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Research Article

Facade as Interface: Building-Nature Integration in Contemporary Healthcare Architecture

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Abstract

While early 20th-century healthcare design emphasized direct engagement with outdoor spaces and natural landscapes, contemporary projects increasingly prioritize efficient spatial organization at the expense of environmental integration. Nevertheless, a growing movement within contemporary healthcare projects seeks to reintegrate nature into buildings through innovative fa çade design, reimagining building envelopes as spatial mediators that strengthen connections between interior and exterior environments. Drawing on modernist visions, these projects challenge conventional hospital typologies by redefining spatial flexibility, dissolving the inside/outside dichotomy, and employing architectural climate control strategies. This paper examines the evolution of nature-integrated design in healthcare architecture through a historical review and qualitative case study analysis. Interweaving recent theoretical discourses and practices, it discusses distinct fa çade design strategies that balance environmental performance, aesthetic quality, and spatial experience in the context of healthcare architecture.

Keywords

Healthcare Architecture, Fa çade Design, Building-Nature Integration, Health-Inducing Spaces, Environmental Performance

1. Introduction

In recent decades, hospital architecture has progressed from small-scale, care-focused structures to complex spatial environments that prioritize patient-centered approaches [1]. Contemporary healthcare design needs to comprehensively accommodate technological, societal, and epidemiological changes, such as those spurred by the COVID-19 pandemic. Consequently, an increased focus on optimizing healthcare spaces by incorporating landscape and naturalistic features into design projects - emphasizing connections to outdoor spaces as a means to enhance aspects of users' comfort and well-being - can be observed in architectural research [2].

Recent architectural design literature has drawn attention to the integration of architecture with the landscape, exploring the functional, aesthetic, and performative impact of such integration. For instance, the edited volume *The Architecture of Hospitals* (2006) categorizes the different ways green spaces can blend with hospital spaces, based on their position - inside, outside, on, and through the building [3], examining the different spatial and perceptual qualities of each approach which may contribute to the creation of a health-inducing environment. The volume *Hospitals: A Design Manual* (2020) provides a comprehensive analysis of design strategies tailored to healthcare institutions of varying scales and contexts [4], showcasing a selection of forty hospital projects categorized into six types - public, children's, university, specialized, community hospitals, and rehabilitation clinics [5] to illustrate

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the aesthetic and functional innovations of each type. This analysis also presents ways in which open green spaces can be integrated into building design, enhancing the connections between indoor and outdoor spaces, ensuring that patients can readily access and engage with green areas, and supporting intuitive wayfinding and orientation [4]. Additionally, the book *Innovations in Hospital Architecture* (2010) broadens the application of biophilic principles in healthcare design by proposing therapeutic strategies that address the diverse needs of patients across various physical settings, from hospitals to palliative care centers [6]. It introduces the concept of "theraserialization," a term that combines the "therapeutic" and "serialize" notions, to describe the relationship between indoor and outdoor spaces in line with biophilic design principles [7], which is aimed at the definition of a restorative environment for patients, staff, and visitors, also manifesting in the shaping of transitions from public areas to semi-public, semi-private and, ultimately, private zones. Whereas the introduction of the exhibition catalog *Imperfect Health: The Medicalization of Architecture* (2012) highlights the pervasive presence of greenery in contemporary design - from green facades to healthcare to mixed-use buildings [8] - underlining interdisciplinary synergies and drawing attention to the placebo effects accompanying such presence in the built environment (Ibid.). These research inquiries are indicative of the current state of the art in architectural design that considers the incorporation of open green spaces into healthcare structures, aligning with broader quests for urban greening, environmental sustainability, and biodiversity.

Building on this thematic framework, the paper explores strategies for integrating architecture with the natural context through façade design to enhance healthcare environments and support environmental performance. By tracing the historical development of building-nature relationships across various case studies, both past and recent, it identifies key patterns of integration, offering valuable insights and design approaches for contemporary healthcare architecture.

