8-2009

The Inside Outside Hospital

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THE INSIDE OUTSIDE HOSPITAL:
A REPLACEMENT HOSPITAL FOR THE MEDICAL UNIVERSITY OF SOUTH CAROLINA, CHARLESTON, SOUTH CAROLINA

A thesis presented to the Graduate School of Clemson University in partial fulfillment of the requirements for the professional degree, Master of Architecture + Concentration in Health.

Robert Andrew Thompson
August 2009
ABSTRACT

This thesis examines how the historical development of healthcare architecture was influenced by social and cultural forces that eventually led to the contemporary thick building form, which is common today. These settings can have a negative impact upon patient and staff health, compromising the optimal medical response needed for patient healing. The hospital environment should be designed to increase day lighting, natural ventilation, and access to nature in order to contribute to the healing process, support the health of care providers, and optimize their effectiveness and efficiency.

This thesis first explores the development of hospital forms and, their impact on healthcare delivery and patient health. These hospital building forms were then evaluated against the needs of the modern healthcare environment, and used to better understand how to create more effective building form to promote health and healing today. This thesis proposes that through the review of historic healthcare building forms that provide better access to natural light and air, contemporary hospital building forms can be derived that will lead the way for healthier hospital design.
DEDICATION

To my uncle, Keith E. Hayes:
Thank you for all that you have taught me, and your ability to inspire perfection.

To my parents, Mark and Phyllis Thompson:
Thank you for all the values that you have instilled in me and for my ability to weather any hardship.

To brother and sister, Michael and Tanya:
Thank you for always being there when I needed you.

To my friend, Matt:
Thank you for your support throughout the entire process.

To my dogs, Bruce and Ivan:
Thank you for always greeting me at the door any time, day or night.

To my daughter, Ellen Violet Thompson (EV):
Thank you for keeping me going during the last few months of this process (6 years)

To my wife, Susan:
Thank you for your understanding, confidence, love and support.
Thanks to:
My Committee:
David Allison, for his unwavering guidance;
Keith Green, for his direction and encouragement;
Robert Bruhns, for his support and guidance;
Kemp Mooney, for his honesty and insight;
Dina Battisto, for her direction, caring, guidance, and determination; and
Kathleen Yancey, for her insight, support, and humor.

My thesis helpers:
Megan and Allen, thanks for all the late nights and putting up with my joking.

My Professors:
Harry Harritos, thanks for all the jokes and the confidence builders C+.
Cris Mills, thanks for introducing me to the third dimension.
Brian Andrews, thanks for giving me the tools and toughness to make it through.
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INTRODUCTION

This thesis analyzes how the historical development of healthcare architecture was influenced by social and cultural forces and healthcare processes and how these forces eventually led to the contemporary thick building form, common today in the modern hospital. It proposes and employs Green and healthy design strategies focused on maximizing day lighting, natural ventilation, and access to nature within hospitals in order to improve therapeutic outcomes, patient and staff satisfaction, and operational effectiveness.

Religious Architecture up to the Enlightenment: Early Christian Monastic caregivers relied heavily on performing the seven acts of mercy, developed from (Matt. 25: 35-36). [1] Healthcare was essentially limited to these works of mercy until the mid 1800’s. The Cross Ward plan was maybe the first intentionally designed hospital forms; it is best illustrated in the architecture of Ospedale Maggiore originally designed by Filarete in 1457. The Ospedale Maggiore plan integrated the spiritual theories closely associated with the church and the beginnings of the theories of natural ventilation and sanitation on the healing process.
Filarete’s Ospedale Maggiore became the first planned care setting that allowed for connections to nature, as well as optimized views to an altar, providing functional spaces that were organized according to the care needed. It employed a perforated building form, where a large percentage of the building skin is open to the outside and the overall building form has open green areas such as courtyards, which provided opportunity for functions to be carried out with access to nature. In this way Filarete combined the religious and the natural realms for the healing benefits of the patients.

Theories beginning in 1859 proposed by Florence Nightingale stated that bad air (miasma), as well as other concerns of cleanliness, efficiency, and disposition of waste drainage caused illness, requiring people to find a solution using natural ventilation and sanitation.[2] The access to natural ventilation, day lighting, and nature became the cornerstones of state of the art healthcare settings by the early 1900’s.
The Age of Reason brought about a greater focus on civic institutions to provide care for the masses. Healthcare shifted from simply saving souls to the practice of medicine and saving lives. Teachings that illness was caused by sin was discarded and replaced by new scientific theories that began to be tested. As health care settings were being developed to address this change in theory, the Pavilion Plan was becoming the best practice of the time for its focus on natural ventilation, day lighting, and sanitation. This plan provided greater opportunity for accessing nature, as well as the ability to organize the building form around the functional needs of the care givers at the bedside, rather than around spiritual needs.

**Modern context:** Industrialism provided the means for rapid scientific advances in medicine, science and technology. World War I let to advancement in medical care because of the sheer number of complex casualties sustained in combat. The increase in the acuity level of surviving soldiers and the broader application of anesthesia allowed doctors to complete painful procedures with less trauma to the patient, increasing the success rate of many surgeries. A growing understanding of germ
theory allowed for more successful surgical outcomes and created a greater awareness of clean surgical procedures, equipment and care practices.

