise of public health and sanitary movements, and the development of various technologies that ultimately formed the basic components of the modern hospital system in the United States.[19] Most historians, however, have avoided this period. Existing scholarship on hospitals reflect a binary historiographical approach. On the one hand, many historians have explained the architectural transformation of the hospital as a consequence of sociocultural or medical practices.[20] On the other hand, numerous historians have considered the architecture of the hospital as a disciplinary mechanism that informs social and even scientific practices.[21] This dissertation aims move beyond that dichotomy by taking an approach aligned with Actor-Network Theory that considers technical systems as a necessary component of socio-cultural negotiations between individuals or institutions. In doing so, the dissertation aims to reveal the reciprocal and reflexive nature of architecture in relation to scientific theories and social practices, and to position architecture in relation to means, methods

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19 C. Logan, P. Goad, J. Willis, "Modern Hospitals as Historic Places," *Journal of Architecture* 15, no. 5 (2010), 601–619.

20 Works that examine the periods prior to the nineteenth century, such as John D. Thompson and Grace Goldin's comprehensive survey, *The Hospital: A Social and Architectural History* (1975), portray hospitals as a representation of "social forces" of their time, while those focused on the nineteenth and twentieth centuries consider medical practices and "the progress of medicine and surgery" as the driving force for the reconfiguration of hospital designs. Lindsay Prior has even described the hospital plans as "archaeological records which encapsulate and imprison within themselves a genealogy of medical knowledge." See: Henry E. Sigerist "An Outline of the Development of the Hospital," *BHM* 4, no. 7 (1936), 573–81; John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975); Lindsay Prior, "The Architecture of the Hospital: A Study of Spatial Organization and Medical Knowledge," *The British Journal of Sociology* 1 (March 1988), 86-113.

21 Michel Foucault, *Madness and Civilization: A History of Insanity in the Age of Reason* (New York: Vintage Books, 1973); Michel Foucault, "The Incorporation of the Hospital into Modern Technology" (1976); Michel Foucault, *Discipline and Punish: The Birth of the Prison*, (New York: Vintage Books, 1979); Thomas Mann, *Tristan,* in *Stories of Three Decades* (1903), trans. H. T. Lowe-Porter (London: Martin Secker and Warburg, 1922); Thomas Mann, *The Magic Mountain* (New York: A. A. Knopf, 1927); Sven-Olov Wallenstein, *Biopolitics and the Emergence of Modern Architecture* (New York: Princeton Architectural Press, 2009).

and techniques of production and dissemination of knowledge. The application of the scientific method and the experimental approach towards the architecture of the Johns Hopkins Hospital is a critical component of that narrative that displaces the conventional understanding of architecture as an application of scientific knowledge. Beyond the use of architecture to test or validate a pre-established scientific hypothesis the dissertation reveals an instance where architecture became an essential ingredient for the development of a scientific hypothesis and the production of an experiment—the Heideggerian notion that *technique* can often precedes *knowledge*.

My goal is therefore to take the discussion of *clinic* beyond bio-politics and the notion of *discipline*, and towards a new domain that emerges from the interaction between architecture and medicine. Existing scholarship in Actor-network Theory and the work of Bruno Latour offers a better methodological approach especially in examining the history of an institution that fundamentally challenged those disciplinary distinctions. The dissertation therefore focuses on specific instances of interaction between humans and non-humans within the hospital where the therapeutic, educational, and research mandates of the institution informed and were informed by its architecture—how they were understood, produced, constructed and even represented.

The chapters are arranged as three phases or episodes within that process by which architecture was subjugated or disciplined. Each chapter addresses different forms of interaction between medicine and architecture in the planning, construction or early operation of the Hospital that resulted in the formation of new methods, objects, materials or solutions in architecture. The episodes follow the layered steps in the design process while addressing their implication on the final built Hospital, moving from discussions of the site and planning of the complex to the design of the buildings and finally the selection of materials and finishes. In discussing these episodes, each chapter focuses on specific drawings or representational techniques through which these forms of interactions were described and designed: from site and block plans, to building floor plans and sections, and finally exterior elevation, perspectival drawings and photographs.

Chapter 1 discusses the planning of the Johns Hopkins Hospital as an iterative process that emerged in the deliberations between the trustees, the consulted physicians, the medical advisor, and the architect, and manifested in the numerous plans of the Hospital. The architectural plan emerged during this period as a requisite professional medium, an instrument of power (both policy and planning) as well as a mechanism for disease prevention or even cure. Through this process, the plan of the Hospital came to be seen not simply as a representation but as an analytical device that ultimately formed the hypothesis of an architectural experiment. As an ensemble of separate and autonomous components, the precedent of the pavilion and the barrack plans allowed Billings to conceive the Hospital as a flexible and provisional *system* where building form, location, materiality, technology, or even lifespan could be altered without affecting the plan. The plan at once mediated the juxtaposition of various, and incompatible, measures of personal, medical, and architectural individuality that while neatly classified in charts and drawings, they were incongruous in reality.

Chapter 2 attempts to build on, and to some extent reframe, the discussion of building technologies within architecture by closely examining the design and implementation of the heating and ventilation system at the Hospital. The chapter has been framed as a response o Reyner Banham framing of the development of systems of environmental control in buildings as something that occurred largely outside architecture and was only reconciled with architectural design in the early twentieth century. I intend to illustrate not only those forms of the integration between architecture and technology did already appear before the twentieth century, but that the two domains were not always seen as mutually exclusive. In that sense, more than a process of *integration* or *subordination* of one domain to the other, the Johns Hopkins Hospital reveals instances of *consolidation* of architecture and technology towards achieving thermal and environmental control. The chapter examines three instances where that *consolidation* took place. These various architectural propositions that emerged from that interaction—from rounded corners, self-closing doors, and exposed pipes to air spaces and glass tubes—conceived the architecture of the Hospital as a single pneumatic machine.

Chapter 3 then examines how the Hospital's bipolar identity, as both a medical and a public institution, resulted in a disjunction between the architectural interior and the exterior: a plain and sterile interior with no colors, cornices or curtains that could hide or harbor germs, and a colorful and ornate exterior, adorned with with vegetal and floral motifs. This disjunction was informed by the division of professional roles and responsibilities during the design, documentation and construction. The interior, the domain of medicine, was prioritized in the design process and worked out and prescribed by the physician in detailed plans and sections, while the exterior, the domain of architecture, was left out to the architect, and designed in elaborate elevations. The disparity between the two domains reflects a fundamental shift in the design process that also informed different representations, reviews and receptions of the project in architectural versus medical journals. The chapter examines three phases where this process of internalization and decontamination took place: From the probing of the architectural mass and the removal of building cavities, to the interrogation of interior surfaces and the stripping of architectural ornament from the interior, and finally the careful examination and selection of building materials, finishes, and colors. These choices, beyond an expression, were the very means and mechanisms that enabled the institution to function as medical and hygienic environment.

# 1. BEDS AND PAVILIONS:
## Planning the Architectural Experiment

In a letter on March 10, 1873, shortly before his death, Baltimore businessman and philanthropist Johns Hopkins instructed his trustees to build a hospital in connection to the medical school of his university that would "compare favorably with any other institution of like character in this country or in Europe."[1] He asked them to devote their time that year to "the most careful and deliberate choice of a plan" and "obtain the advice and assistance of those, at home and abroad, who have achieved the greatest success in the construction and management of Hospitals."[2] The trustees formed a Building Committee and spent the following year consulting the literature, visiting hospitals in Philadelphia, New York, Boston and Washington DC, and debating how to

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[1] Hopkins' own personal life had a profound impact in shaping the twin institutions that he founded later in his life. He was born on May 19, 1795 at Whitehall, a 500-acre tobacco plantation in Maryland. He was the second eldest of eleven children and had a Quaker upbringing. At 17, Hopkins was sent to Baltimore to live with his uncle who had a wholesale grocery business. He left after facing religious objection to marry his cousin Elizabeth. Neither he nor his cousin ever married. Hopkins initially started a business with a fellow Quaker, Benjamin Moore, but the partnership was dissolved later with Moore alleging Hopkins' obsession for capital accumulation as the cause for the divide: "Johns is the only man I know who wants to make money more than I do." Hopkins then embarked on his own business ventures, and in 1819 established his own wholesale company with his three brothers, Hopkins & Brothers Wholesalers, that sold provisions, most notably "Hopkins' Best" whiskey, in the southern states. By 1847, when he retired at the age of fifty-two, he had become the leading financial figure in Baltimore and would move on to accumulate more wealth than any other in America. Hopkins himself made most of his wealth through investments in the Baltimore & Ohio Railroad Company (B&O), the first commercial railroad to be chartered and built in the United States, where he was the largest stockholder and was appointed as the director in 1847. The most referenced biography of Hopkins is written by his grand-niece: Helen Hopkins Thom, *Johns Hopkins, A Silhouette* (Baltimore: The Johns Hopkins Press, 1929).

[2] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 3-4, 8.

approach the project. After much deliberation, in May of 1874, over a year after the letter, they appointed John R. Niernsée as the architect of the Board.[3]

Niernsée was well qualified for the job. Trained as an architect and engineer at Prague Polytechnic, he was among the early members of the American Institute of Architects (founded in 1857), and had established the first professional architectural practice in Baltimore.[4] He had also worked for Hopkins and Francis King, the President of the Board, and was even nominated by President Ulysses S. Grant as the U.S. representative and his personal delegate to the Vienna International Exposition in 1873.[5] He was also well-versed on the subject of hospital construction.[6] Despite this, the trustees remained ambivalent. The Building Committee—comprised of two businessmen, two lawyers, a physician and a railway manager—considered the design and construction of the Hospital as "a technical scientific question," and their lengthy

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[3] The Committee has received multiple application for the position that had initially approached George Aloysius Frederick, the architect of the Baltimore City Hall, and even began preparing his contract in April of 1874 before hiring Niernsée who was hired a fee of $3,000 per annum, payable monthly. *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (April 13-May 13 1874), 19, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

[4] In his 1875 essay proposal, Niernsée introduced himself in the following way: "John R. Niernsée, F.A.I.A., Architect to the Board of Trustees of the Johns Hopkins Hospital, Corresponding member of the Austrian Institute of Architects and Civil Engineers, Member of the U.S. Commission of Science and Art, and Member of the Jury of the Exposition of Vienna in 1873."

[5] Niernsée had designed Hopkins' Clifton country house (1852), the Grocer's Exchange building (1856), and the Rialto Building (1869), as well as a warehouse (1869) for Francis King, the President of the Board of Trustees of the Hospital. While he was not an expert in hospital design and construction, he was well-informed on the subject. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 185. For more on Niernsée see: Rudolph W. Chalfant, Charles Belfoure, *Niernsee and Neilson, Architects of Baltimore: Two Careers on the Edge of the Future* (Baltimore: Baltimore Architecture Foundation, 2006).

[6] In the beginning of his short essay in the appendix of *Hospital Plans,* Niernsee alluded to "Having made hospital construction a close and careful study as regards the various plans and the best authorities, and having examined personally many of the best and latest constructed hospitals in this country and in Europe," before outlining his observations about hospitals. See: John R. Niernsée, "Appendix II," in *Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 335-336.

report on November 13, 1874, they recommended consultation with "five distinguished physicians" with hospital expertise:[7]

> *In this state of opinion, your Committee, who, with only one exception, are unlearned upon the subject do not feel justified in attempting to cope, unaided, with a technical scientific question, where such momentous philanthropic interests are involved. They therefore ask you to authorize them to confer with five distinguished physicians, who have made the subject of Hospitals their special study, chosen from different parts of the country, to obtain from them such advice as they may need and compensate them for it. By this means the Committee and the Board will be relieved from much responsibility and will have the comfortable assurance that they have taken the best possible mode of securing the benevolent intentions of the Founder.*[8]

In March of the following year, King wrote to five prominent physicians.[9] In that letter, he shared the nature and approximate budget for the hospital, attached a copy of Hopkins' letter of instructions along with excerpts from his will, and invited the physicians to submit their suggestions and advice on the relationship between the Hospital and its constituent educational facilities, methods of heating and ventilation, and the organization and management of the

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[7] The Building Committee included: Francis T. King, as the Chairman, along with Galloway Cheston (merchant), Alan P. Smith (physician), George W. Dobbin (lawyer), Charles J. M. Gwinn (lawyer and B&O Counsel), and John W. Garrett (banker and B&O President). Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. 1 (Baltimore: The Johns Hopkins Press, 1943), 17. John Shaw Billings would later describe the Trustees as "businessmen, bankers, lawyers, judges, railway managers merchants, men who knew something of the management of men and money" but had not much experience or expertise in hospital construction. John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 2.

[8] "Report of the Building Committee" (November 12, 1874) in *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (Novemver 13, 1874), 22, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

[9] The five physicians included: John Shaw Billings, Brevet Lieutenant Colonel and Assistant Surgeon in the U.S. Army in Washington; Norton Folsom, superintendent of the Massachusetts General Hospital in Boston; Joseph Jones, Professor of Chemistry and Clinical Medicine at the University of Louisiana in New Orleans; Caspar Morris, a physician and one of the founders and designers of the Protestant Episcopal Church Hospital in Philadelphia; and Stephen Smith, a New York surgeon and designer of the Roosevelt Hospital. Smith later served with Billings as charter member of the National Board of Health (NBH).

institution. The doctors were asked specifically to weigh in on the binary choice between the two dominant hospital typologies: the multi-story permanently-constructed buildings of the "pavilion system," and the single-story temporary structures of the "barrack system." They were also asked whether the "general principles of hospital hygiene and of hospital treatment" can be best applied through the use of one of the two systems, or alternatively through "the selection of the good features of each, and the combining of them all into a harmonious middle course."[10]

In response, the physicians submitted long elaborate essays, populated by statistical charts, tables, and architectural drawings.[11] Impressed with the depth and scope of the essays, the trustees to compile them and publish them in a volume, *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals.* While the *Hospital Plans* offered a comprehensive review of the current knowledge of hospital design and outlined plans of action —it later acquired the status of an American textbook on hospital design—it also revealed the complexity of planning an institution with a heterogenous mandate for medical practice,

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[10] In a section discussing the two building typologies, the letter read: "It will readily occur to you that the subject most prominent at this day, in the professional consideration of the Hospital question as applicable to cities, is the choice between the pavilion system, which admits buildings of two or more stories in height, permanently constructed, of which the Herbert Hospital in England and several in this country may be considered good modern types; and the barrack system of one story structures, destructible in whole or in part, which were so successfully used in the late war, but of which no extensive and prominent example is now in operation." Francis T. King, "Letter Addressed to the Authors of the Essays" (March 5, 1875), in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), x-xi

[11] while architectural drawings were not expected, all essays were accompanied by detailed drawings, including site plans, floor plans, and even a few wall sections showing air flow. In his letter to the five physicians, King wrote: "In the treatment of these subjects, it is not to be expected that you will present architectural drawings, but if your views can be illustrated by such suggestive sketches as your pen or pencil can throw off in aid of your thoughts, they will be gratefully received, and placed in the hands of our architect for more elaborate expression." Francis T. King's letter to the Five Physicians (March 6, 1876), in John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 19.

education and research.[12] The Building Committee found the subject to be "full of professional scientific questions," and in their report, on June 28, 1876, concluded that "daily professional aid and advice of a medical man will be necessary."[13] They recommended one of the five physicians, John Shaw Billings, Assistant Surgeon in the U.S. Army, noting that they have found no one with more knowledge of medical education, hospital hygiene and organization than him.[14]

Billings, while a well-known figure in American Medicine, had developed his career almost exclusively outside the field of Clinical Medicine.[15] In his role as the Assistant Surgeon in the U.S. Army, Billings had been in charge of the American military hospitals and had gained a reputation as an expert in hospital construction and hygiene.[16] In his role as the Assistant Surgeon in the U.S. Army, he had expanded the small collection of books at the Surgeon General's office into the largest collection of medical texts in the world, and devised an indexing system—the *Index-Catalogue,* later supplemented by the *Index-Medicus*—which would form the

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[12] *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (November 9, 1875), p 34, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions (accessed on November 2, 2018). The essays were edited by Billings and published in form of a book: *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875). Jeanne Kisacky has discussed in the impact of *Hospital Plans* briefly in her book: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 187.

[13] *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (June 28, 1876), 38-39, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

[14] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 1-46.

[15] In various scientific articles and books, Billings is known today as a sanitarian, statistician, administrator, librarian, medical historian, educator, and architect. For a biography of Billings see: Fielding Hudson Garrison, *John Shaw Billings: A Memoir* (New York: G. P. Putnam's Sons, 1915).

[16] The Building Committee noted that Billings "has been in general charge, for some years past, of the U.S. Hospitals," and his "highest reputation at home and abroad, as one specially skilled in this subject." *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (June 28, 1876), p 38-39, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

key components of the National Library of Medicine (NLM).[17] The trustees believed that Billings command of that library and his access to all the literature extant "could aid in the successful consummation of our work."[18] He was hired as a "Medical Advisor" to the Board in July of 1876 and charged with leading the design and construction of the Hospital.[19] Niernsée was then reportedly asked "to prepare his plans in consultation with and under the supervision of a surgeon who is a recognized authority in hospital construction."[20]

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[17] Wyndham D. Miles, *A History of the National Library of Medicine, The Nation's Treasury of Medical Knowledge* (Bethesda, MD: NIH Publication, 1982), 119, 127; Harry Miller Lydenberg, *John Shaw Billings: Creator of the National Library and its Catalogue, First Director of the New York Public Library* (Chicago: American Library Association, 1924), 44-45; Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. 1 (Baltimore: The Johns Hopkins Press, 1943), 25-27; National Library of Medicine (NIH), "A Brief History of NLM", Last Reviewed on March 20, 2019, Retrieved on June 23, 2020. Billings was also a leading figure in the sanitary reform and served as the Vice-President of both the American Public Health Association (APHA) and later the National Board of Health (NBH). He headed the U.S. Census Office's division of Vital Statistics and even worked with Herman Hollerith to develop the punch card tabulating machine. The idea of a punch card tabulating machine was proposed by Billings to Hollerith. Hollerith took Billings suggestion and spent the next few years developing a punch card tabulating machine, which he filed a patent for in January 8, 1889, under the title: "Art of Compiling Statistics." For more on the history of the punch card tabulation machine see: Leon Edgar Trunesdell, *The Development of Punch Card Tabulation in the Bureau of the Census, 1890-1940, with Outlines of Actual Tabulation Programs* (Washington, D.C.: U.S. Government Printing Office, 1965). He would later work with Andrew Carnegie to help establish the New York Public Library (1895) and serve as its first director. In various scientific articles and books, Billings is known today as a sanitarian, statistician, administrator, librarian, medical historian, educator, and even architect. For a biography of Billings see: Fielding Hudson Garrison, *John Shaw Billings: A Memoir* (New York: G. P. Putnam's Sons, 1915).

[18] *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (June 28, 1876), p 38-39, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

[19] *Minutes of the Board of Trustees, Johns Hopkins Hospital*, (June 28, 1876), p 38-39, from Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

[20] *The American Architect and Building News,* (October 6, 1877), 318. In his essay proposal, Billings had outlined his "general plan" for the design process, delegating much of the responsibilities to the architecture and the engineer: "I have endeavored to point out the effects which it is desirable to produce, but the means of obtaining these effects, so far as the construction of buildings and the apparatus for heating, etc., is concerned, come more within the scope of the studies of the Architect and Engineer than of the Physician, and I do not doubt but that there are better ways of planning both the individual buildings and their combination into one general plan than those I have indicated." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 44.

In the months that followed, Billings approached the planning of the Hospital as a scientific project. He surveyed the current practices on the basis of literature reviews, visited existing hospitals and medical schools in the United States and Europe, consulted with expert scientists, even conducted limited experiments in two hospitals and carefully recorded his observations and findings in his numerous reports to the Building Committee. However, unable to obtain any reliable data, he opted to use the built Hospital itself as an architectural experiment: "a sort of laboratory of heating and ventilation." To that end, he used different building types and heating and ventilation systems as experimental variables and postulated that a careful comparison of the data obtained would reveal the best architectural solution and contribute to the knowledge of hospital hygiene.

The following pages examine the planning of the Johns Hopkins Hospital as an iterative process that emerged in the deliberations between the trustees, the consulted physicians, the medical advisor, and the architect, and manifested in the numerous plans of the Hospital. The architectural plan emerged during this period as a requisite professional medium, an instrument of power (both policy and planning) as well as a mechanism for disease prevention or even cure. Billings in particular considered the plan as a potent and uniquely utilitarian device, and regularly insisted that the "main purpose" of the Hospital "should be fully worked out in the plans before any attention was paid to external appearance."[21] From Hopkins' plans *for* the Hospital and the five physicians' *Hospital Plans*, to Billings and Niernsée's plans *of* the Hospital

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[21] Billings wrote: "It was therefore decided that, while no utility should be sacrificed for the sake of architectural ornament, and the main purpose which I have referred to should be fully worked out in the plans before any attention was paid to external appearance, it was fit and proper that the buildings should form an ornament to the city, and a suitable monument to the memory of the donor." John S. Billings, *The Plans and Purposes of the Johns Hopkins Hospital*, (1889).

and finally Billings' *Plans and Purposes of the Johns Hopkins Hospital,* the planning process reveals of the multi-faceted and layered condition of the architectural plan. Through this process, the plan of the Hospital came to be seen not simply as a representation but as an analytical device that ultimately formed the hypothesis of an architectural experiment.

This evolution of the plan, from a fixed and deliberate architectural statement to a provisional scientific hypothesis, was predicated on the therapeutic assumptions about the Hospital and its architecture. From the "pavilion plan" to the "Kirkbride plan" and the "barrack plan," nineteenth-century doctors, medical professionals and sanitarians saw the architecture of the hospital as a therapeutic instrument and regularly prescribed their own designs and even drew their own plans.[22] As an ensemble of separate and autonomous components, the precedent of the pavilion and the barrack plans allowed Billings to conceive the Hospital as a flexible and provisional *system* where building form, location, materiality, technology, or even lifespan could be altered without affecting the plan.[23] The basic structure of the pavilion plan, however,

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[22] During the nineteenth century, the belief that poor ventilation and the unsanitary condition of buildings contributed to the spread of disease prompted doctors to make and prescribe their own plans. Doctors regularly published articles in newspapers and engineering journals on principles of hygienic architecture, they discussed plumbing and ventilation, and even regularly critiqued domestic architecture and offered their own solutions. Annmarie Adams has shown how doctors in the nineteenth century regularly critiqued domestic architecture and offered their own solutions. Annmarie Adams, *Architecture in the Family Way: Doctors, Houses and Women, 1870–1900* (Montreal and Kingston, McGill-Queens University Press, 1996), 36–72.

[23] Jean-Nicolas-Louis Durand's *Recueil et Parallèle* (1799-1801) catalogued the various hospital typologies before publishing his own pavilion plan in *Précis des leçons* (1802-1805). Durand's hospital, similar to most other pavilion plan hospitals, organized parallel pavilions around a grand courtyard. See: Jean-Nicolas-Louis Durand and Jacques-Guillaume Legrand, *Recueil et parallèle des édifices de tout genre, anciens et modernes, remarquables par leur beauté, par leur grandeur ou par leur singularité, et dessinés sur une même échelle* (Paris: Gillé fils, 1799-1801; reprint of 1842 éd., Nórdlingen, A. Uhl, 1986); Jean-Nicolas-Louis Durand, *Précis des leçons d'architecture données à l'École Polytechnique,* 1 vols. (Paris: the author, 1802-5; rev. éd., Paris: the author, 1817-19; reprint of rev.éd., Nórdlingen, A. Uhl, 1985). According to Nikolaus Pevsner, the full acceptance of the pavilion plan came only with the construction of Pierre Gauthier's Hôpital Lariboisière in Paris, completed in 1854. Nikolaus Pevsner, *A History of Building Types* (Princeton: Princeton University Press, 1979), 150-157.

imposed a system of classification that while separated the wards, the beds and the patients, it did not ultimately treat them as equal. The plan at once mediated the juxtaposition of various, and incompatible, measures of personal, medical, and architectural individuality that while neatly classified in charts and drawings, they were incongruous in reality.

The rise and fall of the pavilion plan during the second half of the nineteenth century has attracted much speculation on the relationship between architecture and science. The emergence of the pavilion plan, as a *plan* drawn and promoted by medical doctors, has situated it in tangent with medical theories that instigated or promoted it. In various surveys of hospitals and articles on the pavilion plan, historians have drawn a direct correlation between disease theories and the plan itself. Allan M. Brandt and David C. Sloane, for instance, have even used Billings' early sketch plan of the Johns Hopkins Hospital (Figure 1.1) as evidence that the design "used a pavilion style, relying on the miasmatic theory of disease."[24] As a result, many historians, such as Nikolaus Pevsner, Adrian Forty, Anthony King, Guenter Risse, Lindsey Prior and J. T. H. Connor, have attributed the transformation of the American hospital from the low-rise naturally-ventilated pavilions of the late nineteenth century to the mid- and high-rise mechanically-ventilated buildings of the early twentieth century to the epistemic shift in scientific theories of

[24] Allan M. Brandt and David C. Sloane, "Of Beds and Benches: Building the Modern American Hospital," in Peter Galison and Emily Thompson (eds.), *The Architecture of Science* (Cambridge, MA: MIT Press, 1999), 287.

disease.[25] The germ theory of disease, Lindsay Prior has reasoned, “changed medicine and therefore also hospital design.”[26]

This assumption has led others, like Jeremy Taylor, Annmarie Adams, Jeanne Kisacky, David Charles Sloane and Beverlie Conant Sloane, to ask, why then pavilion plan hospitals continued to be built well into the 1930s?[27] Jeremy Taylor has argued that as a powerful architectural concept, an “orthodoxy,” the pavilion plan remained resilient in the face of advances in bacteriology and the shifting scientific theories of disease because it allowed architects, or physicians, to continually modify and improve it. In his view, the pavilion plan adopted smaller-scale innovations informed by germ theory, such as the shift from natural to mechanical ventilation, which allowed it to be refined and adjusted well into the twentieth century.[28] Taylor

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[25] Lindsay Prior, “The Architecture of the Hospital: A Study of Spatial Organization and Medical Knowledge,” *The British Journal of Sociology* 39 (1988); J. T. H. Connor, “Hospital History in Canada and the United States,” *Canadian Bulletin of the History of Medicine* 7 (1990); Adrian Forty, “The Modern Hospital in England and France,” in *Buildings and Society,* Anthony D. King (ed.) (1980); Anthony D. King, “Hospital Planning: Revised Thoughts on the Origin of the Pavilion Principle in England,” *Medical History* 10 (1966); Adrian Forty, “The Modern Hospital in France and England,” in *Buildings and Society: Essays on the Social Development of the Built Environment*, Anthony D. King (ed.) (Boston: Routledge and Kegan Paul, 1980), 83; Nikolaus Pevsner, “Hospitals,” *A History of Building Types* (Princeton, NJ: Princeton University Press, 1976), 158; Lindsay Prior, “The Architecture of the Hospital: A Study of Spatial Organization and Medical Knowledge,” *British Journal of Sociology* 39, no. 1 (1988), 93–95; Guenter Risse, *Mending Bodies, Saving Souls: A History of Hospitals* (New York: Oxford Univ. Press, 1999), 469.

[26] Lindsay Prior, “The Architecture of the Hospital: A Study of Spatial Organization and Medical Knowledge,” *British Journal of Sociology* 39, no. 1 (1988), 93–95.

[27] David Charles Sloane and Beverlie Conant Sloane, *Medicine Moves to the Mall* (Baltimore: Johns Hopkins University Press, 2003), 58; Jeremy Taylor, *The Architect and the Pavilion Hospital* (London: Leicester University Press, 1997), 91; Annmarie Adams, “Reviewed work: *The Architect and the Pavilion Hospital: Dialogue and Design Creativity in England, 1850- 1914* by Jeremy Taylor,” *Victorian Studies*, Vol. 41, No. 3, Victorian Ethnographies (Spring, 1998), 550-553; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 204-209.

[28] Jeremy Taylor, *The Architect and the Pavilion Hospital: Dialogue and Design Creativity in England, 1850–1914,* (London: Leicester University Press, 1997).

and others have therefore argued that the prolonged life of the pavilion plan after the 1880s and 1890s does not necessarily suggest a continued adherence to the miasma theory.

These debates are predicated on the assumption that the various hospital typologies during this period operated as an application of scientific knowledge and theories of disease—the idea of medical science as the cause and the hospital architecture as the effect. The planning of the Johns Hopkins Hospital suggest that the relationship between the two domains were not as straightforward. The specific conditions of the pavilion plan—the spacing and separation of wards, compartmentalization and classification of patients, the disinfecting or even destruction strategies—did indeed make the plan fully compatible to the new sanitary principles of germ theory. And the precedent of barrack hospitals allowed Billings to redefine the pavilion plan as one that could be temporary or perishable, therefore allowing it to be fully disinfected or destroyed when necessary. The choice of the plan, therefore, involved a profound examination of conditions (temporary or permanent building materials, one or two-story pavilions, natural or mechanical ventilation, etc.) that were fundamentally architectural, as well as criteria (social, economic, technological, etc.) that did not always concern, or correspond to, medical science.

The debates around post-germ theory hospitals also do not take into consideration the various external forces, often outside both medicine and architecture, that impacted the plan of these institutions: the increase in patient population and size of hospitals, the shrinkage of available land for its site, the shift from private to public funding, the changing perception of air quality in cities, the introduction of new methods of construction such as steel frame and reinforced concrete, the invention of new building technologies like the elevator or mechanical heating and ventilation, and last, but not least, the sociocultural transformations especially instigated by the modern movement. It wasn't just medicine but architecture too was radically transformed during this period. Professionalization of architecture along with the increased complexity of means of production and construction limited the involvement of doctors and amateur architects in the design and construction. None of these changes worked in favor of the pavilion plan.

This is not to say that the pavilion plan was simply a passive recipient or a representation of medical or architectural ideas. To the contrary, Billings' numerous plans of the Johns Hopkins Hospital represent the disintegration of some of the fundamental elements that constituted architecture during this period—the Vitruvian *firmitatis* or even *venustatis*—in favor of a *system* of isolated and modifiable parts. The incorporation of the corridor, as a building infrastructure, was instrumental in establishing a systematic cohesion between the isolated buildings and pavilions of the Hospital. As a terrace-corridor-tunnel amalgam, the corridor system of the Hospital was conceived as a spatiotemporal organizational device that allowed for both separation, connection and communication of different classes of individuals, categories of air, types of architecture, and methods of treatment. This condition of the corridor was predicated on uniquely modern assumptions about social and class structure, industrialization and labor economy, and sanitation and hygiene, that came to constitute the corridor during this period as an "instrument of modernity."[29]

The plans of the Hospital was continually presented, modified and re-presented as a set of variables: temporary or permanent, wood or brick, one or two stories, twelve or sixteen

[29] Mark Jarzombek, "Corridor Spaces," *Critical Inquiry* 36 (Summer 2010), 767-770.

pavilions, classified by patients or diseases, heated by steam or water, ventilated naturally or mechanically, built at once or in phases, etc. The superimposition of these layers in plan as a set of autonomous and independent variables allowed Billings to ultimately conceive the final plan of the Hospital as an experimental hypothesis, and turn the built Hospital into an architectural laboratory. Rather than a deliberate architectural statement that precedes construction, the plan was used as a provisional framework for exploring and experimenting various architectural ideas in built form. In this way, rather than a product or an application of scientific knowledge, or simply a means to test or validate a pre-conceived scientific hypothesis, the planning process at the Johns Hopkins Hospital reveals an instance where architecture became the essential ingredient for the development of a scientific hypothesis and eventually the construction of an experiment.

### 1.1 Isolated Pavilions

In the 1870s, during the planning of the Johns Hopkins Hospital, medical science was in the midst of an epistemic transition. Challenging the basic assumptions of the miasma theory, the germ theory of disease maintained that diseases are not caused by foul air or effluvia but by minute living particles or microscopic organisms. Advances in bacteriology were well underway in Europe since the 1850s. During the London epidemic of 1854, John Snow had surveyed and plotted cholera incidents on a map and traced their origins to a water pump and an adjacent cesspit, thereby challenging the air-borne assumptions about disease and supporting fecal-oral route mode of its transmission.[30] In the 1860s, through conducting a series of experiments, Louis Pasteur had identified a number of microorganisms as the causes of diseases and had even developed a method of killing them with boric acid.[31] And inspired by Pasteur's experiments, Joseph Lister had developed practical applications of the germ theory to sanitation in medical and surgical practices.[32] Lister's work provided evidence that "hospital diseases" and "hospitalism" was not a product of the hospital air or its architecture but the unsanitary medical practices.[33]

The medical community in the United States were well aware of the advances in bacteriology in Europe and the work of Pasteur, Lister and others. Most early germ theorists, however, still

[30] In 1849, John Snow, a skeptic of the miasma theory, had published an essay "On the Mode of Communication of Cholera," where he suggested that disease replicated itself in the lower intestines and that the fecal-oral route was the mode of disease communication. See: John Snow, *On the Mode of Communication of Cholera* (London: J. Churchill, 1849). Later in 1855, he had even suggested that the structure of cholera was that of a cell.

[31] Pasteur discovered the pathology of the puerperal fever and the pyogenic vibrio in the blood, and suggested using boric acid to kill these microorganisms before and after confinement. He further demonstrated hat fermentation and the growth of microorganisms in nutrient broths did not proceed by spontaneous generation, therefore, living organism that grew in the broths came from outside, and not within. In 1870, he discovered that another serious disease of silkworms, *pébrine*, was caused by a microscopic organism now known as *Nosema bombycis* (1870), and developing a method to screen silkworms eggs for those that were not infected, saving France's silk industry. See: Louis Pasteur, "On the extension of the germ theory to the etiology of certain common diseases," H.C. Ernst (trans), *Comptes Rendus de l'Académie des Sciences,* XC (May 1880) 1033–1044.

[32] Joseph Lister, "On the Antiseptic Principle in the Practice of Surgery," *British Medical Journal* 2, no. 351 (September 21, 1867), 246–248. Considering hospital disease as "septic" diseases—with symptoms and progression that imitated decomposition—Lister experimented with various "antiseptics" in the hospital environment and discovered the use of carbolic acid (phenol) as an effective material capable of killing the germs. For more on the impact of Lister's work on surgery see: Lindsey Fitzharris, *The Butchering Art: Joseph Lister's Quest to Transform the Grisly World of Victorian Medicine* (London: Penguin, 2017).

[33] These developments were further advanced through the work of Robert Koch in the 1880s who developed four basic scientific criteria, known as "Koch's postulates," for demonstrating that a disease is caused by a particular organism. With the discovery of viruses in the 1890s, the germ theory of disease established itself as the prevalent scientific theory.

considered microorganisms to be “atmospheric” entities that floated in the air.[34] The focus, therefore, simply shifted from invisible and immaterial influences like *miasma* or *effluvia,* to microscopic material agents such as *germs*, *particles,* or *disease-dust.*[35] As a result, much of the old sanitary science was reappropriated to the new germ theory, and ventilation continued to be seen as the foremost cause and cure of disease. “Of so-called ‘germs’ we say nothing,” wrote Dr. Winsor in an article in *American Architect and Building News* in 1877, “save that, whatever they may prove to be, they must be least numerous and least dangerous in proportion as the ventilation is most complete.”[36]

At the time he wrote his essay, Billings’ ambivalence towards these new scientific developments reflected a position which to some extent, similar to many in the scientific community in the United States, considered both theories to be true.[37] He discussed this in the third section of his

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[34] Lister wrote, “If it were true that the air does not contain the causes of putrefaction then it would not be necessary for me, in carrying out the antiseptic system of treatment, to provide an antiseptic atmosphere.” Joseph Lister, “A Contribution to the Germ Theory of Putrefaction and Other Fermentative Changes, and to the Natural History of Torulae and Bacteria,” *Transactions of the Royal Society of Edinburgh* 27, no. 3 (1875), 315; See also: Joseph Lister, “On the Effects of the Antiseptic System of Treatment upon the Salubrity of a Surgical Hospital,” *Lancet* 95, no. 2418 (1 Jan. 1870), 4–5.

[35] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 200; Nancy Tomes has shown how the new design manuals continued to make the same recommendations to those of the earlier guides but now promoted ventilation as a means of removing “bacterial clouds” floating in the atmosphere. Nancy Tomes, *The Gospel of Germs: Men, Women and the Microbe in American Life* (Cambridge: Harvard University Press, 1998), 46, 58. Alistair Fair has also noted the strident language used in articles and patents in 1870s and 1880s, such as those by Robert Boyle, as evidence of the continuing ferocity of the discourse on ventilation and its relation to disease. Robert Boyle, *Experiments with Exhaust Ventilators at the Health Exhibition* (London, Robert Boyle, 1884), 2–3; Alistair Fair, “‘A Laboratory of Heating and Ventilation’: The Johns Hopkins Hospital as Experimental Architecture, 1870–90,” *Journal of Architecture* 19, no. 3 (2014), 357–81.

[36] Dr. F. Winsor, “The Ventilating and Warming of Schoolhouses in the Northern United States,” *The American Architect and Building News,* vol. II, no. 93 (October 6, 1877), 319.

[37] For more on the American medical community’s response to germ theory see: Thomas P. Gariepy, “The Introduction and Acceptance of Listerian Antisepsis in the United States,” *JHMAS* 49, no. 2 (1994), 167–206.

essay, “On the Causes of Hospitalism, or the Hurtful Influence of Hospitals,” where he argued that the air in a hospital ward is contaminated in two very different ways: gases and particles. In adhering to the miasmatic tradition, Billings identified the presence of certain gases—carbonic oxide, and carbonic acid, sulphuretted and phosphuretted hydrogen, and ammonia and its compounds and substitution products—as the first source of air contamination but noted that these gases rarely exist in a “dangerous amount,” and that sufficient dilution with fresh air with ventilation would prevent them from being harmful. He then argued that the more serious cause of air contamination in hospitals is from “minute particles of solid or semi-solid insoluble matter” that can grow and reproduce if they come into contact with a living body, and therefore cause or aggravate disease. “It is to these particles, known as disease germs, contagia, microzymes, micrococci, bioplasm, germinal matter, etc.,” he wrote, “that are supposed to be due the majority, if not all, of the contagious and infectious diseases, including those specially prevalent in hospitals and referred to in the term “Hospitalism.””[38]

Billings considered germs to be particularly resilient creatures, able to withstand cold or dry conditions, even resist cleaning agents like soap and water where they can often “gain new powers,” and he believed them to be “almost omnipresent” in the hospital, “in the air, the bedding, the hair, and the clothes of all occupants of the building.”[39] He considered the “theory of good hospital management” (ventilation and thorough scientific cleanliness) ineffective in

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[38] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 11-12.

[39] Joseph Lister, “On the Antiseptic Principle in the Practice of Surgery,” *British Medical Journal* 2, no. 351 (September 21, 1867), 246–248. For more on germs and disease in America see: Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Cambridge, MA: Harvard University Press, 1998).

eliminating germs entirely, saw ordinary disinfecting gases (sulphurous acid, chlorine, and ozone) to be inadequate, and antiseptic liquids to be inefficient for large hospital wards.[40] Billings' solution was to instead apply an "ounce of prevention" through systematic classification and separation of patients, and a complete isolation of contagious or "dangerous" cases.[41] To that end, he proposed that the wards be "totally separated" and "totally disconnected from each other," with at least fifty to a hundred feet space.

Among the most popular hospital typologies during this period was the "pavilion plan," which had been promoted by Florence Nightingale in her influential book, *Notes on Hospitals* (1859), for its organizational and therapeutic merits.[42] Conceiving the hospital as a series of low-rise detached buildings evenly spaced across a large open ground, the pavilion plan aimed to distribute the patients in separate wards in order to minimize the spread of disease (prevention) and maximize the exposure to natural light and air (cure). For much of its history, however, the pavilion plan only existed in the realm of drawings and imagination. From Christopher Wren's proposal for the Greenwich Royal Naval Hospital (1702) to those of Jean-Baptiste Le Roy

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[40] Billings cited the "experiments of Chauveau on the effects of dilution of the Sheep-Pox virus," as well as physician Burdon Sanderson's reports "On the Intimate Pathology of Contagion" in the twelfth Report of the Medical Officer of the Privy Council, 1869 and 1870, as well as his own experience in 1867 and 1868 in "a series of investigations on the minute fungi, bacteria, and microzymes," and argued that dilution of the air may also not address the problem with all the germs. See: John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 13-14.

[41] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 14-15.

[42] Florence Nightingale, *Notes on Hospitals: Being Two Papers Read before the National Association for the Promotion of Social Science, at Liverpool, in October, 1858, with Evidence Given o the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859); Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863).

(1773), Bernard Poyet (1787), Jacques-René Tenon (1788), and Jean-Nicolas-Louis Durand (1802), the pavilion plan only existed in unrealized architectural plans. In remaining in the real of drawing, the plan acquired a status of an architectural icon, a hypothesis wherein its therapeutic propositions could neither be fully accepted or rejected. Even by the turn of the nineteenth century, when Durand' *Précis des leçons* established the pavilion plan as the quintessential archetype of the medical hospital, not a single one was built or planned for construction.

While the pavilion plan existed long before Nightingale, her book had systematized the existing knowledge by transforming the loosely defined guidelines into a codified and standardized hospital design manual populated with charts and statistics.[43] This new condition of the pavilion plan—in form of a printed book written by a medical professional—largely benefited from the British colonization during the second half of the nineteenth century. The pavilion plan was presented as an all-encompassing universal hospital architecture, adaptable to different scales, sites, climates, cultures and countries. Fueled by a global anxiety around disease and the political and economic ambitions of the colonial era, and powered by the technologies of printing,

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[43] Many historians have discussed the influence of Florence Nightingale's book in systematizing the existing knowledge of the pavilion plan hospitals. See for instance: Grace Goldin, "Building a Hospital of Air: The Victorian Pavilions of St. Thomas' Hospital, London," *BHM* 49, no. 4 (1975), 512-535; Jeremy Taylor, *The Architect and the Pavilion Hospital: Dialogue and Design Creativity in England, 1850–1914* (London: Leicester University Press, 1997), 49; Anthony King, "Hospital Planning: Revised Thought on the Origin of the Pavilion Principle in Englad," *Medical History*, vol. 10, no. 4 (October 1966), 360–373; Charles E. Rosenberg, *The Care of Strangers: The Rise of America's Hospital System* (New York: Basic Books, 1987), 122–41; John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975), 165; Cynthia Imogen Hammond, "Reforming Architecture, Defending Empire: Florence Nightingale and the Pavilion Hospital," in *(Un) Healthy Interiors: Contestations at the Intersection of Public Health and Private Space*, Aran S. MacKinnon and Jonathan Ablard (eds.), Studies in the Social Sciences University of West Georgia 38 (Carrollton, GA: University of West Georgia, 2005), 11–12; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 57.

transportation and communication, pavilion plan principles were exported across the colonial world, establishing itself as the universal architecture of the hospital.[44]

By the the 1870s, the pavilion plan principles and the architecture of the Herbert Hospital (1865)—the first hospital designed based on Nightingale's principles by her nephew Douglas Galton—became the guiding model for American architects and hospital designers. In his own essay in the appendix of *Hospital Plans,* for instance, Niernsée argued that the "pavilion system, in various forms, for hospitals has met with more favor and approval than any other."[45] Billings, however, was not particularly enthusiastic about the pavilion plan.[46] For him the "essential feature," of the hospital was its ability to minimize exposure to infection, thereby reducing the spread of disease.[47] To that end, he saw the spatial arrangement of the hospital—whether a pavilion or a barrack plan—as a potential instrument of aerial separation, isolation, and therefore disease prevention. The "cardinal principle" in hospital design and construction, he believed, was "to do

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[44] For more on the pavilion plan hospital see: Jeremy Taylor, *The Architect and the Pavilion Hospital: Dialogue and Design Creativity in England, 1850–1914,* (London: Leicester University Press, 1997).

[45] Alluding to his expertise in hospital construction through careful study of various plans and the examination of some of the best hospitals built in the country and in Europe, Niernsée outlined ten observations. The first was "That the old plan of collecting from 1,000 to 2,000 sick in one block of buildings of several stories in height, whether solid or embracing one or more enclosed courts, has been entirely abandoned and condemned, at least so far as the construction of new buildings is concerned." The second, that "In the construction of every modern hospital, during the past 20 years, the separation or more perfect isolation of the various wards has been aimed at." In the last observation, he endorse the "pavilion system" as the most favorable hospital typology: "That the pavilion system, in various forms, for hospitals has met with more favor and approval than any other. While the foregoing main points met with strong support." John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 335-336.

[46] John Shaw Billings, *A Report on the Hygiene of the U. S. Army with Descriptions of Military Posts* (Circular No. 8. Surgeon General's Office, Washington: Government Printing Office, 1875), iiv-iv.

[47] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 19, 25, 41.

as little harm as possible."[48] The separation of structures and the ventilation of wards, therefore, functioned not so much as means of cure, but as means of aerial and bacterial containment.[49] This "cardinal principle," in Billings' view, would require a "careful classification of the patients, by a methodical system of isolation, and by destruction of the causes of disease as they occur."[50]

The shift from the segregation of patients by age, sex or ability to pay to a classification by disease in western hospitals had begun the late middle ages in response to various environmental factors such as the significant increase in demand for beds during the plagues, the growth of economic inequality and "the poor rate," and the institutional shift from "Christian care" for the sick poor to a public care for the "deserving" poor.[51] Throughout the late eighteenth and much of the nineteenth centuries, hospital patients were typically classified in separate wards on the basis of age, gender, ethnicity, religion, socioeconomic class, and even moral status.[52] Beginning in the

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[48] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Address at the Opening of the Hospital* (privately printed. Baltimore, 1889), 4.

[49] Nightingale's own book was predicated, not on the therapeutic but, on the preventive function of the pavilion plan. "It may seem a strange principle to enunciate as the very first requirement in a Hospital," she wrote in the preface of her book, "that it should do the sick no harm."Florence Nightingale, *Notes on Hospitals,* third ed. (London: Longman, Green, Longman, Roberts, and Green, 1863), preface, iii.

[50] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 39.

[51] Mary Risley, *House of Healing: The Story of the Hospital* (Garden City, NY: Doubleday, 1961); Gwendoline Ayers, *England's First State Hospitals and the Metropolitan Asylums Board 1867-1930* (Berkeley: The University of California Press, 1971), 1-12; John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975); Harry F. Dowling, *City Hospitals: The Undercare of the Underprivileged* (Cambridge, MA: Harvard University Press, 1982); Anthony Vidler, *The Writing of the Walls: Architectural Theory in the Late Enlightenment* (Princeton: Princeton Architectural Press, 1987).

[52] Michel Foucault has written extensively on this. See: Michel Foucault, *The Birth of the Clinic: An Archaeology of Medical Perception,* A. M. Sheridan Smith (trans.) (New York: Vintage Books, 1973); Michel Foucault, "The Incorporation of the Hospital into Modern Technology" (1976), Edgar Knowlton Jr., et al. (trans.), *Space, Knowledge and Power: Foucault and Geography*, Stuart Elden and Jeremy W. Crampton (eds.) (Hampshire: Ashgate, 2007), 141-152.

1860s, through developments in medical science and specialties along with breakthroughs in disease etiology and epidemiology, the classification of patients began to shift from a physiognomical to a physiological approach: from a focus on the characteristics of the patients to that of their diseases.[53]

Private or "voluntary" hospitals during this period, founded and funded by private citizens or philanthropic organizations, typically admitted patients regardless of race, religion, color, or economic means but excluded those with chronic or contagious diseases.[54] Hopkins had also specifically instructed that the Hospital should receive "the indigent sick of this city and its environs, without regard to sex, age or color," and "without charge," but so long as they can be received "without peril to the other inmates."[55] For Billings, however, such form of disease discrimination "would greatly restrict the usefulness of the charity, and would leave unassisted precisely those who have the greatest need of aid, not only for their own sake, but for that of the health and welfare of the community."[56] His solution was to move the central admission office to

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[53] Hospitals during this period mostly classified patients and wards into on four primary categories: male medical, male surgical, female medical, female surgical. In addition, many also incorporated wards for infectious disease, venereal diseases, ophthalmic cases, for delirious or dying patients who required exclusion, lying-in women, burn victims, syphilitics, delirium tremens sufferers, "accident" cases, patients with skin diseases, convalescents and "foul" wards for patients with unsavory symptoms. While many of these disease were not contagious, separating those patients was intended to maintain the moral tenet of the large ward. With the exception of large municipal hospitals, most hospitals did not have enough space in their wards to accommodate the diversity of cases. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 154-155.

[54] Charles E. Rosenberg, *The Care of Strangers: The Rise of America's Hospital System* (New York: Basic Books, 1987), 22–27.

[55] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 6.

[56] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 8.

the city, connected to the Hospital by telegraph, and equipped with two ambulance-wagons to carry the patients to the Hospital. These ambulances were to be furnished with linings that could be easily removed and disinfected. Once arrived at the Hospital, the patient would be carefully examined by the Medical Officer of the day, assigned to a numbered bed in a ward, then subjected to a bath, and be provided with a set of clean hospital clothing before being escorted to the bed. The patient's own clothing would then be disinfected before being placed in store, or "be at once destroyed by fire if it seem proper to do so."[57]

The classification and isolation of patients were therefore all the more critical in a Hospital that was to admit all contagious cases. And determining what classes of patients occupied which wards involved a complex social, medical, and architectural calculus. The growing size and complexity of hospitals during this period had turned them from the healing machine of the Enlightenment to what Jeanne Kisacky has called a "sorting machine," one with a complex matrix of spaces which classified and arranged the variety of patients into efficient socio-economic, medical or therapeutic patterns. By the end of the nineteenth century, as hospitals became increasingly open to all classes, isolation requirement of special cases increased, medical specialization grew, and spaces for diagnostic, treatment, research and education became more

[57] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 8-9. Other hospitals during this period developed similar strategies. In order to minimize the risk of contamination in the wards, many hospital has developed "disinfective" admission procedures that subjected new patients to bath and scrubbing in new "reception" wards equipped bathing facilities. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 200-204.

integrated, the number of spatial categories outgrew those of the pavilions, therefore requiring the combination or mixing of those social and spatial classes.[58]

Billings believed in separating “acute from chronic and convalescent cases” and providing “each sex of each color” with “at least two wards,” medical and surgical, and separate wards for children and medical or surgical patients. In determining the size and number of the wards in his plan, he used a system of classification that relied on the characteristics of both patients and diseases. Using Hopkins’ required number of four hundred patients as a starting point, Billings first divided the anticipated patients into eleven classes on the basis of sex, age, color, medical or surgical, and whether they were private (paying) patients. He then tabulated the estimate number of patients in each category based on statistics of several similar institutions.[59] Using that tabulation, he concluded that no ward should have more than twenty-four beds:

| | |
|---|---|
| *White, Male, Medical* | *75* |
| *White, Male, Surgical* | *75* |
| *Black, Male, Medical* | *25* |
| *Black, Male, Surgical* | *25* |
| *White, Female, Medical* | *30* |
| *White, Female, Surgical* | *30* |
| *Black, Female, Medical* | *25* |

[58] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 371-372.

[59] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 40. This classification provided 37.5% of total beds for white male patients, and 10% for “private” or paid patients, while leaving 7.5% for white female, and 6.25% for black male, black female, male children, female children each. For reference, according to the Baltimore’s 1870 census, 85.2% of the population were white and 14.8% were black, approximately distributed evenly between male and female population.

| | |
|---|---|
| *Black, Female, Surgical* | *25* |
| *Children, Male* | *25* |
| *Children, Female* | *25* |
| *Private Patients* | *40* |
| *Total* | *400* |

Then, in order to determine the number of wards and beds needed, he relied on a different classification on the basis of the patients' diseases. He posited that the maximum number of "acute cases" that require isolation is about twenty-five percent (about 90 beds by his estimate), and that at various stages of their treatment some patients would require different environmental conditions. With the assumption that each ward would be emptied in rotation, one at a time, "with the windows open, undergoing Nature's process of purification," he allocated a total of 428 beds in 42 wards and across six different ward types designated for different cases:[60]

| | | |
|---|---|---|
| *12* | *24-bed wards, for chronic and not dangerous cases* | *288 beds* |
| *2* | *24-bed wards, accident and surgical, dangerous* | *48 "* |
| *14* | *2-bed wards, acute cases, not contagious* | *28 "* |
| *14* | *2-bed wards, for not specially dangerous or acute cases, but for which special temperature, light, etc. is desirable* | *28 "* |
| *20 beds, acute, contagious, and dangerous diseases, in tents* | | *20 "* |
| *Private patients, special rooms* | | *16 "* |
| | *Total* | *428 "* |

[60] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 41.

Using "beds" as the unit of measure, this classification designated the Hospital wards not on the basis of the patients' identity or even their specific type of disease (Diphtheria, Erysipelas, Typhoid Fever, etc.) but based on "cases" and their implication on the organization, or the architecture, of the Hospital. Striped of sexual, racial or class identity, the beds (originally without wheels) were meant to remain in the wards as each emptied in rotation and naturally purified. The anonymous beds, therefore, functioned as an extension of the wards that synchronized their identity with that of the patients not by name but only an assigned number.[61]

Once the number of wards were determined, Billings had to decide on the number of buildings or pavilions in the Hospital. He estimated that in order to accommodate all the patient wards alone —excluding the administration, service, and educational buildings—and a there could be either a total of twenty buildings (with sixteen one-story pavilions), or a total of fourteen buildings (with ten two-story pavilions). Both options would include a number of tents for "dangerous" cases.[62]

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[61] In his essay, for instance, Norton Folsom devoted an entire paragraph to a detailed specification of his proposed bed: "The beds are high enough, as seen in the sections, to allow the air to pass freely below them. This height is recommended for all hospital bedsteads, on account of the great facility for the physical examination of patients, and for the application of dressings, etc., which it affords. The patients enjoy a better view of the world, within and without, than from low bedsteads. The pattern in use for many years in the Massachusetts General Hospital is so satisfactory that I give a figure of it, as Supplied by the Tucker Manufacturing Company. It is made of wrought iron. Its length is $6^{1/2}$ feet, its width 3 feet, its height nearly 2 feet; and on the iron straps, which by a simple contrivance are allowed to spring a little, goes a palm-leaf under-mat tress, 6 inches thick, and on this a firm hair mattress, rounded up at the middle to allow for flattening, 6 inches thick; so that the patient lies 3 feet above the floor. The head of the bedstead rises to the height of $5^{1/2}$ feet, and has a shelf of hard wood, 6 inches wide. An iron semi-circle, for a tester or head-curtain, attaches here, and when attached can be raised to a perpendicular position, out of the way, when desired. The horizontal rods running across the head of the bed are 3/4 inch in diameter, so as not to bend when patients pull themselves up and lift themselves by their aid, as they do constantly. The whole is welded together, and made so strong and heavy as to be very firm. It does not vibrate when touched, like an ordinary iron bedstead, and never needs repair." Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 83-84.

[62] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 42.

The annotated plans in Billings' original essay did not specify the classes of patients distributed in each pavilion or ward. The pavilions were only differentiated by the number of stories, for instance "Pavilion" or "Pavilion 2 Story," and whether they were for "Private Patients." Only in one of the four plans provided "Surgical Pavilions" were distinguished.[63]

In the following two years as Billings continued to develop the plan of the Hospital, the classification of buildings, beds, and bodies was continually refined. In his report accompanying the "sketch plans" of the Hospital submitted prior to construction, Billings redistributed the beds in sixteen wards. In addition to the twelve "common wards" and the two "pay wards," this new classification also included two "isolation wards" and a number of tents or "temporary wooden structures in case of the outbreak of an epidemic."[64]

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|---|---|
| *12 "common wards," of 27 beds each* | *324 beds* |
| *2 isolation wards, 20 beds each* | *40 beds* |
| *2 pay wards, 13 beds each* | *26 beds* |
| *To be placed in tents* | *10 beds* |
| *Total number of beds* | *400* |

The tents were intended for the most "dangerous" or contagious cases, while the Isolation Wards were designated for the most "offensive," in appearance or smell, cases. None of the pavilion wards were to house contagious patients. "No case of contagious disease is to be admitted to any part of these pavilions," he wrote, "and if any case appear it is to be promptly removed, with bed

[63] In the final plans of the Hospital, the Wards were identified by letters: Ward D, E, F, G, H, etc.

[64] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 60.

and bedding. If a second case appear soon after the first, the ward is to be emptied and disinfected."[65]

In the final plan of the Hospital (1877), while the number of wards remained the same (sixteen) the number of patients pavilions were reduced to twelve, including four two-story pavilions with two wards in each floor. In plotting the wards in plan, all the patients pavilions were arranged in two identical rows, a northern row reserved for male patients and a southern row for female patients. Each row then contained a series of different wards: private, common, and isolation. In this way, the pavilion plan of the hospital operated as a grid, with its north-south axis dividing the sexes, and the east-west axis separating the cases in a gradient of social, economic and medical classes—pay, common, contagious, or offensive. the tents were removed and the Isolation Wards were to house both "cases which may be either contagious or offensive."[66]

The design and construction of the Johns Hopkins Hospital took place in a period in American history when the society as a whole was grappling with its own system of classification, shaped by racism and inequality. Equal protection, during the post-Civil War era in the United States, did not translate to equality. Slavery did in fact remain legal in Maryland—one of four slave states that stayed in the Union—until shortly before the end of the Civil War in 1864.[67] The ratification of the Thirteenth Amendment in 1865 and the constitution of the Fourteenth Amendment in 1868

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65 John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 26.

66 John S. Billings, *The Plans and Purposes of the Johns Hopkins Hospital*, (1889), 8.

67 "The not-quite-Free State: Maryland dragged its feet on emancipation during Civil War," *The Washington Post (*September 13, 2013).

had guaranteed *equal* protection under the law to all people, however, the federal government had left racial segregation to individual states, allowing many (in the 1870s and 1880s) to adopt Jim Crow laws in order to *separate* of black and white Americans. Louisiana's Separate Car Act of 1890, for instance, required "equal, but separate" train cars for white and non-white passengers. Railroad companies had opposed the law only on the ground that it would require the purchase of more railway cars.[68]

The history of the Johns Hopkins Hospital is deeply entangled with that of racial segregation that has long remained buried in the institution's records. Hopkins himself has been portrayed as a staunch abolitionist: a son of a Quaker family who, after his father Samuel freed the family's enslaved persons, left boarding school at the age of twelve to work in his family's tobacco plantation farm, went on to become a successful businessman and a committed abolitionist, and founded the nation's first research university and hospital with an unprecedented philanthropic bequest to receive "the indigent sick of this city and its environs, without regard to sex, age or color."[69] This narrative has recently been found to be not entirely true. There has been no evidence that either Hopkins himself or his father ever freed any enslaved person, and documents

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[68] Robert Andrew Margo, *Race and Schooling in the South, 1880–1950: An Economic History* (Chicago: University of Chicago Press, 1990); Jerrold M. Packard, *American Nightmare: The History of Jim Crow* (New York: Macmillan, 2003); Marouf Hasian Jr., "Revisiting the Case of Plessy v. Ferguson," in Clarke Rountree (ed.), *Brown V. Board of Education at Fifty: A Rhetorical Retrospective* (Washington DC: Lexington Books, 2006).

[69] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 6. This narrative was constructed in Hopkins biography, written by his grand-niece Helen Hopkins Thom, and has been repeated in the various historical accounts relating to both institutions. See: Helen Hopkins Thom, *Johns Hopkins, A Silhouette* (Baltimore: The Johns Hopkins Press, 1929); Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 2.

from the 1830s reveal that Hopkins and his firm often acquired enslaved people to settle debts, and census records from 1840 and 1850 listed enslaved individuals in Hopkins' household.[70]

In addition to the Hospital proper that was to admit patients "without regard to sex, age or color," Hopkins had instructed his Trustees to provide an Orphans' Home, in connection with the Hospital, "for the reception, maintenance and education of orphan colored children" that should accommodate three or four hundred children.[71] In his will, Hopkins had specified that the Orphans' Home be built "in a locality different from that selected for the use of the wards for sick poor white persons, or of sick poor colored persons," and "wherever the said wards, or subdivisions, may be located, in such manner that the interests and wants of each of said subdivisions, or wards, may be fully and impartially protected and promoted." He further clarified his intent to separate the spaces for "sick poor white persons" from those for "sick poor colored persons":

> *And I desire that the said trustees of the said 'The Johns Hopkins Hospital,' shall make ample provision out of the property, real and personal, by this my last will and testament devised and bequeathed to the said 'The Johns Hopkins Hospital,' not only for the ward, or building, intended for the use of sick poor white persons, and for the care of such inmates, but also for the ward, or buildings intended for the use of sick poor colored persons, and for the care of such inmates, and for the*

[70] Martha S. Jones, "Johns Hopkins and Slaveholding, Preliminary Findings, December 8, 2020," Hard Histories at Hopkins (December 8, 2020). Also see: "Johns Hopkins's Feet of Clay," *The New York Times* (December 10, 2020).

[71] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873).

*ward, or building intended for the reception and care of colored orphan and destitute children, as aforesaid.*[72]

While Billings and Niernsée's plans did not separate or sort patients on the basis of color, by 1890 when the Hospital finally opened, the classification of beds and buildings became more racially biased, even requiring the construction of new wards. In the first two years of its operation, "colored patients" were separated and placed in the small wards at the north end of the pavilions—originally reserved for special cases—and in the dining rooms.[73] This was in spite the fact that, according to the Hospital statistics, at no point during that period all the approximately 260 beds in the wards were occupied.[74] In his second report in 1891, Henry M. Hurd, the Superintendent of the Hospital conveyed the need for the accommodation of "colored patients," and in the following year he reported plans to build a separate "Colored Pavilion," with at least four wards, each accommodating sixteen patients (sixty-four total). "It is confidently anticipated," Hurd wrote, "that the colored wards will add much to the comfort of colored patients and at the same time render it practicable to restore the small wards and dinning rooms,

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[72] Johns Hopkins, "Extracts from Johns Hopkins' Will and the Codicils Thereto," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), xix-xx.

[73] In addition, due to cost, the only pavilion built in the southern row was the Female Pay Ward, leaving both sexes of the common, contagious and offensive classes with the six wards in the northern row. And without a dedicated ward, a portion of one of the buildings was utilized for the reception of children.

[74] For instance, at the end of the year 1892, there were a total of 176 patients in the Hospital (149 white and 27 colored). During that year, the number of patients in the hospital fluctuated between 133 and 197, with the daily average of 165.5. See: *Third Report of the Superintendent of the Johns Hopkins Hospital, For the Year ending January 31, 1892* (Baltimore: The Johns Hopkins Press, 1892), 19.

now occupied by colored patients, to their original use."[75] In 1892, the same year when the planning of a separate Colored Pavilion was underway at the Hospital, Homer Plessy, a person of mixed ancestry, purchased a first-class ticket and boarded a "Whites Only" car of the East Louisiana Railroad in New Orleans. He was arrested for violating the Separate Car Act, while he argued that the law was against the Fourteenth Amendment. In a long legal battle, *Plessy v. Ferguson* reached the Supreme Court of the United States, which in 1896, ruled a 7-1 decision against Plessy, thereby legitimizing the "separate but equal" as constitutional.

The history of the Johns Hopkins Hospital reveals the entanglement of philanthropy and discipline, what Martha S. Jones has called "a complex mix of benevolence and the institutionalization, in a post-slavery world, of what we have come to call segregation."[76] At the time it opened, the Johns Hopkins Hospital was among the few institutions that treated African American patients and, well into the mid-twentieth century, very few hospitals provided the same quality of care to both black and white patients. Patients of color, even if admitted to a hospital, were typically assigned to the most remote or least desirable ward space in a facility.[77] However, black patients were treated in segregated wards and it wasn't until the 1950s when the Johns

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[75] *Third Report of the Superintendent of the Johns Hopkins Hospital, For the Year ending January 31, 1892* (Baltimore: The Johns Hopkins Press, 1892), 19-20. The "Colored Ward" was completed in 1894, east of the Isolation Ward, and was used exclusively for the African American patients. The building had two levels of wards "in order to care for all the colored patients on the medical, surgical and gynecological services." See: Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 164-165, 176.

[76] "Johns Hopkins's Feet of Clay," *The New York Times* (December 10, 2020).

[77] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 157.

Hopkins began to be desegregated—the full integration of ward services in Surgery occurred in 1959, and inpatient services were not desegregated until 1973.[78]

The basic structure of the pavilion plan of the Hospital imposed a system of classification that while separated the wards, the beds and the patients, it did not ultimately treat them as equal. The plan at once mediated the juxtaposition of various, and incompatible, measures of personal, economic, medical, and architectural identity or individuality that while neatly classified in charts and drawings, they resulted in a conflicting reality—the assumption, for instance, that "colored patients" are not "pay patients." The pavilion plan of the Hospital—not unlike that of the railway system—therefore became architectural instrument that enabled, or even encouraged, segregation. That institutionalized *system* was the underlying structure of the plan that was not defined by or bound to the pavilion buildings but by the architecture of the institution itself, transcending formal, material, or even temporal qualities.

The permanent or temporary nature of the pavilions was among those conditions that enabled the plan to function as a system. Much of the debate during the planning of the Johns Hopkins Hospital revolved around the choice between the pavilion and the barrack systems. Military barracks had long utilized the grouping of buildings as an organization system for medical and treatment facilities as well as housing, training, and storage of equipments and supplies.[79] The

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[78] "Upholding the Highest Bioethical Standards," *Johns Hopkins Medicine* (accessed on March 23, 2021). At the Johns Hopkins University the first undergraduate black student was admitted only in 1945. "Frederick Scott, who became Johns Hopkins' first black undergraduate student in 1945, dies at 89," *HUB, the Johns Hopkins University* (July 20, 2017).

[79] Nightingale's own observations and improvements were originally made in a British barrack hospital at Scutari (Üsküdar district of modern day Istanbul) where she was stationed, not in a pavilion plan hospital. Through that experience, she conceived the wards as barracks.

army barrack hospitals had particularly gained attention during the United States during the Civil War.[80] And the popularization of the pavilion plan had informed the design and planning of the American barrack hospitals of both Union and Confederate armies.[81] While typically much larger in scale, the barracks followed a similar layout to the pavilion plan in distributing the sick and wounded soldiers across a series of detached structures that provided natural light and ventilation. But the barrack hospitals had a provisional plan. They were built cheaply and quickly in the field, allowing the possibility of adding or removing structures when necessary. But most importantly, as low-cost and perishable structures, the barracks could be completely abandoned or incinerated in case of an outbreak, thereby providing a highly effective, and unmatched, disinfecting strategy—one that conventional brick and mortar hospitals could not afford.

The debate around the pavilion and barrack systems, therefore, was not about the need for containment but the risk of contamination. Doctors during this period believed that any building continuously occupied by sick would become contaminated and "its walls and floors will themselves become sources of infection."[82] Building materials were thought to "hold seeds of

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[80] Jeanne Kisacky has noted that the American barrack hospitals during the Civil War impressed the Europeans. During the Siege of Paris in the Franco-Prussian war in the early 1870s, the French resorted to "putting up tents after the American model, for it is proved beyond a doubt that they are the only safeguard against what is termed hospital rot or gangrene." Rudolf Virchow also praised the American barrack hospitals, and the City Hospital in Moabit, Berlin, was designed based on the Mower General Hospital outside of Philadelphia. Germany hospital designers continued to build hospitals similar to the barracks. See: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 122-123.

[81] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 60.

[82] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 15.

death most pertinaciously."[83] During the Civil War, army doctors and sanitary inspectors were particularly wary of infections, regularly spoke of "crowd poisoning," and blamed defects not just in health but in character on dirt: "dirt at one end, and cowardice at the other."[84] William Hammond, an army surgeon, who later became the eleventh Surgeon General of the United States, even believed that the foul exhalations from the patients could "cling to the clothing, the furniture, the walls, and especially the bedding."[85]

Since the wooden barracks were built cheaply, they could be abandoned or incinerated in case of an outbreak. This disinfecting strategy had led some army surgeons to believe that it would be more feasible, from both economic and sanitary standpoint, to build all hospitals, military or civic, in a similar manner. John Maynard Woodworth, for instance, the first Surgeon General of the United States, was adamantly opposed to what he called "the simple pavilion of indefinite existence." He recommended that hospital pavilions be "constructed with the view of destroying them," every ten to fifteen years, or as soon as "the peculiar hospital diseases, such as erysipelas, pyaemia, gangrene, &c., are engendered by the cumulated miasma of the buildings."[86] Billings was also vocal advocate of that view, and believed that the "great advantages" of the barrack hospitals was that, as one-story structures, they are easily ventilated and disinfected, but also

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[83] Thomas K. Cruse, "The Treatment of Compound Fractures of the Leg, at Bellevue Hospital," *Medical Record* 7, no. 4 (15 Apr. 1872), 140.

[84] Frank H. Hamilton, "Our Surgeons upon the Field," *American Medical Times*, VI (March 21, 1863), 133-34.

[85] George Hayward, "History of the Erysipelatous Inflammation That Recently Appeared in the Massachusetts General Hospital," *New England Medical Review and Journal* 16 (1827), 291, cited in Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 142-143.

[86] Marine Hospital Service, *Report of the Supervising Surgeon for the Last Fiscal Year,* NYT, (November 5, 1873), cited in Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 119.

because they cost significantly less to construct, they could be modified, abandoned, or destroyed with much less hesitation (Figure 1.13).[87]

From 1869 to 1870, during his time at the Office of the Surgeon General, Billings was assigned by the War Department, on behalf of the Secretary of the Treasury, to inspect and survey the Marine Hospital Service throughout the country and advice on its reform. During that time, he produced a series of extensive reports—each over 500 pages, populated with floor plans, chart, and tables—that in turn established him as an authority in hospital construction and management.[88] In *A Report on Barracks and Hospitals* in 1870, Billings had adamantly advocated against the construction of permanent "stone and brick hospitals," arguing that with the same capital investment, a temporary hospital could be rebuilt every twelve years for an indefinite period of time:

> *Our hospitals approach more nearly in size and character the so-called Cottage-Hospitals of England than any others. They are satisfactory in one respect, that they are almost all temporary hospitals. This I consider a decided advantage, as I believe that no hospital should be constructed with a view to its being used as such for more than fifteen years. If the money required to put up such structures as the New York Civil Hospitals, the Rhode Island Hospital, or the Cincinnati*

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[87] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 18.

[88] John Shaw Billings, "A Report on Barracks and Hospitals, with Descriptions of Military Posts," *Circular No. 4, War Department, Surgeon General's Office* (Washington: December 5, 1870); John Shaw Billings, *A Report on the Hygiene of the United States Army, with Descriptions of Military Posts* (Washington: Government Printing Office, 1875); John Shaw Billings, *A Report of the Committee on the Plan for a Systematic Sanitary Survey of the United States* (November 10, 1875). In addition, he presented an abstract of the special reports by army medical officers on *The Effect of Mountain Climates upon Health*, and *Notes on Hospital Construction* at the 1874 annual meeting of the American Public Health Association, and his *Bibliography of Cholera* contributed to the government report on The Cholera Epidemic in the United States (1875). Harry Miller Lydenberg, *John Shaw Billings: Creator of the National Library and its Catalogue, First Director of the New York Public Library* (Chicago: American Library Association, 1924), 29.

> *Hospital were divided into two equal parts, one-half being used to erect frame hospitals of the same capacity as the stone and brick hospitals actually built, and the other half being put out at interest at six (6) per cent., a complete new hospital could be furnished every twelve years for an indefinite period to come.*[89]

In his essay proposal for the Johns Hopkins Hospital, however, Billings walked back that statement, noting that while temporary structures have unique advantages, "it is an error to suppose that a Barrack Hospital will prevent Hospitalism" and that he no longer believed it to be necessary to destroy the hospital buildings regularly to prevent infection. Outlining the logistical and organizational differences between the military hospitals and civil hospitals, he noted that barrack structures have certain disadvantages that could result in serious administrative and managerial problems: "their inflammability, the large space and increased number of nurses, attendants, and laborers which they require, the amount of fuel necessary, and the difficulty of enforcing proper discipline among and supervision of the employees and the patients, especially in the location proposed."[90] In this way, the same sanitary material and structural characteristics that had allowed barrack hospitals to be easily ventilated or disinfected—i.e. wood or fabric as a highly inflammable building material, large open and uninsulated wards, separation and lack of

[89] John Shaw. Billings, "Report on the Barracks and Hospitals of the Army," *Circular No. 4,* War Department, Surgeon-General's Office (Washington, D.C., 1870), 22-23.

[90] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 16-18.

connection between structures, etc.—came to be viewed as culturally and economically inapt for a civic hospital.[91]

For Billings, the pavilion plan and the barrack plan each offered unique qualities—One plan presumed permanence, stability, and beauty, the other transience, commutability and efficiency. His initial approach was then to combine qualities of tents and barracks with those of permanent pavilions in order to "secure both the healthfulness of the one and, to a considerable extent, the convenient and economical administration of the other."[92] While proposing a series of pavilions drawn in plans, he noted in his essay that, "either of them could be carried out on the temporary or permanent plan," and recommended that regardless of which plan is adopted, to have about fifteen "hospital tents, United States Army pattern, be kept constantly on hand, and made methodical use of as isolation wards."[93] Billings approach to the planning of the Hospital was one that was concerned primarily with "the causes of the unhealthfulness of hospitals," and the plan's ability to "prevent these causes from being present in the greater part of the buildings, and

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[91] In his short essay in the appendix of *Hospital Plan,* Niernsée had also objected to the use of temporary barrack structures writing, "The military-medical experience of the late wars, both at home and abroad, shows a larger percentage of recovery in temporary wooden buildings (tents and other frail and comparatively open structures) than in more permanent and solid ones. When we consider that the majority of the sick soldiers must not only have been surgical cases, but as soldiers used to the open air, and sleeping in tents or even without them during a campaign of several years, the war experience is not so thoroughly applicable to the civilian sick who occupy our town hospitals." John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 336-337.

[92] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 18.

[93] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 42-43.

to confine them to certain structures, which may be purified or destroyed when necessary."[94] Therefore, more than a permanent or fixed arrangement of buildings, Billings conceived the Hospital plan as a transient ensemble of structures that, much like a military camp, could evolve and transform when needed.

Another parameter that impacted the size or form of the pavilion was its number of floors. In approaching the layout of the Hospital, Billings original essay provided multiple options based on the permanent or temporary nature of the structures, as well as single or multi-story pavilions. Pavilion hospitals during that period rarely used two-story buildings and pavilion-plan advocates maintained that the pavilions were "never to be over two stories in height."[95] One-story pavilions were favored for maximizing air flow and reducing the risk of the spread of bad air from one floor to another. They were also seen as more practical for day-to-day operation of the hospital—the delivery of meals, supplies, bedridden patients, etc.—without relying on stairs or elevators. Despite this, both Billings and Niernsée believed that there is no evidence to support that, and that two-story pavilions can work perfectly fine as long as the ventilation system is appropriately designed.[96]

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[94] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 39.

[95] Francis H. Brown, "Hospital Construction," *BMSJ* 65, no. 3 (22 Aug. 1861), 51. See also William Hammond, *A Treatise on Hygiene, with Special Reference to the Military Service* (Philadelphia: J. B. Lippicott, 1863), 322-23; Frank Hastings Hamilton, *A Treatise on Military Surgery and Hygiene* (New York: Bailliere Brothers, 1865), 127-29.

[96] See: John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 337.

His “General Plan of Hospital” included two main schemes: one with one-story pavilions (Figure 1.1), and another with two-story pavilions (Figure 1.2). He provided cost estimates of each scheme, based on brick or temporary structure, and expressed his preference for the two-story plan for affording better “economy of hospital construction and management of patients and staff.”[97] In his view, while the two schemes would cost approximately the same, the reduced number of buildings—six two-story pavilions compared to fourteen one-story pavilion—would reduce the cost of management by at least $10,000 a year.[98] He then provided two additional “modifications” based on the two-story scheme: one with a modified circulation (Figure 1.3), and the other with the consideration of having some of the pavilions built at a later stage (Figure 1.4). “Either of them,” he noted, “can be carried out on the temporary or permanent plan, and either of them will, in my opinion, be satisfactory, so far as the healthfulness of the institution is concerned.”[99]

In the years that followed, the plan of the Hospital was continually presented, modified and re-presented as one that could adhere to miasma or germ theory, constructed as temporary or permanent, built by wood or brick, constructed of one- or two-story buildings, twelve or sixteen pavilions, classified by patients or diseases, heated by steam or water, ventilated naturally or

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[97] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 27-28.

[98] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 42.

[99] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 42.

mechanically, and built at once or in phases. This condition of the plan, as a set of autonomous components, was the most consequential aspect in the design and later construction and operation of the Johns Hopkins Hospital that transformed the pavilion plan from an architectural proposition into an institutional system that operated through architecture.

## 1.2 External Corridors

The essential feature of the pavilion plan was that it divided the hospital into a series of separate and detached parts, each operating autonomously, having nothing but a shared administration in common. That shared administrative function, however, relied on a system of circulation and communication between the detached pavilions that while it was meant to enable connection, it also maintained separation. This was the impossible task of the corridor.[100] The corridor emerged as a basic component of the pavilion plan hospitals, an organizational structure around which the various pavilions grew. It was the single component that, both literally and figuratively, united all the discrete buildings of the plan into an institution with a singular structure and identity. Architecturally, the corridor was the defining organizational element of the pavilion plan that distinguished it from a town or campus typology.

This organizational approach was already revealed in the *Hospital Plans* of the five physicians. The physicians' block plans represented various layouts that, much like the Hospital's

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[100] The *corridor* is a relatively recent invention in architecture. Even by the turn of the nineteenth century, the corridor rarely appeared in architectural discourse. In its Latin origin and early use in Spanish and Italian in the fourteenth century, the term *corridor* did not refer to a space but a *courier,* an individual who ran fast and carried messages, money, documents, supplies or weapons. Public buildings made very limited use of them, and even large ones, such as John Soane's Bank of England (1788), had no corridors. For more on the corridor see: Mark Jarzombek, "Corridor Spaces," *Critical Inquiry* 36 (Summer 2010), 728-770.

organizational chart, relied on an hierarchical order: an administration building at the dominant top or front, with a series of connections, in form of a continuous corridor, to various buildings.[101] But while the general size, form, and spacing of the rectangular pavilions remained generic and even identical in most of the plans, the corridor system that connected and organized them were radically different. Norton Folsom proposed a fork-shaped corridor system with four branches (Figure 1.5), Joseph Jones proposed a single long corridor running across the site (Figure 1.6), Caspar Morris proposed a central administration building with four corridor branches (Figure 1.7), and Stephen Smith proposed a corridor loop going around the whole site (Figure 1.8).

Billings proposed four plan options in his essay (Figures 1.1-1.4). Three of them (Plates IV, V, and VII) were arranged with a central axis defined by a corridor and a series of secondary corridors branching off from it to the pavilions. The Administration building was placed on one end of the central axis, and the Dispensary and the Amphitheater on the other end. The Kitchen and the Laundry occupied the center of that axis. This meant that all the pavilions had a relatively direct and equal access to the service zone at the center and, through the central axis, to the Administration, the Dispensary and Amphitheater. One of the plans, however, departed from that logic. Billings' plan shown in Plate VI was a modified version of the plan shown in Plate

[101] Even pavilion plan hospitals during this period did not have a hierarchical organization. Most, like Duran's Hospital, were a series of identical pavilions distributed and spaced evenly as in a grid, or those that arranged the wards or buildings around a circulation loop. Kirkbride [psychiatric] hospitals did have a hierarchy but they were conceived as single buildings.

V.[102] The buildings and the pavilions were nearly identical in both plans. But while one relied on a central axis with secondary branching connections, the modified plan connected the pavilions with a curvilinear corridor that connected all the pavilions to each other but only to the service zone at two points in the center. This variation, while using the same layout of buildings and pavilions, implied a completely different system of circulation that privileged the connection within the pavilions over that established between the pavilions and the service and administrative buildings. "In a hygienic point of view there is little difference," Billings wrote, "but in final appearance the plan of Plate V. would probably be preferable."[103]

While a dominant organizational device, the corridor was not itself fixed or prescribed in the Billings' plan, and its layout—and the set of relations it established between the pavilions—continually changed during the design process of the Hospital. In the final block plans of the Hospital that emerged between 1876 and 1877, this organization was altered (Figure 1.9-1.12). The circulation system was conceived in form of a U-shaped corridor, with the Administration building, the Bathhouse, the Kitchen and the Nurses' Home, and the two Pay Wards at the base, and the other eight patient pavilions along the two arms. All other buildings, including the Dispensary, the Amphitheater or the Laundry that used to occupy the central zone were moved to the periphery of the site with no connection to the corridor system. In the final layout of the corridor also established a hierarchy in plan that informed the pattern of circulation within the

[102] The two plans were his own preferred schemes on the grounds that they would significantly reduce the cost of management—by $10,000 per annum. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 42.

[103] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 43.

Hospital. The Administration building, which functioned as the main entrance to the Hospital, was placed at the center base of the U-shaped corridor systen. This meant that, for instance, in order to access the Isolation Wards, one had to enter the Administration Building, pass by the Pay Wards and then through the Octagon Ward and the three Common Wards before reaching destination.[104] It also meant that certain pavilions had better access to the administration or the service buildings compared to others. In this way, while the generic layout of the pavilion plan implied a sense of equity, the corridor created a hierarchy that privileged certain pavilions over others.

The function of the corridor as both a communication and separation device has been a part of its relatively short history in architecture. Robin Evans has traced the origin of the corridor, as a "device for removing traffic from rooms," to the domestic architecture of the late sixteenth and early seventeenth century England.[105] In its early application, the corridor was not an exclusive means of access but functioned as an elongated vestibule primarily to carefully contain and separate the servants' spaces from the masters', to prevent class "interference," and to "preserve the self from others."[106] Evans sees the rise of the corridor "thoroughfares" in the nineteenth-

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[104] The third report of the Superintendent of the Hospital even included a Block plan that, in an unusual manner, had the Administration building on top connected with all the built as well as the unbuilt buildings though branching circulations.

[105] Robin Evans, "Figures, Doors and Passages," (1978) in *Translations from Drawing to Building and Other Essays* (Cambridge, MA: MIT Press, 1997), 70-79.

[106] Evan writes how in a house at Coleshill, Berkshire (c. 1650-67), built by Sir Roger Pratt, this "common way in the middle through the whole length of the house" was meant to prevent the offices or utility rooms from "molesting the other by continual passing through them" and to ensure that "ordinary servants may never publicly appear in passing to and fro for their occasions there." R. T. Gunther (ed.), *Sir Roger Pratt on Architecture* (Oxford, 1928), 62-64, in Robin Evans, "Figures, Doors and Passages," (1978) in *Translations from Drawing to Building and Other Essays* (Cambridge, MA: MIT Press, 1997), 71, 74.

century as “the backbone of a plan not only because corridors looked like spines, but because they differentiated functions by joining them via a separate distributor, in much the same way as the vertebral column structures the body.”[107] For Evans, this “advanced anatomy” enabled the architectural plan to overcome the restrictions of adjacency, proximity, and localization but establishing a system of internal communication. The “paradox,” however, was that in facilitating purposeful and necessary communication, the corridor also reduced unexpected communication and contact, one that “was at best incidental and distracting, at worst, corrupting and malignant.”[108]

The malignant problem of the hospital corridor had to do with ventilation. The pre-pavilion hospitals relied on corridors inside the wards both to access and to separate the rooms. But these dark, and often cramped and congested spaces deprived the hospitals of fresh air, natural light, ample space, and the ability for supervision and surveillance of the patients. Reports of barracks regularly described long narrow corridors in which “the smell is unbearable.”[109] Doctors and sanitarians saw the innate function of the corridor, as a communication device, not only as a major flaw for prisons, hospitals, and institutions that relied on spatial and aerial separation but also as “means of a general contamination” of the whole building.[110] Nightingale, for instance,

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[107] Robin Evans, “Figures, Doors and Passages,” (1978) in *Translations from Drawing to Building and Other Essays* (Cambridge, MA: MIT Press, 1997), 78-79.

[108] Robin Evans, “Figures, Doors and Passages,” (1978) in *Translations from Drawing to Building and Other Essays* (Cambridge, MA: MIT Press, 1997), 79.

[109] “Our Soldiers’ Homes,” *Examples of the Architecture of the Victorian Age* (London, 1862), 109, in Mark Jarzombek, “Corridor Spaces,” *Critical Inquiry* 36 (Summer 2010), 761.

[110] “Sixth Report of the Medical Officers of the Privy Council, with Appendix, 1863,” quoted in “Hospital and Hospital Construction,” *American Journal of Medical Sciences* 56, n.s. (1868), 198. See also Walker Gill Wylie, *Hospitals: Their History, Organization, and Construction* (New York, 1877), p. 205.

saw the double-loaded corridors as "objectionable," for transmitting the foul air from one ward to the rest of the building, turning the whole hospital into "a complicated ward."[111] She observed "the evils connected with corridors" in hospitals across London.[112] By the mid-nineteenth century, the internal corridor of the hospital was seen as an instrument of contamination.

This view of the corridor, as a "malignant" or "evil" component of hospital architecture was not held by all branches of medicine. Thomas Kirkbride, for instance, saw the corridor as a therapeutic device for psychiatric patients.[113] The linear, sprawling Kirkbride plan relied on staggered double-loaded corridors as a necessary component of the ward, and as an instrument of aerial, visual, acoustic separation within the ward. "There is more certainty of the free circulation of light and air," Kirkbride wrote, "better prospects are secured from all the patients' rooms and parlors, there is less opportunity for patients on opposite sides seeing or calling to each other, and less probability of the quire patients being disturbed by those who are noisy."[114] In dividing the

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[111] Florence Nightingale, *Notes on Hospitals: Being Two Papers Read before the National Association for the Promotion of Social Science, at Liverpool, in October, 1858, with Evidence Given o the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859), 40.

[112] Florence Nightingale, *Notes on Hospitals: Being Two Papers Read before the National Association for the Promotion of Social Science, at Liverpool, in October, 1858, with Evidence Given o the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859), 14.