2. Methodology

This paper employs a qualitative research approach to investigate design strategies that facilitate the integration of healthcare buildings with the landscape, placing particular focus on the evolving character and role of the façade. It combines historical and contemporary case studies to trace the evolution of such strategies, focusing on projects from Europe and North America. The study begins by reviewing key hospital projects from the 19th and 20th centuries through a critical historical analysis, such as the ones of Richard Döcker, Alvar Aalto, Richard Neutra, and Erich Mendelsohn, based on the spatial and functional qualities of the façade. It then proceeds to examine how these qualities have been sustained and advanced in hospital designs of the 21st century, considering projects by Herzog & de Meuron, Rogers Stirk Harbour + Partners, and Atelier Kempe Thill. The analysis highlights emerging design patterns and contributes to ongoing theoretical discussions on façade strategies in healthcare architecture, with a focus on environmental sustainability.

3. Historical Review

In the 19th and early 20th centuries, the incorporation of landscaped spaces into the hospital environment was deemed crucial for patient care. As Annmarie Adams and David Theodore have noted, hospital grounds were often designed to mimic natural environments, featuring ornamental gardens, wooded areas, and walking paths for patients [9]. Activities such as walking, delighting in gardens, engaging in sports, and participating in holiday parades, within thoughtfully designed outdoor spaces, were recognized for their therapeutic benefits and their promotion of both social interaction and physical activity [9, 10]. Progressively, in the early decades of the 20th century, exposure to fresh air and sunlight was considered a vital component of medical treatment [11]. Concerns about pollution and the spread of airborne diseases in industrialized cities further strengthened the belief in the healing benefits of nature. As Beatriz Colomina has observed, healthcare buildings of this era appeared to be immersed in settings away from cities and oriented towards the sun, as the search for optimal sunlight, fresh air exposure and access to nature advanced architectural practices [12], through the introduction of features such as glass walls, flat roofs, terraces, balconies, and specifically designed furniture which intended to reduce the physical and visual barriers between inside and outside.

These developments signify a reevaluation of hospital and healthcare architecture as part of a broader reassessment of the relationship between buildings, nature and human well-being. Rather than viewing hospitals as isolated, highly regulated entities, modern design strategies explored new ways to integrate medical spaces with their surrounding environments, envisioning healthcare architecture that is both functionally effective and environmentally responsive.

3.1. The Nineteenth Century Hospital: Indirect Contact Between Architecture and Nature

The pavilion-plan type hospital, which emerged in the 18th century and gained prominence in the 19th century, introduced design aspects that promoted relationships between interior and outdoor spaces, and envisioned new functions for the intermediate spaces of the building, linked to the therapeutic programs of the time. It embodied the principle of integrating interior spaces with the surrounding context through the articulation of the hospital building into separate units, characterized by relatively low heights and linked through an external breezeway. This facilitated connections to outdoor spaces and allowed for the segregation of patients based on their specific illnesses.

A key aspect of this building type was the inclusion of multiple windows on different sides of the nursing wards within each building, in order to provide ample access to natural sunlight, cross-ventilation, and visual connections to the natural environment [10]. Notable examples of hospitals that adopted the pavilion plan and exemplified these principles include Hôpital Lariboisière in Paris (Pierre Gauthier, 1839-1854), St. Thomas's Hospital in London (Henry Currey, 1866-1871), and the reconstructed Hôtel Dieu in Paris (Emile Jacques Gilbert, 1866-1876) (Figure 1).