**Contemporary context:** The increase of technology produced in the 20th century led to hospitals designed to function with the machine-like quality of a factory. Hospital forms built after WWII have been primarily designed to be functionally efficient and cost effective for the practices of medicine and care delivery at the time of their construction. They require the use of extensive mechanical systems to condition the enclosed built environment.

The integration of technology within the medical field has produced highly specialized, but costly equipment that must be centrally located to provide efficient access for all patients. This condition reinforces the move toward hospital forms that block out day light because of the sheer size of the diagnostic and treatment areas that
are typically planned to be close to one another. These hermetically sealed and artificially conditioned forms lend themselves to the integration of medical equipment because of the controlled environmental conditions needed to maintain such complex technology. As the integration and cost of the equipment has become greater the practice of providing access to adequate day lighting, natural ventilation or views to nature in US hospitals has declined. This is also driven by increasing building skin construction costs.

**Contemporary Care Techniques**: A return to more therapeutic environments is beginning to emerge and deal with the separation from nature and is being implemented to improve health outcomes and caregiver performance. This approach to a more holistic form of care combines natural healing remedies with the integration of nature into traditional healing techniques and settings. The environmental attributes of more therapeutic settings should include day lighting, natural ventilation, and the ability to access or view nature directly.
Benefits of settings designed to be more therapeutic include: lowered stress as measured by pulse rates and blood pressure, reduced need for pain medication, shortened length of stay, and improved patient and staff satisfaction.

**Medical Technologies**

Techniques using recent technological advancements that have occurred are improving the mobility and accessibility of highly specialized diagnostic equipment. Decreases in size and weight allow for greater ability to bring more sophisticated technology to the patient’s bedside. Along with the decrease in size and weight, integrated information systems and a growing array of diagnostic equipment are becoming increasingly smaller and in many cases wireless. This frees the equipment from a centralized model of care where patients are transported to designed settings for diagnostic and treatment procedures. The increasing ability to bring diagnostic and treatment equipment to the patient is transforming centralized delivery of care models to more patient centered care models, where the doctor and equipment move to the patient’s bedside. When these decentralized patient centered care models are employed, the distance staff must travel decreases, and the need for
compressed functional relationships between diagnostic and treatment services is reduced. Due to the flexibility and decentralization brought about by more patient centered care models, these trends increase the potential to integrate nature within the healing environment, for a more therapeutic setting.

**Design Principles:** The architectural design principles developed in this thesis involve implementing a checkerboard of open spaces, perforated and articulated building forms, self regulating facades, integrated building systems / structures, and functional placement that will improve the access to day lighting, natural ventilation, and views to nature within the built environment.

Hospitals should be designed with a checkerboard of open spaces, where an urban fabric master planning strategy is employed consisting of non-“functional” open space providing access to day lighting, natural ventilation, and views to nature for adjoining programmed spaces. These spaces will provide opportunities for
inhabitants of the built environment to access naturally planted areas that may be utilized for social gatherings, private reflection, or places for pause.

The planning checkerboard then allows the creation of a more perforated and articulated building fabric applied to the overall form and building volume. This strategy is inspired from traditional healthcare building typologies that have been developed throughout the history of hospital design in a manner that will provide greater opportunity for inhabitants to access day lighting, naturally ventilated spaces and planted areas.

The treatment of each facade should be determined by the need to balance the response to the solar orientation and their ability to address heat gain (comfort) and health (life). Therefore, each building facade should be designed to respond to its particular solar orientation and, when appropriate, should be self regulating in ways that dynamically balance exterior climate conditions with interior environmental
needs over time. Building facades with southern exposure should be designed with elements that automatically respond to day lighting and heating / cooling conditions required by the adjacent functional areas.

The complexity of healthcare settings requires high densities of building systems, technologies, and utilities to serve them. Organizing these elements into highly integrated building systems not only allows greater flexibility over time but also enables easier planning for access to day lighting natural ventilation and access to nature. An integrated building system approach can provide improved connections and access to nature over the life of the structure.
The thoughtful placement and orientation of functional spaces is crucial to enabling access to natural elements from within staff and patient areas. However, hospitals are large building where access to daylight to all interior spaces is not feasible. Priority must be given to patient care spaces and other spaces where patients, families and staff spend the most time. Locating all patient care spaces so that they can have windows with views to nature, daylight and ideally opportunities for natural ventilation can improve patient satisfaction, and has been demonstrated in some studies to decrease lengths of stay. The location of primary staff work areas for direct or indirect access to daylight and views to nature can improve job performance and decrease medical errors, especially in those areas where staff work for extended periods of time under high periods of stress.

**Proposal:** These strategies have been applied to redesign a new greener, healthier replacement hospital for the Medical University of South Carolina in Charleston South Carolina. The Medical University of South Carolina is planned as a replacement hospital that will continue the tradition of a thick hospital building form.
By applying the strategies mentioned above the redesign of the hospital building form using the same program provided by MUSC, this thesis proposes a healthier healing and working environment for the patients, family, and staff who will use the facility. The current plan for the hospital replacement consists of a 200 bed facility with all supporting elements that are needed to sustain such a facility in this environment.
Cultural beliefs and forces historically have influenced the healthcare practices of the time. Both cultural forces and healthcare practices in turn also influenced the form and design of the hospitals being built at that time. While cultural forces have changed through time there remain viable lessons that can be learned and practiced in creating hospitals today. As societies have advanced two distinct hospital plans have developed, designed and derived. Designed hospitals were those in which an attempt was made to plan for the function of nursing care. Derived hospitals were actually borrowed from building forms used for monasteries, palaces, estates, prisons, barracks or they were consciously constructed in current architectural forms of the time.[3]