[113] Kirkbride's book included detailed design specifications, from heating and ventilation to size of the building, layout of the rooms, even design of the bathrooms, doors, and dumb waiters. The key component of his treatise, however, was an architectural plan, later known as the "Kirkbride plan," that conceived the hospital as a single linear building with a central administrative zone in the middle and a set of two bat-wing wards sprawling outwards. The exposure to natural light and air circulation, the social in the public corridors and even the picturesque views of the landscape outside were believed to have therapeutic effects. The Kirkbride plan became particularly popular in the United States and between 1845 and 1910 approximately seventy-three Kirkbride hospitals were built across the country, some of which were designed by the likes of Samuel Sloan, Eldridge Boyden, and Frederick Law Olmsted. Thomas Kirkbride, *On the Construction, Organization, and General Arrangement of Hospitals for the Insane* (Philadelphia: Lindsay & Blakiston, 1854). See for instance: Frederick Clarke Withers, Calvert Vaux and Frederick Law Olmsted, Hudson River State Hospital for the Insane (1868-71).

[114] Thomas Kirkbride, *On the Construction, Organization, and General Arrangement of Hospitals for the Insane* (Philadelphia: Lindsay & Blakiston, 1854), 36.

wards into a series of private rooms on its sides, the Kirkbride corridor functioned as a communal therapeutic space, a public avenue that encouraged social interaction and potentially cure. The wide corridors also divided the space of the wards and distributed the program, carried the pipes, ducts and conduits for mechanical, electrical and plumbing systems within its thick walls, and allowed for the linear expansion of the building. In that way, the corridor functioned as internal backbone of the Kirkbride plan.

In pavilion plan hospitals, however, seen as a disease carrier, the corridor was removed from the ward and exiled to the exterior. The absence of the corridor allowed the wards to have an open, flexible floor plans with windows on three sides that admitted light and cross-ventilation. The long external corridors, often built as open passageways or cloisters, maintained aerial separation and acted as a buffer zone between the potentially contaminating wards. In large Civil War barrack hospitals, which usually included over a dozen pavilions, the corridors took various forms, from grids and en echelon forms to radial plans, with some even incorporating railways to facilitate the distribution of supplies. The corridor was therefore the only autonomous element of the pavilion plan that was not only separate but also connected to all other components.

In connecting the pavilions, the corridors not only defined the circulation space but also demarcated the grounds between the pavilions. In the early pavilion plans—such as Wren's Greenwich Royal Naval Hospital (1702), Durand's Hospital (1802) or Gauthier's Hôpital Lariboisière (1854)—the corridor was designed as cloister, an open passageway leveled with and accessible from the ground. Without any physical and aerial separation, this form of circulation allowed for a cross-circulation, and a cross-ventilation, between the open spaces or garden.

Without walls or doors, the open-air corridor was deliberately without an interior—it was both an *external* and *exterior* space. The early pavilion plan corridor was therefore drawn in plan neither as a void within the building nor a figure within the grounds, but one and the same as the ground, delineated merely by a dotted line of the colonnade.

Beginning in the 1860s, in order to provide more comfort and control for the circulating staffs or supplies, pavilion plan hospitals began to conceive the corridor as an enclosed space. In connecting the pavilions, the enclosed corridor now separated the grounds of the hospital. In Galton's Royal Herbert Hospital (1865), for instance, the corridor was a two-story structure, a fully enclosed building with walls, floors and a roof. With a clear physical and aerial separation, the corridor segregated the circulation space from the hospital grounds, limiting the movement of both people and air. While *external*, the corridor was no longer an *exterior* space; it even had its own interior. In that way, the corridor emerged as a dominant *figure* in the plan which, much like the pavilions, was drawn and delineated with a solid line of the walls.

When the planning of the Johns Hopkins Hospital commenced in the 1870s, the corridor had not yet established its role in the pavilion plan. On the one hand, the corridor was meant to function as an instrument of aerial separation and containment between the wards, as an *exterior* space that allowed for free circulation of air between the pavilions. On the other hand, the corridor was to function as a device for connection and communication between the wards and to provide an enclosed and environmentally regulated access for distribution of food, supplies, medicine, etc. In other words, much like fresh air, doctors, nurses and staff and what they carried needed to circulate freely and comfortably between the wards, while the "vicious" or contagious patients, and the foul air they produced, needed to be contained within the wards, or diluted in the open space between the pavilions. This was the paradox of the hospital corridor.[115]

The corridor was a key component of all the five physicians' plans. While all proposed external circulation systems that connected separate pavilions, they differed in their function within the Hospital. Stephen Smith's plan called his corridor "Perron," and Norton Folsom marked his as "Covered Way." Even Niernsée's proposals in the Appendix section of the *Hospital Plans* included "corridors" marked and annotated in plan. Some were enclosed, and others were open; Some leveled with the ground, and others with the floor of the wards. Joseph Jones, even proposed to connect the pavilions with a "central railroad" system that operated in the basement corridor (Figure 1.6). His central railroad was intended for "All the business of the Hospital, such as the conveyance of sick and wounded to the different wards; distribution of food, medicine and clothing, removal of the dead, etc."[116]

Billings proposal was to use both the "open corridor" and the "closed corridor" in an arrangement that combined the two in section. He envisioned all the pavilions to have basements —"about 9 feet high, entirely above ground, and floored with asphalt, which are to contain

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115 Billings was not only concerned with the containing foul air within the wards but also the "vicious" patients. In his essays, he wrote: "It must be remembered that, in an institution of this kind, we have to provide not only for the care of the sick, but to some extent for the restraint of the vicious" particularly diseases related "directly or indirectly to Alcohol and Venery." He therefore argued to make the wards "inaccessible to visitors and to patients and attendants from other wards who have not proper authority to enter them." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 28.

116 Joseph Jones, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 163.

nothing but heating and ventilating apparatus"—and ward floors that above the basement level, and well above the ground level.[117] The corridor was then conceived as a two-story structure where the bottom level, "a closed corridor," would connect the basements of all the pavilions to the "central building," while the top level, "an open corridor," would connect all the ward floors to each other. In that sense, Billings' external corridor was both an *exterior* and *interior* space—an architectural *figure* and a *ground* at once. In his essay, he noted the advantages of his scheme in providing a systematized separation and connections:

> *It is to be noted that with the pavilion thus elevated, and by the use of iron gates, etc., a very considerable amount of control is given over the movements of patients, and of visitors to them. The corridors leading to the central building divide the grounds, while, being entirely below the level of any ward, they do not interfere with ventilation.*[118]

The idea of a multi-story corridor was also endorsed by Niernsée. In discussing the connection between the various wards and buildings of the Hospital, he had suggested using "the basement and its connecting corridors" be used to distribute and transport "food, patients, utensils, furniture, clothing, etc." and "the upper connecting corridors," be used "merely by the attending physicians, visitors, and as a place of in-door exercise for convalescent patients." He observed that if the upper corridors were to be left open—as in the Free Hospital in Boston—they offer little protection against rain, snow or cold, and if they were to be fully enclosed—as in the Herbert Hospital and most other new pavilion hospitals—they obstruct "the perfect free

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[117] In the final plans and the built Hospital, some of these basement level corridors fell below the level of the ground due to grading difficulties but they were never fully submerged.

[118] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 27.

circulation of air around and between the blocks." His proposals, similar to that of Billings, was to provide a combination of an open and closed corridors: "closed basement corridors with sashes and ventilators, available at all seasons," that connected all the various buildings, with "a flat terrace roof on a level with the first floor, surrounded by a railing or balustrade" that provided a space for the general communication and the exercise of patients in fair weather, "thus the free circulation of air all around the wards would be left entirely unobstructed above the first floor."[119]

By the time Billings and Niernsée prepared the final plans of the Hospital, the corridor had turned into a three-story structure (Figure 1.15). The top level was an open corridor, which Billings described as "an open terrace walk." It was positioned at the same level of the ward floors "at 124 feet above mean tide," and created an elevated circulation ground reserved for medical staff, students, patients and visitors (Figure 1.16). "This arrangement," Billings wrote "permits a perfectly free circulation of air between and around the buildings above the level of the ward floors, and secures the best influence of the prevailing southerly winds."[120] The open terrace corridor was meant to always remain an exterior space even when it was internalized. In instances where the terrace walk penetrated or passed through a pavilion, it always maintained its aerial separation as an open passageway or tunnel, an exterior space within the building interior. In the ward floor plans, the open terrace walk was drawn as the *ground*.

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[119] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 340-341.

[120] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 60.

The “open terrace walk”—later becoming known as “the bridge”—not only regulated or controlled the pattern of circulation between the wards, but it also functioned as a disinfecting device.[121] The circulation to and from any of the wards was designed in such a way that it was “not possible to pass to or from the octagon or either of the common wards without going into the free external air, so that there can be no communication between the air of different wards.”[122] This condition was prescribed not only for the circulation between the buildings but also within them. Stairs were intentionally placed in the exterior space adjacent to the corridor, so that one had to leave the interior to the exterior in order to go from one floor or ward to another. Even the service personnel who traveled in the lower level had to exist the closed corridor into the exterior first before being able to enter the wards.

Below the open terrace walk, there was a closed corridor, which Billings simply called the “corridor.” At “114 feet above mean tide,” the corridor was at the same level as the main floors of the Administration and Apothecaries’ Building, the Kitchen, Nurses’ Home, and the Bathhouse, thereby connecting all the service and administrative spaces of the Hospital (Figure 1.17).[123] In keeping with its domestic tradition, the closed corridor was reserved exclusively for the Hospital’s service personnel and the supplies, food or medicine they carried. This arrangement kept the patients, visitors, or even the medical staff away from the closed corridor in order to prevent the spread of disease, while allowing the service personnel, and the things they

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[121] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 62.

[122] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 60.

[123] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 60.

carried, to move freely between the buildings. Enclosed by walls and punctured by windows, the "corridor" appeared in the plans as a *figure*.

At the lowest level, below the closed service corridor, Billings envisioned an entirely different kind of corridor, which he called the "pipe tunnel." Placed below the ground for much of its length, the pipe tunnel was a fully enclosed underground space reserved for all the pipes, ducts and wires that traversed between the buildings (Figure 1.18). The Hospital used a complex system of heating and ventilation with central hot water and steam boilers in the Nurses' Home and the Kitchen buildings. Air, water and steam then circulated from these locations to the "ventilating chamber" at the basement of the pavilions via a series of ducts and pipes in the pipe tunnel.[124] The pipe tunnel was therefore delineated in the plans as a *void.*

The Administration Building, the Kitchen Building, the Nurses' Home, and the Apothecaries' Building were connected to the patient pavilions via the corridor system, and were all heated by "a system of circulation" of hot water furnished by boilers at the Kitchen and Nurses' Home.[125] There were a total of six hot water boilers, four in the vaults at the Kitchen Building, and two in the cellar of the Nurses' Home. Hot water from the boilers passed into a 26-inch cast-iron pipe, "the great outflow main," that was hung on rollers from the ceiling of the pipe tunnel. From this main flow pipe, smaller pipes went off at each building, supplying the pipes in the heating coils. The cooled water would then return from the heating coils via a similar system of pipes and

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[124] Pipes, ducts or wires during this period usually did not have their own space in the buildings. They often ran across spaces, along the walls or occasionally inside them, but never shared the same space, or circulated the same way, as the building inhabitants. Even by the turn of the twentieth century, the placement of ducts along the basement corridor of the Royal Victoria Hospital in Belfast (1903) was considered a radical innovation. See: Reyner Banham, *The Architecture of the Well-Tempered Environment* (London: Architectural Press, 1969). 80-82.

[125] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

mains back to the boilers (Figure 1.19). "This circuit," Billings wrote, "is practically a closed one; none of the water being drawn off, or used, at any point, so that there is very little loss."[126] The valves on all the mains as well as on the supply and discharge pipe to each coil would enable the rate of "the circulation," and therefore temperature in each building, to be controlled manually.

In addition to heating and ventilation apparatus, the pipe tunnel also carried iron pipes used for the disposal of the "fouled water" from the buildings. While Baltimore at the time had no sewerage system, these iron pipes separated the soiled water and excreta of the water closet and ward sink sewerage from those of the kitchen sinks or wash basins, and carried them to multiple temporary wells and traps around the site (Figure 1.12).[127] The corridor and all the buildings were also wired for electricity even though electrical service was not yet available in the city.[128] By designating it as a dedicated space for mechanical, electrical, and plumbing apparatus, Billings turned the corridor into a a form of building infrastructure or core—one that could easily accommodate, and adjust to, the operation of the building.[129]

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[126] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 67.

[127] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 77-80.

[128] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 80. In addition, there were rooms in the Kitchen Building (marked E. L. P. In plan) for "the electric light plant, including engines, dynamos, etc., when it is thought best to provide these." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 100.

[129] In 1894, for instance, just five years after the Johns Hopkins Hospital opened, the seventeenth-story Manhattan Life Insurance Building would create a system air propulsion through the large ducts along the elevator shaft that branched off to each floor via the corridors. See "Power and Heating Plant, Manhattan Life Insurance Building," *American Steam and Hot-Water Heating Practice* (New York, 1895), 212–17.

If the “open terrace” on top functioned as means of aerial separation, decontamination and disinfection, and the closed “corridor” in the middle provided means of physical connection and servant circulation, the underground “pipe tunnel” functioned as means of transportation and communication. In this type of corridor, things did not simply traverse or move (on foot or wheels) but flowed, and literally *circulated* incessantly, in pipes, ducts and wires. And this form of communication also involved telecommunication. Communication in the Hospital was centralized in the Administration Building and was distributed to other buildings via telephone lines in the pipe tunnel. The switchboard inside the clerk’s office allowed “any building of the hospital” to be put in “direct telephonic communication with any other building of the institution” and with the general telephone service of Baltimore.[130] Patient rooms in the Pay Wards as well as some rooms in the Nurses Home were also equipped with electric bells that would send sound signals, via the corridor, to the enunciators in the upper levels of the Administration building where the Superintendent and the resident physicians and students resided.[131] This system of telecommunication was also intended to be used to register and communicate air pressure and temperature. Billings had devised a “telemeter system,” a system of registration by electrical dials, that recorded the amount of air passing out of a ward, and the temperature at one or two points inside the ward, and transmitted that information.[132] The pipe

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[130] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 81. The first recognizable voice sound transmission was made on June 3, 1875. For a brief history of the telephone and its use in the railroad industry see: Warren H. Hay, “The Beginnings of Telephone Dispatching,” Railroad History, No. 130 (Spring 1974), 55-60.

[131] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 83, 85, 103.

[132] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 81.

tunnel therefore functioned as an architectural conduit for both physical and remote communication.

Information exchange and record-keeping had to rely on a uniform timekeeping. Time, during this period was not yet fully synchronized in the United States. The railroad's nation-white time zone of 1883 was adopted gradually in the 1890s but would not become law until 1918.[133] The emergence of electrical telegraphic technologies such as stock tickers, time signals, and remote detection systems provided sense of simultaneity within the new managerial structures and financial markets.[134] This synchronized temporal awareness, manifested in the popular demand for personal watches, and the propagation of clocks on civic monuments, in offices, factories, or railroad stations, reflected the perceived value of punctuality, time-thrift, and the application of time to discipline.[135] In factories, the spatial concentration of production and the functional subdivision of labor prompted greater synchronization of workers' routine.[136] Billings saw this synchronization an essential condition for the Hospital. To that end, he had devised a uniform

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[133] *Records of the New England Association of Railroad Superintendents* (Washington, DC: Gibson Brothers, 1910), 37; Carlene E. Stephens, "Partners in Time: William Bond & Son of Boston and the Harvard College Observatory," *Harvard Library Bulletin* 35, no. 4 (Fall 1987): 351–84; Alexis McCrossen, *Marking Modern Times: A History of Clocks, Watches, and Other Timekeepers in American Life* (Chicago and London: The University of Chicago Press, 2013), 113.

[134] For more on time-keeping and management practices in the nineteenth century see: Jeremy Stein, "Reflections on Time, Time-Space Compression and Technology in the Nineteenth Century," in *TimeSpace: Geographies of Temporality*, Jon May and N. J. Thrift (eds.) (New York: Psychology Press, 2001); Alexis McCrossen, *Marking Modern Times: A History of Clocks, Watches, and Other Timekeepers in American Life* (Chicago and London: The University of Chicago Press, 2013); JoAnne Yates, *Control Through Communication: The Rise of System in American Management* (Baltimore: Johns Hopkins University Press, 1993).

[135] Alexis McCrossen, *Marking Modern Times: A History of Clocks, Watches, and Other Timekeepers in American Life* (Chicago: University of Chicago Press, 2013); Robert H. Wiebe, *The Search For Order: 1877–1920* (New York: Hill and Wang, 1967), 42–43.

[136] On the relationship between the division of labor and temporal order see: Karl Marx, *Capital: A Critique of Political Economy* (New York: Modern Library, 1906).

timekeeping system that relied on a series of pneumatic clocks placed in all the wards, the corridors, the Kitchen, the Administration Building, and Nurses' Home. These clocks were driven by "pulses or puffs of air," generated in central apparatus in the Administration Building and transmitted across the Hospital buildings via small iron pipes in the pipe tunnel.[137]

In this way, the terrace-corridor-tunnel amalgam was conceived as an instrument for the spatiotemporal organization of the Hospital. Beyond managing and regulating the circulation of people and the things they carried (supplies, food, medicine, germs, etc.), the corridor managed the circulation of air, steam, water, sewage, electricity and telecommunication signals. The pipes, ducts, and wires running along the corridor managed the regular flow of energy, information, and even the passage of time. This condition of the corridor, as Mark Jarzombek has argued, was not predicated on the domestic conditions of the Victorian or post-Victorian era—as Robin Evans has suggested—but "purely modern ones," built around the nation-state identity, social and class structure, industrialization and labor economy, and sanitation and hygiene, that constituted the corridor an "instrument of modernity."[138] This allowed the corridor in the Johns Hopkins Hospital to escape the limitations of the plan—a heterogeneous architectural element that was now a *void*, a *figure*, and a *ground* at once—leading to the production of multiple plans (block plan, heating plan, plumbing plan, electrical plan, etc.). By the turn of the twentieth century, this modern reformulation of the corridor, as a multi-layered device, would transform the architecture

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[137] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 81.

[138] Mark Jarzombek, "Corridor Spaces," *Critical Inquiry* 36 (Summer 2010), 767-770.

of the hospital, prompting many physicians and hospital planners to argue against the single-story pavilion plan in favor of the multi-story "corridor plan."[139]

## 1.3 Independent Variables

Billings approach toward the plan of the Hospital, as a provisional kit of parts or a *system*, enabled the isolation and abstraction of specific components or conditions of its architecture and allowed them to become subject to independent scientific study and analysis. By the time he entered his role as the Medical Advisor, on July 1, 1876, the Building Committee had carefully studied the five essays and prepared a "condensed" version of those proposals.[140] On the basis of those, the Trustees had informally agreed on six architectural principles and had Niernsée prepare a series of preliminary drawings in relation to them:

> *I. That the main administration building shall front on Broadway, and that its centre shall come opposite the centre of McElderry Street.*
>
> *II. That a special feature of the Hospital shall be a large, open central space, ornamented with trees, flowers, a fountain, etc.*
>
> *III. That the main or Broadway front shall form the memorial or monument part of the structure, and shall consist of handsome, though not elaborately ornamented buildings.*
>
> *IV. That the buildings of the Hospital shall be of brick.*
>
> *V. That the south ends of all wards shall be clear of rooms or buildings, and be fully exposed to air and light.*

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139 Ernst Beyer, "Die Heilsta¨ttenbehandlung der Nervenkranken," *Zentralblatt für Nervenheilkunde und Psychiatrie* 31 (1908), 715, cited in Mark Jarzombek, "Corridor Spaces," *Critical Inquiry* 36 (Summer 2010), 762-763.

140 *"Hospital Plans," Condensed for the Use Only of the Trustees of the Johns Hopkins Hospital* (Baltimore: Steam Press of William K. Boyle & Son, 1875).

*VI. That the wards and the main administration buildings shall be connected by corridors, the top of which shall rise to, but not above, the floor level of the wards, and the floors of which shall be level, and entirely above the surface of the ground.*[141]

These six principles formed the basic criteria for the design and construction of the Hospital. In his first report to the Board of Trustees on July 15, 1876, Billings agreed to the general principles but focused mostly on the question of cost.[142] He emphasized that "detailed working drawings of every building" should be prepared before construction begins, but noted, "I strongly prefer not to attempt to positively decide these questions at this time."[143] He recommended that the work of grading the site be postponed until the following year to allow him to better study and develop the plans.[144] The Building Committee granted his request to suspend the work and approved the proposed budget, while requesting that "the expenditure shall be judiciously made to produce the best permanent, working results, without the expenditure of money upon mere architectural

[141] Johns Hopkins Hospital, *Reports and Papers Relating to Construction and Organization,* No. 1 (July 15, 1876), 1-2.

[142] Advocating for a more elaborate plan, he estimated that the cost would be around one million dollars, which meant, given the annual earnings of the corporation outlined by Hopkins, it would take four years to secure funding for the construction of the buildings. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 1 (Johns Hopkins Hospital, July 15, 1876), 16.

[143] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 1 (Johns Hopkins Hospital, July 15, 1876), 16.

[144] He offered the Trustees an option of "good, substantial buildings […] making cost a secondary consideration," or to limit the amount and reduce the quality of buildings to remain within budget. He argued cautioned not to miss this opportunity by narrowing or restricting the benefits of the Hospital. "This Hospital," he wrote, "should advance our knowledge of the causes, symptoms and pathology of disease, and methods of treatment, so that its good work shall not be confined to the city of Baltimore, or the State of Maryland, but shall part consist in furnishing more knowledge of disease and more power to control it, for the benefit of the sick and afflicted of all countries and of all future time." He went on to argue that the budget should be sufficient to provide adequate space and equipment for the staff to study their patients carefully and minutely, which would in turn attract qualified physicians, and therefore the Hospital should be built based on a more elaborate plan. Johns Hopkins Hospital, *Reports and Papers Relating to Construction and Organization,* No. 1 (July 15, 1876).

show."[145] Much of the work to that point had been done in drawings and this allowed Billings to invest the time and resources he deemed necessary to evaluate some of those architectural assumptions.

As a scientist, Billings took a different approach toward the design of the Hospital was a direct application of the *scientific method* to architecture.[146] He spent the first few months researching current practices and surveying the field on the basis of literature review and visits to existing American hospitals. He then took a three-month long leave of absence to visit Europe in order to "obtain certain data there which I require."[147] During that trip, Billings examined hospitals and medical schools across Europe, including in Dublin, London, Oxford, Cambridge, Leeds, Liverpool, Manchester, Edinburgh, Glasgow, Amsterdam, Bonn, Leipzig, Berlin, Dresden, Vienna, Venice, Verona, Milan and Paris.[148] He also met and corresponded with scientists and experts on "the subject of Hospital Construction and Organization"—including Joseph Lister, Thomas Henry Huxley, and Florence Nightingale—with whom he shared the sketch plans of the

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145 Letter from Office of the Johns Hopkins Hospital to John S. Billings (July 22, 1876), General Correspondence, (July-Sept, 1876), Box. 2, John Shaw Billings Papers, The New York Public Library.

146 Alistair Fair as illustrated this in his essay on the Johns Hopkins Hospital. See: Alistair Fair, "'A Laboratory of Heating and Ventilation': The Johns Hopkins Hospital as Experimental Architecture, 1870–90," *Journal of Architecture* 19, no. 3 (2014), 357–81.

147 Billings, *Reports and Papers Relating to Construction and Organization,* No. 1 (Johns Hopkins Hospital, July 15, 1876), 16.

148 Letter from John S. Billings to Daniel Gilman (1876), General Correspondence, Oct. 1876 - May 1877, John Shaw Billings Papers, The New York Public Library.

Hospital and sought their opinions and criticisms.[149] And he carefully documented his observations and the feedback he received.

Upon returning from his grand tour, Billings gave an account of the trip in a spacial meeting of the Board of Trustees on January 11, 1877. His report covered his findings and recommendations on medical education, training of physicians and nurses, as well as the "vexed question of heating and ventilation" that he considered to have been the main subject of his inquiries abroad. He wrote that the general plan of the Hospital "is approved by the majority of the experts to whom I submitted it," and that he does not think there is much to learn from Europe on Hospital construction and management or methods of heating and ventilation as "these things cannot be said as yet to be settled on any scientific basis of observed facts, and there are nearly as many opinions as persons."[150] Despite the valuable information and feedback he obtained during that trip, he reported that he "did not fid it possible to obtain positive reliable data as to the effects of various plans of Hospital construction or ventilation."[151]

In order the settle the "vexed question of heating and ventilation," Billings relied on a series of experiments conducted at his request in two hospitals in Boston and in Washington DC, carefully monitoring the heating and ventilation performance in order to gather what he termed "positive

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[149] Z. Cope, "John Shaw Billings, Florence Nightingale and the Johns Hopkins Hospital," *Medical History* 1, no. 4 (1957), 367–68, cited in Alistair Fair, "'A Laboratory of Heating and Ventilation': The Johns Hopkins Hospital as Experimental Architecture, 1870–90," *Journal of Architecture* 19, no. 3 (2014), 367.

[150] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 3 (Johns Hopkins Hospital, July 11, 1877), 4.

[151] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 3 (Johns Hopkins Hospital, January 11, 1877), 5; John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Profession of Baltimore, February 5, 1877," *Medical Record* XII (July 1877), 130-131.

data." He hoped that the results of these experiments would reveal the merits of different methods of hearing and ventilation in hospitals "with a fair degree of scientific precision."[152] Billings' purity test for a "perfect ventilation" was that "a man shall inhale no air or suspended particle which has recently been in his own body, or in those of his companions."[153] There were, however, various consideration to determine the method of ventilation in a hospital: From what makes "pure and impure air," and the "standard of purity, and quantity of fresh air required," to the "effects of moisture in the air," and the method of "supply and distribution of air." There were three methods of ventilation at the time that Billings was considering—the natural method, ventilation by aspiration, and ventilation by propulsion—as well as the possibility of using a combination of two or all three of those methods.[154] In addition to ventilation, Billings was also weighing the choice between heating by hot water or steam. The various possibilities and options presented by the available heating and ventilation systems provided basic premise of his experiments in the two existing hospitals, which both were similar structures and in comparable sites and climates to his proposed Hospital.

[152] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 75.

[153] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 5.

[154] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 21.

The Barnes Hospital of the Soldiers' Home in Washington DC was a multi-story brick structure that used low temperature hot water heating.[155] Billings was particularly interested in the Barnes Hospital because it allowed him to compare natural ventilation, used in the summer, with ventilation by both propulsion and aspiration that was necessary in the winter. In the Barnes Hospital, air supply was drawn into the buildings through a single vertical shaft and then through ducts below the hospital into the wards. Exhausting the air could then be done through numerous heated ducts that led two main exhaust stacks, as well as the use of a six horse power fan that could propel the air through the building in order to cool it in warm weather or simply accelerate air exchange. At Billings' request, the fan was run at different rates to test the quantity of air supplies in "all possible rates, and with varying amounts of steam and coal." This experiment, for instance, was conducted once with all registers, doors, windows, and ventilation outlets open, and another time with all windows and doors closed but the usual ventilating registers and outlets left open.[156] There were also observations on the amount of carbonic acid or "impurity" in the air, however, since no instrument could accurately detect or measure it, the observations relied on the "sense of smell."[157] These trials and observations were conducted over the period of a full year and were carefully documented by Surgeon D. L. Huntington of the U.S. Army.[158]

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[155] The heating coils were housed in brick chambers in the basement, at the sides of the windows, and were equipped with a valve at the point of supply pipe entry to each coil which allowed the amount of air supply to be regulated. While air could be admitted to the wards through either the ceiling or the floor, floor level was favored. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 21-31.

[156] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 29-30.

[157] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 33-34.

[158] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 19.

In the Boston City Hospital similar experiments and observations were conducted, under Billings' direction, by Dr. Edward Cowles, Superintendent of the hospital, on one of the one-story wards of the Hospital. This ward had a similar size—94 feet long by 26 $^{1/3}$ feet wide and 20 feet high—to those recommended by Nightingale and proposed by Billings for the Johns Hopkins Hospital.[159] Similarly again to Billings own proposal, the wards had seven windows on each side, and the ground floor was devoted entirely to ventilation—a space where only the hospital engineer had exclusive access to enter and adjust the equipment. Air supply entered the ward through the openings in the walls of the ground floor, and could either enter directed into the ward or pass over steam coils to be heated. In line with Billings own proposed arrangement for the Johns Hopkins Hospital, air entered the ward from the floor and was exhausted at the ceiling. The experiments, conducted over a period of two weeks, were intended to show the amount of air supply and return from the ward, the amount of heat transfer, and the approximate amount of coal consumed for that purpose.[160]

In his fifth report to the Trustees, submitted on February 12, 1878, Billings published the findings from these experiments along with "carefully prepared tables of the results obtained" (Figure 1.20).[161] While the result of these experiments provided much valuable data,

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[159] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 62-69.

[160] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 63.

[161] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 62.

the varied condition of the hospitals revealed discrepancies and even problems.[162] For instance, in the Boston City Hospital, Billings observed that the "fresh air" was was escaping at the ceiling and not mixing with and diluting the "foul air" in the ward. This prompted Billings to have Cowles to conduct another series of experiments, using smoke, in order to determine the exact pattern of air circulation.[163] Despite these, the results remained inconclusive. Billings wrote in his report that "it is not easy to explain the different results obtained in the three analyses, but it is evident that a much larger number would be necessary to obtain positive conclusions."[164] He argued, "If we only had a year's careful observations" from similar hospitals around the country, "we should have the data for a treatise in Hospital heating and ventilation that would be really valuable and useful."[165]

A detailed study of heating and ventilation at a national scale, however, was not available to him. Unable to obtain any reliable data, Billings opted to use the final built buildings at the Johns Hopkins Hospital as the a full-scale experiment: "a sort of laboratory for heating and

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[162] Based on his findings and a review of other hospitals, Billings identified various problems with hospital ventilation, which included: poor arrangement of the buildings, insufficient flue sizing, improper arrangement of flues to secure constant and uniform dilution, negligence on the power and influence of the wind on ventilation, unwillingness or inability to use the equipment provided by architect and engineer because of energy saving or simply "carelessness," and finally the lack of what he called "intelligent, careful and continuous supervision." John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 73-74.

[163] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 71.

[164] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 71.

[165] Billings listed the Massachusetts General Hospital: the Presbyterian, Roosevelt and New York Hospitals of New York: the Presbyterian, Episcopal and University Hospitals, of Philadelphia: the Cincinnati Hospital, and the Cooke County Hospital of Chicago as examples. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 72.

ventilation." In his report, Billings justified this experimental approach as an epistemological, pedagogical, economic, and even moral imperative—one that less-endowed institutions could not afford to carry out:

> I. *I am not sufficiently assured of the superiority of any one system of minor details above all others to be willing to recommend its exclusive adoption. […]*
>
> II. *I think that by careful and scientific trial of several different systems this hospital will be able to settle with a fair degree to precision, some of the vexed questions with regard to relative efficiency and economy of various plans, and this at a comparatively small expense. This would be one of the most important contributions which this institution can make to our knowledge of Hospital hygiene, and its decision of the matter can be made authoritative.*
>
> III. *This hospital is to contribute, among other things, to education—an among the things which it is to teach is sanitary construction of buildings, such as those it contains, and it can present a fair variety. Now to teach effectively it should be able to show various methods and their results: it would be a sort of laboratory of heating and ventilation.*
>
> IV. *This variety can be secured at comparatively small expense. The buildings are so large and numerous that several boilers will be needed—and a part of these can be for steam, and others for hot water. […] So far as ducts and registers are concerned they are not expensive, and they can be shifted above and below the wards to almost any extent, when the most satisfactory distribution has been determined. In order to facilitate experiments and observations upon the working of the ventilating apparatus, care should be take that in all important ducts, flues and chimneys, means of access to the interior are provided, so that anemometers, thermometers, etc., can be conveniently introduced and observed. […]*[166]

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[166] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 75-76.

To that end, Billings utilized the pavilion system as a set of independent variable for architectural experiment. He recommended using a varied systems of heating and ventilation in the wards and "not employing any one system alone at first," in order to "compare steam with hot-water heating, to determine the velocity of water at different temperatures, to compare ventilation by aspiration with that by propulsion, or by upward currents with those drawn downward."[167] In addition to heating and ventilation systems, Billings also used different building designs as experimental variables. Rather than a standard "Nightingale pavilion," his plan of the Hospital included variations in form, size, and interior layout. Even the seemingly identical Common Wards were equipped with different ventilation systems to allow them to be studied in isolation.

The culmination of Billings research, field-work, and experimentations was the development of a hypothesis that manifested itself in the final Block Plan of the Johns Hopkins Hospital in 1878 (Figure 1.11). The plan was an assortment of all the architectural variables he had studied and considered: permanent structures and temporary tents, one and two-story buildings, rectangular and octagonal pavilions, private rooms and open wards, heating by water and steam, and ventilation by natural means, by aspiration and by propulsion. He postulated that through careful comparisons and observation of the buildings' performance, reliable data might be obtained which would enable the Hospital to make "most important contributions" to the "knowledge of Hospital hygiene."[168] These controlled architectural variations, along with a detailed system of

[167] For instance, while most wards used water heating systems, the amphitheater was heated by steam in order to provide "the means of experimental comparison of the two systems." John S. Billings, "The Plans and Purposes of the Johns Hopkins Hospital: An Address delivered at the opening of the Hospital, May 7, 1889," *The Medical News*, (May 11, 1889), 12.

[168] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 75.

record-keeping, were therefore intended to allow Billings to go beyond hypothetical speculation and theory by correlating environmental data with disease incidence, and ultimately determine at the most effective design solution.

The plan included over twenty buildings, twelve of which were patient wards. The Administration Building was placed at the dominant center, with two sets of patient wards on either side running along the east-west axis of the site. In each set, there were four different pavilion types: a Pay Ward, an Octagon Ward, three Common Wards, and an Isolation Ward. Private Wards and Isolation Wards, at the south and north ends of the site, were laid out with individual patient rooms while Octagon Wards and Common Wards had an open floor plan with patients sharing the same space. All the pavilions were oriented north-south, connecting to the corridor on the north end of the wards, leaving those with open wards—Octagon Wards and Common Wards—with a “sun room” to the south. Pay Wards and Octagon Wards were two-story buildings, with a ward on each floor, while Common Wards and Isolation Wards were single-story buildings with a ward on the first level. There were, therefore, a total of sixteen wards, distributed in twelve buildings of four different types. Other buildings, such as the Laundry, the Stable, the Pathological Building, Amphitheater and Dispensary, were all placed around the periphery of the site with access from the street.[169]

The plan also provided variations for heating systems (Figure 1.19). The Administration Building, the Kitchen Building, the Nurses Home, and the Apothecaries Building were heated by

[169] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 59.

hot water, furnished by boilers at the Kitchen and Nurses Home.[170] Other buildings of the Hospital, including the Amphitheater, Dispensary, and Bath House, were heated by low-pressure steam produced from boilers at vaults of the Kitchen Building. The Pathological Building and the Laundry were also heated by steam, but each were provided with their own boiler. The choice of steam-heating for these buildings was partly due to practical reasons—the fact that they were not occupied continuously, and steam would allow them to be heated more rapidly than hot water —and partly to provide "the means of careful comparison of the two systems of heating for experimental and teaching purposes."[171] To that end, and "for purposes of experiment and observation," thermometers and other apparatus were placed at various points along the pipes to measure both the temperature and even the velocity of the currents in the pipes.[172] In designing the ventilation, Billings took a similar experimental approach. Each ward was equipped with a combination of three various means of ventilation: windows provided means of natural ventilation, the buildings' ventilation system worked with aspiration, and ceiling fans were placed in some wards, with the possibility to add to others, to provide ventilation by propulsion.

Architectural experimentation was not unprecedented during this period. Experiments and demonstrations were especially fundamental to the environmental design of major nineteenth-century buildings. These experiments, however, were usually conducted in temporary structures,

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[170] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

[171] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 68-69. In order to "compare the effects of low pressure steam heating in a ward with those of hot water," Billings had even suggested the possibility of furnishing one of the wards with both hot water and steam heating but he decided against that due to the additional cost. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 81.

[172] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 69.

models or mock-ups. For instance, following the 1834 fire of the House of Commons in London, the committee in charge of reconstruction demanded that the new heating and ventilation system "be tested by experiment as nearly as possible, under the conditions in which it would be practically executed."[173] David Boswell Reid, a Fellow and Chair of Chemistry at the Royal College of Surgeons in Edinburgh who had designed and built a special laboratory to conduct experiments on heating and ventilation, built a one-to-one scale model to conduct a series of experiments on his new heating and ventilation systems and recorded his observations in detail.[174] Billings was well aware of these precedents and had even cited Reid's experiments multiple times—both in his "A Report on Barracks and Hospitals" in 1870, and in his essay proposal for the Johns Hopkins Hospital in 1875.[175]

Trustees of the Johns Hopkins Hospital had also suggested a scientific approach. In a November 13, 1874 report, before Billings was engaged in the project, the Building Committee had expressed frustration that little progress had been made in improving hospital construction and management "as the result of carefully considered and well tried experiment." They added that finding out "the cause of this mastery of disease and death, in public institutions" is a difficult problem to be solved, "and it is all the more difficult because its solution cannot be made by limited individual experiment, but must be demonstrated by proofs upon a large and

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[173] W.S. Inman, *Report of the Committee of the House of Commons on Ventilation, Warming and Transmission of Sound* (London: John Weale, 1836), 8.

[174] David Boswell Reid, Illustrations of the Theory and Practice of Ventilation (London: Longman, 1844), 273–309.

[175] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 22-23.

commanding scale."[176] And even in their letter to the five physicians in 1875, the trustees had suggested scientific, verifiable method in approaching the design, writing that "there must be some general principles of hospital hygiene and of hospital treatment fixed and immutable in their character, the discovery and proof of which are the result of close, careful observation and judgement."[177] The use of the built Hospital itself as an experiment, however, was unanticipated and unprecedented.[178]

Billings' intended experiments considered not just systems of heating and ventilation, but also building form which, unlike Reid's experiments for the House of Commons, was not predetermined or fixed. The sheer number of variables and available possibilities, would have made it impractical to conduct the experiment in a laboratory setting. For instance, in order to test best combination between three ward types and two heating mechanisms alone, Billings would have had to build at least six models or mock-ups. If he added three methods of ventilation, that would increase the number of conditions to eighteen. As a set of isolated and independent objects within a larger assembly, the pavilion plan offered an ideal sampling for an

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176 Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 20.

177 Francis T. King's letter to the Five Physicians (March 6, 1876), in John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 18.

178 Billings believed that despite the abundance of literature on the subject of heating and ventilation, there is "no positive data" in those texts, and that he had found no "precise information" on the cost or the amount of air heated and supplied in existing hospitals. In his essay, Billings had suggested using the built pavilions of the Hospital as site for temporary experimentation on heating and ventilation at first before adopting the best method as the final one for the Hospital. He wrote: "I cannot pretend to propose a system which shall be perfect in all respect, as as this Hospital must be considered as an experiment, to a certain extent, I should endeavor to so arrange it that the system first tried need no necessarily be a final one, but should admit modifications as found necessary by careful, practical trial in the first one or two pavilions erected." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 22.

architectural laboratory where these variations could be manifested not only independently but also simultaneously, allowing multiple experiments to be conducted at once.

But the ultimate measure for the experiment was not just temperature or human comfort but health and recovery. Therefore, in order to narrow the range of the architectural and the environmental *independent variables* of the experiment, Billings also had to rely on an *experimental group* that was otherwise impossible simulate in a model: the presence living patients and the continuous observation of their health over a long period of time. The use of hospital patients as clinical, teaching or research material was also not unusual in the nineteenth century. As medical education increasingly emphasized clinical experience, hospitals offered doctors and medical students with an adequate supply of clinical material for research and experimentation.[179] And these experimental treatments in the hospital had allowed doctors to consolidate their professional authority.[180] However, those who submitted to being used for medical education or experimentation were not the private patients, who paid for their treatments, but patients who were admitted without charge who tacitly paid for their treatment by serving as a "clinical material."[181]

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[179] The medical hospitals that emerged in the late eighteenth century, as Foucault as shown, functioned as a laboratory for experiments on human populations, justified by the pursuit of advancing medical knowledge. See: Michel Foucault, *The Birth of the Clinic: An Archaeology of Medical Perception,* A. M. Sheridan Smith (trans.) (New York: Vintage Books, 1973); Michel Foucault, "The Incorporation of the Hospital into Modern Technology" (1976), Edgar Knowlton Jr., et al. (trans.), *Space, Knowledge and Power: Foucault and Geography*, Stuart Elden and Jeremy W. Crampton (eds.) (Hampshire: Ashgate, 2007), 141-152.

[180] Adrian Forty, "The modern hospital in England and France: the Social and Medical uses of Architecture," in *Buildings and Society: Essays on the Social Development of the Built Environment*, Anthony D. King (ed.) (London, Routledge and Kegan Paul, 1980), 61–93.

[181] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 132.

Jeanne Kisacky has suggested that the Johns Hopkins Hospital was designed as "a tool for scientific research" and that Billings intended experiments were meant to "provide the objective data necessary to prove or disprove the long-accepted but scientifically unproven assumptions about design and health."[182] The experiment of the Johns Hopkins Hospital, however, was of a different nature. Medical science had already assumed a correlation between the environment and health and there was no question about the benefits of better spatial planning or ventilation in hospitals. There was, however, an on-going debate around how to best achieve it. Billings' own justification for the experiment and the parameters he selected suggest that the goal was not to evaluate the scientific assumptions about design and health but the architectural assumption about systems of heating, ventilation or ward design. The main subject, or the *independent variable,* of the experiment was not the patient population but the very architecture of the Hospital.

Billings did not provide the detailed criteria of his experiments but an examination of the plans and the description of the heatings and ventilation systems provide some information as to the nature of the experiments he had in mind, and what constituted the *constants*, *independent* and *dependent variables*, and *control* and *experimental groups,* as well as the possible flaws in the intended experiments. The plans were typically drawn with the North facing left, which would place the the Administration building on the West end of the site at the center bottom of the plan, with all the wards as two series on its sides running in the East-West direction. Variations of the ward types were introduced in the vertical (east-east) axis, while similar ward types for different

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182 Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940*, (Pittsburg: University of Pittsburg Press, 2017), 212-213

sexes aligned in the horizontal (north-south) axis. Based on these conditions described or drawn, Billings should have been able to conduct at least three different types of experiments: first, on heating; second, on ventilation; and third, on building form.

The first set of experiments, would have been to evaluate the effectiveness of steam heating compared to hot water—one mentioned by Billings himself. All the steam-heated buildings would therefore constitute the *experimental group,* while all others heated by hot water would be the *control group* of the experiment. The *independent variable* would be the steam heating system of the building—varied on purpose by the experimenter—and the *dependent variables* would be the temperature inside the buildings would would presumably change based on the method of heating. The temperature outside would then be the *constant* between the groups. In this case, since none of the buildings in the *experimental group*—the Amphitheater, the Dispensary, or the Bath House—have the same form as those in the *control group*, the comparison between the two heating systems would be inconclusive. In other words, the *experimental group* has different variables, other than the *independent variable,* that is different with the *control group*. In order to make that experiment work, at least one of the steam-heated buildings should have have been similar in form to one of the others heated by hot water.[183] There was, therefore, no way to scientifically test the steam heating system beyond simply measuring the temperature inside and comparing that to a desired or intended number in mind.

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[183] It is possible that Billings originally envisioned one of the two set of wards to be heated by steam and the other by hot-water but in the final plan when most of the building on the south side were eliminated, he opted to have all the wards heated by hot water.

The second set of possible experiments, would be to test the ventilation system. There were three types of ventilation systems utilized in combination in each ward—natural ventilation, ventilation by aspiration, and ventilation by propulsion—and the use of valves and fans in the wards would have enabled each to be switched on or off. Since the *experimental* and *control groups* should have everything but the *independent variable* in common, only the buildings with two or more identical wards could have been used for this experiment—at least one ward as the *control group,* and one as the *experimental group.* All the patient pavilions could have qualified since there were at least two copies of them in the final plan. For instance, to test which method of ventilation would work best, an experiment could have been conducted using three Common Wards as *experimental* and *control groups,* each using only one of the three methods of ventilation. In this experiment, with the outside air quality as the *constant,* the various methods of ventilation (natural, by aspiration, and by propulsion) would constitute the *independent variables,* and the presence of carbonic acid in the air of the wards would be the *dependent variable.* If the naturally ventilated Common Ward is used as a *control group,* then measuring the amount of carbonic acid in each of the other two *experimental groups* (the Common Wards ventilated by aspiration or propulsion) would have revealed which method of ventilation is most effective in improving air quality inside the wards. Similar type of experiments could have been conducted using less than three wards by changing the condition in multiple experimental trials.

Finally, a third and a similar type of experiment could have been to evaluate which open ward form would maintain the highest air quality. If that experiment is conducted using the Common Wards and the Octagon Wards as the *experimental* and *control group,* the ward form or geometry (rectangular or octagonal) would constitute the *independent variables*. Assuming that the heating and ventilation inside and the air quality outside the wards remain *constant,* then the presence of carbonic acid in the air of the wards would again constitute the *dependent variable* of the experiment. For instance, if the result of that experiment revealed a lower quantity of carbonic acid inside the Octagon Wards compared with that of the Common Wards, it would suggest that the octagonal form of the ward would maintain a better air quality than the rectangular form. More experimental trials could be imagined within the parameters set in the plan.[184]

These hypothetical experiments, however, rely on various environmental and technological assumptions that, at least at the time, were not warranted. For instance, the heating system worked with the ventilation systems and the variation in one would have inevitably effected the other. Also, the presence of carbonic acid—the purity test for air—could not be detected by any instrument and was only measured by the sense of smell. And most importantly, all the experiments considered the patients inside the wards—the air they exhaled or the heat they generated—as an experimental *constant*, at best, and quite possibly as *dependent variables*, at worst.[185]

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[184] For instance, one could imagine more experimental trials within the plan using the three methods of ventilation or the four ward types as *independent variables*. And with two sets of identical buildings on each side multiple experiments to be conducted simultaneously—for instance, one group (side) could switch to natural ventilation and the other to ventilation by aspiration or propulsion. In this way, the Wards between each side or column (North-South axes or horizontal direction in plan) would participate in an experiment on ventilation systems (the second type of experiments) while the Wards within each side (East-West axes or vertical direction in plan) would participate in an experiment on building form simultaneously.

[185] The patients were also not randomly assigned to the wards. These specific *blocking variables,* based on gender, race, type of disease or even socioeconomic class diminished the reliability of the experiments by turning the patient populations into another set of variables. As Chapter Four will illustrate, because these conditions were inscribed in the plan of the Hospital, ultimately only a certain class of patients were subjected to the experiments.

When Billings submitted a revised set of drawings along with his fourth report, he acknowledged that while he could not say that the plans are the best possible one, he believed it complied with Hopkins' wishes, and "from the point of view of the physician, the hygienist, the architect, and educator, and the investigator, in all respects, as good as an in some better, than that of any Hospital now in existence, or which has been proposed." While requesting for approval, he noted that "this is not a medical, architectural or scientific question, but one of finance, which belongs peculiarly to the Trustees to determine."[186] The Board approved the final block plan of the Hospital on February 20, 1877, and Niernsée was instructed to prepare the detailed drawings. In April of that year, the Building Committee was authorized to proceed with the construction.

In his letter of instruction, Hopkins had outlined the financial support for the construction and maintenance of the Hospital and the University. Hopkins divided his assets, about seven million dollars in total, equally between the two institutions. In his will, signed on July 9, 1870, Hopkins left all his bank stocks, real and leasehold estate to the Hospital, and his 330-acre country estate of Clifton along with all his common stock in the B&O to the University.[187] He had offered to pay $100,000 a year during his time for the construction of the Hospital and the Orphans' Home. In addition, he estimated the revenue from his property (worth two million dollars) would amount to $120,000 per annum. "If the Hospital and Orphans' Home are not built at my death,"

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[186] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 4 (Johns Hopkins Hospital, January 11, 1877).

[187] A significant portion of Hopkins' wealth at the time was invested in the common stock of B&O, fifteen thousand shares in total. Hopkins also recommended to the Trustees of the University in his will that the stocks not be disposed of but held as an investment, and to vote and represent that stock with diligence and to exercise their influence in promoting the usefulness of the Company. This condition tied the funding for the University—and by extension, the Medical School and the Hospital—to the B&O Railroad Company. Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. 1 (Baltimore: The Johns Hopkins Press, 1943), 18.

Hopkins wrote in his letter of instruction to the Trustees, "it will be your duty to apply the income arising from this property to their completion. When they are built, the income from the property will suffice for the maintenance."[188]

In his first report to the Board on July 15, 1876, Billings agreed to the general principles but raised the question of cost. Advocating for a more elaborate plan, Billings estimated that the cost would be $1,200,000, which would mean, given the annual earnings of the corporation outlined by Hopkins, it would take several years to secure funding and construct the buildings.[189] While Billings was responsible for the general supervision of the project, the responsibility for carrying out the provisions of the Hospital trust and managing the finances of the project fell in the hand of the trustees and specifically Francis T. King, the President of the Board.[190] The construction proceeded slowly since the funding for construction had to be secured through the annual income of the corporation. And because of that, the trustees could not let a contract for the entire construction. Instead, each year they had to estimate the annual income from the trust and authorize as much building during the year as the funds would allow. But this process was further hindered by the increase in construction cost and a progressive decrease in the annual income from the Hospital's endowment (diminishing from $234,022.27 in 1876 to $191,364.23

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[188] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 6.

[189] Billings, *Reports and Papers Relating to Construction and Organization,* No. 1 (Johns Hopkins Hospital, July 15, 1876), 16.

[190] King became so preoccupied with that task that he became ill and, in April 1884, he tendered his resignation to the Board of Trustees. The Board refused to accept his resignation but adopted a new by-law to delegate some of the duties of the "Executive Office" to the Finance Committee. Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 71-73.

in 1881), and the addition of medical facilities demanded by Billings. These factors continued to delay the construction and the anticipated date of completion of the Hospital.[191]

The trustees initially entertained the possibility of opening the Hospital for partial operation prior to its final completion. Billings had estimated that all the ward pavilions on the north side of the lot as well as the service buildings would be completed by October 1, 1885, and the Hospital trustees decided to set that date for the opening of the Hospital, with the assumption that the ward pavilions planned for the south side could be constructed at a later date. By October 1885, the buildings on the northern half of the Hospital were still not completed, and the construction, initially estimated to take four years, lasted twelve years.[192] When the Hospital finally opened on May 7, 1889, only half of the original patient wards built (Figure 1.12). Even in his *Description of the Johns Hopkins Hospital,* published a year after the opening, Billings presented the built block plan as an unfinished plan that showed the buildings "thus far erected," and argued that the size of the Administration and service buildings are suited to the original plan and "will be ample when all the wards are erected."[193] The pavilions on the south side, however, were never built.

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[191] Fielding Garrison, *John Shaw Billings: A Memoir* (New York: G. P. Putnam's Sons, 1915), 200-204; Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 68-73.

[192] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 95-97.

[193] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 59-60.

Through this process, Billings challenged the basic assumptions of the architectural plan, as a projective and an a priori act that grounds or plants the architect's ideas.[194] The plan of the Hospital was conceived not in terms of a set of permanent, corporeal and fixed components but as a transient and commutable system of interchanging parts, an analytical device, that would welcome addition, modifications or even destruction. This condition, therefore, removed the plan from the linear process of architectural production—one that begins with conception and ends with construction—and enabled it to operate as a document that existed outside of that process. The plan of the Hospital was neither prescriptive nor descriptive, it was not a priori or posteriori, but operated in parallel to the built reality of the Hospital. Billings preoccupation with the Hospital itself as a laboratory was to an extent that he forgot to include an actual clinical laboratory in his final plan.[195]

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[194] Sylvia Lavin has more recently examined the origin of the architectural plan as a plant. See: Sylvia Lavin, "Trees Make a Plan," *Log* 49 (2020); Sylvia Lavin, "Reclaiming Plant Architecture," *Positions,* e-flux Architecture (August 21, 2019); See also: "Architecture Arboretum" exhibition, curated by Sylvia Lavin, Princeton University School of Architecture (November 4, 2019-January 21, 2020).

[195] In the absence of a designated space in the final buildings, a temporary clinical laboratory was set up in the basement of one of the pavilions until a permanent laboratory was constructed near the hospital wards. Harvey Cushing, *The Life of Sir William Osler,* vol. 1 (London: Oxford University Press, 1925), 314; A. McGehee Harvey, Gert H. Brieger, Susan L. Abrams, and Victor A. McKusick, *A Model of Its Kind: Volume I, A Centennial History of Medicine at Johns Hopkins* (Baltimore: The Johns Hopkins University Press, 1989), 35.

# 2. GLASS TUBES AND EXPOSED PIPES:
## Dissecting the Atmospheric Machine

Between 1879 and 1883, John Shaw Billings published a series articles, in the *Plumber* and later in its successor the *Sanitary Engineer*, titled "Letters to a Young Architect on Ventilation and Heating."[1] Assumed an expert in heating and ventilation, Billings' "letters" were written in response to questions submitted to the journal. Among the first was a question from an architect who had found the books on the topic to be "chiefly made up of long-winded scientific speculations about the physics of gases, the composition of the atmosphere, units of heat, etc." and had asked for "some plain, practical directions." In response, Billings argued that, just as in diagnosing and curing a disease in a body, designing the heating and ventilation in a building "cannot be done by following a formula":

[1] John S. Billing, "Letters to a Young Architect on Ventilation and Heating." *Plumber* 3 (1879–80), 132, 154, 171, 191, 211, 233, 251, 271, 291, 311, 331, 351, 371, 392, 415, 432, 463; Continued in *Sanitary Engineer* 4 (1880–81), 8, 37, 68, 83, 110, 131, 155, 180, 203, 228, 253, 274, 305, 329, 470, 496, 536, 554; *Sanitary Engineer* 5 (1881–82), 6, 99, 266; *Sanitary Engineer* 6 (1882), 369, 492; *Sanitary Engineer* 7 (1882–83), 6, 122, 219, 339, 434, 602; and *Sanitary Engineer* 8 (1883), 523. In 1884, Billings assembled and published the letters in form of book. In that book, he noted that the "letters" were not intended as a systematic manual for "the skilled architect or engineer," but were to present "the general principles which should guide one in judging of the merits of various systems of, and appliances for, ventilation, more especially as applied to large public buildings." Assuming that architects lacked technical knowledge and expertise on the subject, he attempted to present his general principles in a simplified and easily comprehensible format for architects, "without the use of technical expressions, or of any but the simplest mathematical formulæ." See: John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884).

*This request reminds me of the demand for medical education made by some young men I have met. They do not wish to take the trouble to learn anatomy and physiology; they want to learn how to cure the ordinary diseases of the country—typhoid fever, inflammation of the lungs, etc.—and they want this information neatly packed and labeled in the form of recipes or formulas contained in a vest-pocket manual, which can be consulted as occasion demands.*

*There is no such royal road to knowledge as these demands presuppose. One must learn the alphabet before one can become a schoolmaster.*

*The arrangement of the plans of a large building, so as to secure satisfactory results in its heating and ventilation, is not such a simple matter as this demand would indicate. It cannot be done by following a formula.*[2]

Instead, Billings offered to present the subject and the general principles "in such a way that architects will appreciate its importance in their work […] more fully than many of them seem to do at present." He drew a stark contrast between what he considered the "necessary" engineering and mechanical systems, compared to the architectural and ornamental considerations, and then went on to display his mastery on the subject by outlining the key principles for securing a "perfect ventilation": an explanation of its scientific basis and amount of air necessary to secure it, factors that influence performance in various climates, ways to measure the quantity of carbonic acid in the air and prevent the admission of contagious particles, and even a description of instruments to be used for that purpose.[3]

Unimpressed by Billings' elaborate response, the architect replied that he does not care for "scientific theorizing and speculations" but seeks "practical rules." Billings second letter then

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[2] John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884), 13.

[3] John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884), 13-26.

went a step further by arguing that much of the theorizing that goes into the day-to-day design and construction of a building are in fact on the basis of "scientific theories," and that it is necessary to understand those in order to ensure that the "rules" applied are ultimately "practical":

> *My architectural friend, in the letter to which allusion was made at the commencement of the last chapter, said: "I do not care for scientific theorizing and speculations in this matter; what I want are practical rules." Probably he would class as "scientific theorizing" the following statements with regard to some of the laws in accordance with which heat is produced and transmitted, and the movements of air and gases take place, yet it is necessary to understand them in order that the "rules" which depend upon them may be applied in each particular case, so as to be really "practical" and useful.*
>
> *This "science," in regard to which distrust, and often more or less contempt, is so frequently expressed is, after all, only another name for the results obtained by trained common sense from comparisons of facts carefully observed and accurately recorded.*
>
> *As to theorizing, we must do that at nearly every step, for there are few of our plans in which we are not compelled to rely on probabilities instead of certainties. That the amount of daylight next year will be about the same as in preceding years; that we shall have life and health to finish the plans which we promise to prepare; that the coldest day during the next twenty years will not be colder than the coldest day during the past twenty years; and that the price of labor and materials will not vary beyond a certain amount within the next two or three years —all these are theories which we accept and act on when we proceed to make plans and estimates for a building, and, moreover, they are scientific theories. What we should really wish to avoid is unscientific theorizing, and the best way to do this is to learn to recognize it when we meet with it—which will be daily.*[4]

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[4] John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884), 27.

While acknowledging the value of "knowledge which comes from practical experience," acquired by "intelligent workman" and useful to a "scientific engineer," Billings argued that these "detached observations" are of little value if they are not seen in relation to the science and the general principles or laws that govern the operation of the system. He concluded his argument by quoting English astronomer, William Herschel, to draw a distinction between a form of art that is "empirical" and what he described as a "scientific art":

> *"Art is the application of knowledge to a practical end. If the knowledge be merely accumulated experience, the art is empirical; but if it be experience reasoned upon and brought under general principles, it assumes a higher character and becomes a scientific art."*[5]

The exchange between the scientist and the architect in these letters reflects the untenable condition of architecture during this period in the face of growing domination of science and engineering, concerns over public health and sanitation, which coincided with the development of new systems of mechanical heating and forced ventilation. Billings' "letters" and the book that followed were composed based on the assumption that architects were unequipped with the technical knowledge and expertise on the subject and were instead more interested in, or easily persuaded by, aesthetic and ornamental considerations. For Billings, and many other doctors and engineers regularly publishing articles in the *Sanitary Engineer*, architecture was the Herschelian "scientific art," and it was precisely the *sanitary* as well as the *engineering* nature of new

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[5] John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884), 28.

building systems that enabled doctors and engineers to extend their expertise and authority to architecture.[6]

Doctors, engineers, and sanitary reformers during this period seized the opportunity to cement their professional authority on heating and ventilation through production of various articles, papers and books. From the late eighteenth to mid-nineteenth century, heating and ventilation remained a peripheral topic in architecture, only occupying a brief paragraph in architects' books and treatises. The second half of the nineteenth century, however, saw a significant increase in the publication of technical treatises, papers and articles, and by the late nineteenth century, even architectural treatises had a section on heating and ventilation.[7] The work of American scientists in the 1880s and 1890s dominated the discourse globally, most notably William J. Baldwin's *Steam Heating for Buildings* (1881), and *Hot Water Heating and Fitting* (1889), as well as Billings' *Ventilation and Heating* (1893), and his *Principles of Ventilation and Heating and their*

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[6] The emergence of mechanical heating and ventilation and the growing complexity of those systems created new professional problems. In the early nineteenth century, architects were able to understand and apply the rudimentary heating and ventilation technology without much assistance from an engineer. By the mid-nineteenth century, however, the technology and its application in large buildings became so complicated that necessitated the involvement of a new professional engineer in the project. Engineers were able to secure their professional authority by maintaining that heating and ventilation affected the health of the building's occupants and was therefore more important than any other aspect of the design. For a brief history of the impact of central heating and forced ventilation in architecture see: Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978).

[7] David Boswell Reid, for instance, frequently criticized a book of architecture of over a thousand pages with only one paragraph on heating and ventilation—likely Joseph Gwilt's *Encyclopedia of Architecture* (1842). Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 153.

*Practical Application* (1884), which was essentially the collection of his "Letters to a Young Architect" assembled in the format of a book.[8]

The rapid development of knowledge, expertise and equipments during this period, and the undefined roles of architects and engineers in the design of building systems, had resulted in tensions and often disputes between the two professions. The dispute between physician David Boswell Reid, who was appointed as the heating and ventilating engineer of the New Houses of Parliament, and architect Charles Barry is a well-known example of that.[9] These professional disputes were even more pronounced in the planning and construction of hospitals where both sanitary and engineering requirements were paramount.[10] In fact, while the development and adoption of central heating throughout the nineteenth century was primarily driven by

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[8] Engineers from other countries, including France and Germany, also produced major treatises on ventilation but with less influence than their American counterparts. See: Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 153.

[9] A physician and a fellow, and later chair of chemistry at the Royal College of Surgeons in Edinburgh, David Boswell Reid had successfully tested and designed the heating and ventilation at the Temporary House of Commons in 1835. Reid held his classes in a laboratory which he had specifically designed and built for conducting experiments on heating and ventilation. In 1839, he was appointed as the heating and ventilating engineer of the New Houses of Parliament, that was being designed by architect Charles Barry. While Barry had initially incorporated Reid's suggestions, including the addition of a new central tower as an air exhaust stack, by 1846 the relationship between the architect and the doctor-engineer broke down as the completion of the building was continually delayed due to the increasing cost of heating and ventilation modifications. Reid complained that Barry's design blocked acmes to air intakes and outlets, while Barry charged that Reid's removal of structural columns jeopardized the building's solidity and compromised its fireproofing. As a result of the dispute, Reid was stripped of his responsibilities and was ultimately dismissed. An account of this dispute can be found in: *Parliamentary Papers,* 1841, Sess. II, 51. I. 161-173. See also: Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 152-153.

[10] As early as 1814 in a report on Marine hospitals for sailors, Benjamin Henry Latrobe acknowledged the importance of architectural hygiene and emphasized ventilation. Latrobe proposed smaller wards of six patients with windows only on one wall, arguing that the layout allowed for better classification and isolation of patients, and reduced foot traffic. See: Benjamin Henry Latrobe, "Report of B. Henry Latrobe on His Design for a Marine Hospital," in William Paul Crillon Barton, *A Treatise Containing a Plan for the Internal Organization and Government of Marine Hospitals in the United States* (Philadelphia: Howard Parker for the author, 1814), 111-130.

consideration of cost and economy, mechanical ventilation was developed, and continuously debated, on the basis of health and hygiene.[11] The interest and the prolonged scientific attention on the topic of ventilation in hospitals was not a matter of environmental comfort but of public health, which had prompted many medical professionals to write extensive treatises on hospital design and principles of hygienic architecture.[12]

The specific and detailed ventilation requirements for hospitals not only determined the layout of the buildings or the materials and finishes used, but also who was qualified to design them. As a result, the architects who were most successful in gaining hospital commissions, Niernsée included, were those with an engineering or construction background. But because of the perceived correlation between interior environment and disease incidence, doctors were seen as more qualified to design hospitals than architects.[13] In fact, the majority of early American

[11] This made forced ventilation a crucial, even vital, component of ships, mines, prisons and hospitals. Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 148-149.

[12] The majority of publications on hospital design during this period was written by doctors and sanitary reformers rather than architects. And to prevent the spread of germs, most advocated for more space and less beds. Some of the examples from the early nineteenth century include: John Jones, *Plain, Concise, Practical Remarks on the Treatment of Wounds and Fractures* (New York: John Holt, 1775); William Paul Crillon Barton, *A Treatise, Containing a Plan for the Internal Organization and Government of Marine Hospitals in the United States* (Philadelphia: Howard Parker for the author, 1814); James Tilton, *Economical Observations on Military Hospitals* (Wilmington: Wilson, 1813). A few of the most influential American texts from the 1860s and 1870s include: John H. Griscom, "Hospital Hygiene," *Transactions of the New York Academy of Medicine* 1, no. 2 (1853), 167–178; John Green, *City Hospitals* (Boston: Little, Brown, 1861); William Hammond, *A Treatise on Hygiene, with Special Reference to the Military Service* (Philadelphia: J. B. Lippincott, 1863); Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866); John Shaw Billings, *A Report on Barracks and Hospitals with Descriptions of Military Posts. Circular No. 4. Surgeon General's Office* (Washington: Government Printing Office, 1870).

[13] Various contemporary historians have discussed the role of doctors in designing hospitals and other buildings. Most notable works include: Annmarie Adams, *Architecture in the Family Way: Doctors, Houses, and Women, 1870-1900* (Buffalo: McGill-Queen's University Press, 1996); Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Cambridge, MA: Harvard University Press, 1998), 9, 58-60; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 74-76.

hospitals during the eighteenth and the nineteenth century—including the Pennsylvania Hospital (1752), or the Commercial Hospital in Cincinnati (1852)—were designed by doctors and hospital administrators with little or no input from architects.[14] And well into the 1870s, architectural journals continued to caution their audience against designing hospitals: "For to plan a hospital properly, even a simple one, is a matter of special skill and knowledge, and it is a hazardous thing for anybody to attempt who has not acquired these by special study."[15]

As a result, the architects who were most successful in gaining hospital commissions were those with an engineering or construction background.[16] Niernsée himself was trained in both architecture and engineering, had spent most of his career as railroad engineer before being hired as the architect for the Johns Hopkins Hospital. Particularly relevant to the trustees was his experience in heating and ventilation systems in a project he had designed in Baltimore the early

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[14] Jeanne Kisacky has argued that this condition was partly due to shortage of professionally educated and trained architects in the United States, and as the number of professional architects increased, so did their involvement in hospital projects. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 78-79.

[15] "Common Councilmen as Architects," *American Architect and Building News* 3, no. 128 (June 8, 1878), 203. By the 1860s, architects and doctors regularly collaborated on hospital projects. For instance, the governors of the Roosevelt Hospital hired architect Carl Pfeiffer but also retained local surgeon, Stephen Smith—who was among the physicians invited to submit his proposal for the Johns Hopkins Hospital—"to study and report to the Board the principles of hospital construction now recognized as most appropriate to the ends to be attained in a public hospital." (Thomas E. Vermilye, *Address at the Opening of the Roosevelt Hospital, November 2, 1871* (New York: Evening Post Steam Presses, 1871), 8-9.) Smith provided medical guidelines, while Pfeiffer translated those into architecture. Smith went on to become a major public health figure, and Pfeiffer became an advocate for "sanitary" principles in architecture, even suggesting that an architect's success should be measured not by the beauty of the buildings but by the health of the occupants. See: Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866); Carl Pfeiffer, "Sanitary Relations of Health Principles of Architecture," NYT, (November 12, 1873); Carl Pfeiffer, "Light: Its Sanatory Influence and Importance in Buildings," *American Architect* 2, no. 79 (June 30, 1877), 205-208.

[16] John W. Ritch, who designed multiple hospitals, was an engineer and an architect and had expertise in ventilation design. Samuel Sloan, who also designed numerous hospitals and asylums, began his career as a carpenter. Carl Pfeiffer, was in fact educated only in engineering but with "a considerable amount of architectural study." "Obituary —Carl Pfeiffer," *American Architect* 23, no. 648 (May 26, 1888), 241.

1850s—built with Bartlett, Hayward & Co., the same engineering firm for the Hospital.[17] Even after Billings was installed as the Medical Advisor to oversee the design and construction and he continued to defer decisions on heating and ventilation to Niernsée, writing to the trustees that "the question is one that is within the province of your Architect, rather than of your medical adviser."[18] Despite these, and just over a year later, the relationship between the two faltered over

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[17] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7; John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 13; Alistair Fair, "'A Laboratory of Heating and Ventilation': The Johns Hopkins Hospital as Experimental Architecture, 1870–90," *Journal of Architecture* 19, no. 3 (2014), 365.

[18] In his 1875 essay proposal for the Johns Hopkins Hospital, Billings had deferred making a decision on the best methods of heating and ventilation, arguing that "while the knowledge of what it is desirable to effect in heating and ventilation may be possessed by the physician, he has usually no practical knowledge as to the means of doing it." Billings had then concluded by writing while he can make theoretical recommendations, "the means of producing the effects desired and the question of cost pertain rather to the architect and engineer than to the physician." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 21-22. Even in his third report to the trustees in 1877, he wrote "I find so much diversity of opinion among engineers, as to the best means of effecting the desired rarefaction of the air in such a chimney, that I can make no positive recommendation—the question is one that is within the province of your Architect, rather than of your medical adviser, and still further inquiry, and perhaps experiment will be required before a decision can be judiciously made." John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 3 (Johns Hopkins Hospital, January 11, 1877), 14.

a dispute, which ultimately led to Niernsée's resignation in November of 1877. And that dispute was over the heating and ventilation system of the Hospital.[19]

The introduction of new building systems in architecture during the nineteenth century was therefore entangled with professional tensions and disputes that became increasingly visible in the design and construction of the buildings. This fundamental dichotomy and disjunction between technology and the reactionary "Battle of Styles," in Sigfried Giedion's view, was only resolved by the masters of the modern movement in the twentieth century.[20] In reframing the problem around environmental technology, Reyner Banham has also argued that development of systems of environmental control in buildings, like central heating and forced ventilation, occurred largely outside architecture and was only reconciled with architectural design at the turn of the twentieth century. For Banham, the *integration* of the two domains took place in three

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[19] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 54-55. While it is not clear what exactly the disputes between the two was about, and what circumstances led to Niernsée's decision to resign, Billings and Niernsée had difference of opinion on multiple major issues related to heating and ventilation of the Hospital. Niernsée, for instance, had objected to the use of "large and expensive heating apparatus concentrated in one place" but on the grounds that such system would require "an engineer and fireman employed to attend to the engine, and hoisting and heating apparatus," and that in a pavilion plan hospital, it would result in "an extent of pipes of over a thousand feet in length, with a consequent expense and loss of heat." Instead, he had advocated for using a "small boiler within the central chimney and ventilator in the basement of each pavilion." Niernsée had also recently accepted a commission to design the capitol building in South Carolina, where he had resided and worked before, and returned there upon his resignation. He continued to visit the construction site in Baltimore, and was listed in the project's final drawings as the "consulting architect." The tension between Billings and Niernsée may have not just been a professional rivalry, but stemming from political differences. The two fought not just on the opposite professional grounds but in opposition during the Civil War: Billings who was a Union Army officer, against Niernsée who had served, almost circumstantially, as a major in the Confederate Army. For Niernsée own proposal and views on heating and ventilation of the Hospital see: John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 339-340. For a biographical account on Niernsée see: Randolph W. Chalfant and Charles Belfoure, *Niernsee and Neilson, Architects of Baltimore* (Baltimore: Baltimore Architecture Foundation, 2006).

[20] Sigfried Giedion, *Space, Time and Architecture,* 3rd ed. (Cambridge: Harvard University Press, 1954), 181-182, 209-216.

instances: the subordination of architectural design to the dominating heating and ventilation technology, which allowed William Henman's Royal Victoria Hospital in Belfast (1903) to abandon some of the basic features of the pavilion plan; the use of hot air ventilation and heating technology to solve design problems, which enabled the use of large north-facing glass windows in Charles Rennie Mackintosh's Glasgow School of Art (1904); and finally the desire to express the heating and ventilation technology as an exterior design feature, that emerged as the four large corner ventilation towers and grilles in Frank Lloyd Wright's Larkin Building (1906).[21]

The following pages attempt to build on, and to some extent reframe, the discussion of building technologies within architecture by closely examining the design and implementation of the heating and ventilation system at the Johns Hopkins Hospital. As the chapter will illustrate, not only Banham's three instances—of the integration of heating and ventilation technology with architectural design—did already appear at the Hospital well before the twentieth century, but also that the two domains were not seen as mutually exclusive.[22] Considering architecture a "scientific art," Billings saw the systems of heating, ventilation or plumbing just as "necessary" as the walls, floors or windows of the buildings. In that sense, more than a process of *integration* or *subordination* of one domain to the other, the Johns Hopkins Hospital reveals instances of

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[21] Reyner Banham, *The Architecture of the Well-Tempered Environment* (London: Architectural Press, 1969), 71-92.

[22] Robert Bruegmann has shown that those instances provided by Banham can also found in various buildings well before 1900—such as the use of heating and ventilation systems in John Soane's Museum (installed in 1831), Watson and Pritchett's Wakefield Asylum (1818), George B. Post's New York Hospital (1875), or Henry Hornbostel's Carnegie Institute of Technology and its Machinery Hall (designed in 1900). Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 154-155.

*consolidation* of architecture and technology towards achieving thermal and environmental control.[23]

The chapter is organized around three instances where that *consolidation* took place. Beyond a product of interactions between architecture and technology, these instances were inextricably tied to the institutional mandate of the Hospital. The first instance illustrates how the technical requirements for heating and ventilation along with the disciplinary mandates of the medical institution transformed the buildings into hermetically sealed, pneumatic machines, challenging and reconfiguring the fundamental conventions of the architectural interior. The second instance examines how the new mechanical heating and forced ventilation systems allowed for complete aerial separation of patients, which ultimately transformed the concept of architectural space from one that was defined by physical walls and partitions into a controlled atmospheric environment measured by units of air displacement and temperature. Finally, the third instance reveals how the educational mandate of the institution conceived the Hospital as a "laboratory for teaching the practical applications of the laws of hygiene to heating, ventilation, house drainage, and other sanitary matters." Here, beyond a means of integration with architectural design, the glass tubes, ventilation grilles, and exposed pipes of the Hospital interior functioned as didactic instruments for observation and education of building systems and their behavior.

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[23] Building on Banham's theoretical framework, Lisa Heschong and later Luis Fernandez-Galiano have considered architecture as a matter of energy and thermodynamics. For Galiano, for instance, the energy is imbedded within architecture not just through the energy consumption if buildings and their users but also through the energy needed to organize, modify and repair the built domain itself: "through the energy consumed by the processes that the building houses, and through the energy consumed by the process that the building itself is." See: Lisa Heschong, *Thermal Delight in Architecture* (Cambridge: MIT Press, 1979); Luis Fernández-Galiano, *Fire and Memory: On Architecture and Energy,* Gina Cariño (trans.) (Cambridge: MIT Press, 2000).

In discussing these instances of consolidation, the chapter relies primarily on plan and section drawings of the Hospital. This is not because those representational techniques were commonly used in the fields of engineering and medicine during this period, but simply because they were the only type of drawings of the Hospital produced or publicized by Billings.[24] For instance, when the project was first appeared in *American Architect and Building News* in December 16, 1876, the only published drawings where the site plan and the individual floor plans without any exterior elevations.[25] Even in Billings' *Description of the Johns Hopkins Hospital* (1890), a book that offered the most detailed account of its architecture with over a hundred pages of text and 56 plates, all the published drawings were only plans and sections of the buildings, and not a single elevation was included. In dissecting and anatomizing the buildings of the Hospital, these drawings expose their intricate internal systems in such a way where the distinction between the architectural design and environmental or sanitary technologies become indiscernible.

## 2.1 Rounded Corners

In approaching the topic of "Heating and Ventilation" in his 1875 essay proposal, Billings presented four detailed meteorological tables, showing records of monthly and annual temperature, wind, moisture, and rainfall in Baltimore, some dating back over fifty years (Figure 2.1).[26] The tables, Billings posited, illustrated the "peculiarities of the climate of Baltimore"

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[24] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).

[25] "The Johns Hopkins Hospital, Baltimore, MD," *American Architect and Building News* 1 (December 16, 1876), 405-406.

[26] Billings obtained the information from the Chief Signal Officer of the Army. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 19, 44-46.

where the temperature could vary over a hundred degrees throughout the year. A "perfect hospital," he argued, would be one that could function simultaneously in both in the tropics or northern Russia, "in either Calcutta or St. Petersburg."[27] For Billings, this was the "impossible" task of the heating and ventilation system of the Hospital: "to insure that in all parts of each room at all times the air shall be as free from dangerous impurities, or perceptible odors," whether the outside temperature at 0° or 100° F, whether the air is windy or still, dry or humid, and that "all this *must* be done at a reasonable cost for construction and maintenance, and it *should* be done as cheaply as possible."[28] For that reason, he concluded that "air supply and ventilation in this climate are inseparably connected with heating."[29]

Billings was not the first physician to become involved in the design of heating and ventilation system. Even before the nineteenth century, the ventilation requirements for Hospitals had prompted many physicians to become involved in the design of such systems. From the ventilating dome of the Hôpital St. Louis (1607-12) to Antoine Petit's exhaust cone for the Hôtel Dieu (1774) and Benjamin Franklin's ventilating stoves for the Pennsylvania Hospital (1775), numerous seventeenth and eighteenth century hospitals included specifically designed ventilation systems. Despite innovations in mechanical ventilation systems—as in Jean Desagulier's fan-ventilator, *Cour de Physique* (1727) or Stephen Hale's bellows-like ventilator (1741)—these

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[27] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7; John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 73.

[28] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 2.

[29] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

systems were not considered for hospitals until the late eighteenth century, and it wasn't until the mid-nineteenth century when the first one was installed in the Hôpital Beacon (1846).[30] And even then, extensive use of mechanical ventilation in hospitals did not begin until the construction of the Lariboisière Hospital (1853).[31]

Ventilation requirements in general, and mechanical ventilation in particular, were continuously debated among architects, engineers and hospital planners since the mid-eighteenth century. By the 1860s, the publicized failures of mechanical systems in numerous buildings—such as the Lariboisière Hospital and the British House of Commons—led many designers and medical professionals, including Nightingale, to consider the use of mechanical heating and ventilation in hospitals a complete waste of time and money, and potentially a dangerous proposition for patients. In his 1868 article on "Ventilation and Heating" in *Sloane's Architectural Review and Builder's Journal*, for instance, engineer Lewis Leeds wrote, "it is folly to imagine, that we shall discover some automatic ventilating machine, that will keep us supplied, at all times, with perfectly pure air."[32] Meanwhile, there were dozens of wind, water, and steam-powered ventilating systems patented and installed in public buildings, military hospitals and even private

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[30] John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975), 127; Walker Gill Wylie, *Hospitals: Their History, Organization, and Construction* (New York: D. Appleton and Company, 1877), 20; Dale R. Brown, "The Expanding Role of the Physician in Defining 19th Century Hospital Architecture: as Evidenced in Dr. John Shaw Billings' designs for Johns Hopkins Hospital (1876-1889)," (Department of Architecture, University of California, Berkeley, 1990), 33-35.

[31] "A Short Description of the Plans of Hospitals at Paris, Munich and St. Petersburgh," *Proceedings of the Royal Institute of British Architects* (1865); John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975), 127-130; Walker Gill Wylie, *Hospitals: Their History, Organization, and Construction* (New York: D. Appleton and Company, 1877), 19-30.

[32] Lewis Leeds, "Ventilation and Heating," *Sloane's Architectural Review and Builder's Journal* (August 1868), 152-154.

homes.[33] And various scientific studies invested on examining the amount of ventilation and the specific ventilating characteristics of building structures and materials.[34]

However, most buildings and hospital during this period were still heated and ventilated naturally through two conventional but distinctly separate mechanisms: fireplaces for heating, windows for ventilation. For Billings, however, the peculiar condition of the local climate necessitated using mechanical heating and ventilation so that the air is warmed (by hot water or steam) before it enters the space—what he called the "method of indirect radiation."[35] Hot water and steam heating, developed in the late eighteenth century, were "central" systems with single boiler and a closed circuit of pipes that circulated hot water, hot air, or a steam to multiple rooms within a building. In a pavilion plan hospital with a decentralized layout and multiple "totally separated" buildings, locating a single center was not straightforward, and Billings had debated whether the  heating system was to be centralized "so that the supply may all come from one or

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[33] Most notable examples included Hayworth's Archimedean ventilator, Watson's syphon ventilator, Muir's four-point ventilator, Taylor's ventilating stove, and Arnott's valved ventilator. See: "A Discussion Upon the Practical Ventilation of Buildings," *Proceedings of the Royal Institute of British Architects* (February 7, 1863).

[34] There were numerous articles on heating and ventilation published in architectural journals and proceedings during this period, such as the *American Architect and Building News* and the *Architectural Review and Builder's Journal* in the United States, the *Builders* magazine and the *Proceedings of the Royal Institute of British Architects* in Britain. In addition, even before Billings, there were multiple books devoted entirely to the study of heating and ventilation in buildings, including: David Reid, *Ventilation in American Dwellings; with a series of diagrams presenting examples in different classes of habitation* (New York: Wile & Halstead, 1858); B. F. Sturtevant, *Ventilation and Heating: Principles and Application* (Boston, 1886); Isaac Smead, *Ventilation and Warming Buildings: Upon the Principles as Designed and Patented* (Chicago: H. O. Shepard & Co., 1889).

[35] Billings also believed that the ventilating effect of fireplaces could be better achieved by mechanical ventilation. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 19-20. For ventilation [replacing fireplace] he used high pressure steam coils in the aspirating shafts along with a fan ("ten feet in diameter with suitable ducts") powered by two high pressure steam boilers in the vault of the Kitchen Building. These boilers were also used to heat the hot water reserved for bathrooms and lavatories in each building. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 82-83.

two boilers," or "divided into several sections, even to the extent of giving one to each building."[36]

In his essay, Billings had recommended to provide each building with its own heating and ventilation system in order to maintain complete separation. By the time the Hospital was built, however, in order to reduce complexity and cost, only two of the buildings had their own independent systems.[37] The Hospital used two different central heating systems, hot water and steam, each with multiple centers. The hot water heating system, used for most of the buildings including all the ward pavilions, used a total of six boilers distributed in two locations—four in the vaults at the Kitchen Building (Figure 2.2-2.3) and two in the cellar of the Nurses Home.[38]

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[36] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 19.

[37] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 25. In a lecture "on the Plans for the Johns Hopkins Hospital" in 1877, Billings discussed the cost and benefits of central systems of heating and ventilation: "The latest and best of the German hospitals, the prince has bee adopted of making the heating and ventilation of each building independent of every other. The results, as I observed them, were good, but the arrangements are complicated and expensive, and require careful superintendence. The principal authorities whose I consulted, prefer system of aspiration to those of impulsion, but are of the opinion that although it mat be theoretically possible to effect ventilation of an extensive and scattered series of building by means of one great aspirating chimney, yet that the practical difficulties in the war of adjustment of ducts and apertures to secure in all parts the flow of air desired, will be so great, that it will not be prudent to attempt it." He added, "There is a general feeling of timidity about attempting to use large and powerful but complex systems, which is due to sad experience of failures of such, and hence the recommendation to heat and ventilate each building by itself, or, in other words, to give up the problem of concentration and simplification of the apparatus as unsolvable." John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 132.

[38] The "great advantage" of hot water heating system for Billings was "the uniformity of action, the comparative low temperature of the heating surfaces over which the air is passed, the ease with which different temperatures may be secured in different rooms, or even for different beds in the same room, and, above all, that it ensures the delivery of a large supply of air heated to the temperature required for comfort without the risk of overheating or of sudden changes." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 68.

From the boilers, about 175,000 gallons of water circulated through a 26-inch cast-iron pipe called the "great outflow main," hung on rollers from the ceiling of the pipe tunnel, then branching off via smaller "mains" to the heating coils in the basement of each building, and then back to the boilers via a similar system of pipes and mains.[39] The remaining buildings were heated by low-pressure steam. The Dispensary, Amphitheater, and Bath Houses had a shared central heating with steam boilers at the vaults of the Kitchen Building. Only the Laundry and the Pathological Building were provided with their own independent steam heating and boilers.[40]

In contrast to the Hospital's complex and interconnected central heating system, the ventilation system for each building operated independently. This provision was made to provide complete aerial separation of the pavilions, and it was "not possible," as Billing noted, "to go from one ward into another without going into the open air on the way, so that foul air, of any forms, cannot spread from one building to another."[41] However, the two systems, while operating autonomously, were "inseparably connected" to one another: the central heating system delivered hot water to the coils in the basement of the pavilions, and the separate ventilation system in each building regulated the flow of air around the coils to warm it before admitting it into the main floors.[42] This combination of the two systems offered an efficient and economic solution for

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[39] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 67. Earlier in his opening address, Billings had stated that the entire hot water heating system of the Hospital contained 80,000 gallons of water. John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

[40] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

[41] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7-8.

[42] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

heating the Hospital while providing each pavilion with a complete aerial separation, and an ability to regulate the wards' air flow, and therefore temperature, independently.

There were two methods of mechanical or "forced ventilation" used in the Hospital: ventilation by *aspiration* that used the drawing power of heat, and ventilation by *propulsion* that used the mechanical power of fans or bellows to force the air to or extract it from the rooms. Both methods, however, relied on a delicate arrangement whereby any minute change in air temperature or pressure, for instance an open door or a window, could interfere with the air flow and disrupt the whole system. This desire to preserve the order and stability of the artificial interior environment against the erratic and disruptive behavior of the natural exterior forces had prompted engineers to proposed buildings to be hermetically sealed, with minimal openings, fixed windows and revolving doors.[43]

By the 1860s, with the rising popularity of the pavilion plan, the hermetic precondition of mechanical ventilation came to be seen as a major flaw, and antithetical to the basic principles of the pavilion plan hospitals that relied on separate, distantly-placed buildings that were naturally

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[43] The simplest way of forcing air was to use the drawing power of heat, often using the gas chandelier (especially in theaters), steam cylinders, and more commonly hot air furnace as safer alternatives. The problem with all those delicate systems, however, was that any subtle change in air temperature or pressure, an open window or a door, could disrupt the air flow. In order to solve the problem, some proposed sealing all opening in a building, using fixed windows and revolving doors, however, the solution was deemed "too drastic." Engineers then turned to air pumps and fans, which ultimately led to the development of forced ventilation—also known as mechanical ventilation. The ventilating power was initially tried with water power, springs, falling weights, even human power, but the system was not widely used until the availability of steam power. Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 149-150.

lit and ventilated.[44] Pavilion plan advocates like Florence Nightingale saw mechanical ventilation as an expensive and inefficient method, and argued that "natural ventilation and open radiating fire-places, are the only suitable means of renewing and warming the air in hospitals."[45] Well into the twentieth century, many architect like Alvar Aalto who designed hospitals believed that "Mechanical ventilation does not enter the picture because natural ventilation with fresh, ozone-rich air is of the utmost importance in the healing process."[46]

The shift from natural to mechanical ventilation in hospitals in the 1870s and 1880s was also informed by an epistemological transformation brought about by the emergence of germ theory of disease. For Nightingale and other miasmatists "pure air" was synonymous with "fresh air"—one that was not "foul," and was free of impurities.[47] With the increasing acceptance of germ

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[44] A number of American hospitals, including the Massachusetts General Hospital (1822), the South Building of the New York Hospital (1855), had experimented with centralized heating and ventilation in the first half of the nineteenth century. The ward of the South Building of the New York Hospital, for instance, was designed on the basis of mechanical heating and ventilation with very few windows. See: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 104-105.