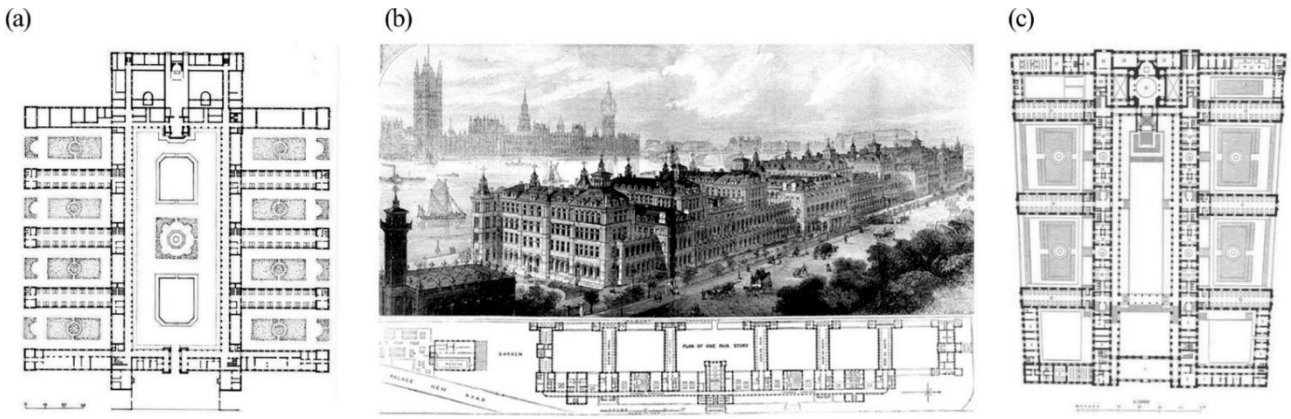

Figure 1. *Notable examples of pavilion plan hospitals: (a) Hôpital Lariboisière, Paris, 1839 - 1854 [13], (b) St. Thomas Hospital, London, UK, Henry Currey, 1866-1871 [14], (c) Hôtel-Dieu, Paris, Emile Jacques Gilbert, 1866-1876 [15].*

3.2. The Twentieth Century Sanatorium: Architecture and/Within Nature

In the early 20th century, the emergence of tuberculosis sanatoriums gave rise to specialized healthcare facilities aimed at preventing the spread of the disease [9]. Some of the most significant projects of that period include Jan Duiker and Bernard Bijvoet's Zonnestraal Sanatorium in Hilversum (1925-31), Richard Döcker's tuberculosis sanatorium in Waiblingen (1926-28) (Figure 2), and Alvar and Aino Aalto's Paimio Sanatorium (1929-33) (Figures 3, 4). Situated in remote locations such as forest, lakeside, and mountain contexts, these sanatorium projects commonly featured south-facing inhabitable intermediate spaces with integrated greenery, selected for its therapeutic effects [18, 19]. In addition, they employed architectural strategies that emphasized access to sunlight, fresh air, and the natural environment in response to the prevailing methods of medical treatment at the time [17, 20, 21]. They explored how design could support disease prevention and treatment, combining modern architecture principles with concepts of health, hygiene, and human well-being [11]. Design placed particular attention on architectural means - especially multi-level, inhabitable terraces of varying depths [22] - to ensure optimal natural illumination throughout the year, while also addressing aspects of indoor thermal comfort and environmental efficiency [23]. The integration between built and natural environments shaped architectural discourses of that period and influenced the development of health-oriented design approaches [8, 11, 12]. Within this context, the façade became a central design element, carefully engineered to manage natural energy flows, enable optimal illumination and cross-ventilation, and provide visual and physical access to the surrounding landscape - all with the aim to enhance patient experience and, ultimately, recovery [10, 12, 17]. Glass played a key role not only in reflecting advancements in material technologies but also in reinforcing the therapeutic value of light, whose function was regarded as extending beyond mere aesthetic perception [24, 25].