Hospitals historically have been designed with the ideals of public-mindedness taking into account the most advanced building technology of the time, advanced care techniques of the time. They integrated the most advanced technology of the time to
provide better and more comprehensive care. Over time, hospital designs progressed to be thought of as functional machines, emphasizing efficient space planning and function as major drivers. The influence of planning and function produced a healthcare setting with greater privacy and supervision. With the evolution of more complex hospital designs, more detailed studies were conducted to understand and optimize the efficiency of the work flow and functions of the care providers. The influence of more sophisticated techniques of comparison, like those used in the Yale Index Studies, illustrates how quantitative analysis aided in the development and implementation of a more efficient care environment. [4] Advances in technology also influenced both the care environment and equipment used for treatment. Today advanced technology and equipment is being used in diagnostics and treatment environments to improve outcomes. With the development of more advanced technology and the integration of wireless networks and equipment the healthcare environment is evolving toward more decentralized patient care, a care model that brings a greater number of diagnostic and treatment technologies and procedures to the patient bedside. This has the potential to once again re-emphasize the hospital
room and patient bed as a more dominant and diverse care site as it was before the advent of modern diagnostic and treatment modalities.

Improvements in mobile wireless healthcare technology may in turn allow the return to healthier, more sustainable, and more articulated / perforated hospital building forms that meet the technological and functional needs of healthcare today – and in the future. The greater use of wireless and mobile technologies have increased the mobility of both staff and equipment to travel to the patient, and allowed the reduction in size of some equipment making it easier to have it placed at the bedside. This has the potential to transform current models of care focused on shorter distances for patient travel and care provider interaction into more decentralized care. By decreasing thick diagnostic and treatment areas needed for patient care the overall building form can be manipulated with greater care for views to nature, greater infiltration of daylight, and opportunities for natural ventilation.
UP TO AND THROUGH THE RENAISSANCE

**Cultural Forces and Healthcare:** Before and during the Renaissance people in Christian dominated parts of the world were cared for in Hospices, Inns, or Monasteries and eventually church affiliated hospitals. Christian acts of mercy blurred between caring for the ill, impoverished, and many conditions of spiritual and physical needs. Before the Renaissance, Hospices and Inns were located along pathways used by Pilgrims generally outside of major cities. The social and religious context consisted of people relying heavily on spiritual and natural elements to maintain or restore health.

The earliest forms of healing provided spiritual care to the poor and the dying as dictated by the works of mercy spelled out by (Mathew 25:35-36) which were adoped as church doctrines. The healthcare provided at the time was most often to attempt to ease pain and suffering and care for the soul in preparation for death, but with little to no medical treatment as we know it today.
Hospitals prior to the renaissance were predominantly run by the church in a quest to save souls. As a result the church was adopted as the first hospital forms because of the common knowledge of construction techniques as well as the well established social context of highly influential church teachings. This was well illustrated in the early hospital designs with the placement of an alter in the center of the circulation allowing visual to religious services for patients.

In one of the first designed hospitals the influence of the Christian church and the focus on spirituality was very important at the time and thus was incorporated in to the Filarete plan of Ospedal Maggiore. “Filarete’s original design shows two cross wards with an alter in the center of each, on either side of an oblong court, in the center of which he placed the church.”[5]

**Architecture:** Hospitals designed during the renaissance were derived from the traditional building practices of church architecture. These plans accommodated the influence of spiritual care with the functional needs of visual connection to an altar.
“The derived hospitals of the Renaissance were actually borrowed from monasteries, palaces, estates, prisons, barracks or they were consciously constructed in current architectural forms of the time.”[6] Hospitals during the renaissance were being designed with the ideals of public-mindedness taking into account the most advanced building technology of the time, advanced care techniques of the time, and integrating Christian church doctrines of the time to provide care.

Priests, Monks, Nuns, and laypeople associated with the church served as the care providers in the hospitals in many communities.

“The pre-twentieth century culture held the belief that homeopathy was an effective method of treatment, allowing nature to take its course (of healing).” [7] The religious building forms influenced the architecture of the hospitals of the time for two important reasons: the integration of care of the spirit with care of the body, and knowledge of the religious building type and technology would have been more predominate in most communities. The combined influence of spiritual aspects of the
church and natural healing theories up through the Renaissance is perhaps best illustrated in the architecture of Filarete previously noted, where views to altars, natural ventilation, and the use of courtyards with programmatic purposes related to supporting caregiving and resulted in the Cross Ward Plan.

Ospedale Maggiore was the first known “planned” hospital in Europe, and was designed to optimize the functional needs of patients and staff at the time, including access to daylight and fresh air, also a functional need. This was best expressed in the cross wards developed to provide functional, well ventilated and, naturally lit wings that serve as the patient care areas. The regulated rectangular form allowed for typical building construction while providing visual connectivity between multiple wards and central alters at the intersection of the crossing wards. This allowed mass to be provided from a single point to more patients of differing classifications. The plan provided segregation for different patient populations that were centered on spiritual and bedside care. Ospedale Maggiore was also designed to optimize nursing care in what was considered at the time “a place to die”. The form consisted of eight
courtyards that served as both functional and therapeutic spaces. The interior wings of the cruciform plan served as patient wards which were organized between these courtyards. The building form also allows for the perimeter wings to be support spaces and administration areas for the clergy.