[45] Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863), 75-79.

[46] Karl Flaig and Elissa Aalto, eds., *Alvar Aalto: Das Gesamtwerk/ L'œuvre complète/ The Complete Work,* vol. 1, *1922-1962* (Basel: Birkhäuser, 1963), 31.

[47] Since the mid-seventeenth century, air had become an object of scientific study and analysis. The physical properties of air were increasingly understood and defined by experiments with the barometric tube and the air-pump, and Robert Boyle had established that air has its own physical laws that linked its pressure to its volume (Boyle's Law). In the mechanical worldview of the eighteenth century, air was a quantifiable entity that could receive and contain minute corpuscles, spirits, and effluvia, some of which could cause disease. See: James C. Riley, *The Eighteenth-Century Campaign to Avoid Disease* (New York: St Martin's Press, 1987), 9-13. With the advancement of chemistry in the second half of the eighteenth century, the components of air were isolated and distinguished. Joseph Black and Joseph Priestley demonstrated that atmospheric air is in fact a mixture of "airs" or gases, only a fifth of which supported life and the remainder extinguished it—that "eminently respirable air" was later called by Antoine Lavoisier as *oxygen*. For an overview history of the scientific and medical approach towards air and atmosphere see: Caroline Hannaway, "Environment and Miasmata," in the *Companion Encyclopedia of the History of Medicine*, Vol. 1, W. F. Bynum and Roy Porter (eds.) (London: Routledge, 1993), 305-306.

theory, *pure air* no longer implied *fresh air* but "freedom from, or at least a minimum number of, microscopic germs floating in it."[48] Billings, for instance, considered "pure air" as "the article of prime necessity," and used the two terms (*pure* and *fresh*) interchangeably. His definition of "foul air" was one that included both dangerous gases as well as particles. But while he believed natural ventilation systems is sufficient in diluting poisonous gases, he did not deem it as effective in removing the microscopic particles or germs floating in the air. "The dangerous thing in a hospital ward," he wrote in his third report to the trustees in 1877, "is not a gas, but dust—an excessively fine organic dust."[49]

The increasing availability of mechanical ventilation technology during this period offered a means of mitigating the dangers associated with hospitals. The system, however, was still considered too elaborate and expensive for most projects. Even in the Johns Hopkins Hospital, Billings was convinced that the only efficient and effective solution was not ventilation but prevention—not to allow for any source of infection in most of the wards, and therefore no need for any "special and costly appliances for their ventilation."[50] The breakthrough in ventilation

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[48] Henry D. Noyes, *Laying of the Corner-Stone of the New York Eye and Ear Infirmary* (New York: De Vinne, 1890), 19, in Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 284.

[49] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 3 (Johns Hopkins Hospital, January 11, 1877), 14.

[50] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 21-22. In his original essay proposal, Billings went as far as no allowing any contagious cases to be housed in the pavilions but instead in the temporary barracks and tents. "No case of contagious disease is to be admitted to any part of these pavilions," he wrote, "and if any case appear it is to be promptly removed, with bed and bedding. If a second case appear soon after the first, the ward is to be emptied and disinfected." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 26.

was therefore was not the novelty of the architectural form or that of the mechanical technology but an epistemological transformation brought about by the emergence of germ theory of disease, and the conceptual reformulation of *air,* foul or fresh, and the nature of physical or chemical properties in it that was believed to cause disease. The ventilation system of the hospitals in the post-germ theory era was therefore designed to control, not the flow of foul air but, the floating microscopic germs in the air.[51]

The rise of the mechanical heating and ventilation systems had a direct impact on the design of the ward. The hospital ward in much of the western world during this period was a large rectangular room with a row of windows and beds along its longer sides—a formal and spatial arrangement that remained nearly unchanged in the United States from the eighteenth well into the twentieth century. In the 1860s, the popularization of the pavilion plan led to the standardization of the ward. This process was informed by the two necessary requirements outlined by Nightingale: "health and facility of administration and discipline." It implied that each patient be provided with enough space (both areal and aerial) to preserve health and prevent the spread of disease, and that the beds were to be laid in a spatial arrangement to secure a line of sight between each patient and the attending nurse and ensure that a single nurse was able "to see the whole of her or his patients at once."[52] The "Nightingale ward" was therefore conceived as a large well-lit and well-ventilated rectangular space with no interior walls or partitions so that no

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[51] For more on the impact of germ theory of disease on the ventilation of hospitals see: Jeanne Kisacky, "Conservative and Liberal Architectural Interpretations of Germ Theory," *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 214-2018.

[52] Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863), 92.

patient, or microscopic germ, could escape the medical gaze.[53] Through this process, the hospital ward emerged as a disciplinary visual and aerial instrument that facilitated medical supervision and intervention at once.

By translating the two disciplinary requirements for the ward into codified spatial units, Nightingale had determined not just the size of the ward but also the number of patients. The aerial requirement established a minimum spatial unit for each patient—8 feet long, 12.5 feet wide, and 15 feet wide—which provided a 100 square feet of area, and 1,500 cubic feet of space per bed. Meanwhile, the visual requirement implied that for a single nurse to supervise a ward, there should be between 20 to 32 patients—assumed to be sufficient to establish a disciplinary quorum but not too crowded to deter supervision. Nightingale's ideal ward, for 20 patients, was then "80 feet long, 25 (or 26) feet wide, and 16 (or 15) feet high," which offered "1600 (or 1560) cubic feet of space to each bed" and provided "11 (or 12) feet between foot and foot."[54] Anything outside these requirements was believed to impede on either ventilation or supervision.

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[53] Nightingale argued that "the utmost simplicity of plan is an essential of good hospital construction. Complication of plan interferes with light, ventilation, discipline, facility of supervision. Every hole and corner, every passage, every small ward, which need not have been there, interferes with these four vital conditions of the hospital. Every skulking place which can be spared must be avoided. As an invariable hospital rule, rather more than elsewhere in military hospitals, publicity may be considered as the best police and the best protection. It is far better that 30 patients should see the nurse's door than one or none. It is quite necessary that the chief ward attendant should be able to see the whole of her or his patients at once." Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863), 92. For a spatial analysis of the Nightingale ward see: Cynthia Imogen Hammond, "Reforming Architecture, Defending Empire: Florence Nightingale and the Pavilion Hospital," in *(Un) Healthy Interiors: Contestations at the Intersection of Public Health and Private Space*, Aran S. MacKinnon and Jonathan Ablard (eds.), Studies in the Social Sciences University of West Georgia 38 (Carrollton, GA: University of West Georgia, 2005), 1-25; John D. Thompson, Grace Goldin, *The Hospital: A Social and Architectural History* (New Haven, CT: Yale University Press, 1975), 155-169; Charles E. Rosenberg, *The Care of Strangers: The Rise of America's Hospital System* (New York: Basic Books, 1987), 122-141.

[54] Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863), 61-67.

Billings' original ward, proposed in his 1875 essay, was precisely based on Nightingale's minimum spatial unit per patient, but the ward was larger in size—96 feet long and between 26 to 30 feet wide—to house 24 patients and over a 100 square feet of floor area per patient. He provided two floor plan options, one for a one-story pavilion, and another for a two-story pavilion (Figure 2.4).[55] Similarly again to Nightingale's ward, each scheme included three additional smaller wards reserved for patients who required separate rooms. These wards were intended not for contagious or "dangerous" diseases but for those who suffered from "nervousness or irritability, weak eyes, etc., etc." or "acute, febrile, and doubtful cases, in which special modifications of light and temperature are desirable."[56] And similarly, to control the unintended excursion of both patients and germs, the ward had only a single entrance, on the side of the service area, giving the nurse control over who, or what, entered or existed the ward.

Windows during this period were thought to actively participated in the disciplinary function of the ward: they admitted light into the ward, therefore allowing for better supervision of the patients, and they acted as additional ventilation devices by enabling the air flow or temperature for the beds to be adjusted individually. In wards that were naturally lit and ventilated,

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[55] The wards in both schemes contained twenty-four beds but they showed a variation on the number of windows, and therefore the placement of beds, in the main ward. In the one-story pavilion, the beds were spaced evenly with a window on either side of each bed (thirteen windows on each side, twenty-six total). In the two-story ward, the beds were paired, with a window on either side of each pair (seven windows on each side, fourteen total). Billings argued that having a window for every bed in a two-story building would make it more difficult to be heated and ventilated in cold weather. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 26-27.

[56] Nightingale had promoted the provision of a small room adjacent to a large ward that could house dying or disruptive patients and by the 1860s most American general hospitals included such accessory wards. See: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 155.

Nightingale had specified at least one window for every pair of beds, no less than 4 feet 8 inches wide, with the sills within 2 to 3 feet from the floor, "so that the patient can see out."[57] The alignment of windows on opposite sides were also meant to allow the air to cross the ward from one side to another, creating aerial walls between the beds. Even in Billings' proposal where the ward was mechanically ventilated, windows were the necessary component of individual spatial units. Billings scheme for a one-story pavilion had a window for every pair of beds, and in his two-story pavilion there was even a dedicated window for each bed (Figure 2.4). The window therefore functioned as both a lighting and a ventilation device within the hospital ward.

By the 1870s, windows also acquired a hygienic function. Experiments during this period revealed that sunlight—what was later discovered to be the ultraviolet radiation—was germicidal. Already considered a positive psychological remedy in the hospital ward, windows came to be seen as disinfecting devices. Hospital designers during this period strived to maximize sunlight exposure in the ward by increasing the size or even the number of windows. The new antiseptic quality of the sunlight also resulted in the reorientation of the ward itself.[58] American hospital designers increasingly opted for a north-south, rather than a east-east, orientation so that "every day of the year in which the sun shines, at least three walls of a

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[57] Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863), 67.

[58] W. B. Hugo Downes and Thomas Porter Blunt, "The Influence of Light upon the Development of Bacteria," *Nature* 16 (1877), 218.

rectangular ward will be bathed in sunshine."[59] For instance, all the five physicians' proposals for the Johns Hopkins Hospital consisted of north-south oriented pavilions.

But the solar reorientation of the ward had a more pronounced impact on its interior organization. In order to maximize sunlight in the ward, the Hospital trustees had requested a solarium or "sun room" in the southern end of the wards, which became a standard component of the final ward pavilions.[60] Allowing for solar exposure in the eastern, southern, and western faces, also meant that the secondary smaller wards, the entrance, and all the auxiliary service spaces had to be relocated to the northern side of the pavilion.[61] This was also evident in the five physicians' proposals where nearly all of them had the service spaces conglomerated at the north (Figures 2.4-2.8). Stephen Smith's essay had gone even further, proposing to relocate all the service spaces—the ward dining room, laundry, linen room, water closets, the stair, etc.—to a detached structure, north of the open corridor or "perron," that both separate and connected the ward from its service area (Figure 2.8).[62] This separation created two distinct components within

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[59] Nightingale, for instance, had favored wards running east to west to maximize souther exposure along one of the walls, and had recommended locating sanitary facilities in projections off one short end wall. See: Florence Nightingale, *Notes on Hospitals* (third ed.) (London: Logman, Green, Logman, Roberts, and Green, 1863).

[60] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 28-29.

[61] Nightingale's ideal ward had included only four accessory ward spaces: toilets, a bath, a nurses' room, and a scullery. By the 1880s, head houses in American hospitals included small "quite" or "separation" wards, diet kitchens and dining rooms, linen rooms, patient clothing storage areas, and occasionally examination or surgical rooms. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 342-343.

[62] Stephen Smith, "Hospital Construction and Organization," in *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* (New York: William Wood & Co., 1875), 302-304.

the pavilion—what came to be known as the "island" ward, and the "head house" service area.[63] The scheme offered more design flexibility and control over the ward, and became the basis of the design of the ward pavilions developed by Billings and Niernsée.[64] Solar orientation of the ward was therefore not simply a means of environmental control but a critical hygienic factor that corresponded to the programmatic organization and disciplinary control of the ward.

The Common Ward of the Johns Hopkins Hospital reflected the evolution of the standard Nightingale ward and the culmination of the ideas proposed by the five physicians, and especially those further developed by Billings and Niernsée. The three Common Wards were rectangular buildings, oriented north-south, with a main ward on the south side and a service area on the north (Figure 2.9-2.11). The main ward, intended for 24 patients, was slightly larger than what Billings had originally proposed: 99'6" long and 27'6" wide, with a 15' to 16' ridged ceiling height, providing each bed with "7'6" wall space, 106.9 square feet of floor area, and 1768.9 cubic feet of air space." The south wall of the ward had a large bay window, forming a

[63] For more on the evolution of island wards, head houses, and centralized wards in American hospitals see: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 341-350.

[64] Billings described this strategy later: "The service rooms are collected at the north end, leaving the south end free of obstruction and fully exposed to the sun, the end of the ward being a large bay window looking out on the central garden, and with a floor which can be warmed so that the patients, above to sit there, can be thoroughly comfortable."John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8.

solarium, “a sort of sun room,” with a heated floor.[65] The terrace walk split the “head house” in two, forming an “octagonal hall” at the intersection with a series of service rooms around.[66]

All the ward pavilions were heated by a hot water heating system, with six boilers distributed in the Kitchen and the Nurses Home. In the Common Wards, hot water entered the pavilion from the mains in the pipe tunnel and passed through coils of three-inch cast-iron pipe that were arranged in stacks and placed in brick chambers along the basement walls (Figure 2.11).[67] The supply and return valves for each coil allowed the velocity of the current of hot water, and therefore its temperature, to be individually adjusted.[68] The basement itself was to function as an air chamber, accessible from the corridor only with an air-tight door. “Fresh air” entered the building via openings in the exterior walls of the basement and into galvanized-iron flues that were connected both to the heating chambers below and the air registers above in the ward. A cast-iron valve inside the flue, operable from the ward floor, allowed the incoming air to be directed fully downward to the heating chamber, fully upward without being heated, or

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[65] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 87.

[66] The service area included the nurses’ closet, the bath-room, lavatory, and water-closets, the tea kitchen, dinning-room, two wards for one or two beds each, and clothing and linen closets. There were special provisions made in these rooms, for instance, the tea kitchen was equipped with a small gas stove and a steam table, the clothing closet —reserved for the patient with a separate compartment for each—had a separate air supply and exit flues, the nurses’ closet had a drying closet heated by steam, and the bath tub was movable and could be raised on a truck and carried to any bedside. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 91.

[67] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 87.

[68] The temperature in the coils was typically 150° F. Reducing the velocity of the current of hot water in the coils would allow the temperature in the ward to be reduced up to the outside temperature. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 87.

positioned in between, which enabled the air temperature to be adjusted without affecting air flow (Figure 2.11).[69]

Inside the ward, air entered through 26 wall registers between the beds, placed below the windows and nine inches above the floor.[70] There were, however, two systems of air return "to remove fouled air," one at the floor and another at the ceiling.[71] The lower system consisted of a series of circular openings underneath every bed, a foot in diameter, which were capped by a "nearly hemispherical dome of wire netting" to prevent objects being dropped into the flues. The openings drew the air through a series of diagonal galvanized-iron tubes to the "lower foul air duct" that ran along the length of the ward. These lower ducts ran underneath the ward floor but were suspended from the ceiling of the basement so they could be "thoroughly cleaned

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[69] Although there was a valve at the lower end of the galvanized-iron fresh air flue that could be closed "to regulate the amount of incoming air," during cold and windy weather. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 87-88.

[70] In his essay proposal, Billings had considered three possible methods of ventilating the ward based on existing systems. The first and "theoretically, the most perfect system of heating and ventilation," was a method similar to that used by David Boswell Reid in the House of Commons, where "fresh warm air" was introduced at the floor and removed at the ceiling. This would keep the temperature in the lower and upper areas of the room consistent, and allow for an uninterrupted, and maximum, air flow upwards "to remove impurities as fast as produced." The second and the "most economical method," was to introduce warm air at the ceiling and remove it at the floor, but he considered it a "system of dilution rather than removal," and argued that it would result in the upper parts of the room having a higher temperature than the floor. The third method was to both introduce and remove the air at the floor, but noted that this method would not be satisfactory during moderate weather. The choice between these methods of heating and ventilation, in his view, was ultimately "a question of money." He estimated that the first method would cost about $10,000 more per year than the second, and concluded that "it seems to me that this amount of money can do better service in other ways, I recommend the employment of the second method, except for a few of the smaller wards, or perhaps for one pavilion, for purposes of comparison and experiment." Billings also estimated that regardless of the method of heating and ventilation selected, the amount and cost of fuel would appear excessive especially during cold weather. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 22-25. For more on the ventilation of the built Common Wards of the Hospital see: John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 74.

[71] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 88.

throughout."[72] The second system of air return consisted of six square-shaped openings, two feet by two feet, positioned at the center of the ceiling and 13 feet apart. These openings connected directly to the "upper foul air duct" that ran along the length of the ward, above the ward ceiling sitting on the attic floor. "Foul air" from both lower and upper systems was directed into an 75-feet tall octagonal chimney (4'2" in diameter) in the octagonal hall (Figure 2.12). An "accelerating coil" inside the chimney, heated by high-pressure steam, allowed it to function as an aspirating shaft, increasing the velocity of the upward current of air.[73]

The use of the two systems of downward and upward ventilation allowed the temperature of the ward to be better regulated during different seasons. The openings in the ceiling were built with shutters that could be opened or closed with an iron lever in the ventilating chimney to regulate the air flow. Typically, in cold weather, the ceiling registers were closed to allow only for downward ventilation in order to conserve the warm air above, while in warm or moderate weather, both sets of registers remained open. The velocity or the "aspirating power" of the upward current in the chimney could also be regulated with an iron lever that allowed a pair of valves near the top of the chimney to be opened or closed (Shown in Figure 2.11).[74] One of the Common Wards (adjacent to the Octagon Ward) was equipped with a steam-powered propelling

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[72] The lower foul air duct increased in diameter as it approached the ventilating chimney "to provide for the additional flues entering it." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 89.

[73] The upper foul air duct similarly increased in diameter as it approached the ventilating chimney. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 89. In his earlier plans, Billings offered the option of placing a double open fire-place at the center of the ward to provide another method of ventilation. See: John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 85-90.

[74] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 89-90.

fan in the basement, connected via ducts to each of the coil chambers, to allow "a large amount of air" to be forced into the ward, "securing a thorough aerial flushing, and the prompt removal of unpleasant odors," and also to provide some cooling during hot and still weather (Fan and Fan Ducts are marked as "F" and "FD" in the Basement Plan in Figure 2.10).[75]

The ventilation, supervision, and sanitation criteria of the hospital during this period also came into conflict with some of the basic components of its architecture. Among those were the ward corners. Viewed as a dark spaces where dirt, dust, germs, and even patients could hide, corners threatened the fundamental disciplinary conditions of the ward. In defiance to "all the old objectionable dark corners and useless passages" that constituted much of the hospitals in the nineteenth century, Nightingale had advocated for "the utmost simplicity of plan" to provide what she considered the "vital conditions" of a hospital, namely: light, ventilation, discipline, facility of supervision. "Every hole and corner, every passage, every small ward, which need not have been there," she argued, "interferes with these four vital conditions of a good hospital."[76] By the 1870s, the rejection of architectural corners had become widespread within the medical community. In his essay proposal for the Johns Hopkins Hospital, for instance, Caspar Morris

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[75] In his original essay, Billings had argued that natural ventilation "cannot be relied upon in warm, still weather," and had recommended using fans—with a capacity of about 600 cubic feet per second—for ventilating and cooling the air but also to regulate and control air supply and supplement "defective action of the aspirating flues in certain conditions of the weather." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 25. While only one of the Common Wards were built with a propelling fan, all other ward pavilions were fitted to receive similar fans and ducts in the future. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 90.

[76] Florence Nightingale, *Notes on Hospitals: Being Two Papers Read before the National Association for the Promotion of Social Science, at Liverpool, in October, 1858, with Evidence Given o the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859), 92, 106.

echoed that sentiment, writing that “No dark corners or recesses, should afford opportunity for concealment; or for the accumulation of dust and dirt. Every part should be well lighted, well aired, and open to observation.”[77]

For Nightingale and others, the main problem with corners, or more specifically “closed corners,” was that they “stagnate the air, more or less,” and disrupt its flow—in other words, they are not *aerodynamic*. “The only safe plan,” Nightingale had argued, “is to leave the corners entirely open.”[78] As a result, most hospital planners did away with corners when possible, or conceived various solutions when opening the corners was not possible. Billings original plans (Figure 2.4), for instance, had all the corners of the walls chamfered either by a fireplace or a wall and a door, and he had argued in his essay that “all corners in all wards should be made segments of circles instead of right angles.”[79] But unlike the patients or visitors who traversed or remained on the ground, the microscopic germs in the air moved in all directions. So while disciplinary provision concerned with supervision of patients impacted only the corners between the walls—and hence, the architectural plan— those concerned with ventilation, hygiene, and the

[77] Caspar Morris, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 262.

[78] Florence Nightingale, *Notes on Hospitals: Being Two Papers Read before the National Association for the Promotion of Social Science, at Liverpool, in October, 1858, with Evidence Given o the Royal Commissioners on the State of the Army in 1857* (London: John W. Parker and Son, West Strand, 1859), 34.

[79] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 29. Billings’ original section drawing of the ward included rounded corners where the walls and the ceiling met, but left the corners between the walls and the floor at a right angle.

whereabouts of microscopic germs impacted also where the walls met the floor or the ceiling—the architectural section.

This problem of corners was further complicated by the need, and difficulty, of cleaning and disinfecting them, especially when one side involved the floor. The corner between the walls and the floor—the space where two perpendicular planes with fundamentally different functions, mode of construction, and material finishes intersected—emerged as a critical detail in hospital design and construction. Among the rare solutions to the problem was one offered by Norton Folsom in his essay proposal for the Johns Hopkins Hospital. Folsom, who had also advocated for using rounded corners, had proposed a rounded baseboard to connect the floor and the wall to facilitate air flow and cleaning (Figure 2.13). "However constructed," Folsom wrote, "the walls should have all corners and angles rounded to prevent accumulation of dust, and allow for ready cleansing. This is especially desirable at the junction of the base-board and the floor, where a broom is apt to leave more or less dust in spite of care."[80]

Folsom's corner detail was readily adopted by Billings and became a key design detail in the Hospital. In the final Hospital wards, all right angled junctions were "avoided as far as possible" by rounding all the corners, including those between the walls and the floor where, and following Folsom's detail, Billings used "a curved strip of hard wood instead of the ordinary washboard" to mediate the transition from one plane to another (Figure 2.11).[81] In his address at the opening of

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[80] Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 67.

[81] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 87.

the Hospital on May 7, 1889, Billings hailed this "peculiarity" of rounded corners as a way to facilitate "easy cleansing, and to prevent possible accumulation of dust in corners and crevices." Calling out the curved hard wood corner between the walls and the floor, Billings advocated for this detail to become a new standard: "I advise you to look at it and see how it has been produced, for it ought to become fashionable, and take the place of the old mop-boards in all well-constructed houses."[82]

Conceiving the interior as an aerodynamic container was not unprecedented. Even before the introduction of mechanical ventilation or the rounding of the corners, buildings utilized windows, chimneys and openings in the ceiling and the roof to better regulate the flow of air. In most traditional construction with sloped roof structures, roofs were never airtight. Throughout the nineteenth century, roofing materials (slate or tile on lath) were porous to allow for a continuous flow of indoor air upward and out of the building so that the building itself often acted as a large chimney.[83] Full-ridge ventilation, for instance, used a vent opening at the peak of a sloped roof to allow warm, humid air to escape a building's attic and facilitate air circulation in the interior. Natural ventilation strategies, however, had rarely challenged the conventional elements of the architecture.

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[82] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8. The rounded corners between the floor and the walls did in fact become widely used in the following decades. In Alvar and Aino Aalto's Paimio Sanatorium (1929-1933) for instance, the intersection of floor and wall beneath the windows was curved to stop dust buildup. Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019), 63.

[83] William B. Rose, *The history of attic ventilation regulation and research*, Proceedings of the Thermal Performance of the Exterior Envelopes of Buildings VI, Clearwater Beach, Florida, December 4-8 (1995), 125-126.

With the introduction of mechanical ventilation and the increased air flow in the interior, all elements of the building's interior participated in the ventilation of the space. The new condition of ventilation challenged not just the basic assumptions about the right-angled corners but also those of the flat ceiling. In his essay proposal, for instance, Billings had placed a ridge ventilation opening that spanned from the middle of the ceiling, through a shaft inside the attic, to the peak of the roof (Figure 2.14). He had then argued, that "it is desirable that the ceiling shall not be flat," but have "an arched or peaked ceiling," to allow for "full ridge ventilation."[84] In the final pavilions of the Hospital, in addition to rounded corners, all the wards had an arched or sloped ceilings to facilitate air flow and ventilation. However, since the Common Wards were ventilated mechanically, the openings in the ceiling did not connect directly to the roof but to the "upper foul air duct" in the attic instead (Figure 2.9-10). In this way, mechanical ventilation and provisions for health and hygiene imposed a new environmental and formal criteria to the ward that challenged the basic conditions, or conventions, of architecture: namely, closed corners and flat ceilings. Beyond a set of standards or codes that specified the size, shape or number of the beds or windows, the provisions for rounded corners or arched ceilings were fundamentally *architectural* conditions that no longer conceived the building as a spatial container but a pneumatic and aerodynamic machine.

The most visible instance of consolidation of the various disciplinary, hygienic and environmental domains with architecture was the Octagon Ward. The reorientation and

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[84] Billings also noted that with full ridge ventilation it is more difficult to heat the room in the Winter. He also specified that the ceilings should not be too high as they are more difficult to heat, especially when the temperature outside drops below freezing point. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 24-25.

reorganization of the pavilions had offered an opportunity to rethink the ward space in isolation. Already in 1844, for instance, and in a break from the traditions of the rectangular ward typology, Boston architect George Minot Dexter had designed a square ward with a central chimney for the new Massachusetts General Hospital. The idea of a centralized ward, while briefly suppressed by the popularization of Nightingale's principles, resurfaced in the essay proposals for the Johns Hopkins Hospital. In his essay, Folsom—who, as the superintendent of the Massachusetts General Hospital, had overseen the construction of Dexter's square wards—proposed a "nearly square" ward with a ventilating shaft and chimney at the center, and the patient beds arranged around the periphery (Figures 2.5 and 2.15).[85] The central chimney included two fireplaces and two large registers at opposite sides of the shaft, therefore placing all the patients at an equal distance from the source heat and air. For Folsom the "nearly square" ward held several advantages over the typical rectangular ward: the layout offered "*privacy"* for each bed, the heating and ventilation arrangement created an "absence of *draughts,*" and the compact form of the ward and the relatively equal proximity of all the beds to the head house provided an "ease of administration."[86]

Highly influenced by Folsom's proposal, Niernsée conceived his own centralized ward. Similar to Folsom, Niernsée's preference for centralized ward was based not on better ventilation but on

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[85] Folsom's central shaft allowed for "two large 'Franklin stoves' or detached fireplaces, for soft coal, wood, or coke, made of soapstone, placed on the northerly and southerly sides, the flues of which are cast-iron pipes 10 inches in diameter. On the easterly and westerly sides are two large drums or registers, with grated fronts and ends, which supply fresh, warm air to the ward." Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 75-76.

[86] Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 76.

better heating distribution. Unlike Billings, Niernsée was not keen on the idea of using central mechanical heating, and had even argued that "open fireplaces, or stoves, should be chiefly relied upon for heating and ventilating hospitals." His critique of the way fireplaces or stoves have been placed in long rectangular wards, however, was that while all well adapted for ventilation, "they distribute the heat to the various beds in a very unequal ratio—the parties nearest the stove or fireplace being necessarily over-heated, while those at the extremities must be uncomfortably cool, if not cold."[87] And while the Dexter or Folsom's square wards largely resolved the problem, for Niernsée the four corners of the square ward resulted in irregular placement of beds, and created "dead spaces for stagnant air." To resolve these "defects" and to eliminate the right-angled corners altogether, he transformed the square into an octagon, therefore "placing all the beds at equal distances from each other, and from the fireplaces and ventilators."[88] With all the service spaces at the head house of the pavilion, Niernsée claimed: "we have *more* sides of the ward entirely free *for the largest possible amount of sunlight and heat* than in any of the other forms."[89]

Niernsée's proposal, published along side the five essays in the Appendix section of the *Hospital Plans,* included three schemes: a one-story pavilion (with a 65' outside, and 61' inside diameter)

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[87] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 337.

[88] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 337-338.

[89] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 338.

for 24 patients; a one-story pavilion (with a 75’ outside, and 71’ inside diameter) for 39 patients, which included a variation of the head house; and a two-story pavilion (with a 65’ outside, and 61’ inside diameter) for 24 patients in each floor. He included a series of floor plans and sections of the three schemes along with an elevation of the smaller one-story pavilion (Figure 2.16-2.20).[90] Resisting the use of a large central heating system for the Hospital, Niernsée designed his octagon pavilion with four fireplaces in each side of the central chimney and a small hot water boiler in the basement. And while the octagon ward no longer had a right-angle corner in plan, similar to Folsom’s and Billings’ recommendations, the corner between the walls and the ceiling were rounded, and the ceiling itself was not flat but sloped up towards the central shaft.

At the end of his essay, and in order to make the case for his Octagon Pavilion, Niernsée presented a “Comparative Table of Diagrams” (Figure 2.21). This table compared the properties of various ward typologies, including Dexter’s original square ward at the Massachusetts General Hospital, Folsom’s proposed square ward for the Johns Hopkins Hospital, the rectangular ward of the Herbert Hospital, and the two different versions of his own octagon ward. These various wards were compared on the basis of eleven different criteria, such as the “height of ward required for 1800 cubic ft. per bed,” “square feet of window per bed,” “area of ward, deducting centre shaft,” etc. “From the following table,” he argued, “it will appear evident that in planning hospital wards, where the largest area per bed for the minimum of cost is desirable, it is certainly

[90] John R. Niernsée, “Appendix II,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 335-342. The Octagon Ward was the only element in the Hospital Billings which Billings specifically credited Niernsée for its design. See: John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 92.

worthy of consideration not to ignore entirely the axiom, "that the same length of line (*ergo*, wall) encloses a larger area of space within the *circle* than in any other form.""[91]

While the Octagon Ward provided greater amount and a more even distribution of light and air, and even increased the area and space per bed, it still did not convince Billings to adopt it as the standard pavilion type for the Hospital. Records from the early planning of the Hospital suggest that while Billings has intended the first two pavilions to be two-story wards, they were planned to be rectangular pavilions similar to the plan of the Common Ward. To convince Billings to include the Octagon Ward, Niernsée had to make a case not on the basis of the design ingenuity of the building but simply based on the fact that the Octagon pavilions occupied less space. Niernsée met with Francis King, the President of the Board of Trustees in January of 1877 to make his case. King then wrote to Billings that "Niernsee is very anxious to have the two story ward, nearest the administration an octagon in order to give more space where it is most needed."[92] In the *Description of the Johns Hopkins Hospital,* Billings suggested that the decision to include the Octagon Ward "proposed by Mr. Niernsee," was only because it could fit in a small area in the site where a regular Common Ward would not have. "It was selected for this position," Billings wrote, "mainly because in carrying out the correspond row of buildings on the

[91] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 342.

[92] Francis T. King, Letter to John S. Billings dated January 10, 1877, John Shaw Billings Papers, the New York Public Library, General Correspondence: January - February 1877, Box. 2.

south side of the lot the ordinary rectangular ward would have come too close to the nurses' home."[93]

The final Octagon Ward was the only two-story ward pavilion in the Hospital, with a main ward on each floor, and while the general form and layout of the pavilion remained unchanged, there were a number of alterations to Niernsée's original design (Figure 2.22-2.23).[94] The pavilion was slightly smaller than Niernsée's original proposal—the inside diameter was reduced from 61' to 57' 8", which ultimately decreased its area from 122 to 114 square feet of area, and the space from 1800 cubic feet of space per bed to 1760.8 cubic feet.[95] The most notable alteration, however, was the integration of central heating, with direct implication on the ventilation. Centralized wards offered improved ventilation by eliminating cross-drafts that were believed to

[93] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 92. This justification has been disputed by Alan Short who has instead attributed the decision to a quarrel between the architect and the doctor. The early plans of the Hospital included sixteen ward pavilions, which limited the space between the first ward pavilion in each row and the Kitchen and Nurses Home. In later revisions when the ward pavilions were reduced to twelve, the Octagon Wards could have been replaced by Common Wards without coming close to the Nurses Home or the Kitchen buildings. C. Alan Short had noted that "this was manifestly not the case as can be seen in the plan of the first phase." C. Alan Short, "Hospitals," *The Recovery of Natural Environments in Architecture* (CRC Press, 2017).

[94] In addition, the sun room in the Octagon Ward was more separated from those in the Common Wards, projecting out of the octagonal building envelope to form a five semi-octagonal space. The service area and private wards in the head house in each floor of the Octagonal Ward were very similar to those in the Common Wards.

[95] Billings offered a detailed measurement of the ward in the *Description of the Johns Hopkins Hospital*: "The diameter of this ward, measured from opposite faces, is 57 feet 8 inches; the length of each face on the inner surface is 23 feet 10 inches. The height at the centre against the central chimney is 16 feet, the height at the walls is 15 geet, the average wall area per bed is 120 square feet, the number of square feet of flooring area per bed is 114 square feet, and the number of cubic feet per bed is 1760.8. The cubic capacity of the whole ward, including the bay window, is 42,160.8 cubic feet." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 92.

potentially carry germs across a ward from one patient to another.[96] But the introduction of a central shaft in a square or an octagon ward also offered new possibilities for air supply and return. If the ventilation strategy and the provisions for air supply and return in the rectangular ward was primarily debated and designed in section (at the floor versus the ceiling), the central wards reoriented that discussion to plan (at the center versus the periphery).

With the removal of the open fireplaces and stoves introduction of central heating and mechanical ventilation, the central shaft was no longer a chimney, dictating the pattern of air or heat circulation. This offered the possibility of two, diametrically opposed, ventilation strategies: to introduce the air at the center and remove it at the periphery, or to introduce it at the periphery and remove it at the center. For both Folsom and Niernsée, the even distribution of heat was more important than that of air, and the two were distinctly separate systems in their proposals. Since the open fires or stoves occupied the dominant center, fresh air, similar to radiant heat, was introduced at the center and removed through exhaust vents at the bedhead levels at the periphery. For Billings, on the other hand, air supply and ventilation in the ward was more critical that heating or its even distribution, and it was more important to place the air supply as close as possible to the beds in order to ensure each patients receives their own "fresh air," to allow for the air temperature to be adjusted locally, and to reduce the risk of air contamination.

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[96] Billings had previously acknowledged that in discussing his rectangular ward in his essay. He wrote: "As ventilating shafts give better results in the centre of the room than in the corners, partly because the air-currents to them do not cross patients' beds, and partly because the air in the shaft is kept at a higher temperature, I should prefer to have them in the centre." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 21.

In the built Hospital, the Octagon Ward fresh warm air was entered the ward through the air inlets between the beds in the outer periphery walls, flowed inward and was removed through the exhaust shaft at the center (Figure 2.24). The central shaft was a large octagonal brick chimney, eight feet internal diameter and thirteen feet external diameter, with two-and-a-half feet thick walls. Each of the eight faces of the octagonal chimney in each of the two ward floor had two openings (measuring 20" X 26"), one near the floor and other near the ceiling (Figure 2.25).[97] In cold weather, air was removed through the lower registers of the central shaft "in order to secure uniform diffusion of the fresh air and to prevent undue loss of heat." In warm weather, or when the air in the ward needed to be flushed out, the upper registers of the central shaft were also opened to remove the warm air more easily—the amount of the opening in the upper registers were adjustable with valves to allow the interior temperature to be better regulated.[98]

Reminiscent of the radial-plan hospitals of the fifteenth and sixteenth centuries with central octagonal chapels or Jeremy Bentham's panopticon of the eighteenth-century with a central watchtower, the Octagon Ward reflected a new disciplinary order where the spiritual or civic authority was substituted with a medical one. No longer operating on the basis of what Foucault has called an "economy of visibility," the individually heated and ventilated beds of the Octagon

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[97] Inside the brick chimney was a large boiler-iron tube (5' 9" in diameter), resting on a projecting cast-iron base built into the walls. The boiler-iron tube extended from the floor of the lower ward to above the ceiling of the upper ward. The openings from the upper ward entered into the space between the boiler-iron tube and the outer chimney. A ring of steam pipe was placed above the boiler-iron tube to function as accelerating coil. Additionally, while the Octagon Ward did not have any open fireplaces, a cast-iron pipe, one foot in diameter, was placed at the very center of the chimney as a smoke flue if a fireplace was to be added in the future. This smoke flue extended down to the basement floor with a large opening that allowed it to be cleaned, and also extended up and above the fixed cowl that capped the top of the chimney. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 93.

[98] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 93-94.

Ward, placed at equal distance from the central ventilation tower, established an new thermal and environmental economy of control. And ironically, its "minor defect" was that the dominant ventilation shaft at the center hindered visibility.[99] The solid central shaft blocked the views from across the ward, interfering with the nurse's supervision of the patients. It was a panopticon without an optical center.

Both Folsom and Niernsée were well aware of this, but believed thermal and aerial discipline to be more important a hospital ward than a close visual surveillance. But they also claimed their plans offered greater visual, as well as aerial, *privacy* to patients. In his original proposal, Niernsée wrote:

> *The employment of either the square or octagonal form of ward for hospital purposes seems only to interfere in some degree with one of the requirements of a sick ward, viz., "that the beds should be so arranged as to allow the attendants a view of every patient"; but as this does not mean the necessity of such minute and close individual surveillance as in the workshops of a penitentiary or other penal institution, and as there is generally more than one attendant present, it can*

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[99] In contrast to the solid and opaque ventilating tower of the Octagon Ward of the Johns Hopkins Hospital, the Stuyvenberg Hospital in Antwerp used a central ring of hollow iron columns with registers at the bottom of the perimeter wall next to each bed. This arrangement kept the center of the ward open with a central, glass-enclosed nurses' station that allowed for supervision of the patients. Jeanne Kisacky has noted that American hospitals that incorporated centralized wards were typically patterned after the Johns Hopkins Hospital model, with an inward air flow and solid centers. For more on the centralized hospital ward see: Jeremy Taylor, *The Architect and the Pavilion Hospital: Dialogue and Design Creativity in England, 1850–1914,* (London: Leicester University Press, 1997), 134–67; Jeremy Taylor, "Circular Hospital Wards: Professor John Marshall's Concept and Its Exploration by the Architectural Profession in the 1880s," *Medical History* 32, no. 4 (1988), 433; C. H. Blackall, "The Stuyvenberg Hospital, Antwerp," *American Architect and Building News* 19, no. 528 (February 6, 1886), 63. Some of the American hospitals that incorporated centralized wards include the New York Cancer Hospital, the Mary Hitchcock Memorial Hospital, the Wesley Hospital in Chicago, the Memorial Wards of the Pennsylvania Hospital in Philadelphia, temporary wards at the Lakeside Hospital in Cleveland, and the Children's Ward of the Presbyterian Hospital in Philadelphia. See: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 344-346.

> *amount only to a very minor defect when we consider how many other important requisites are accomplished by the adoption of that form of ward.*[100]

Through this process, the Octagon Ward marked a radical departure from the visual disciplinary order of the eighteenth and the early nineteenth century hospitals. No longer operating on the basis of the "medical gaze" or the "economy of visibility," the architecture of the ward favored environmental control and regulation over visual inspection or surveillance. In doing so, the Octagon Ward also inverted the disciplinary hierarchy of the eighteenth century institutions. Power, just like air or heat, now began to flow from the periphery to the center, from the patients' beds and their individual air registers to the central ventilating shaft.[101]

## 2.2 Air Spaces

There was an ongoing debate during this period on whether the space of the hospital ward is measured by area or volume. Increasing the space was presumed to dilute the concentration of carbonic acid in the air—assumed to be the source of disease—but there was no consensus on whether the square footage or the cubic footage per bed was the key measure. In the 1850s, the Herbert Hospital Commission had concluded that maximizing the area per bed was more important that the volume of space. For instance, in his analysis of the Octagon Pavilion, Niernsée had cited the Herbert Hospital Commission's report, which had established "that the

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[100] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 340.

[101] This was not unlike Bentham's panopticon, where the main advantage of his surveillance machine was that it did not matter whether a watchman occupied the tower at the center. It was the visibility of the tower itself—not the watchman—and the appearance of supervision that maintained order and enforced discipline, autonomously and automatically.

great point to be considered in a ward is to obtain *the largest area per bed*, as of more importance than mere cubic contents."[102] Others argued for maximizing the volume since "foul air" or poisonous gases were not bound to the floor and moved freely in space. As a result, hospital designers continued to consider both metrics in relation to the number and placement of the beds.[103] From the late eighteenth to the mid-nineteenth century, American hospital wards typically provided between between 100 to 120 square feet of area, and between 1,000 to 2,000 cubic feet of space per patient, with a minimum of three feet between each bed.[104]

The introduction of mechanical ventilation shifted debate from the question of space, measured by area or volume, to that of air, its quantity and velocity. "Undue importance has been given by many writers to this question of cubic space in hospital wards," Billings wrote in his fifth report, "If the necessary amount of fresh air be supplied and properly distributed, so that unpleasant

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[102] Using the ward of the Herbert Hospital as a reference, Niernsée maintained that his 61' diameter octagon ward offered 122 square feet of area per bed compared to 99 2/3 of the Herbert plan, while both housed 24 patients, and that the octagon ward at 14 3/4 feet height offers the same amount of space (1800 cubic feet per bed) as the Herbert plan at 18 feet height. "*Ergo*," he concluded, "more area by 22 per cent. is gained at the same expense." John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 342.

[103] Niernsée had cited these findings in his essay. John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 340. Theses principles were laid by the Royal Commission of 1857 on the Sanitary State of the Army, further developed by the Barrack and Hospital Improvement Committee of 1858. The commission composed of Sidney Herbert, John Sutherland, Dr. Burrell, and Douglas Galton. For a brief history of the Royal Herbert Hospital see: B. A. Gavourin, "From Plain to Royal," *Journal of Royal Army Medical Corps,* no. 122 (1976), 94-107.

[104] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 98-99, 285-286; see also: Richard Harrison Shryock, "The History of Quantification in Medical Science," *Isis* 52, no. 168 (June 1961), 227. "Circular Hospital Wards," *American Architect and Building News* 18, no. 512 (October 17, 1885), 186; John Harvey Kellogg, *Practical Suggestions Respecting the Ventilation of Buildings* (1891).

currents of air are avoided, cubic space is of minor importance."[105] This shift, brought about by technological innovation, converged with the emerging medical theories and knowledge of the time that, rather than dilution of air, increasingly saw the rate of air exchange as the primary mechanism for removing floating particles and germs from the ward. The focus, therefore, was not just the supply of "fresh air," or *positive ventilation*, but also the removal of "foul air," or *negative ventilation,* which placed the bedridden patient in a constant flow of air. "A theoretically perfect ventilation," Billings had argued, "implies that a man shall inhale no air or suspended particle which has previously been in his own body or in those of his companions."[106] *Space,* therefore, was no longer understood as a passive physical container bound by walls, a floor and a ceiling, but an active aerial condition, measured by volume of air displacement over time.

By divorcing space from its physical container, the architecture of the hospital was transformed from what was a homogeneous spatial or ventilating container to a heterogeneous network of aerial zones or air spaces. Positive ventilation (in operating suites and wards) offered a large supply of fresh air while negative ventilation (in bathrooms, isolation facilities, morgues, or laboratories) prevented the intrusion or spread of "foul air" into other areas of the hospital. This complex ventilating system created unique and remarkably distinct internal environments within the hospital which, even when spatially adjacent, were aerially separate.[107] Most importantly, the

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105 John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 7.

106 John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 21.

107 Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 292.

ventilation system offered the possibility to conceive individual air spaces for the patients in open and shared wards. As a result, the rate of air exchange, described as a unit "per person," "per patient" or "per bed," was not simply a median or average distribution of air in a ward, but it was precisely the measure for individual spaces within the ward. Air emerged as the most potent architectural material in the Hospital

The minimum standard of air supply during this period was 1,000 cubic feet of air per hour per bed, but the number varied across regions and through the years. In the 1850s, for instance, the Hôpital Lariboisière (1854) had an air supply of 1,400 cubic feet per hour per bed. By the 1870s, the Krankenhaus im Friedrichshain (1874) in Berlin, could supply between 2,500 to 3,000 cubic feet of air per hour per bed. And hospital experts, such as Francis de Chaumont, well-known British Army Surgeon, had recommended 3,000 cubic feet of air per hour per bed.[108] In his original essay in 1875, Billings had gone even further, recommending 4,800 cubic feet of air supply per hour per person.[109] By the time he wrote his third report to the Building Committee in 1877, however, he settled for 3,600 cubic feet of air per hour per person, amounting to one cubic foot per second per person.[110]

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[108] Billings made a reference to de Chaumont's recommendations in his fifth report to the trustees, which focused exclusively on heating and ventilation. See: John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 7. Billings also had lecture notes on Chaumont's "Theory of Ventilation." See: John Shaw Billings Papers, the New York Public Library, Box. 45.

[109] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 21-22.

[110] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 3 (Johns Hopkins Hospital, January 11, 1877), 14. In his fifth report to the trustees in February of 1878, Billings discussed this question in length again and argued for one cubic foot per second per bed as the minimum allowance, with the possibility of doubling that when needed. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 7-8.

This formula remained the minimum standard air supply for much of the wards and determined nearly every aspect of its ventilation design and construction. “The whole system of ventilation, sizes of ducts, flues and registers, and provision of power to ensure movement of air,” Billings wrote, “is intended to secure one cubic foot of fresh air per second for each of the twenty-four beds in the room, and to provide a reserve capacity of doubling this supply if it be desired to do so.”[111] In the Common Wards and the Octagon Ward, where patients were placed in large open wards, the air supply registers between each pair of beds provided “complete aerial separation” of patients despite their physical and spatial proximity.[112] In the wards where patients were placed in separate physical rooms, air supply was even higher. In the Pay Wards, for instance, air supply was one and a half cubic feet per second per bed (5,400 cubic feet per hour per bed). In the Isolation Ward—“designed for cases giving rise to offensive odors or in which a large amount of organic matter is thrown off, or in which, for other reasons, a large amount of air is desirable”—the air supply was fixed at two cubic feet per second per bed (7,200 cubic feet per hour per bed). Three special rooms in the Isolation Ward were equipped with special ventilation systems that could provide four cubic feet of air per second per bed (14,400 cubic feet per hour per bed), with the capacity for doubling that, amounting to eight cubic feet of air per second per

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[111] Billings emphasized that the Common Wards were “not intended for cases of contagious disease, not for cases such as uterine cancer, etc., which give rise to very offensive odors.” He also noted that the increased in air supply in the Isolation Ward was in part due to the larger amount of heating surfaces. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 90-91, 95.

[112] “The Johns Hopkins Hospital, Baltimore, MD,” *American Architect and Building News* 1 (December 16, 1876), 405-406; A. A. Cox, “The Johns Hopkins Hospital, Baltimore, Maryland,” *American Architect and Building News* 35, no. 837 (January 9, 1892), 24–26.

bed, or 28,800 cubic feet of air per hour per bed—equivalent to air displacement produced by a 1,200 horsepower jet engine.[113]

The provision for individual air spaces for every bed, or every pair of beds, was not just a means of aerial separation—ensuring the patients kept their germs to themselves—but also offered the opportunity to regulate and control the temperature of their environments. Central heating and ventilation system, while offering better distribution of heat or air throughout the building, they limited the degree of control for individual rooms or spaces. In buildings that relied on natural heating and ventilation, fireplaces and windows allowed the temperature and air flow in each room to be independently regulated by their occupants. By the mid-nineteenth century, in buildings equipped with central heating, gas lights, running water, and waste disposal all the rooms were connected to a larger central system, and fixed windows and automatic controls increasingly left the occupants with less control over their immediate environment.[114]

In hospitals, the perfectly even distribution of heat by central heating systems was seen as a medical disadvantage. Most hospitals during this period were heated by open fireplaces—usually placed in a corner of the ward—creating a gradient map in the room where radiant heat

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[113] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 73.

[114] These developments, Robert Bruegmann has argued, ultimately transformed the fundamental assumption about the nature of buildings. Bruegmann has illustrated how the building's autonomy was diminished as building systems increasingly came to be connected to supply lines from outside the structure. In 1879, Birdshill Holly pioneered district steam heating in Lockport, New York, marking a new chapter in the central heating. See: Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 159.

diminished by distance.[115] For many physicians, Billings included, fireplaces not only provided "a cheerful appearance to the room," but also had "physiological" advantages by providing a direct but "agreeable" radiant heating without increasing the temperature of the air itself. "When cool air is breathed" Billings argued, "transpiration from the lungs goes rapidly, thus favoring the removal of effete organic matter" which, "if not removed will produce discomfort, and if in excess, disease."[116] For hospitals that typically housed different cases in a same ward, this uneven distribution of heat offered an environmental flexibility by keeping the overall temperature of the ward low for the febrile cases while allowing the non-febrile cases, or those who needed more heat, to gather around the fireplace.[117] Therefore, despite reliance on central heating, it was desirable to allow for variation of temperature within the ward.

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[115] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 20.

[116] Billings believed that while the air at a temperature of 70° Fahrenheit or higher does not have any "evil or debilitating effects," the air entering the lungs, "from the physiological side of the question," is better to be at a temperature between 45° to 60° Fahrenheit. This differential physiological effect was attributed not to the air temperature but to moisture. For instance, the air exhaled (at a temperature of about 95°) would contain 50% more moisture if the temperature of the air inhaled is 45° compared to 60° (assuming the previous relative saturation is the same). However, if the moisture in the air remains the same when temperature decreases from 60° to 45°, the air would contain the same amount of moisture when exhaled at an increased temperature of 95°. The "important difference," Billings noted, is that "the moisture in the former case will be largely derived from the lining membranes of the nose, mouth, and windpipe, while in the latter it will be taken from the smaller cells of the lungs, and with it certain organic matters and products of their decomposition which if not removed will produce discomfort, and if in excess, disease." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 20; also see: John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 17.

[117] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 20.

Meanwhile, systems of environmental control during this period had enabled the possibility of regulating the temperature automatically.[118] In his original essay, Billings has speculated about automatic regulation of air supply and temperature in wards. He referenced "Dr. Sternberg's automatic valves" and "the apparatus employed by Mr. Winans" by which "the temperature and air supply of a ward may be made self-regulating, or if these are allowed to vary it is possible by galvano-electricity to register their variations either at regular intervals or continuity," and had even recommended using a series of dials in the Central Office of the Hospital that displayed "for any given ward to room, or for all of them, the temperature and the amount of air passing through either the fresh or foul air ducts, or both."[119] Despite the availability of these technologies, Billings intended to have control not just over the temperature of each ward, but that of every bed.

In a space heated by indirect radiation, whether by using hot water or steam, the room temperature was typically regulated by adjusting the air supply, which meant that, for instance, if a space was too warm, the air supply was shut off, stopping the flow of heat but also of that of air. Changing the heating inadvertently changed the ventilation. Billings had maintained that there should be to unintended changes to the air flow and ventilation, and had even specified that the air supply openings in the ward should be arranged in such a way that they are not movable, and the valves that control air supply "should not be accessible to the inmates of the ward" so

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[118] Michael Osman has recently examined systems of environmental control in buildings in relation to broader cultural and economic trends in management and regulation of risk. See: Michael Osman, *Modernism's Visible Hand: Architecture and Regulation in America* (Minneapolis and London: University of Minnesota Press, 2018).

[119] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 32.

that "it is impossible for the patients to close them."[120] While air supply was meant to be at a fixed minimum rate, temperature had to be adjusted from time to time, or often from bed to bed. The challenge was therefore how regulate and adjust the temperature without affecting the air supply and ventilation—what constituted the very definition of space.

Billings' solution relied on two different valve mechanisms within the pavilion. The first method was intended to regulate and control the flow of hot water in the heating coils, therefore their temperature. The central boilers were connected to all buildings via flow and return pipes that connected to heating coils in the basement of the wards, one reserved for every pair of beds.[121] The valves on all the mains as well as on the supply and discharge pipes to each coil allowed the amount of hot water circulating in each coil, and therefore its temperature, to be controlled.[122] The second method was to allow for regular control and adjustment of the flow of warm air that entered the ward by passing above the heating chamber. The "chief registers" between every pair of beds were equipped with an iron arm by which, "under the control of the nurse," the air flow could be directed down through the heating chamber to have it warmed, or up to bypass it

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[120] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 14.

[121] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

[122] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 67.

altogether.[123] Through these two mechanism, the temperature of the heating coils or that of the incoming air for each pair of beds could be increased to 150° F—maximum afforded by the heating coils—or reduced to that of the external air, all without affecting the air velocity or flow.[124] "Thus it is quite possible," Billings declared in his address at the opening of the Hospital, "to give one pair of beds a temperature of 70° and another pair in the same room, at a little distance, a temperature of 60° F., to suit the needs of different cases."[125]

Insulation was therefore critical not only to maintain the internal temperature during hot or cold days, but also to preserve the aerial structure and the delicate pattern of air circulation inside the pavilions. The central heating system of the Hospital allowed multiple pavilions to be heated together, but also exposed the risk of losing or wasting heat in the mains that carried hot water or

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123 In his address at the opening of the Hospital, Billings called attention to this mechanism: "I will only call your attention to the fact that the temperature of the incoming air by any bed is easily changed by turning a valve, while the quantity of air is not changed; to the arrangement for taking foul air from either the bottom or top of the ward, or from both, and to the fact that all this has been thoroughly tested during two winters and found to give the results hoped for." John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8. For more on the valve mechanisms see: John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 14.

124 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 74.

125 John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

steam from the boilers to the buildings.[126] To prevent that, the pipes were covered with felt, enveloped in asbestos paper, and then enclosed with stout canvas and thoroughly painted.[127] The insulation of the pavilions themselves, however, relied not on any specific material but on air itself. The exterior walls were designed as "double walls, with air spaces."[128] Inside the walls, "a two-inch air space nine inches from the inner surface" extended from the horizontal layers of slate at grade all the way to two or three courses of brick at the top.[129] Similarly, the high-pitched roofs offered large ventilated attics with "ample space" to insulate the wards and ensure "the heat of the sun upon the slate roofs during the hot summer months does not affect the wards."[130]

Compared to exterior walls and roofs, glass windows not only held a much lower thermal resistance, or "R-value," but also posed a greater risk of disrupting the air flow—they affected

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[126] While all the buildings in the Hospital had a complex system of heating dealing with variations of temperature during the year, no building had a demand for maintaining extreme temperatures within itself than the Kitchen Building. In addition to the areas reserved for preparation of food, the Kitchen Building also contained cold rooms for storage of food as well as hot water and steam boilers that supplied the whole Hospital. The Kitchen was a square three-story building, measuring seventy-five feet on each side and contained a cellar that housed the boilers. The building sat on Monument Street, in the ear of the male Pay Ward and at the north end of the corridor connecting it to the Nurses Home on the south side of the site. The main floor of the Kitchen was leveled with, and opened to, the corridor. In addition to areas for food preparation, there were two "cold rooms, or refrigerators" on this level, built with hollow walls to prevent conduction of heat. The walls were made of brick and covered with a layer of thick paper, one-and-a-half inch battens, seven-eighth of an inch lining of popular boards, another layer of paper, another later of battens, and another later of seven-eighth of an inch poplar sheathing, providing it with two insulating spaces one-and-a-half inches in width. In the smaller cold room, an additional lining of galvanized iron was laid over the inner poplar sheathing. For more on the Kitchen Building at the Johns Hopkins Hospital see: John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 97.

[127] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 68.

[128] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

[129] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 63.

[130] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 65.

not just heating but also ventilation.[131] The pavilions at the Johns Hopkins Hospital, however, were nevertheless designed to rely on natural ventilation during warm weather—this is was also why, despite the intricate heating and ventilation system in the Hospital, the windows were not designed to as fixed and were to function as auxiliary ventilation devices. In his essay in *Hospital Plans,* Niernsée had advocated for double sash windows for offering more ventilating control, and had even suggested using double casement and double-glazed windows.[132] In most of the built pavilions of the Hospital, however, the windows were not double-glazed but simply double-think, "first quality French double-thick."[133] To compensate for the down draughts "produced by the chilling of the air through the glass of the window," Billings devised dedicated air registers underneath the windows to be used in "very cold weather."[134] The system was nearly identical to that used in Charles Rennie Mackintosh's Glasgow School of Art (1904) over a decade later—celebrated by Banham as a twentieth-century instance in the integration of systems of environmental control with architectural design.[135]

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[131] The R-value is a measure of how well a two-dimensional barrier resists the conductive flow of heat. Kreith, Frank; Goswami, D. Yogi (eds.). *CRC Handbook of Mechanical Engineering* (Second ed.) (Boca Raton, FL: CRC Press, 2004).

[132] In his essay, Niernsée wrote: "The necessity of doubling the windows in some way has been felt and acknowledged by the almost universal employment of the French casement double-window on the continent of Europe; by the glazing of some of the more modern hospital single windows with plate-glass three-eighths of an inch in thickness; and also by the putting into single sashes two sheets of extra thick (one-eighth inch) common glass, set half an inch apart from each other." John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 338-339.

[133] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

[134] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 74.

[135] Reyner Banham, *The Architecture of the Well-Tempered Environment* (London: Architectural Press, 1969), 71-92.

The need to isolate and insulate the environment was therefore not just limited to the areas between the interior and the exterior—to create a hermetically sealed environment—but also included the spaces within the interior itself. Unlike the exterior environment, filled with "fresh air," the Hospital's interior was presumed to be a possibly contaminated environment where aerial communication between the spaces could potentially, and rapidly, spread germs and therefore disease. In this way, insulating the interior environments against one another was deemed more critical than that between the interior and the exterior. So if the combination of natural and mechanical ventilation relied a limited and controlled air exchange between inside and outside—to admit "fresh air" and remove "foul air"—the pavilions were designed to establish a complete aerial separation between the interior spaces. And Billings had repeatedly expressed concern over "the greater obstacles" in a system of ventilation by aspiration, which "arise from doors, windows, and other openings than the fresh air flues."[136]

Doors in particular were problematic. The regular and unpredictable use of doors threatened the order and stability of the interior environment, especially when they were left open.[137] Billings was especially concerned with the connection between the wards and the service rooms and, in his fifth report to the Building Committee, he had argued that "the doors shall be kept closed as much as possible." To secure this, he proposed using "self-closing" door in the wards that are "double-hung, self-closing by springs, and closing as tightly as possible." He further specified

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[136] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 16.

[137] For a sociology of automatic door closers and other mundane artifacts see: Bruno Latour, "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts," in *Shaping Technology/ Building Society: Studies in Sociotechnical Change,* Wiebe E. Bijker and John Law (eds.)(Cambridge, MA.: MIT Press, 1992), 225–258.

that the hung doors "should be as light as possible to avoid strain, and should not be liable to be affected by moisture," suggested them be made of "light galvanized iron, hollow, the interspace being filled lightly with felt" and noted, "if of wood, they should be as plain and smooth as possible."[138] In the final built Hospital, Billings used the British Archibald Smith & Stevens "Patent Door Springs," the first self-closing door system that used double-acting springs sunk in the threshold under the floor (Figure 2.26).[139] He emphasized that the large self-closing doors in the wards "should never be blocked open, expect in very warm weather when all the windows are up and the patients are as nearly out-of-doors as possible."[140]

The Hospital's systems of environmental control functioned best when there were as little architectural "obstacles" as possible. In this way, the open space of the ward—with no interior partitions, a single self-closing door, rounded corners, and individual air supplies and returns for every bed—emerged as an ideal well-tempered and well-ventilated environment. The need for separating patients in individual rooms was therefore not so much a matter of health and hygiene but social classification and privacy. Pavilions with individual patient rooms, the Pay Ward and the Isolation Ward, were designed to allow separation of certain classes of patients from the rest

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138 John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 16.

139 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 65. Founded by Archibald Smith, am ironmonger, the business was established in 1770 when Smith patented his first spring door-closing device, the first automatic door closing mechanism using a spring. In 1878 he was joined by a successor, forming Archibald Smith & Stevens. Aside from the spring door-closing device, which continued production under the name "Janus," they also made hand powered and hydraulic lifts and rope stranding machines. Smith's company later evolved to become the Express Lift Company Limited, a UK-based company that manufactures and supplies passenger elevators. See: "A Brief History of the Express Lift Company Ltd." in *The Express Lift Company Limited (1770-1982)* (Northampton: Mathew Fraser Ltd.), 1-2 (http://www.hevac-heritage.org/electronic_books/lifts/7-express_lift_Co_Ltd.pdf)

140 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 91.

The walls that defined these individual rooms, therefore, were not so much a means of aerial but physical and visual separation. For instance, in the Male and Female Pay Wards—two-story pavilions "devoted exclusively" for the reception of "private, or pay, patients"—private rooms were arranged in each floor on either side of a central corridor (Figure 2.27-2.28).[141] The heating and ventilation system, and the arrangements for regulating the temperature in these rooms, were "substantially the same as those for the common wards."[142] In addition to the hot water heating and ventilation system that operated at one-and-a-half capacity compared to the Common Wards, these individual rooms were also equipped with open fireplace, therefore providing heating by both direct and indirect radiation.[143] The increased air and heat supply in these private rooms were intended to compensate for the smaller volumetric space and better dilute the air. The physical walls, while offering privacy, also impeded on the nurses supervision and care of patients. As a result, each room was equipped with an electric bell to call for assistance, as well

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[141] Depending on circumstances, some pay patients would also be placed in the private rooms of the Common, Octagon, or the Isolation Wards, however, the Pay Wards were "devoted exclusively" for paying patients. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 84-85.

[142] "Fresh air" entered the room from a register near the floor in the external wall and exited through a flue in the inner or corridor wall. These flues then went up to the attic where they converged into a single galvanized iron flue that connected to the vertical shaft with accelerating steam coils and out of the building. This system was essentially the same as that used in the Common Wards, with the exception that the air supply in the Pay Wards was taken from the interior rather than the exterior. Billings does not offer an explanation for this. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 85.

[143] During cold weather, the fire-places were meant to provide all the ventilation necessary but in other circumstances, the ventilation was effected by flues on the inner or corridor walls. The flues would pass up to a foul air box in the attic that contained an accelerating steam coil. That box was then connected with a shaft obliquely upwards to the central ventilating shaft, which was capped by a ventilator. When the flues were in operation, the throat of the fire-place was covered by a soap stone slab. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 84.

as an “iron crane, or winging bracket,” with a suspended leather strap, so that “the patient can assist himself to turn or rise in bed” (Figure 2.29).[144]

Even in the Isolation Ward, “especially arranged for cases which may be either contagious or offensive,” the physical walls were similarly a function of visual separation and disciplinary control.[145] Isolation wards during this period were typically ad hoc additions in form of temporary structures, tents, wooden shacks or “huts” to protect the vulnerable patients or separate the contagious one.[146] The Isolation Ward at the Johns Hopkins Hospital, was among the few planned and constructed specifically for that purpose.[147] Largely based on Norton Folsom’s “Isolating Ward” proposed in his essay proposal (Figure 2.30), the building was a one-story pavilion with twenty individual isolating rooms laid out on either side of a central corridor

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[144] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 84-85.

[145] John Shaw Billings, “The Plans and Purposes of the Johns Hopkins Hospital,” from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8.

[146] Isolation wards typically protected the vulnerable patients from the hospital diseases, and separated patients with infectious diseases from the rest of the hospital. These isolated pavilions typically had a traditional pavilion-ward layout, but built with extra ventilation technologies or features that maximized air flow. The open floor of the isolation wards, however, still posed risks of cross-infection. In 1872, Henry Greenway proposed an isolation ward with numerous glass cubicles within a larger rectangular ward to maintain aerial isolation between the patients or their visitors. For more on Greenway’s Isolation Ward see: Henry Greenway, “A New Model of Hospital Construction,” *British Medical Journal* 1, no. 593 (May 11, 1872), 495-497. In 1876, the directors of the Presbyterian Hospital in New York City built a twenty square feet space that came to be known as the “Hut.” The hut included rooms for two patients and a nurse and had an elaborate structure consisting of a double wooden wall, an air space between the floor and the ground, and air duct running beneath the floor. For more on the history of isolation wards in American hospitals see: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 159-162.

[147] In 1896, the southern half of the Isolation Ward was blocked off by a transverse wall in order to provide an obstetrical ward. In 1922, the entire building was significantly altered to form what became the western wing of the Woman’s Clinic.” Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 64-65.

(Figure 2.31-2.32).[148] The building also provided living accommodation for four nurses (in two bedroom) who were expected to remain in that ward for several days at a time in order to limit contact and "secure as little communication as possible" between that ward and the rest of the Hospital.[149]

Heating and air supply in the Isolation Ward was of a similar system used in other ward pavilions, however, each room was provided with its own fireplace and chimney, and the minimum air supply was double that of the common wards.[150] Air entered most of the individual patient rooms through wall registers in the corner of the room and was removed by chimneys in each room that were also equipped with accelerating coils. There were a total of 26 aspirating chimneys in the Isolation Ward, one for every room, that projected out to the roof. All the patient rooms were also provided with their own water-closets with elaborate ventilation and discharge mechanism. With provisions for autonomous heating and ventilation systems in each room, therefore, the reliance on physical walls here again was less a means of aerial isolation of "contagious" cases but visual separation of "offensive" ones. But unlike the Pay Wards, the individual rooms in the Isolation Ward offered a better integration of heating and ventilation systems with the design architectural elements. Three of the rooms were built slightly larger for special cases. After passing through heating coils in the basement, the warm air entered the room not through the wall register but a perforated floor with 5,000 quarter-inch holes "slightly funnel-

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148 See: Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 84-88.

149 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 94-97.

150 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 95.

shaped." The intent was to supply each isolating patient with about four cubic feet of air per second, and to have this air pass constantly upwards, "so that no portion of this air shall be rebreathed to come a second time in contact with the patient, thus placing him in the condition of being our-of-doors in a very gentle current of air."[151]

A unique feature of the Isolation Ward was a central corridor, an interior space where "the wind is always blowing."[152] The corridor, "freely open to the external air at either end," was about 30 feet heigh, projecting above roof and forming a clerestory fitted with movable glass louvers. To compensate for the potential heat loss and minimize aerial communication, the walls of this corridor were nearly double the thickness of regular walls of the Hospital, and they required air-lock double doors with a small vestibule in between, to connect the corridor with the isolating rooms.[153] In contrast to the autonomous, enclosed and internalized exterior corridors of the Hospital, the open and externalized interior corridor of the Isolation Ward directly participated in the architecture and environmental management of the pavilion—an interior street that preserved a complete aerial separation between the spaces on either side while maintaining physical, and architectural, connection.

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[151] There were 50 holes in each square foot within the over 94 square feet of floor space in each room. The holes were "slightly funnel-shaped" and twenty of them were estimated to be equal to one square inch of clear inlet. This arrangement was meant "to supply a large amount of air, about 4 cubic feet per second, to each inmate, and to have this air pass constantly upwards, so that no portion of this air shall be rebreathed or come a second time in contact with the patient, thus placing him in the condition of being out-of-doors in a very gentle current of air." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 95-96.

[152] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8-9.

[153] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 94.

Reyner Banham has argued that the notion of atmospheric space, "the primacy of space over mass," was developed with the use of thin walls, inflatable structures, thermal barriers, and the increasing concern with energy consumption, and only became comprehensive and acceptable in the twentieth century.[154] The concept was nevertheless theorized and discussed over a century before. As early as 1837, David Boswell Reid had argued that "the great and primary object of architecture is to afford the power of sustaining an artificial atmosphere." Reid, however, still considered the visible architectural structure as a necessary requisite, an existential container, for the interior atmosphere. "Though the invisible air is apt to be forgotten amidst the more obvious attractions of architectural art," he wrote in his *Illustrations,* "still in a practical point of view, the visible structure is only the shell or body of that interior atmosphere without which existence could not be supported."[155] By the 1870s and 1880s, new developments in heating and ventilation technology along with the codified spatial and disciplinary requirements afforded the possibility of an artificial atmospheric space in the Johns Hopkins Hospital. Through this process, air emerged as the most active agent or material of the architecture that not only defined space, but also functioned as a means of both isolating and connecting various interior environments. The result was an interior atmosphere without a physical or visible body.

### 2.3 Exposed Pipes

In 1867, when Johns Hopkins formed "The Johns Hopkins Hospital" and "The Johns Hopkins University" as two separate corporations, he divided his assets, about seven million dollars in

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[154] Reyner Banham, *The Architecture of the Well-Tempered Environment* (London: Architectural Press, 1969).

[155] David Boswell Reid, *Brief Outline Illustrations of the Alterations in the House of Commons* (1837), 70.

total, equally between the two institutions.[156] In his 1873 letter of instruction to the trustees of the Hospital, Hopkins expressed his wish that "the institution shall ultimately form a part of the Medical School of that University for which I have made ample provision by my will."[157] The statement in Hopkins' letter constituted the charter of the School of Medicine as a part of the Hospital by legitimizing the existence of such a school within the University, but also ensuring that the School would have continuous access to the Hospital facilities. Through this unprecedented institutional alliance, the Johns Hopkins Hospital became the first institution in the United States to combine higher medical education with practice.[158]

Billings had recognized the opportunities the union of the two institutions can afford and saw the Hospital as an "instrument of medical education." In the opening paragraph of his 1875 essay proposal, he emphasized that in planning the Hospital, "it is necessary first to consider the probable organization of the Johns Hopkins' University, for the reason that the plan of the Hospital must depend upon the extent to and the manner in which it is to be used as an instrument of medical education, and upon the more or less intimate connection which it is to have with the Medical School." Building on the Hopkins' original mandates for the Hospital to

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[156] A significant portion of Hopkins' wealth at the time was invested in the common stock of B&O, fifteen thousand shares in total. In his will, signed on July 9, 1870, Hopkins left all his bank stocks, real and leasehold estate to the Hospital, and his 330-acre country estate "Clifton" along with all his common stock in the B&O to the University. Hopkins also recommended to the Trustees of the University in his will that the stocks not be disposed of but held as an investment, and to vote and represent that stock with diligence and to exercise their influence in promoting the usefulness of the Company. This tied the funding for the University—and by extension, the Medical School and the Hospital—to the B&O Railroad Company. Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. 1 (Baltimore: The Johns Hopkins Press, 1943), 18.

[157] *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873).

[158] For more on the early history of the two institutions see: Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. 1 (Baltimore: The Johns Hopkins Press, 1943).

“properly care for the sick poor” and “aid in the education of Physicians and Nurses,” Billings argued that the institution should have a third objective: “to promote discoveries in the science and art of medicine, and to make these known for the general good.” To that end, Billings saw the Hospital primarily as an “experimental work”—a laboratory that would reveal new forms of knowledge, about the transmission or treatment of disease, medical practices, research and education, and function as an institutional mechanism “to increase and diffuse knowledge.”[159]

The nineteenth century saw the transformation of medicine from scholastic practice that relied classical texts, theoretical or narrative cues to a modern science that operated on the basis of clinical observation, physical examination and anatomical evidence.[160] This shift was instigated in part by the growing interest in the practice of autopsy and dissection in the late eighteenth century—through the work of John Baptist Morgagni, Leopold Auenbrugger and others—which by the turn of the nineteenth century began to interpret anatomical changes in relation to disease. Through the work of Marie-François-Xavier Bichat and others, diseases were no longer seen as a general impairment of the entire organ but rather a local injury to one of an organ’s several tissues. The growing interest in physical examination and the theory of anatomical localization of

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[159] John Shaw Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 5, 7, 18.

[160] Medical education and practice prior to the nineteenth century was largely hands-off. Physical examination of patients rarely took place and physicians often relied on the patients’ own narratives. With introduction of postal mail services in the eighteenth century, doctors began to diagnose illnesses and prescribe treatments by mail. The practice reflects the doctor’s continued confidence in the patient’s own description of the symptoms as the primary source for diagnosis, reliance on written statements, as well as the willingness to forego physical observation or examination. In 1765, for instance, John Morgan, an American physician and a chief founder of the medical school of the University of Pennsylvania, declared his willingness to render “an opinion in writing on the complaints of patients at a distance from Philadelphia, whenever the history of the case is properly drawn up and transmitted to me for advice.” John Morgan, *A Discourse Upon the Institution of Medical Schools in America* (Philadelphia: William Bradford, 1765), ii. See also Richard Harrison Shryock, *Medicine and Society in America: 1660-1860* (New York: New York University Press, 1960), 8.

pathology led to the emergence of what has been referred to as an "anatomical perspective"—an interest in anatomical changes and the impact of disease on internal organs.[161]

A visible impact of this epistemological and pedagogical shift in medicine was the emergence of anatomical and operating theaters—where bodies were laid bare, observed and examined, dissected and exposed—as the locus of medical knowledge and instruction. Operating theaters were a common component of hospitals since the early nineteenth century. The New York Hospital, for instance, added an amphitheater in 1801, the Pennsylvania Hospital in 1802, and the Massachusetts General Hospital incorporated one into its original building in 1821. To accommodate more space for spectators without obstructing the view, amphitheaters were typically double-height spaces with tiers of seating. Before gas and electric lighting, the amphitheaters also relied on large windows and skylights, domes, or cupolas to provide enough lighting.[162] And by the 1840s and the introduction of ether and anesthesia, the anatomical object on the table was no longer a lifeless cadaver but a living body whose physiological functions and

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[161] By 1821 English physician John Forbes was urging his colleagues to examine any part of the body in which diseases was suspected freed from "every species of covering that can impede the necessary examination, — always by the hand, and often by the eye; and wherever the case is at all doubtful," acknowledging "the repugnance of our patients to the measure."John Forbes, in translator's preface, R. T. H. Laennec, *A Treatise on Diseases of the Chest,* 1st ed. (London: T. And G. Underwood, 1821), xvi.

[162] Francis H. Brown, "Hospital Construction," *BMSJ* 65, no. 3 (22 Aug. 1861), 80; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 124-125.

internal organs could now be revealed and exposed, not just for the purpose of medical education but also medical treatment and cure.[163]

At the Johns Hopkins Hospital, the institution's bipolar identity made the surgical and anatomical theaters ever more charged. Surgical operations took place in the Amphitheater, a separate building designed for that purposes, while autopsy and dissections occurred in the autopsy theater inside the Pathological Building. Viewed as "the buildings having special relations to the educational features of the institution, " the Amphitheater and the Pathological Building, along with the Dispensary, were placed on the north and northeastern area of the Hospital grounds, in order to be in closer proximity to an adjacent property anticipated to house the Medical School.[164] With the exception of the Amphitheater that was connected to the Administration Building and one of the Common Wards via an enclosed corridor, these buildings remained separate from the other pavilions and had their own separate street entrances.

Intended specifically "for the use of students," the Amphitheater was a one-story building that contained a large amphitheater with a seating capacity for 280, along with a series of rooms for the reception, etherization, operation, treatment, recovery, and even photographic documentation of patients (Figure 2.33). The seats in the amphitheater, made of three laminated layers of birch

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[163] The introduction of anesthesia in the 1840s transformed both surgical operations and spaces. Surgery went from a last resort to an "elective" procedure. Meanwhile, surgical operations became increasingly longer and more complex, allowing surgeons to venture to areas of the body that had previously been hidden or sacrosanct. For more on the impact of anesthesia on surgery and operating spaces see: Martin S. Pernick, *A Calculus of Suffering: Pain, Professionalism, and Anesthesia in Nineteenth-Century America* (New York: Columbia University Press, 1985); Guenter Risse, *Mending Bodies, Saving Souls: A History of Hospitals* (New York: Oxford University Press, 1999), 339–61; Owen H. Wangensteen and Sarah D. Wangensteen, *The Rise of Surgery: From Empiric Craft to Scientific Discipline* (Minneapolis: University of Minnesota Press, 1978); Christoph Mörgeli, *The Surgeon's Stage: A History of the Operating Room* (Basel, Switzerland: Editiones Roche, 1999).

[164] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 59.

wood and were perforated with holes, rested on iron brackets and above the steam heating coils. The perforated seats allowed for better flow of warm air, to the student-spectators when occupied, and to the space when empty.[165] Attached to the Amphitheater with a covered corridor was the Dispensary, which contained a large central waiting room with seating capacity for 400 patients and rooms for physicians, surgeons and specialist on either sides of that space. The benches in the waiting room were designed with special air registers at their base through which "fresh warm air" entered the space (Figure 2.34).[166] If the perforated seats in the amphitheater reflected the integration of the heating and ventilation system with architectural design, here the waiting area benches represented an instance where the heating and ventilation devices were consolidated with architectural design. The benches functioned as architectural and mechanical elements of the building at once.

The most pronounced example in the consolidation of the two domains occurred in the autopsy theater of the Pathological Building. A two-story building on the northeast corner of the site, the Pathological Building contained a morgue or a "room for the dead," a waiting room "for friends of the dead," an autopsy theater with a 60-70 people capacity, and a number of staff rooms for the pathological and bacteriological private study and research (Figure 2.35-2.36)—and later housed the pathological laboratory of the University.[167] While a semi-circular space similar to the

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[165] With each successive row of seats slightly raised to offer a better view, and the semi-circular space underneath functioned as a circulation hall, connecting the rooms on either side of the building. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 104-105.

[166] The temperature of the air could be regulated with valves, in a similar way as in the other buildings. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 105-106.

[167] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 106-107.

amphitheater, the autopsy theater was designed to have the “observers” standing, rather than sitting, in order to allow them to be as close to the autopsy table as possible. The audience stood closely on semi-circular elevated platforms with tubular steel railing attached in front of each level. Similar to the Amphitheater and the Dispensary, the autopsy theater was heated by steam and was equipped with its own ventilation system. And in order the allow for regular cleaning of the autopsy table, the space was equipped with a movable crane, attached to wall behind the autopsy table at 9’6” above the floor, that projected out about ten feet from the wall and carried running water to the autopsy table.[168]

The key feature of theater was the autopsy table itself. Originally designed by Henry Jacob Bigelow, American surgeon and Professor of Surgery at Harvard for the Massachusetts General Hospital, and proposed by Norton Folsom in his essay proposal, the autopsy table was equipped with its own ventilation and plumbing system (Figure 2.37).[169] “The autopsy table,” in Bigelow’s own description, “is supported upon a single hollow iron leg, intended to insure ventilation and drainage.” Made of tinned copper, the table-top was a dished rectangular surface with rounded edges and grating at the center, “upon the trunk of the subject, from which alone objectional odors emanate.” The grating allowed air, water and other fluids to move downwards to the “table-leg” which functioned as a large ventilation and plumbing pipe. The table-leg consisted of

[168] The room also had its own ventilation shaft, and contained a large sink with three stop-cocks for running water and a drainage tray. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 107.

[169] The design and interior organization of the Amphitheater, Dispensary, the Pathological Building, the Isolation Ward as well as the rounded corner detail of the wards was directly taken from Norton Folsom’s essay proposal and his drawings, even though Billings never properly credited Folsom for those. See: Norton Folsom, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 49-103.

a "table leg for air & water," a hollow iron cylinder at the bottom that extended below the floor, and a "flaring legtop," a single cast lined with porcelain with a circular opening at the bottom that expanded into "an oblong square" on top to connect with the grated opening of the table-top. The upper and lower legs fitted into each other to allow for rotation. The bottom "table leg" was connected to an "air-tube" and a "water tube and trap." Water fell down directly to the trap in the cellar, while the air-tube drew the foul air laterally to a special chimney that used the drawing power of fire to accelerate air return. "With these appliances," Bigelow claimed, "an autopsy is almost, if not quite, Odorless."[170] Bigelow's autopsy table was a piece of furniture and a mechanical apparatus at once, consolidating architectural design with ventilation and plumbing.

These forms of integration or consolidation of the two domains also transformed the understanding of buildings. Robert Bruegmann has shown how the integration of building systems into architectural design relied on overcoming various problems, from doubts in the medical community about ventilation, the rivalry between architects and engineers, to the difficulties in reconciling the design of spaces with the mechanical equipment.[171] By the 1870s, much of these problems were resolved, the technology was standardized and made available to the architect, the engineer and the general public through various publications. This new building technology transformed the nature of various building types that largely depended on central heating and forced ventilation—such as prison, theatre, greenhouse, and hospital—and increased

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[170] Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 96-97.

[171] Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 143-160.

comfort and safety in others. The most profound change, Bruegmann has argued, was the reconceptualization of the building itself as "living organisms or machines," tasked with enclosing and servicing an interior atmosphere.[172]

There is a longstanding relationship between the conception, representation and education of medical bodies and architectural buildings. With the introduction of dissection and anatomical studies during the Renaissance, architecture's central reference was no longer the whole body but a fragmented, dissected and analyzed body drawn and described in detail. As Beatriz Colomina has shown, just as the medical schools during the Renaissance used casts of body parts for educational purposes, design schools—such as the very first one, the Accademia Delle Arti Disegno in Florence, founded in 1563 by Giorgio Vasari—used cast fragments of historical buildings for teaching. The design students of the academy were even required to attend the anatomical dissection at the Santa Maria Nuova hospital and draw for days even as the body putrefied and some students fell ill.[173] Doctors and architect alike began to investigate the mysterious interior of bodies and buildings through dissections and section cuts. The fragmented and sliced architectural interiors in Leonardo da Vinci's sketchbooks appear alongside anatomical sections that reveal the interior of the womb or the brain. Architecture was seen analogous to a body that could only be understood or explained through observation, dissection and analysis of its interior.

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172 Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 143, 159.

173 Karen-Edis Barzman, *The Florentine Academy and the Early Modern State: The Discipline of Disegno* (Cambridge: Cambridge University Press, 2000), 163-164. In 1563, the requirement of attending the annual dissection was added to the founding statues of the academy. See: Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019), 15.

By the mid-nineteenth century, that physical and conceptual analogy began to permeate into architectural representation and even language. Influenced by George Cuvier's *Leçons d'anatomie comparée* (1800-1805) and Jean-Marc Bourgery's *Traité complet de l'anatomie de l'homme, comprenant la médecine opératoire* (1830-1849), Viollet-le-Duc considered medieval architecture as an "animate being" that required "dissection." His perspectival section drawings in his *Dictionnaire raisonné de l'architecture française du XI au XVI siècle* (1854-1868), similar to those of Auguste Choisy, represent architecture as a body that is dissected, analyzed and annotated in order to reveal its function. His own design interventions into medieval buildings has been understood as surgical procedures that introduced iron technology as a prosthesis.[174] Meanwhile, building systems came to be seen analogous to the cardiovascular, respiratory or nervous systems within which gases, fluids, and neurons circulated. In 1858, the "large pipes" of the central heating system of the British Museum was described in the *Builder* as reminiscent of "the leading arteries which might convey blood through the body of some enormous giant."[175] French architectural critic César Daly had extended the organic analogy to the building as a whole, writing in 1844 that "architects knew how to make beautiful forms, but they had to learn how to make their buildings imitate nature and breathe."[176] In an article in 1857, describing Charles Barry's Reform Club in London, Daly called the building "modern" not because of its style but because of its heating, ventilating, water supply, and electrical bells, which transformed

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174 Martin Bressani, "Prosthetic Fantasies of the First Machine Age: Viollet-le Duc's Iron Architecture," *AA Files* 68 (2014), 43-49.

175 *Builder,* XVI (1858), 289, in Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 159.

176 César Daly, *Revue générale d'Architecture,* II (1844), 118-121, in Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 159.

the building from “a simple mass of stone” into “a living organism with a kind of circulation and nervous system.”[177]

The emergence of these metaphors in the language of architecture during this period suggests an ontological realignment of the discipline with medical and biological science. But in their attempt to draw an analogy, metaphors also rely on a conceptual distinction. Adrian Forty has therefore suggested that the absence of metaphors in the lexicon of architecture before the 1700s reflects the intertwined premodern identity of architecture and science, which made the analogic function of scientific metaphors superfluous. The very existence of bio-mechanical metaphors in the language of modern architecture, therefore, suggests architecture’s attempt to devise a sense of autonomy by drawing expression and identity, and at the same time separating itself, from sciences. This analogic relationship, Adrian Forty has argued, enabled architecture to approximate a scientific practice: to isolate and abstract specific features or properties from the complex phenomenal reality of the building, and to subject those abstractions to independent analysis.[178]

By the 1860s, biological concepts such as *organization, circulation,* or *metabolism* became key metaphors for conceptualizing and configuring the patterns of relations and flow of water, sewage, energy and air within buildings and cities. By the twentieth century, these biological metaphors and analogies would become the measure of modern architecture. Le Corbusier would

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[177] César Daly, *Revue générale d’Architecture,* II (1857), 346. In Robert Bruegmann, “Central Heating and Forced Ventilation: Origins and Effects on Architectural Design,” *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 159-160.

[178] Adrian Forty, ““Spatial Mechanics”: Scientific Metaphors in Architecture,” in *The Architecture of Science,* Peter Galison and Emily Thompson (eds.), (Cambridge, MA: MIT Press, 1999), 213-231.

make his "outrageous fundamental proposition" that "architecture is circulation."[179] And Sigfried Giedion traced the rise of modern architecture to three institutional buildings in which "the various parts are fully integrated—like the organs of a body."[180] But if their premodern identity was linked to scientific disciplines such as mechanics or biology, these metaphors acquired new meanings as they associated themselves with architectural elements (rooms, corridors, stairs, ramps, etc.) and building systems (heating, ventilation, electrical, plumbing, etc.). And while the earlier organic or mechanical metaphors in architecture were predicated on the visible formal and material quality of buildings, the adoption of biological concepts like *organization* or *circulation* referred instead to the patterns of invisible relations within building—heating, ventilation, plumbing, electrical or telecommunication systems.