Figure 2. *View of the terrace in the Waiblingen Sanatorium [16].*

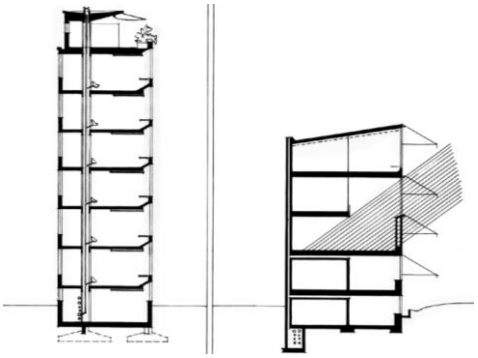

Figure 3. *Diagrammatic sections of the Paimio Sanatorium [17].*

Figure 4. *View of the terrace in the Paimio Sanatorium [17].*

The post-war period saw the emergence of hospital projects adopting facade design techniques that functioned as adaptive climate control devices while enhancing therapeutic effects [16, 26, 27]. Notable building designs of that era - including Richard Neutra's San Bernardino Medical Center in California (1953), the Rural Health Center in Puerto Rico (1944-45), and Erich Mendelsohn's Maimonides Hospital in San Francisco (1946-50) - showcased innovative spatial layouts and façade elements that adhered to inside-outside continuity and environmental control. In line with the growing architectural discourses of the 1950s, which emphasized the value of vernacular architecture as a meaningful reference for modern design, these projects incorporated climate-responsive elements such as verandas, porches, patios, loggias, exterior corridors, and sun-control devices [28].

Figure 5. *Internal views of the San Bernardino Medical Center [29].*

In particular, the San Bernardino Medical Center in California by Neutra featured garden patios, winter gardens, porches, and extensive glazed surfaces with sun-control elements such as vertical metal louvers [29]. Neutra drew attention to how "no single feature introduced in South American architecture has garnered as much attention as the prominent blinds and integrated architectural shading methods on exterior window fronts" [30, 31] (Figure 5). The project also introduced a clear circulation system with naturally lit corridors, which supports intuitive wayfinding and promotes psychological well-being [32]. It seamlessly integrated aesthetics, technology and a strong emphasis on connections between indoor and outdoor spaces [33]. Furthermore, it prioritized cross-ventilation and shading strategies to enhance thermal comfort and energy efficiency, considering the specific characteristics of its regional context [34]. In their entirety, these design aspects served as crucial interfaces between indoor and outdoor environments, effectively regulating thermal comfort while promoting health-inducing environments.

At a different scale and programmatic level, the Maimonides Hospital by Mendelsohn incorporates curvilinear forms and generous use of glass to the hospital's façade, softening the institutional rigidity that characterized many early 20th-century healthcare buildings [35, 36, 37]. A notable feature is the integration of continuous loggias into the façade that form both a climatic filter and inhabitable space running along the building exterior, offering patients and staff access to fresh air and expansive views [38], thereby contributing to a more therapeutic and restorative environment (Figure 6).

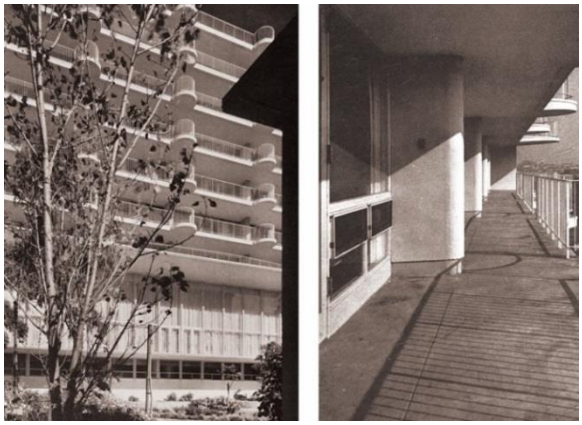

Figure 6. *Views of the façade in the Maimonides Hospital [36].*

Late modernist hospital designs therefore placed a strong emphasis on functionality and user experience, advancing the implementation of climate-responsive elements and bioclimatic principles [39]. This approach improved the environmental and cultural adaptability of healthcare buildings, contributing to a shift in design reasoning that had emerged in early 20th century designs; these built artefacts were no longer considered as isolated objects but were instead viewed as integrated systems able to respond to local climate and geography [16, 34].

3.3. The Twenty-First Century: Adapting Buildings to the Environment

By the end of the 20th century, the character of hospitals had undergone a significant transformation, moving away from earlier therapeutic ideals. As Irina Davidovici points out, hospital design increasingly adopted a stance similar to commercial districts and large office complexes, leading to buildings which "reserved their spectacle for the interior, while projecting a relative indifference towards the sur-

rounding public realm" [40]. In recent decades, hospital architecture has become constrained by evolving medical, constructional, and servicing systems, as well as complex building and environmental standards, often resulting in introverted designs that are disconnected from their surrounding contexts [40]. In contrast to this inward-facing tendency, a growing number of contemporary healthcare projects respond to environmental, energy, and health concerns with a more integrated approach to design.