During the Renaissance, the theory of miasma maintained that bad vapors would cause the body to become ill. “Before the discovery of microbial pathogens late in the nineteenth century, the prime source of disease was believed to be miasma – poisonous gases given off by unhealthy environments.” [8] This in part led to an increasing concern with natural ventilation and access to nature within spiritual healing environments. The need to service a large number of people in a small space required that day light, air, and sanitation were important to appropriate care.

Health concerns of the Renaissance resulted from the impact of such contagious illnesses as the pneumonic plague, which occurs when the disease bacilli, called \textit{Yersinia pestis}, invade the lungs. This variety is highly contagious from one person to
another, and is spread by airborne droplets. [9] Illnesses such as the pneumonic plague increased the need for natural ventilation within healing environments. The health of the staff and patients of primitive hospitals increased with the ability of the healing environment to vent harmful airborne contingents. The increase of natural ventilation was thought to decrease the possibility of contracting airborne contingents from infected patients and equipment.

The form of Ospedale Maggiore also provides an example of how early hospitals were beginning to address the removal of human waste in an innovative way. The sanitation canals beneath Ospidale Maggiore were connected to a canal along the Naviglio River and provided running water around the four cross wards. One branch of the sanitation canal also served the laundry. This innovation in effect created a sewer system removing human waste from the nursing wards, albeit a design that is of questionable value today. The Ospedale Maggiore was therefore one of the first hospital structures to be developed purely for health purposes. The building form is an early example of integrating day lighting, natural ventilation, and access to nature.
ELIGHTENMENT UP TO THE 20TH CENTURY

Cultural Forces and Healthcare: The Age of Reason brought about a greater focus on science, medicine and the growth of civic institutions to provide healthcare. The focus of healthcare began to shift from simply caring for the sick and saving souls to the practice of medicine linked to scientific inquiry outside the auspices of the Church. The enlightenment was associated with the influence of science, with the systematic scientific approach to understanding the natural world including more rigorous, observation techniques, and symptomatic inquiry. The teachings that illness was caused by sin was discarded and replaced by new scientific theories that were being tested through more rigorous and accurate observation of cause and effect. With new scientific understanding of the human body and diseases theories healthcare would leap forward from the limited knowledge of the early Renaissance to, the germ theory. Scientific and technical innovations led to the development of such things as the first surgery in 1809 by Ephraim McDowell in Kentucky. The Stethoscope was invented by Rene Laennec in 1815 providing a valuable diagnostic
tool. Surgical antisepsis was introduced in 1865 by Joseph Lister and asepsis was soon to follow.

The scientific method provided a vehicle that would allow many different scientists to evaluate their work in a consistent level of quality. The theories of disease forced a shift from spiritual healing to the medical practice of treating disease and injury. The theories of the time focused on environmental causes and effects. The scientific method was developed to provide a consistent procedure: Determine the problem, form a hypothesis, research the problem and similar findings, test your hypothesis against your research findings, interpret the outcome of the test, and report to others your findings to benefit the larger group of work. This method was adopted by science to develop consistent results to problems. The scientific inquiry of the time focused on the environmental cause and effect of illness and disease.

This focus on environmental cause and effect also influenced the design of hospital buildings of the time. Experience had demonstrated the potential benefits of a well
ventilated, easily cleaned, logistically efficient ward for nursing care away from the crowds of the city.[10]
Architecture: Hospitals as Machine for Light and Air: The French Academy in an attempt to provide a well designed healthcare environment sought out design proposals for a new Hotel Dieu. Proposals were sought that provided improved sanitation, natural ventilation, and access to day light. The use of natural ventilation in hospital design is best illustrated by the plan developed by Julien David LeRoy and Charels Francois Veil. It illustrates the use of open wards, articulated building forms allowing green space between buildings, and decreased building thickness. Julien David LeRoy proposed a grandiose plan with 14 pavilions, large courts and a garden.[11]

The Pavilion Plan centered on the introduction of day lighting, natural ventilation, and sanitation all meant to combat miasma. By the late 19th century much of the medical thought with respect to appropriate settings for patient care was influenced by Florence Nightingale’s discoveries during the Crimean war in 1854-56 and the military hospitals that developed along that same line during the American Civil war where there was considerable success in raising the rate of survival in well ventilated
settings. Nightingale advocated open air, bed rest, and sanitation. Refined pavilion plans were developed using the efficient layouts of the military hospitals visited by Nightingale. The open wards of a military hospital provided efficient organized care spaces with adequate space for circulation of people and added day light for care procedures. The effect was an increase in air circulation and natural day lighting. The pavilion hospital form consisted of highly articulated nursing wards designed to function as a machine for capturing light and air optimizing natural ventilation and day lighting. The specific form for the Nightingale Wards was developed in great detail by Nightingale after visiting military hospitals abroad which were used to service large numbers of people in a short period of time. The organization required and developed by the military hospitals of the time was carried through to the pavilion layout, open patient wards with adequate circulation and organization served by a procedural area at the bedside. The need to care for such large numbers of people forced the machine like organization of the building and staff work habits.
The pavilion typology was able to provide a positive impact on healing rates and outcomes. “The miasma theory focused on sanitation and nature as a healthy environment advocating the pavilion style hospital as a healthy form for building that is centered on ventilation and sanitation.” [12] Thus, the spread of infectious diseases within hospitals was reduced after the adoption of the Pavilion style hospital.