For Billings, however, there was no conceptual distinction between the two domains. While he too viewed the Hospital a "living organism," it wasn't the buildings alone but the institution as a whole—the buildings and their systems, the patients, the staff, and the environment they all shared—that was akin to a living and functioning body:

> *A Hospital is a living organism, made up of many different parts, having different functions, but all these must be in due proportion and relation to each other, and to the environment, to produce the desired general results. The stream of life which runs through it is incessantly changing; patients and nurses and doctors*

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[179] Le Corbusier, Precisions on the Present State of Architecture and City Planning (1930) (Cambridge, MA: MIT Press, 1991), 47.

[180] These buildings included: Alvar and Aino Aalto's Paimio (1929-1933), Walter Gropius' Bauhaus (1926), and Le Corbusier's unrealized project for the League of Nations Palace (1927). Sigfried Giedion, *Space, Time, and Architecture: The Growth of a New Tradition* (Cambridge, MA: Harvard University Press, 1949), 643, 466.

*come and go; to-day it has to deal with the results of an epidemic, to-morrow with those of an explosion or a fire.*[181]

In dissolving the conceptual distinction between architecture and building systems into a single multi-faceted concept of "organism," Billings also equated the "stream of life" that runs through this organized body with the fluids and gases that traversed in its internal building systems. This unique conceptual approach towards architecture was embodied in the design of the Hospital. Throughout the nineteenth century, the building systems remained largely invisible. Much like the body's internal organs and physiological systems, the building's the pipes, ducts and wires were hidden and internalized within the wall cavities or tucked away in the basement or the attic. Architects went into great expense to conceal the pipes and ducts in their buildings.[182] In the Temporary House of Commons (1835-1851), for instance, Reid concealed the gas pipes and jets behind glass ceiling panels.[183] Others used the ornamental cornices, moldings or even the furniture, to conceal the pipes. In his house and museum (1812), John Soane used the newly developed Perkins high pressure hot water heating system but concealed the small bore pipes under the bases of the marble antiquities in the Belzoni Chamber, placed a coil of pipes under the table in the Monk's Room, and ran a circuit of piping around the base of his numerous skylights to counter the flow of cold air from above.[184]

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181 John S. Billings, "'The Plans and Purposes of the Johns Hopkins Hospital', Address delivered at the opening of the Hospital, May 7, 1889," *Maryland Medical Journal,* Vol XXI, No. 2 (May 11, 1889), 29.

182 An interesting example appeared in Joseph Constantine's "Ventilation devices," published in his *Practical Ventilating and Warming* in 1881, which showed an ornate cornice with ventilating tubes and registers imbedded within it. See: Joseph Constantine, *Practical Ventilating and Warming* (London, 1881).

183 A section perspective drawing of this detail is shown in David Boswell Reid's *Brief Outline Illustrations of the Alterations in the House of Commons* (1837).

184 Robert Bruegmann, "Central Heating and Forced Ventilation: Origins and Effects on Architectural Design," *Journal of the Society of Architectural Historians*, vol. 37, no. 3 (Oct., 1978), 154-155.

Well into the twentieth century, chimneys and ventilation shafts were the only mechanical elements that escaped the architectural shell and only to make their presence known in the exterior.[185] Even in discussing the *integration* of building systems with architectural design, Banham, Bruegmann and other historians have primarily focused on the expression of mechanical system on the building exterior, and have dismissed their presence in the interior. This historiographical approach towards the relationship between building technology and architecture reflects the conceptual distinction between the two domains, which inevitably leads to conclusions that suggest the subordination of one domain to the other—for instance, the formal rearrangement or even the visual ornamentation of mechanical systems in order to make them *architectural,* or the foregoing of architectural elements and principles in favor of mechanical systems. As a scientist and an amateur engineer, more than a formal integration of buildings technology with architectural design, Billings was interested in the functional consolidation of the two. From the rounded corners, ridged ceilings, and perforated floors, to the self-closing doors and ventilated seats, he saw the architecture of the Hospital as a single organized body, a pneumatic and atmospheric machine, where architectural and engineering requirements are consolidated and resolved through design. "Buildings and machinery" Billings noted in his address at the opening of the Hospital, "are only means to an end, tools which must be handled by skilled workmen to produce the desired result."[186]

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[185] Hospitals, not unlike factories, usually had numerous chimneys and ventilation towers. Jeanne Kisacky has argued that by the 1860s, many hospitals used them as design features. It is, however, not clear whether they had much choice on the matter. See: Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 110-111.

[186] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 14.

What distinguished Billings approach in the expression of building systems, however, was his commitment to the educational mandate of the institution. Beyond a functional and spatial container or even an experimental object, Billings saw the architecture of the Hospital as an "instructional" device, a "great laboratory" for both medical and architectural education:

> *Many of the arrangements of the hospital have been constructed with reference to this instruction; it is a great laboratory for teaching the practical applications of the laws of hygiene to heating, ventilation, house drainage, and other sanitary matters. All pipes and traps are either exposed to view or can be seen by merely opening a door, and in the tunnel beneath the corridor you can study at your leisure the complicated and yet simple arrangement of pipes for gas, steam, water, sewage, etc., which are usually buried and remain a profound mystery to every one except the plumber, and often puzzle even him.*[187]

Therefore, it wasn't just the numerous ventilating shafts and chimneys in the exterior, but all the pipes, ducts, traps and apparatuses in the interior that were exposed to view and accessible for observation and study (Figure 2.38). The Hospital's pamphlet guide printed for the opening of the Hospital described each building in a few sentences, often focusing exclusively on the heating and ventilation systems, even instructing the visitors to "note mixing valves in walls at head of beds for regulating temperature of fresh air supply without interfering with quantity."[188] In this way, Billings conceived the Hospital as a giant laboratory, an anatomical theater, where the internal building systems were now laid bare and exposed, not only made accessible for observation and adjustment, but also for the purpose of architectural instruction and education.

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[187] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 9-10.

[188] *The Johns Hopkins Hospital, Baltimore,* MD. John Shaw Billings Papers, the New York Public Library, Box. 48.

The Johns Hopkins Hospital was not the only hospital at the time to have exposed pipes or wiring. Hospitals during this period increasingly relied on pipes, ducts, shafts, chimneys and other mechanical equipment to convey fluids and gases within the building. In hospitals constructed with solid walls, the increasing use of building systems and technologies associated with them—from water, gas and sewage pipes to air ducts, electrical and telephone wiring, pneumatic and speaking tubes, etc.—left these elements exposed in the building interior. Aside from germ- and fire-proofing, the exposed mechanical, electrical or plumbing components allowed for the easy detection and repair of defects.[189] But while these provisions were primarily in response to necessities of construction to health and safety regulations in hospitals, the exposition of the mechanical systems at the Johns Hopkins was in response to the research and educational mandate of the institution.

Billings' approach towards architecture was largely informed by the rise of experimental medicine and the laboratory in Europe. The laboratory revolution during this period emerged in Germany—in part because it was the only country that benefited from full-time scientists—and spread to the United States through American physicians who were educated in Germany, or were subjected to German influence, leading to the rise of American medicine in the late nineteenth century. The most influential of these physicians were a group known as the "big four"—which including William Henry Welch, William Stewart Halsted, William Osler, and

[189] For instance, following a fire that started in the air space under the roof of the New York Presbyterian Hospital and destroyed much of the building in 1889, the new buildings were built with masonry and iron, with all the wiring for electrical lighting and telecommunication were neatly painted, arranged on the walls and the ceiling and exposed to view. "The wires, covered with rubber and tinted the colors of the ceilings and walls," an observer noted, "are strung in lines so narrow and regular that they look like some delicate and novel style of ornament." "Founded by James Lenox. The Chief Features of the Presbyterian Hospital," *The New York Times* (July 3, 1892), 8.

Howard Kelly—who came together at the Johns Hopkins Hospital and Medical School, and established new models of medical education and practice.[190] The introduction of residency, fellowship and internship programs, as well as the integration of "ward-work" or principles of "clinical clerkships," and "ground rounds," into the curriculum were among the new educational methods that shifted medical education away from the textbooks and lecture halls towards the hospital wards and around the patients' beds.

Meanwhile, the consolidation of medical knowledge was also instrumental in that process. Billings in particular is credited in playing a key role in "the stimulation of American medical scholarship."[191] He founded the Surgeon General's Library, that became known as "the greatest medical library in the world," developed two medical bibliographical tools—the Index Catalog of the Surgeon General's Library (now the National Library of Medicine), and the Quarterly Indexes—but also was deeply involved in the planning and organization of the Johns Hopkins University Medical School. "It is in this work of discovery," Billings noted in his address at the opening of the Hospital, "that it is hoped that this hospital will join hands with the university, and it is in this hope that some of the structures around you have been planned and provided."[192] The stricter educational standards in institutions like the Johns Hopkins along with stricter licensing

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[190] Erwin H. Acherknecht, *A short History of Medicine,* 2nd ed. (Baltimore: Johns Hopkins University Press, 2016), 203-205.

[191] Erwin H. Acherknecht, *A short History of Medicine,* 2nd ed. (Baltimore: Johns Hopkins University Press, 2016), 203-205

[192] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 11.

procedures and professional practice established by the American Medical Association, marked the beginning of what is now referred to as a revolution in American medicine.[193]

Beyond its own educational function within the buildings, the complex heating and ventilation system of the Hospital also informed the education and training of the staff. The intricate system of heating and ventilation in the Hospital, along with the various methods of environmental control, required regular manipulation and adjustment of apparatus and instruments. Within each ward, for instance, there were about forty-four valves operating the registers and vents that controlled the delicate circulation of air, its quantity, velocity, pattern of movement or temperature. To maintain both environmental and disciplinary control, Billings had charged the Hospital nursing staff with the responsibility of operating the heating and ventilation apparatus. To that end, the Hospital nurses were trained to attend both "the apparatus and the patients" as well as keeping an hourly record of temperatures, humidity, and air pressure using special forms. This required responsibility was reflected in the educational curriculum of the nurses at the Johns Hopkins Hospital. The nurses began their training with courses that equipped them with the necessary knowledge to attend the heating and ventilation apparatus rather than the patients. The first lectures, taught by Billings' assistant, Alexander Crever Abbott, were on "Physical Properties of the Atmosphere," "Diffusion of gases as seen in the so-called "natural ventilation,"" "Practical methods of studying ventilation" or "Demonstration of different plans of ventilation, shown upon a model specially constructed for the purpose." Only after six weeks of instruction,

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[193] Erwin H. Acherknecht, *A short History of Medicine,* 2nd ed. (Baltimore: Johns Hopkins University Press, 2016).

once equipped with the knowledge to attend the apparatus, they were introduced to subjects like "The digestive system," "Cell life," or "Bacteria; their relations to health and disease."[194]

The most visible sign of that educational integration was the incorporation of "Hygiene" into the curriculum of the Medical School. During the first year of the Hospital's operation, 1890-91, medical instructions in Pathology, Bacteriology, Medicine,Surgery, Gynecology, Hygiene, Psychiatry, and Diseases of the Nervous System, were given at the Johns Hopkins Hospital. These instructions consisted of "lectures, demonstrations, laboratory courses, bed-side teaching and general clinics in the laboratories, wards, dispensary, amphitheatre and private operating rooms." Billings was appointed as a Lecturer at the Medical School and put in charge of the department of Hygiene. The course of instructions he designed consisted of "didactic lectures" and "practical work in the hygienic laboratory." The lectures, given by Billings himself, were intended for "advanced students in hygiene and vital statistics" and took place within a month. The description of the three-months long "Practical Courses, following the lectures, covered topics such as "ventilation and heating," "building sites," or "habitations":

> *These will consist of familiar lectures, and demonstrations and practical work by students. They will comprise physical, chemical, and bacteriological investigations of the air; methods of ventilation and heating; physical, chemical, bacteriological, and general investigation of water; investigations as to the healthfulness of building sites, with reference to vegetation, soil, hound-air,*

[194] "Schedule of Lectures," *First Report of the Superintendent of the Johns Hopkins Hospital, from May 15, 1889 to January 31, 1890* (Baltimore: the Johns Hopkins Hospital, 1890), 11, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions. For more on education of nurses at the Johns Hopkins see: A. M. Carr, "The Early History of the Hospital and the Training School," *The Johns Hopkins Nurses Alumnae Magazine* (June 1909), 54-87. For more on the history of nursing education in the United States see: *Enduring Issues in American Nursing,* Ellen D. Baer, Patricia D'Antonio, Sylvia Rinker, Joan E. Lynaugh (eds.) (New York: Springer Publishing Company, 2002).

*ground-water, ground-temperature, and moisture and organic impurities; the study of ferments and disease-producing micro-organisms; the practical study of foods, clothing, habitations, etc.*[195]

But critical to the functioning of the Hospital as a controlled laboratory environment was the careful and regular observation and measurement of systems of heating and ventilation. This requirement was further necessitated by the experimental assumption of the heating and ventilation systems. These means of observation and study concerned both the temperature and the velocity of not just the air in the wards but also those of the hot water inside the pipes. "For purposes of experiment and observation," Billings placed thermometers in various points in the flow and return pipes of the hot water system "in order to determine the temperature of the water at various distances from the source of heat, and before and after it has passed through the heating coils and given off some of its caloric to the air passing up between the heating surfaces."[196]

While measuring the temperature of the water was easily achieved by using thermometers, the measurement of the velocity of hot water inside the closed and opaque pipes was more challenging. The solution came, not from medicine and anatomical studies but uniquely from the domain of the laboratory: the glass tube. Since the antiquity, glass had emerged as an ideal material for experimentation mainly because its transparency allowed the chemical transformation or behavior of substances to be easily observed. First century alchemist Maria Hebraica—credited with the invention of distillation apparatus—had famously hailed glassware

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[195] *The Johns Hopkins Hospital, Baltimore. Courses of Instruction for Graduates in Medicine, 1890-91,* John Shaw Billings Papers, the New York Public Library, Box. 48.

[196] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 69.

for allowing her to “see without touching.”[197] During the thirteenth century, new glassmaking processes had improved the durability of glass by increasing its the thermal and chemical resistance, turning it into a durable, inexpensive, versatile material for laboratory apparatus. In the early nineteenth century, Jons Jacob Berzelius had described the boiling tube in an 1814 article, and Michael Faraday had noted the usefulness of small glass tubes for test reactions in his 1827 book, *Chemical Manipulation.*[198] By the mid-nineteenth century, the glass tube established itself as a standard laboratory equipment for observation and experimentation.

Billings’ solution to measure the velocity of hot water inside the pipes was to substitute the building’s hot water pipe with a “glass tube.”[199] To achieve this, he devised a special by-pass mechanism that was installed in two locations within the Hospital—one at the basement of the Octagon Ward, and another in the Isolation Ward, “the most distal point from the boiler.” The apparatus consisted of a “glass tube” connected to the supply pipe, both having the same diameter. A valve allowed the hot water in the pipe to be fully diverted to the glass tube where “the velocity of the stream can be measured by injecting a small quantity of colored fluid, such as solution of carmine, and noting the time required for it to pass a measured distance in the glass

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[197] For ancient history of glassware see: Marco Beretta, *The Alchemy of Glass: Counterfeit, Imitation, and Transmutation in Ancient Glassmaking* (Sagamore Beach, MA: Science History Publications, 2009).

[198] William B. Jensen, “Michael Faraday and the Art and Science of Chemical Manipulation,” *Bulletin for the History of Chemistry*, no. 11 (1991), 65–76. The origin of the glass test tube, while debated, is estimated to date to the early nineteenth century since the form does not appear in eighteenth century chemistry sets, and earlier texts suggest carrying out test reactions in wine glasses. See: https://americanhistory.si.edu/collections/search/object/nmah_1391948

[199] In his 1877 book on hospitals, Walker Gill Wylie had also suggested that air ducts be exposed and made of transparent glass, so that it was impermeable, could allow sunlight to “purify” the air within the duct, and made any accumulating contaminating debris visible. Walker Gill Wylie, *Hospitals: Their History, Organization, and Construction* (New York: D. Appleton and Company, 1877), 119–20.

tube" (Figure 2.39).[200] The "two pieces of apparatus," Billings wrote, "have been inserted for the purpose of determining the velocity of the current of hot water in the pipes under various circumstances of external temperature, and thus obtaining data as to the amount of water producing a given heating effect in a given time." He observed, for instance, that with a temperature of 92.6° F in the flow pipe and 85.4° F in the return, the rate of flow in the glass tube was 13.5 feet per minute. But with the temperature of 134.8° F in the flow pipe and 129.7° in the return, the velocity was increased to 16 feet per minute.[201]

In the *Description of the Johns Hopkins Hospital*, published shortly after the opening of the Hospital, Billing included a series of detailed tables showing the radiating surface areas of both the steam and hot water coils in relation to the cubic volume of space heated in each system (Figure 2.40), the location, dimension and capacity of all boilers (Figure 2.41), and finally the surface area of steam pipe in each accelerating coil in relation to the area and height of the shaft in which it is placed (Figure 2.42).[202] These tables offered a glimpse of the complex and intricate heating system of the Hospital, using both hot water and steam, from the size, dimension or capacity of the boilers down to those of the heating coils in the aspirating shafts.

To test the effectiveness of the heating and ventilation system, Billings had his assistant Abbott record observations made in one of the Common Wards during December 1889, a few month after the Hospital officially opened, with an average of twenty-four patients present in that ward.

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[200] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 69.

[201] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 69.

[202] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 70-72.

During that time, Abbott observed, for instance that when the accelerating coil in the main ventilating shaft of the ward was heated, the velocity of the ascending air current was 3.8 feet per second—providing a total flow of 95 cubic feet of air per second, or about 4 cubic feet per second per person—but when the accelerating coil was not heated, the velocity was 2.8 feet per second. Abbott also discovered that the valve mechanism for controlling the temperature of the air supply did in fact affect air flow. His study revealed that the velocity of the air currents entering through the wall registers varied from 1.6 to 3.3 per second, depending on the adjustment of the valve.[203]

Abbott's observations were recorded in a memoranda, with a summary of his findings published in the *Description of the Johns Hopkins Hospital* along with a table, showing the average temperatures, the mean relative humidity, and the mean dew point of the outside air as compared with the corresponding figures for the air in the wards (Figure 2.43). These quantitative methods of description reinforced the idea of the Hospital not as a finished product, an architectural or mechanical container, but as an atmospheric laboratory—a medical and an architectural one at once. The experimental hypothesis of the project laid out during the planning of the Hospital, therefore, became the underlying premise for the buildings' design, just as the buildings ultimately became a didactic demonstration of that experiment.

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[203] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 74-76.

# 3. GERMS AND ORNAMENTS:
## Decontaminating the Architectural Interior

In his 1873 letter of instruction to his trustees, Johns Hopkins had expressed his wish that the Hospital grounds function as an "ornament" to the city: "I wish the large grounds surrounding the Hospital buildings to be properly enclosed by iron railings, and to be so laid out and planted with trees and flowers as to afford solace to the sick, and be an ornament to the section of the city in which the grounds are located."[1] While explicitly referring to the grounds surrounding the building rather than the buildings themselves, Hopkins' use of the term *ornament* instigated fervid responses from the five invited physicians. Norton Folsom argued that "ornament, and even to some extent symmetry in construction, should be subordinate, in a hospital, to usefulness and convenience."[2] Caspar Morris believed that "Proper symmetry of proportion will render ornament unnecessary," and that "No useless expenditure upon ornament or furniture should be indulged."[3] And without using the term ornament, Billings portrayed ornamental features of buildings as a harbor for germs, arguing that "Wherever there is a ledge, or projection, or crack

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[1] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 7-8.

[2] Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 49.

[3] Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 200-203.

in the ward, these invisible particles are liable to lodge, and becoming dried, to be displaced by currents of air."[4]

Among the five physicians, Stephen Smith was the most vocal opponent of ornament in the hospital. Referencing his own 1866 report, "Principles of Hospital Construction," Smith considered the "extravagance" of ornamentation in hospitals "vain" and even "criminal":

> *Hitherto we have studied too exclusively architectural effect, and in our zeal to vie with other public buildings have lost sight of the humble, but sacred purpose to which a hospital is dedicated. If richly carved work, fanciful windows, imposing towers, etc., were essential elements in the successful treatment of the sick, the former style of hospital architecture would ordinarily fulfill the purposes of life saving. But when we recall the fact that the largest success in the treatment of the most dangerous and fatal forms of disease is in the simple tent on the open field, we fully realize how vain, indeed how criminal, is the expenditure of money in efforts at mere architectural extravagance.*[5]

In order to reconcile the public or symbolic character of the institution's architecture with its medical and hygienic necessities, Smith proposed to separate the design and material specifications of the Hospital's interior from those of its exterior so that the treatment of the interior could be determined on the basis of the hygienic necessities by medical professionals, while the exterior could be "left to the good taste and judgment of the architect":

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[4] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 12-13.

[5] The report was written while Smith oversaw the design and construction of the Roosevelt Hospital in New York. Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866), 10-11; Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 297.

*Architectural Features.—As permanent pavilions are erected with a view to no other renewal than perhaps the interior wall, it is important that they should be so constructed as to allow or as little accumulation of filth as possible, and to admit of the most thorough cleansing. The architectural designs of the exterior of the pavilion must be largely left to the good taste and judgment of the architect. To what extent it is wise to lavish money in mere ornamentation of the exterior of the wards, those charged with the responsibility of the expenditure of funds must determine. We can only advise that nothing in the arrangements of the exterior should be allowed to interfere with the largest possible exposure of the wards to the sun and air. But we must assert in the strongest terms that the interior of the ward shall be finished without ornamentation. There should be no jutting cornices, no projecting casings; in a word no surface which, by its position and construction, naturally collects and retains filth.*[6]

While Billings' essay remained silent about ornament, his approach throughout the design and construction of the Hospital adopted that spatial and professional separation. In his address at the opening of the Hospital on May 7, 1889, Billings explained the weight of the founder's wish on the ornamental function of the Hospital, and how the mandate informed the design process:

*Mr. Hopkins gave no specific directions as to the buildings, but he directed that the grounds should be properly enclosed by iron railings, and so laid out and planted as to be a solace to the sick and an ornament to the city, and it was evident that the buildings should be of the same character so far as their purpose would admit. It was therefore decided that, while no utility should be sacrificed for the sake of architectural ornament, and the main purpose which I have referred to should be fully worked out in the plans before any attention was paid to external appearance, it was fit and proper that the buildings should form an ornament to the city, and a suitable monument to the memory of the donor.*[7]

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[6] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 297.

[7] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 6.

The following pages examine how the dual medical and institutional mandates of the Hospital resulted in a disjunction between the interior and the exterior of the buildings. This process occurred in a unique historical moment, marked by an epistemological shift in medicine, brought about by the introduction of germ theory of disease and the antiseptic principle, and promoted through the great public health and sanitary movements. In this new *episteme*, diseases were no longer caused by a form of bad air or poisonous gas, but microscopic organisms, with physical and material properties that could now settle on interior surfaces or grow and spread through building cavities. With the threat no longer being outside but inside, architecture turned itself inside out, internalizing the need to acknowledge the "invisible."[8] Through this process, architecture came to be seen as container much like the body that needed to be cleansed and disinfected, not only from germs and various forms of impurities, but also from its own elemental components that now harbored germ and disease.

The separation between the interior and exterior of the Hospital informed the division of professional roles and responsibilities during the design, documentation and construction, the methods of design and production, modes of documentation, types of materials and construction, and even the representation and reception of the project. The interior, the domain of medicine, was prioritized in the design process and worked out and prescribed by the physician in detailed plans and sections, while the exterior, the domain of architecture, was left out to the architect, and designed in elaborate elevations. The result was radical disjunction between the two domains: a plain and sterile interior, with no colors, cornices or curtains that could hide or harbor germs and finished with hard polished materials, and a colorful and ornate exterior, designed in

[8] Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019), 71.

“Queen Anne” style and adorned with vegetal and floral motifs of Cheat River stone and molded terra-cotta.

The evolution of *ornament* from a metaphorical term in Hopkins’ letter to the elevations of the Johns Hopkins Hospital and the vegetal and floral motifs on its facade reflect the tenuous condition of ornament at a time when its functional utility was questioned both in medicine and in architecture. In medicine, ornament was seen as an unsanitary, unnecessary, and even a “useless” element and expenditure that disrupted air flow and ventilation, harbored germs, and increased the cost of construction and cleaning at the expense of the health, or wealth, of the institution and its occupants. Smith and other physicians’ choice of the word “criminal” to describe the use of ornament was therefore not a polemic or literary analogy—as with Loos and other twentieth-century architects—but a literal equation that saw ornament in the hospital *literally* as threat to human life.

Meanwhile, the discourse of ornament in architecture during this period was predicated on an assumption that ornament as an outward expression of that architecture’s internal logic or “life”—what Sullivan called “an organic system of ornamentation.” The disparity between the interior and the exterior, and the application of the stone and terra-cotta ornaments at the Johns Hopkins turned the ornament into outward expression of something that was absent in the interior—architectural signifiers without a real signified. This disparity also reflects a fundamental shift in the design process that prioritized interior plans over exterior elevations. At a time when architects began with the design of the elevation before approaching the plans, Billings focused on the planning of the Hospital ground and working out the interior layout and the configuration of building systems in plans and sections, leaving the elevation of the buildings entirely out of the early design process. Even when Niernsée left the project and was replaced by Cabot and Chandler two years later, while the construction of the buildings were well underway, the Hospital had no elevations. The new architect's scope of work was confined almost entirely to the facades of the "principal" buildings facing Broadway, provided only through elaborate elevation drawings. This disparity in the design and documentation also resulted in radically different representations, reviews and receptions of the project in architectural and medical periodicals.

The chapter is organized around three phases where the process of internalization and decontamination took place. The first phase involved the probing of the architectural mass and the removal of building cavities, which in turn instigated new or unusual approaches towards the use of building technologies and insulation, circulation, and sanitation strategies within the Hospital. The second phase involved the interrogation of interior surfaces and the stripping of architectural ornament and woodwork from the interior, which ultimately resulted in plain and smooth surfaces with novel construction details. The third phase involved the careful examination and selection of building materials, finishes, and colors, that resulted in bright, polished and sterile environment.[9] More that a formal or aesthetic choice, these architectural strategies were predicated on new therapeutic and hygienic assumptions about architecture.

### 3.1 Ventilating Cavities

In the late eighteenth and early nineteenth century, the introduction of hollow- or "cavity-wall" construction allowed the poché space of conventional "solid walls" to be conceived and constructed as a void. Cavity wall consists of two masonry walls or "skins," separated by an internal air space. Since masonry is an absorbent material, the outer wall acts as a protective skin, absorbing the moister or rainwater to keep the inner wall dry. The cavity between the masonry skins—typically about two-inches—prevents the moisture from penetrating the interior, therefore protecting any woodwork, decorative linings or interior finish from damp and decay. This cavity also functions as a thermal insulation, preventing the transmission of heat between the interior and exterior, thereby maintaining a uniform interior atmosphere against the destabilizing variations of exterior environment.[10] By the 1860s cavity wall construction was marketed not only as an effective insulation against the infiltration of water or the escape of heat, but also as an architectural barrier against impurities that caused disease. If the system could

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[9] Other hospitals during this period also relied on various strategies such as rounded corners, no ledges or cracks, modest ornamentation, hard smooth materials, and minimal spatial divisions in order to create a hygienic environment. At the New England Hospital for Women and Children in Roxbury, Massachusetts, for instance, there were also "no cornices or ornaments to hold dust or bad air." Corners were also rounded, cracks were minimized, materials were joined as seamlessly as possible, ward finishes and furnishings were white, and there was no ornament. "Committee of the Board of Directors of the New England Hospital, *History and Description of the New England Hospital* (Boston: W. L. Deland, 1876), 14. Stephen Smith had also implemented some of these strategies in the Roosevelt Hospital in New York. See: Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866).

[10] While common in ancient Greek and Roman construction, modern cavity wall construction was introduced in England in the late eighteenth and early nineteenth century and gained widespread use in the 1920s. See: David Pickles, "Energy Efficiency and Historic Buildings: Insulating Early Cavity Walls," Historic England (April 2016).

prevent the infiltration of water or heat through the air, many architects assumed, it could do the same to the transmission of germs and other “compounds of heterogeneous impurities.”[11] Cavity wall construction therefore emerged as an architectural mechanisms that insulated the atmospheric interior against the infiltration of all the elements that threatened it: moisture, cold weather, and airborne germs.

While widely accepted as an effective moisture and thermal barrier, the hygienic advantages of cavity walls were disputed. On the contrary, most physicians and sanitarians saw building cavities as dark, stagnant, and inaccessible spaces that could hardly be cleansed and could “equalize the foulness of each room.”[12] This bipolar characteristic of the cavity wall was due to the fact that the air within the cavity of the wall acted as both an insulation material, reducing the infiltration of water or heat from exterior to the interior, but also as a conductive vessel, enabling the aerial transmission of harmful gases or particles from one interior space into another. For medical professionals, the double wall’s ability to prevent the infiltration of germs between the interior and the exterior was a marginal advantage compared to the air cavity’s function as a

[11] Henry Roberts, “The Essentials of a Healthy Dwelling and the Extension of its Benefits to the Laboring Population,” *Proceedings of the Royal Institute of British Architects* (January 20, 1862), in Dale R. Brown, “The Expanding Role of the Physician in Defining 19th Century Hospital Architecture: as Evidenced in Dr. John Shaw Billings’ designs for Johns Hopkins Hospital (1876-1889),” (Department of Architecture, University of California, Berkeley, 1990), 30-31.

[12] “The Permeability of Walls as Affecting Ventilation,” *American Architect and Building News*, vol. 13, no. 373 (February 17, 1883), 78–79.

perfect passage for the spread of germs in between the interior spaces.[13] This medical perspective resulted in a complete rejection of not just cavity wall construction but all forms of cavities in hospitals. By the late nineteenth century, architects and hospital designers began to advocate for a new "principle to be followed as carefully as possible" in hospital construction: "to leave as few cavities in the construction as consistent with the conditions of integrity and endurance."[14] Cavities in buildings, just as in bodies, came to be seen as harbors for germs and infections.

Despite this, many architects and designers still believed that the insulating benefits of cavity wall construction outweighed its hygienic risks. In his essay outlining his proposal for the Johns Hopkins Hospital, for instance, Niernsée had recommended using "double or hollow walls" in order to maintain "a more uniform temperature."[15] Even physician and hospital planner Stephen Smith hailed hollow walls for "much warmer" and "less liable to dampness, than solid walls."[16] Billings also emphasized keeping the walls "as dry as possible" an important factor in

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[13] It wasn't just "foul air" or germs that could sneak in and spread through the building but air-filled cavities also provided a perfect passage for the spread of fire. The anxiety around the spread of fire and disease—heightened by the high fatality and mortality rates in hospitals—prompted a return to "solid wall" construction and the use of noncombustible or "fireproof" materials in hospitals. In 1889, for instance, the fire that destroyed much of New York Presbyterian Hospital began in an air space under the mansard roof and spread rapidly, through the building cavities, to the rest of the building. The regular hospital fires in the United States—estimated between one to two hospitals every month—were particularly deadly because of the bedridden condition of the inhabitants. By the 1880s, fireproof construction in Hospitals—solid masonry and iron construction with impermeable finishes—was increasingly regulated by the early building codes. For more on fire in the early history of building codes see: Sara Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century City* (Baltimore: Johns Hopkins University Press, 2000).

[14] Addison Hutton, "Planning of Hospitals," *The American Architect and Building News* 65, vol. 45, no. 978 (August 18, 1894), 64.

[15] John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 339.

[16] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 298.

maintaining a hygienic environment. “New hospital wards in brick buildings are very part to be unhealthy,” he stated in one of his lectures, “and this seems to be due to excess of moisture in the walls.”[17] The debate and discussions, especially within the medical community, therefore centered instead around strategies to disinfect and decontaminate the cavity walls rather than abandoning them.

Among those disinfecting strategies was to ventilate the cavity. Early cavity walls were already built with ventilating cavities to allow the evaporation of any condensation or moister absorbed through the outer skin. To achieve this, when the cavity was closed at window or door openings and beneath the roof line, small holes or “weep vents” were placed at the bottom and the top of the outer skin to allow external air to enter and exit the cavity. This ventilating strategy provided a small degree of air circulation within the cavity that prevented the accumulation of moisture.[18] As a result, early cavity wall construction—especially those built with softer, lime-based

[17] In his lecture to the Medical Professions of Baltimore, Billings said: “This involves isolation, and the methodical use of antiseptics and disinfectants in connection with all excreta and discharges. It also involves keeping the wards, floors, and walls as dry as possible. New hospital wards in brick buildings are very part to be unhealthy, and this seems to be due to excess of moisture in the walls. When the new building for the Royal Southern Hospital at Liverpool was occupied by patients, the results for the first year or two were not as good in the fine airy pavilion wards, in which each man had 2,000 cubic feet of air space, as they had been in the old crowded building which had been previously occupied. Erysipelas and other hospital diseases appeared; and not until the thousands of gallons of water, which the new **bricks and mortar** contained, were removed by the slow process of evaporation, did the building become a healthy one.” John S. Billings, “On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877,” *The Medical Record XII* (July 1877), 132.

[18] David Pickles, “Energy Efficiency and Historic Buildings: Insulating Early Cavity Walls,” Historic England (April 2016), 5. See also Henry Adams, *Building Construction* (London: The Waverley Book Company, 1906).

mortars, renders and plasters—were considered "breathing" structures since they allowed for the exchange of air and moisture between the inside and the outside of the wall.[19]

Conceiving the cavity wall as a breathing skin allowed physicians and sanitarians to consider injecting disinfecting gases into cavity to decontaminate them. In his essay proposal for the Johns Hopkins Hospital, Stephen Smith had recommended using cavity walls and had suggested "forcing powerful gases, as chlorine and sulphurous acid, into these hollow spaces, thence through the bricks and plaster" in order to disinfect them.[20] Following Smith, Billings had also emphasized the importance of the "transpiration" that occurs within brick and plaster walls and had proposed to construct the "hollow walls" in such a way that the space in between "can be filled with disinfecting gas such as chlorine or sulphurous acid, when desirable, as suggested by Dr. Stephen Smith."[21] In the built Hospital, all perimeter walls were built as cavity walls, "with a two-inch air space nine inches from the inner surface," that extended from the horizontal layers of slate at grade all the way to two or three courses of brick at the top where it closed. With the exception of the three "main" buildings at the front, all pavilions were built with "sand brick," which also allowed for better transpiration or breathability of the walls.[22]

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[19] This "breathability" is still considered an important factor in the longevity and long-term performance of buildings. David Pickles, "Energy Efficiency and Historic Buildings: Insulating Early Cavity Walls," Historic England (April 2016), 10.

[20] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 298.

[21] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 28.

[22] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 63.

The anxiety around the accumulation or spread of germs through building cavities did not stop at the cavity walls but also extended to some of the most elemental components of hospital architecture. For instance, Billings was fond of fireplaces and saw them as "cheerful" architectural elements, as well as effective heating and ventilation devices with a unique "physiological" advantage.[23] And since fireplaces were inherently self-ventilating and self-disinfecting, they did not pose the same type of risks cavity walls did. But they also had major disadvantages. Billings acknowledged that fireplaces "waste fuel, increase labor, cause noise and dust, and are somewhat dangerous," and that "there is also always a liability that the smoke and irritating gases would circulate in the room."[24] Billings therefore abolished the fireplace from all the wards and only used them in the smaller rooms and buildings that were not meant to house any patients.[25]

More menacing for Billings were the class of building cavities that were intended to connect two or more floors within the same building, namely vertical circulation. In addition to stairways, American and European hospitals during this period increasingly relied on elevators, dumbwaiters, service lifts, trash and laundry chutes to facilitate the movement of patients, staff, food, clothes, medicine and supplies. Numerous hospitals during this period—including

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[23] Billings believed fireplaces provided a direct but "agreeable" radiant heating, and they offered useful variations of temperature within a ward. John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 20.

[24] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 20-21.

[25] Theses included the isolating rooms in the Isolation Ward, and spaces in the Administration Building or the Nurses Home. John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

Presbyterian Hospital, the Roosevelt Hospital and the German Hospital in New York, and the Hospital of the Protestant Episcopal Church in Philadelphia—made extensive use of small utility lifts, chutes and dumbwaiters.[26] Already in the 1860s, hospital design guidelines in architectural journals, such as *The Architectural Review and American Builder's Journal*, recommended that "dumbwaiters and lifts should abound and one of the latter, centrally located, be provided, for the easy conveyance of the sick."[27] By the 1870s and 1880s, elevators, dumbwaiters, as well as dust flues, laundry chutes had become standard components of hospitals.

There was little or no resistance, even among the medical community, towards elevators or lifts. In fact most physicians who were engaged in design and construction of hospitals regularly promoted them. For instance, nearly all of the five physicians who submitted submitted essay proposals for the Johns Hopkins Hospital strongly recommended using elevators, lifts, dumbwaiters and laundry chutes: Norton Folsom proposed a steam-engine operated lift in the laundry;[28] Caspar Morris included a pair of small lifts in his pavilions, one "to be used only for food" and another to convey "soiled articles" and "coal and ashes";[29] and Stephen Smith suggested using "an elevator to convey all articles to and from the ward, except dirty linen" as

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[26] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 113-118.

[27] "Hospital Construction," *The Architectural Review and American Builder's Journal* (January 1869), in Dale R. Brown, "The Expanding Role of the Physician in Defining 19th Century Hospital Architecture: as Evidenced in Dr. John Shaw Billings' designs for Johns Hopkins Hospital (1876-1889)," (Department of Architecture, University of California, Berkeley, 1990), 24.

[28] Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 66.

[29] Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 211, 219.

well as a food lift in every pavilion that connected the ward floor to the basement.[30] The most enthusiastic about these new building technologies was Joseph Jones. In his essay, Jones outlined twelve "rules" concerning the construction of hospitals through which he mandated the use of stairways, lifts, shafts, tramways, speaking tubes and other contrivances in order to better distribute "patients, medicines, food, etc." and to reduce labor and "all unnecessary noise and bustle about the wards":

> *10th. Each ward should be connected with the lower arched corridor by means of lifts and stairways, so as to permit of the ready distribution of patients, medicines, food, etc. By this means, all unnecessary noise and bustle about the wards will be avoided, and the service rendered by the nurses and attendants will be more efficient. The patients of each ward will thus also have free and ready access to the Hospital grounds. […] Every contrivance, as lifts, shafts, tramways, and speaking tubes, to save labor, should be employed, in order that the time of the attendants should be expended as far as possible in nursing, and not in other duties.*[31]

Jones further specified that "all provisions, food, poultices, dressings, medicines, clothing, bedding, utensils, fuel, etc., should be as much as possible brought into the wards or to the doorways by lift, and nothing should be fetched by the nurses." In his view, this would "enable the nurses to do their duty more effectively, and also to obviate the inconvenience and

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[30] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 300, 304.

[31] Joseph Jones, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 118.

demoralization consequent on the congregating together in numbers of the nurses, patients, and men servants."[32]

The least enthusiastic of the five was Billings. For him, these cavities posed the greatest risk by enabling the circulation of potentially contaminated air, objects or bodies, from one ward to another. More than the communication between the interior and the exterior or the contamination of the building cavities themselves, Billings was concerned with the transmission of germs within the interior, in between the rooms and wards. He therefore resisted using elevators, dumbwaiters, lifts and other similar technologies inside the building. Even for his originally proposed two-story pavilion, Billings emphasized that "an essential feature" of the pavilion is that "the two floors are entirely cut off from each other." Not only the stairway was placed outside the wards in the service area, accessible only through open air, but the dumbwaiter and lift were also placed in the farthest location from the wards and they were to "open only to the outer air" (Figure 2.4).[33] The exclusion of elevators also had an impact on the human circulation

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[32] Jones even proposed using the lifts and his central railroad system for the removal of the dead. Later in his essay he added: "When the stairway is made with a broad tread and easy rise , and the buildings of only two stories, patients of every kind , whether sick or wounded , may be carried up or down on stretchers, or in chairs suspended on a fulcrum between bearing poles so that they adjust themselves to the level, with less inconvenience and suffering than by an elevator. These stairs may be made to open on the veranda , instead of into the corridor or passage, and thus if there be no shaft for a lift , there will be no channel of direct communication between the ward below and above. When not in use the shafts are shut up and the air in them be comes stagnant, and the machinery must be kept oiled and thus promote foulness. If possible, they should be avoided. Properly constructed stairs supersede the necessity of an elevator." Joseph Jones, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 142, 150, 210-211.

[33] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 26; *"Hospital Plans," Condensed for the Use Only of the Trustees of the Johns Hopkins Hospital* (Baltimore: Steam Press of William K. Boyle & Son, 1875), 7.

within the pavilions. In the absence of elevators, in the final buildings, bedridden patients patients were placed on stretchers were carried up or down the stairs by hand.[34]

Billings intended to isolate all patient wards from each other and prevent any aerial communication between one pavilion, or ward, with another. Since any individual, object or their surrounding air could be infected, all circulation spaces were deemed a risk. He ensured all public corridors were placed in the exterior, and even when one interior floor had to be connected to another, the connection took place out in the open. And in instances were an interior circulation space was necessary, he conceived them to be open to exterior air and naturally ventilated. He took a similar approach towards those cavities that could not be removed from the interior. For instance, Billings did propose using a dumbwaiters and multiple lifts for “coal,” “foul linen,” and “clean linen” in the Kitchen and the Laundry buildings: “One lift for the kitchen is for coal, ashes, and slops, the other is for food; one lift for the laundry is for soiled and the other for clean articles.” But he emphasized “all these lifts should be ventilated at the top into the main chimney.”[35]

In that way, all these circulation spaces—from corridors and stairways to lifts and dumbwaiters shafts—were either pushed out of the interior into the exterior, or were externalized through ventilation to an extent that they no longer functioned as cavities within the building. This

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[34] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 63.

[35] Billings also used a lift in the “third building” that housed the amphitheater, outdoor dispensing-rooms, dead-house, and pathological laboratory. See: John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 34-37

*externalization,* intended to provide physical connection without aerial transmission, was then achieved by two different means: the first was to ensure all forms of vertical circulation, including those confined within shafts, were placed against the building envelope and only opened to exterior (such as the stairways, lifts or dumbwaiters in patient pavilions) so that the circulating users or articles were forced to go through "outer air" before re-entering the building; and the second was to place circulation spaces either entirely in the exterior (like the "open terraces") or naturally ventilated (as with the ventilating shafts or the corridor of the Isolation Ward) in such as way to create an *external* environment, even if in the interior.

The absence of elevators or chutes in the wards created new challenges for the circulation and removal of materials that were inherently deemed contaminated. Billings provided "no dust flues or clothes shoots in the pavilion," and instead, waste and soiled linen was loaded onto "galvanized iron boxes with tight-fitting covers to be moved about the ward on cars with large, rubber-tired wheels":

> *There are no dust flues or clothes shoots in the pavilion. I would have galvanized iron boxes with tight-fitting covers to be moved about the ward on cars with large, rubber-tired wheels. When bedding is to be removed, one of these boxes should be taken to the bed, the clothing placed in it, the cover fastened, and the box wheeled off to be sent down the lift to the basement, and thence on another car to the centre building, where its contents can be treated as may be desirable.*[36]

Billings' decision to rely on stretchers carried by hand or carts with large rubber wheels—in lieu of available building technologies like elevators, dust flues or clothes chutes—predicated on the

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[36] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 26.

introduction of new antiseptic practices during that time. The growing acceptance of germ theory and the antiseptic principle made bodily discharge more infectious and dangerous than foul air. Even those who challenged Pasteur and Lister theories, such as English physician John Hughes Bennett, still considered germs as the primary source of diseases.[37] For that reason, many hospital, especially those built before the availability of these technologies, continued to rely on boxes or baskets on wheels as a more sanitary alternative for transportation of trash or clothes—it allowed the hospital staff to pack and seal the contents at the bedside, move them about the ward with ease, and remove without risking contamination.

This provision to rely on a manual and mobile method was not an oversight but a conscious decision. During that trip, as the newly-appointed Medical Advisor to the Board of Trustees of the Johns Hopkins Hospital, Billings had prepared a multi-page "Memorandum" form to record his "examination" of various European hospitals. The forms included twenty-four line items relating to particular hospitals, from the size and conditions of the site, and "character" of the soil or the buildings, to information on the heating and ventilation systems, beds, windows, doors or material finishes (Figure 3.1). On October 19th, 1876, while visiting the Sir Patrick Dun's Hospital (built in 1808) in Dublin, Billings recorded his observations in a memorandum. One item stood out to him during that visit, which did not fit into any of his prescribed categories: a "Basket Covered Wheel Carriage." Billings drew a sketch of the cart in the back of the the last

[37] In 1868, a year after Lister published his essay, John Hughes Bennett, a professor of medicine at Edinburgh who had discovered leukemia, published an article arguing that Pasteur and Lister's approach was entirely misconceived. Bennett reported the results of his own experiments that proved germs are in in fact spontaneously generated, and that one could never create a germ free environment. John Hughes Bennett, "The atmospheric germ theory," *Edinburgh medical journal* 8 (1968), 810–34. While Bennett believed he had disproved germ theory, it was the fact that he had not sterilized his instrument that led to those results. See also: David Wootton, "Understanding the history of medicine," *British Medical Association,* vol. 334, no. 7597 (2007), 762.

page of his memorandum and noted: “Lister’s antiseptic Principle; no difference between Bennet[t] & Butchinks.” (Figure 3.2). Upon his return from Europe, Billings looked for similar carts in manufacturers catalogues and finally selected the “Platform Truck,” manufactured by George P. Clark, that was typically used for “general Mill, Store and Warehouse use.” The truck was mounted on “12 inch diameter Rubber Wheels in the rear, with 6 inch diameter Swivel Rubber Wheel Casters in front” to allow easy maneuvering especially in a limited floor space (Figure 3.3). He also ordered “Socket Rubber Wheel Casters” that could fit regular furniture legs (Figure 3.4).

Through this elimination or decontamination process, circulation lost its designated space within the architecture of the Hospital. The mobile carts or containers, powered by the human motor and moved by hand or rubber wheels, afforded a degree of control and containment that their new architectural or technological surrogates did not. In this new aseptic environment, the physical and material friction between mobile surfaces and skins, between floors and rubber wheels, offered a more hygienic solution than the static and fixed spatial voids of building cavities. The hygienic architecture of the Hospital favored the *literal* motion of carts, trucks and stretchers over the *phenomenal* motion of elevator shafts, stairways, and corridors.[38]

But none of these building cavities were as “dangerous” as those which contained or conveyed sewage, the ultimate source of diseases. Sewage was not only considered a source of “emanations” or foul gases such as methane, ammonia and carbon monoxide, but also a source

[38] For more on literal and phenomenal motion in architecture see: Greg Lynn, *Animate FORM* (New York: Princeton Architectural Press, 1999).

of “microbian organisms of disease” that infected the soil and created “death-germs.”[39] The supply of water and management of sewage had been a crucial aspect in the design of hospitals in the nineteenth century. Early American hospitals were typically situated near a river, steam, pan or a lake, and in the absence of central plumbing or sewage systems, many architects had to rely on manual techniques for the supply of water or removal of sewage. In his Marine hospital design, for instance, Latrobe had recommended a small “tub room” with a large vessel that collected the wastes from ambulant and bedridden patients. The vessel lowered, once or twice a day, to the ground and then carted to a distant corner of the site where it was emptied.[40] As hospitals grew in size and complexity, they required even larger supply of water not just for bathing patients, cleaning rooms, bedding, instrument, or for removing waste, but also for mechanical heating systems that relied on water and steam.[41] The amount of waste water and sewage produced therefore increased in proportion, necessitating the use of plumbing not just for water supply but also for waste water and sewage.

When the construction of the Johns Hopkins Hospital commenced in April of 1877, the drainage of the site and its buildings also posed a complex engineering and plumbing problem. Baltimore

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[39] “A discussion,” *American Architect and Building News*, vol. 14, no. 405 (September 29, 1883), 145.

[40] Benjamin Henry Latrobe, “Report of B. Henry Latrobe, on His Design for a Marine Hospital,” in William P. C. Barton, *A Treatise Containing a Plan for the Internal Organization and Government of Marine Hospitals in the United States: Together with A Scheme for Amending and Systematizing the Medical Department of the United States Navy* (1814), 114.

[41] Billings for instance estimated in his essay that the Hospital would need a supply of 22,500 gallons of water per day, and storage for at least 50,000 gallons in underground cisterns: “Tanks or cisterns will be desirable to serve as reservoirs in case of any accident to the water supply from the city pipes. I do not recommend that the water from rain-fall should be collected and preserved. The amount of water which will be required by this institution will be about 22,500 gallons per day, and storage for at least 50,000 gallons in underground cisterns would be desirable.” John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 39.

did not have a central sewage system at the time, leaving every property to rely on its own arrangements. This was further complicated due to the presence of two springs and "several marshy places" on the site. Hospital trustees were aware of the inadequate and dangerous condition of the sewage system. In their report in 1879, the Building Committee stated that while it was "exceedingly unwilling to have recourse to this expedient to dispose of the Hospital sewage," it would be obliged to do so unless the city would provide an efficient sewage system which the Hospital could connect to. The Committee went on to recommend:

> *Every effort should be made on the part of the Trustees to have a proper system of sewerage provided for the city, not only for the immediate convenience of the Hospital buildings, but because the business interests of the community which are those of the Hospital, demand such a system to avoid great pecuniary loss from some form of epidemic disease either generated or promoted by the present mode of disposing of the excreta of the city.*[42]

In the absence of any municipal support—it took twenty-five years for the city of Baltimore to authorize and fund the construction of a modern city-wide sewage system—the Johns Hopkins Hospital relied on the construction of its own sewage system.[43] Billings hired Ernest W. Bowditch, a Bostonian engineer, surveyor and "landscape gardener," who designed an underground drainage and sewage system for the Hospital. The surface water was drained with a system of underground plumbing that discharged into a slit trap at the southwest corner of the site, and then via a 16-inch tile pipe to an open stream several blocks away. Sewage from the

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[42] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 7 (Johns Hopkins Hospital, 1879), in Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 66-67.

[43] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 68.

interior of the buildings was removed through an intricate plumbing system to several wells on the site that were buried 75 feet below ground (Figure 1.12). The bottom of the wells were covered with a stratum of coarse gravel and pebbles that moved the water "slowly but constantly" to the southwest corner.[44]

Plumbing, however, was still generally perceived as dangerous building technology, especially in hospital. Not only pipes often leaked, but what they leaked—whether it was water or waste—could damage and harm both the building and its occupants. Physicians regularly blamed hospital outbreaks on plumbing and even considered it a "biohazard."[45] In response, hospital designers often isolated toilets, baths, sinks, and plumbing associated with them in separate spaces or sanitary "towers." Nightingale's ideal ward, for instance, placed the sanitary towers at the far end of the ward, which created long travel routes from nurses and ambulatory patients. Other hospitals included two sanitary towers, one at either side of the ward, but with the risk of multiplying the risk of contamination.[46] The anxiety around sewage also resulted in the development of special "hospital" fixtures and the emergence of what Nancy Tomes has called

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[44] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 66-67.

[45] For instance in the 1880s, various outbreaks of hospital disease were traced to plumbing related problems: an obstructed drain in Saint Luke's Hospital in New York, sewer pipes damaged by rats in the City Hospital in Boston, and a number of rooms with no plumbing at all in Bellevue Hospital. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 261-262.

[46] Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 113-118.

“entrepreneurs of the germ”—numerous manufacturers and services that used germ theory of disease to develop and market new products like white porcelain toilets or the sanitary trap.[47]

These concerns also led architects, engineers and hospital designers to experiment with different strategies to decontaminate pipes and the cavity spaces they occupied. Some allowed the cavity spaces for pipes as long as they could be disinfected or purified with an antiseptic or a fumigant, others accepted fresh air as a decontaminant and proposed ventilating the cavities in a similar manner to the wards.[48] In “The Planning of Hospitals,” for instance, architect Addison Hutton argued that in an ideal hospital “All the water fixtures are arranged for special artificial ventilation separate from the Ward ventilation.”[49] In a number of hospitals during this period, including the Presbyterian Hospital, pipes were housed in separate rooms that were independently “ventilated by the suction-ducts.”[50]

In his essay proposal for the Johns Hopkins Hospital, Billings had recommended an independent ventilation system for the water-closets and bathrooms through a central flue. The “motive-power” in the flue was supplied by “a stove in the basement, which is to furnish the hot water supply by means of a circulating boiler.”  The water-closets and slop sinks were then arranged

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[47] Nancy Tomes, *The Gospel of Germs: Men, Women and the Microbe in American Life* (Cambridge: Harvard University Press, 1998), 68–88.

[48] Hospital Construction and Organization, II,” *Medical Record,* vol. 11, no. 5 (29 Jan. 1876), 73, in Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 263-264.

[49] Addison Hutton, “Planning of Hospitals,” *The American Architect and Building News* 65, vol. 45, no. 978 (August 18, 1894), 64-67.

[50] “Report of the Building Committee,” Presbyterian Hospital, New York City, *AR* 23 (1891), 18, in Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 263.

around the central flue and ventilated downwards.[51] In the built Hospital, he took a similar approach, but rather than using a boiler to facilitate air flow, the ventilating shafts were heated by high pressure steam coils. “By this arrangement,” Billings wrote in his report to the Trustees, “by taking care that no pan or hopper closets, and no bell or D traps are employed in the buildings, and by securing thorough ventilation for all sewers, soil pipes and traps, I think there need be little fear of any nuisance or danger from this part of the service.”[52]

These hygienic and engineering requirements also resulted in the separation of the sanitary spaces from the main building structure and envelope. Throughout the Hospital, the water closets, bath tubs and sinks, were placed in the head houses or separate structures, away from the main buildings or pavilion wards. In each building, there were designated spaces for flush toilets, sinks and baths with their own separate ventilation. In the Common Wards and the Octagon Ward, the water-closets, the lavatory and bathrooms were placed in the service area, away from the main ward and opened to the central hall. In the Pay Wards and the Administration Building, a grouping of a stairway, lavatory, water closet, bath rooms and a janitor room formed a projection in plan that connected the building to the corridor system. These conglomerated service areas functioned as intermediary thresholds, occupying a space between the building envelope and the open grounds, between the interior and the exterior.

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[51] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 32.

[52] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 16.

Similar to other physicians and hospital designers during this period, Billings believed that the risk of contamination is not limited to the sanitary spaces but extends beyond that through plumbing. For that reason, he did not provide any "unnecessary" plumbing inside the main wards. "So far as it is possible to foresee," he wrote, "ventilation should have only necessary contaminations to deal with. The unnecessary ones should be prevented, and it is surprising how many will be found unnecessary when carefully examined."[53] The absence of fixed plumbing meant that there were no running water and sinks inside the wards—no accommodation for patients to be bathed in the wards, or even for doctors to wash their hands or instruments—resulting in aberrant sanitary solutions. For instance, the bath tubs were designed to be movable so that they could be raised on a cart and carried to any bed in the ward.[54] There were also special wooden movable washstands, with pitchers for hot and cold water, for doctors to wash their hands in the wards (Figure 3.5). But the slop jars—where the waste water from the bowls were discharged into—had to be regularly taken away and emptied by the orderlies who, not always aware if the jars were empty or full, often failed to remove them in time. The doctors also had trouble using the washstands, especially in removing the properly pulling out the stopper. As a result, slop jars frequently spilled, covering the ward floor with a "rich soapy flood." The portable sinks and bath tubs, and the regular flooding of the floors, continued for years at the Johns Hopkins Hospital until fixed wash basins with running water were installed in the wards.[55]

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[53] John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 16.

[54] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 91.

[55] Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 64.

The unique requirements for the Isolation Wards created an even more complicated arrangement. While the limited plumbing in most of the pavilion wards allowed patients and staff to have a single designated areas for sanitary facilities, the Isolation Ward, by definition, could not offer a shared sanitary facility. The Isolation pavilion was designed to establish a complete isolation of "contagious or offensive" cases where patients were placed in separate rooms, equipped with an elaborate heating and ventilation system.[56] "The object of this arrangement," Billings wrote in his *Description of the Johns Hopkins Hospital,* "is that each patient taken to this ward shall not only be isolated from the rest of the Hospital, but also, as far as possible, from all other patients in the ward." And for that reason, there were "no common water-closet or bath-room, and no risk that the air from one room may pass into another by means of the common corridor, since this last is practically an open air passage."[57] The absence of shared facilities meant that each individual room had to be provided with its own separate water closet and bath tub—a luxury at the time, only used in George Vanderbilt's 1885 bathroom in New York.[58]

To resolve this without having to provide separate plumbing in each room, the "bath-room" in the Isolation Ward was "mounted on a truck, and could be wheeled into any room when needed."

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[56] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8.

[57] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 95.

[58] In 1885, George Vanderbilt's bathroom in New York incorporated the water closet, wash stand, and bathtub all adjacent to each other in one space within the bedroom. And unlike the English principles of the "ruling taste," Vanderbilt's bathroom exposed the nickel-plated pipes and the lead plumbing. Taking advantage of the innovations in plumbing and flushing technology, the placing of the water closet, the shower, and basin in a counterintuitive proximity was unlike anything anyone had seen before. The compression of all these elements in one private room occurred at a time where the room itself could not even be precisely or universally named. This new arrangement set the new standard for the American bathroom. By the turn of the century, bathroom and bedroom eventually formed a unit. See: Sigfried Giedion, *Mechanization Takes Command,* 1948. p 682-687,

Although similar to the portable bath tubs in the other patient pavilions, the bath tub in the Isolation Ward was mounted and fixed on a cart, and rested permanently on wheels. Each isolation room was also equipped with its own fireplace and chimney, with vestibule doors on one side, and a "small closet" on the other—the trio occupied the cavity of the double-thick wall between the rooms and the corridor. Inside the closet there was a traditional "commode containing a chamber utensil." The closet was lined with galvanized iron, so that the entire closet could be disinfected and "cleansed with flame." Each closet had an exit flue, with an accelerating steam coil inside, that connected the the chimney (shown in "Fig. 1" and "Fig. 6" of Figure 2.32). "Foul air" from the closet exited through the iron flue into the chimney, accelerated by steam coil placed above the closet, and then extended to the top of the chimney and above the roof (shown in "Fig. 9" of Figure 2.32). While the foul air and smoke flues occupied the same cavity within the chimney, the two remained separate inside.[59]

Despite what Billings himself considered "the peculiar arrangement of these ventilating closets, with their flues and accelerating steam coils," none of the isolating rooms were provided with plumbing for water and sewage. Instead, there was an opening in the outer wall of the closet, facing the corridor, so that the camber utensils in the closet could be removed "without the necessity of entering the patient's room." When removed from the commode, the chamber utensils were taken to a "special sink" enclosed by "glass doors" and equipped with its own

[59] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 95-96. Originally conceived as a bowl kept in a bedroom, chamber pots emerged in a range of faux furniture and push boxes. The same practice was particularly used in France during this period. From Chaise bath *(Bain de Salon)* to nightstands, cabinet makers went to great lengths to camouflage chamber pots within fine furniture. Even by 1857, the implementation of the *Cabinet d'aisances* (*a water closet*) with the flushing devices, installed by Viollet-de-Duc for Napoléon in the Chateau de Pierrefonds, hid the toilet inside a cupboard. For a historical overview of the toilet see: Rem Koolhaas, *Elements: Toilet*, la Biennale di Venezia 2014 (Marsilio, 2014).

ventilation and air supply so that "the excreta can be thoroughly disinfected before being through into the sink."[60] (Marked K on the plan, Fig. 1, in Figure 2.31)

The hygienic approach to the design and placement of the building cavities—whether dealing with insulation, circulation, or sanitation—illustrates the first step in decontaminating the architecture of the Hospital. Seen as dark, dangerous and germ-laden orifices, the building cavities were filled with fresh air, injected with disinfecting gases, sterilized with flames and antiseptic solutions, even entirely externalized or exterminated. Through the cleansing and the clearing of the internal components, the architectural interior turned into a voided atmospheric space, a debrided hollow chamber defined and protected by a porous breathing skin.

### 3.2 Septic Ornaments

When Johns Hopkins used the term *ornament* to refer to the "trees and flowers" planted in the Hospital grounds, he assumed an aesthetic and therapeutic function associated with them: "to afford solace to the sick, and be an ornament to the section of the city in which the grounds are located."[61] Landscape during this period had emerged as a natural element that softened the forbidding appearance of large medical institutions, but also as one that participated in their therapeutic function. Kirkbride hospitals—designed by the likes of Samuel Sloan, Eldridge Boyden, and Frederick Law Olmsted—had been devised as architectural viewing machines,

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[60] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 95-96

[61] Johns Hopkins, *Letter of Johns Hopkins to the Trustees of "The Johns Hopkins Hospital,"* (Baltimore: WM. K. Boyle & Son, 1873), 7-8.

especially planned and planted to present the picturesque landscape as a remedy for psychiatric disorders.[62]

For many scientists and physicians during this period, plants not only offered “solace,” order or sanity, to hospitals, but they were also sanitary instruments. The functional benefits of plants in taking carbon dioxide from the air and producing oxygen through photosynthesis, known since the late eighteenth century, had prompted a sanitary movement in cities through major investments in the creation of urban parks, as well as the conception of various urban typologies and garden cities.[63] More than a picturesque elements of hospital grounds, scientists and physicians saw plants, sunlight, and fresh air as integral elements of its architecture. In pavilion plan hospitals in particular, the open grounds offered a reservoir of fresh air, acted as buffer zones between the pavilions, and allowed sunlight to enter the wards’ interior. Hospitals conceived their ground as a “garden,” and an element of pride and even competition.[64] By the 1870s, when the concept of *ecology* was just beginning to take shape, the natural functioning of plants began to be seen in direct relations to that of humans and animals with whom they shared

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[62] Thomas Kirkbride, *On the Construction, Organization, and General Arrangement of Hospitals for the Insane* (Philadelphia: Lindsay & Blakiston, 1854).

[63] The various projects for the modern city during this period were conceived in relation to health and well-being. Some of those include: Ebenezer Howard’s *Garden City* (1897), Arturo Soria y Mata’s *Ciudad Lineal* (1897), Otto Wagner’s *Die Groszstadt* (1911), Le Corbusier’s *Radiant City* (1935), and Tony Gardier’s *Industrial City* (1904), in which the heliotherapy hospital building occupied the highest point of the plan and the sports center at the middle of town replacing the cathedral.

[64] In cities like New York, hospitals were designed as oases. Sant Luke’s Hospital was surrounded by trees and lawn interspersed with flowers, and the original Jews’ Hospital had its open grounds “laid out in beautiful style, as a garden for the invalids.” “New Buildings,” *The New York Times* (May 15, 1870); “The Hebrews. Laying the Corner-Stone of a New Jewish Hospital,” *The New York Times* (November 25, 1853).

an environment. In this new ecology, the hospital patients and plants were complementary components of the same milieu.

These ideas had surfaced in the early planning of the Johns Hopkins Hospital. In his essay proposal, for instance, Stephen Smith had argued that "trees, judiciously selected and arranged, are not more essential to the beauty of the landscape than to the purity of the air." "Man and vegetation," he wrote, "are the complements of each other in their effects upon the surrounding atmosphere."[65] Quoting German pharmacist and botanist Hermann Schacht, Smith presented trees as air-purifying and oxygen-producing machines.[66] The foliage of trees, he posited, not only absorb "poisonous emanations from the earth," rendering innocuous "the most dangerous marsh miasms," but they also "greatly modify the temperature and humidity of the surrounding air" and, in effect, "equalize the temperature." To that end, he argued to "secure a large supply of vegetation, and especially of trees," and proposed to plant "the entire margin of the grounds"

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[65] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 279-280.

[66] Quoting Schacht, Smith wrote: "[Plants] imbibe from the air carbonic acid and other gaseous or volatile products exhaled by animals, developed by the natural phenomena of decomposition. On the other hand, the vegetable pours into the atmosphere oxygen, which is taken up by animals and appropriated by them. The tree, by means of its leaves and its young herbaceous twigs, presents a considerable surface for absorption and evaporation; it abstracts the carbon of carbonic acid, and solidifies it in wood fecula, and a multitude of other compounds. The result is that a forest withdraws from the air, by its great absorbent surface, much more gas than meadows or cultivated fields, and exhales proportionally a considerably greater quantity of oxygen."" Edouard Morren, Hermann Schacht, *Les Arbres: Études Sur Leur Structure Et Leur Végétation* (Bruxelles, Leipzing, Gand: Charles Muquardt, 1862), in Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 279.

with trees to "serve the purpose of intercepting foul air, of supplying needed shade, and of modifying temperature."[67]

The aesthetic function of plants was not lost to Smith and other physicians either. For his part, Smith saw "the cultivation of flowers" as "an important feature in the management of the grounds" because "they add greatly to the beauty of the scenery, and afford great pleasure to the sick." He advocated for using "Fountains, with one or many jets" since they "add much to the scenery, and, if numerous enough, tend also to purify the air by washing out the floating impurities."[68] In this way, the trio elements of the hospital garden—trees, flowers, and fountains—emerged as essential therapeutic instruments, with both physiological and psychological functions. Foliage and flowers, the original ornaments of architecture, acquired a medical function in the hospital.

Smith's insistence on the utility of plants informed the early plans of the Hospital. Billings and Niernsée's first Block Plan of the Hospital in 1876 (Figure 1.9) included an elaborate landscape: a monumental "Central Garden," 170 by 500 feet, that occupied the large space between the two

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[67] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 279-280.

[68] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 280-281. In the "Drainage and Sewage" section of his essay, Joseph Jones also considered water "the best disinfectant, and the best means of removing filth, and noxious gases from the sewers." He argued that a system of fountains can prevent flow of the "fecal matters" in the sewers. "The fountains," he wrote, "whilst thus adding to the beauty and attractions of the grounds, and to the comfort of the patients, may be made of the greatest practical benefit in flushing out and cleansing the sewers." Joseph Jones, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 111.

rows of pavilions. At the dominant center—the sacred space traditionally reserved for a chapel in Renaissance hospitals—there was a large circular fountain. The gardens covered with grass, trees and plants of difference shapes and sizes were carefully arranged in lines around the peripheries or in circular and oval patterns. The gardens and the plants, painted green in the lithographic plans, stood out in contrast to the pale pink colored buildings, and the colorless grounds that nearly vanished into the background. Facing the Central Garden at the east, there was even a building devoted for "Gardener" and "Plants." Plants dominated the Hospital plan.

In the revised Block Plan issued just a few months later (Figure 1.10), however, nearly all the trees that covered the site disappeared, leaving only a few to mark the cross-shaped paths of the Central Garden. Even the "Plants" pavilion was replaced by a chapel. Instead, and in an apparent attempt to create a more "ornamental" front, the Administration Building and the two Pay Wards were pulled away from the street in order to make room for a new garden with three fountains, radial pathways, and a densely planted areas marking the entrance and the carriage road. By the time Billings and Niernsée issued the final Block Plan of the Hospital, just about a year after the first, the gardens were indistinguishable from the grounds—there were no material or physical differentiation between the two, no color or lines in plans (Figure 1.11). While the buildings were now cut in plan, revealing their intricate interior, the Central Garden was represented as a desolate ground, with no trees, plants or even a fountain. Plants only conglomerated the Western edge of the site, framing the three frontal buildings. In their evolution—or near extinction—in the plans of the Johns Hopkins Hospital, the plants lost their medical and therapeutic functions.

If Hopkins' use of the term *ornament* did not instigate enough incentive towards the design of the gardens, as he had in fact intended, it did prompt strong responses towards architectural design and ornamentation. Norton Folsom, for instance, responded that ornament "should be subordinate, in a hospital, to usefulness and convenience" and advocated for a focus on the "finishing" and "slight elaboration of the necessary parts" rather than "extrinsic or superadded ornamentation."[69] Caspar Morris went a step further by positioning architectural ornament in a direct conflict with the visual, fiscal and hygienic mandates of a hospital.[70] While considering architectural "style" as "a matter of taste," Morris argued that "some regard to appearance and effect" is warranted "due to the community." If prisons and police stations were to be made "forbidding and repulsive in appearance," and schools and universities "spacious and cheerful-looking," Morris posited, "a hospital should have an expression of comfort inspiring a sense of repose, and tranquillity, and hope of restoration of health." For him, this architectural *expression* was an outward one: "The very exterior should be attractive to the approaching sufferer," just as he recalled the wounded soldiers describing their arrival at the hospital "like the approach to paradise." But he warned, "Too great display of ornament is out of place, not only as involving a

[69] Folsom's full passage read: "I do not intend to discuss purely architectural matters, except so far as is necessary to give practical shape to my ideas. I believe, however, that ornament, and even to some extent symmetry in construction, should be subordinate, in a hospital, to usefulness and convenience; and that that building or part of a building which best serves the purpose it is designed for will look the best in the end; and that, indeed, the "finishing" or slight elaboration of the necessary parts of a building will usually prove more satisfactory than any amount of extrinsic or superadded ornamentation." Norton Folsom, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 49.

[70] Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 200.

needless expenditure of money better appropriated to provisions for the comfort of the patients, but as repugnant to the inherent sense of propriety."[71]

Morris' most pointed criticism of ornament, however, was that it threatened the sanitary condition of the hospital. Just as he saw "cracks and fissures" as "harbors for vermin and pockets for the retention of the morbid emanations and exhalations from the sick," he objected to the use of all cornices and ornament: "No projecting points or ledges, or mouldings, whether for ornament or use, can be allowed in any part of the buildings." For Morris, as for many physicians at the time, in their outward projections from the interior wall or ceiling surfaces, ornaments disrupted air flow, captured the floating dust, concealed dirt, and provided a haven for germs:

> *Proper symmetry of proportion will render ornament unnecessary. It is impossible to lay too much stress on the necessity of avoiding, in every part of the building, everything which shall have a tendency to catch dust, conceal dirt, or afford a harbor for vermin of any kind. The disgusting results of want of precaution in this respect are indescribable; to say nothing of the injurious influence on the sanitary state of the hospital.*[72]

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[71] Morris' full paragraph in his essay read: "The style of architecture is a matter of taste; the interior arrangements and adaptation of the several parts to the purpose designed, and to each other, is the point of essential importance. Still some regard to appearance and effect is due to the community; and any violation of the rules of proportion of the parts, or of the canons of taste in ornament, should be avoided. Prisons and police-stations should be made forbidding and repulsive in appearance, even though regard for the sanctity of life demands that there should be nothing detrimental to health in the interior arrangements. School-houses and college-buildings should be spacious and cheerful-looking; and so, preeminently, should be the structures designed for the reception of the sick. A hospital should have an expression of comfort inspiring a sense of repose, and tranquillity, and hope of restoration of health. The very exterior should be attractive to the approaching sufferer. Wounded men, brought to the hospital of the Protestant Episcopal Church in Philadelphia, from the terrible discomforts of field exposure, declared it was "like the approach to paradise." Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 198.

[72] Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 200.

It wasn't just that ornament was "unnecessary" or that its construction was a "useless expenditure," but that by its existence, ornament also endangered the healthfulness of the hospital and imposed additional cost for cleaning it: "No useless expenditure upon ornament or furniture should be indulged," Morris emphasized, "there should be nothing requiring extra service to preserve cleanliness; nothing to occasion needless expenditure."[73]

In that way, the public or symbolic function of ornament in the hospital came to contradict the medical and hygienic mandate of the institution.[74] One the one hand, ornament functioned as a visual and symbolic expression of the hospital (as a public institution) by invoking a sense of "paradise." On the other hand, it impeded the sanitary order of the hospital (as a medical institution) by harboring germs and "vermin of any kind." This conflicting identity of ornament

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[73] In discussing the main central building of his proposed hospital, Morris wrote: "The main central building should contain all the apartments necessary for the comfortable accommodation of the various resident officers , professional and executive , and these should be provided with such liberality as shall promote the cheerfulness and health of those who, in the discharge of their arduous duties, are subject to influences depressing to the feelings, and injurious to the health. No useless expenditure upon ornament or furniture should be indulged. Here, as in the other departments of the hospital , there should be nothing requiring extra service to preserve cleanliness; nothing to occasion needless expenditure, or the employment of more servants than are absolutely necessary. The greater the number of these, the more to be fed and lodged, the greater the difficulty of preserving order and discipline and cleanliness." Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 203.

[74] As a symbol of philanthropy, hospitals during this period strived for a visible civic and institutional presence. Hospitals, according to David Rosner, "resembled a home, a church, or a prison, depending upon the underlying purposes of those organizing the facility." As a result, hospitals were more aesthetically restrained than other public buildings, and even architects who regularly relied on ornamentation approached the hospital in a different way. Richard Morris Hunt, for instance, a Beaux-Arts trained architect, argued that the best approach towards the design of a hospital was "by accentuating certain prominent features existing in the plan, in a quiet, unpretending manner." Hunt's design for the Presbyterian Hospital in New York was more somber and less ornate than his other buildings. Similarly, and unlike their other projects, Frank Furness and George E. Hewitt's design for the Jewish Hospital in Philadelphia had barely any ornamentation. David Rosner, "Social Control and Social Service: the Changing Use of Space in Charity Hospitals," *Radical history review* vol. 21 (1979), 183-197; Richard Morris Hunt, "General Description," in Presbyterian Hospital, New York City, *AR* 1 (1869), 34; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 115-116.

in the hospital prompted a radical break between the architectural interior and exterior, how they looked like or functioned, and how, or by whom, they were designed. The interior, the realm of medicine, was thought to be devoid of ornament or any form of projection that could accumulate germs or hide dirt, while the exterior, the realm of the public, was meant to express the character of the institution through architectural features and ornamentation. This precondition then determined who was qualified or authorized to design them: the interior became the domain of the physician and the engineer, the exterior that of the architect.

Stephen Smith was the first to advocate for this spatial and professional distinction within the architecture of the hospital. A decade before writing his essay, and while hired to work with architect Carl Pfeiffer to oversee the design and construction of the Roosevelt Hospital in New York, Smith had outlined his position in an 1865 report, later published as *Principles of Hospital Construction.* In that report—and over four decades before Adolf Loos' infamous "Ornament and Crime"—Smith had considered the "extravagance" of architectural ornamentation in a hospital "vain" and even "criminal." "When we recall the fact that the largest success in the treatment of the most dangerous and fatal forms of disease is in the simple tent on the open field," he wrote in his *Principles,* "we fully realize how vain, indeed how criminal, is the expenditure of money in efforts at mere architectural extravagance."[75] In his essay proposal for the Johns Hopkins

[75] Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866), 10-11; Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 297. Smith had also criticized several hospitals, including Gridley Bryant's neoclassical Boston City Hospital and John W. Ritch's State Emigrant Hospital in New York City for the use of expensive "architectural accessories, most of which are positively injurious." Following Smith, in 1871, James Beekman, New York arts patron and politician who served as the vice president of the New York Hospital also called "architectural display in a hospital a crime." James William Beekman, *Centenary Address Delivered before the Society of the New York Hospital* (New York: Society of the New York Hospital, 1871), 21.

Hospital in 1875, Smith reiterated that sentiment and asserted, "in the strongest terms," that treatment of the interior must be determined on the basis of the hygienic necessities by medical professionals, but the exterior could be "left to the good taste and judgment of the architect."[76]

The tenuous condition of the ornament in the discourse of nineteenth-century architecture has often been framed around an ontological debate between Gottfried Semper and proponents of ornament—who saw the functional and structural requirements of buildings subordinate to its symbolic or semiotic purpose—and Loos and the modern masters who equated ornament with crime and ultimately abolished it from architecture.[77] For many of its nineteenth-century proponents, however, exterior ornamentation was inextricably tied to the interior, or the *internal*, logic of the building. Beyond challenging the necessity of ornament in a fundamental way, or critiquing its socio-cultural status as an architectural signifier—as in the turn of the twentieth century in the writings of Frank Lloyd Wright (1901), Adolf Loos (1908), or Owen Jones (1910)[78]—these debates centered around the relationship between the interior and exterior, and

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[76] Stephen Smith, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 297.

[77] For instance, in the introduction of her book, *The Function of Ornament,* Farshid Moussavi writes: "The relationship between the interior and the exterior of buildings range from the *poché* space of the Romans to the theatrical effects of the Baroque, from Gottfried Semper's theory of ornament to Adolf Loos's opposition to it. For Semper, the functional and structural requirements of a building were subordinate to the semiotic and artistic goals of ornament. For Loos, on the other hand, ornamentation was a crime. In his view, ornament was used in traditional societies as a means of differentiation; modern society needed not to emphasize individuality, but on the contrary, to suppress it. Hence for Loos, ornamentation had lost its social function and had become unnecessary." Farshid Moussavi, "The Function of Ornament," in Farshid Moussavi and Michael Kubo (eds.), *The Function of Ornament* (Barcelona: Actar, 2006), 6.

[78] Louis Sullivan, "The Tall Office Building Artistically Considered," *Lippincott's Magazine* 57 (March 1896), 403-409; Frank Lloyd Wright, "The Art and Craft of the Machine," *Brush and Pencil*, vol. 8, no. 2 (May, 1901), 77-90; Adolf Loos, "Ornament and Crime" (1908), *Ornament and Crime: Selected Essays* (California: Ariadne Press, 1997); Owen Jones, *The Grammar of Ornament* (London: Bernard Quaritch, 1910).

the role of ornament as a mediator between the two. Challenging the established Albertian distinction between structure and ornament, ornament came to be redefined as an outward expression of the internal logic of the building.

The formulation of the concept of beauty, the fascination with the machine and industrial aesthetics, and a renewed interest in Greek and Gothic architecture during this period had especially prompted German-speaking architects and theorists to debate the nature of style, and ornament as its culprit.[79] In the 1840s, in an attempt to synthesize the symbolic and representational function of ornament (attributed to the Greek) with its organic or ontological one (attributed to the Gothic), Karl Bötticher posited the future possibility of an unnamed third architectural style capable of engendering a new cultural entity. Unlike Kant and Schiller's concept of *Architektonik* beauty—wherein a subjective perception led to an objective reality—Bötticher saw the beauty of architecture precisely in the delineation of its *tektonik* logic, its structural and engineering necessities. In his reformulation, Bötticher distinguished between *Kernform* (core-form), the structural or mechanical components, and *Kunstform* (art-form), the expression or representation of those elements—the structure pushed out to become ornament. For Bötticher, the true tectonic tradition, what he refers to as the "eclecticism of the spirit," resided not in the appearance of any one style, but rather in the essence that lay behind it. The writings of Hübsch and Bötticher, as Kenneth Frampton has observed, imbued a certain kind of naturalism to architecture. Architecture was seen analogous to a living organism, with an external

[79] Most notable examples include: Immanuel Kant, *Critique of Judgement* (1790); Friedrich Schiller, *Letters on Aesthetic Education* (1795); Heinrich Hübsch, *In What Style Shall We Build?* (1828); Augustus Welby Northmore Pugin, "On the Wretched State of Architecture at the Present," *Contrasts* (1836); Gottfried Semper, *The Four Elements of Architecture* (1851), and "Science, Industry, and Art" (1852); John Ruskin, "Modern Manufacture and Design" (1858-59); Adolf Loos, *The Principle of Cladding* (1898), and "Ornament and Crime" (1908).

physical body that expressed an internal metaphysical, even spiritual, essence—a synthesis of ornament and structure, the interior and the exterior.[80]

In the United States, this organic approach towards ornament only emerged in the late nineteenth century. In his 1892 essay, "Ornament in Architecture," Louis Sullivan declared that buildings "must have, almost literally, a life." In a much similar way to Bötticher, he went on to draw a distinction between the internal "mass-composition" and the external "decorative ornamentation" of architecture.[81] Rather than calling for abolition of decorative ornamentation Sullivan argued for what he called "an organic system of ornamentation":

> *It must be manifest that an ornamental design will be more beautiful if it seems a part of the surface or substance that receives it, than if it looks "stuck on," so to speak. A little observation will lead one to see that in the former case there exists a peculiar sympathy between the ornament and the structure, which is absent in*

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[80] Karl Botticher, *Die Tektonik der Hellenen* (1844). According to Kenneth Frampton, Bötticher, was highly influenced by Heinrich Hübsch's structural rationalism and by Aloys Hirt, German art historian and archaeologist, and his unwavering faith in the symbolic superiority of Greek form. Bötticher envisaged a reciprocally expressive interlocking of structural elements, as *Körperbilden* (body-form)*,* that not only responded to the demands of construction, but also enabled these assemblies to attain symbolic status in architecture—the structure being forced to become ornament. Kenneth Frampton. "Bötticher, Semper, and the Tectonic: Core Form and Art Form," in *What is Architecture?,* (ed.) Andrew Ballantyne (New York: Routledge, 2002), 139-140.

[81] Louis H. Sullivan, "Ornament in Architecture," *The Engineering Magazine* 3 (August 1892), 633-644. In that essay, Sullivan wrote: "Why, then, should we use ornament?" when without it, a building "may convey a noble and dignified sentiment by virtue of mass and proportion" and he expressed doubts on whether "ornament can intrinsically heighten these elemental qualities." Sullivan argued to "refrain entirely from the use of ornament for a period of years," in order to "concentrate acutely upon the production of buildings well formed and comely in the nude." For Sullivan, this step would allow for an assessment on the necessity of ornaments in architecture: "to what extent a decorative application of ornament would enhance the beauty of our structures—what new charm it would give them." He wrote: "If I answer the question in entire candor, I should say that it would be greatly for our esthetic good if we should refrain entirely from the use of ornament for a period of years, in order that our thought might concentrate acutely upon the production of buildings well formed and comely in the nude. We should thus perforce eschew many many undesirable things and learn by contrast how effective it is to think in a natural, vigorous and wholesome way. This step taken, we might safely inquire to what extent a decorative application of ornament would enhance the beauty of our structures—what new charm it would give them." Louis H. Sullivan, "Ornament in Architecture," *The Engineering Magazine* 3 (August 1892), 633.

*the latter. Both structure and ornament obviously benefit by this sympathy—each enhancing the value of the other. And this, I take it, is the preparatory basis of what may be called an organic system of ornamentation."*

*If not we bring ourselves to close and reflective observation, how evident it becomes that if we wish to insure an actual, poetic unity, the ornament should appear, not as something receiving the spirit of the structure, but as a thing expressing that spirit by future of differential growth. […] It follows then by the logic of growth, that a certain kind of ornament should appear on a certain kind of structure, just as a certain kind of leaf must appear on a certain kind of tree.*[82]

These organic and vegetal analogies—predicated on the union of *form* with *function* and *structure,* in the original biological sense of the terms—implied a vital relationship, even a fusion, between the interior *essence* or *life*, and the exterior appearance or expression in architecture. Ornament, just like physiognomy or foliage, came to be understood as a natural and outward expression of the interior structure. And this naturalized bond could only be broken in the hospital when the vitality of architecture threatened that of its human occupants.

In his essay proposal for the Johns Hopkins Hospital, and without addressing ornament or style directly, Billings argued that germs are the biggest threat to the hospital, and saw ornamental features of the buildings as elements where not only "invisible particles" can lodge and hide, but also disrupted the air flow or spread by it:

*Whatever may be the opinions held as to the nature of these diseased germs, and their mode of origin and propagation, they are what we have to fear and to*

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[82] Louis H. Sullivan, "Ornament in Architecture," *The Engineering Magazine* 3 (August 1892), 641. Calling this approach towards ornament "a dream," Sullivan argued that "America is the only land in the whole earth wherein a dream like this may be realized; for here alone tradition is without shackles, and the soul of man free to grow, to mature, to seek its own." Louis H. Sullivan, "Ornament in Architecture," *The Engineering Magazine* 3 (August 1892), 644.

*provide against in the construction of a hospital. They are on and in the dressings, the sponges, the instruments and apparatus, the bedding and clothing of the patients, the persons and clothing of the physicians and attendants. The finger-nails of the latter are full of danger. Wherever there is a ledge, or projection, or crack in the ward, these invisible particles are liable to lodge, and becoming dried, to be displaced by currents of air. Under certain circumstances it is probable that a single one of these particles is sufficient to set up a morbid process if brought in contact with the living body.*

*It is very desirable that this subject of contagium should be clearly understood in this connection, and that the above statements should be considered not as theories, but as an account of facts which it is easy to verify.*[83]

Similar to the other physicians and hospital designers of his time, Billings believed that ornament, as an unnecessary architectural expenditure, increased the cost of construction at the expense of more necessary engineering requirements. In discussing the "essential difficulty" of managing cost of construction and maintenance in his "Letters to a Young Architect," for instance, Billings complained that many architects "cheerfully" allocated a large portion of their budget to "ornamental stonework and cornices" but did not spend a fraction of that on "the necessary hot water or low pressure steam apparatus" to keep the building well-tempered and ventilated. Billings believed that "in his capacity as expert professional adviser," it is "the duty of the architect not only to advise, but to insist upon proper arrangements for heating, ventilation,

[83] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 12-13.

drainage and plumbing," and not to defer to the client's "ignorance in these matters" to ensure such necessary measures are not jeopardized for the sake of "ornamental work."[84]

Architectural ornamentation, therefore, stood in the way of two critical mandates of the Hospital for which Billings, as the Medical Advisor, was responsible for: to create a hygienic environment, and to do so at a minimal cost. His solution, then, was to strip the architectural interior of all ornaments that clung onto wall or ceiling surfaces. There were no cornices or any form of protrusion in the interior. Even elements like doors were built "as plain as possible," without the standard moldings and flushed with the walls: "The doors have not the usual moulding about the panels, giving recesses which it is almost impossible to clean."[85] The interior of the Hospital was therefore conceived as a hermetically sealed environment, with rounded corners, ridged ceilings, ventilated cavities, and not ornament or protrusion that could interfere with ventilation or hygiene.

The architectural exterior, on the other hand, remained outside the domain of medicine. Billings approach to the design of the exterior, following Smith's recommendation, was to dislodge it

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[84] Billings believed that the first question an architect needs to ask the client is "How much money can be afforded to secure good ventilation?", and that the design of such systems should be determined in the earliest steps and sketches of the project. Using the example of an architect asked to design a house, Billings wrote: "It is his duty also to see that, after the various additions to the plan which will be made at the suggestion of the owner's wife and several of his friends on whose taste he relies, have increased the cost above what he had intended, he does not, in the spasm of economy and retrenchment which will attack him, make a reduction in some point which will affect the ventilation rather than on some of the ornamental work outside." John S. Billings, *The Principles of Ventilation and Heating and their Practical Application* (New York: The Sanitary Engineer, 1884), 14-15.