This section presents a selection of contemporary design projects that exemplify the seamless integration of architectural structures with natural environments with particular emphasis on the layout typologies - horizontal and vertical - and the design of the façade. These projects prioritize connections between indoor and outdoor spaces, the integration of intermediate zones, and climate control systems.

The selection includes works by architectural firms such as Herzog & de Meuron, Rogers Stirk Harbour + Partners, and Atelier Kempe Thill. Spanning a broad range of healthcare functions, these projects demonstrate visionary design strategies that foster the relationship between architecture and the environment.

3.3.1. Horizontal Layout

The first group includes projects characterized by a horizontal layout, where the building is articulated into expansive, low-rise structures interconnected by corridors or courtyards, often resembling a campus-style configuration [4]. This design strategy integrates green spaces within the building structure, by means of elements such as courtyards, patios, and threshold spaces. By fragmenting the architectural volume, it improves access to natural light and ventilation, thereby enhancing the space's environmental quality. Notable examples include three healthcare facilities designed by Herzog & de Meuron - the REHAB Basel Centre (1998-2002), the Children's Hospital of Zürich (2014-24), and the New North Zealand Hospital (2014-26) - that conceptualize the hospital as a microcosm of a city, integrating urban planning principles into healthcare design [40]. Through innovative design strategies for the building's facade, they promote a comfortable interior environment and allow users to directly connect with the natural surroundings while being protected by timber screens.

Several other projects demonstrate innovative façade solutions that respond to environmental elements, incorporate shading systems, and foster connections to nature. For instance, the façade designs of the Circle Bath (2009) and the Ten Kerselaere Residential Care Center (2012-20) feature diverse architectural elements such as balconies, loggias, and winter gardens, which facilitate direct engagement with the natural environment. Similarly, the Copenhagen Centre for Cancer and Health (2010-11) exemplifies the strategic use of materials in façade design, combining vertical wooden slats with extensive glazing to achieve a harmonious balance of warmth, transparency, and a tangible connection to nature.

3.3.2. Vertical Layout

The second group includes projects characterized by a vertical layout, in which the building is organized as a multi-story or high-rise structure, with various services vertically stacked to optimize space utilization [4]. This layout is particularly suited to urban environments with limited land availability. However, it often reduces access to natural light and ventilation, especially on lower floors or core areas. Despite these challenges, innovative design solutions have emerged to enhance both functionality and aesthetics. Projects following this design approach, such as the Cancer Centre at Guy's Hospital in London (2010-2016) and the SJD Pediatric Cancer Center in Barcelona (2022), demonstrate how multi-story healthcare buildings can create functional and visually striking façades through the integration of intermediate inhabitable spaces and the strategic use of exposed structural elements.

4. Results and Discussion

4.1. Horizontal Layout: The Healthcare Building as Landscape

The horizontal layout is increasingly met in Herzog & de Meuron's healthcare projects which challenge conventional hospital design by rethinking spatial flexibility and engagement with the external environment (Table 1). Their projects feature adaptable interiors, space-containing façades, and a strong emphasis on linking indoor and outdoor spaces, encouraging patient recovery through access to nature. Unlike conventional mat-building hospitals designed for endless expansion, these designs incorporate courtyards, landscaping, and natural light to create a layout similar to an urban tissue, where interior spaces mimic exterior facades and public areas resemble urban streets [40].

Table 1. *Three contemporary healthcare architecture projects of Herzog & de Meuron.*

Project	Façade Space	Strategies
REHAB Basel Centre		1) Balcony/Gallery 2) Horizontal louvers shading systems 3) Indirect nature contact
Children's Hospital of Zürich		1) Loggia/Private balcony 2) Vertical louvers shading systems 3) Direct/Indirect nature contact

Project	Façade Space	Strategies
New North Zealand Hospital		1) Flowing Façade/Balcony 2) Wooden shading 3) Indirect nature contact

Notably, the REHAB Basel Centre demonstrates effective bioclimatic design through its multi-courtyard layout, green flat roof, and articulated façade, which includes a continuous terrace framed by a continuous glazed surface and a timber screen. This shading solution reduces solar heat gain and enhances indoor thermal comfort while highlighting the functional role of the façade [41].