By the mid 19th century, surgery was just emerging as a form of treatment, although most care was still delivered in the ward at the patient’s bedside. The large pavilion hospital plans of the enlightenment and through the early 20th century typically provided a series of open wards for patients organized along a service spine linking the wards to some of the first surgical theaters. Emerging surgical procedures were performed in more controlled centralized environments, both for the improved conditions of the operating theater and the teaching of other physicians. Surgical theaters were more appropriate for teaching than providing effective treatment until the widespread introduction of anesthesia and sterilizing protocols, since most patients rarely survived early surgeries due to infections.
In the early 1900’s advances in building technology allowed the high rise pavilion to be developed. The high-rise hospitals were exemplified by the introduction of sun balconies, private rooms, diagnostic and treatment services provided on each ward, and a separation of medical practices. The high rise hospital was made possible by the development of the elevator which provided the opportunity to stack pavilions vertically, reducing overall building footprint and travel distances resulting in improved access to increasingly centralized diagnostic and treatment services. Patient care pavilions were complimented with areas designed for emerging diagnostic and treatment technologies such as x-ray and surgical suites to provide fast and efficient care. The high-rise pavilion retained the connection to daylight and natural ventilation found in the conventional pavilion still considered to be beneficial for both general patient well being and as a treatment for diseases such as Tuberculosis.
The high-rise pavilion hospital could also be placed on smaller parcels of land within cities. Beaujoin hospital (1935 Paris, France) became one of the first urban high rise hospitals, incorporating pavilion typologies. This high-rise hospital was exemplified by sun balconies, a mix of wards and private rooms, diagnostic and treatment services provided on each ward, and a separation of medical practices. The open wards of the Beaujoin Hospital were possible because of the limited diagnostic and treatment procedures that were possible. The majority of patient care was still provided at the patient’s bedside, but emerging diagnostic and treatment activities were located on each floor.
INDUSTRIALISM

The era of industrialism brought about many advances in science and technology fueling advancements in both medicine and architecture. Each of the advancing areas then provided the building blocks for advancements in other areas, technology and science on medicine, technology on architecture, etc. During the industrial era while great leaps forward were being discovered in science, medicine, and architecture; the resulting effects of increased mechanization and production were having adverse health effects on people living in cities and communities that were being served by such increased productivity. Increased air pollution, water contamination and increased urban crowding were byproducts of the increase in rapid and unregulated growth in mechanized factories and production sites. World War I triggered added stimulus for industrial production with nations needing to build a larger mechanized Armies and Navies to wage war abroad. Both the war itself and the by-products of the industrial revolution meant that healthcare settings needed to counter both the effects of industrialism on people stateside and soldiers returning from battle requiring care from wounds sustained in the war. Healthcare began to
apply the management practices of industry in an attempt to improve the operations and efficiency of through-put of the facilities. With the increased need for efficiency in management and performance came the needed improvement of the architecture to function efficiently and allow for greater through-put, thus producing an architecture of the hospital as a factory or machine.

**Cultural Forces and Healthcare:** The era of Industrialism is anchored by the two great world wars which triggered rapid advances in both the practices and technologies of medicine, but also resulted in the need to treat and care for large numbers of critically wounded soldiers. Injuries that would previously have not been treatable and resulting in death were now treatable through advances in medical technologies and procedures. The increased use of anesthesia allowed doctors to complete procedures with less pain and trauma to the patient increased the viability and success rate of many surgeries. Improved surgical outcomes were also attributed to the awareness and application of sterile surgical practices and sterilization of instruments and equipment.
Industrialism also brought about the rapid development of new medical technologies. The invention of radiology and other diagnostic equipment allowed doctors to better understand the inner structures of the body, nature and scope of disease and injury, and treat patients with greater precision. The increase of tests that could be performed increased the information the physician had available to make a diagnosis, thus improving outcomes. This led to a greater clinical impact of both diagnostic and surgical interventions and resulted in increasing numbers of diagnostic and treatment actives performed away from the bedside. These new technologies were expensive and required specialized training of clinicians resulting in the increased movement of patients between wards and centralized treatment settings. This in turn dramatically increased the importance of distance from these specialized technologies, staff and settings to patient wards.

With the advent of the industrial model of manufacturing, healthcare settings incorporated the same model for hospital management. The functionalism of the healthcare setting was now driven by parallels to the factory, and led to efforts to
improve the efficient movement of patients and supplies between increasingly distributed but centralized points of care and treatment.