[85] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 28-29; John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 8.

from the interior. In mediating the demands of the founder and those of the institution he was in charge of, Billings defined the architecture of the Hospital within two separate domains: the interior, the realm of science, medicine and "utility," operating under the authority of doctors and engineers, and worked out in "plans"; and the exterior, the realm of the public, and of "architectural ornament," left to the judgement and taste of the architect, and designed in elevations.[86] He then articulated the six "main principles" that informed the design and construction of the Hospital, including: "to provide for the proper care of the sick, both rich and poor, to provide for the highest class of medical education, to increase and diffuse knowledge, to provide trained nurses for both hospital and city, to provide a dispensary, and," last but not least, "to make the buildings and grounds ornamental and attractive."[87]

Billings felt that the three "principal buildings" facing Broadway, the Administration Building along with the two Pay Wards, formed the "front" face and the dominant facade of the Hospital and therefore "should harmonize in style of decoration." These buildings were designed in "Queen Anne style," built of "the best quality of pressed brick" with trimmings of Cheat River stone and molded terra-cotta (Figures 3.6-3.9).[88] The Cheat River stone, "a very fine-grained, compact sandstone of a bluish-gray color," was obtained from quarries in West Virginia, was particularly selected as it "harmonizes excellently with the red brick." The stone, Billings claimed, "is one of the most durable of our building stones, especially when laid on its natural

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[86] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 6.

[87] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 7.

[88] For more on the "Queen Anne" style and its use in hospitals during this period see: Mark Girouard, *Sweetness and Light: The "Queen Anne" Movement 1860-1900* (Oxford: The Clarendon Press, 1977), 84-85.

bed, i. e., in the same relative position which it had the quarry," and he ensured it was laid in the same way in the buildings.[89] The Administration Building, "the largest and, from the architectural point of view, the most important building of the hospital," and carefully placed on "the centre of the main front," was intended to represent the Hospital's civic and institutional presence in the city: "crowned with a dome and a spire in the centre," it had a 150-feet front on Broadway, set back and raised on terraced gardens, "with an ascent of granite steps and winding drives, somewhat after the manner of the front grounds of the capitol of Washington"[90] (Figures 3.10-3.13).

Despite the ornate design and choice of materials in the three "Principal buildings," the rest of the Hospital buildings were much more modest in appearance or quality. While those three buildings were built of "the best quality of pressed brick" with "a solid concrete base" foundations, the other buildings were constructed with sand brick, "being intermediate in quality between pressed brick and the ordinary hard brick of commerce," with foundations made of

[89] In his description of the Hospital, Billings wrote: "The buildings are constructed of brick, with trimmings of Cheat River stone and of moulded terra-cotta. The Cheat River stone is a very fine-grained, compact sandstone of a bluish-gray color, which harmonizes excellently with the red brick. It is obtained from West Virginia, and is one of the most durable of our building stones, especially when laid on its natural bed, i. e., in the same relative position which it had the quarry—and care has been taken that it should always be so laid in these structures. The buildings on the main, or west, front are constructed of the best quality of pressed brick; the other buildings of what is known in this vicinity as sand brick, being intermediate in quality between pressed brick and the ordinary hard brick of commerce." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 63.

[90] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 80-82; *The Baltimore Sun*, (May 9, 1877); In his essay proposal, Billings had suggested that the Administration Building along with the two Pay Wards could vary in appearance based on the taste and skill of the architect: "Taken in connection with the pavilions on each side intended for private patients, this building admits of such variations as the taste and skill of the architect may dictate, as will be more plainly seen by reference to the general plan of the Hospital given hereafter." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 33.

"broad flags of Port Deposit granite," and without any ornamentation.[91] Even the exteriors of the Octagon Ward, the Common Wards and the Isolation Ward were blank brick facades with punctured windows, only distinguished by the multiplicity of the ventilation shafts and chimneys penetrating out of their roofs—there were no terra-cotta or Cheat River stone, no trimming or ornament (Figures 3.14-3.17). In his own *Description of the Johns Hopkins Hospital,* Billings presented the three buildings on the "main front" as those that "embody the architectural features of the Hospital" while "all the other buildings having comparatively plain exteriors."[92]

This disparity was also informed by a disjunction in the professional responsibilities and production of the drawings and documentations during the design process. In prioritizing "utility" over "architectural ornament," Billings, "aided by the architect of the board," had worked out the "plans" without paying much attention to "external appearance."[93] In 1877, when Niernsée resigned and left the project, Billings hired the Boston architectural office Cabot and Chandler to replace him. At this time, while the construction of the Hospital was already underway and the interior of the buildings were fully worked out through detailed plan and

[91] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 63. The discrepancy in the exterior design of the three main buildings compared to the pavilions was not unique to the Johns Hopkins Hospital. The architecture of hospital during this period straddled the line between their medical or hygienic necessities and their bureaucratic and institutional demands—civic presence, reputation, recruiting, fundraising, etc. Many hospitals—such as Saint Luke's Hospital designed by Ernest Flagg, and New York Cancer Hospital designed by Charles C. Haight—invested in ornate and lavish administration buildings at the expense of simpler pavilions.

[92] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 59.

[93] In his address at the opening of the Hospital, while crediting all parties involved in the design and construction of the Hospital, Billings did not mention Niernsée at all. In describing his work as a Medical Advisor at the onset of the project, he wrote of himself (in third-person): "He set to work, aided by the architect of the board, and the result was a set of sketch plans which he took abroad and obtained much counsel and criticism on, examining at the same time the model hospitals of Europe." John S. Billings, John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 3.

section drawings, the exteriors were still not designed—there were no elevations drawn. Cabot and Chandler's work was therefore entirely confined to the "external designs" of the buildings. In fact, the surviving Cabot and Chandler drawings are elaborate elevation drawings of the Administration Building alone: partially colored exterior elevations showing the facade and ornamentation details (Figures 3.18-3.19), or the elevation details of the fireplace mantle in the visitors parlor (Figure 3.20).[94]

Billings own description of the design process, in his address at the opening of the Hospital, reveals how that disjunction between *utility* and *architectural ornament*—the separation of "the architectural design and external appearance of the buildings," or "the laying out and ornamentation of the grounds" from the internal functions of the medical institution—determined the professional responsibilities and design decisions:

> *With regard to the architectural design and external appearance of the buildings, and the laying out and ornamentation of the grounds, I can only say that you must see and judge for yourselves whether Mr. Hopkins' wish that they should be an ornament to the city has been successfully complied with. So far as external ornamentation is concerned, it is confined almost entirely to the large buildings on the west, or Broadway, front, which it was felt should harmonize in style of decoration. These central buildings, consisting of the administration, with the one pay ward on either side, are constructed of pressed brick with ornamentation of a dark blue, fine grained, hard, and durable stone, known as Cheat River stone, and*

[94] It wasn't just the exterior but the building also had an ornate interior, with simpler a heating and ventilation system, and an ornamental fireplace in each room. The Administration Building was heated by hot water and by open grates or fireplaces in several rooms that also acted as foul air flues. The "fresh air" was supplied primarily through the windows. Each room had its own fresh air flue or flues, and its own fire-place and chimney-flue. The flues that passed through the rooms—similar to those in other buildings heated by hot water—were 9 x 14 inches, made of galvanized iron. Because the building did not house any patients, did not have any medical function or a dining room, or "other sources of unpleasant odors" the heating and ventilation was much simpler. John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 83-84.

> *of moulded terra-cotta of the color of the brick. The external designs for these, as for all the other buildings, were furnished by Messrs. Cabot & Chandler, of Boston, and I think we have good reason to be well satisfied with the results they have produced.*[95]

The emphasis on the plans over the elevations in the design of the Johns Hopkins Hospital was unusual during this period. While most nineteenth-century architects approached projects by designing the facades in elevation first before moving to the interior plans, the design of the Johns Hopkins Hospital began with the plans and the interior organization and only later, during the construction, moved to the elevations and the design of the facade. Annmarie Adams has even considered this planometric approach towards design of the Johns Hopkins Hospital a hallmark of late nineteenth and early twentieth century hospital.[96] The disjunction between the interior and the exterior, therefore, was not just a product of the institutional mandates, hygienic requirements or an objection to ornament, but also the result of a fundamental shift in the design process that prioritized the production of plans over elevations.

This approach towards the "architectural design" of the Hospital, the exterior appearance and ornamentation, was not unlike that taken towards the landscape. When the grading and excavation of the grounds began in 1877 ahead of construction, all sorts of "dangerous" and toxic materials were found buried under the ground: a whole cemetery full of dead bodies, and an excessive amount of carbonic acid gas to an extent that construction had to be suspended due to workers falling ill. Ernest W. Bowditch, a Bostonian engineer, surveyor and "landscape

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[95] John Shaw Billings, "The Plans and Purposes of the Johns Hopkins Hospital," from *Johns Hopkins Hospital: Addresses at the Opening of the Hospital* (Baltimore: Privately printed, 1889), 12-13.

[96] Annmarie Adams, *Medicine by Design: The Architect and the Modern Hospital, 1893–1943,* (Minneapolis: University of Minnesota Press, 2008), 90.

gardener"—who regularly worked with Olmsted—was hired to design the grounds. Even so, it was Bowditch as an engineer rather than a landscape gardener that was hired for the job. the overall design of the hospitals grounds remained the same as it was drawn in Billings' final Block Plan, and the only surviving drawing from Bowditch is a drainage plan for the site, without minimal information on plants, flowers or fountains (Figure 3.21).[97] In this way, the design of the landscape, similar to the "architectural design," was primarily concerned with the removal or expulsion of elements that were seen as toxic or unsanitary: germs, dust, dirt or sewage.

For Billings, the plants functioned in the same way as the exterior of the principal building: both were concentrated at the front of the Hospital forming a facade, an "ornament to the city," both were absent in the plans and only visible in the elevations, and ultimately, both were "stuck on." In fact, it wasn't just that the living plants were reduced to a facade, but the architectural ornaments were literally vegetal and floral. The terra-cotta pediments and moldings were adorned with foliage and flower motifs, and even the Cheat River stone frieze around the dome was decorated with modeled flower figures, single daisies each with a stem and two leaves (Figure 3.22). At its formal opening on May 7, 1889, held at the rotunda of the Administration Building, the Hospital, appearing "Magnificent in her beauty and her glory" as described by the *Baltimore American,* was adorned with foliage and flowers. The Baltimore *Sun described* the

[97] Drainage of surface water from the grounds was accomplished by having a system of under-surface drains discharge into a slit trap at the corner of the lot and then to an open stream a few blocks away. Sewage from the interior of the buildings was transferred via pipes to several wells on the lot sunken at about seventy-five feet deep. The site required considerable amount of grading to an extent that by the time the work was completed, Billings claimed, "not a single foot of the surface of the lot is at its original level." John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 53-56, 77-80.

elaborate ceremony where guests were handed multicolored tickets, the various spaces where they assembled “ornamented with blooming flowers,” the speakers’ stand “handsomely decorated with foliage plants, potted plants in bloom and cut flowers,” Chandeliers “hung with smilax,” “floral baskets hung from the first gallery, the octagon faces of which were festooned with evergreens,” and even the oil portrait of Hopkins himself “edged with smilax and evergreens.”[98] Whether natural or artificial, made of organic matter or of stone and terra-cotta, the foliage and flowers constituted the ornament of the Johns Hopkins.

The disparity and disjunction in the design of the Hospital was also reflected in the representations of the project. Billings descriptions of the project in his lectures and various publications, especially in medical journals, focused on the interior organization, presenting plans and sections alone and often without any elevations, exterior views or photographs. Even in his *Description of the Johns Hopkins Hospital* (1890), a book that offered the most detailed overview of the Hospital architecture with over a hundred pages of text and 56 plates, all published drawings included only plans and sections of the buildings, and not a single elevation was included. In his draft notes outlining the number of plates, Billings even crossed out numerous views of the buildings’ exterior or interior spaces and replaced them with “plans and sections” (Figures 3.23-3.24).

Meanwhile, articles in newspapers and architectural periodicals instead focused primarily on the exterior appearance, using photographs and perspectival etchings of the street views of the

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[98] *The Baltimore American* (May 8, 1889); *The Baltimore Sun* (May 8, 1889); Alan M. Chesney, *The Johns Hopkins Hospital and the Johns Hopkins University School of Medicine: A Chronicle,* Vol. I: Early years 1867-1893 (Baltimore: The Johns Hopkins University Press, 1943), 145-146.

Hospital showing the buildings and the landscape (Figure 3.25-3.26). The interior and the exterior of the Hospital, therefore, conceived and communicated in two distinct, and even autonomous, realms. Each domain responded to a different institutional mandate, was designed by different professionals, built with different materials and modes of construction, represented through different drawings or illustrations, and ultimately spoke to different audiences. The Hospital was conceived and constructed as two separate projects that only coexisted in the same site or buildings.

This bipolar identity of the Hospital resulted in radically different reviews and receptions of the project. At the time when architects were debating appropriate style best suited and most adaptable to "beautifying the hospital," Billings' approach to the design of the Johns Hopkins was seen as a total disregard for architecture. Philadelphia architect Addison Hutton—who was a student and later partner of Samuel Sloan—praised the Johns Hopkins Hospital and called it, "from the medical point of view, an ideal hospital." But then he went on to criticize the architecture and the treatment of the exterior of the buildings. Hutton argued that architecture "as an art" seems to have been subordinated to the demands of medical science:

> *The plans of Johns Hopkins Hospital in Baltimore, recently published by Dr. Billings, illustrate more fully than any other yet built, the thorough study of the subject which is being given in modern times. It is in effect from the medical point of view, an ideal hospital. No thought, time, trouble or expense was spared to make it so; to carry into practice the most advanced ideas of hospital design and construction. I shall refer to this frequently as it is a convenient landmark and object lesson. There can be no objection to doing so, as the plans and their publication have become common property. If a copy of Dr. Billings' book is not already in your library, it ought to be place there.*

> *In the Johns Hopkins Hospital, beyond the Administration and Pay Wards, it is difficult to discover the touch of the artist. Architecture as an art seems to have been subordinated to the demands of hospital science, and any thought of architectural beauty in the treatment of the external appearance of the common wards, particularly ignored. I wish to suggest the point that there are no compelling requisites of size, proportion or detail in hospital plans, that may not be softened and rounded by artistic care, so as to give token of regard for beauty.*[99]

Hutton went to discuss the importance of architectural appearance and beauty in hospitals at length. "I am the more moved to speak as I do," he wrote, "because some of the medical advisers have strongly intimated their disregard for architectural beauty, as if it were not worth an effort." The planometric approach towards architecture, as Hutton observed, implied that "certain irregularities of plans and arrangement of openings, because the wants of the interior are dominant, and interfere with the symmetry."[100] This meant that hospitals received a stripped-down of more flexible styles, like gothic or Romanesque, that could tolerate irregularity or asymmetry, but more importantly, that more than aesthetics, hospital exteriors were informed by utility and function. "Granted that a hospital is a machine, if you will," Hutton wrote but added, "it seems reasonable that it may be and ought to be an agreeable looking machine." Speculating

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[99] Addison Hutton, "Planning of Hospitals," *The American Architect and Building News* 65, vol. 45, no. 978 (August 18, 1894), 65.

[100] Addison Hutton, "Planning of Hospitals," *The American Architect and Building News* 65, vol. 45, no. 978 (August 18, 1894), 66.

the use of “the ogival or Gothic form of architecture,” Hutton ultimately settled on the most appropriate style for hospitals: “a modded Renaissance or some derivatives of Classic.”[101]

If Hutton and most of his contemporaries were more concerned with beautifying the machine and giving it a style, Sullivan considered the functional machine inherently beautiful. Billings approach to the design of the Johns Hopkins straddled the two ideological approaches towards architecture. The elaborate and ornate exterior of the principals buildings was “stuck on” just as the plain and modest exterior of the rest of the buildings was deemed to lack “architectural beauty.” Meanwhile, by separating the medical interior from the architectural exterior, Billings challenged the natural or even spiritual essence of architecture that had, to some extent, reconciled the distinctions between *form* and *function*, ornament and structure, in the nineteenth century—what Sullivan called “organic system of ornamentation.” Sullivan’s writings on ornament appeared too late, three years after the construction and opening of the Hospital, but it

[101] In discussing the choice of style for hospitals, Hutton wrote: “I am the more moved to speak as I do because some of the medical advisers have strongly intimated their disregard for architectural beauty, as if it were not worth an effort. I plead that the skill of the architect can modify the appearance of almost anything having walls, windows and roof, so as to render it a thing inoffensive, and with perhaps a slight addition to the expense, a thing of beauty. Mr. Tollet, a French writer on hospitals, thinks that the ogival or Gothic form of architecture was adopted in the Middle Ages, as much for sanitary as for architectural reasons. Whether he be correct or not (it appears to be a conjecture only), this writer sees no objection to its use, except that it does not seem to lend itself so readily to the rigid conditions imposed by modern sanitary science. But there is one point worth noting in regard to this. Doctors for a wonder, do not differ in their recommendations for top ventilation; in one-story wards this easily becomes what is termed ridge ventilation. In all wards it is very desirable to slope the ceiling upwards from the sides to the middle. So that we have in the ceiling of any ward, especially of the one-story ward, a hint of Gothic which might well be followed in the external architecture of the building. If one were requested to design a hospital group in the Gothic style, he should not seriously resist the pressure to do so; it is possible to do it without trespassing the code of hospital science so far as I know it. One should be allowed and should take much freedom in such an instance; he would be glad, of course, if the state of the treasury would admit of stone as a material for external walls. But if you ask what type of architecture appears best suited or most adaptable to beautifying the hospital, I am obliged to answer, a modded Renaissance or some derivatives of Classic; that is, so far as detail is concerned. There can scarcely be such a thing as perfectly regular or symmetrical handling of the voids and solids, as is necessary to give the best developed results in Renaissance.” Addison Hutton, “Planning of Hospitals,” *The American Architect and Building News* 65, vol. 45, no. 978 (August 18, 1894), 66.

did not escape Billings attention. Among the stack of papers and documents relating to the design and construction of the Johns Hopkins Hospital, Billings kept a cut-out of a published essay by Louis Sullivan from the 1892 issue of the *Engineering Magazine*: “Ornament in Architecture” (Figure 3.27).[102]

### 3.3 Sterile Finishes

In the second half of the nineteenth century, advances in germ theory and bacteriology through the work of scientists and physicians like Louis Pasteur, Joseph Lister, and later Robert Koch challenged the miasmatic assumptions about the cause of disease and infection that led to an increased focus on sanitation in hospital design and management. Hospital diseases were considered as “septic” diseases since their symptoms and progression imitated decomposition. Through a series of experiment studying fermentation in the 1860s, Pasteur had developed three methods to eliminate bacteria: filtration, exposure to heat, and exposure to chemical solutions. Inspired by Pasteur’s work, Lister focused on developing techniques to eliminate micro-organisms in human tissues. Since the filtration and exposure to heat could not be used on a living human body, Lister focused on finding an “antiseptic” solution that could be used in medical and surgical practices.

Lister experimented with carbolic acid, now known as *phenol,* which he derived from coal-tar creosote. At the time, coal-tar creosote was not a medical but a industrial material, as a preservative to protect wood, typically used in railroad and ship construction, as well as for

[102] In addition to Sullivan's essay, Billings had saved an engraving of the “Golden Doorway” of Sullivan's Transportation Building at the 1893 World’s Columbian Exposition. John Shaw Billings Papers, the New York Public Library, Box 48.

treating sewage.[103] Lister developed his antiseptic techniques first by spraying his surgical instruments and dressing of the wounds with carbolic acid, and subsequently applying it directly to the wound in order to sterilize it. He published the result of his experiments in his influential 1867 paper, "On the Antiseptic Principle in the Practice of Surgery," and advocated for following antiseptic practices in hospitals, especially in surgical operations.[104] As a practical application of germ theory of disease, the introduction of carbolic acid and antiseptic techniques to medicine had a direct impact on the design and construction of hospitals. The focus shifted from ventilating strategies, circulation and dilution of air (a physical action), towards sanitary practices, elimination of microorganisms through antiseptic solutions (a chemical reaction).

Billings, while acquainted with Lister's work, had "assented to them in a theoretical sort of a way," considering "the antiseptic method as being the latest fashion, and therefore probably overpraised."[105] His position, however, changed during his Grand Tour in 1876 as the newly appointed Medical Advisor, where he saw the application of antiseptic principles in the hospitals

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[103] In 1834, Friedlieb Ferdinand Runge had discovered *phenol*, also known as carbolic acid, which he derived in an impure form from *creosote*—carbonaceous chemicals formed by the distillation of various tars and pyrolysis of plant-derived material, such as wood or fossil fuel. For a history of Creosote see: C Schorlemmer, "The History of Creosote, Cedriret and Pittacal," *Journal of the Society of Chemical Industry* 4 (30 March 1884), 152–157.

[104] At the Royal Infirmary at Edinburgh, Lister required surgeons at his wards to use carbolic acid solutions to wash their hands and instruments, and had the assistants spray it in the operating theatre to disinfect the space, which ultimately led to the rise of "aseptic surgery." See: Joseph Lister, "A Contribution to the Germ Theory of Putrefaction and Other Fermentative Changes and to the Natural History of Torulae and Bacteria," *Transactions of the Royal Society of Edinburgh*, Vol. 27 (Edinburgh: Printed for the Society by Neill and Company, 1875); Joseph Lister, "A Further Contribution to the Natural History of Bacteria and the Germ Theory of Fermentative Changes," ', *Quarterly Journal of Microscopical Science* 13, (1873) 381–408; Joseph Lister, "On the Antiseptic Principle in the Practice of Surgery," *British Medical Journal* 2, no. 351 (September 21, 1867), 246–248. For more on the impact of Lister's work on surgery see: Lindsey Fitzharris, *The Butchering Art: Joseph Lister's Quest to Transform the Grisly World of Victorian Medicine* (London: Penguin, 2017).

[105] John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 131.

at Bonn, Leipzig, Berlin and London, and even examined Lister's own wards, his specimens and apparatus, at the Royal Infirmary at Edinburgh. In a lecture he gave to the Medical Professions of Baltimore shortly upon his return, Billings considered Lister's antiseptic method as "the most important contribution to our resources in surgery which has been made since the discovery of anesthesia." Aligning himself with Pasteur, Lister, and other germ theorists, he maintained that the various organic changes, such as fermentation or putrefaction, are due to "minute microorganism" that are not spontaneously generated but develop from similar organisms. He argued while the details of the antiseptic method or the material used is not perfected, Lister has "I think, beyond doubt," devised a method to keep germs out of a wound or neutralize them.[106]

For Billings, Lister's antiseptic method had direct implications on the planning and operation of the Hospital. He considered germs as "the dangerous thing" in a hospital, with specific material qualities and physical behavior that make them "almost omnipresent":

> *I think it may be considered as certain that the dangerous thing in a hospital is a dust, an excessively fine, organic dust, which is almost omnipresent, which is in the air, the bedding, the hair, and the clothes of all occupants of the buildings, and the particles of which are so minute, and have so low a specific gravity, that their*

[106] In that lecture Billing said: "I came to the conclusion that this method is the most important contribution to our resources in surgery which has been made since the discovery of anesthesia. Not that the details of the method are perfected, for probably much may yet to be done to simplify it, and we may perhaps discover a better material for the purpose that carbolic acid; but we now may be said to know positively, instead of merely conjecturing, that the process of putrefaction is due to minute solid or semi-solid particles floating in the air, and that Mr. Lister has devised a method by which these particles can either be kept out of a wound made by the surgeon, or by which they will have their power of producing the putrefactive change destroyed, is, I think, beyond doubt." John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 131.

*rate of fall through the air when it is perfectly still, may not exceed two inches per hour.*[107]

Billings classified germs into three categories. The first two constituted living micro-organisms, which he described as “microzymes”: first, “the ordinary forms, which are found everywhere,” that cause mould, mildews, fermentations and putrefactions, and cannot develop within healthy living human tissues; and second, “contagium,” which arise “only in diseased men and animals” and cause disease. Billings considered contagium as the main subject of the germ theory of disease and believed “all problems of isolation and disinfection in a hospital have reference to these contagia only.” In addition to the two microzymes, he described a third class, “particles of organic matter,” that are “not living” and are derived from the skin, mucous membranes, the mouth and air-passages, and provide the nutriment to the living microzymes.[108] Going to some extent against his own earlier classifications outlined in his essay, Billings posited that there are

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[107] John S. Billings, “On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877,” *The Medical Record XII* (July 1877), 131.

[108] “For our purposes, we may divide these living organisms or microzymes into two classes. The first includes the ordinary forms which are found everywhere, and which are the efficient causes of mould and mildews, and of fermentations and putrefactions. […] It is believed by Mr. Lister that healthy living tissues are capable of preventing the development of these low organisms in their immediate vicinity. […] The second class of microzymes includes those which are not everywhere present, but for the most part arise only in diseased men and animals, and appear to have the power of producing diseased action even in perfectly healthy tissues. These constitute what is called contagium, and are what we have in mind when we speak of the germ theory of disease. All problems of isolation and disinfection in a hospital have reference to these contagia only, for there is no isolation or disinfection which will rid us of the microzymes of the first class. […] Besides these microzymes we have also, in a hospital ward, other particles of organic matter, not living, derived from the surfaces of the skin and mucous membranes and especially from the mouth and air-passage during respiration, which are important as furnishing nutriment and means of development to the microzymes above mentioned.” John S. Billings, “On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877,” *The Medical Record XII* (July 1877), 131.

usually not enough "poisonous gases" in a ward and, despite widespread popular lectures on ventilation discourse, carbonic acid is "never a dangerous impurity in a hospital."[109]

The shift from miasma to germ theory challenged the efficacy of ventilation in hospitals. Unlike miasma or "poisonous gases," germs were considered physical and material particles, subject to gravity and natural laws. Even when airborne, germs did not equally diffuse in the air, and did not lose their density and danger through displacement or dilution. Dilution simply implied that "the probability of infection for one exposure may be diminished, but when the small particle does happen to be present, its effects will be the same as though no dilution had been attempted." Billings even considered contagia to be "more or less gelatinous in consistence," which would allow them to "adhere to any surface with which they come in contact."[110] For Billings, then, the only effective method of controlling or eliminating airborne contagia was "isolation, and the methodical use of antiseptics and disinfectants in connection with all excreta and discharges," and "a real removal," rather than displacement, of all dust. "The thing of prime importance in a

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[109] The full passage read: "Perhaps, although with our present knowledge we can hardly sat that is its probable, we may also have in the ward certain complex vapors or gases of organic origin which are dangerous. It rarely occurs that in any ward there are enough of the known poisonous gases, such as sulphuretted hydrogen and carbonic oxide, to produce poisonous effects, and I presume that I need hardly assure you that that great bugbear, carbonic acid, about which popular lectures on ventilation discourse so learnedly, is never a dangerous impurity in a hospital. I saw, however, two hospitals in Europe where openings had been made from the ward to the external air at the level of the floor, in order "to let the heavy gases, and particularly carbonic acid had, run off." As there are no heavy gases near the floor in any greater proportion than there are at the ceiling, it is clear that the result desired could not be obtained." John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 131-132.

[110] John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 131.

hospital," he argued, "is minute care of, and cleanliness in, every part and person about it, and in the management which will insure this."[111]

The growing acceptance of the germ theory of disease during this period resulted in re-evaluation of not just hospital ventilation but also building materials, finishes, furniture, bedding, clothing, and all the various components that could potential harbor germs. The interior surfaces of the hospital were expected to be "incapable of absorbing the exhalations of the sick," which meant not only the materials were required to be antiseptic, but the entire hospital was thought to be an *aseptic* environment.[112] The Johns Hopkins Hospital itself was even represented as a sacred fortress, repelling germs and various forms impurities, with the physician as a saint overlooking the battle from the sky (Figure 3.28). The fear of airborne particles settling on interior surfaces renewed an interest in building materials, their physical as well as chemical properties. Permeability and porosity of materials came to be seen as dangerous defects not only for harboring microscopic germs but also hindering a thorough cleaning and disinfection—Lister himself had discouraged using porous materials in manufacturing the handles of medical instruments.[113]

The criteria for what constituted an impermeable material was also revised during this period through various scientific studies. In the 1880s, Bavarian chemist and hygienist Max von

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[111] John S. Billings, "On the Plans for the Johns Hopkins Hospital at Baltimore: A Lecture Given to the Medical Professions of Baltimore, February 5, 1877," *The Medical Record XII* (July 1877), 132.

[112] Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866), 24.

[113] Peter Metcalfe and Roger Metcalfe, *Engineering Studies: Year 11* (Glebe, New South Wales: Pascal Press, 2006), 151.

Pettenkofer conducted a series of laboratory experiments that involved blowing out a candle through common building materials. Pettenkofer's experiments revealed that many materials that were assumed to be hard and impermeable, such as brick, wood or plaster, were in fact porous and permeable. The work of Pettenkofer and others resulted in a reevaluation of building materials used in hospitals.[114] Unglazed brick was considered "porous enough to absorb and filter out from the air they enclose the noxious vapors and organic impurities it contains," plaster was discovered to "contain forty per cent of its weight of a sort of offensive mud, deposited from the air which had passed through its pores," and it was believed that wooden moldings "jeopardized the lives of the inmates by rendering them subject to erysipelas and other contagious diseases."[115]

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[114] These studies included: Max von Pettenkofer, *Über den Luftwechsel in Wohngebaüden* (Literarisch-Artistische Anstalt der J. G. Cottaschen Buchhandlung, 1858); Louis W. Atlee, "Our Clothing and Our Houses," *The American Architect and Building News, v*ol. 16, no. 470 (December 27, 1884), 306; Henry C. Burdett, *Hospitals and Asylums of the World,* vol. 4 (London: J. & A. Churchill, 1893) 10–11. See also: Didem Ekici, "Skin, Clothing, and Dwelling: Max von Pettenkofer, the Science of Hygiene, and Breathing Walls," *Journal of the Society of Architectural Historians*, vol. 75, no. 3 (September 2016), 281–98; and Gail Cooper, *Air-Conditioning America: Engineers and the Controlled Environment, 1900–1960* (Baltimore: Johns Hopkins University Press, 1998), 59–60; Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 254-257.

[115] In 1880, for instance, physician Edward H. Janes of the New York Board of Health considered unglazed brick in the ward interior "porous enough to absorb and filter out from the air they enclose the noxious vapors and organic impurities it contains." Laboratory study of an old plaster from a hospital ward with a high rate of septicemia found it to "contain forty per cent of its weight of a sort of offensive mud, deposited from the air which had passed through its pores." And in 1882, the Mount Sinai Hospital's medical board argued that the wooden moldings and other absorptive material "jeopardized the lives of the inmates by rendering them subject to erysipelas and other contagious diseases," prompting the hospital governors to tear out and replace all "absorptive" materials with impervious ones in order to provide "every possible protection against hospital infection." "Mount Sinai Hospital, New York City," *Annual Report* (1882), 5, 14; "A Difficulty," *The American Architect and Building News,* vol. 7, no. 213 (January 24, 1880), 25; "M. Boussard," *The American Architect and Building News,* vol. 26, no. 721 (October 19, 1889), 178. For more on the material and finishes in relation to ventilation and sanitation see: "The Permeability of Walls as Affecting Ventilation," *The American Architect and Building News,* vol. 13, no. 373 (February 17, 1883), 78–79 (reprinted from Builder 44 [January 20, 1883], 65–66); "The Sanitary Aspect of Plastering," *The American Architect and Building News,* vol. 8, no. 256 (November 20, 1880), 248.

What constituted best impermeable material was debated, some advocated for Parian cement, stucco, glazed tile, and glass-like materials, others for properly sealing common but permeable materials like hard-finished plaster or wood. But it wasn't only that the physical properties of materials had to repel germs, but that they also had to have a chemical composition to withstand the increasingly caustic antiseptic solutions and disinfectants. Cleaning strategies in hospitals went from dry-rubbing or wet-washing with materials like soapy water, that simply had to dissolve dirt, to the use toxic and corrosive antiseptic substances.[116] For example, after Lister made carbolic acid the "king of disinfectants," Griffeth's Enamel—a glaze washed over existing wall surfaces—became a standard hospital finish since it resisted carbolic acid etching.[117] Hospital designers increasingly sought building materials offered "an absolutely impervious surface capable of being washed down and thoroughly cleansed without its impermeability being affected."[118] Throughout the second half of the nineteenth century, porous materials like wood,

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[116] While made to be impermeable in the early nineteenth century, interior surfaces in hospitals were rarely wet-washed. The assumption that "vapor in a ward tends to suspend the miasmatic emanations and diffuse them more widely" had led to unusual cleaning strategies for hospitals and a preference for dry-rubbing or "frottage"--a term used by Nightingale. Stephen Smith, *Principles of Hospital Construction, Being an Abstract of a Report on Hospital Construction Made to the Trustees of the Roosevelt Hospital* (New York: Holman, 1866), 25. In the Mower United States Army General Hospital in Chestnut Hill, Pennsylvania, for instance, orderlies were required to request permission from the chief executive officer to wet-scrub a floor, and the the surgeons were ordered "to see that water is not thrown on the ward floors." *Rules and Special Orders of the Mower United States Army General Hospital at Chestnut Hill* (Philadelphia: J. B. Lippincott, 1865), 14.

[117] Leonard Paul Wershub, *One Hundred Years of Medical Progress. A History of the New York Medical College Flower and Fifth Avenue Hospitals* (Springfield, IL: Charles C. Thomas, 1967), 118; "Notes and Clippings: Griffith's Enamel," *The American Architect and Building News,* vol. 1, no. 10 (February 26, 1876), 72; "Notes and Clippings: Among the Many Devices," *The American Architect and Building News,* vol. 1, no. 14 (April 1, 1876), 112.

[118] Henry C. Burdett, *Hospitals and Asylums of the World,* vol. 4 (London: J. & A. Churchill, 1893), 10-11. Varnishes, enamels, and resins were used in hospitals of this period to seal less impervious materials. The walls of the Presbyterian Hospital in New York City, for instance, had eight-foot high wainscots of "cream-colored English tile, the surface of which is as hard and smooth as a piece of flint glass." "Founded by James Lenox. The Chief Features of the Presbyterian Hospital," *The New York Times* (July 3, 1892), 8.

brick or plaster were gradually sealed, removed or fully replaced by smooth, impermeable substitutes like asphalt, concrete, glass and later steel.[119]

In their essay proposals for the Johns Hopkins Hospital, the five physicians devoted significant attention to the specification of interior materials and finishes. Caspar Morris, for instance, had recommended the plastering of the interior walls to "be of the best materials and have what is known as the hard polish for the finishing coat." He advised against wooden moldings "as shrinkage will allow or form cracks and fissures, harbors for vermin and pockets for the retention of the morbid emanations and exhalations from the sick," and had even suggested the baseboard should be made cement rather than a wood.[120] Niernsée had also recommended having the interior walls "coated with Parian cement and polishes" in order to "form an impermeable interior coating, and at a reasonable cost, with no joints whatever." He argued the same effect can be obtained by covering the walls with "Dutch tiles, or glazed earthenware" or "large sheets of 4

[119] While the emergence of aseptic finishes in hospitals has typically been associated with the introduction of germ theory and the antiseptic principle, some historians have treated it as a "historical dilemma." In the *Rise of the Modern Hospital,* Jeanne Kisacky has shown that while hospital finishes were well-established by the first half of the nineteenth century, the materials of choice varied over the year: from the use of hard-polished, seamlessly joined varnished wood in the 1850s, to marble and enameled plaster of the 1880s, and finally glass, ceramic tile, and metal in the 1900s. "Hospital finishes," Kisacky argues, "were not a consequence of asepsis; they were an exaggeration, even a refinement, of an already existing spatial strategy." See: Jeanne Kisacky, "Introduction," *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017).

[120] "During the second winter much indoor work may be done, and preparation made for the plastering, which should be done so soon as the weather permits. This should be applied directly to the walls; be of the best materials and have what is known as the hard polish for the finishing coat. All joints and projections should be rounded. Wooden mouldings are wholly inadmissible, as shrinkage will allow or form cracks and fissures, harbors for vermin and pockets for the retention of the morbid emanations and exhalations from the sick. Similar objections apply with equal force to all cornices and ornament to the ceiling, of moulded plaster. The base where the wall and floor join should be guarded by a projection of cement, and not by a wooden base strip. No projecting points or ledges, or mouldings, whether for ornament or use, can be allowed in any part of the buildings." Caspar Morris, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 200.

inch corrugated glass" to make them "absolutely impermeable." He proposed to have the floors laid with "encaustic tiles, or plain hardwood parquete-tablets well impregnated with a disinfecting solution (silica), or stained and waxed," and recommended replacing the hardwood window frames with cast-iron to make them "less absorbent and more fire-proof."[121]

While they generally agreed on the material properties of the interior finishes, the impermeability of walls was debated. In his essay, for instance, Billings had specified that "the window-sills should be of slate or marble," and that "the woodwork of the pavilions should be picked hard pine, all joints, including floors, to be put together with white lead saturated with oil and resin, but not painted or varnished." But he had objected to making interior walls impermeable as it would limit transpiration and evaporation of moisture. "The amount of transpiration which goes on through an ordinary brick and plastered wall is very considerable," Billing wrote, "and to make it impermeable is somewhat like varnishing a man's skin to keep his underclothing from being soiled." Instead, he had proposed filling the wall cavity with disinfecting gas, and "a good

[121] In discussing the materials and finishes of the Hospital, Niernsée wrote: "Constructing the outer walls double or hollow, as in the Herbert Hospital, with floors and ceilings fire-proof, the whole coated with Parian cement and polished, it will form an impermeable interior coating, and at a reasonable cost, with no joints whatever. The same effect may be obtained by a covering of Dutch tiles, or glazed earthenware; but it should be used in large slabs, as in the German stoves of that material; or the walls could be lined with large sheets of 4 inch corrugated glass, both of which latter materials would be absolutely impermeable, but their cost would be materially greater than the Parian cement, which also can be tinted to any desired shade in the *material itself, before its application*. The floors can be laid with encaustic tiles, or plain hardwood parquete-tablets well impregnated with a disinfecting solution (silica), or stained and waxed, as in some of the French and German hospitals. All unnecessary woodwork on doors, windows, and casings should be avoided. Both the boxes and sashes of the windows can be made of cast-iron at a small advance over the cost of hardwood frames, and have the advantage of being less absorbent and more fire-proof." John R. Niernsée, "Appendix II," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 338.

ordinary hard finish" on the interior surfaces and a "periodical scrapings and whitewashings."[122] Despite specifying the building materials and finishes, Billings maintained that the danger is not limited to them: "One soiled blouse of an attendant, or stuffed chair, or baize screen, is more dangerous as a source of infection than many square feet of plastered wall."[123]

The careful selection of materials and their treatment in hospitals was not only to seal the building surfaces against the impurities of the interior emanating from the patients, but also that of the exterior, particularly moist and impure emanations from the soil. The ground on which the building rested posed the greatest danger, and many nineteenth-century hospitals relied on impervious floors, like asphalt or concrete, in order to seal the ground level and "exclude both the dampness and also emanations from the soil."[124] In the Johns Hopkins Hospital, with the heating apparatus also occupying the basement level of the pavilions, the basement floor had to

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[122] In emphasizing the transpiration of walls in his essay, Billings wrote: "I doubt very much the advisability of attempting to make the walls and ceilings of the wards impermeable, by the use of cement, silicates, paint, or paraffine. The amount of transpiration which goes on through an ordinary brick and plastered wall is very considerable, and to make it impermeable is somewhat like varnishing a man's skin to keep his underclothing from being soiled. While not prepared to speak positively on this subject until the results of the two processes can be compared , which will be done in a hospital now in process of construction near this city, I should prefer a good ordinary hard finish, with the space between the plaster and the wall, or in the hollow wall, so constructed that it can be filled with a disinfecting gas such as chlorine or sulphurous acid, when desirable, as suggested by Dr. Stephen Smith, bearing in mind that moisture must precede the application of the gas; and to rely upon this, periodical scrapings and whitewashings, leaving the room empty occasionally, etc. One soiled blouse of an attendant, or stuffed chair, or baize screen, is more dangerous as a source of infection than many square feet of plastered wall. All corners in all wards should be made segments of circles instead of right angles." John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 28-29.

[123] John S. Billings, "Hospital Construction and Organization," in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 28-29.

[124] An article on Hospital Construction read: "the whole ground surface […] in some of the better examples of hospital buildings has been covered with a layer of cement-concrete or asphalt, or it has been otherwise prepared so as to exclude both the dampness and also emanations from the soil." "Hospital Construction," *The American Architect and Building News, v*ol. 12, no. 364 (December 16, 1882), 291.

form not only a barrier for moisture and air, but also for heat. The floor of the basements consisted of "artificial stone laid in large blocks" with "a heavy coat of asphalt" underneath all flues and heating coils "to prevent the passage of ground air up through the coil," and to make the ground floor "impervious to any exhalation from the soil."[125]

In the selecting the building materials for the Hospital throughout the design and construction process, Billings took an interest in associating material properties to the function of the various spaces they served. Floors in particular—where germs, dust, or water settled most—were the most vulnerable surfaces. The floors of all the buildings and the corridor were made of "moulded hollow blocks of hydraulic lime of Teil laid between iron beams of suitable size," since Billings believed the material and mode of construction to be more "fire-proof" and "much lighter" than the typical solid brick arches. But the hydraulic lime floors were then covered with different materials depending on their use. In the basements, bath rooms, water closets and lavatories, where the impermeability towards water, air or heat was the primary factor, the floors were made of asphalt.[126] In the pipe tunnel, the main kitchen, and all tea kitchens around the hospital, areas of high foot or wheel traffic that required material hardness and endurance, the floors were made of concrete. And the floor of the corridor and of the bath house was covered of blocks of

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125 John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64; Fielding Garrison, *John Shaw Billings: A Memoir* (New York: G. P. Putnam's Sons, 1915), 201.

126 In 1882 the directors of Mount Sinai Hospital in New York City had also coated their floors "with asphalt, to make them as impervious to taint of disease as the ceilings and walls." Other hospitals that experimented with asphalt floors included the Saint Luke's Hospital in Chicago, the Mount Sinai Hospital, Bellevue Hospital, and the the Reception Hospital in New York. Jeanne Kisacky, *Rise of the Modern Hospital: An Architectural History of Health and Healing, 1870-1940* (Pittsburg: University of Pittsburg Press, 2017), 183-184.

"granolithic," a mixture of cement and ground granite, "forming a very hard, smooth and durable covering which is easily cleaned."[127]

The patient wards posed the greatest challenge, where traditional use of wood flooring had come into direct conflict with the new antiseptic practices. In addition to being a porous and permeable material, wood also contained soluble matter that was considered a hygienic risk. Despite this, with considerations of cost, comfort and cleaning, hospital wards continued to rely on wood flooring but focused instead on the type and treatment used. The most suitable type at the time was considered to be oak, typically used in European hospitals, but the scarcity of the material in the United States had prompted American hospitals to use "closely-jointed Georgia pine" as a the best, albeit softer, alternative.[128] Billings' used the same standard material for the ward floors, "edge grain Georgia pine 1$^{1/8}$ inches thick," but subjected it to a methodical and thorough treatment. The wood tiles were first "soaked in water for six months," and then "preserved dry for several years before it was dressed for use, in order to secure the removal of all soluble matters and thorough seasoning."[129] The hardwood floors were then finished in hard oil.[130]

The choice of materials and finishes for walls and ceilings were equally complex, involving a process that began months before their construction. All brick walls stood for "at least two

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[127] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64.

[128] In *Hospitals: Their History, Organization, and Construction,* Walker Gill Wylie wrote: "in Europe oak seems to be the best material, but in this country the best hospital floors we have seen are made of closely-jointed Georgia pine […] The reason why our oak floors are not usually as good is, that the *Quercusalba* variety is the only oak-wood which will make good floors, and it is scarce here in America." Walker Gill Wylie, *Hospitals: Their History, Organization, and Construction* (New York: D. Appleton and Company, 1877), 107.

[129] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64.

[130] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 66.

seasons" before being plastered "in order to permit of thorough settling and to minimize the risk of cracking of the plastering as much as possible." The walls were then plastered in three coats and finished with "a hard troweled sand finish" and finally painted in oil. Given that the all perimeter walls were cavity walls, the plastering was applied directly on the inner surface of the brick. In a few buildings, including the pathological laboratory, the bath house, and the female pay ward, the interior walls were finished with "finely-ground soapstone with plaster of Paris." The finish, Billings reported, "is more elastic and less brittle than the ordinary hard finish, and therefore less liable to crack, becomes sufficiently hard after about a year's exposure to permit of cleansing by rubbing with soap and water, and has an agreeable French gray color." In the patient wards and other rooms with wooden beams, a wire netting was used in lieu of wooden lath "in order to prevent cracking of the plastering, and to secure a fairly fire-proof construction." And to make them both fire- and germ-proof, the stairs in the wards were made of iron, with a layer of asphalt in the treads.[131]

The most visible impact of the antiseptic principles in the Hospital ward was the removal, or the formal and material alternation, of doors, windows and woodwork.[132] "In all wards and rooms occupied by the sick," Billings wrote in his *Description of the Johns Hopkins Hospital,* "woodwork is very sparingly used." Window sills were made of slate, and all the interior woodwork, including moldings around doors and windows, were made of smooth ash "free from

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[131] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64-65.

[132] The choice of materials, finishes and colors at the Johns Hopkins Hospital was not unusual. Hospitals during this period were designed with the assumption that "all unnecessary embellishment or architectural adornments […] should be avoided." John Eaton, "Hospital Construction," *American Architect and Building News,* vol. 19, no. 526 (January 23, 1886), 43–44.

quirks, grooves and broken surfaces." The windows had "plain half-rounded heads and mouldings" with bevelled or rounded edges so that they "do not afford catch-places for dust, and are easily cleaned by rubbing with a damp cloth."[133] The introduction of antiseptic principles to hospital design also challenged the use of basic and necessary interior elements of the wards. Curtains, for instance, while considered necessary for limiting sunlight, were assumed to disrupt air flow and provide a harbor for dust, germs and other impurities. In lieu of curtains, Billings devised window shutters that were made of two parts, allowing them to be opened both above and below. The lower half of the shutters could be titled outwards to form "a sort of awning, permitting free admission of air, while largely excluding light."[134] For Billings, these "peculiarities of the wards"—the absence of curtains, limited woodwork, the rounded moldings, corners and baseboards, seamless joints, as well as the choice of materials and finishes—were intended not just to facilitate the flow of air, or airborne germs, but also enable "easy cleaning."[135]

While the physical or chemical properties of interior building materials and finishes were to allow them repel germs and facilitate air flow and cleaning, hospital interiors were also expected to look aseptic. With the assumption that color hid dirt, the interiors increasingly favored light colored finishes. White in particular became a color of choice. Many physicians and hospital designers believed that by making dirt more visible, the white color instilled better hygienic and

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[133] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64-65.

[134] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 65.

[135] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 36.

sanitary practices.[136] By the turn of the century, the whiteness became the defining characteristic or "style" of medical institutions—its buildings, landscape and inhabitants—and a symbol of mental and physical health. Thomas Mann's novel *Tristan* (1903)*,* for instance, is set in an imaginary sanatorium called Einfried, "a long, white, rectilinear building" sited in a "spotless white region" covered in snow, with "white-enamelled" armchairs, "white folding doors," "white-painted gallery," inhabited by the "white, slightly bloated" faces and "white hands" of the patients with their "white-veiled desires, by passion driven."[137]

For Billings, however, the choice of interior colors was not an aesthetic or even a psychological choice, but primarily a therapeutic one related to light. He believed light to be "a powerful tonic and stimulant agent, with peculiar powers and modes of action," many of which yet to be fully understood, and that "Nothing can compensate for its absence or in sufficient supply in health, in many cases of disease, and in convalescence." Despite this, Billings considered the glare of

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[136] While many hospitals used white color to make dirt more visible or to instill and encourage better hygiene, others, like architect Robert J. Reiley, believed "the white enamel interior" to be sickening to patients and advocated for using colors instead. Robert J. Reiley, "The New Hospital of the House of Calvary," *Modern Hospital,* vol. 3, no. 2 (Aug. 1914), 82. See also: "Beauty as a Curative Agent," *Modern Hospital,* vol. 6, no. 2 (Feb. 1916), 112–13; Victor C. Twiss, "Interior Decorations in Hospitals," *Modern Hospital,* vol. 7, no. 4 (October 1916), 337; Jeanne Kisacky, "Blood Red, Soothing Green, and Pure White: What Color Is Your Operating Room?," in *Color and Design*, ed. Marilyn Delong and Barbara Martinson (London: Berg, 2013), 118–24.

[137] Thomas Mann's novel *Tristan,* written in 1903, is set in an imaginary sanatorium called Einfried, "a long, white, rectilinear building," designed for patients suffering from various illnesses: "lung patients," "sufferers of gastric disorders […] people with defective hearts, paralytics, rheumatics, nervous sufferers of all grumblings." When one of the patients, Herr Kloterjahn's wife, asks another patient called Herr Spinell "Why are you in Einfried, really? … What cure are you taking, Herr Spinell?" He, who wears a "white jacket" and "white hat," answers: "Cure? Oh, I'm having myself electrified a bit. Nothing worth mentioning. I will tell you the real reason why I am here, madame. It is a feeling for style. […] Obviously, people feel one way among furniture that is soft and comfortable and voluptuous, and quote another among the straight lines of these tables, chairs, and draperies. This brightness and hardness, this cold, austere simplicity and reserved strength, madame—it has upon me the ultimate effect of an inward purification and rebirth." Thomas Mann, *Tristan,* in *Stories of Three Decades* (1903)*,* trans. H. T. Lowe-Porter (London: Martin Secker and Warburg, 1922), 141, 154. See also: Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019), 81-84. For more on the origins of whiteness in modern architecture and its relation to fashion see: Mark Wigley, *White Walls, Designer Dresses* (Cambridge, MA: MIT Press, 2001).

white-walled wards to be equally harmful as it is irritating: “I am satisfied from observation that in many cases of acute disease the glare of a large, white-walled, many windowed hospital ward does harm very much in the proportion in which it inflicts discomfort.”[138] For that reason, the interior color palette of the Hospital consisted primarily of shades of gray. All the ward walls were painted in oil, “of a French gray color, some what darker below for a height of six feet,” likely to limit the glare from the windows. Similarly, the “finely-ground soapstone with plaster of Paris” finish of the interior walls in the Pathological Laboratory, the Bath House, and the Female Pay Ward, had “an agreeable French gray color.” In the upper stories of the Administration Building and Nurses’ Home, the woodwork was painted white, and in the Kitchen and the upper stories of the Apothecaries’ Building, the woodwork was painted in light gray (Figures 3.29-3.35).[139]

In this way, more than the expression of the therapeutic and hygienic function of the institution, the careful selection of interior materials, finishes and colors in the Johns Hopkins Hospital was the very means and mechanisms that enabled them. And it was precisely this *modern* quality of the interior—informed by new institutional, scientific, technological, and professional standards of modernity—that distinguished it from the “architectural” exterior: one represented the bureaucratic image of a public institution, ornate and colorful in appearance, the other embodied the medical and therapeutic function of a hospital, plain and simple. No longer bound by a

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[138] John S. Billings, “Hospital Construction and Organization,” in *Hospital Plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by their Authors for the use of the Johns Hopkins Hospital in Baltimore* (New York: William Wood & Co., 1875), 39-40.

[139] John S. Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), 64-66.

semiotic or even a material connection, the modern interior had dislodged itself from the exterior, literally separated by a two-inch cavity filled with disinfecting gases.

# CONCLUSION

Since the birth of the clinic, architecture has been entangled with the disciplinary methods of observation, experimentation and education in medicine that have both shaped the hospitals and the discourse around them. The preceding attempts to challenge that historical narrative. Unlike Foucault's formulation where knowledge affirms itself through a legitimating program of discourse, here we can see that there is a shared knowledge and discourse: a mutual legitimation program and a reciprocal reinforcement of professional expertise where disciplinary typologies appeared increasingly anachronistic. The Johns Hopkins Hospital therefore represents a moment when the entanglement of the disciplinary methods of observation, experimentation and education became salient. And this entanglement was simultaneously phenomenological and discursive, requiring both architecture and new forms of documentation and representation. From the use of the architectural plan as a scientific hypothesis, or even a device, that enabled the built hospital to function as a full-scale experiment, the consolidation of mechanical systems and building technologies with architecture in form of rounded corners, ventilating benches and self-closing doors, to the use of plain and polished materials and finishes in the aseptic interior spaces and the representations and publications of the Hospital, the project reveals a moment when the notion of discipline dissolves under the pragmatic mandates of the institution.

This approach, not only provides an alternative history of the hospital in the nineteenth century, but also offers new way to engage the history of modernism in relation to contemporary discourse both within and outside architecture. For instance, the "modern" appearance of the late nineteenth century hospitals and medical facilities has often been considered as a source of inspiration for the twentieth-century architects like Le Corbusier, Alvar Aalto or Richard Neutra who saw the sterile and hygienic image of medical institutions as something that instilled a sense of health and wellbeing. From the adoption of open flexible floor plans, rounded corners, and the exposition of structural or mechanical systems to the removal of ornaments and colors in favor of smooth polished finishes and impermeable materials like metal, glass or concrete, the basic characteristics of medical institutions of the late nineteenth century established the formal, spatial, and material ingredients of modern architecture in the twentieth century. Modernism, as it were, was born in the medical hospital.[1]

This prenatal association between modern architecture and medicine has often been explained in psychological terms. Beatriz Colomina, for instance, has argued that more than a strive for functional efficiency and machine aesthetics, the rejection of ornament or color in modern architecture was not an aesthetic theory but psychological reaction.[2] In their initial appearance in

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[1] Numerous historians have traced the origin of modern architecture to the medical institutions of the late nineteenth and early twentieth centuries. See for instance: Robert Musil, *The Man without Qualities,* trans. Eithne Wilkins and Ernst Kaiser (New York: Capricorn Books, 1965), 16; Heinz Geretsegger and Max Peintner, *Otto Wagner 1841-1918: The Expanding City, the Beginning of Modern Architecture,* trans. Gerald One (London: Academy Editions, 1979), 140; Walter Benjamin, "On Some Motifs in Baudelaire," trans. Harry Zohn, in *Walter Benjamin: Selected Writings, Vol. 4 1938-1940,* ed. Howard Eiland and Michael W. Jennings (Cambridge, MA: Belknap Press of Harvard University Press, 2003), 328; Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019), 94-95.

[2] Beatriz Colomina, "X-Ray Architecture: The Tuberculosis Effect," *Well, Well, Well, Harvard Design Magazine,* no. 40 (Spring-Summer 2015); Beatriz Colomina, "X-Screens: Röntgen Architecture," *e-flux journal* no. 66, October 2015; Beatriz Colomina, *X-Ray Architecture* (Zürich: Lars Müller Publishers, 2019).

the late nineteenth century, however, the architectural provisions in medical hospitals operated primarily in the physiological rather than the psychological realm. More than aesthetic or even anesthetic choices, they were simply antiseptic and aseptic provisions that, more often than not, were made by doctors rather than architects. The disjunction between the two approaches towards architecture is nowhere more visible that at the Johns Hopkins Hospital, where the ornate and colorful exterior stood in stark contrast to the plain and sterile interior: one embodied the therapeutic function of the institution, configured by a doctor in plans and sections, the other its public and bureaucratic image, designed and drawn by an architect in elaborate elevations and perspectives; one functioned as a sanitary and physiological instrument, the other a visual and a psychological device.

These architectural strategies were therefore deeply entangled with new assumptions about social class and institutional structure, industrialization and labor economy, scientific methods and its applications, professionalization and modes of practice, building technology and construction techniques, sanitation and hygienic standards, and advances in methods of higher education and research, which at times even exceeded the ideological premises of modernism. In this way, rather than an aesthetic or symbolic expressions of health and well being, the early appearance of modern architectural characteristics reflected the inherent functional and didactic ambitions of architecture that were uniquely modern. It was therefore architecture's interaction with these new conditions of modernity at the Johns Hopkins Hospital that constituted it as *modern,* not simply because of its appearance, but often in spite of it.

FIGURES

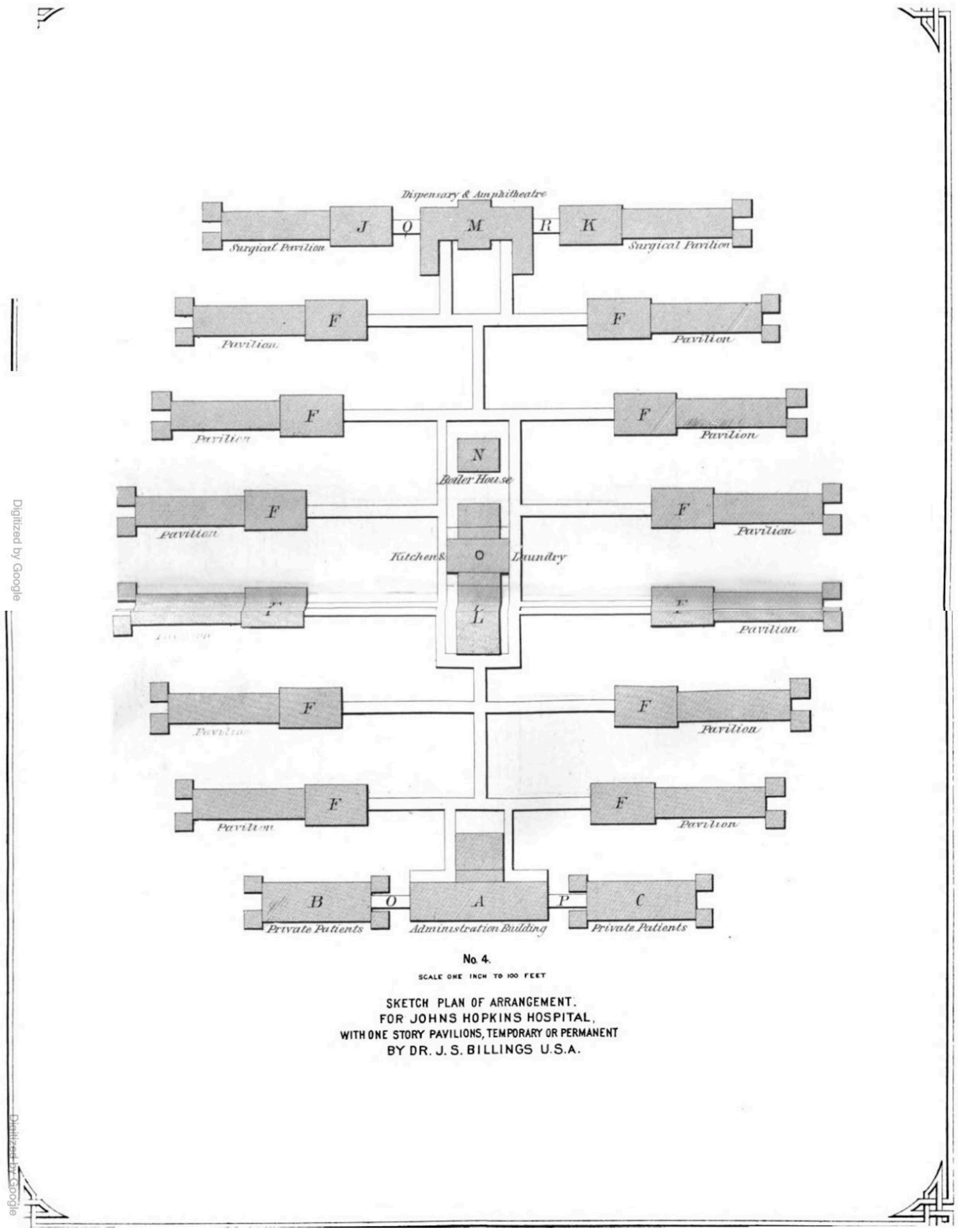



Figure 1.1: John Shaw Billings, "Sketch Plan of Arrangement for Johns Hopkins Hospital with One Story Pavilions, Temporary or Permanent," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

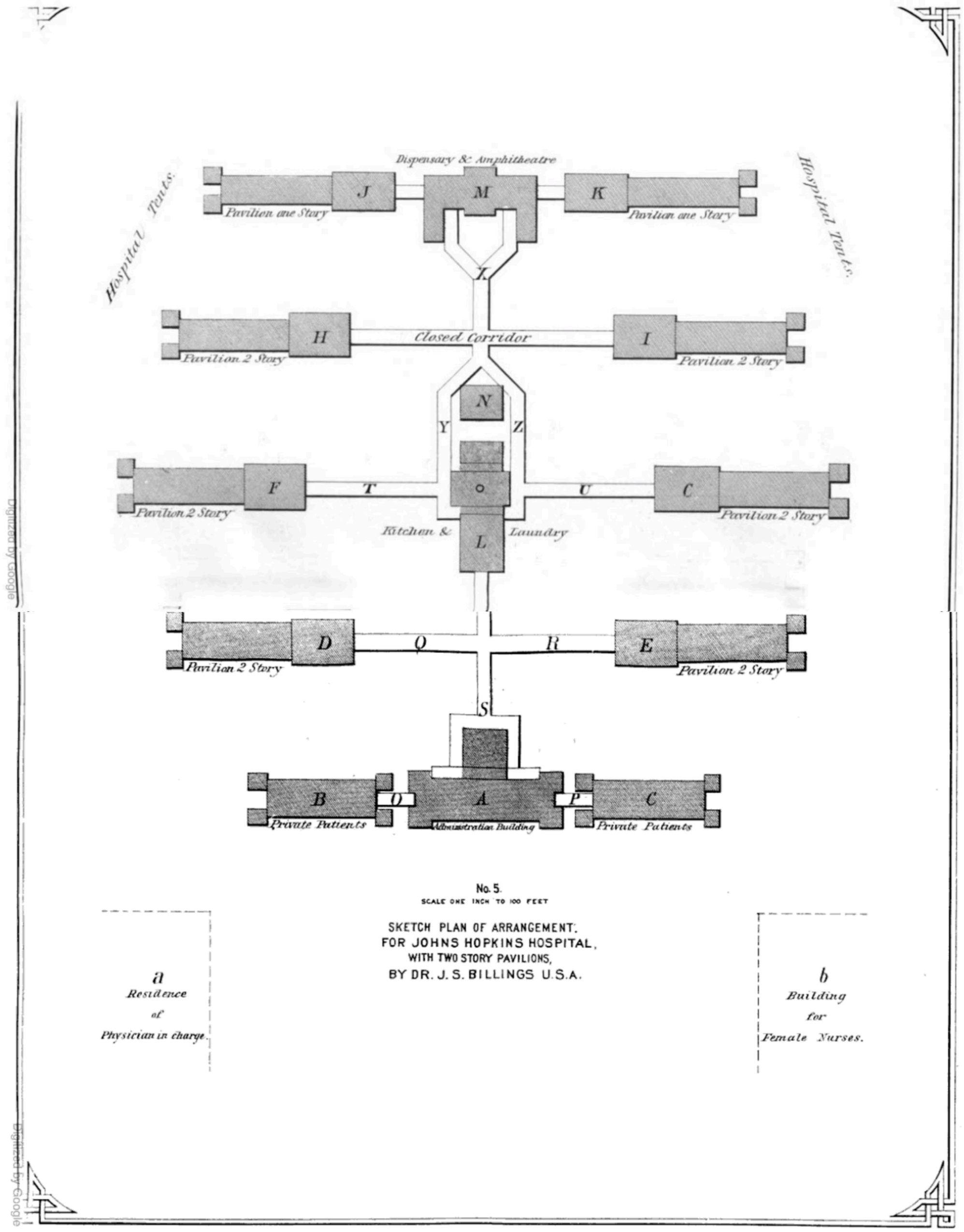



Figure 1.2: John Shaw Billings, "Sketch Plan of Arrangement for Johns Hopkins Hospital with Two Story Pavilions," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

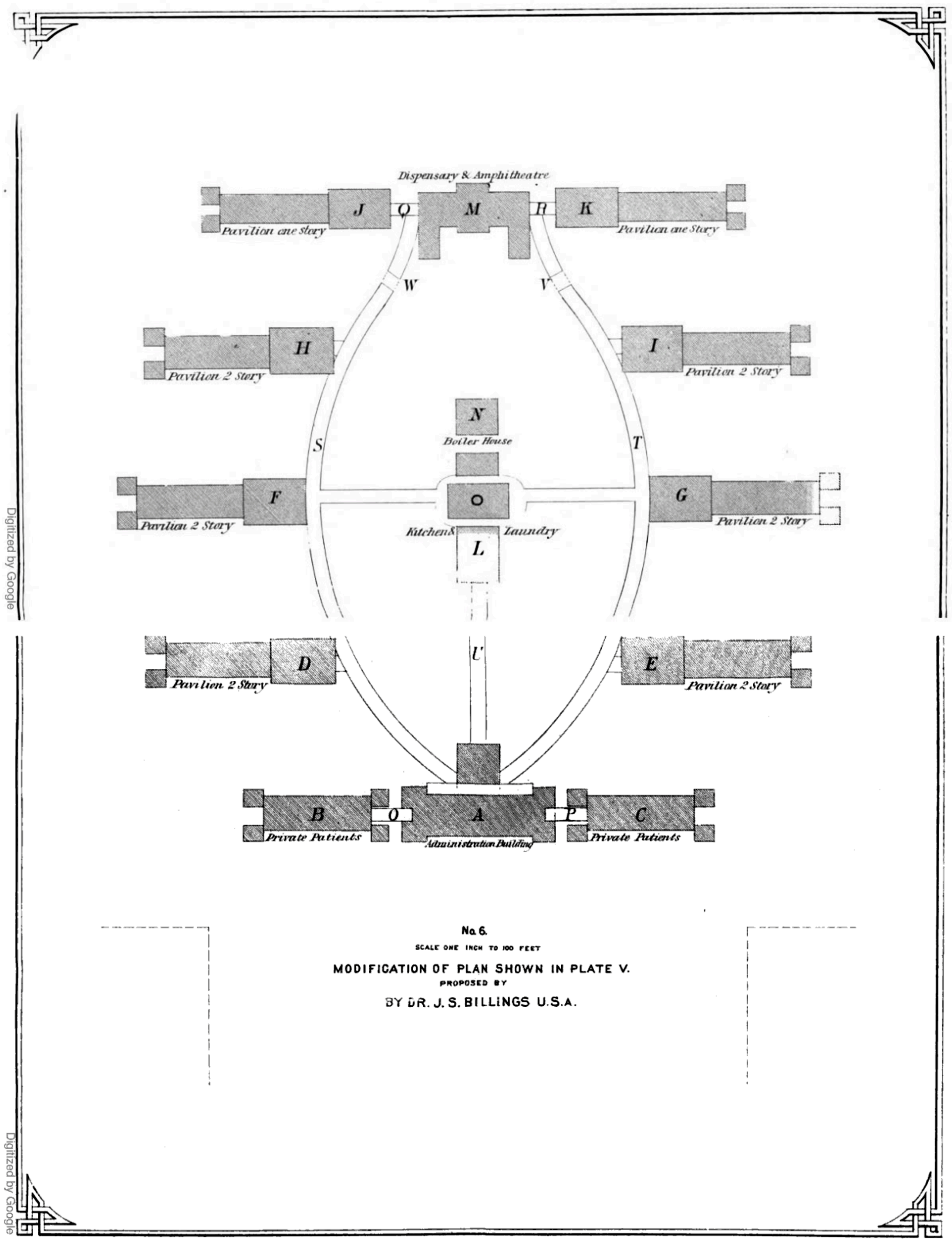



Figure 1.3: John Shaw Billings, "Modification of Plan shown in Plate V," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

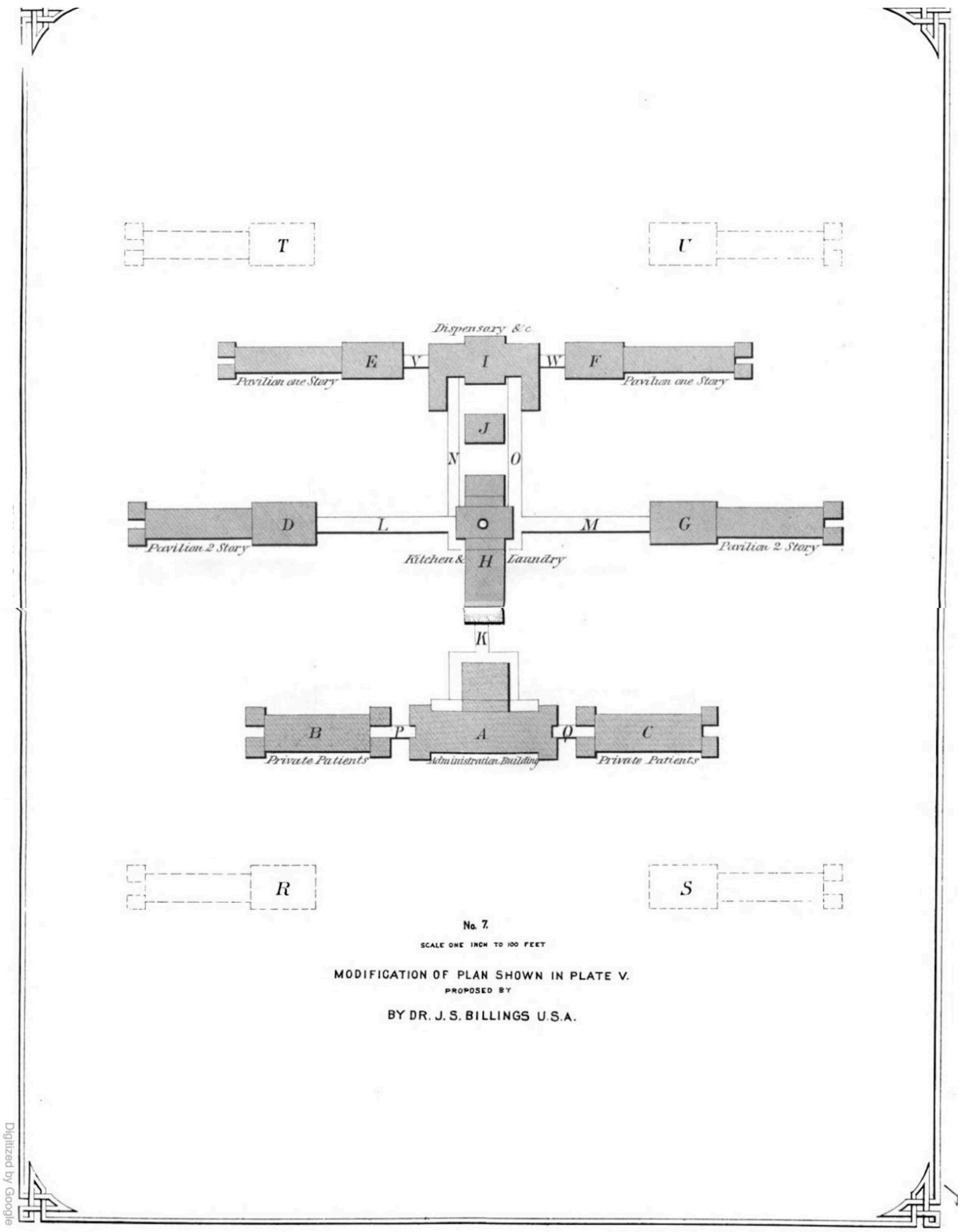



Figure 1.4: John Shaw Billings, "Modification of Plan shown in Plate V," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

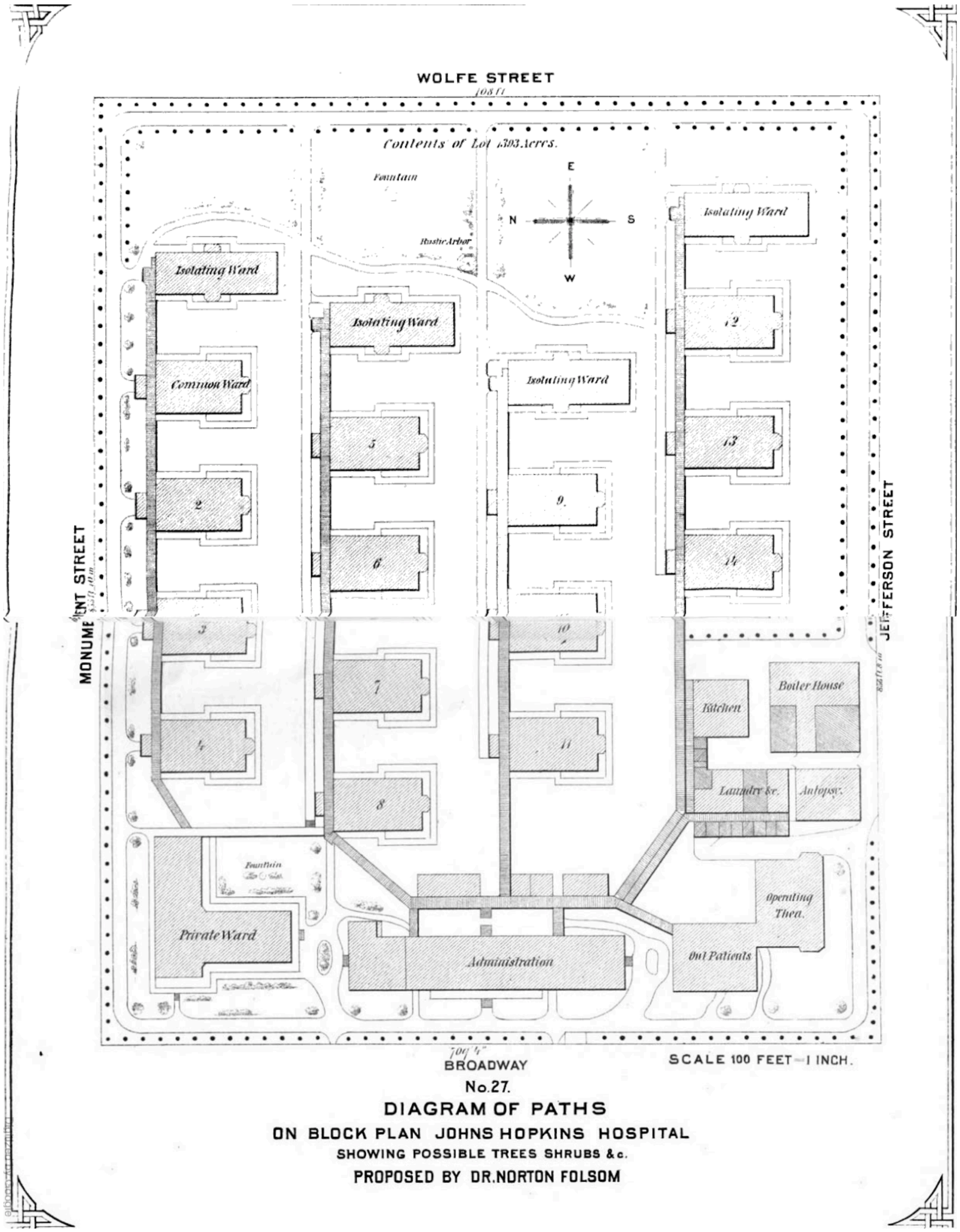



Figure 1.5: Norton Folsom, "Diagram of Paths," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

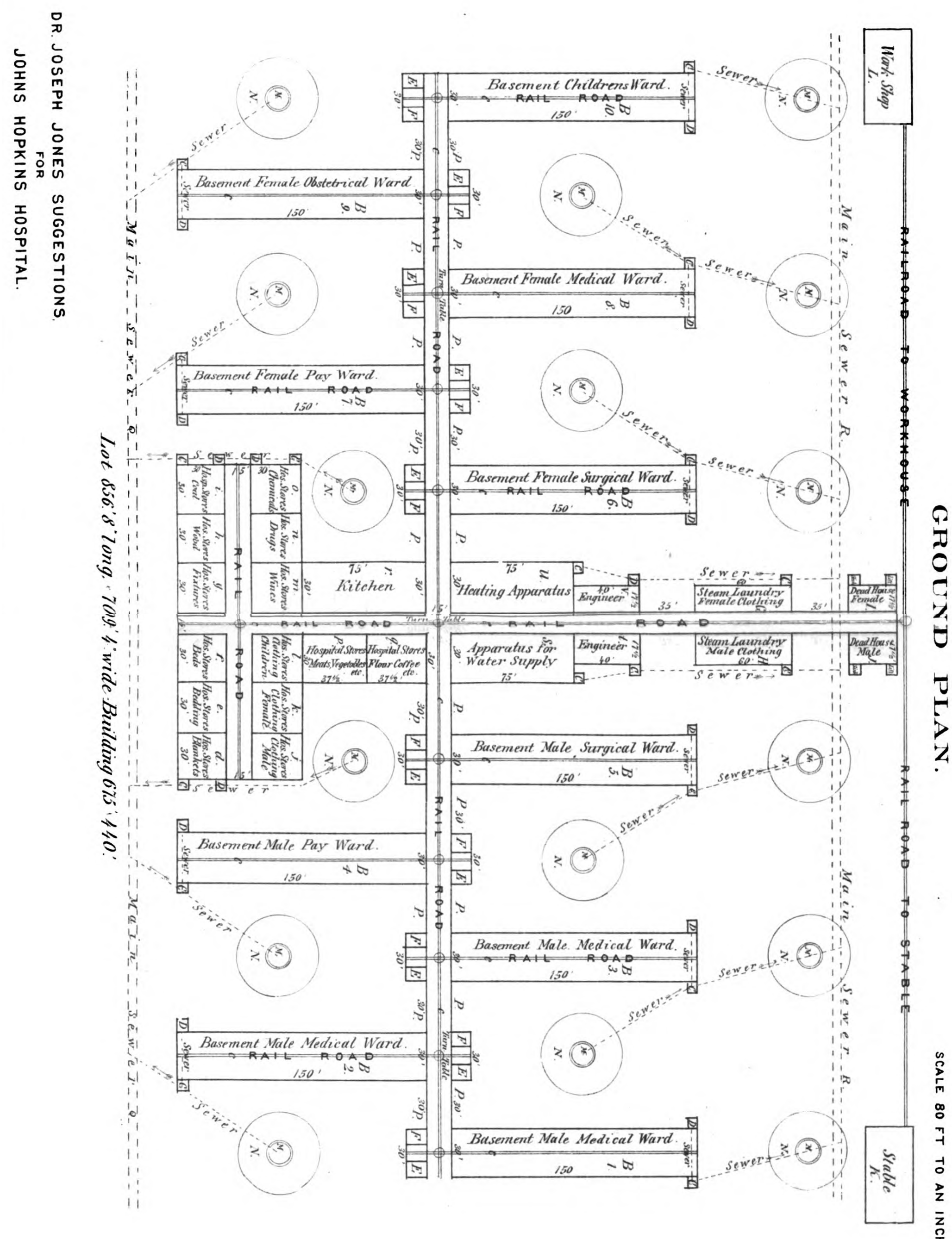



Figure 1.6: Joseph Jones, “Ground Plan,” *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

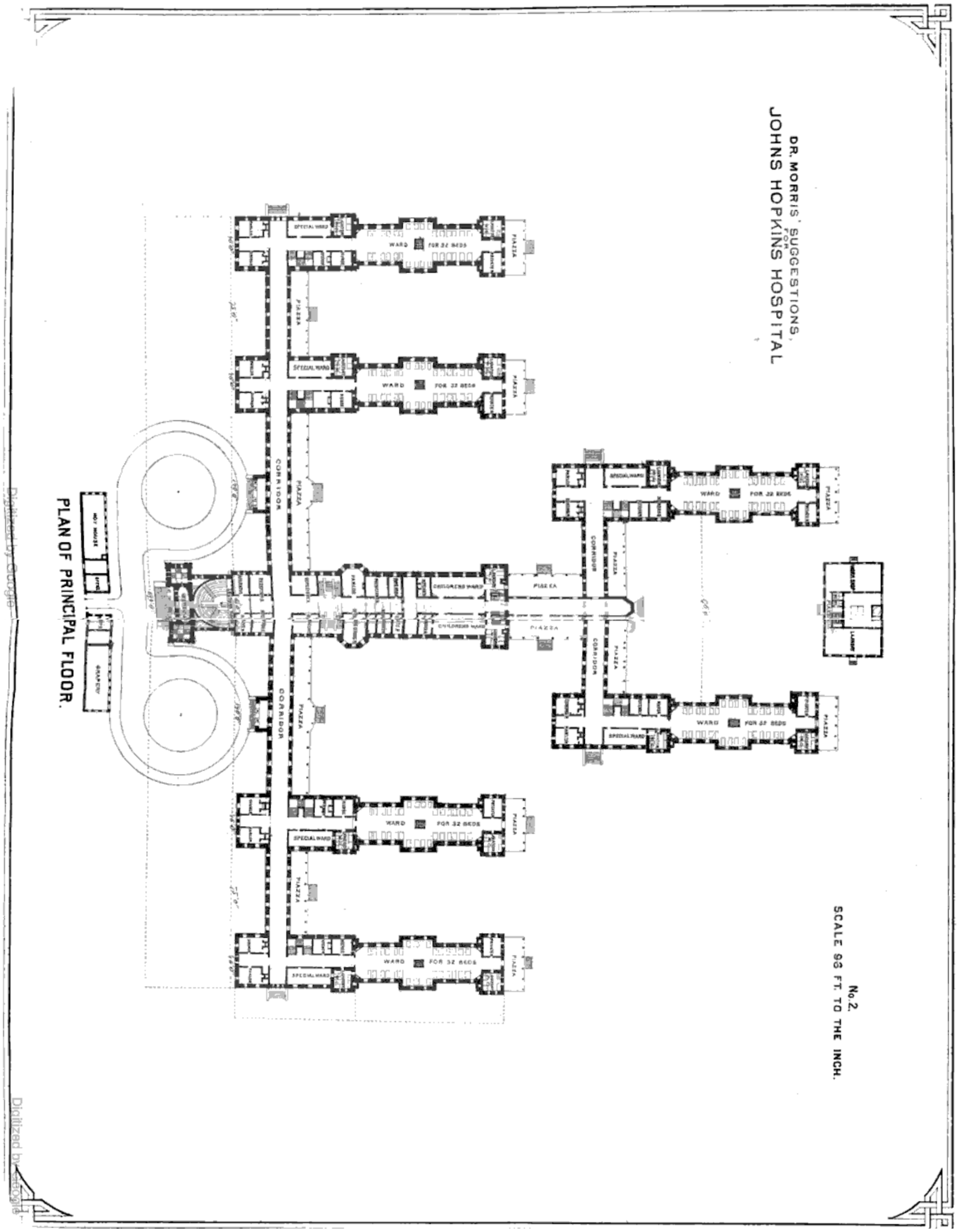



Figure 1.7: Caspar Morris, "Plan of Principal Floor," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

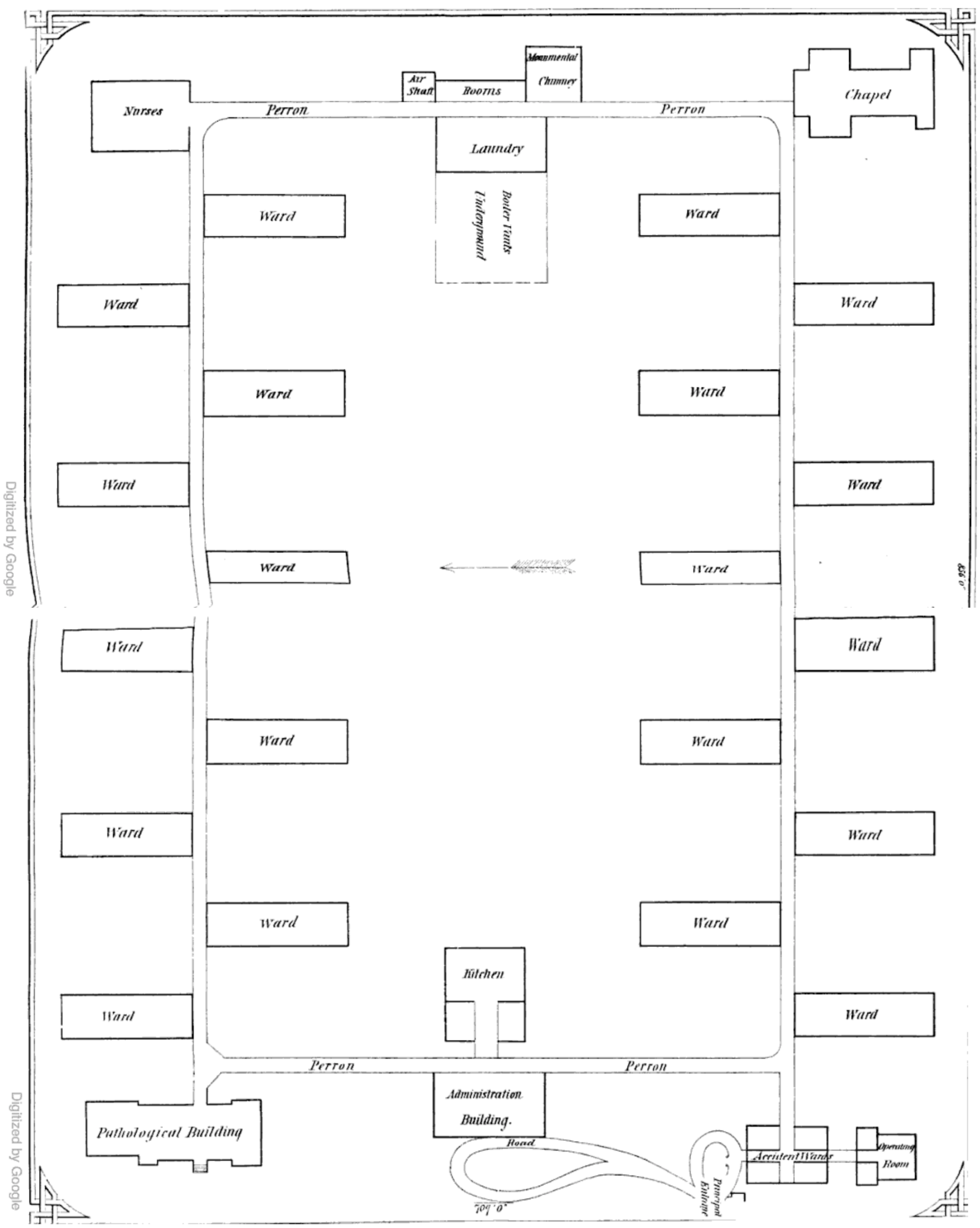



Figure 1.8: Stephen Smith, Proposed Plan (untitled), *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