In addition, vertical-louvered loggias at the Children's Hospital of Zürich help break down institutional character, creating a spatial environment that evokes domesticity, human-scale and familiarity [42]. The intricate timber façade serves both an environmental and a decorative function [43].

Finally, the New North Zealand Hospital exemplifies innovative façade design through multiple integrated features, including extensive glazed circulation spaces which provide continuous garden views on one or both sides and windows and balconies positioned behind a unified timber skin [44]. This design approach is further complemented by a transparent roof garden that blurs the boundaries between interior and exterior spaces.

4.2. Vertical Layout: The Healthcare Building as Inhabited Envelope

Vertical layouts are increasingly seen as a solution to the challenges of urbanization and climate change with the application of ecological aesthetics principles [5, 46]. The Cancer Centre at Guy's Hospital, designed by Rogers Stirk Harbour + Partners (RSHP), for example, demonstrates how verticality can be leveraged to create a compact yet permeable healthcare facility with balconies and terraced gardens. Integrating green spaces at multiple levels transforms the vertical layout into a *breathing* ecosystem that supports healing and sustainability [47]. The building combines four stacked villages of two or three floors, marked by colored glass panels and structural elements that create a vibrant and uplifting aesthetic [48]. The strategic use of colored glazing in facade design modulates daylight penetration, creating psychologically stimulating interior environments.

The expansion of the University Hospital of the Santa Fe de Bogotá Foundation incorporates sustainable design features, including green facades, vertical gardens, and energy-efficient systems, to minimize its environmental impact. The innovative facade combines metallic elements with tension-supported brickwork, creating a textile-inspired pattern that enhances daylight penetration (Table 2).

Table 2. *Two vertical layout contemporary healthcare architecture projects.*

Project	Façade Space	Strategies
Cancer Centre at Guy's Hospital		1) Balcony/Gallery 2) Colored Glass Panels 3) Indirect nature contact
Expansion of the University Hospital of the Santa Fe de Bogotá Foundation		1) Winter Garden 2) Organic patterns of prefabricated concrete panels 3) Direct nature contact

In conclusion, horizontal building configurations maximize the fragmentation of the built mass by incorporating courtyards, intermediate spaces, and external circulation areas into the spatial layout. They emphasize physical and visual continuity between interior and exterior spaces, as well as between building and landscape. Vertical building configurations, on the other hand, integrate stratified intermediate, inhabitable and green spaces, into the building envelope. Both approaches aimed to mitigate urban detachment in contemporary hospital environments, enhance environmental performance and provide access to outdoor and semi-outdoor spaces.

5. Conclusion

The evolution of hospital building façades reflects a fundamental shift in design practices, driven by growing environmental and functional considerations. Three distinct building types have marked this progression: (1) early twentieth-century sanatoriums that prioritized physiological needs through integrated multi-level terraces for heliotherapy; (2) mid 20th-century hospitals which focused on climatic adaptability via passive climate control systems; and (3) recent design projects that have synthesized these approaches while incorporating green elements, circulation systems, climate control elements, and adaptable inhabitable spaces into the building exterior.

Regarding contemporary design, the two distinct building configurations discussed in this paper testify to the central role of façade design in promoting aspects of openness, inside-outside continuity and access to nature in healthcare architecture. This evolution has redefined facades from solid physical boundaries to active mediators between built and natural environments [49, 50], balancing concerns about user experience and well-being with environmental concerns and

thereby contributing to the definition of health-inducing and meaningful spaces.

Author Contributions

Stamatina Kousidi: Conceptualization, Methodology, Research Framework, Literature Review, Writing, Supervision, Review & Editing, Validation.

Liheng Zhu: Data curation, Investigation, Writing, Visualization, Reference Check.

Zhihang Lin: Formal Analysis, Software, Investigation, Writing, Visualization, Reference Check.

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Data Availability Statement

No data was used.

Conflicts of Interest

The authors declare no conflicts of interest.

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