“With this need recognized a study was performed at the New Haven Hospital (The Yale Studies in Hospital Function and Design), to determine the quality of the medical care, the nursing care, and the food they were served. This study then provoked The Yale Traffic Index which measured the efficiency of American nursing units in conceived variety of floor plan configurations in use at the time. This study determined the functional efficiency of a unit by measuring the number of steps a nurse would take between critical patient care and support locations to provide care on the unit. These factors were then developed into a single index where the various design configurations could be compared for functional efficiency. “ [13]
**Architecture: Hospital as Machine for Light, Air, and Technology:** With the increase of centralized diagnostic and treatment procedures and spaces, traditional sprawling pavilion hospital plans became increasingly inefficient. Diagnosis and treatment was increasingly provided away from the bed within rapidly expanding diagnostic and treatment departments in the hospital. The equipment needed to perform such treatments was evolving rapidly, becoming more dependent on specialized infrastructure and specially trained staff that increased the cost of delivering care. These factors limited the ability to provide these medical technologies and treatments at the bedside to widely decentralized patient populations in wards. For the first time specialized diagnostic blocks were developed and built to address the increasing need to collocate these technologies and diagnostic and treatment procedures. This diagnostic portion of the hospital was typically located centrally to the patient wards organized along a service spine.
MODERN ERA

Cultural Forces and Healthcare: The modern context is characterized by an increased use of technology in everyday life. With the increase in technology use “hospitals grew more specialized, containing newly formed departmental groupings, each with unique functional planning requirements for diagnostic, treatment, surgery, administration, meals, and other support functions, it grew exponentially in size and spatial complexity” [14]

Along with the increase of technology and manufacturing, World War II led to significant advances in surgical and medical practices in response to the large numbers of injuries sustained by soldiers in combat. Many of the injuries resulted in deep bullet and shrapnel wounds and amputations which required surgical treatment employing anesthesia. With the increase of injured and disabled soldiers, along with
a large number of combat surgeons returning from war, the nation was under great pressure to increase the healthcare system. “Depression and war had taken their toll on hospitals by the end of World War II. Many hospitals had become obsolete, and over 40 percent of the nation's counties had no hospital facilities at all.” [15] Thus the Hill Burton Act was developed to create large numbers of community hospitals throughout the country.

Medical and technological advances led to an increasing amount of large, complex and expensive equipment to aid in the diagnosis and treatment of patients. The increase in both building and medical technologies within the care environment of the modern general hospital, along with the development of air conditioning contributed to the emergence of thick artificially conditioned diagnostic and treatment blocks of the late 20th century.
“In the early years the Hill Burton program resulted in hospital buildings to house as many beds as possible per floor, with the diagnostic and treatment functions housed on lower floors. These facilities were nearly completely focused on costly inpatient care. As the hospital grew in size, it required larger areas for technology and for the growing armada of administrators and managing support personnel.” [16] As the nation was developing the new model of healthcare architecture the technology housed in these diagnostic floors required more and more space with each developing piece of equipment.

Increasingly rapid advances within science, technology, and medical fields were occurring during this time period. “By 1953, James D. Watson, Francis Crick and Rosalind Franklin clarified the basic structure of DNA, the genetic material for expressing life in all its forms.” [17] Salk discovered the polio vaccine in 1955. Diagnostic and treatment services and technologies were being developed to meet the
demands of the patients needing care. Heart-Lung pumps were developed for open-heart surgery in 1953 allowing longer surgical procedures on vital organs. With dramatic leaps forward in understanding the human body the importance on research and implementation of new technologies within the diagnostic portions of the hospital became ever more important to patient care thus driving greater space needs for these diagnostic and treatment services.

**Architecture: Hospital Design:** Emerging from the findings of the Yale Index and the Hill-Burton era hospital construction boom was the 1960’s Race Track nursing unit configuration, improving upon the functional efficiency of nursing care by allowing more care to be provided to more patients in less time. The 1960’s Race Track designs of this period typically employed semiprivate and in some cases ward rooms housing up to 6 beds wrapped around a centralized support core, which provided efficient links between patient care at the bedside and support functions in the core. Along with the Race Track nursing units of the 1960’s, ever expanding
diagnostic and treatment blocks housed the increasingly larger and more expensive equipment used to treat and examine patients.

The grouping of the diagnostic and treatment equipment within a central block was also designed to improve functional efficiency allowing patients who needed treatment and staff to move more frequently between many different pieces of expensive medical equipment housed in close proximity to each other. Such expensive, large and complex equipment also required more controlled environmental conditioning. The equipment housed in the diagnostic block increasingly had to be supported by extensive electrical and plumbing interfaces and operated in highly controlled light, thermal and humidity conditions made possible through mechanical air conditioning. Another factor in the move to mechanical conditioning was the desire for a more controlled “clean” environment and better control of the airborne transmission of infectious disease agents.
The ability to create mechanical environmental controls in the hospitals and buildings of the 1960’s and 1970’s and the drive to reduce travel distances to and between diagnostic and treatment functions led to ever thicker footprints. With the limitations of early information and communication technologies these functionally driven spaces remained dependent on physical proximity for the efficient movement of patients, staff and paper records. With the increase of specialized medical practices, the increase in technology, the reduced lengths of stay, and increase in outpatient care, the percentage of diagnostic and treatment areas of the total hospital area became much larger. “The number of doctors reporting themselves as full-time specialists grew from 55% in 1960 to 69%.” [18] With the increase in specialty practices the increase of equipment used in specialized treatment also increased. Thus the areas used to house specialized diagnostic and treatments increased dramatically.
Today’s society is driven by consumerism, rapid technological advances, a rapidly changing health context, and increasing environmental concerns including concerns over the health of the indoor environment. With society focused on a more sustainable and healthier environment, both outdoor and indoor, there is increasing interest in greening settings that provide the healthcare. Consumers are more informed and concerned about the environment and how it affects health and wellbeing than generations of the past and are demanding that healthier building practices and materials to be used with the design of healthy hospitals for the future. The planning and development of hospitals today needs to better balance the need for healthier and more therapeutic settings for patients and providers with the more traditional performance goals strived for in earlier healthcare settings.
Consumer Trends

There is an increasing consumer awareness and interest in healthcare settings that support patient safety, improve health outcomes and provide patient centered care. Hospitals should be places that support positive health outcomes and experiences both through the functions being carried on in them as well as from buildings that house these functions. Consumers can be a powerful changing force in society today, and given the market driven healthcare “system” in the US today, can influence what we as a society seek from the hospital of the future.