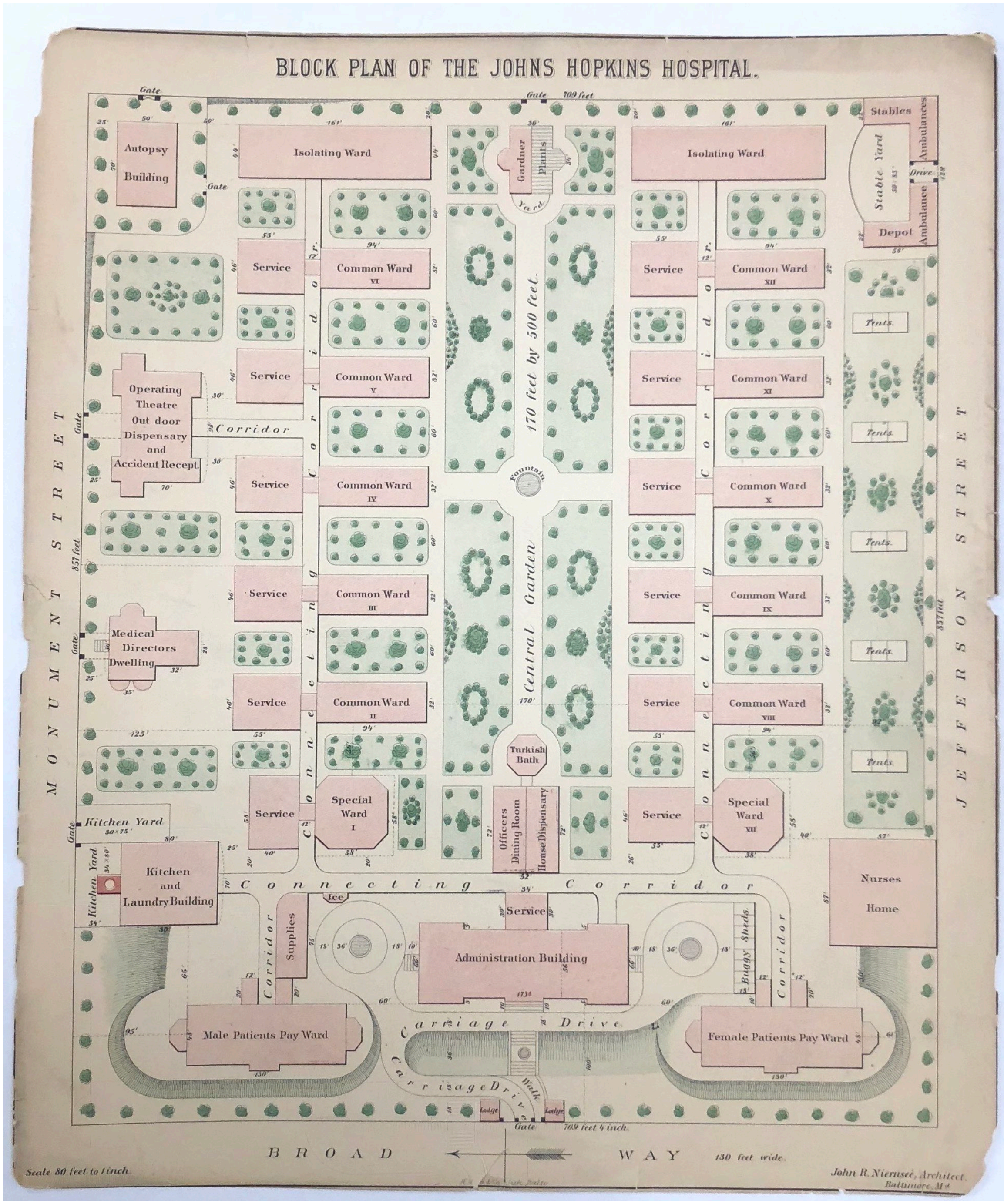



Figure 1.9: John R. Niernsee Architect, "Block Plan of the Johns Hopkins Hospital" 1876, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

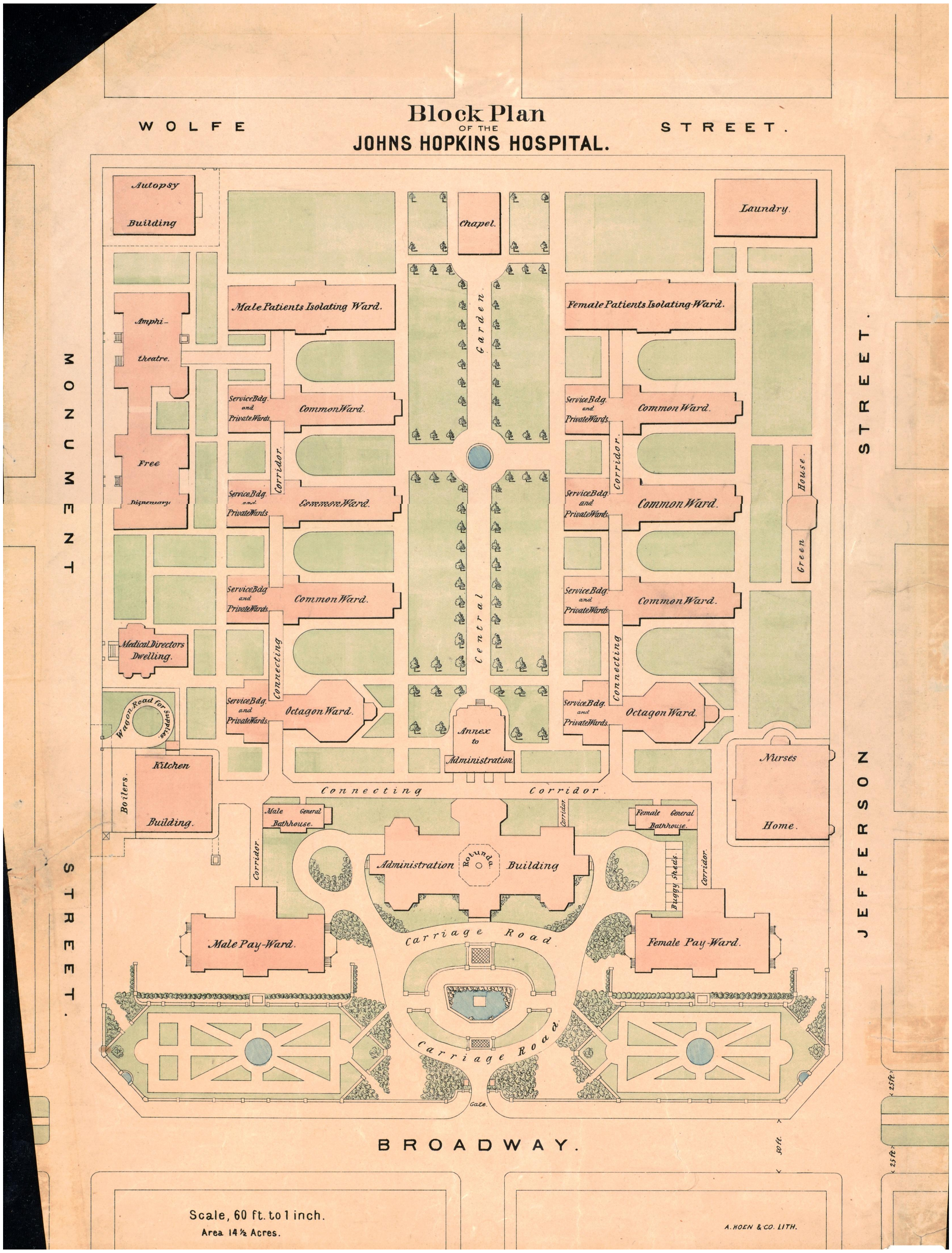



Figure 1.10: Revised "Block Plan of the Johns Hopkins Hospital" 1876, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

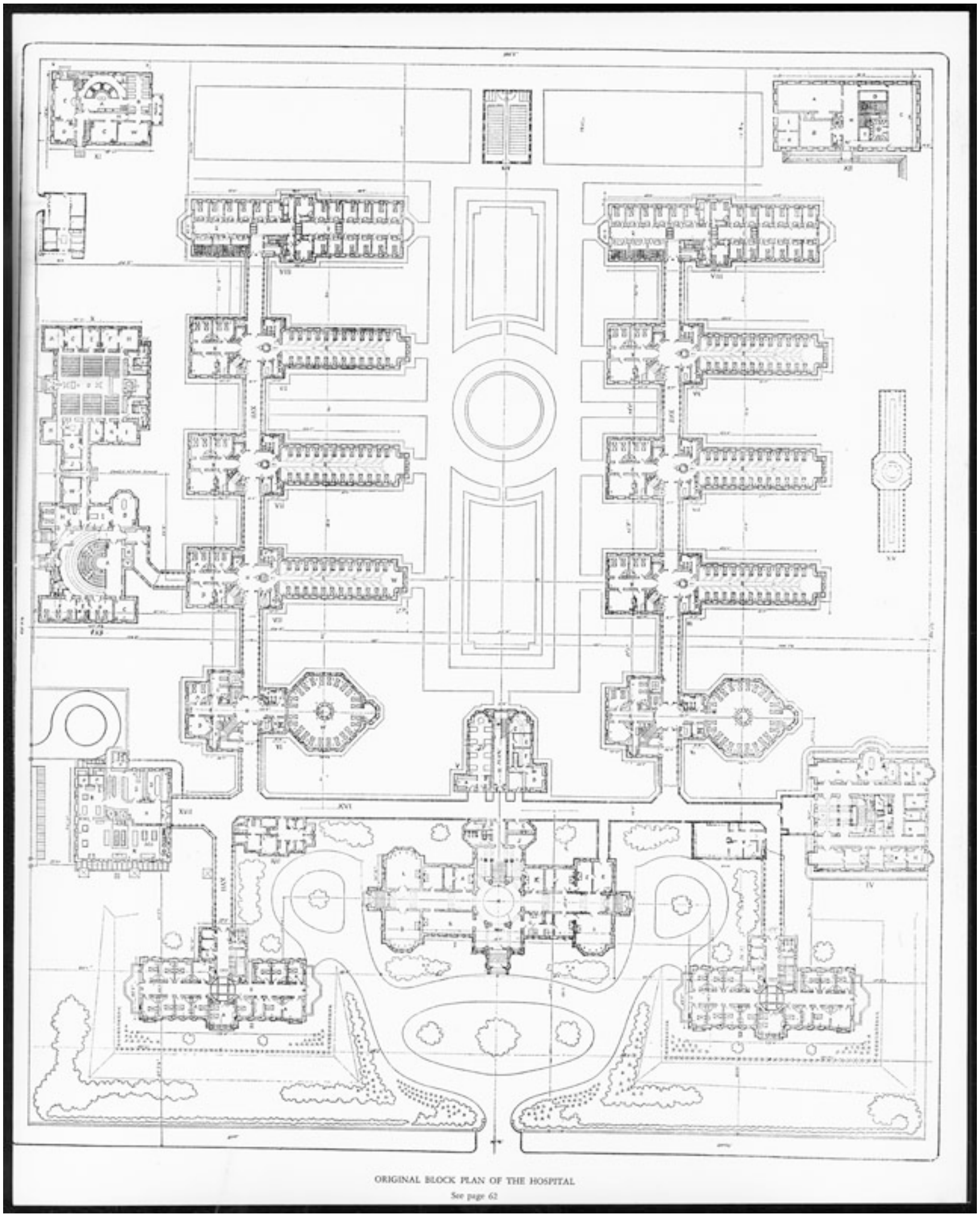



Figure 1.11: "General Block Plan of the Hospital," 1877, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

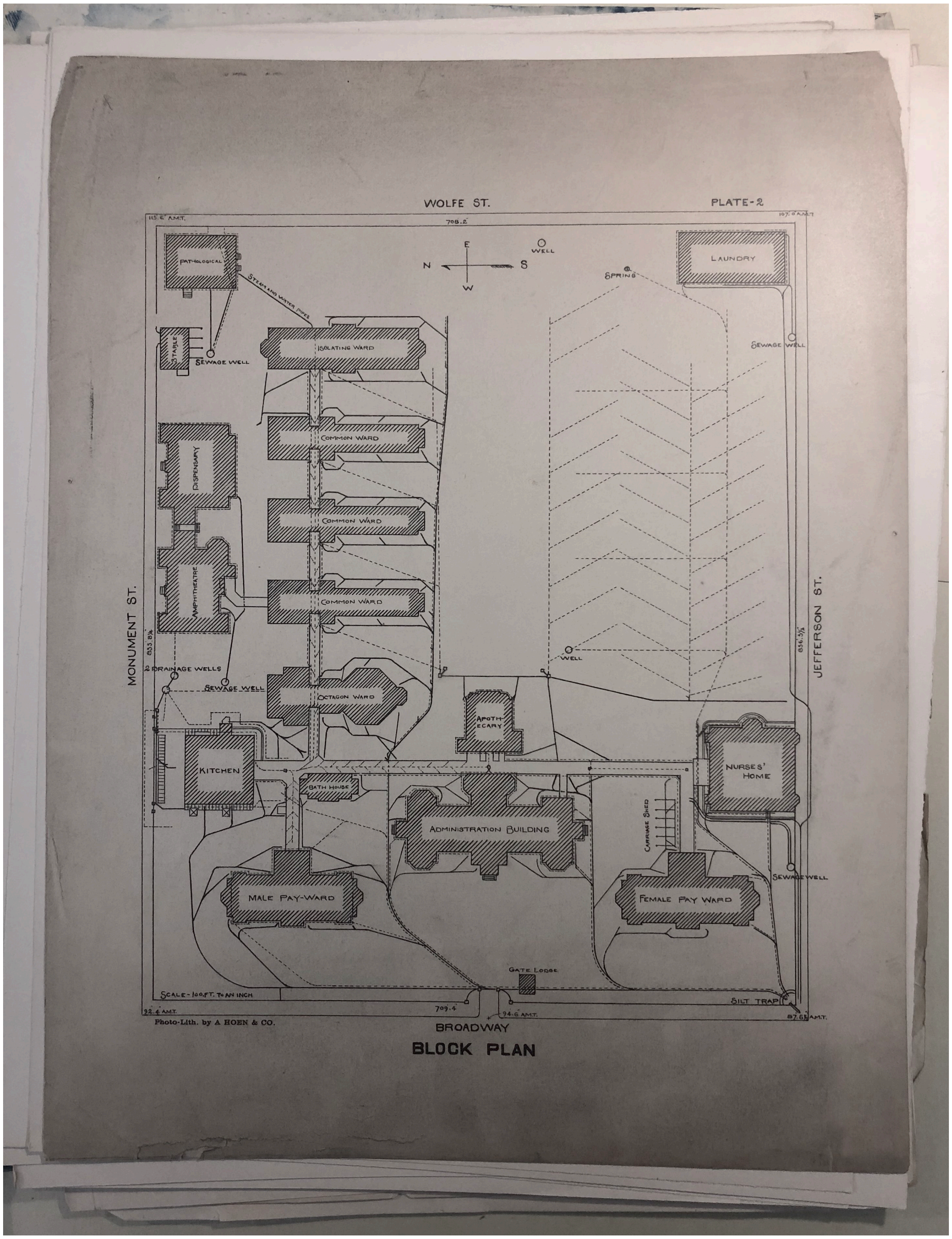



Figure 1.12: "Block Plan," 1889, John Shaw Billings Papers, the New York Public Library, Box. 84.

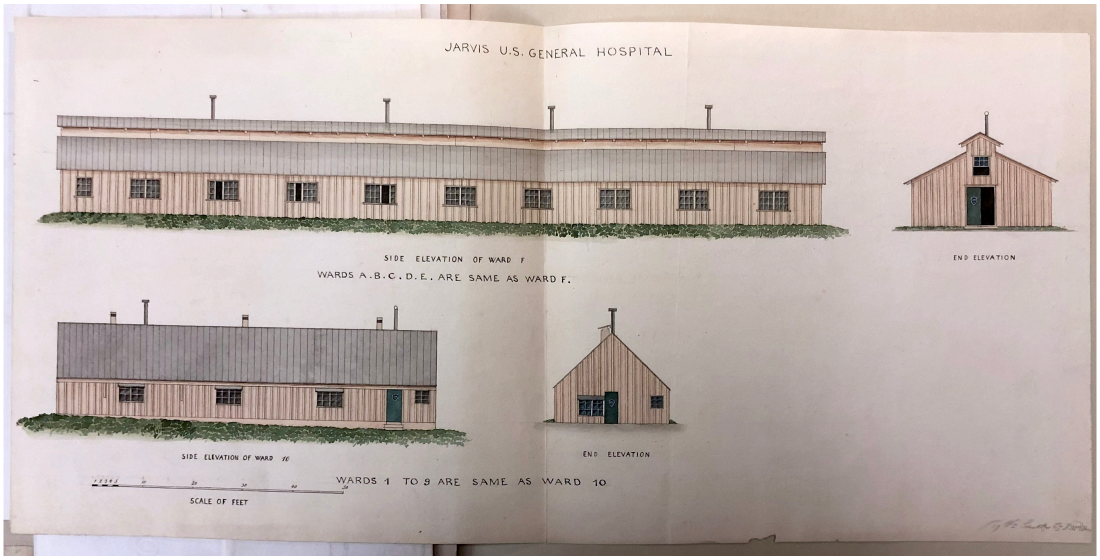



Figure 1.13: Typical Barrack Wards at the Jarvis U.S. General Hospital, Baltimore, MD (built 1861), John Shaw Billings Papers, the New York Public Library, Box. 84.


Figure 1.14: Tent Ward at the Jarvis U.S. General Hospital, Baltimore, MD (built 1861), John Shaw Billings Papers, the New York Public Library, Box. 84.

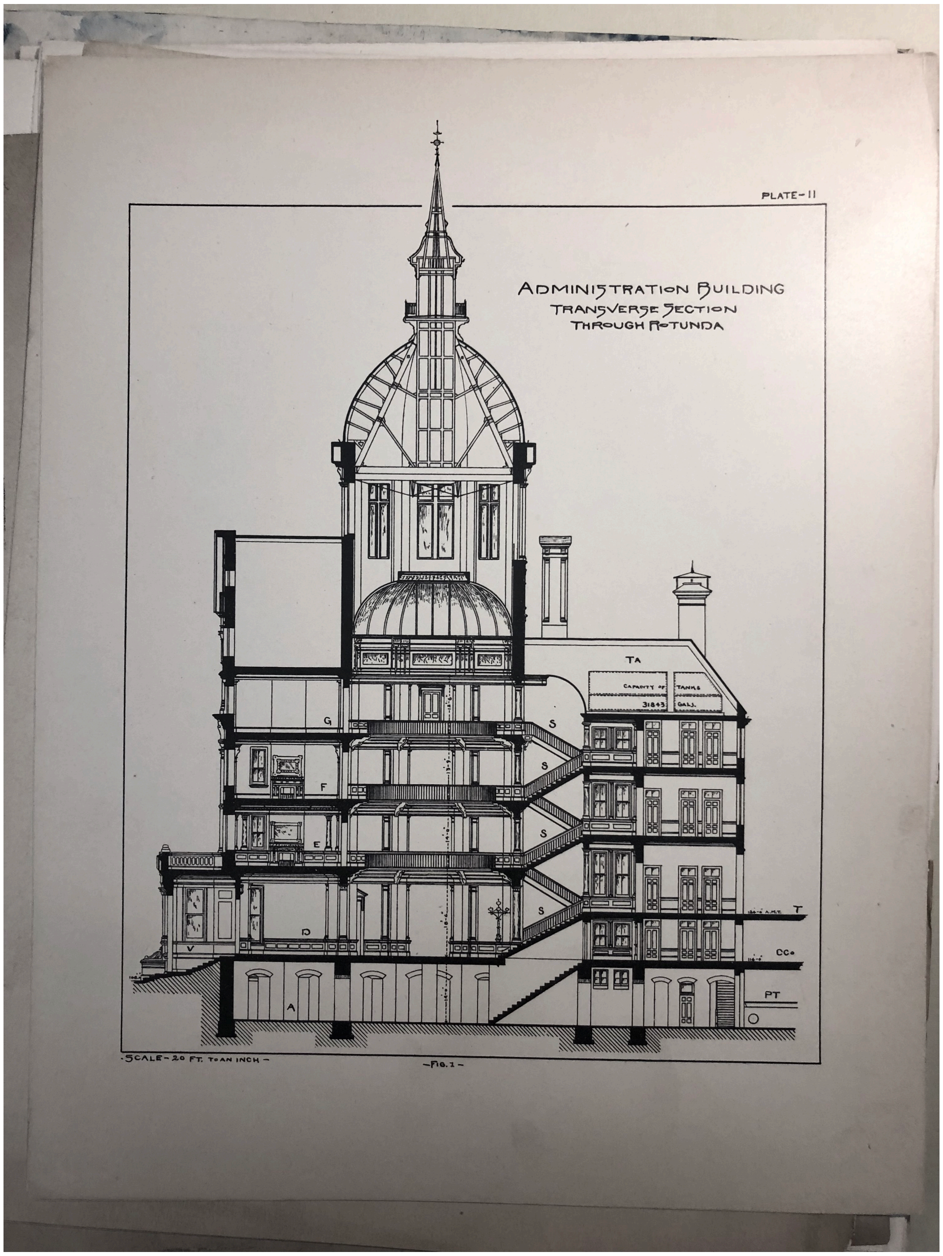



Figure 1.15: “Administration Building Transverse Section through Rotunda” (1889) showing the three-level corridor system on the right with the Terrace (T) on top, the Closed Corridor (CCo) in the middle, and the Pipe Tunnel (PT) at the bottom. John Shaw Billings Papers, the New York Public Library, Box. 84.

Figure 1.16: View of Open Terrace Walk between the Administration Building and the Annex, Johns Hopkins Hospital, circa. 1900, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions, item 148166.


Figure 1.17: "Corridor, Interior View Looking South from Kitchen," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 4.

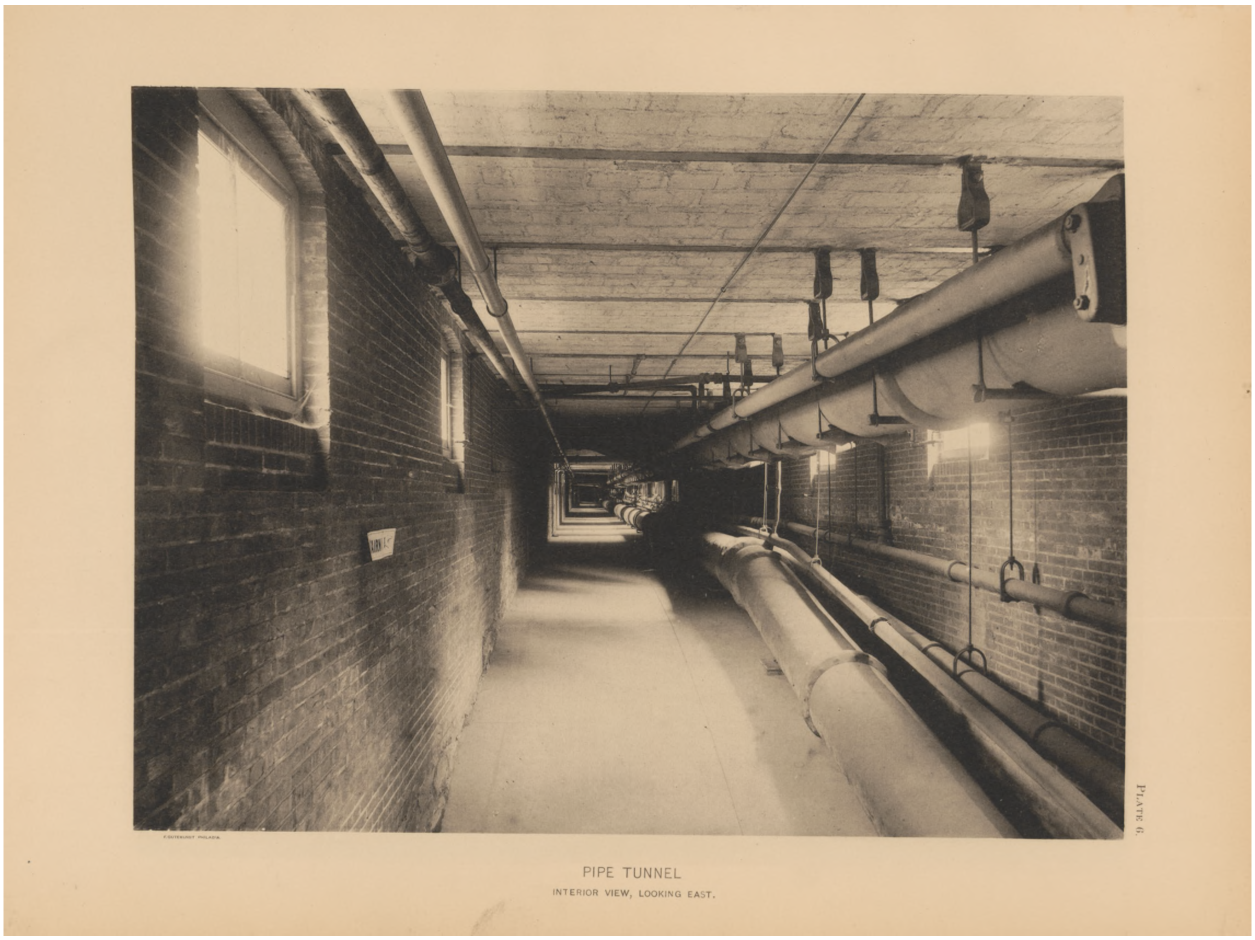



Figure 1.18: "Pipe Tunnel, Interior View, Looking East" (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 6.

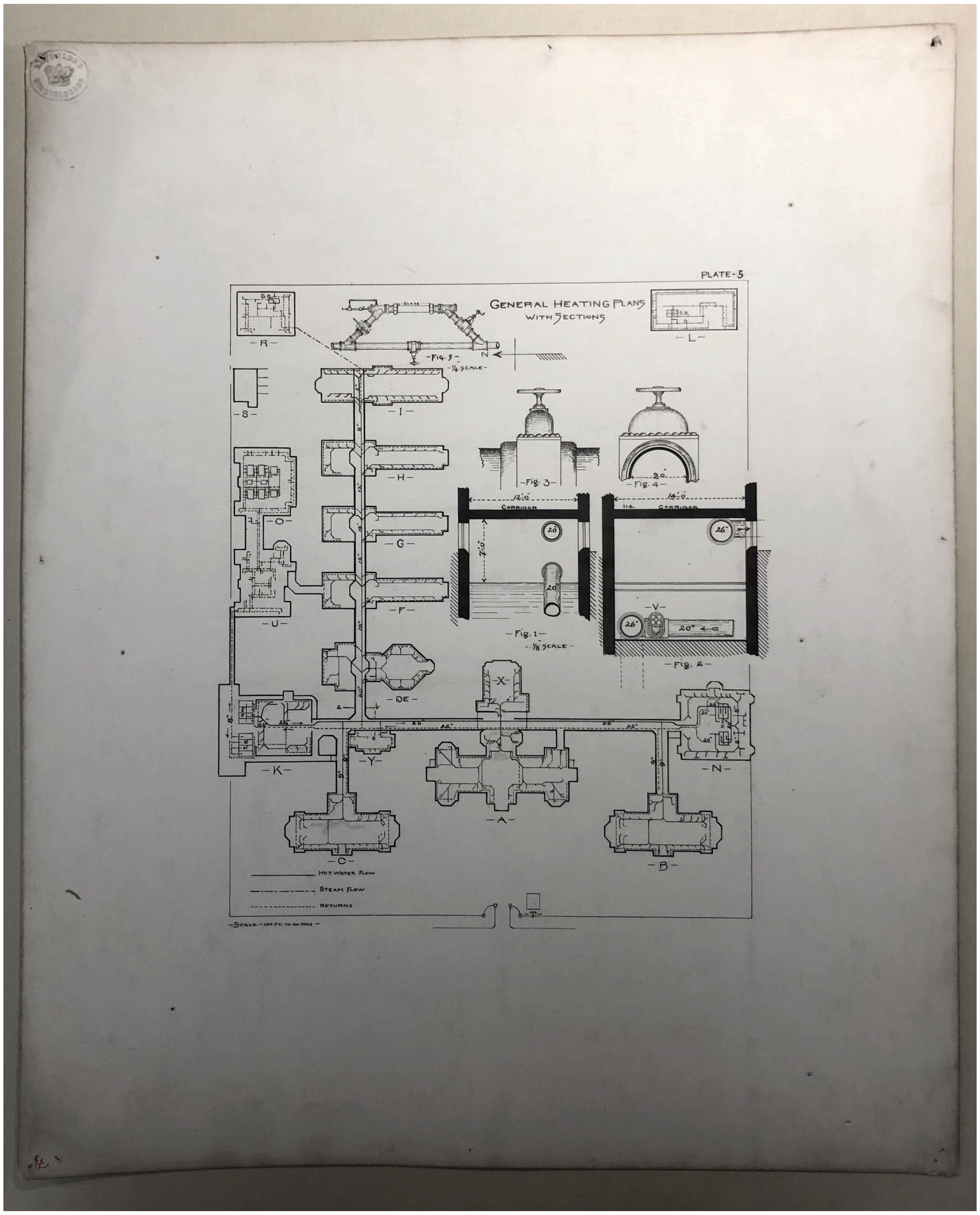



Figure 1.19: “General Heating Plan with Sections,” John Shaw Billings Papers, the New York Public Library, Box. 84.

## RECORD OF OBSERVATIONS

*On Heating and Ventilation, made at the Boston City Hospital during the week ending January 12, 1878.*

| Day of the Month of January | | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|
| Daily mean of Barometer | | 30.10 | 30.43 | 30.66 | 30.45 | 29.75 | 29.17 | 29.93 |
| External Temperature | 7 A. M. | 12. | 6. | 2. | 23. | 32. | 34. | 37. |
| | 2 P. M. | 21. | 13. | 13. | 35. | 38. | 37. | 44. |
| | 9 P. M. | 14. | 5. | 17. | 31. | 42. | 46. | 40. |
| Relative Humidity | 7 A. M. | 61. | 76. | 67. | 73. | 84. | 95. | 63. |
| | 2 P. M. | 36. | 36. | 62. | 49. | 91. | 90. | 37. |
| | 9 P. M. | 64. | 50. | 83. | 79. | 100. | 76. | 65. |
| Direction and Velocity of Wind | 7 A. M. | S. W. 8 | W. 6 | N. W. 6 | S. 4 | N. 4 | W. 12 | N. W. 24 |
| | 2 P. M. | W. 7 | N. W. 16 | S. E. 5 | N. E. 3 | N. E. 17 | S. W. 14 | N. W. 20 |
| | 9 P. M. | N. W. 8 | N. W. 6 | S. 10 | S. 2 | N. E. 40 | N. W. 15 | N. W. 20 |
| Velocity in feet per minute of air intering Ward, at a point 4 inches from centre of Register | 7 A. M. | 240.26 | 211.66 | 170.76 | 224.26 | 178.97 | 132.42 | 151.38 |
| | 2 P. M. | 261.22 | 187.60 | 204.54 | 218.78 | 242.83 | 147.63 | 166.30 |
| | 9 P. M. | 209.04 | 214.76 | 192.85 | 227.64 | 247.52 | 160.16 | 137.47 |
| | Daily mean. | 236.84 | 204.67 | 189.38 | 223.56 | 223.10 | 146.73 | 151.71 |
| Hourly supply per bed | | 7,105 | 6,140 | 5,681 | 6,706 | 6,693 | 6,602 | 6,826 |
| Temperature of air entering Ward | 7 A. M. | 102. | 111. | 108. | 120. | 95. | 85. | 95. |
| | 2 P. M. | 114. | 118. | 109. | 109. | 109. | 85. | 91. |
| | 9 P. M. | 115. | 121. | 122. | 89. | 103. | 90. | 86. |
| Temperature of air at floor of Ward in centre | 7 A. M. | 53. | 63. | 65. | 64. | 65. | 67. | 67. |
| | 2 P. M. | 64. | 63. | 61. | 68. | 64. | 64. | 66. |
| | 9 P. M. | 64. | 66. | 64. | 64. | 64. | 69. | 68. |

## RECORD OF OBSERVATIONS—Continued.

| Day of the Month of January | | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|
| Temperature of air at head of beds | 7 A. M. | 57. | 67. | 67. | 70. | 68. | 69. | 70. |
| | 2 P. M. | 69. | 68. | 67. | 72. | 70. | 71. | 71. |
| | 9 P. M. | 68. | 70. | 70. | 68. | 71. | 71. | 69. |
| Temperature of air in ridge, Ventilating chamber | 7 A. M. | 73. | 80. | 69. | 81. | 78. | 81. | 83. |
| | 2 P. M. | 86. | 80. | 77. | 94. | 87. | 89. | 83. |
| | 9 P. M. | 87. | 77. | 83. | 78. | 84. | 87. | 82. |
| Velocity of air in outlets in ceiling | 7 A. M. | 101.40 | 97. | 338.91 | ...... | 268.83 | 97.53 | 91.40 |
| | 2 P. M. | 112.60 | 103.26 | 318.91 | 122.83 | 143.75 | 91.73 | 105.93 |
| | 9 P. M. | 71.80 | 342.41 | 1541.66 | 124.50 | 140.86 | 106.53 | 103.20 |
| Volume of air discharged per hour | | 292,756 | 260,094 | 199,799 | 377,657 | 434,584 | 307,201 | 305,919 |
| Volume of air entering Ward per hour by Registers | | 198,945 | 171,922 | 159,079 | 187,790 | 187,404 | 184,798 | 191,154 |
| Estimated consumption of coal per hour, lbs* | | 51.19 | 60.71 | 52.33 | 40.47 | 27.38 | .......... | .......... |
| Relative Humidity in Ward | 7 A. M. | 23. | 22. | 20. | 35. | 24. | 40. | 33. |
| | 2 P. M. | 18. | 18. | 18. | 29. | 33. | 32. | 26. |
| | 9 P. M. | 18. | 17. | 27. | 29. | 32. | 26. | 39. |
| Relative Humidity in Ventilating Chamber | 7 A. M. | 9. | 69. | 8. | 25. | 44. | 37. | 22. |
| | 2 P. M. | 41. | 39. | 13. | 46. | 33. | 47. | 33. |
| | 9 P. M. | 41. | 39. | 26. | 48. | 20. | 27. | 23. |

* Estimated by weighing condensed water from return steam pipe.

Figure 1.20: "Record of Observations on Heating and Ventilation, made at the Boston City Hospital during the week ending January 12, 1878," John S. Billings, *Reports and Papers Relating to Construction and Organization,* No. 5 (Johns Hopkins Hospital, February 12, 1878), 67-68.

## *Meteorological Record of the Weather at Baltimore, Maryland, for* 1871, 1872, 1873, *and* 1874.

| | Temperature. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Monthly. | | | | Highest and Lowest. | | | | | | | |
| | 1871. | 1872. | 1873. | 1874. | 1871. | | 1872. | | 1873. | | 1874. | |
| January...... | 36.1 | 35.0 | 34.0 | 39.1 | 64° | 11° | 56° | 11° | 58° | -4° | 69° | 13° |
| February..... | 40.8 | 36.0 | 35.5 | 37.3 | 67 | 8 | 61 | 14 | 62 | 2 | 78 | 15 |
| March........ | 49.7 | 37.0 | 40.3 | 43.7 | 71 | 29 | 65 | 9 | 68 | 5 | 72 | 23 |
| April......... | 58.9 | 56.0 | 51.9 | 46.9 | 85 | 40 | 88 | 38 | 75 | 38 | 68 | 27 |
| May.......... | 66.0 | 68.0 | 62.3 | 63.1 | 92 | 47 | 89 | 48 | 89 | 44 | 89 | 41 |
| June.......... | 74.7 | 75.2 | 73.9 | 75.9 | 93 | 59 | 94 | 58 | 95 | 49 | 97.5 | 54 |
| July ........ | 75.3 | 81.2 | 79.4 | 77.3 | 93 | 60 | 97 | 68 | 96.5 | 62 | 95.5 | 62.5 |
| August....... | 77.7 | 79.3 | 76.3 | 72 8 | 92 | 63 | 96 | 62 | 94 | 57 | 97 | 52 |
| September ... | 63.7 | 69.5 | 68.0 | 69 9 | 83 | 45 | 94 | 50 | 93 | 40 | 90 | 53 |
| October...... | 59.0 | 58.3 | 54.8 | 56.6 | 78 | 40 | 80 | 38 | 73.5 | 30 | 78 | 35 |
| November.... | 45.0 | 43.6 | 41.0 | 45.3 | 69 | 28 | 63.5 | 17 | 64 | 22 | 71 | 24 |
| December.... | 33.0 | 32.2 | 40.4 | 39.0 | 53 | 5 | 55 | 8.5 | 66.5 | 22.5 | 67 | 21 |
| **Yearly Mean..** | 56.6 | 55.9 | 54.8 | 55.5 | 78.3 | 36.2 | 78.2 | 35.1 | 77.8 | 30.6 | 81 | 35 |

| | Moisture. Mean Monthly. | | | | Wind. Mean Direction. | | | |
|---|---|---|---|---|---|---|---|---|
| | 1871. | 1872. | 1873. | 1874. | 1871. | 1872. | 1873. | 1874. |
| January.......... | 65.6 | 62.8 | 65.5 | 72.9 | N.E. | N.W. | N.W. | W. |
| February......... | 66.6 | 60.3 | 61.1 | 71.3 | N.E. | N.W. | N.W. | N.W. |
| March........... | 82.4 | 58.6 | 55.6 | 67.2 | S.E. | N.W. | N.W. | N.W. |
| April............. | 65.3 | 47.4 | 57.3 | 66.5 | W. | W. | N. | N.E. |
| May.............. | 65.9 | 51.5 | 65.5 | 59.7 | N.E. | N.W. | E. | S.E. |
| June............. | 69.0 | 61.3 | 64.8 | 64.8 | S.W. | S.W. | S. | S.E. |
| July ............ | 66.1 | 62.6 | 62 9 | 64.5 | N.W. | S.W. | W. | S.W. |
| August........... | 72.6 | 66.1 | 78.5 | 61.4 | S.E. | S.W. | N.E. | N. |
| September........ | 67.8 | 66.6 | 76.8 | 72.1 | N. | N. | N. | E.S.E. |
| October .......... | 68.8 | 62.5 | 75.1 | 65.4 | N.W. | N.W. | N.W. | N.W. |
| November.. ..... | 66.7 | 57.0 | 70.6 | 63.5 | N.W. | N.W. | W. | N.W. |
| December ........ | 65.0 | 58.4 | 71.6 | 63.6 | S.W. | W. | N.W. | N.W. |
| **Yearly Mean......** | 69.3 | 59.6 | 67.1 | 66.1 | N.W. | N.W. | N.W. | N.W. |

| | Number of Days on which Rain fell. | | | | Rain-Fall (for 50 Years). | | | Temperature. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Extreme Fall. | | |
| | 1871. | 1872. | 1873. | 1874. | Mean. | Max. | Min. | Mean. |
| January...... | 5 | 8 | 13 | 12 | 2.85 | 6.10 | 1.02 | 32.0° |
| February..... | 7 | 8 | 12 | 7 | 3.23 | 4.90 | 0.94 | 34.0 |
| March........ | 10 | 14 | 8 | 8 | 3.71 | 6.30 | 1.70 | 42.0 |
| April......... | 7 | 10 | 14 | 15 | 2.20 | 9.10 | 0.41 | 52.5 |
| May.......... | 6 | 9 | 14 | 10 | 3.65 | 5.77 | 1.19 | 63.0 |
| June......... | 8 | 9 | 8 | 10 | 3.66 | 9.20 | 0.60 | 71.5 |
| July......... | 15 | 10 | 11 | 9 | 3.85 | 6.89 | 1.26 | 76.5 |
| August....... | 12 | 18 | 21 | 10 | 4.30 | 9.10 | 0.31 | 74.7 |
| September.... | 4 | 9 | 14 | 11 | 4.45 | 10.50 | 0.50 | 67.5 |
| October...... | 10 | 8 | 11 | 2 | 2.98 | 7.35 | 1.30 | 55.5 |
| November.... | 10 | 8 | 10 | 8 | 3.20 | 7.90 | 1.06 | 45.0 |
| December.... | 10 | 11 | 11 | 14 | 2.90 | 8.80 | 1.50 | 35.0 |
| Total for the year....... | 104 | 122 | 147 | 116 | 40.98 | | | 54.1 |
| Mean of Spring............. | | | | | 9.56 | .... | .... | 52.5 |
| " " Summer............. | | | | | 11.81 | .... | .... | 74.23 |
| " " Autumn............. | | | | | 10.63 | .... | .... | 56.00 |
| " " Winter............. | | | | | 8.98 | .... | .... | 33.66 |

| | Rain-fall. | Temperature. | | |
|---|---|---|---|---|
| | Inches. | Max. | Min. | Mean. |
| 1817 | 48.55 | 92 | −4 | |
| 1818 | 32.60 | 94 | −2 | |
| 1819 | 28.75 | 98 | 10 | |
| 1820 | 42.50 | 98 | −2 | |
| 1821 | 50.20 | 95 | −6 | |
| 1822 | 29.20 | 92 | 8 | 53.3 |
| 1823 | 44.55 | 93 | 18 | 55.2 |
| 1824 | 42.28 | 90 | 11 | 56.4 |
| 1825 | 24.45 | 94 | 10 | 53.5 |
| 1826 | | 96 | Zero. | 53.9 |
| 1827 | 26.39 | 98 | 9 | 52.1 |
| 1828 | 23.55 | 94 | 16 | 55.7 |
| 1829 | 43.09 | 92 | 8 | 52.6 |
| 1830 | | 98 | 4 | 54.9 |
| 1831 | 54.15 | 93 | Zero. | 53.7 |
| 1832 | 53.05 | 91 | Zero. | 53.9 |
| 1833 | 55.24 | 94 | 10 | 53.7 |
| 1834 | 55.68 | 100 | 10 | 54.6 |
| 1835 | 52.99 | 91 | −10 | 53.6 |
| 1836 | 51.55 | 92 | 1 | 51.0 |
| 1837 | 45.00 | 98 | 5 | 53.1 |
| 1838 | 47.10 | 102 | 10 | 53.1 |
| 1839 | 51.70 | 96 | 4 | 54.5 |
| 1840 | 37.50 | 91 | Zero. | 52.9 |
| 1841 | 43.90 | 95 | Zero. | 52.1 |
| 1842 | 35.10 | 92 | 10 | 54.0 |
| 1843 | 48.79 | 92 | 3 | 52.9 |
| 1844 | 32.46 | 94 | 5 | 53.3 |
| 1845 | 28.39 | 97 | 9 | |
| 1846 | 46.66 | 95 | 8 | 53.6 |
| 1847 | 33.01 | 98 | 10 | 54.6 |
| 1848 | 34.42 | 99 | 12 | 56.2 |
| 1849 | 30.63 | 100 | 6 | 55.2 |
| 1850 | 44.80 | 92 | 12 | 56.4 |
| 1851 | 38.10 | 92 | 7 | 56.2 |
| 1852 | 51.50 | 89 | −5 | 53.9 |
| 1853 | 36.00 | 91 | 9 | 55.3 |
| 1854 | 59.02 | 98 | 14 | 55.6 |
| 1855 | 29.03 | 95 | 4 | 54.84 |
| 1856 | 22.09 | 92 | −6 | 53.09 |
| 1857 | 38.04 | 92 | −6 | 53.97 |
| 1858 | 40.10 | 94 | 10 | 55.78 |
| 1859 | 51.45 | 96 | 5 | 55.10 |
| 1860 | | | | |
| 1861 | | 90 | | 55.66 |
| 1862 | | | | |
| 1863 | | | | |
| 1864 | | 97 | 8 | 56.27 |
| 1865 | | 96 | 5 | 57.16 |
| 1866 | | | | |
| 1867 | | 92 | 10 | 54.66 |
| 1868 | | 97 | 5 | 54.33 |
| 1869 | | 95 | 19 | 55.46 |
| 1870 | | 95 | 12 | 57.53 |

Figure 2.1: John Shaw Billings, “Meteorological Record of the Weather at Baltimore, Maryland, for 1871, 1872, 1873, and 1874,” *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

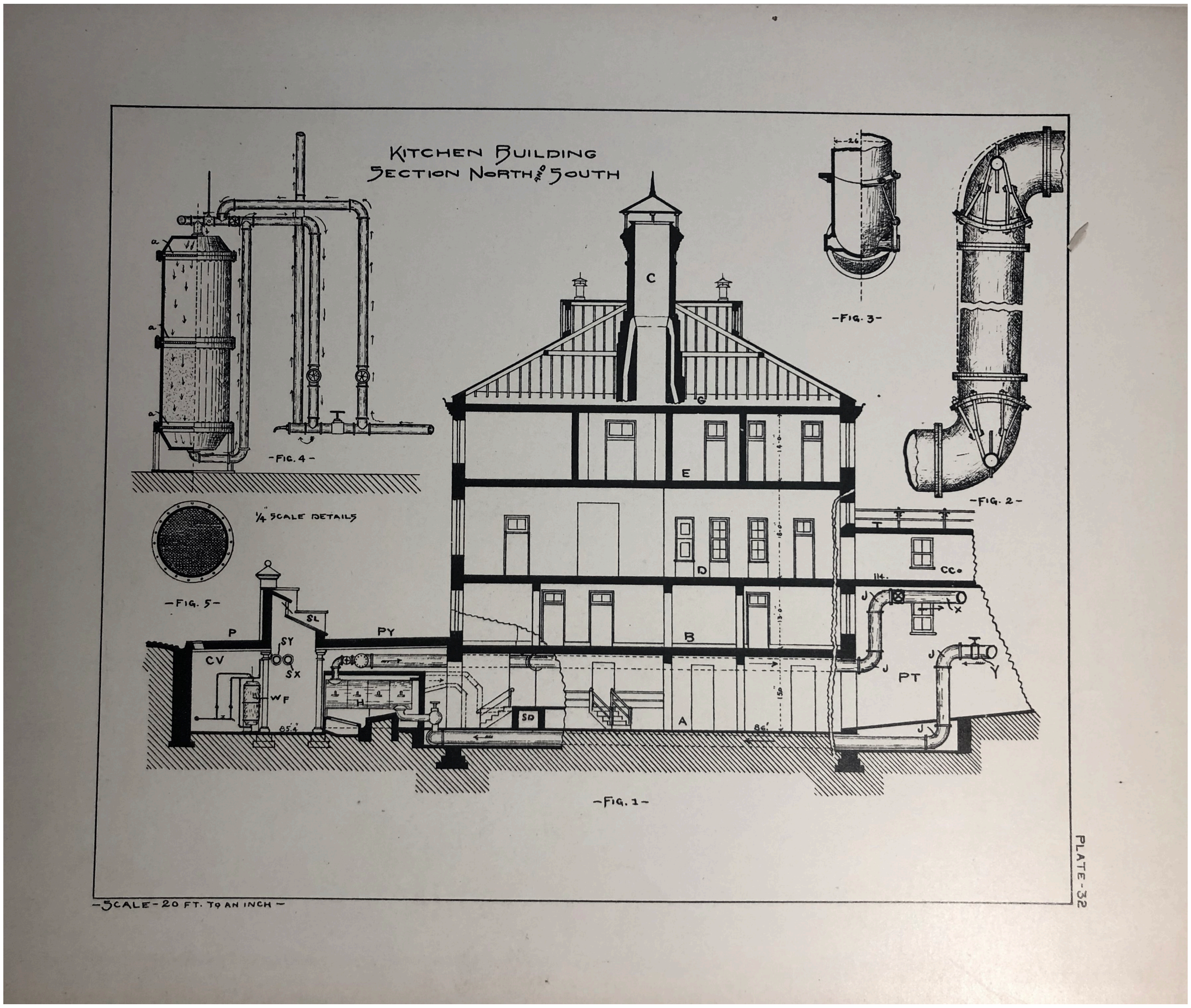



Figure 2.2: John S. Billings and John R. Niernsée, “Kitchen Building Section North and South” showing the boilers in the cellar, John Shaw Billings Papers, the New York Public Library, Box. 84.

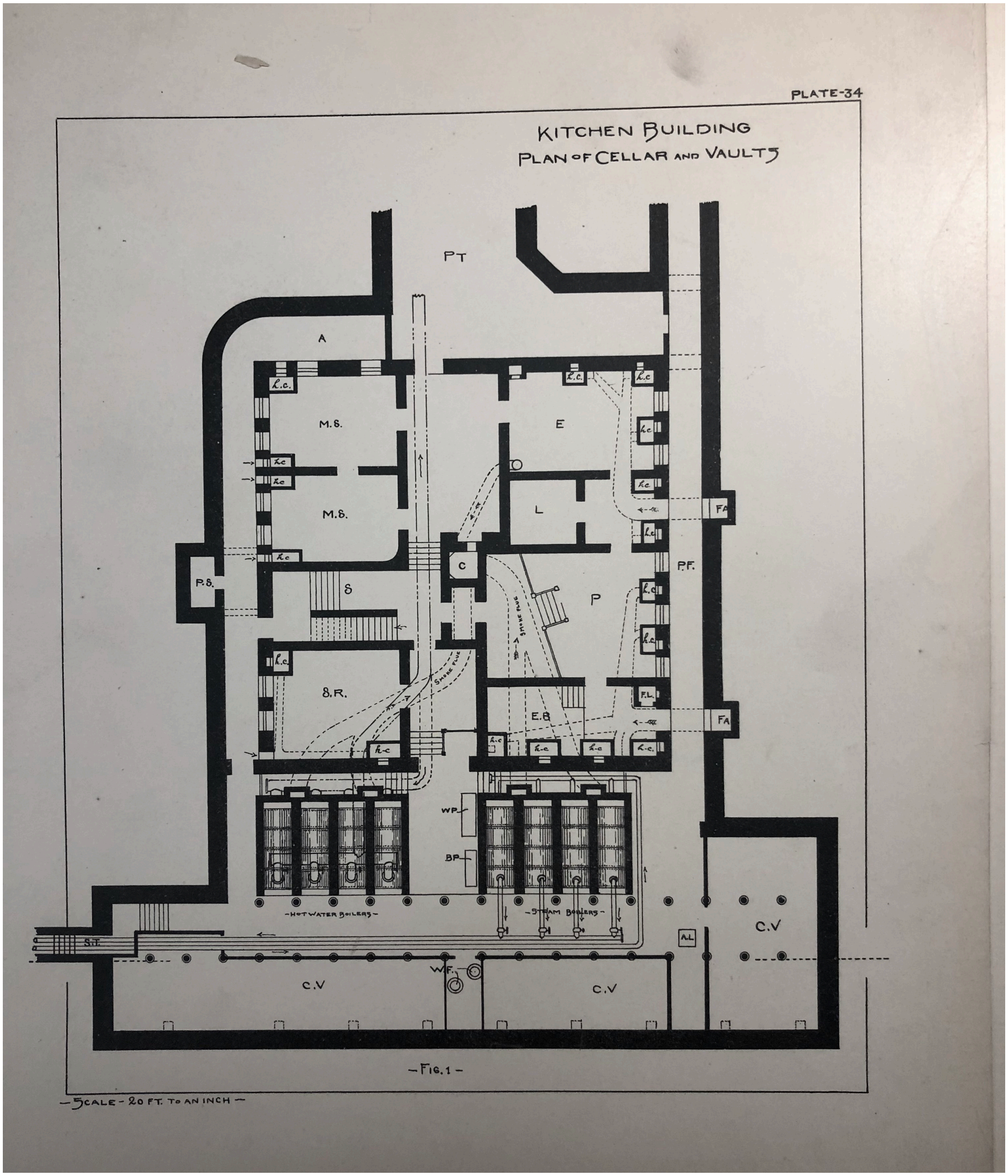



Figure 2.3: John S. Billings and John R. Niernsée, "Kitchen Building Plan of Cellar and Vaults," John Shaw Billings Papers, the New York Public Library, Box. 84.

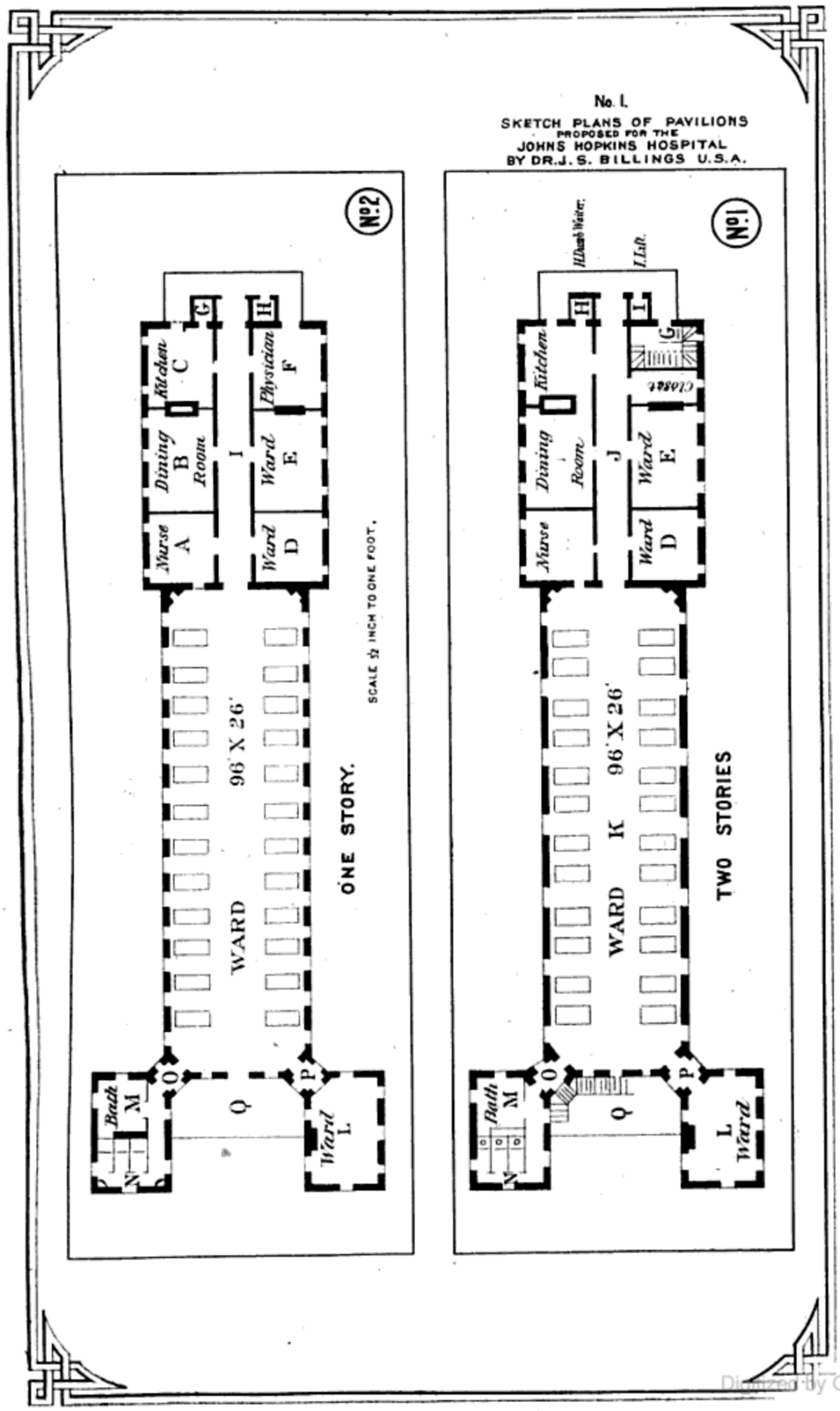




Figure 2.4: John Shaw Billings, "Sketch Plans of Pavilions Proposed for the Johns Hopkins Hospital," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

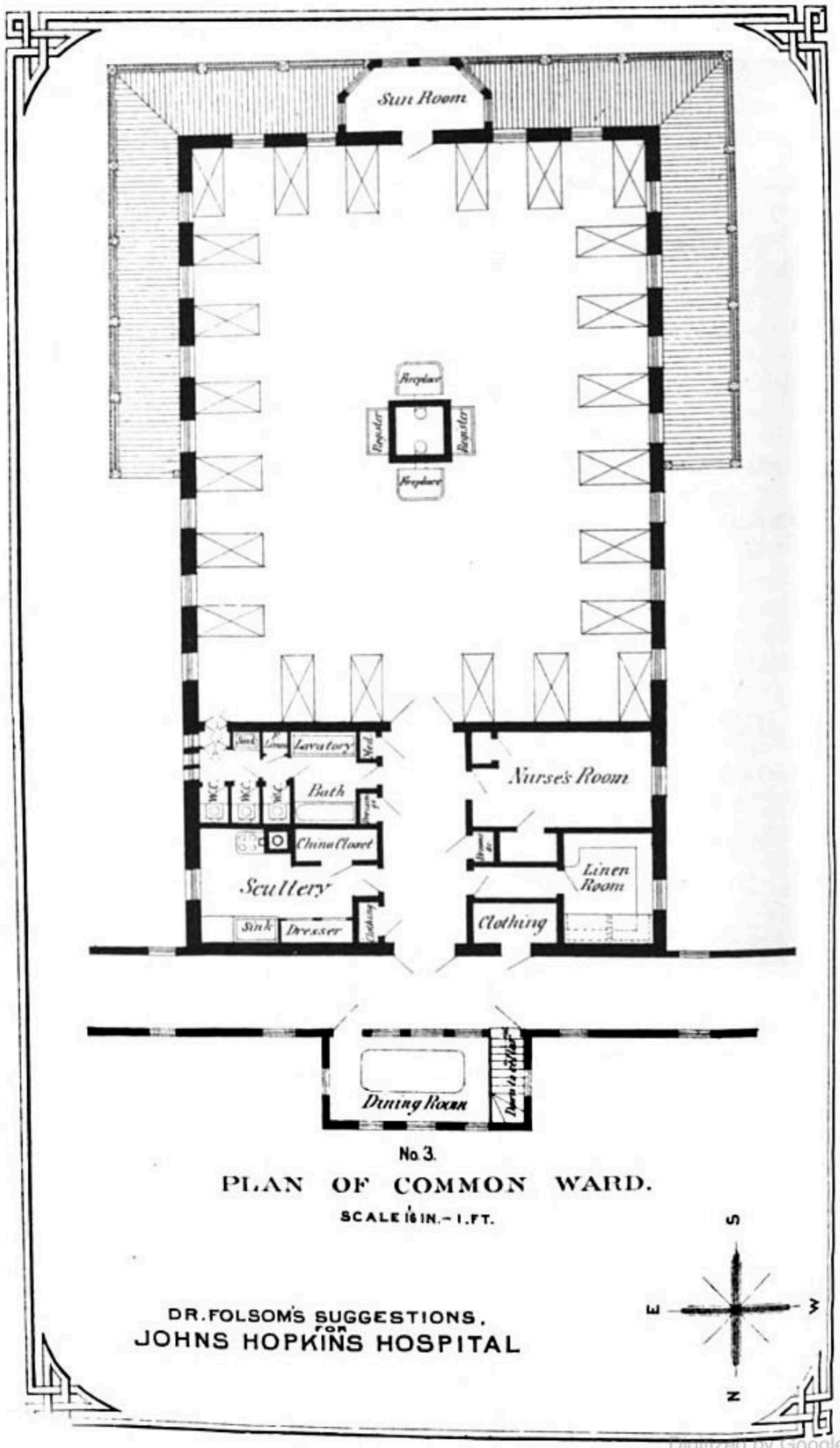




Figure 2.5: Norton Folsom, "Plan of Common Ward," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

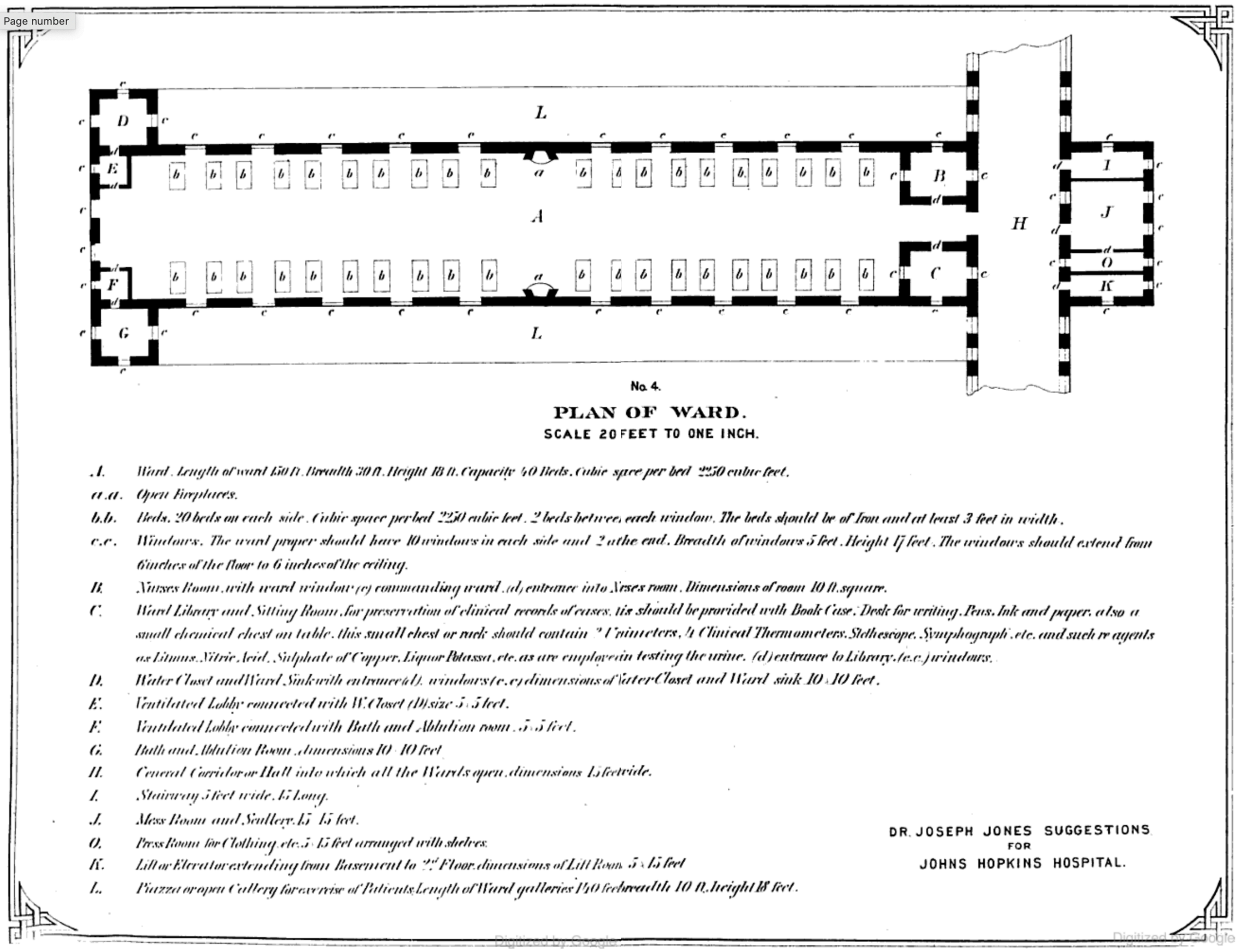



Figure 2.6: Joseph Jones, “Plan of Ward,” *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

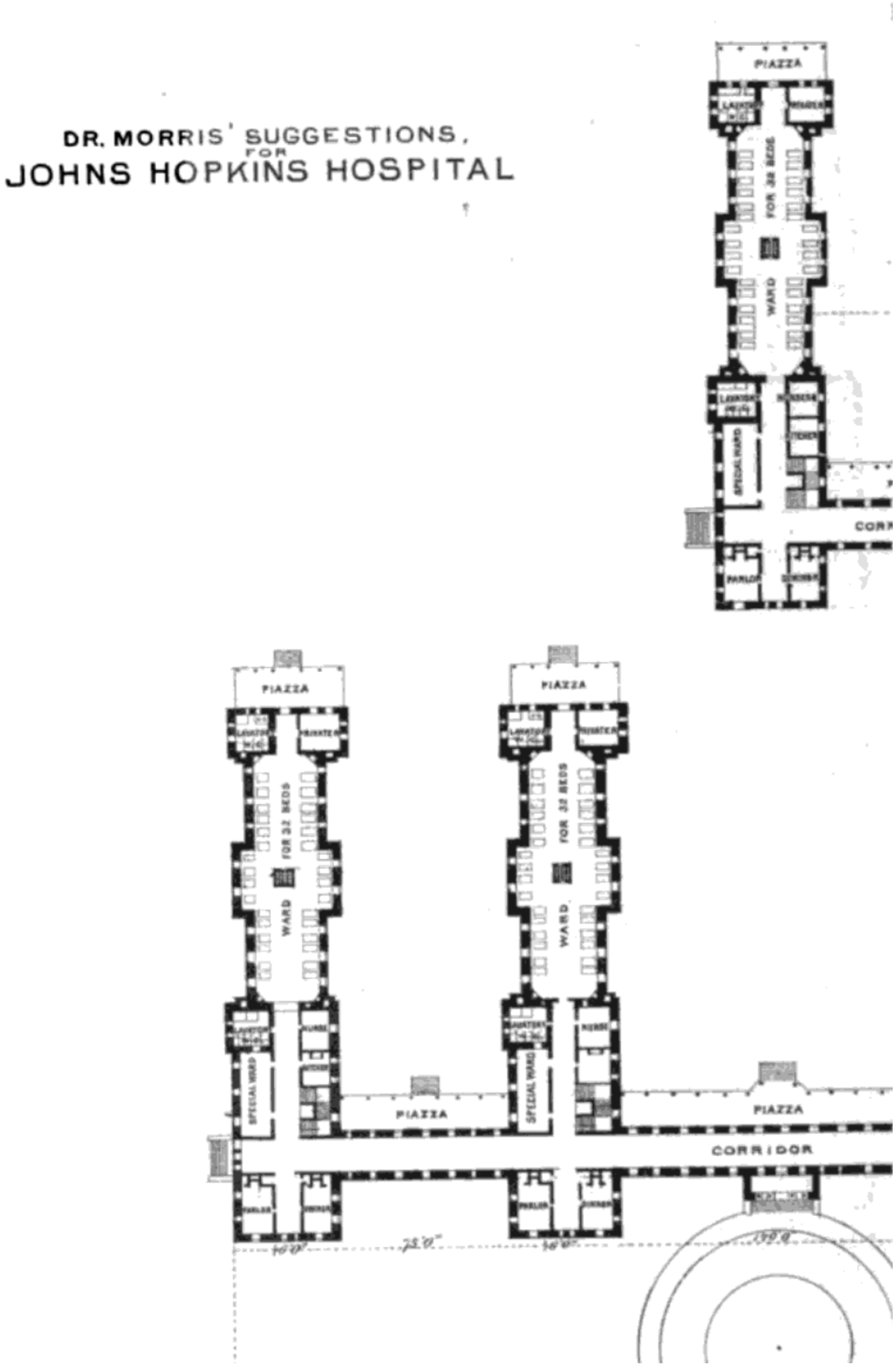



Figure 2.7: Caspar Morris, "Plan of Principal Floor," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875. Cropped from original by author.

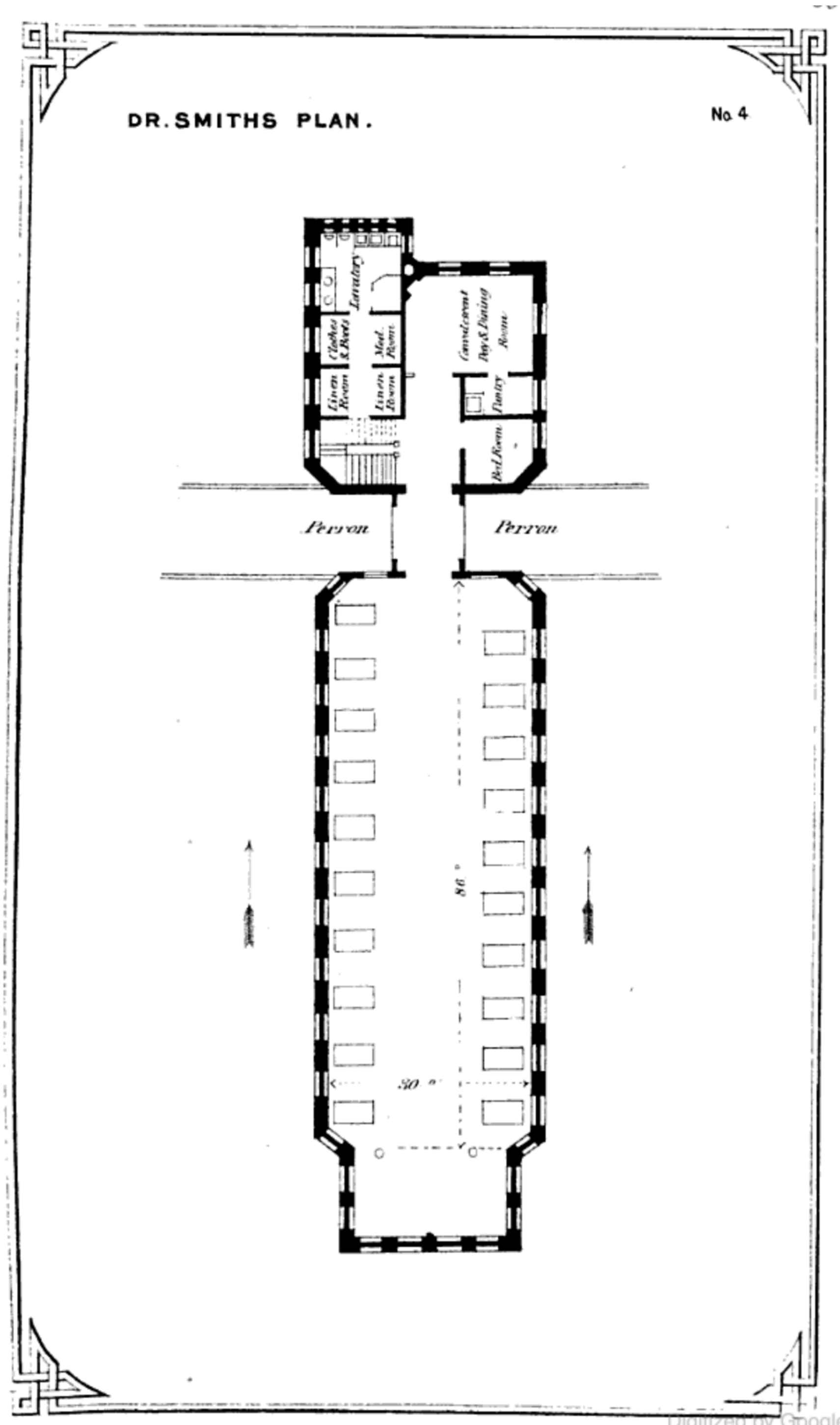



Figure 2.8: Stephen Smith, "Dr. Smith's Plan," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

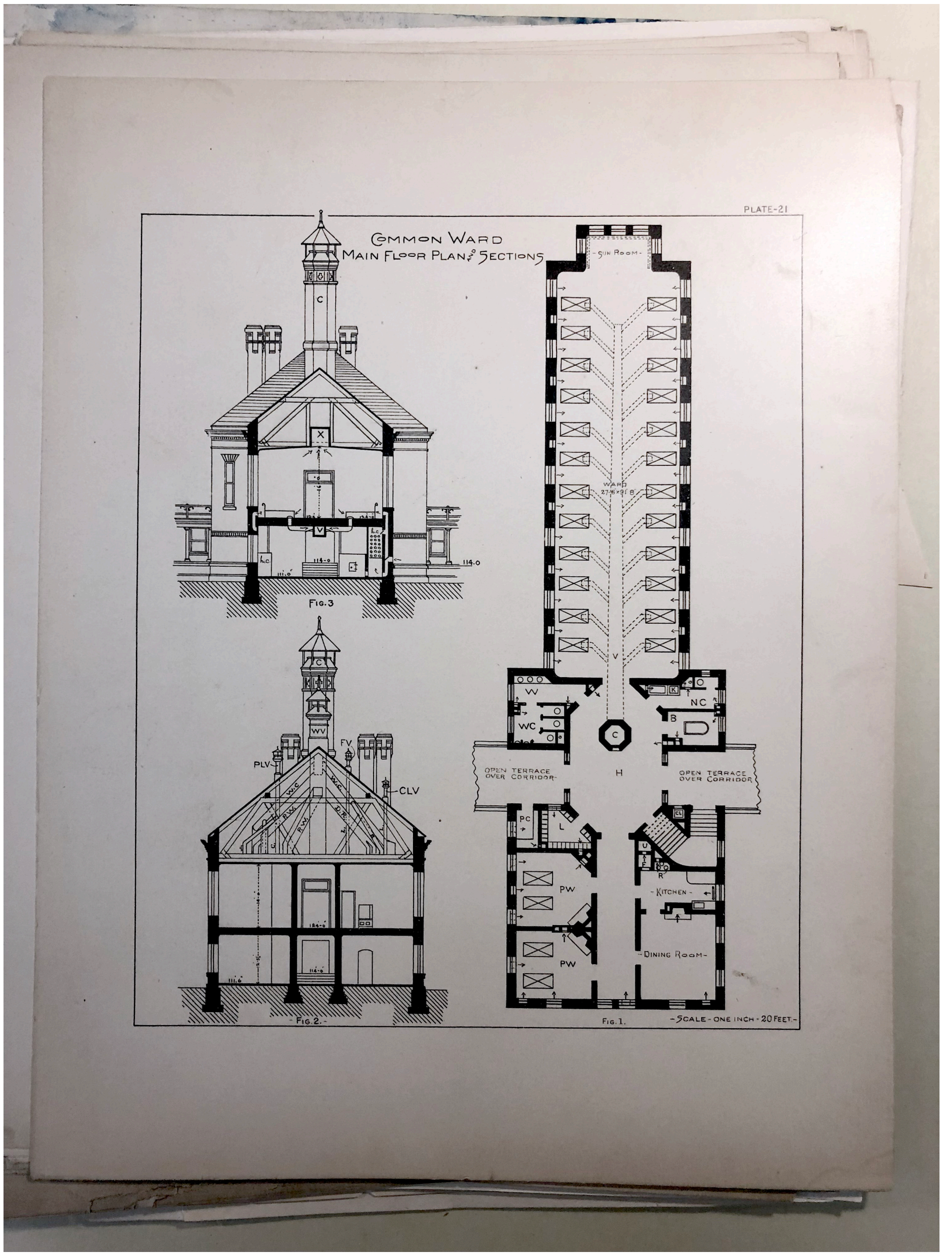



Figure 2.9: John S. Billings and John R. Niernsée, "Common Ward Main Floor Plan and Sections," John Shaw Billings Papers, the New York Public Library, Box. 84.

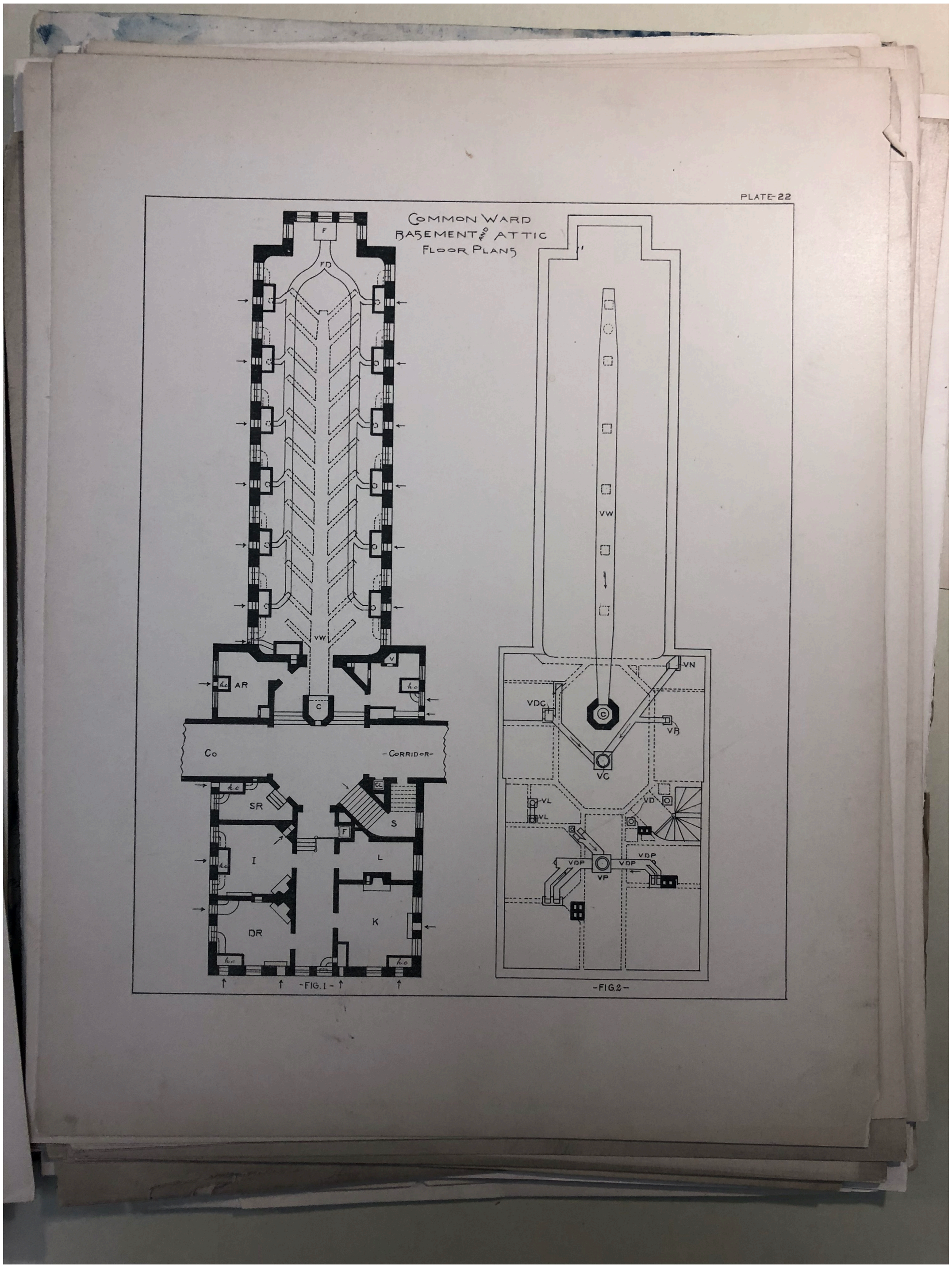



Figure 2.10: John S. Billings and John R. Niernsée, “Common Ward Basement and Attic Floor Plans,” John Shaw Billings Papers, the New York Public Library, Box. 84.

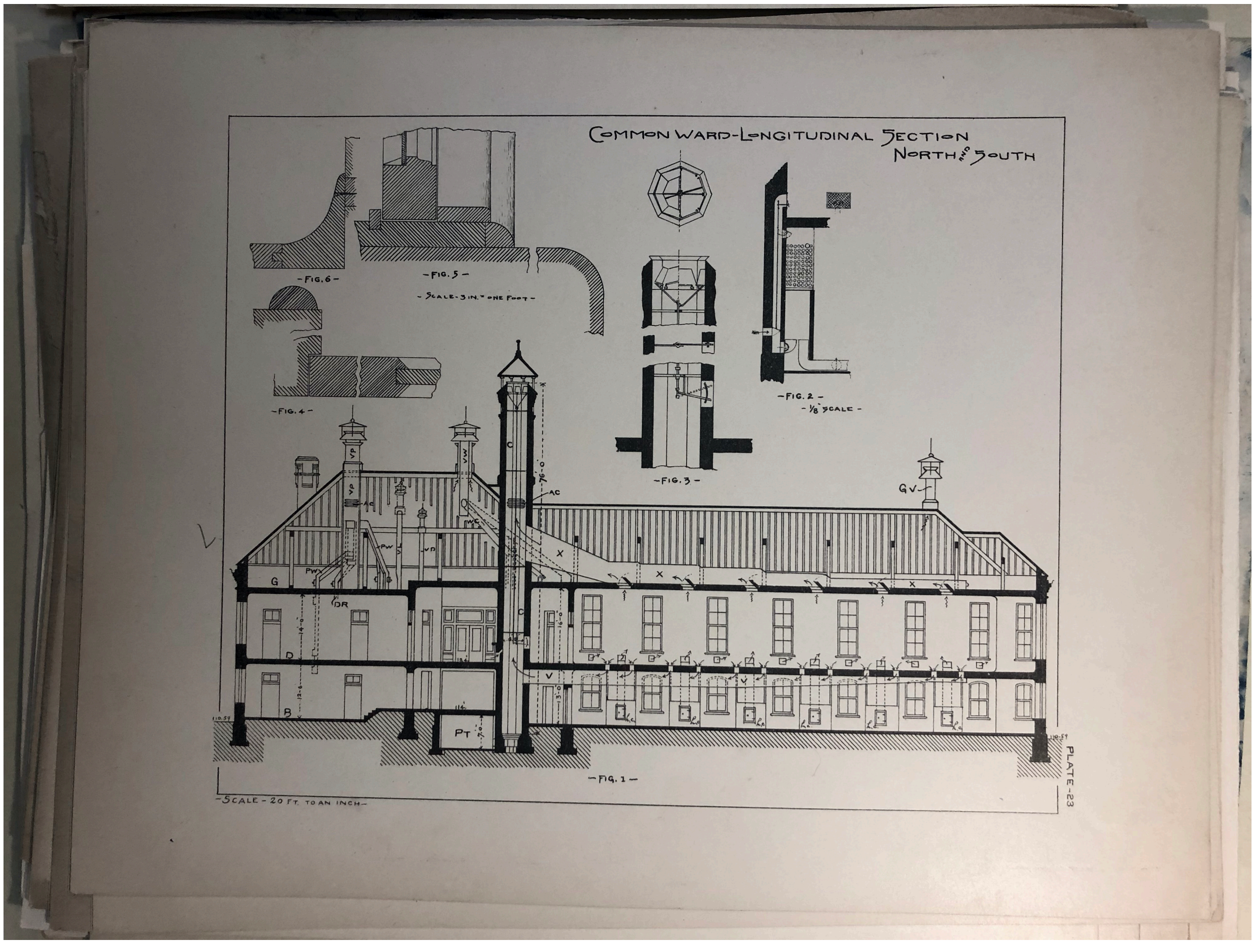



Figure 2.11: John S. Billings and John R. Niernsée, "Common Ward-Longitudinal Section, North and South." Fig. 2 on this plate shows the section detail of the fresh air valve mechanism. Fig. 3 is the plan and section of the aspirating shaft. Fig. 6 shows the rounded baseboard, and Fig. 5 and Fig. 6 show the wood work details of windows and doors. John Shaw Billings Papers, the New York Public Library, Box. 84.