In the US consumer driven healthcare market, providers must attract people with good health insurance to pay for those without it through what is known as cost shifting. In order to attract a balanced mix of patients, they must provide facilities that not only support high quality care but also improve consumer’s experiences. The current consumer focus in healthcare today impacts hospital design through the provision of expanded outpatient services and facilities, greater and more complex
diagnostic equipment and more hotel-like hospital settings such as lobbies and patient rooms. What has not been the focus to date is to generally improve the overall character and healthfulness of the hospital environment outside of the patient room and lobby.
Technological Trends

Technological trends within society have influenced many factors of our everyday lives and the way that healthcare is being delivered. The access to general knowledge in society has increased rapidly with the progression of information technology. In healthcare, this has enabled an increasing percentage of patients to become much more informed consumers of healthcare services. In growing areas of the country, the performance of hospitals and are providers is becoming publically available. As a result, healthcare providers are seeking ways to provide more efficient, effective and safe patient care settings and procedures.

**General Technological Trends:** The general trend with the evolution of many technologies is that they become faster, better, smaller and more readily available at lower costs. The computer is a classic example. The ease of use of technology is increasing and the proliferation of technology in our everyday processes and lives has
increased over the recent years. We as a society are relying on technology to make our lives easier and more comfortable.

**Information Technology**: The rapid increase in information available to society as a whole has grown exponentially over the past 20 years. “Information Age is a term that has been used to refer to the present era, generally beginning within ten years of 1990.” [19] The contributions of the advances in information technology to healthcare are widespread, allowing more accurate diagnostics to be performed faster and, to an increasing degree, back at the bedside, a place that has proven throughout history to be beneficial to the patient. This opportunity for more bedside care is the result of greater use of mobile medical technologies and point of care testing used to treat and diagnose the patient.

**Mobile Technologies**: Mobile technologies are improving the manner and changing the locations in which care is delivered within the modern healthcare setting. Patients today are receiving more procedures with mobile equipment in their patient room (X-
Ray, CT) decreasing the risk to the patient during transport. Technological advances such as WiFi, Bluetooth, and Cellular broadband transmissions have provided greater opportunities for virtual functional relationships decentralizing the diagnostic and treatment procedures and moving more of them into patient nursing units. Mobility and smaller medical equipment allows for the transport of the equipment to the patient rather than the patient to the equipment. This development provides the opportunity to create a more patient centered care environment in hospitals today and in the future has the potential to reduce the amount of area needed for thick diagnostic and treatment blocks housing large immobile expensive equipment.

The degree to which information is now transported and organized is less dependent on human face to face interaction and is becoming increasingly easier and faster to access at multiple locations simultaneously. The need to physically transport hard copies of data from one care location to another will no longer be a priority to provide care. The ability to digitally store and transport information is already impacting patient record storage in the hospital.
The use of wireless technology further increases the mobility of patient care and care providers. Wireless technology allows easier change in technology over time with little to no impact upon the built environment with respect to information cabling or equipment itself. Technology that can be used when needed, more easily and removed when not, limits the impact of technological changes over time on the building itself.
Sick Buildings and Their Impact on Healthcare

Sick Buildings are environments that have the potential to impact health in several ways. First, they can create an opportune environment for mold and other harmful biological organisms to grow. They can also negatively impact health when they are constructed with materials that contain carcinogenic or other chemicals that are harmful to the inhabitants as they decay and age. Sick buildings can also impact health through their overall configuration resulting in thick building forms where there is little or no provision for natural ventilation, access to daylight and views or connections to the exterior environment for building occupants.

Sick Building Syndrome is a health disorder contracted by inhabitants of buildings containing two or more elements that negatively affect human health. Causes of Sick Building Syndrome can be attributed to poor construction techniques, deterioration of building materials, biological infestations of mold and mildew, and many other chemicals and gases found in the typical healthcare setting. Sick Building Syndrome
can also be the product of inadequate ventilation due to the inability to access outside air through widows or doorways. Biological contaminants such as mold spores or fungi often caused by damp areas within the buildings can cause or contribute to Sick Building Syndrome. Sick Building associated illnesses have been linked to: Symptoms such as cough, chest tightness, fever, chills, and muscle aches. Symptoms can be clinically defined and have clearly identifiable causes, airborne building contaminants. [20]

**Building Materials:** Many building materials in the modern hospital are made with unhealthy raw materials that emit toxic gasses over time. When used in conjunction with thicker, sealed and mechanically ventilated hospital buildings, these combined practices produce measurably increased health risks. In particular the uses of many common moisture prohibitive chemicals within building materials have been found to be carcinogenic (such as formaldehyde). These materials when contained within sealed air conditioned spaces off gas causing illness for inhabitants. Along with these
gases moisture can be trapped causing the growth of mold spores, thus negatively impacting the health of the inhabitants.

**Thick Building Forms:** These structures typically involve a large building footprint that has limited natural ventilation and air circulation in all or most interior spaces, thus providing enhanced opportunities for biological growths to take place. Many areas in these types of structures are often under ventilated, under lit, and with little to no access to the outside. While these buildings may be efficient to build and may be easier to maintain in some ways, they can be very detrimental over the long term to the health of their inhabitants.