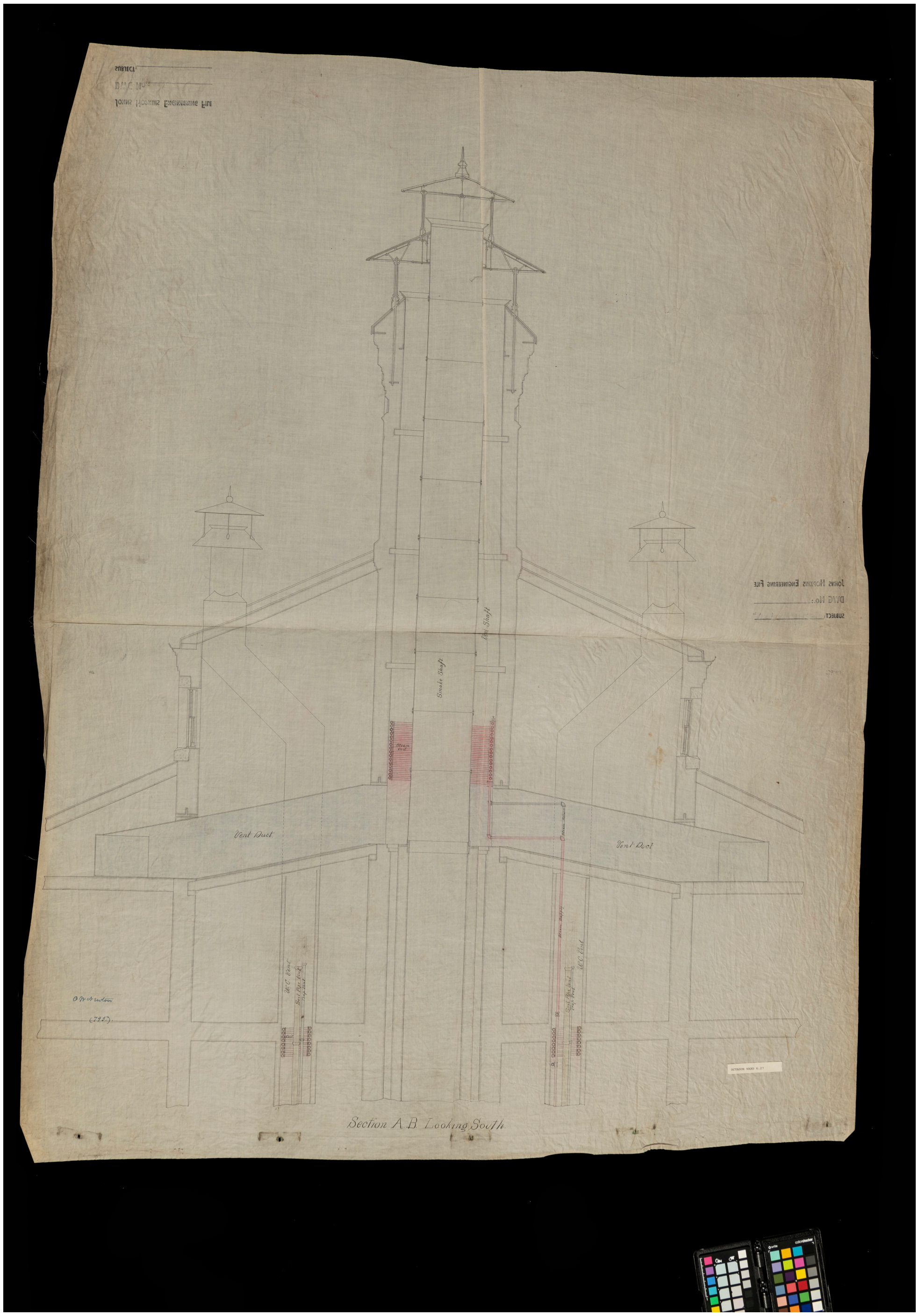



Figure 2.12: John S. Billings and John R. Niernsée, "Section A B Looking South," an undated section drawing of the octagonal hall and chimney of the Common Ward. The drawing is mislabeled as that of the Octagon Ward. Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

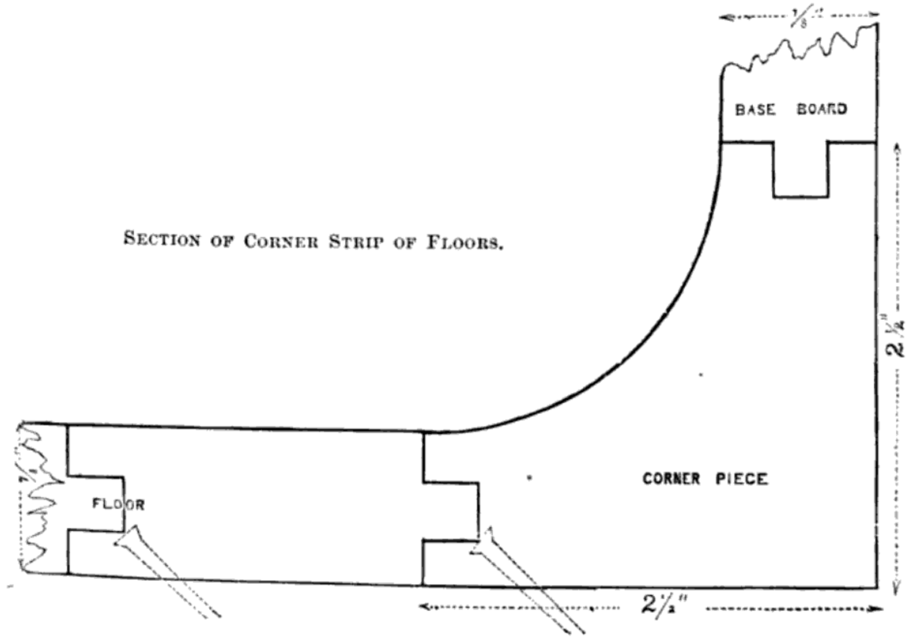



Figure 2.13: Norton Folsom, "Section of Corner Strip of Floors," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

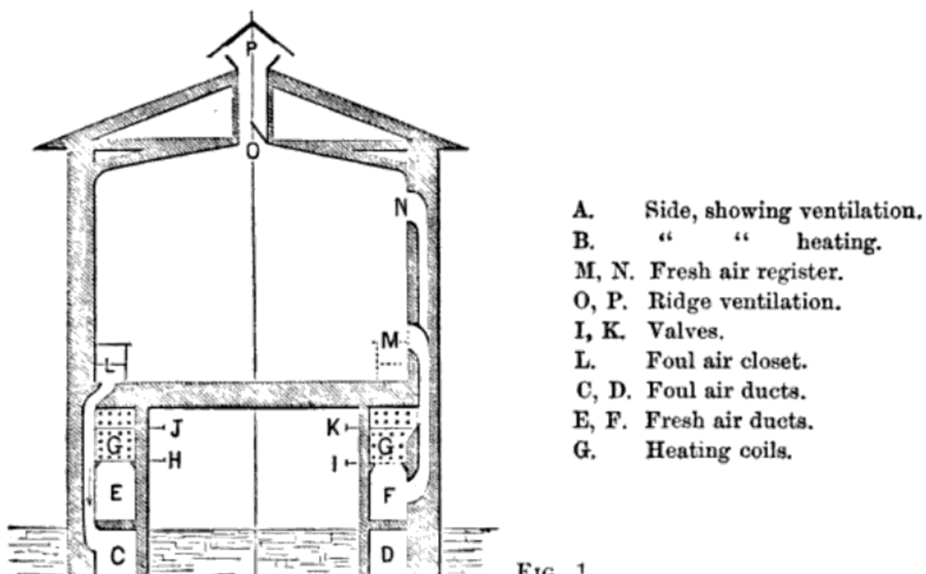



FIG. 1.

Figure 2.14: John S. Billings, Section of the pavilion showing the general arrangement of heating and ventilation, *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

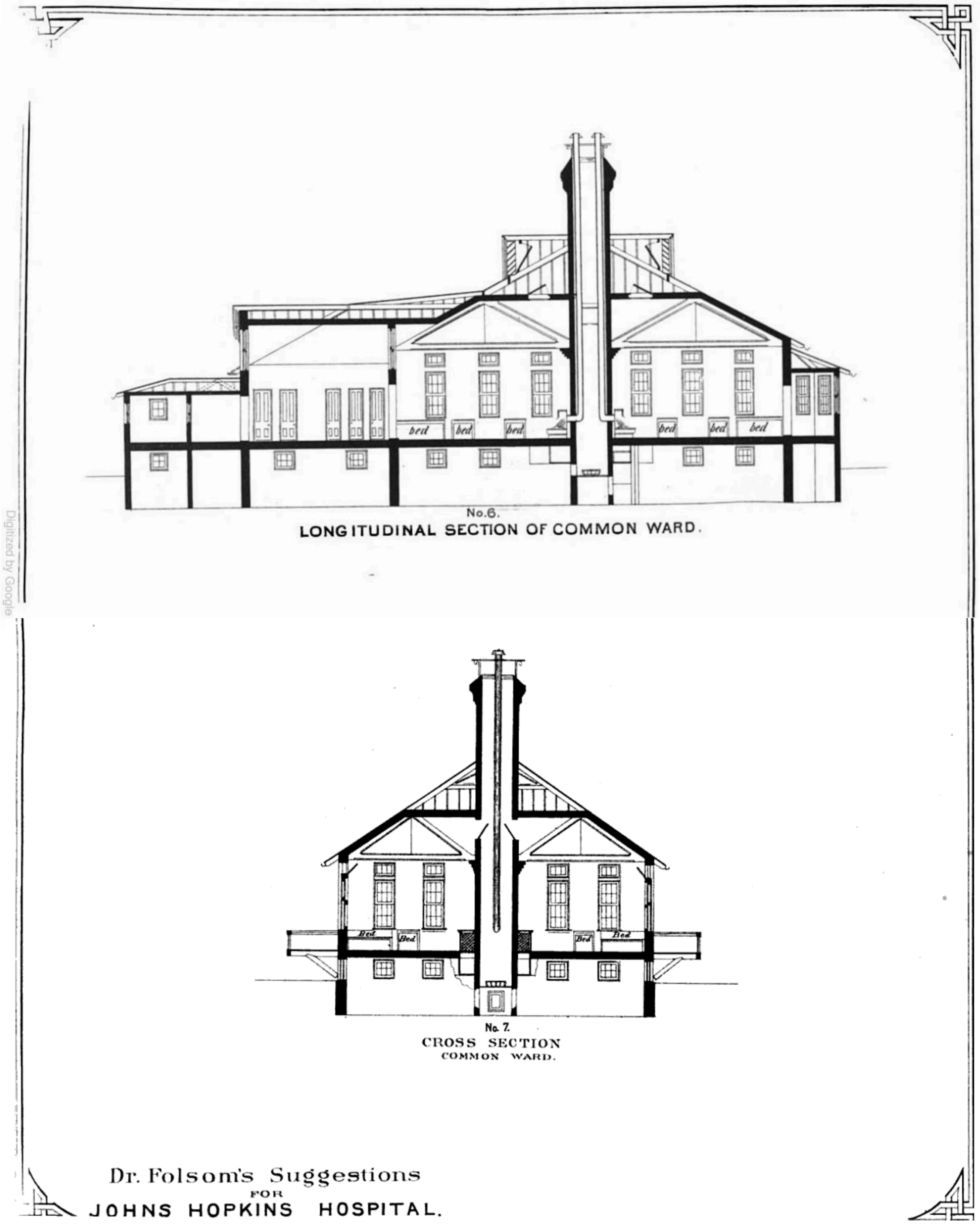



Figure 2.15: Norton Folsom, "Longitudinal Section of Common Ward" (top) and "Cross Section, Common Ward" (bottom), *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

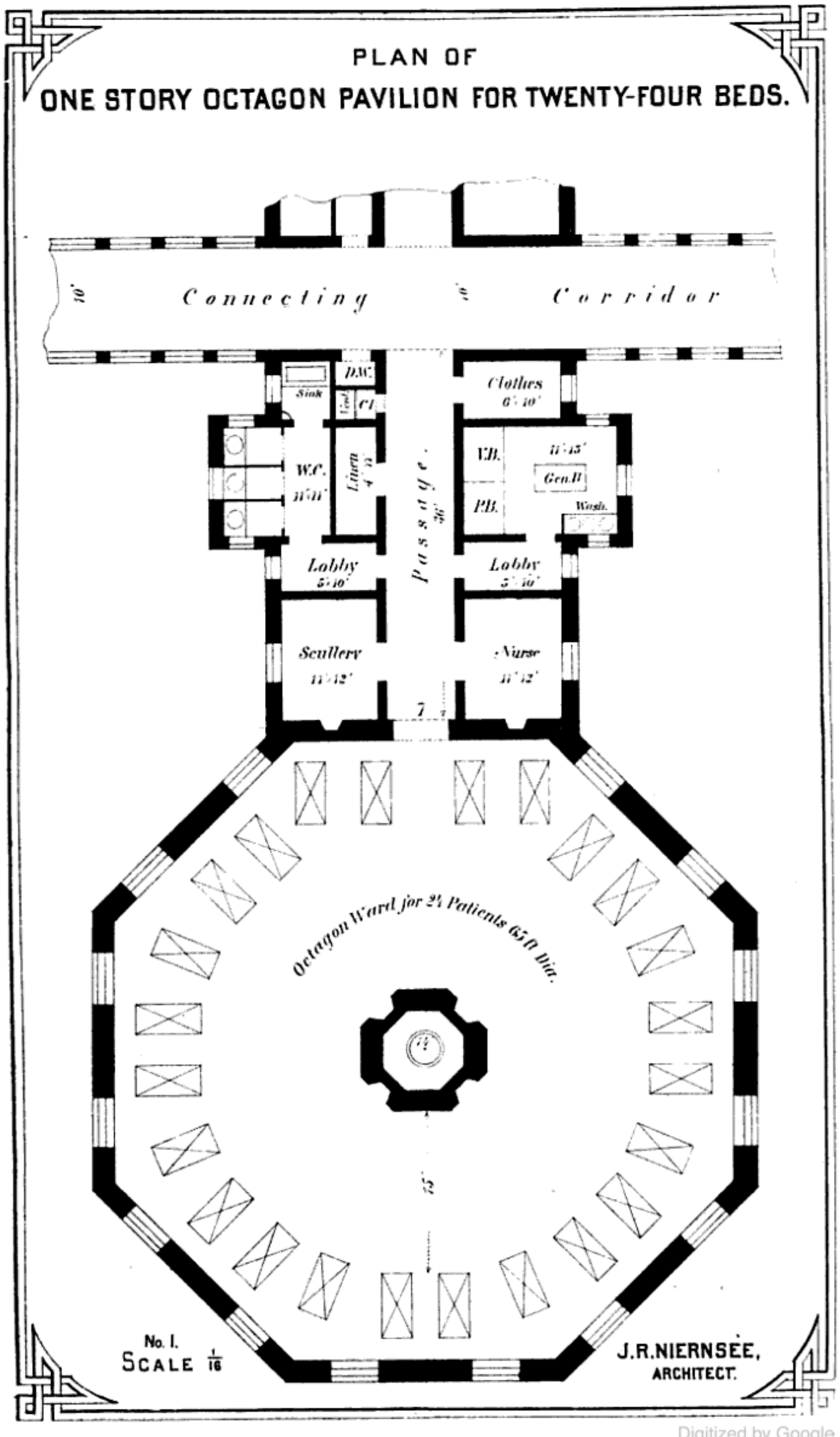



Figure 2.16: John R. Niernsée, "Plan of One Story Octagon Pavilion for Twenty-four Beds," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

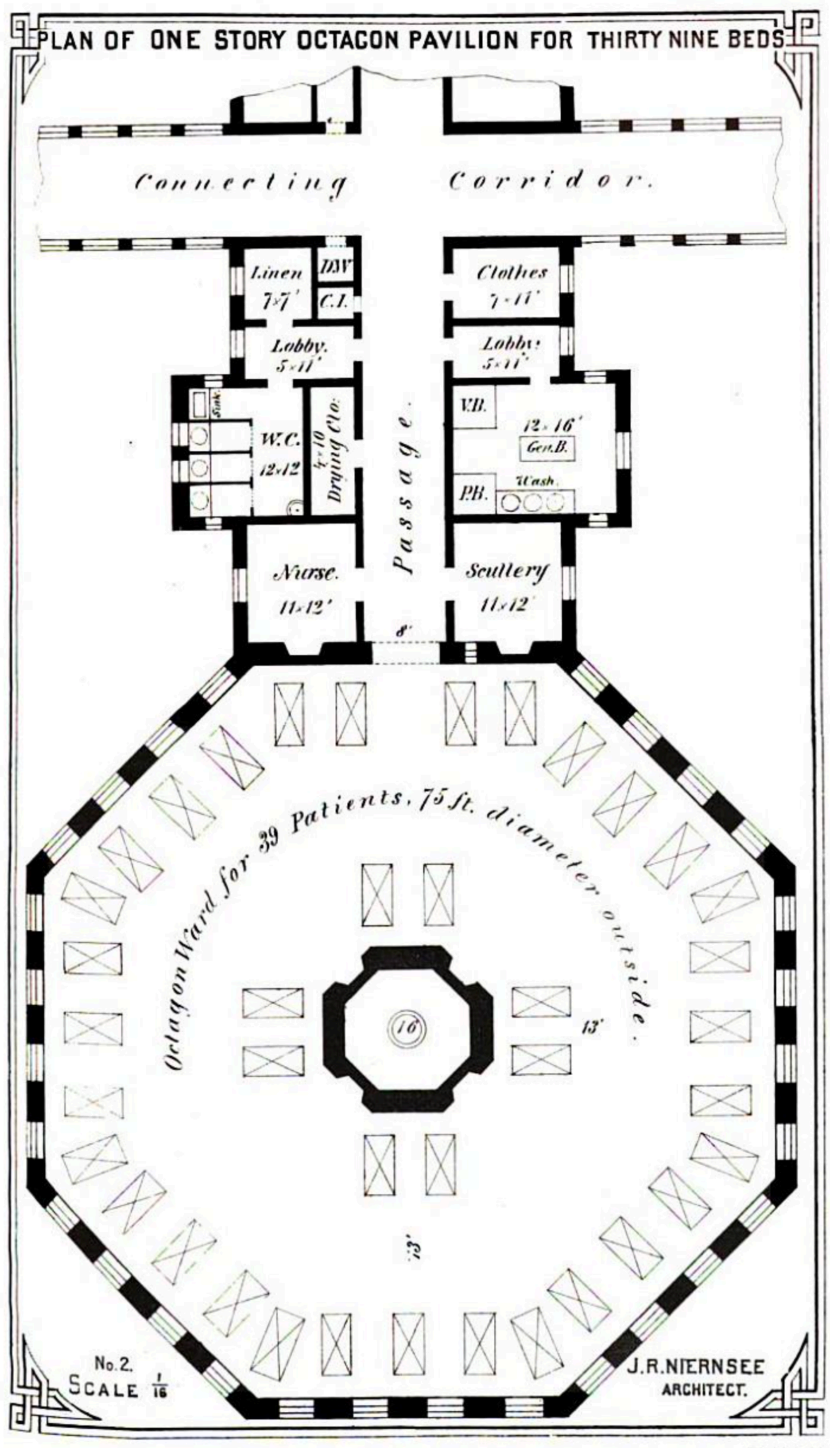



Figure 2.17: John R. Niernsée, "Plan of One Story Octagon Pavilion for Thirty-nine Beds," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

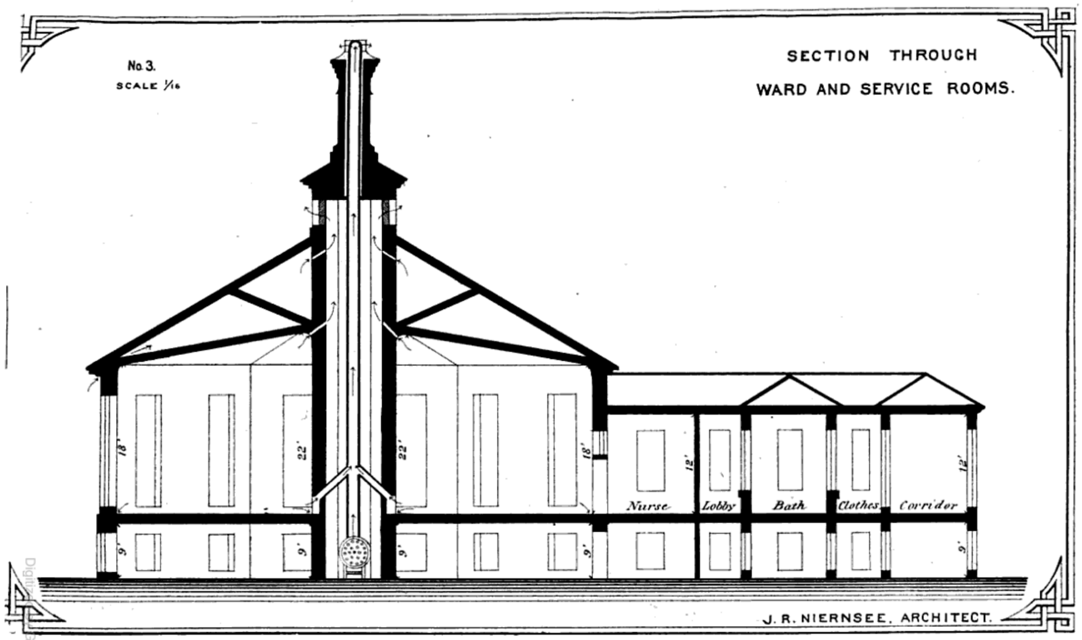



Figure 2.18: John R. Niernsée, "Section Through Ward and Service Rooms," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

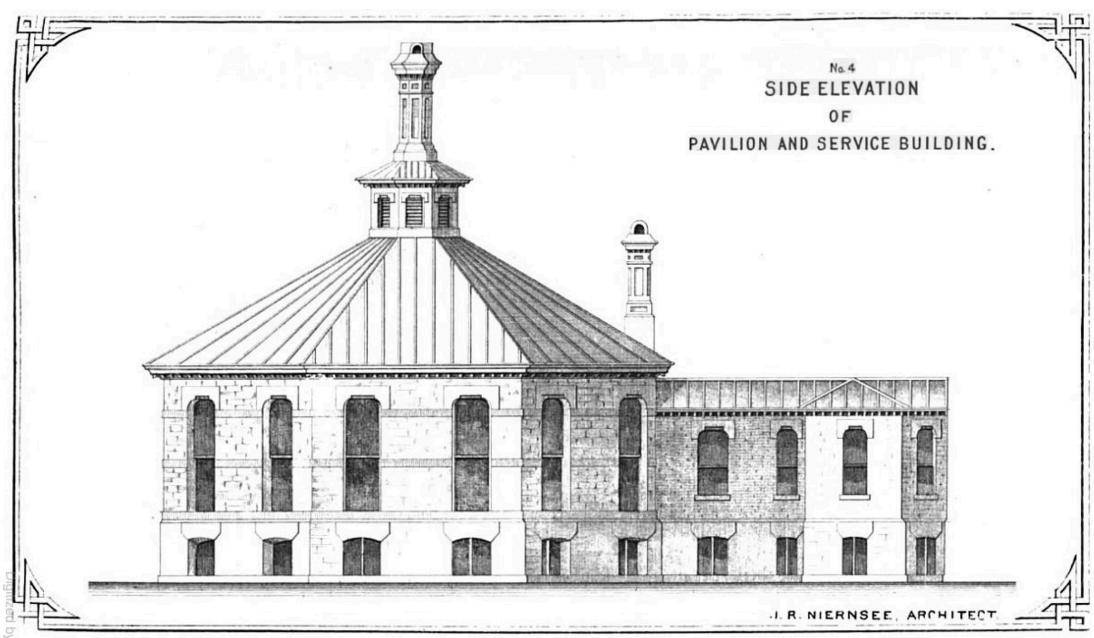



Figure 2.19: John R. Niernsée, "Side Elevation of Pavilion and Service Building," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

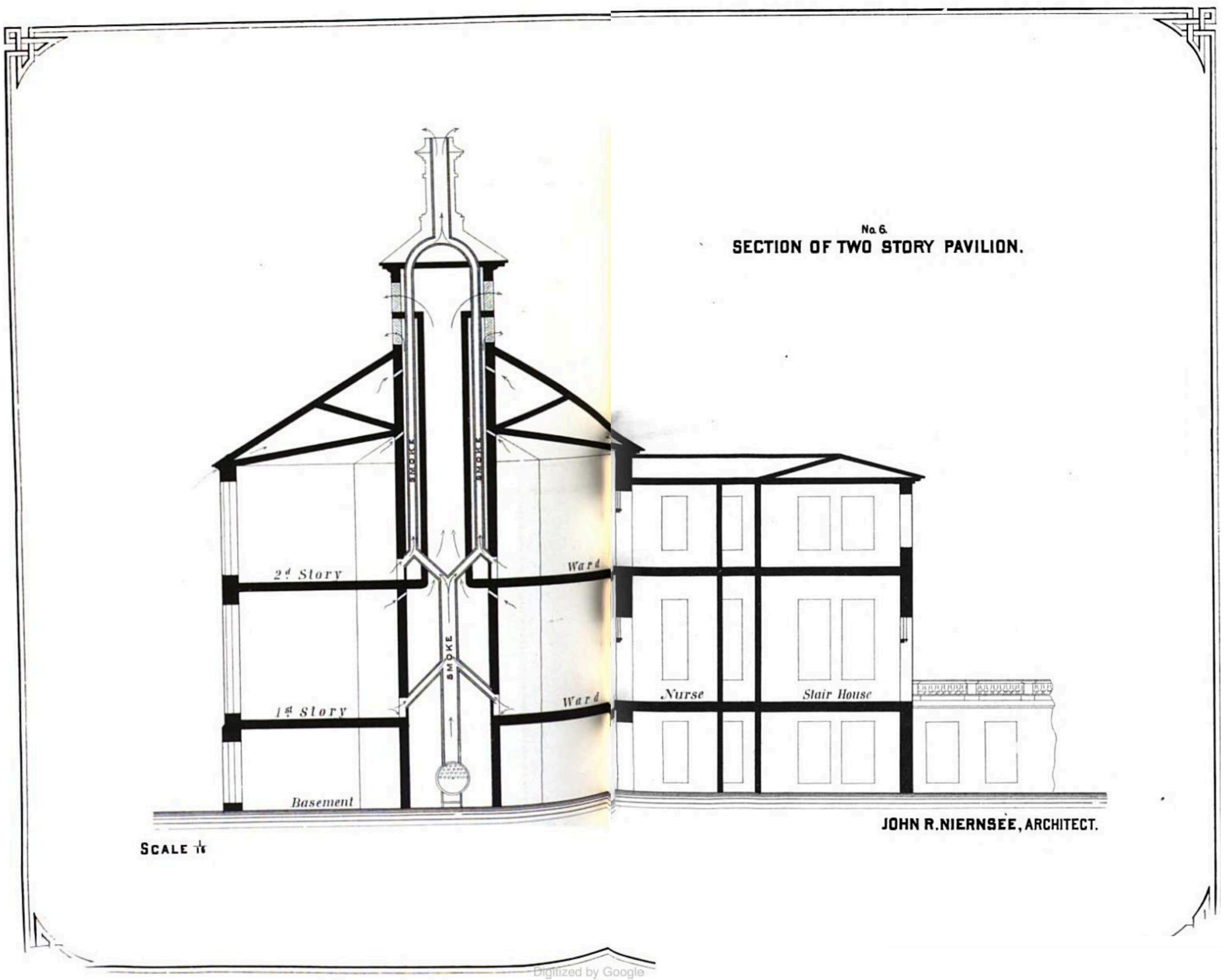



Figure 2.20: John R. Niernsée, "Section of Two Story Pavilion," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

344 APPENDIX II.

# COMPARATIVE TABLE OF DIAGRAMS.

| Comparative Table of Diagrams and Properties of various kinds of Wards. | Length of circumference in feet. | Length of outside walls and centre shaft. | Area enclosed, in square feet. | Area of ward, deducting centre shaft. | Number of beds per ward. | Area of bed per ward, without the shaft. | Square feet of window per bed. | Cubic contents of ward 18 ft. high inclusive of centre shaft. | Cubic contents of ward 18 ft. high exclusive of centre shaft. | Real cubic feet per bed for ward 18 ft. high. | Height of ward required for 1800 cubic ft. per bed. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 feet diameter. Octagon | 200 | 232 | 3.050 | 2.930 | 24 | 122 | 47 | 54.900 | 52.740 | 2.197½ | 14¾ |
| 71 feet diameter. Octagon | 236 | 280 | 4 188 | 3.980 | 39 | 102 | 42 | 75.384 | 71.640 | 1.837 | 17¾ |
| Dr. Folsom's Square Ward of 44 feet. Massachusetts General Hospital | 176 | 198 | 1.936 | 1.900 | 20 | 95 | 60 | 34.848 | 34.200 | 1.710 | 19 |
| Dr. Folsom's Square Ward | 200 | 236 | 2.500 | 2.400 | 24 | 100 | 60 | 45.000 | 43.200 | 1.800 | 18 |
| Herbert Rectangular Ward of 50 feet | 202 | .... | 1.950 | ..... | 20 | 97½ | 40 | ...... | 35.100 | 1.755 | 18½ |
| do. do. do. | 236 | ... | 2.392 | ..... | 24 | 99½ | 44 | ...... | 43.056 | 1.794 | 18 |
| do. do. do. | 286 | .... | 3.051 | ..... | 32 | 95¼ | 40 | ...... | 54.918 | 1.716 | 18¾ |
| do. | 346 | .... | 3.822 | ..... | 40 | 95½ | 40 | ...... | 68.796 | 1.720 | 18¾ |

The principles laid down by the Herbert Hospital Commission are: 7 ft. 3 in. wall space for each bed. Height of ward, 14 ft., width 26 ft. Area for each bed, 87 sq. ft. Cubic contents per bed, 1200 ft. The largest superficial window space per bed is 31 ft., used in the Netley Hospital.

APPENDIX II. 345

Figure 2.21: John R. Niernsée, "Comparative Table of Diagrams," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

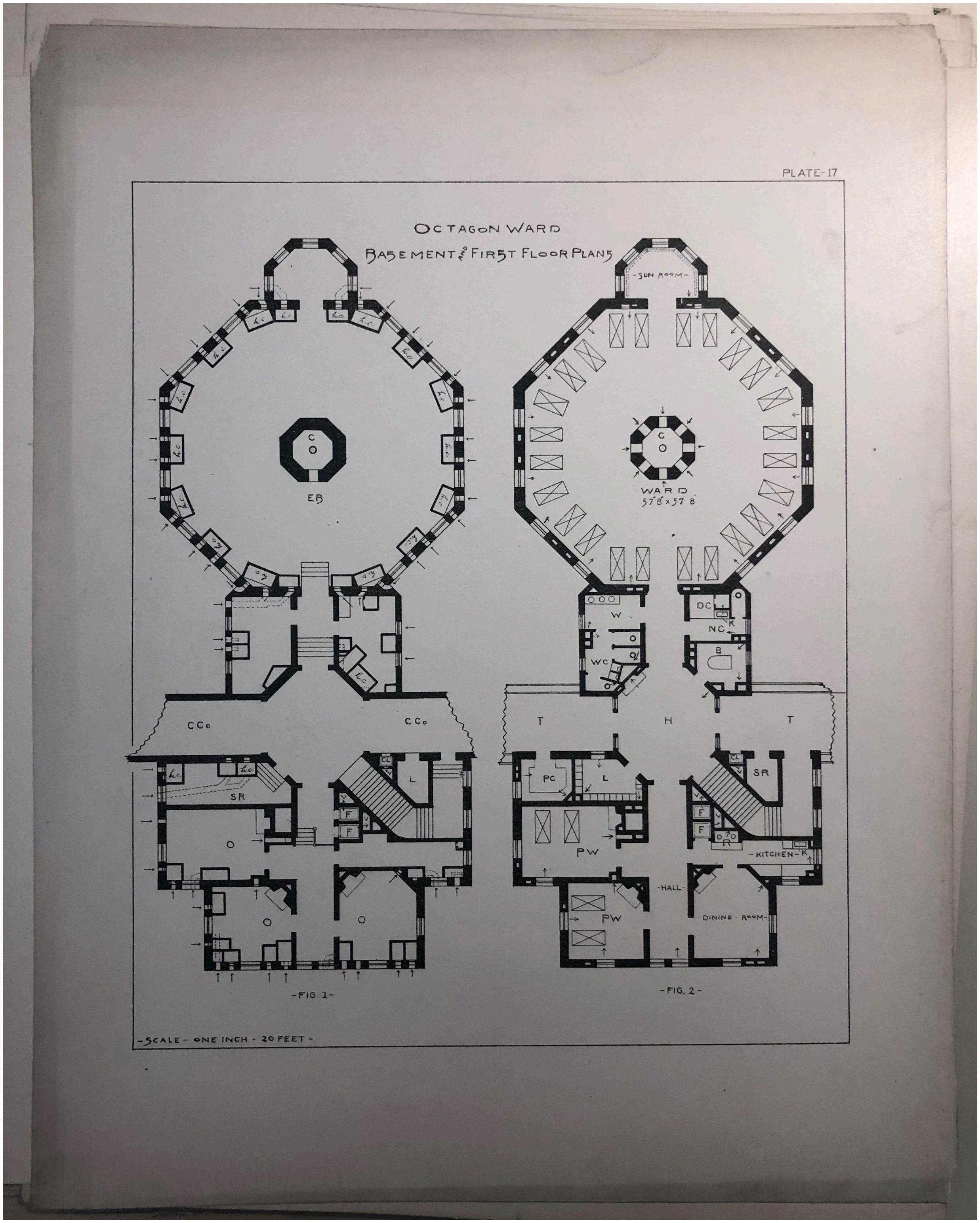



Figure 2.22: John S. Billings and John R. Niernsée, "Octagon Ward Basement and First Floor Plans," John Shaw Billings Papers, the New York Public Library, Box. 84.

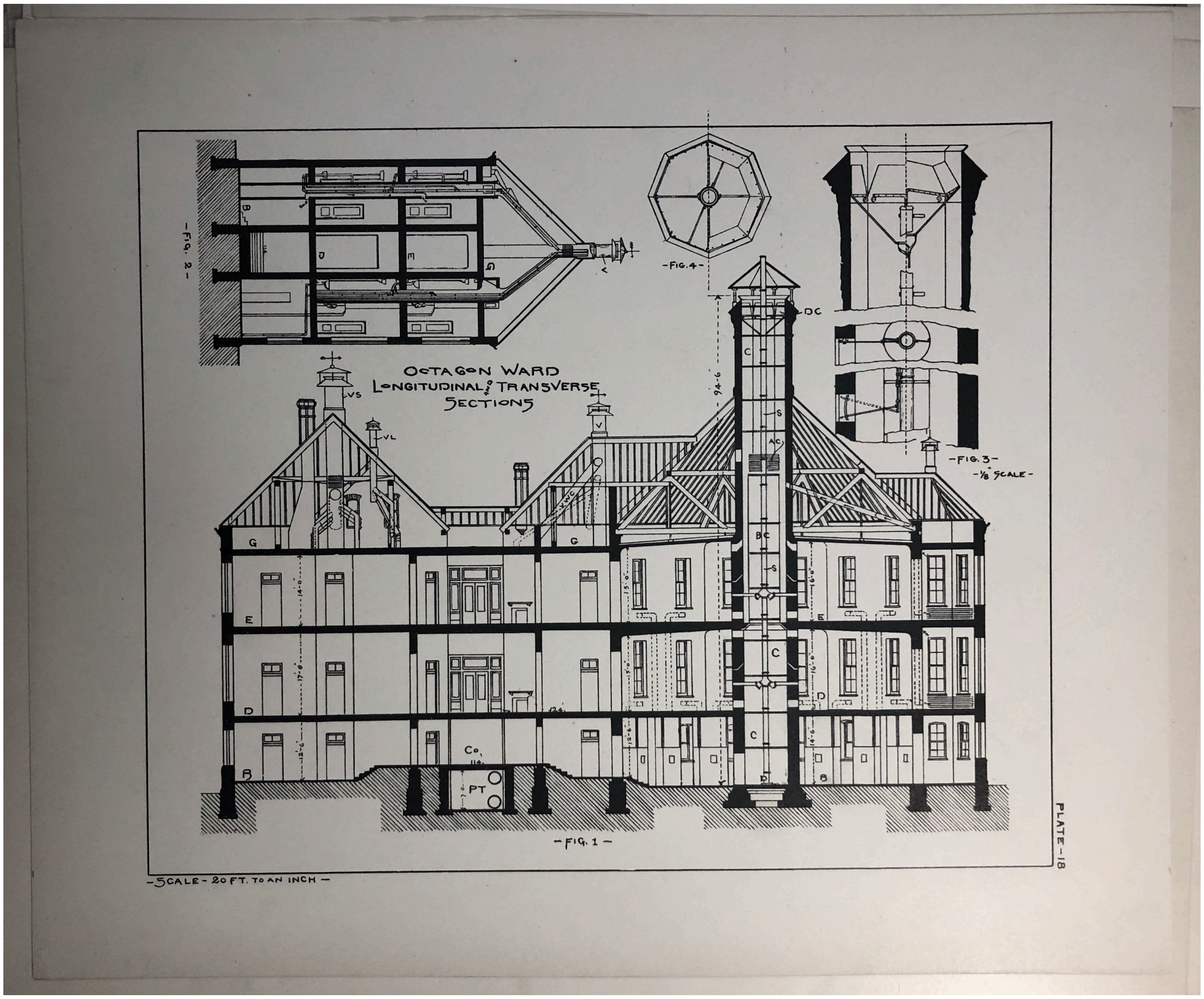



Figure 2.23: John S. Billings and John R. Niernsée, "Octagon Ward Longitudinal and Transverse Sections," John Shaw Billings Papers, the New York Public Library, Box. 84.

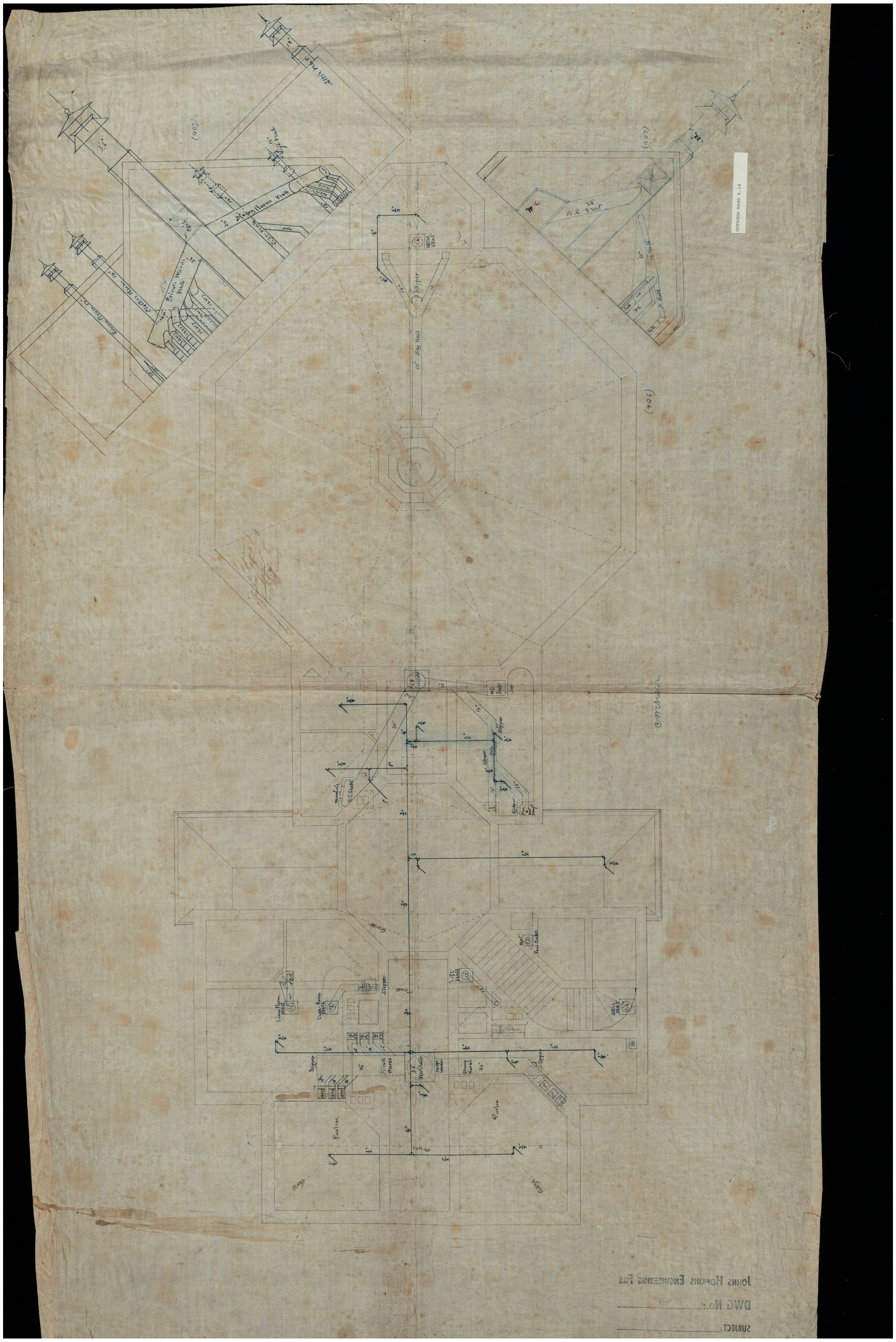


Figure 2.24: John S. Billings and John R. Niernsée, ventilation plan and elevations of the Octagon Ward, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

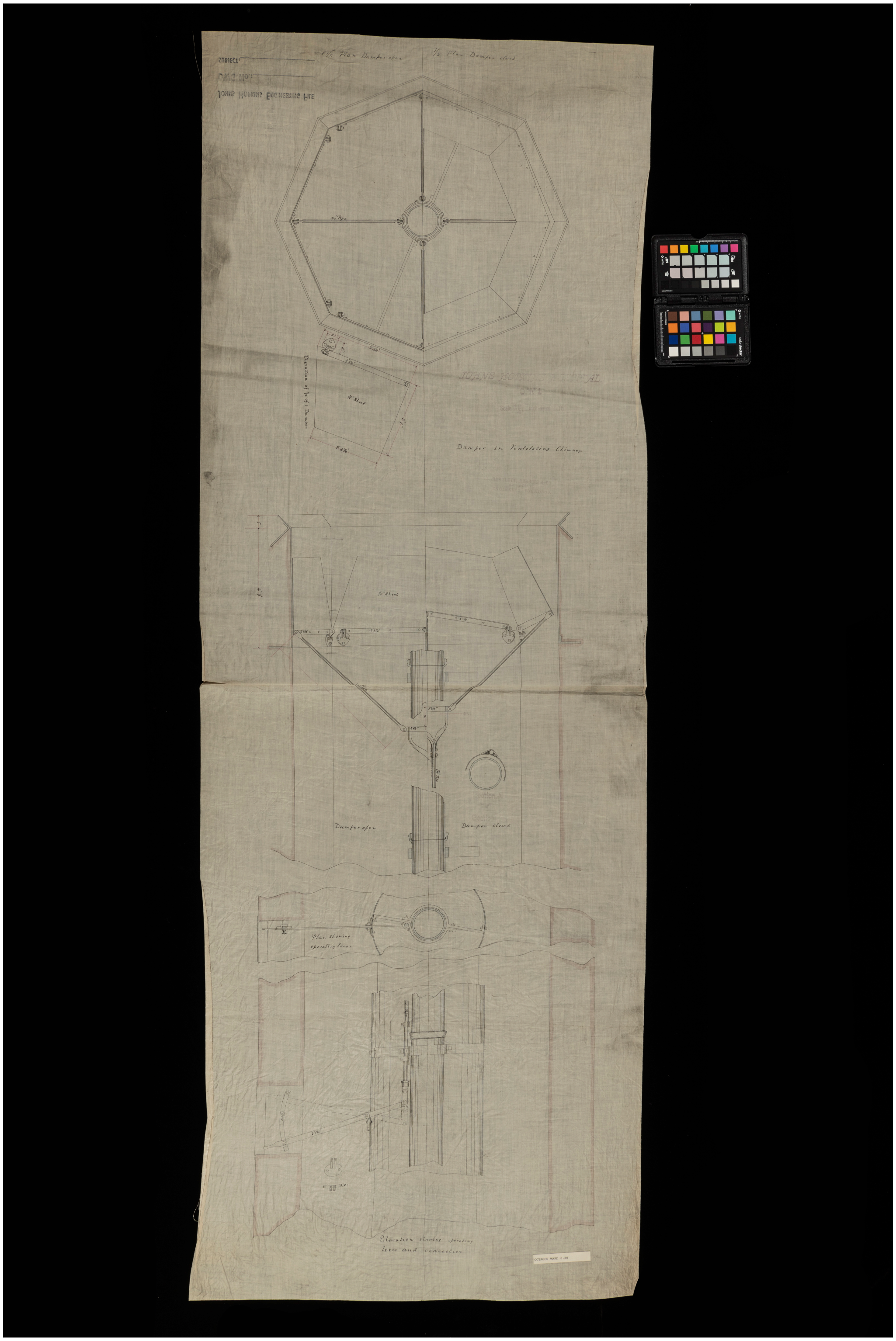


Figure 2.25: John S. Billings and John R. Niernsée, detail drawing of the ventilating shaft of the Octagon Ward showing the the lever and connections, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

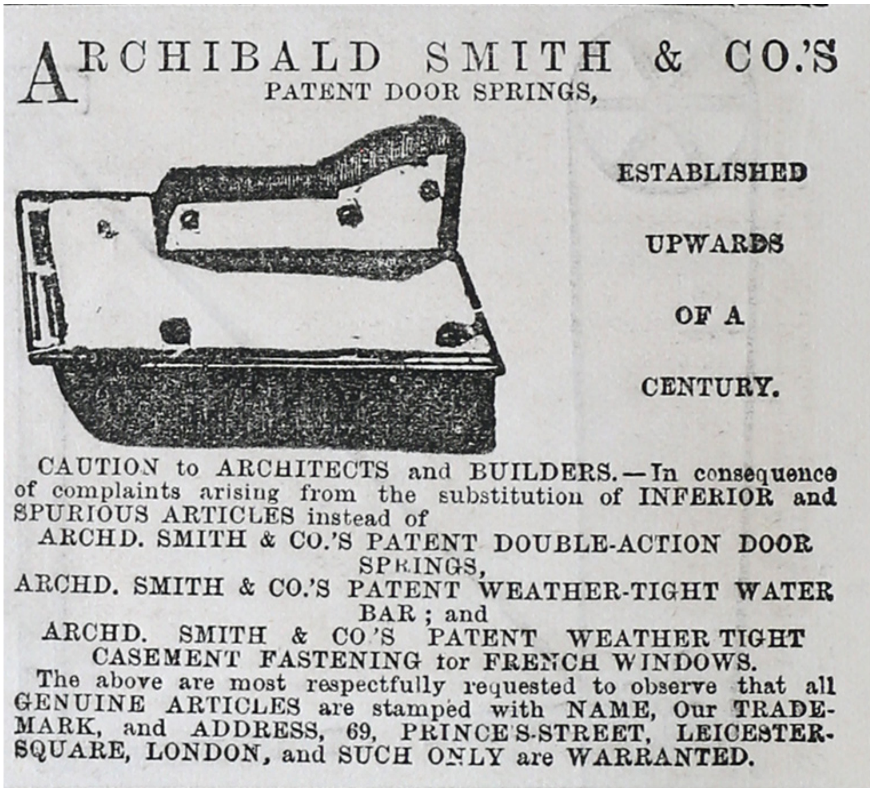



Figure 2.26: Advertisements for Archibald Smith's "Patent Door Springs" from 1876 (top) and 1878 (bottom), Grace's Guide to British Industrial History (https://www.gracesguide.co.uk/Archibald_Smith_and_Stevens).

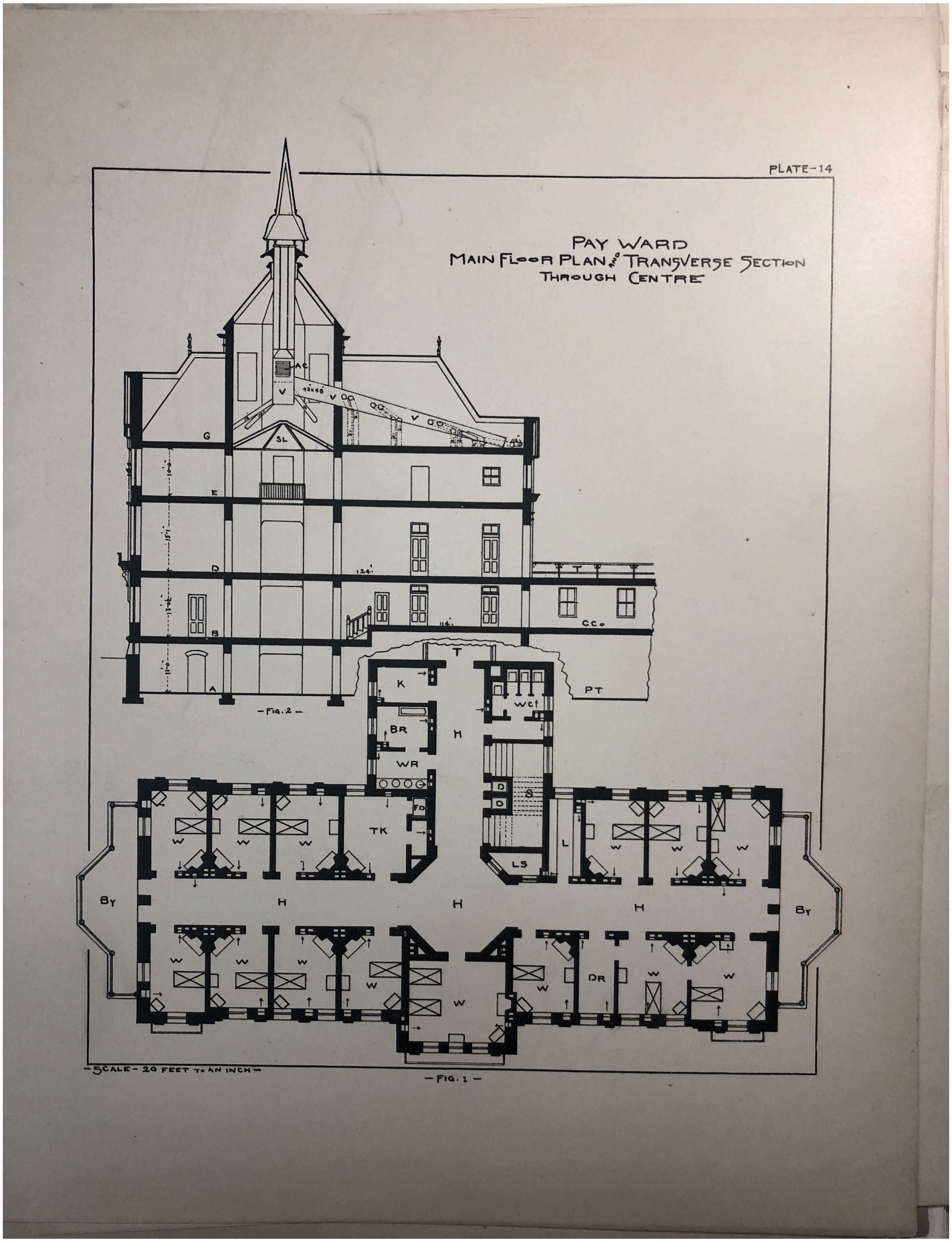



Figure 2.27: John S. Billings and John R. Niernsée, "Pay Ward Main Floor Plan and Transverse Section through Centre," John Shaw Billings Papers, the New York Public Library, Box. 84.

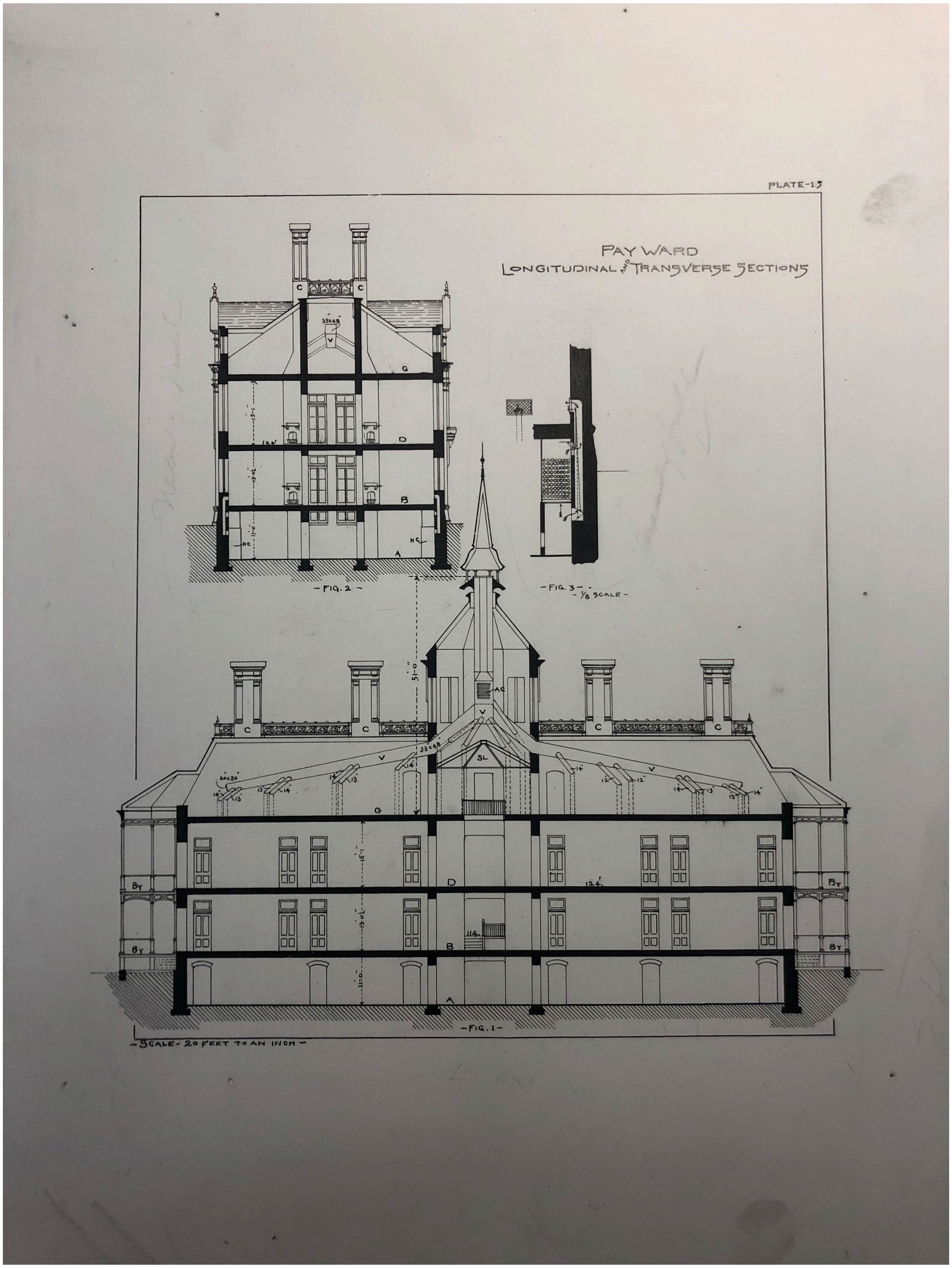



Figure 2.28: John S. Billings and John R. Niernsée, "Pay Ward Longitudinal and Transverse Sections," John Shaw Billings Papers, the New York Public Library, Box. 84.

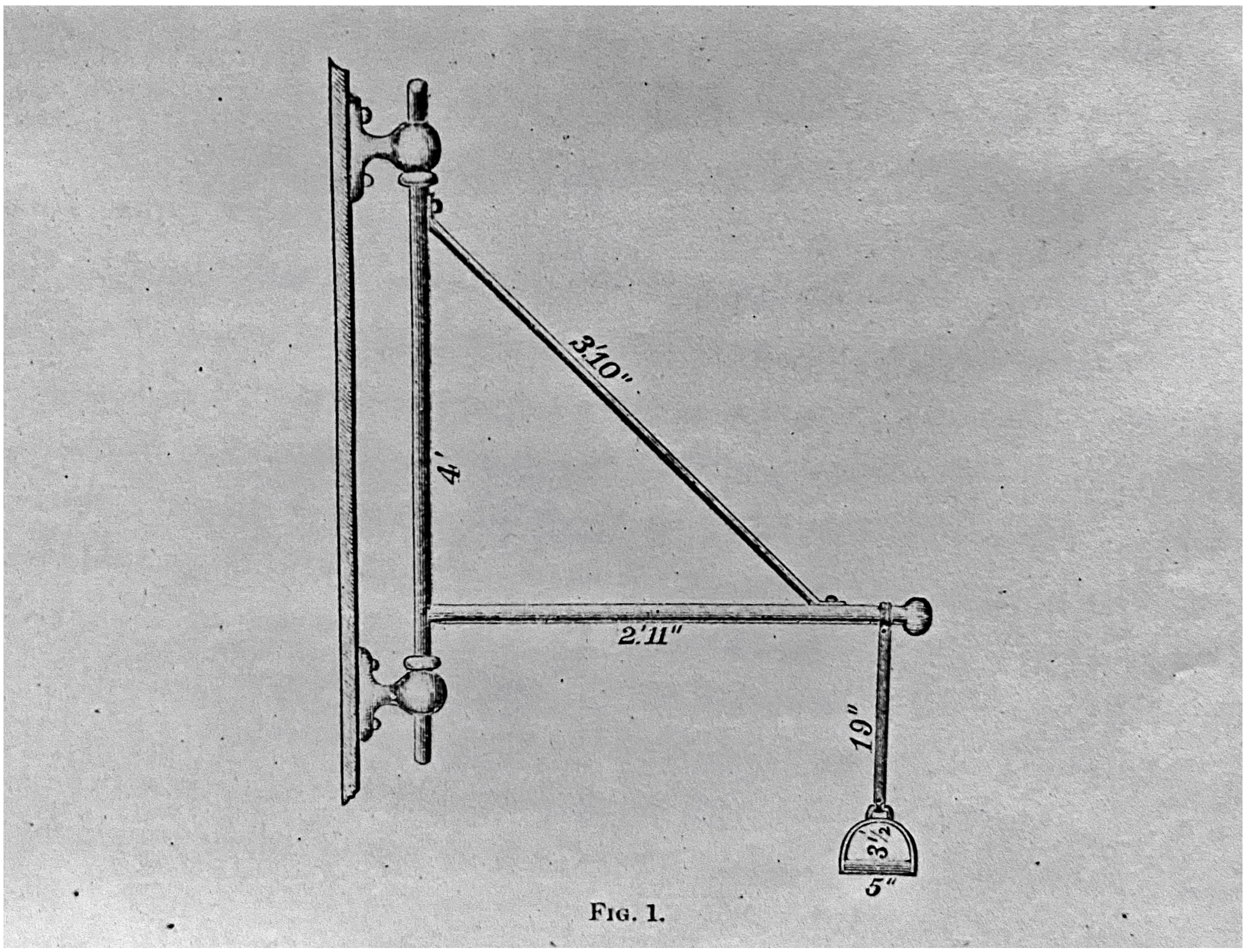



Figure 2.29: A drawing of the "iron crane, or winging bracket" with a suspended leather strap, used in the private patient rooms of the Pay Wards, John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).

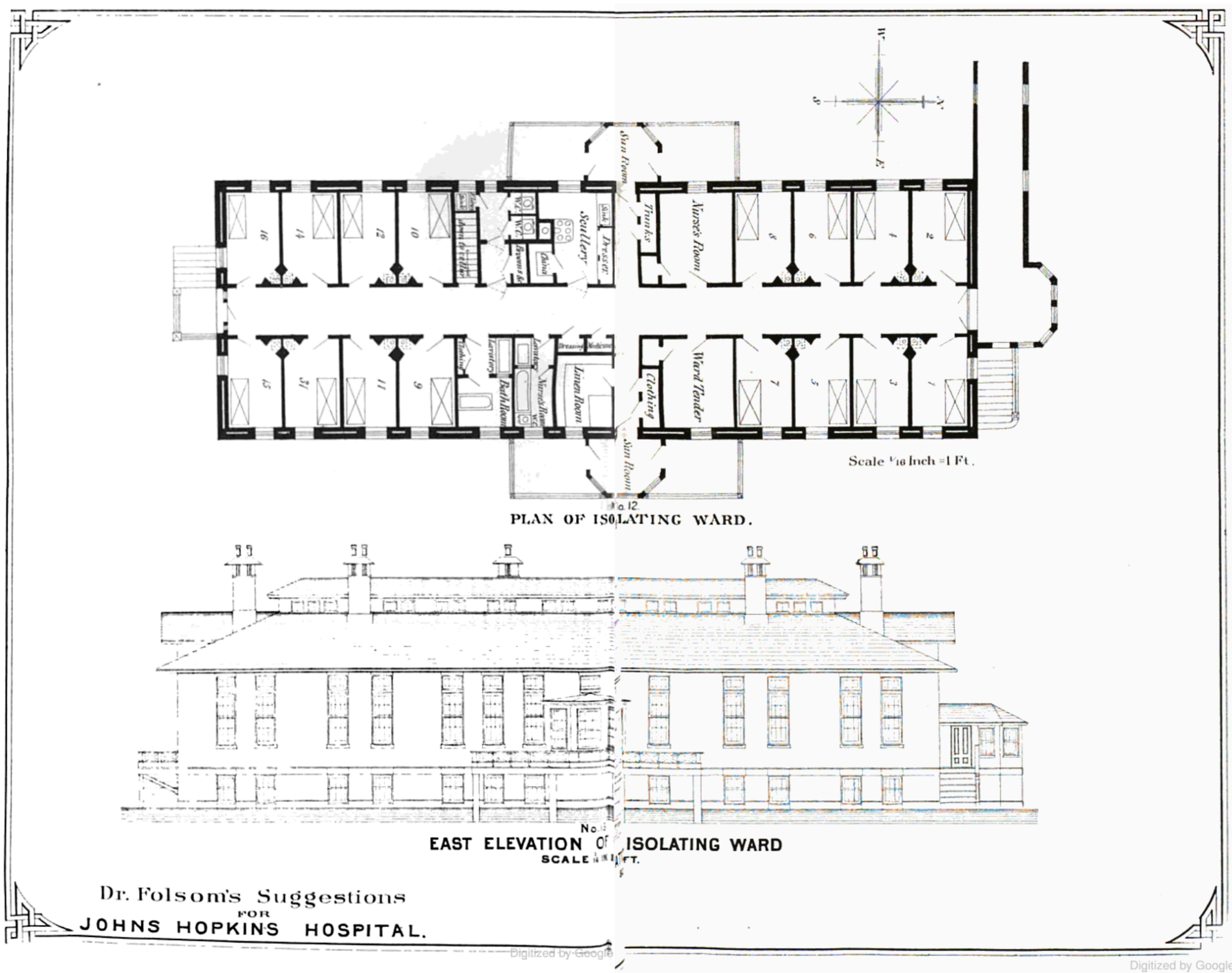



Figure 2.30: Norton Folsom, Plan and East Elevation of Isolating Ward, *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

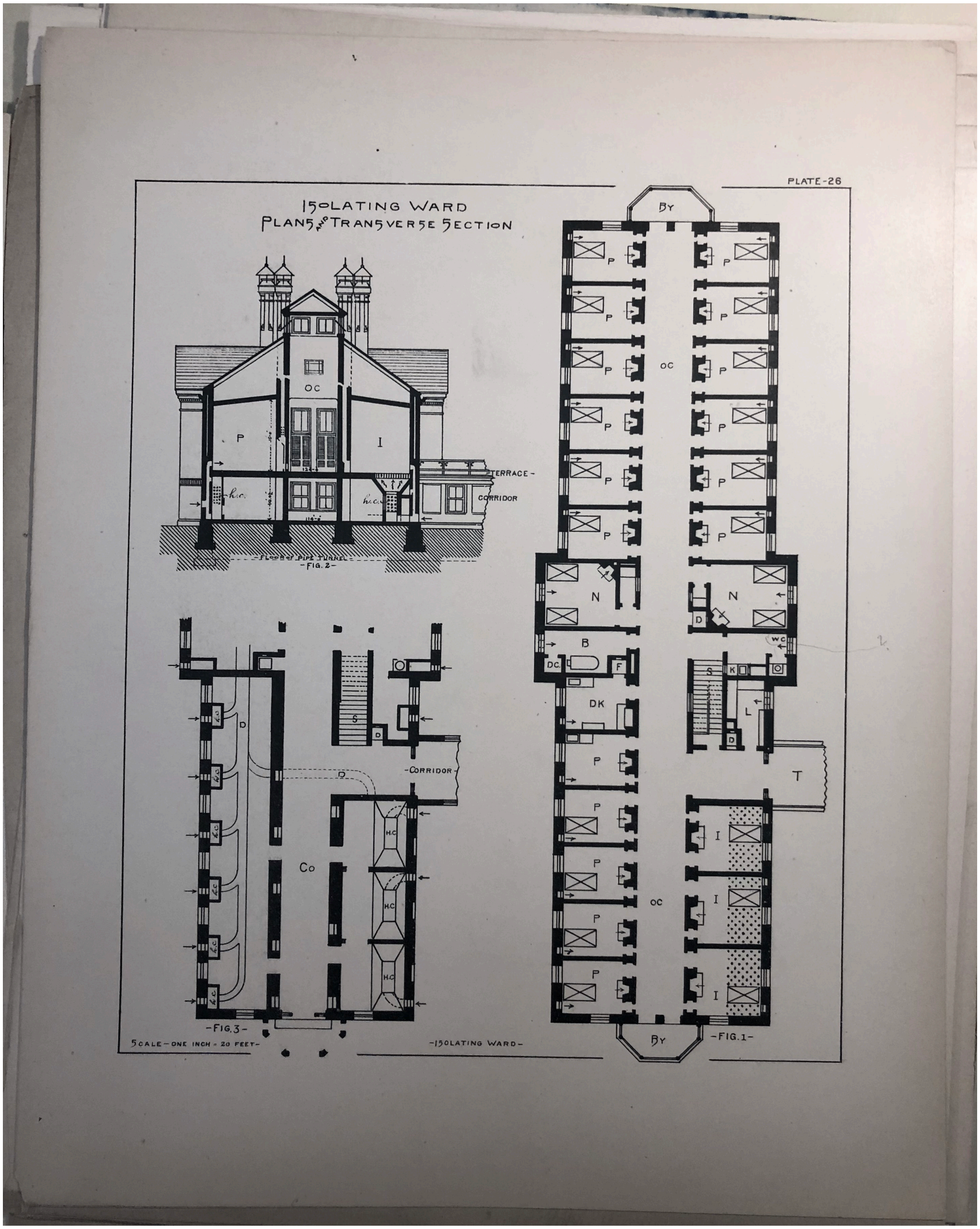



Figure 2.31: John S. Billings and John R. Niernsée, “Isolating Ward Plans and Transverse Section,” John Shaw Billings Papers, the New York Public Library, Box. 84.

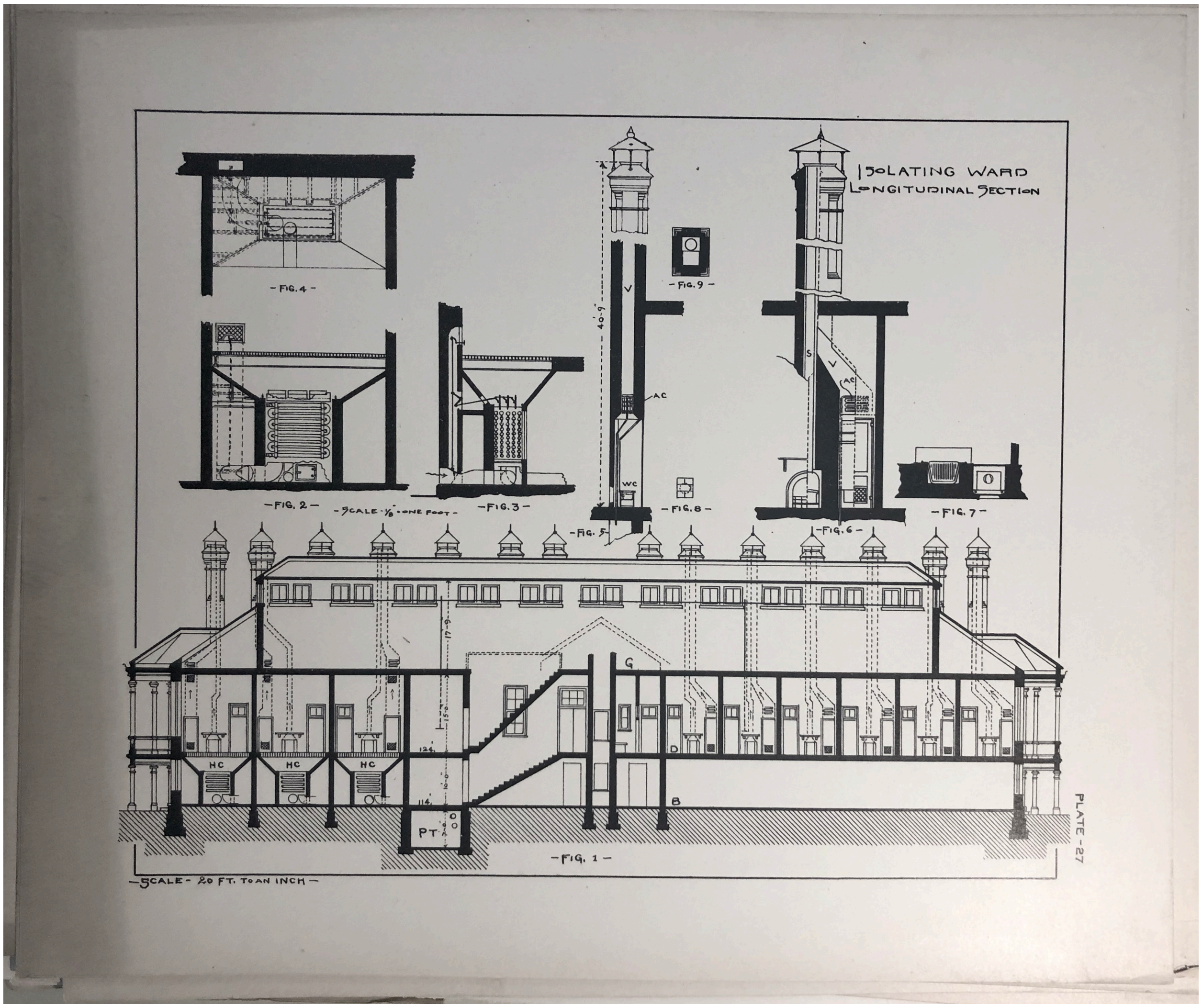



Figure 2.32: John S. Billings and John R. Niernsée, "Isolating Ward Longitudinal Section," John Shaw Billings Papers, the New York Public Library, Box. 84.

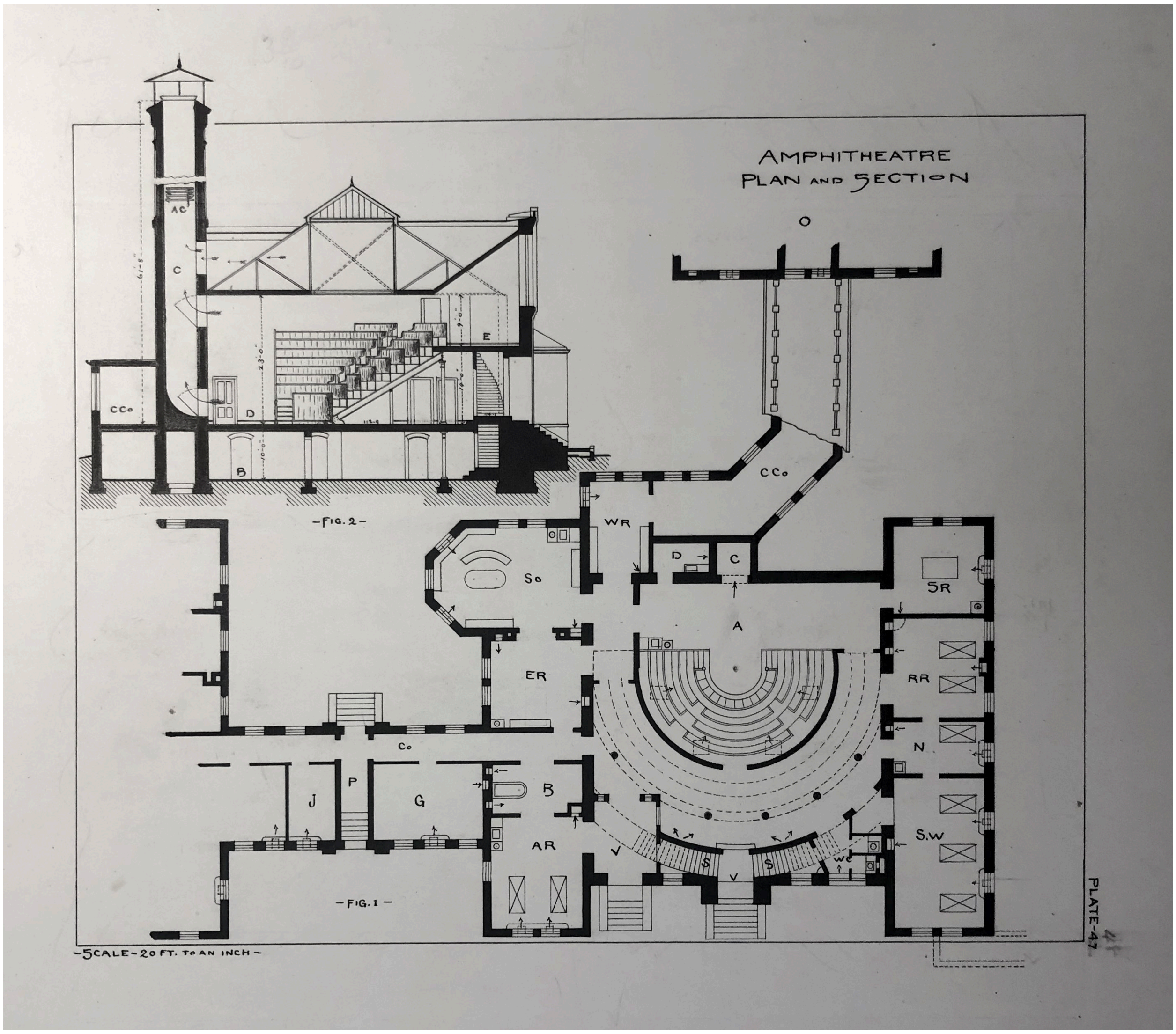



Figure 2.33: John S. Billings and John R. Niernsée, “Amphitheatre Plan and Section,” John Shaw Billings Papers, the New York Public Library, Box. 84.

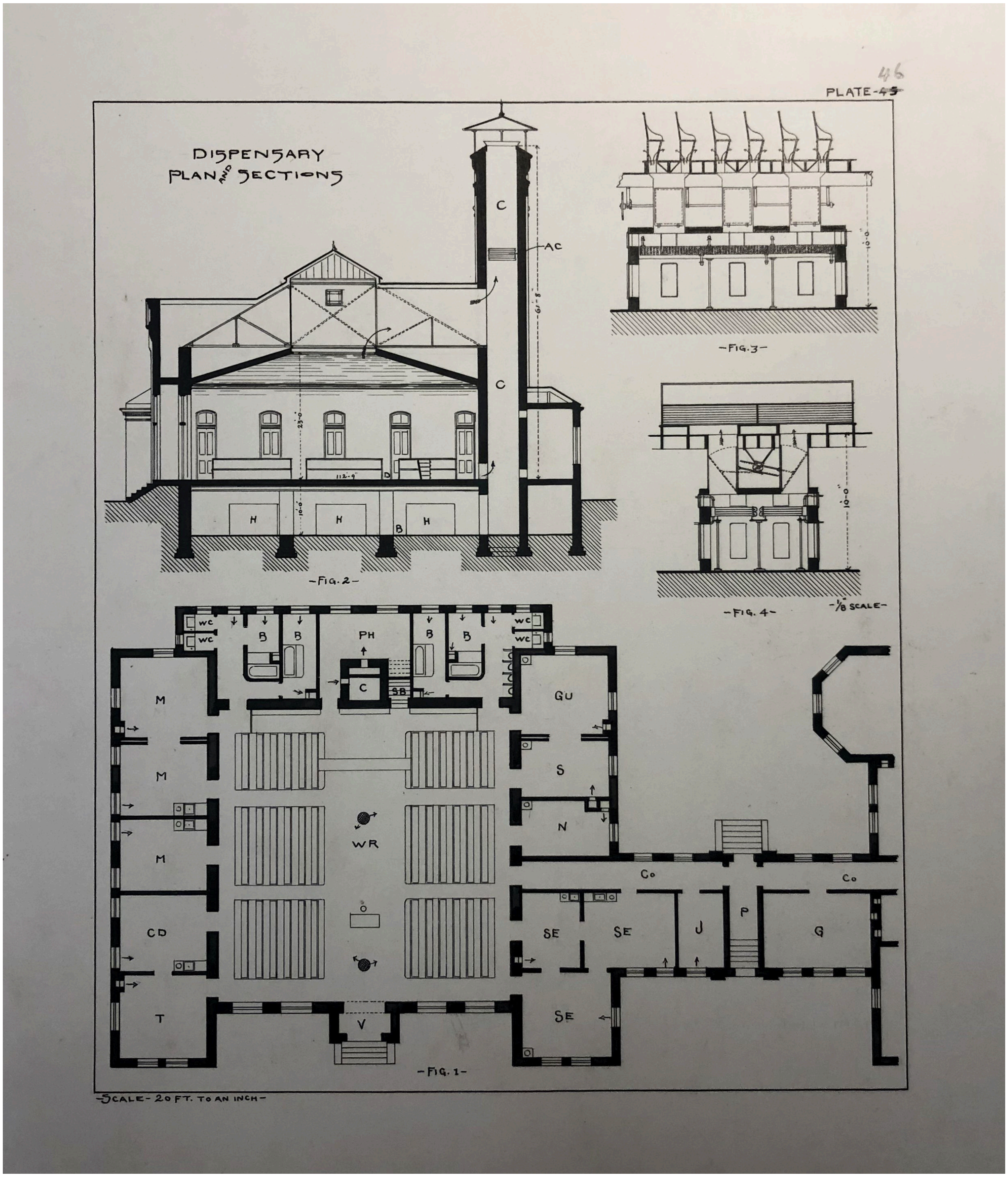



Figure 2.34: John S. Billings and John R. Niernsée, “Dispensary Plan and Sections,” with details of the ventilation system underneath the benched shown in Fig. 3 and Fig. 4, John Shaw Billings Papers, the New York Public Library, Box. 84.

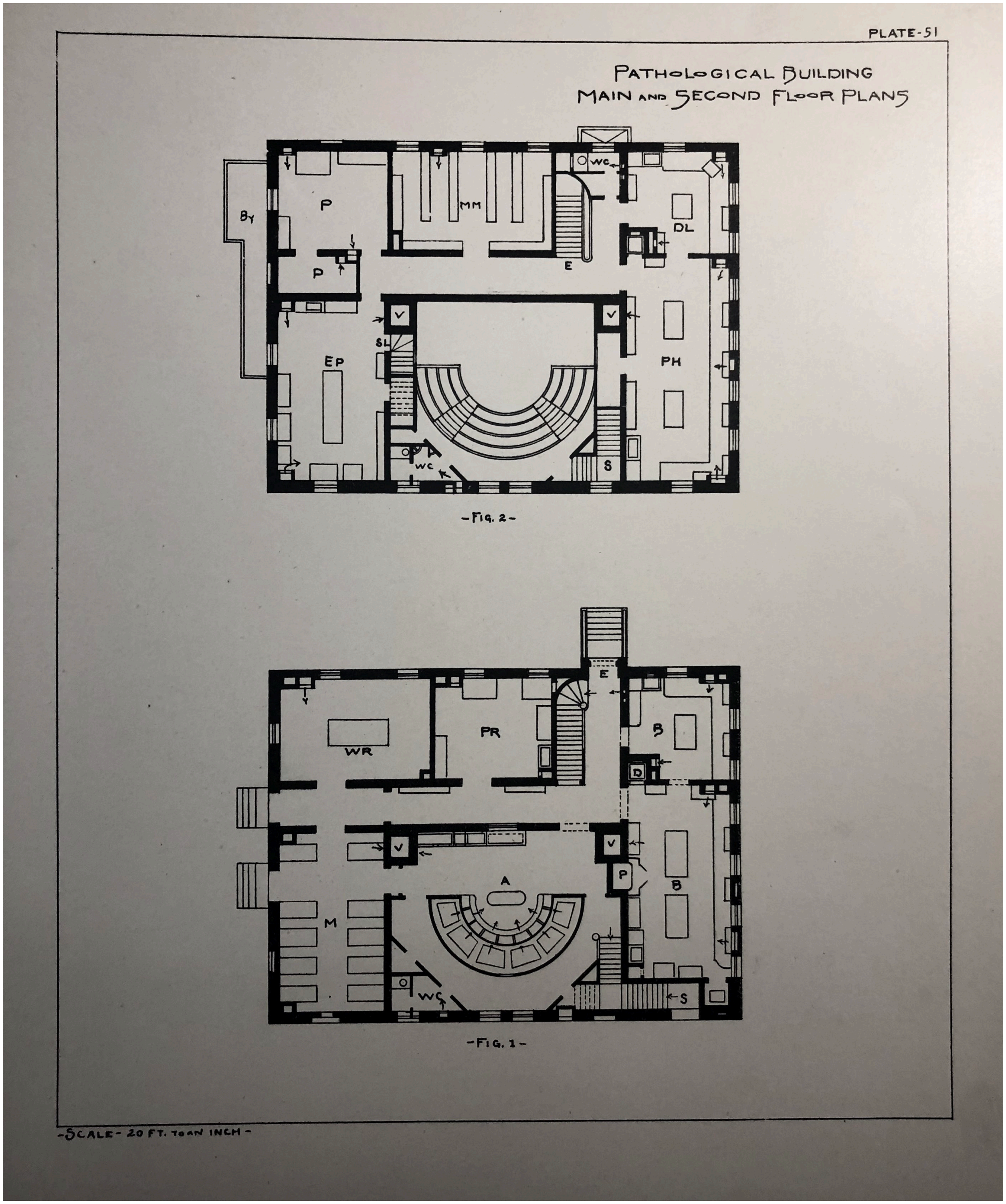



Figure 2.35: John S. Billings and John R. Niernsée, “Pathological Building Main and Second Floor Plans,” John Shaw Billings Papers, the New York Public Library, Box. 84.

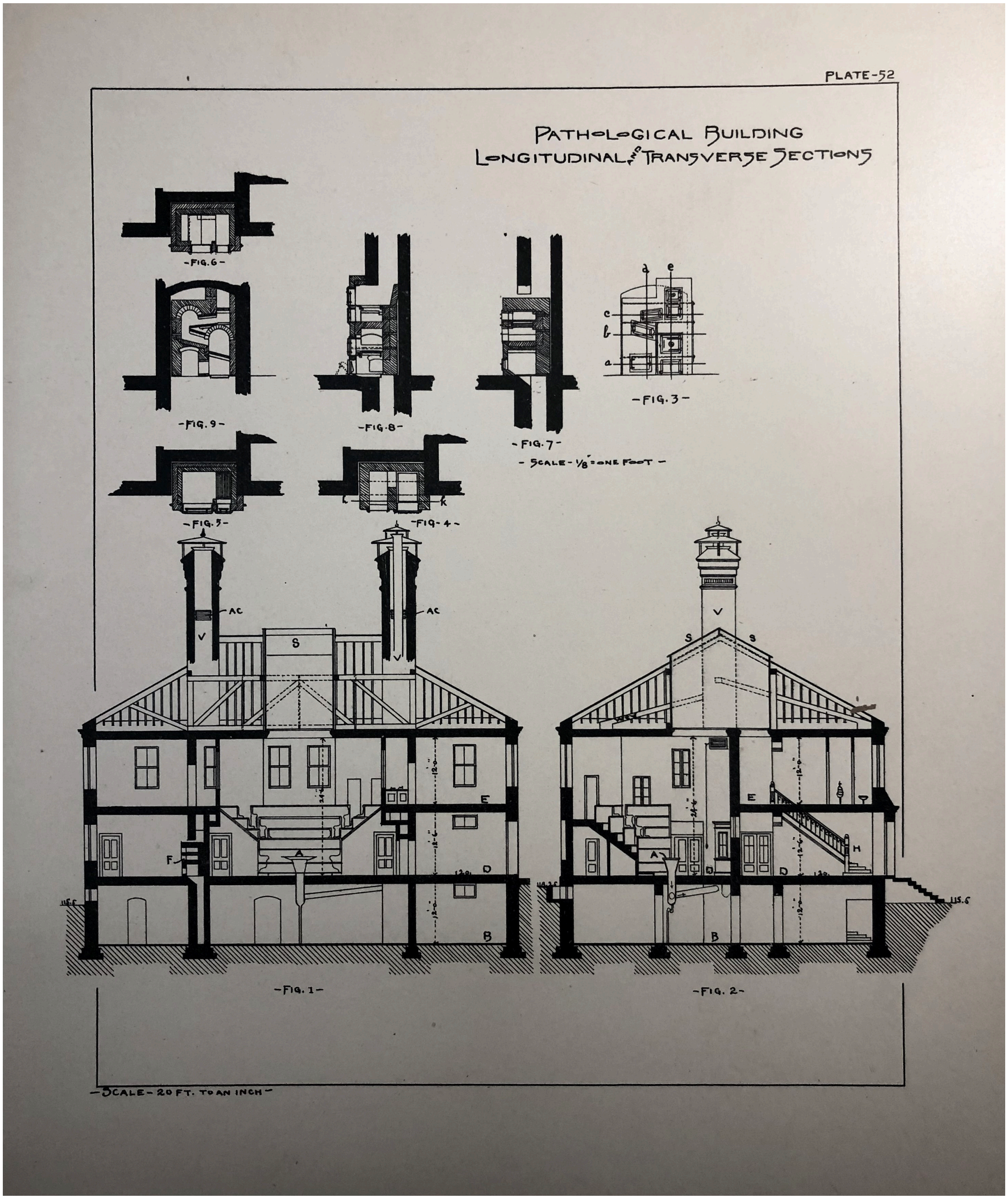



Figure 2.36: John S. Billings and John R. Niernsée, "Pathological Building Longitudinal and Transverse Sections," John Shaw Billings Papers, the New York Public Library, Box. 84.

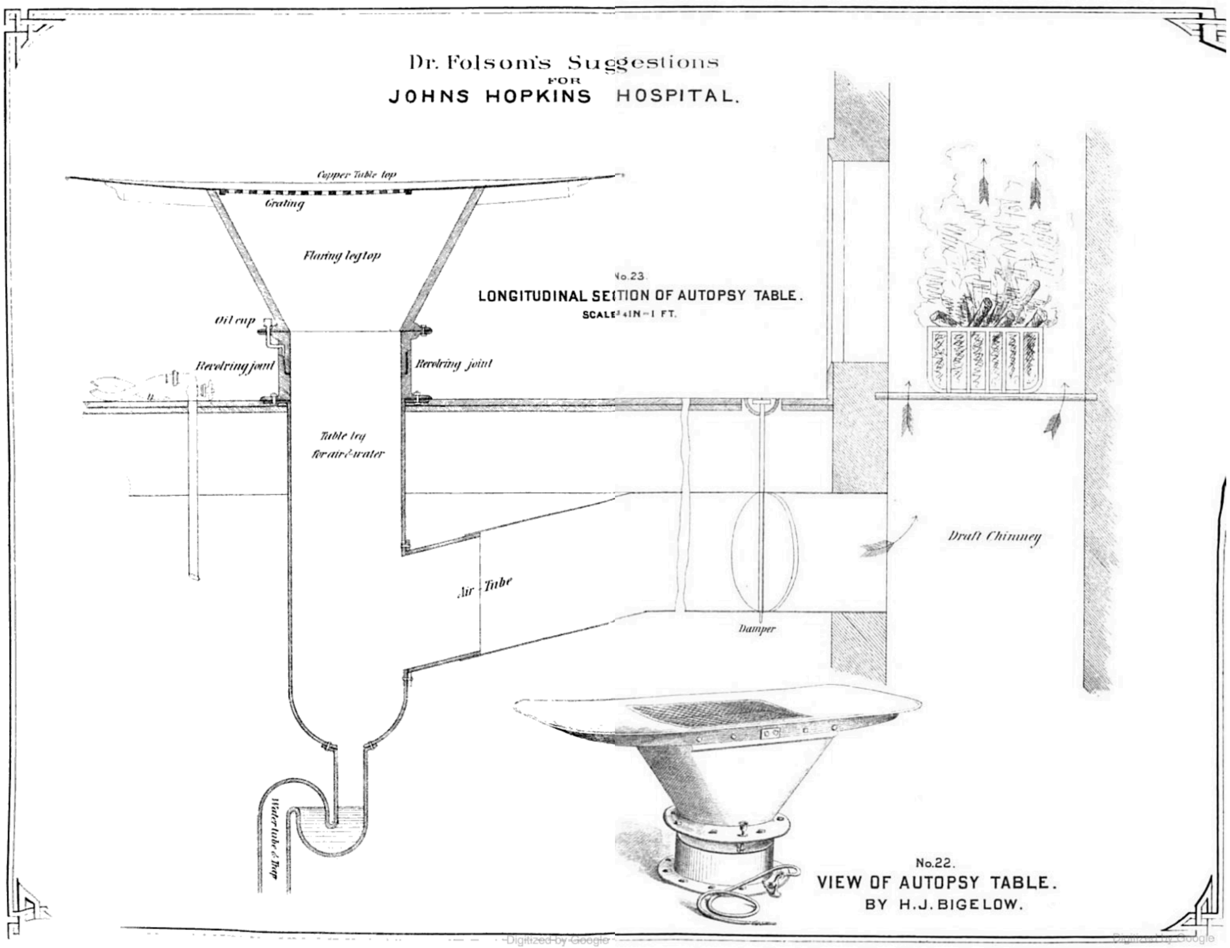



Figure 2.37: Norton Folsom, "View of Autopsy Table by H. J. Bigelow," *Hospital plans: Five Essays Relating to the Construction, Organization & Management of Hospitals, Contributed by Their Authors for the Use of the Johns Hopkins Hospital of Baltimore,* 1875.

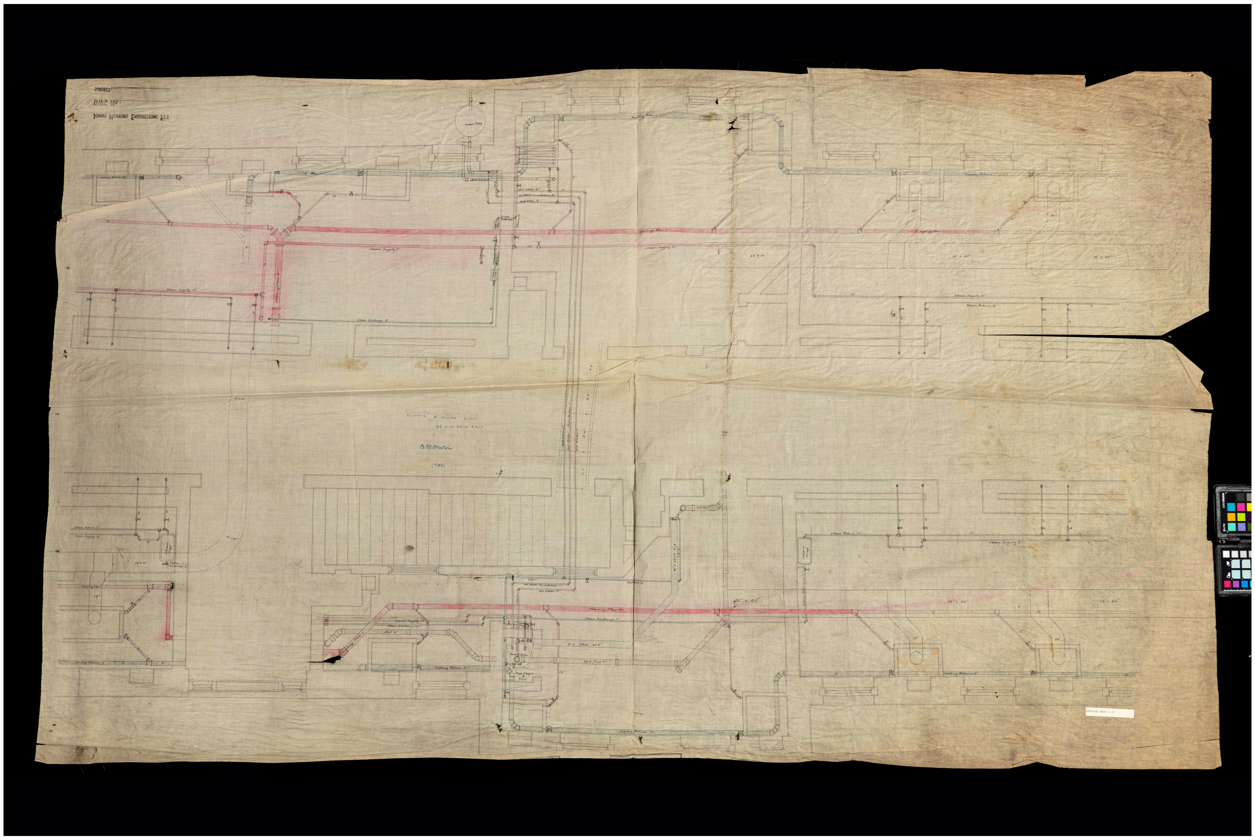


Figure 2.38: John S. Billings and John R. Niernsée, "Plumbing and Heating Plan," an undated detailed drawing showing the exposed pipes running above the spaces at the basement level of the Isolation Ward. The drawing is mislabeled as that of the Octagon Ward. Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

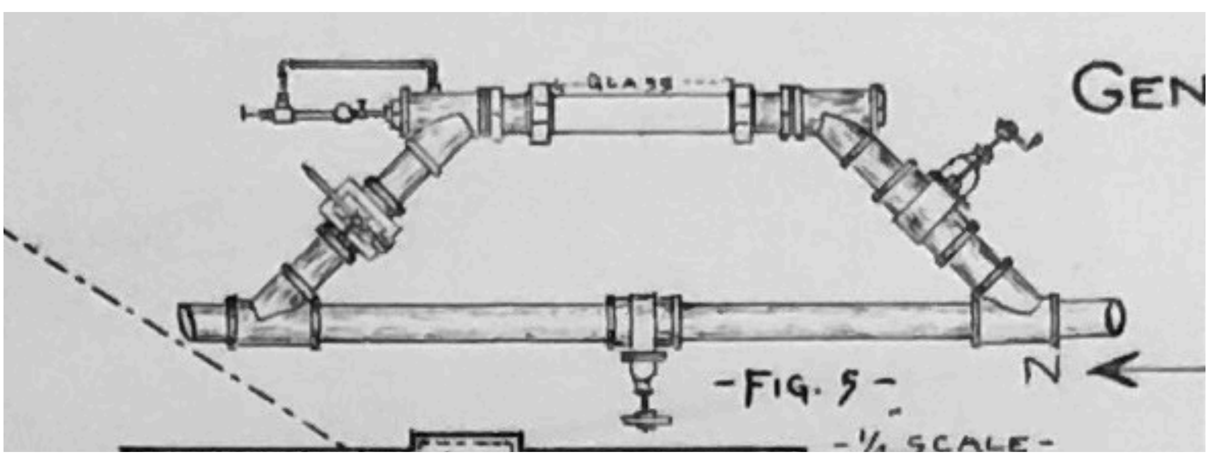



Figure 2.39: John S. Billings and John R. Niernsée, Detail of the by-pass mechanism with a glass tube, drawn on top of the "General Heating Plans" (Figure 1.19), John Shaw Billings Papers, the New York Public Library, Box. 84.

*Table Showing the Radiating Surface in the Steam Coils for Buildings and Rooms Heated by this System.*

| Building or Room. | Cubic Feet of Space Heated. | Square Feet of Radiating Surface. |
|---|---|---|
| Amphitheatre—Main Room | 55,614 | 1,216 |
| Dispensary—Main Room | 56,911 | 4,824 |
| Pathological Building—Amphitheatre | 26,019 | 492 |
| Laundry Building—Total | 59,544 | 1,071 |
| Ironing Room | 15,194 | 160 |
| Drying Room for Patients' Clothing | 1,664 | 340 |

*Table Showing the Number of Square Feet of Radiating Surface in the Hot Water Coils for the more Important Buildings and Rooms Supplied by this System.*

| Building or Room. | Cubic Feet of Space Heated. | Square Feet of Radiating Surface. |
|---|---|---|
| Administration Building—Total | 429,441 | 17,881 |
| Superintendent's Office | 14,973 | 630 |
| Pay Ward—Total | 147,554 | 7,947 |
| Single Room for Patients | 2,606 | 162 |
| Nurses' Home—Total | 229,104 | 9,394½ |
| Each Room | 1,760 | 85 |
| Octagon Ward—Ward | 44,192 | 2,400 |
| Bay Window in Ward | 2,400 | 60 |
| Nurses' Closet and Bath Room | 3,184 | 150 |
| Dining Room | 4,323 | 200 |
| Common Ward—Total | 78,880 | 5,307 |
| Main Ward | 39,766 | 3,150 |
| Private Ward | 3,570 | 262½ |
| Dining Room | 3,570 | 262½ |
| Water Closet and Lavatory | 2,924 | 162 |
| Foot-plate in Sun Room | 1,886 | 131 |
| Isolating Ward—Total | 59,295 | 4,645½ |
| Single Room | 2,145 | 162 |
| Apothecaries' Building—Total | 79,463 | 3,410 |

Figure 2.40: John S. Billings, "Table Showing the Radiating Surface in the Steam Coils for Buildings and Rooms Heated by this System" (top) and "Table Showing the Number of Square Feet of Radiating Surface in the Hot Water Coils for the more Important Buildings and Rooms Supplied by this System" (bottom), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).

*Table Showing Dimensions of Bath or Hot Water Boilers—Wrought Iron.*

| BUILDING. | NUMBER. | DIMENSIONS. | CAPACITY. |
|---|---|---|---|
| Isolating Ward . . . . . . . . . . . . . . | 1 | 2′6″ diam. × 5′6″ long. | 200 Gallons. |
| Common " . . . . . . . . . . . . . . | 1 | 2′6″ " × 6′0″ " | 220 " |
| Octagon " . . . . . . . . . . . . . . | 1 | 3′0″ " × 7′0″ " | 370 " |
| Amphitheatre Building . . . . . . . . . . | 1 | 2′6″ " × 5′0″ " | 183 " |
| Dispensary " . . . . . . . . . . . | 1 | 2′0″ " × 7′0″ " | 165 " |
| Kitchen " . . . . . . . . . . . | 1 | 3′0″ " × 8′0″ " | 423 " |
| Male Pay Ward . . . . . . . . . . . . . | 1 | 3′0″ " × 7′0″ " | 370 " |
| Administration Building . . . . . . . . . | 1 | 3′0″ " × 7′0″ " | 370 " |
| Apothecaries' " . . . . . . . . . . | 1 | 3′0″ " × 7′0″ " | 370 " |
| Nurses' Home " . . . . . . . . . | 1 | 3′0″ " × 7′0″ " | 370 " |
| Bath House " . . . . . . . . . | 2 | 2′6″ " × 6′0″ " | 440 " |
| Laundry " . . . . . . . . . | 1 | 2′6″ " × 13′0″ " | 477 " |

The following gives the dimensions of the steam boilers:

*Steam Boilers—Horizontal Tubular.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kitchen Building, | 3 | 60″×16′ 0″ | Boilers | with | 58 | 3½″ | tubes each. |
| Laundry " | 2 | 42″×11′ 0″ | " | " | 38 | 3″ | " " |
| Pathological " | 1 | 36″× 9′ 0″ | " | " | 28 | 3″ | " " |

Figure 2.41: John S. Billings, "Table Showing Dimensions of Bath or Hot Water Boilers—Wrought Iron" (top) and "dimensions of the steam boilers" (bottom), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).

*Coils in Aspirating Shafts.*

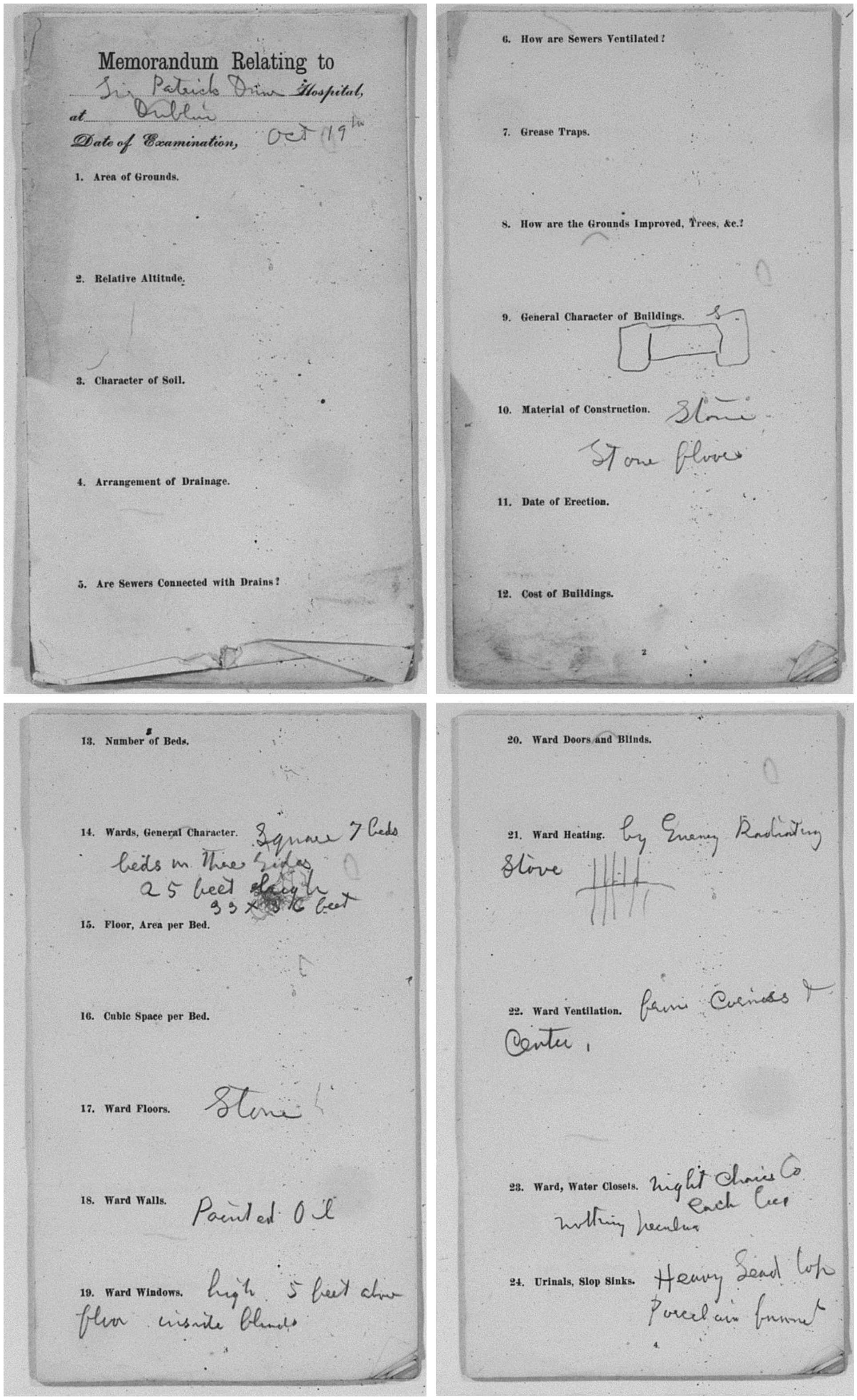
| | SQUARE FEET OF RADIATING SURFACE. | AREA OF SHAFT. | HEIGHT OF SHAFT ABOVE COIL. |
|---|---|---|---|
| Administration Building, W. C. Shaft . . . . . . . . | 50 | 28″× 36″ | 15 feet. |
| " " Bath Room Shaft . . . . . | 40 | 24″× 30″ | 15 " |
| Apothecary " W. C. Shaft . . . . . . . . | 30 | 3′5″× 14″ | 12 " |
| " " Vent, 2 cylinders 36″ inside | 25 | | Coil in S. E. only 20 feet. |
| Nurses' Home " W. C. Shaft . . . . . . . . | 30 | 24″× 32″ | 25 feet. |
| " " " " " . . . . . . . . | 30 | 24″× 32″ | 25 " |
| " " " Vent " . . . . . . . . | 150 | 6′× 3″× 6′3″ | 25 " |
| Male Pay Ward " " " . . . . . . . . | 72 | 2′ × 2′6″ | 20 " |
| " " " W. C. " . . . . . . . . | 40 | 30″× 24″ | 20 " |
| " " " Slop Sink Shaft . . . . . . | 30 | 30″× 24″ | 20 " |
| Female " " Vent " . . . . . . | 72 | 2′ × 2′6″ | 20 " |
| " " " W. C. " . . . . . . | 40 | 30″× 24″ | 20 " |
| " " " Slop Sink " . . . . . . | 30 | 30″× 24″ | 20 " |
| Bath House " W. C. and Vent Shaft . . | 50 | 30″× 18″ | 12 " |
| Kitchen " W. C. Shaft . . . . . . . . | 60 | 36″× 24″ | 12 " |
| Common Wards, each Ward " . . . . . . . . | 70 | 5′2″× 5′2″ | 30 " |
| " " Service " . . . . . . . . | 56 | 4′ × 4′ | 12 " |
| " " W. C. " . . . . . . . . | 60 | 24″× 36″ | 30 " |
| Octagon Ward, Ward " . . . . . . . . | 130 | 8′ × 8′ | 30 " |
| " " Service " . . . . . . . . | 64 | 4′ × 4′ | 12 " |
| " " W. C. " . . . . . . . . | 50 | 3′ × 3′ | 30 " |
| Isolating " Commode Closets, each Shaft . . . . | 40 | 2′6″× 18″ | 40 " |
| " " W. C. Shaft . . . . . . . . . . . . | 40 | 36″× 2′ | 10 " |
| Amphitheatre Building, Vent Shaft . . . . . . . . | 160 | 6′ × 6′ | 25 " |
| " " W. C. " West . . . . . | 20 | 1′ × 4″ | 2 " |
| " " " " East . . . . . | 20 | 1′ × 2″ | 2 " |
| Dispensary " Vent " . . . . . . . . | 160 | 6′ × 6′ | 25 " |
| " " W. C " . . . . . . . . | 20 | 8″× 12″ | 2 " |
| " " " " . . . . . . . . | 20 | 8″× 12″ | 2 " |
| Autopsy " North Vent Shaft . . . . . | 54 | 3′ × 3′6″ | 30 " |
| " " South " " . . . . . | 54 | 6′ × 6′ | 30 " |
| Laundry " Main " " 5′0″×5′0″ | Boiler Smoke, 24″ diam. | | |
| " " Drying Room " 5′0″×5′0″ | Ironing Stove, 12″ " | | |
| " " W. C. " 14″×13″ | Steam Pipe, 4″ 7 sq. ft. rad. sur. | | |

Figure 2.42: John S. Billings, "Coils in Aspirating Shafts," John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).

| MONTH. | TEMPERATURE OF OUTSIDE AIR. | | | TEMPERATURE OF AIR IN WARD. | | | MEAN REL. HUMIDITY. | | MEAN DEW POINT. | | MEAN TEMP. IN COILS. | | VELOCITY OF INCOMING AIR. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean. | Max. | Min. | Mean. | Outs'e. | Inside. | Outs'e. | Inside. | Flow. | Ret'rn. | Average. |
| November | 67° | 27° | 44.2° | 75.5° | 62.4° | 70.4° | 70.7% | 33.2% | 34.7° | 38.5° | 119.7° | 110° | 3 feet. |
| December | 50.1° | 33.3 | 43.6° | 74.5° | 67.3° | 70.5° | 73% | 34.2% | 34.8° | 39.8° | 134.8° | 129.7° | 3.3 feet.* |

* *i. e.* 1.6 feet per bed per second.

Figure 2.43: John S. Billings, Table showing "the average temperatures, the mean relative humidity, and the mean dew point of the outside air as compared with the corresponding figures for the air in the wards," John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890).


Memorandum Relating to
Sir Patrick Dun Hospital,
at Dublin
Date of Examination, Oct 19th

1. Area of Grounds.

2. Relative Altitude.

3. Character of Soil.

4. Arrangement of Drainage.

5. Are Sewers Connected with Drains?

6. How are Sewers Ventilated?

7. Grease Traps.

8. How are the Grounds Improved, Trees, &c.?

9. General Character of Buildings.

10. Material of Construction. Stone
Stone floors

11. Date of Erection.

12. Cost of Buildings.

2

13. Number of Beds.

14. Wards, General Character. Square 7 beds
beds on three sides
25 feet high
33 × [illegible] feet

15. Floor, Area per Bed.

16. Cubic Space per Bed.

17. Ward Floors. Stone

18. Ward Walls. Painted Oil

19. Ward Windows. high 5 feet above
floor inside blinds

3

20. Ward Doors and Blinds.

21. Ward Heating. by Emery Radiating
Stove

22. Ward Ventilation. from corners &
center.

23. Ward, Water Closets. night chairs to
each bed
nothing peculiar

24. Urinals, Slop Sinks. Heavy lead tops
Porcelain funnel

4

Figure 3.1: John S. Billings, "Memorandum Relating to Sir Patrick Dun's Hospital," (October 19, 1876), John Shaw Billings Papers, the New York Public Library, Box 48.

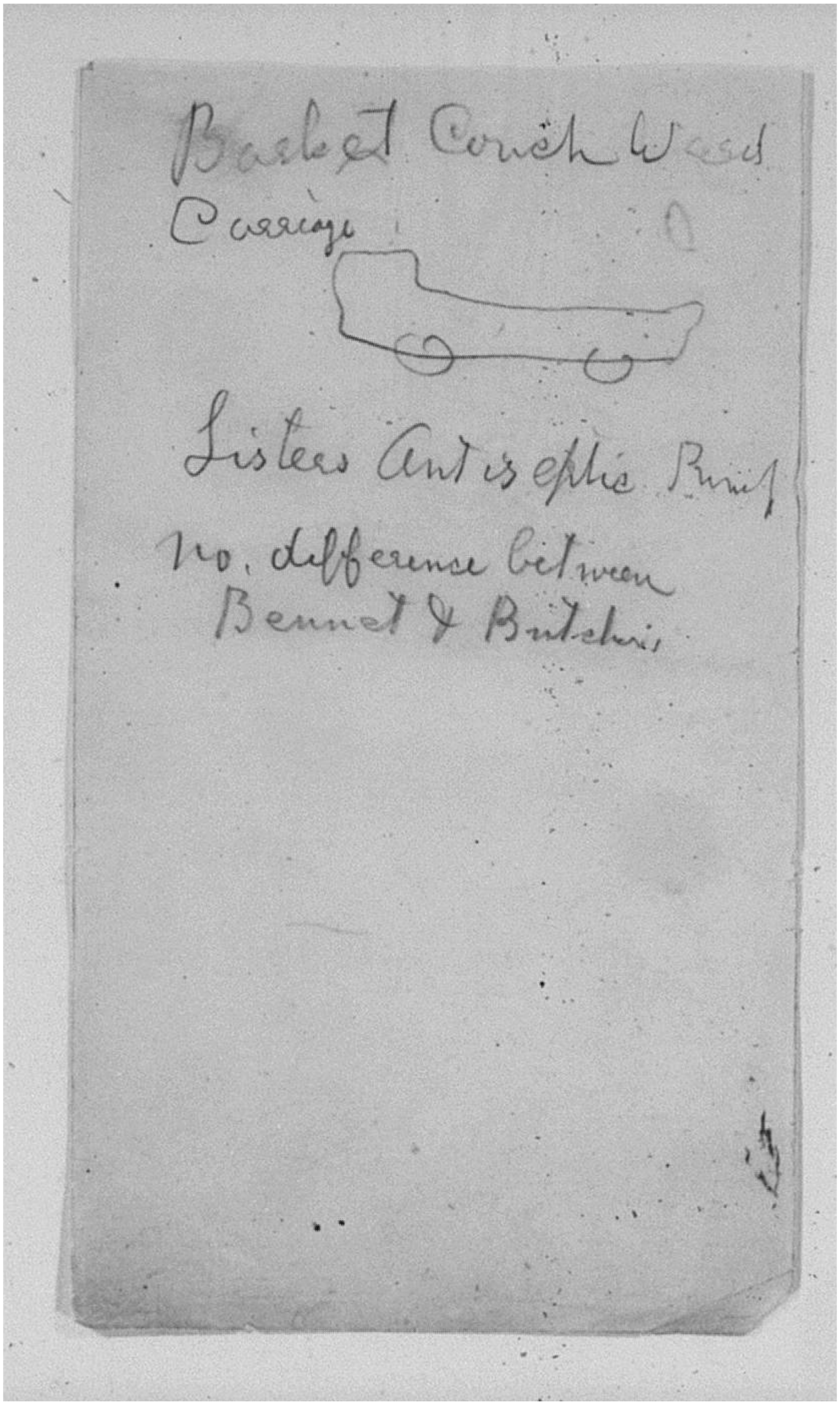



Figure 3.2: John S. Billings, Notes and sketch on the back of "Memorandum Relating to Sir Patrick Dun's Hospital," (October 19, 1876), John Shaw Billings Papers, the New York Public Library, Box 48.

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## PLATFORM TRUCK.

***Style 28.***

This is an excellent form of Truck for general Mill, Store and Warehouse use. It is mounted on Wheels of large diameter, runs with great ease, and can be turned and handled in less floor space, than is required by other patterns of Trucks. It is built in the strongest manner.

The above cut represents Truck with Platform 2 feet x 4 feet, mounted on 12 inch diameter Rubber Wheels in the rear, with 6 inch diameter Swivel Rubber Wheel Casters in front.

| | | |
|---|---|---|
| Price, with Iron Wheels, | . . . . | $23.00 |
| " " Rubber, | . . . . | 31.50 24.00 |

These Trucks made to order promptly with any size of Wheel or Platform.

Figure 3.3: Johns Shaw Billings' annotated copy of George P. Clark, "Catalogue of Rubber Wheels, Casters, Trucks, Etc." showing a selected "Platform Truck." Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.




All Styles of Casters furnished with Iron Wheels when ordered.

Prices given upon application.

**Socket Rubber Wheel Caster.**

***No. 8.***

Made to fit legs from 1¼ so 3 inches square.
In ordering, please state size of Socket wanted.

Price per Dozen.

| Diameter Wheel. inches. | |
|---|---|
| 3 in. swivel, | $13 00 |
| 4 in. " | 18 00 |
| 5 in. " | 26 00 |
| 6 in. " | 38 00 |

Figure 3.4: Johns Shaw Billings' annotated copy of George P. Clark, "Catalogue of Rubber Wheels, Casters, Trucks, Etc." showing a selected "Socket Rubber Wheel Caster." Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

Figure 3.5: The movable washstands visible in an interior view of the Octagon Ward. (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 19.


Figure 3.6: "Front View of Buildings from Northeast" (photographed by Frederick Gutekunst in 1889), showing the Administration Building and the two Pay Wards facing Broadway, John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 1.

Figure 3.7: "Front View of Building and Grounds" (1889), Buildings Photograph Collection, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

Figure 3.8: “Johns Hopkins Hospital viewed from the northeast corner,” taken at the corner of Broadway and Monument street (1889), Buildings Photograph Collection, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

PLATE 3.

REAR VIEW OF BUILDINGS AND GROUNDS FROM SOUTHEAST.

Figure 3.9: “Rear View of Buildings and Grounds from Southeast,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 3.

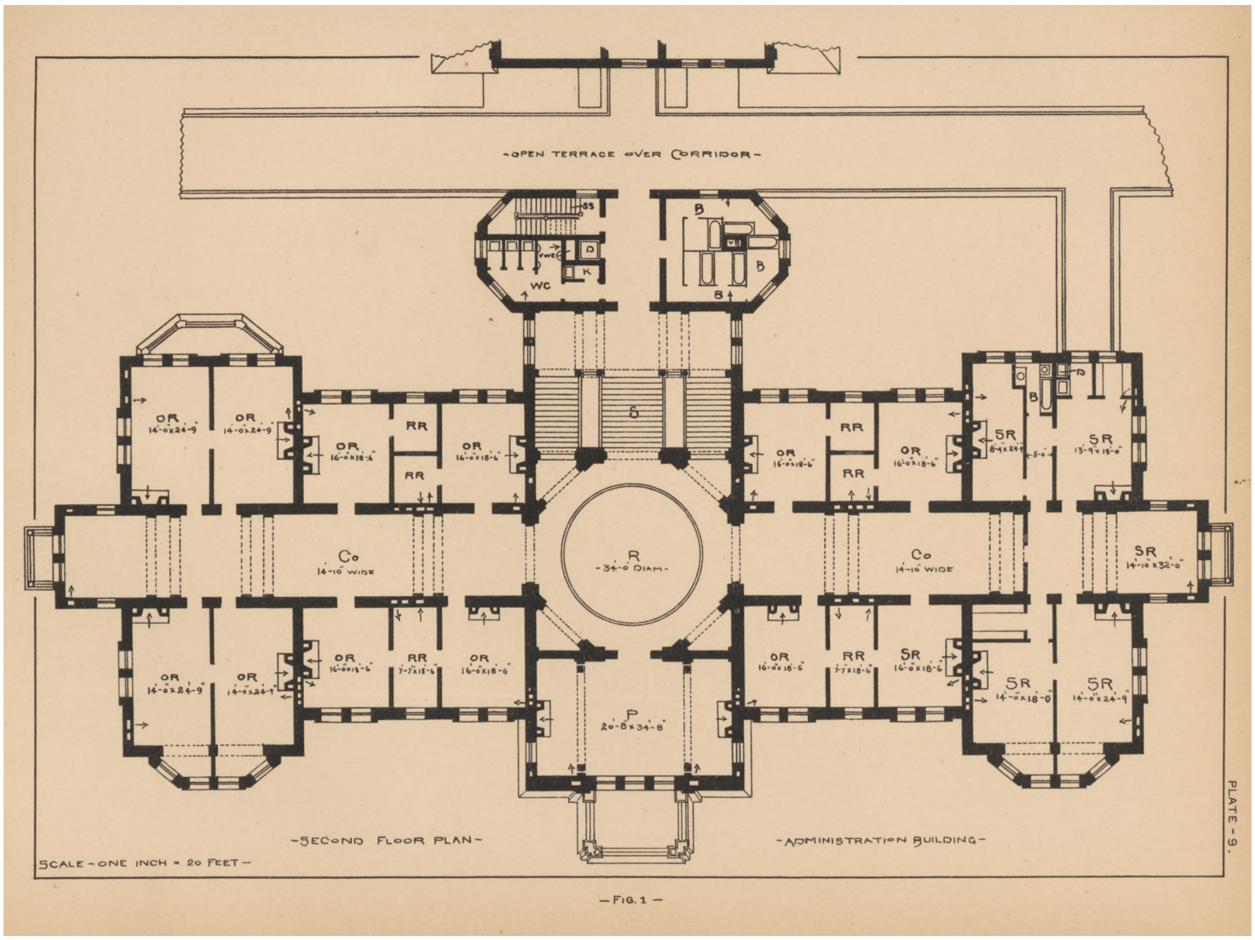



Figure 3.10: "Second floor plan, Administration Building," John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 9.


Figure 3.11: “Administration Building, Longitudinal Section,” John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 10.

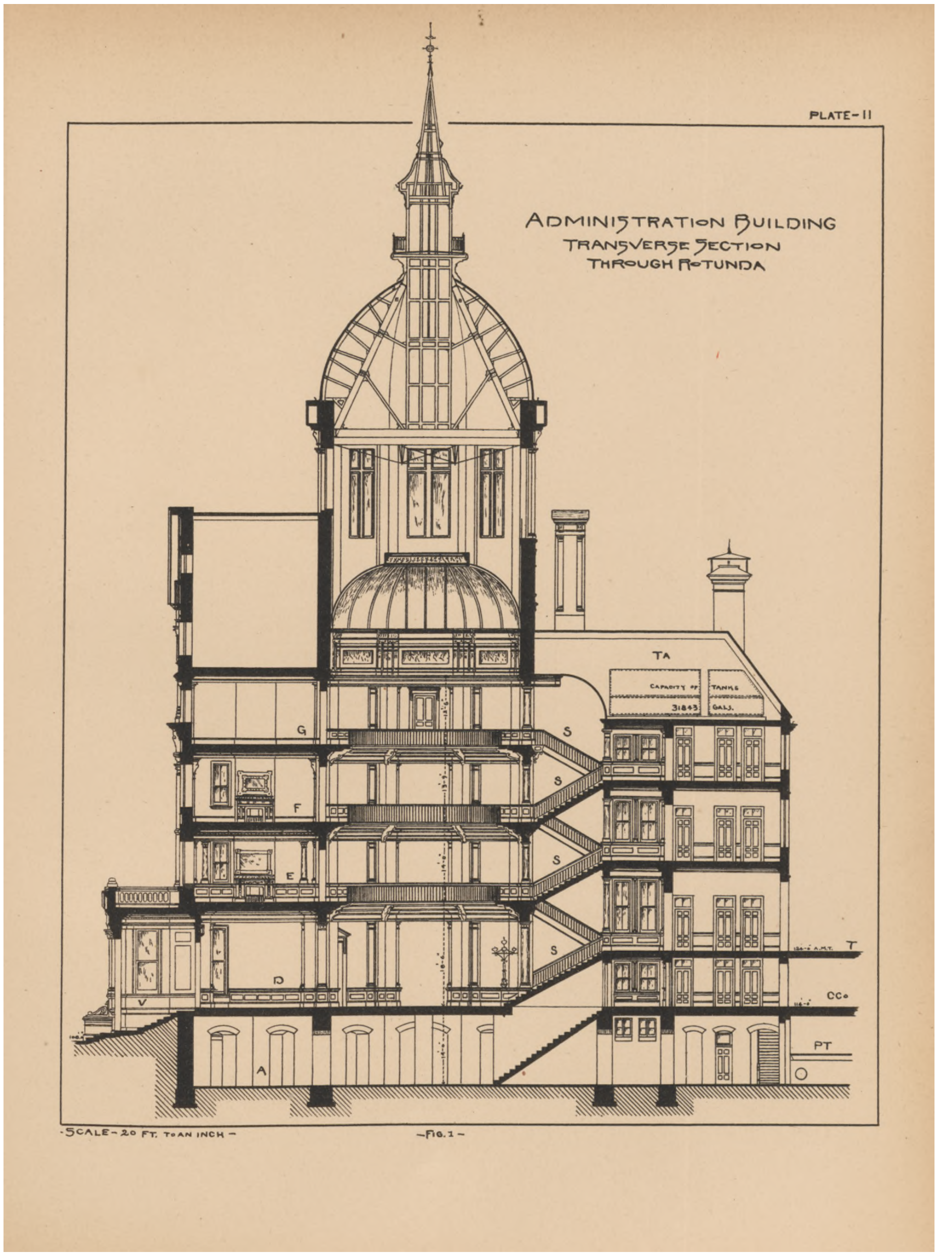



Figure 3.12: "Administration Building, Transverse Section through Rotunda," John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 11.

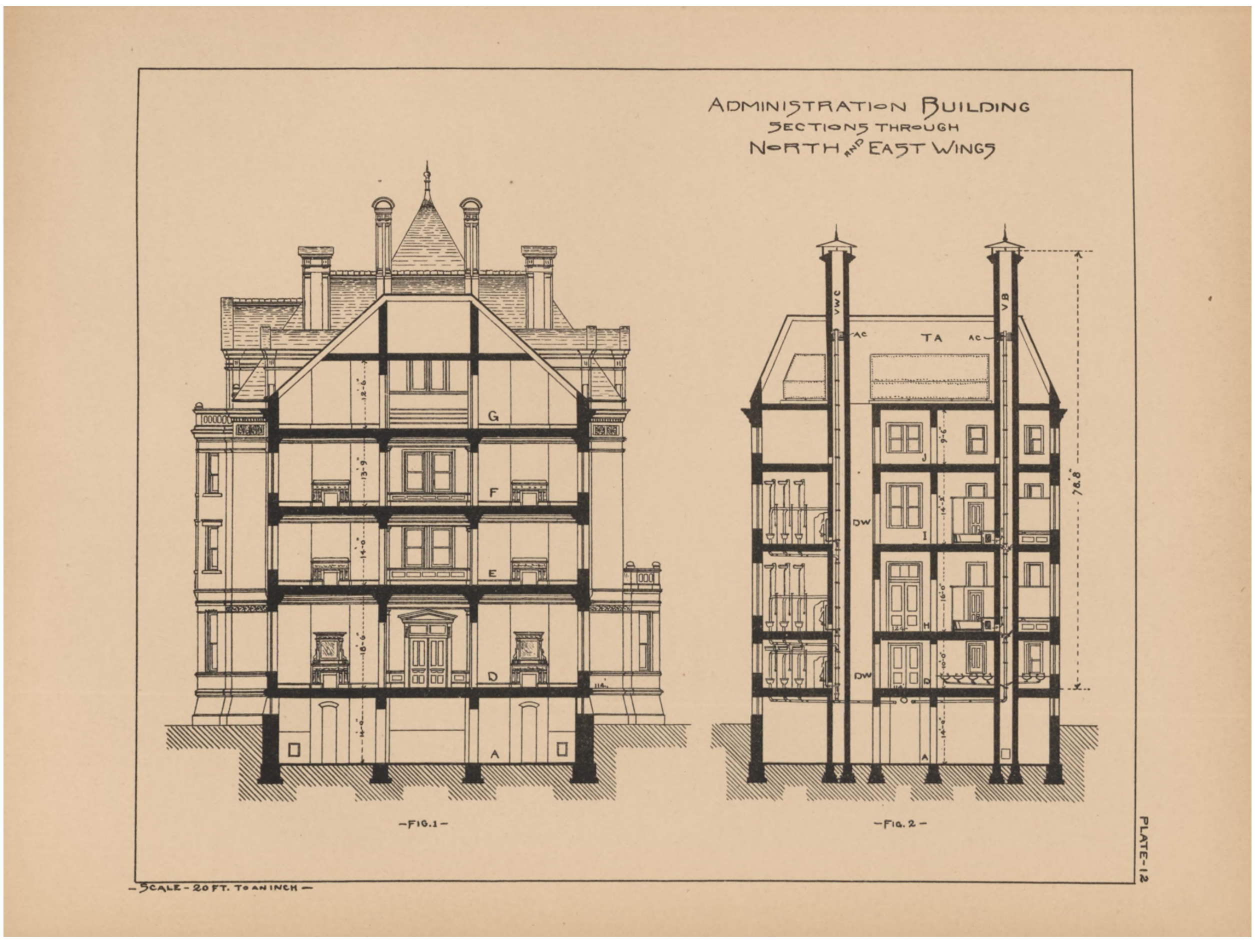



Figure 3.13: "Administration Building, Sections through North and East Wings," John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 12.


Figure 3.14: "Octagon Ward, View from Southeast," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 20.


Figure 3.15: "Common Ward, View from Southeast," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 25.


Figure 3.16: “Isolating Ward, View from Northeast,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 28.


Figure 3.17: "Nurses' Home, View from Northeast," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 41.

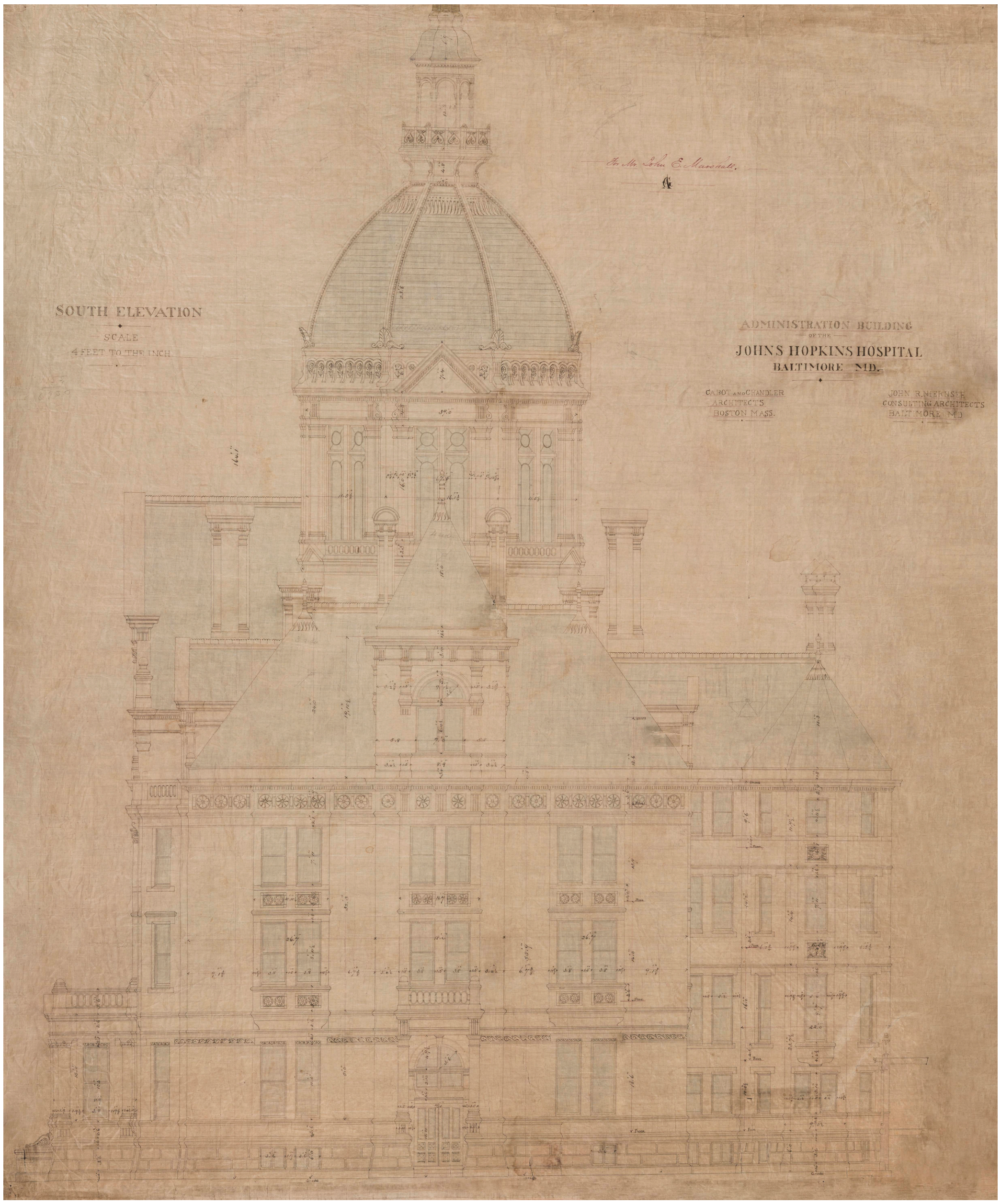



Figure 3.18: Cabot and Chandler Architects, South Elevation of the Administration Building of the Johns Hopkins Hospital, (circa. 1879), Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

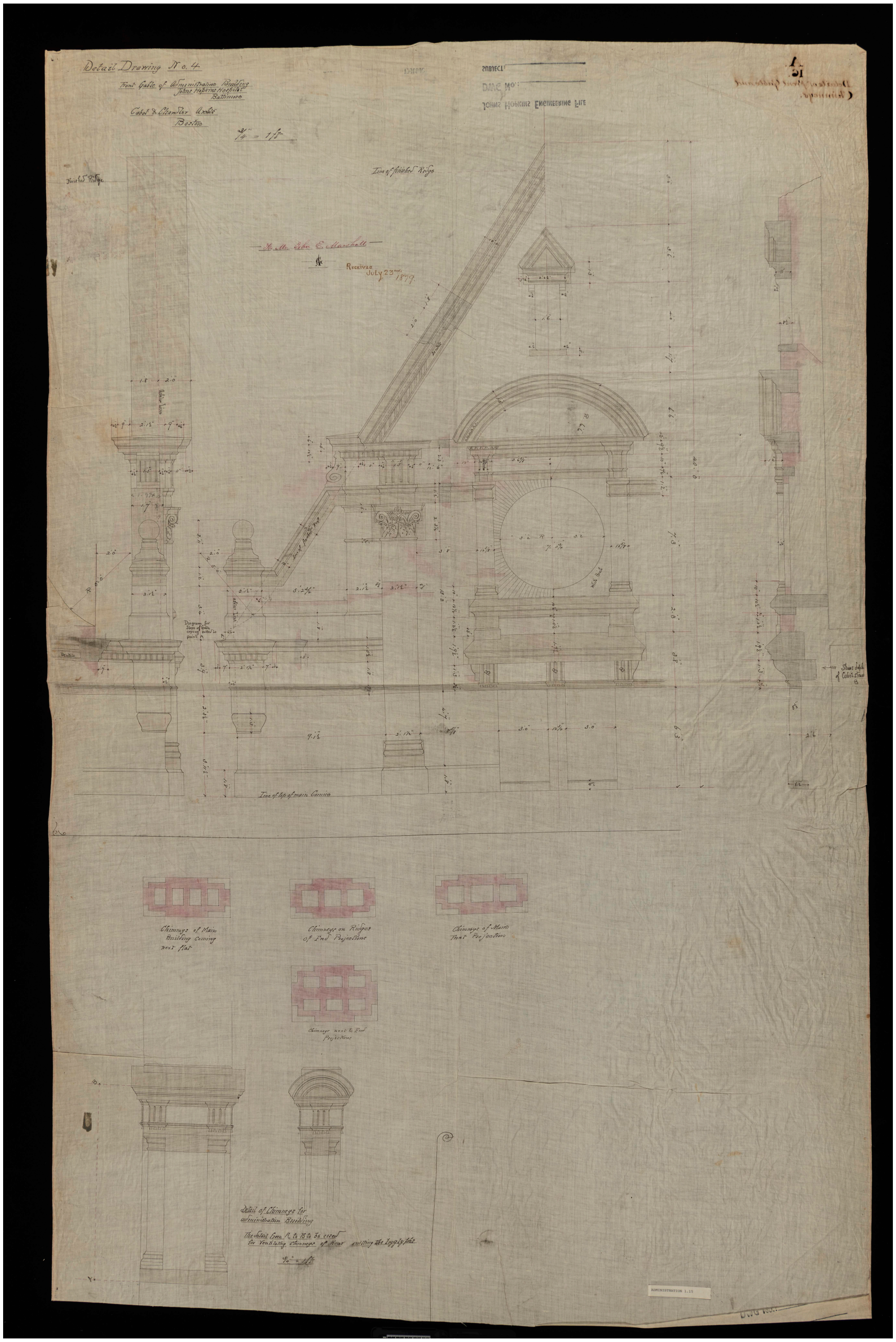



Figure 3.19: Cabot and Chandler Architects, “Detail Drawing No. 4, Front Gable of Administration Building,” the Johns Hopkins Hospital, (received on July 23, 1879), Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.


Figure 3.20: Cabot and Chandler Architects, “Mantle in Visitors Parlor in the Administration Building,” the Johns Hopkins Hospital, (circa. 1879), Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.

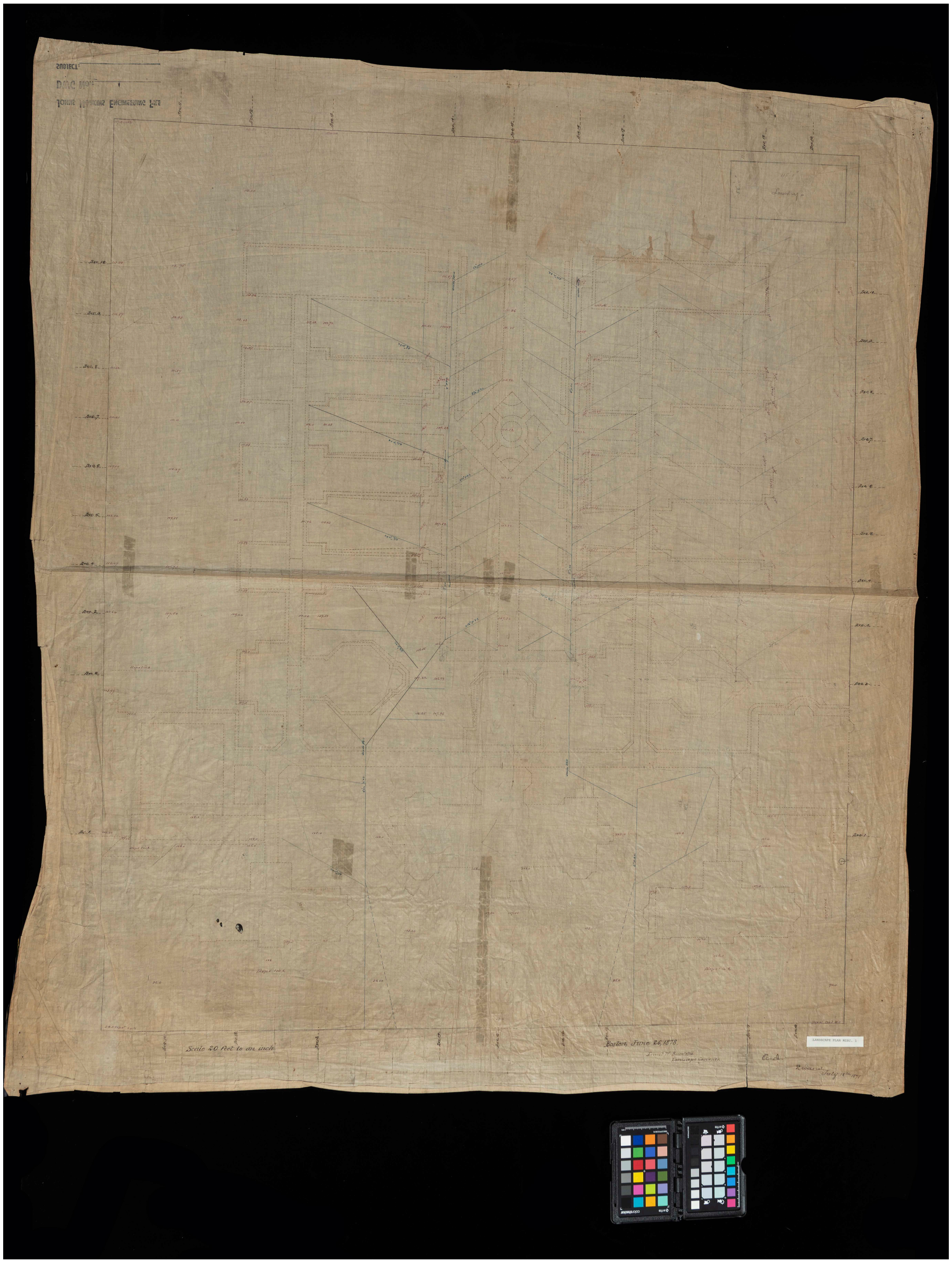
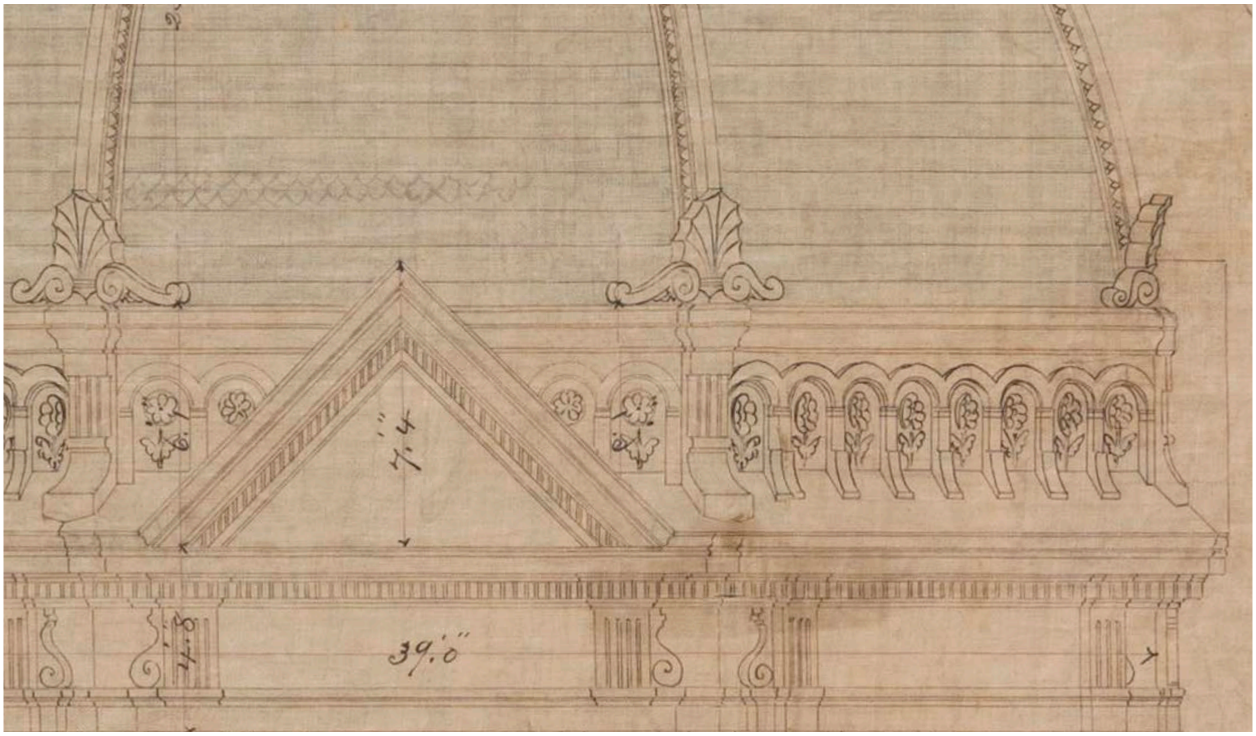


Figure 3.21: Ernest W. Bowditch, “Landscape Plan,” the Johns Hopkins Hospital, (June 26, 1878), Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.



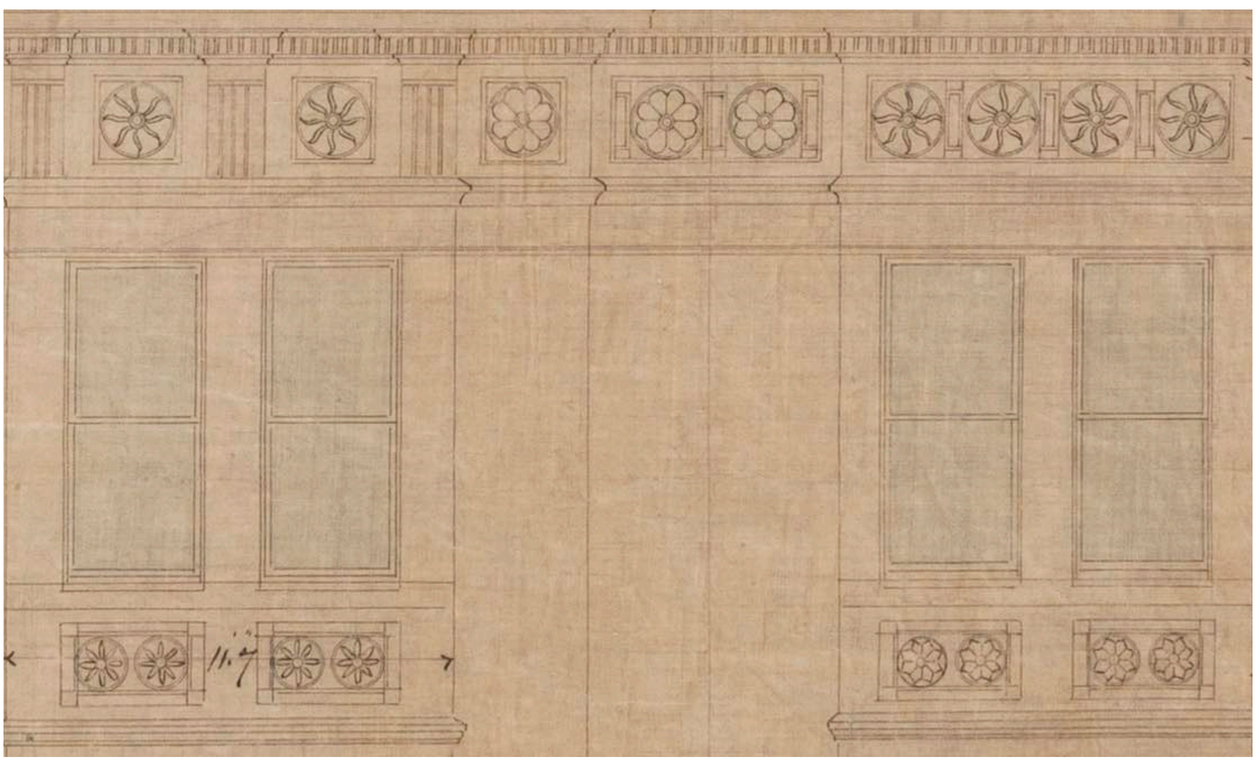
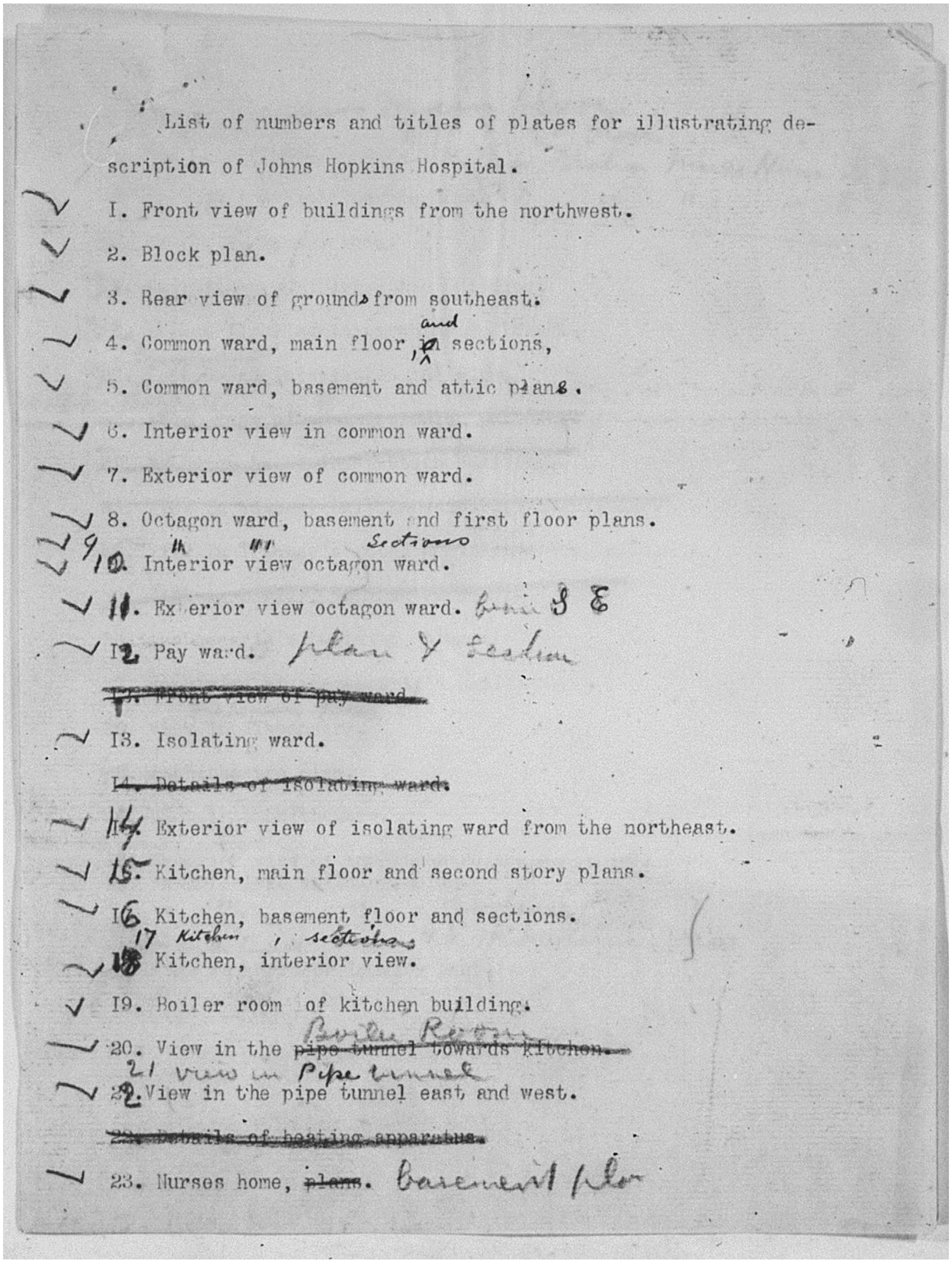




Figure 3.22: Floral ornaments of Cabot and Chandler Architects, South Elevation of the Administration Building of the Johns Hopkins Hospital, (1879), Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions.



List of numbers and titles of plates for illustrating description of Johns Hopkins Hospital.

I. Front view of buildings from the northwest.

2. Block plan.

3. Rear view of grounds from southeast.

4. Common ward, main floor, and sections,

5. Common ward, basement and attic plans.

6. Interior view in common ward.

7. Exterior view of common ward.

8. Octagon ward, basement and first floor plans.

9 sections
10. Interior view octagon ward.

11. Exterior view octagon ward.

12. Pay ward. plan & section

~~I2. Front view of pay ward.~~

I3. Isolating ward.

~~I4. Details of isolating ward.~~

14. Exterior view of isolating ward from the northeast.

15. Kitchen, main floor and second story plans.

16. Kitchen, basement floor and sections.

17 Kitchen, sections
18 Kitchen, interior view.

I9. Boiler room of kitchen building.

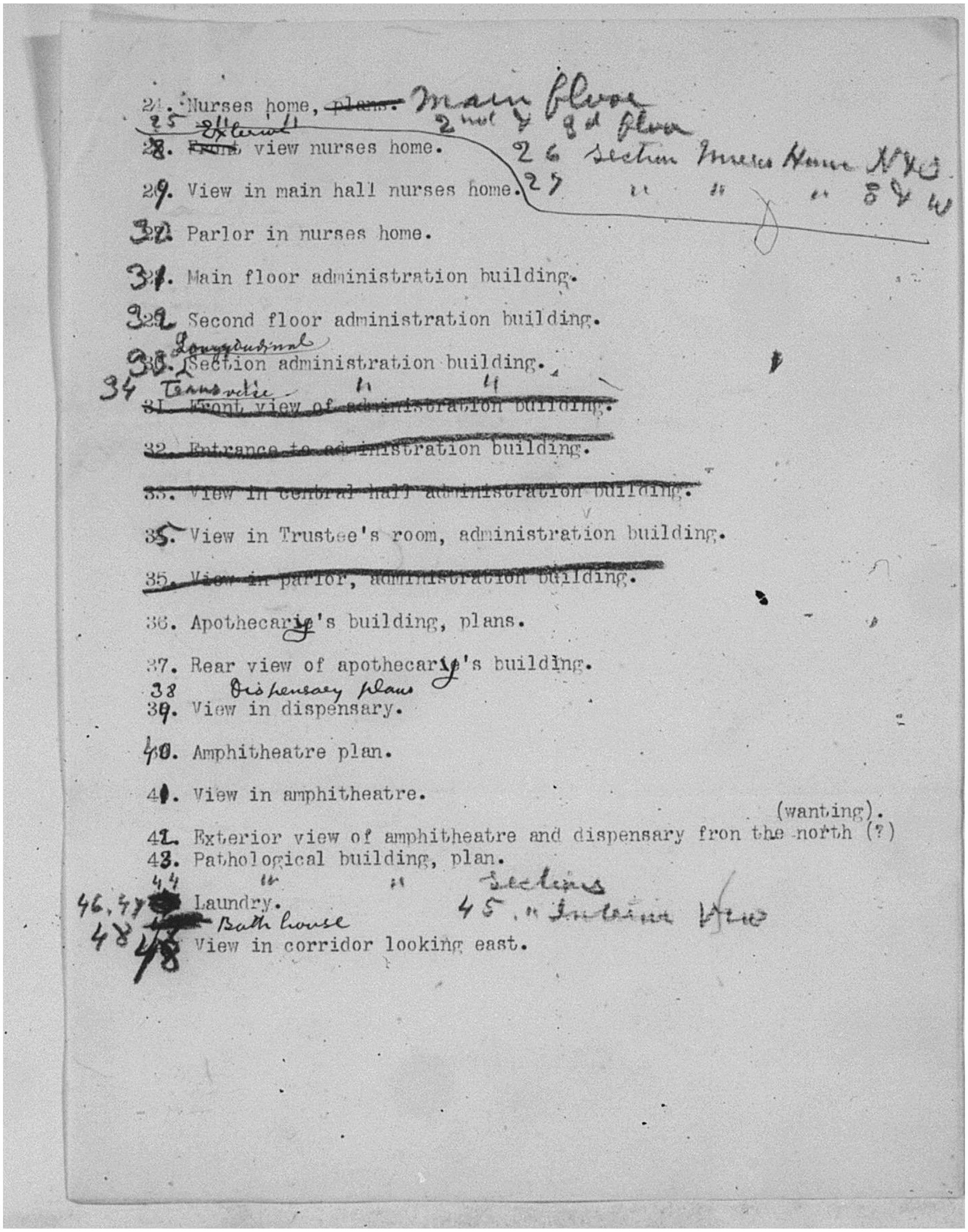
20. View in the ~~pipe tunnel towards kitchen.~~ Boiler Room

21 view in Pipe tunnel
22. View in the pipe tunnel east and west.

~~22. Details of heating apparatus.~~

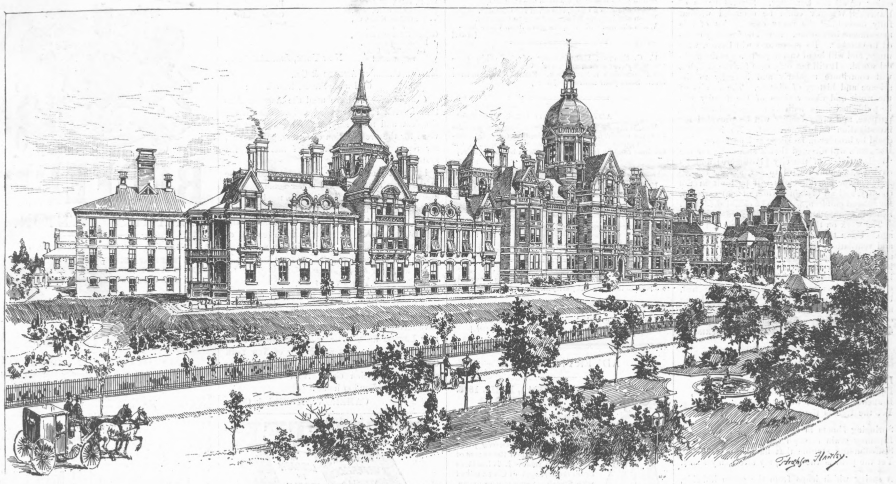
23. Nurses home, ~~plans.~~ basement plan

Figure 3.23: John Shaw Billings, “List of number and titles of plates for illustrating description of Johns Hopkins Hospital,” John Shaw Billings Papers, Miscellaneous Papers of the Johns Hopkins Hospital & Medical Dept., Box 48.



24. Nurses home, ~~plans.~~ Main floor 2nd & 3d floor
25 External
28. ~~Front~~ view nurses home. 26 Section Nurses Home N & S
29. View in main hall nurses home. 27 " " " E & W
30. Parlor in nurses home.
31. Main floor administration building.
32. Second floor administration building.
33. Longitudinal Section administration building.
34 Transverse " "
~~31. Front view of administration building.~~
~~32. Entrance to administration building.~~
~~33. View in central hall administration building.~~
35. View in Trustee's room, administration building.
~~35. View in parlor, administration building.~~
36. Apothecary's building, plans.
37. Rear view of apothecary's building.
38 Dispensary plans
39. View in dispensary.
40. Amphitheatre plan.
41. View in amphitheatre.
(wanting).
42. Exterior view of amphitheatre and dispensary from the north (?)
43. Pathological building, plan.
44 " " Sections
46, 47 Laundry. 45 " Interior View
Bath house
48 View in corridor looking east.

Figure 3.24: John Shaw Billings, "List of number and titles of plates for illustrating description of Johns Hopkins Hospital," John Shaw Billings Papers, Miscellaneous Papers of the Johns Hopkins Hospital & Medical Dept., Box 48.



THE THREE MAIN BUILDINGS FRONTING ON BROADWAY.

## THE JOHNS HOPKINS HOSPITAL.

JOHNS HOPKINS died in December, 1873. He left a fortune of upward of eight millions of dollars. This he had accumulated by persistent thrift and judicious investment. He was from one of the oldest Quaker families in Maryland. He began in Baltimore as a clerk. With his uncle's assistance he branched out in business for himself, and entered upon a career of money-making that monopolized all his time and energy. He became the financial authority of the city. He was a somewhat singular character. Close in his dealings, indifferent in his dress, and curt in his manner, he was a man of undoubted breadth of mind and soundness of judgment; and although he is largely remembered in Baltimore for his parsimony, he did much good in a charitable way that the public never knew of. He was an influential factor in the prosperity of the Baltimore and Ohio Railroad during JOHN W. GARRETT's presidency, and it was his coolness that saved the banks of Baltimore in 1873.

Of his fortune he left about one million dollars to his relatives, and the remainder for the establishment of a university and a hospital to bear his name. To the university, which is doing admirable work, he gave about $3,000,000 and his country-seat; to the hospital, which he intended to be the finest institution of its kind in the world, he gave more, the endowment being worth about $3,400,000, and including fourteen and a half acres of ground on Broadway—a splendid elevation on one of the most beautiful thoroughfares of Baltimore. The President of the Hospital Board of Trustees is Mr. FRANCIS T. KING. He was a trusted personal friend of Mr. HOPKINS, and he has devoted a large part of fourteen years to the successful carrying out of the purposes of the trust.

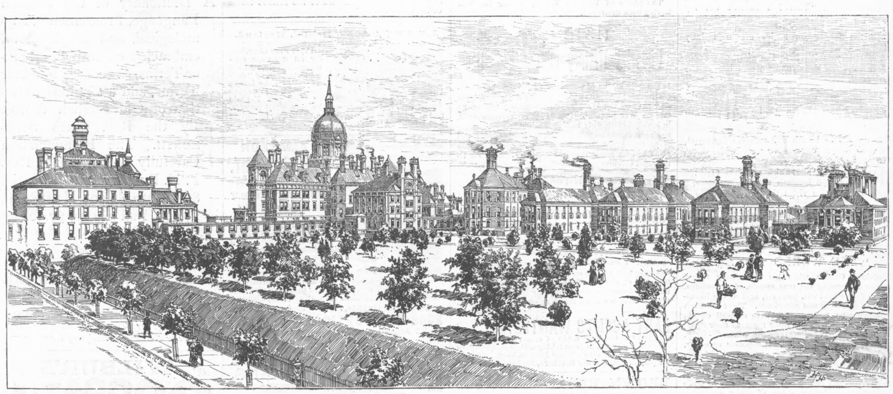
In 1875 the trustees selected Lieutenant-Colonel JOHN S. BILLINGS, U.S.A., Dr. STEPHEN SMITH, of New York, Dr. CASPAR MORRIS, of Philadelphia, Dr. NORMAN FOLSOM, of Boston, and Dr. JOSEPH JONES, of New Orleans, as the most competent authorities upon hospital organization in this country, and solicited from them a full expression of their views. The papers of these gentlemen, as published in a handsome octavo volume, are considered the best work on the subject in existence. Dr. BILLINGS, who accepted the invitation to act as medical adviser to the Board, and who still occupies that relation, visited all the noted institutions in Europe for suggestions to be used in the Hopkins Hospital, and there is not a successful feature of hospital construction and arrangement that he has not either introduced or adapted. The utmost care was taken in the architectural designs, and some of the plans went through as many as a dozen revisions.

The result of this unusual thoroughness is seen to-day in the hospital, which is the largest in this country and the finest in the world. It comprises seventeen buildings, covers under roof over four acres of ground, and stands conspicuously in a large square one hundred and fifteen feet above tide-water. The buildings are arranged in the shape of an E. The architecture is Queen Anne, severely plain. The interior finishings are perfect in their good taste and excellence, but are not elaborate. Over twenty million pressed bricks, nearly three thousand tons of iron, thirty thousand barrels of cement, and three million feet of lumber were used in the construction. There are over forty-five miles of pipes in and around the buildings. These figures will give some idea of the size of the institution. An entire day could be spent in the buildings with interest and profit.

The Administration Building stands in the front centre of the group. Its dome rises 315 feet above tide-water. In it will be the executive offices, the reception-rooms, and several lecture halls. The dome is partially utilized for a tank, with a capacity of 60,000 gallons of water for emergencies. Wide and lofty corridors, with an aggregate length of over 2500 feet, connect the buildings. The top of these corridors forms an open terrace walk. Below is another corridor, in which are all the pipes, varying from the 26-inch main to the small electric-wire conduit. These pipes are hung or laid on rollers, so as to provide for all expansion and contraction. No pipes are covered. All are immediately accessible, and are so arranged that one section can be cut off without affecting the general system. It is the largest and most complete arrangement of its kind in the United States. The heating of thirteen buildings is done by hot water, of which one hundred thousand gallons will be required to fill the heating pipes. The furnace and boiler rooms are as large as those of an engine manufactory.

Seven of the buildings contain the various wards. They may be generally described as the perfection of comfort and sanitation. The capacity is 400 patients. This number could be easily increased, but the intention is to make the supply of air about two thousand cubic feet to each patient, which is much larger than in any other hospital. The air is changed every fifteen minutes. Four systems of ventilation are used, and some of the wards are equipped with them all. There are rooms with perforated floors and other arrangements for special diseases. Each ward has a sun parlor looking out upon a beautiful park. The sanitary features of the hospital are the pride of Dr. BILLINGS and the delight of every one who has examined them. Nothing has been omitted to make them the most thorough that science and money could provide. An abundance of light pours in through two thousand windows.

A feature of the hospital that will attract general interest is the nurses' home. It is a four-story building, admirably equipped, and as an institution is entirely unique. It will be a training school for giving the student nurses a thorough education in the art of properly tending the sick and preparing food for invalids. A course of several years under careful medical instruction will be required before certificates will be given. There will be three departments of the work — nursing in the hospital, nursing in families, and district nursing among the poor. Already applications are pouring in from all parts of the country from women of education and experience who wish to take the course. Another interesting building is the amphitheatre, in which the students of the medical school, to be erected on a neighboring square, will gather for lectures and clinics. Near it are the dead-rooms, the pathological laboratory, and the crematory for consuming the dissected fragments of bodies. The bath-house contains all the latest inventions for every kind of bath. There are handsome quarters for histological research and photomicrography. The free dispensary is as large as an ordinary hospital, and the same can be said of the laundry, which is one of the most complete and inter-



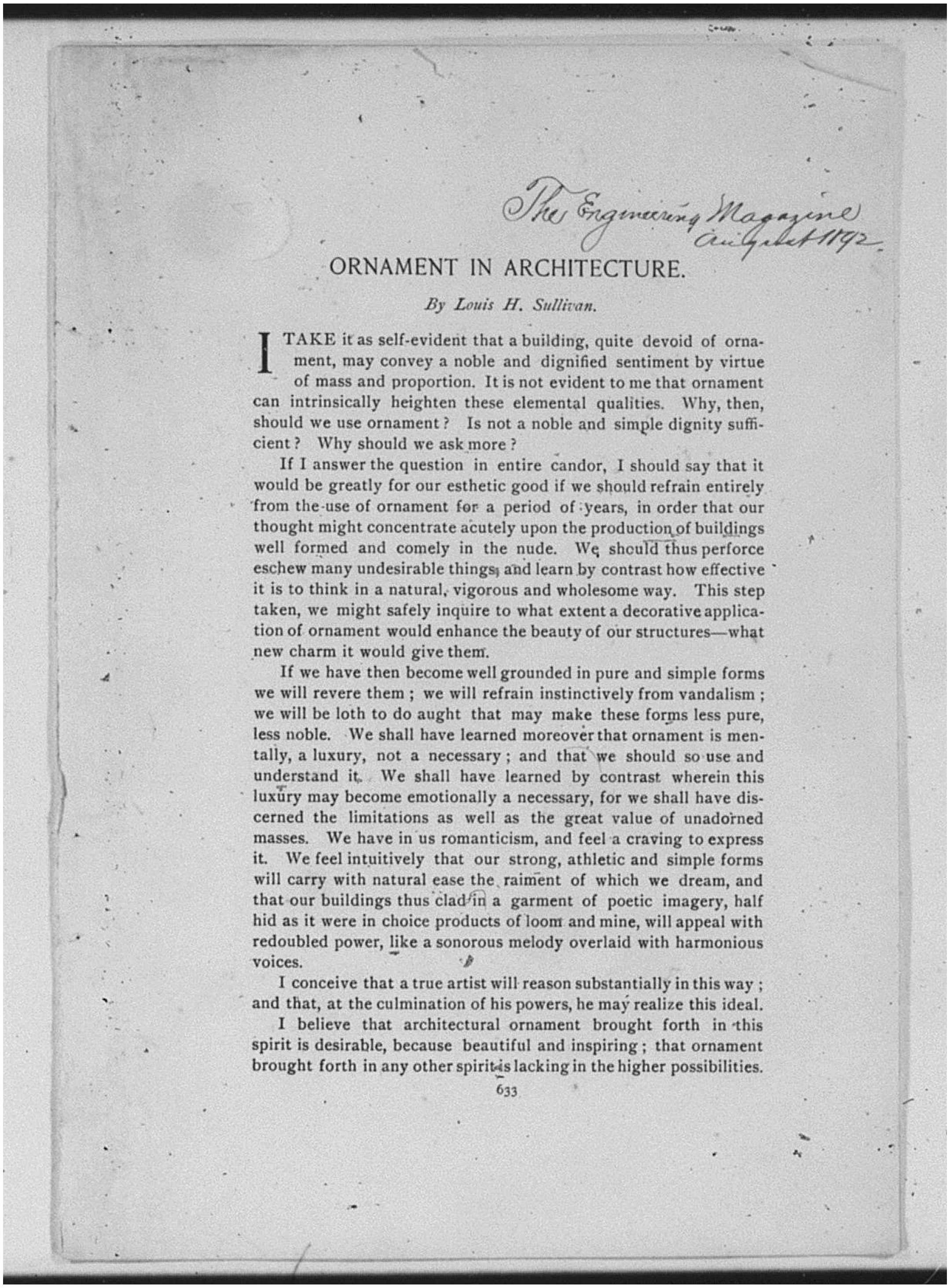
THE REAR OF THE MAIN BUILDINGS FROM THE PARK.

THE JOHNS HOPKINS HOSPITAL, BALTIMORE.—FROM PHOTOGRAPHS.



Figure 3.25: "The Johns Hopkins Hospital, Baltimore," *Harper's Weekly: A Journal of Civilization*, vol. 32, no. 1655 (September 8, 1888), 667.


Figure 3.26: "Johns Hopkins Hospital, Administration Building," *American Architect and Building News,* vol. 3, no. 124 (May 11, 1878).



The Engineering Magazine August 1892

ORNAMENT IN ARCHITECTURE.

*By Louis H. Sullivan.*

I TAKE it as self-evident that a building, quite devoid of ornament, may convey a noble and dignified sentiment by virtue of mass and proportion. It is not evident to me that ornament can intrinsically heighten these elemental qualities. Why, then, should we use ornament? Is not a noble and simple dignity sufficient? Why should we ask more?

If I answer the question in entire candor, I should say that it would be greatly for our esthetic good if we should refrain entirely from the use of ornament for a period of years, in order that our thought might concentrate acutely upon the production of buildings well formed and comely in the nude. We should thus perforce eschew many undesirable things, and learn by contrast how effective it is to think in a natural, vigorous and wholesome way. This step taken, we might safely inquire to what extent a decorative application of ornament would enhance the beauty of our structures—what new charm it would give them.

If we have then become well grounded in pure and simple forms we will revere them; we will refrain instinctively from vandalism; we will be loth to do aught that may make these forms less pure, less noble. We shall have learned moreover that ornament is mentally, a luxury, not a necessary; and that we should so use and understand it. We shall have learned by contrast wherein this luxury may become emotionally a necessary, for we shall have discerned the limitations as well as the great value of unadorned masses. We have in us romanticism, and feel a craving to express it. We feel intuitively that our strong, athletic and simple forms will carry with natural ease the raiment of which we dream, and that our buildings thus clad in a garment of poetic imagery, half hid as it were in choice products of loom and mine, will appeal with redoubled power, like a sonorous melody overlaid with harmonious voices.

I conceive that a true artist will reason substantially in this way; and that, at the culmination of his powers, he may realize this ideal.

I believe that architectural ornament brought forth in this spirit is desirable, because beautiful and inspiring; that ornament brought forth in any other spirit is lacking in the higher possibilities.

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Figure 3.27: John Shaw Billings' copy of Louis Sullivan, "Ornament in Architecture," T*he Engineering Magazine,* (August 1892), John Shaw Billings Papers, the New York Public Library, Box 48.

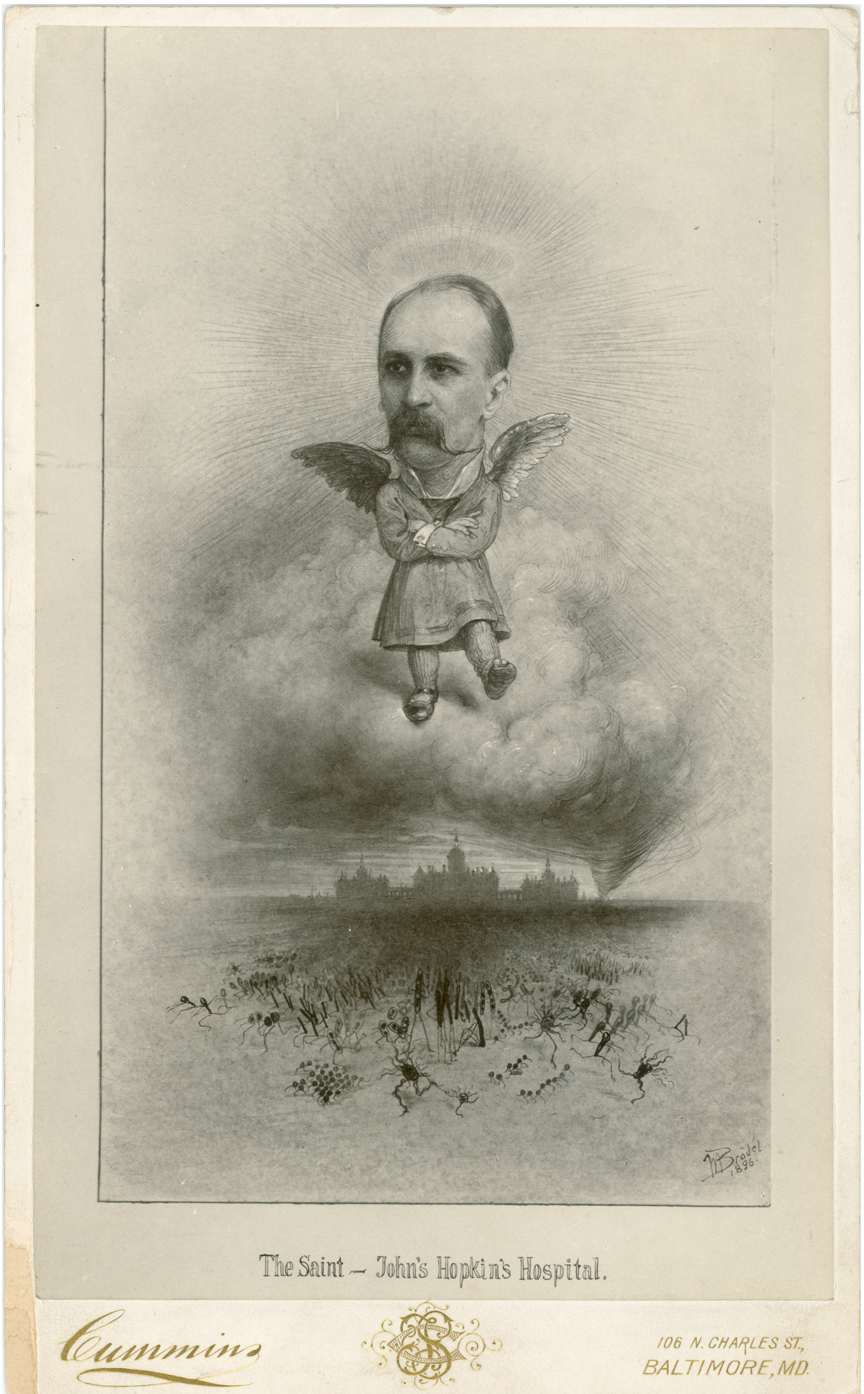


Figure 3.28: Max Brodel, "The Saint—John's Hopkin's Hospital"(1896). A cartoon of William Osler as a cherub in charge of a cyclone which is banishing all germs from the Hospital. Brodel was a medical illustrator at the Hospital. His title is inspired by Osler's habit of referring to the institution as "the St. Johns." Osler Library of the History of Medicine, McGill University.


Figure 3.29: “Octagon Ward, Interior View,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 19.


Figure 3.30: "Common Ward, Interior View," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 24.


Figure 3.31: “Kitchen Building, View in Kitchen,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 33.


Figure 3.32: "Dispensary, View in Waiting Room," (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 47.


Figure 3.33: “Amphitheatre, View in Lecture Hall,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 49.


Figure 3.34: “Pathological Building, View in Bacteriological Rooms,” (photographed by Frederick Gutekunst in 1889), John Shaw Billings, *Description of the Johns Hopkins Hospital* (Baltimore: The Johns Hopkins Hospital, 1890), Plate 53.

Figure 3.35: Gynecological Building operating room (1892), Buildings Photograph Collection, Alan Mason Chesney Medical Archive, Johns Hopkins Medical Institutions

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