The thick building forms of the contemporary hospital also limit the amount of daylighting that the staff and patients receive. Inpatients must be provided by code at least one window in the patient room, which is typically required to be closed and non operable in most facilities due to safety protocol. Clinical staff working on nursing
units typically only have access or connections to daylight and views outside through the patient room windows or when leaving or entering the building. Diagnostic and treatment staff often work in spaces with no windows and are not required to have windows within their spaces. On a typical work shift of 12 hours, staff may enter the building in the dark and leave the building in the dark most of the year.

The need for day lighting since the inception of mechanical air conditioning has been resisted with the increased heat gain and mechanical system cost that occurs when windows and daylight is allowed to infiltrate the built envelope. “The majority of this solar heat gain comes through your windows, glazed doors, and skylights. The most effective way to manage the amount of solar gain that enters your home or office is to block it before it gets into the building.”[21]
The lack of day lighting has detrimental effects to the human body over an extended period of time. An extended lack of exposure to day lighting can cause Seasonal Affective Disorder (SAD). “Potential causes of SAD - Lack of light may upset your sleep-wake cycle and other circadian rhythms. And it may cause problems with a brain chemical called serotonin that affects mood.”[22]

Seasonal Affective Disorder can be considered a type of depression and has affected a half million people. It is caused by a biochemical imbalance in the hypothalamus due to the lack of daylight. SAD can be seriously disabling, preventing them from functioning normally without continuous medical treatment. [23] Most sufferers show signs of a weakened immune system and are more vulnerable to infections and other illnesses.

Symptoms mostly associated with Seasonal Affective Disorder are: desire to over sleep, difficulty staying awake, fatigue and inability to carry out normal routines, and an inability to tolerate stress. [24]
Melatonin, a sleep-related hormone secreted by the brain, has been linked to SAD. This hormone, which may cause symptoms of depression, is produced at increased levels when the subject is in the dark. [25]

The effects of the hospital environment can be detrimental to staff due to the length of time spent within many hospital work areas without any access to day light. Since the majority of a healthcare staff work shifts with little to no contact with natural day light the symptoms associated with SAD are higher and may be experienced with a correlation to medical errors. If and when healthcare staff experience symptoms of depression and fatigue, the impact on patient care may be quite detrimental. The effects of such symptoms could contribute to an increased potential for medical errors.

These effects on caregivers can in turn negatively affect patient care and outcomes. The numbers of medical errors are on the rise. The Institute of Medicine (IOM) report estimates that up to 98,000 people die every year from errors made in hospitals.
Errors range in type from medication errors to surgical errors (instruments being left behind). Nearly two-million patients will get infections in U.S. hospitals this year. At least 90-thousand of them will die, according to the CDC.
Creating More Therapeutic Environments

In reaction to increased awareness and concern for the health, safety, patient satisfaction and cost of healthcare today, many healthcare organizations are seeking to create more therapeutic environments as part of a goal of improving the quality of care with lower cost. The development of therapeutic environments may contribute to shortened lengths of stay and improved health outcomes. “A healthcare environment is therapeutic when it does all of the following: Supports clinical excellence in the treatment of the physical body; Supports the psycho-social and spiritual needs of the patient, family, and staff; Produces measurable positive effects on patients' clinical outcomes and staff effectiveness”[28]

Therapeutic Environment Theory is derived from the area of environmental psychology (psycho-social effects of environment), psychoneuroimmunology (effects of environment on the immune system), and neuroscience (specifically how the brain perceives architecture). [29] Patients are often confronted with a large complex
environment of equipment and spaces that contributes to the stressful situations that occur while being treated. The added stress can cause the immune system to be suppressed, slowing recovery and healing time [30]

These are four measurable key therapeutic environmental factors which, if addressed appropriately, can improve patient outcomes: The reduction or elimination of environmental stressors; the provision of positive distractions; enabling social support; and giving a sense of control. [31] The reduction or elimination of environmental stressors such as noise can provide a improved healing environment. The use of private rooms and walls that extend to the deck above can help with sound attenuation and privacy. Positive distractions such as a view to nature or a garden can provide something for patient to view outside their own room. The development of more open nursing units to connect working staff with each other, their patients and families can promote positive attitudes and support in decision making efforts. Providing the opportunities for patients to control the television volume, adjust the natural light and views to nature, and control the ability to communicate with staff
can improve patient satisfaction and improving both the perceived and real quality of care. [32]

Evidence gathered from ongoing research relating to patient and staff satisfaction indicates that certain design strategies can have a measurable therapeutic impact by influencing health status, health outcomes and patient/staff satisfactions. Hospitals with consistent patient types across different room types show measurable impacts on lengths of stay, perceived quality of care and patient experiences reflected in patient satisfaction scores which can be directly contributed by the room design itself. The elements expressed in satisfaction scores were defined to be windows that allow for visual connections to nature, and the calming areas for patients families and staff to decompress in stressful situations. [33] These factors are traditionally primarily focused on the patient and family.
Staff and caregiver satisfaction, effectiveness, and staff retention, can also be influenced by environmental factors such as: appropriate lighting, providing 'off-stage' areas for respite, proximity to other staff, and appropriate use of technology

Appropriate lighting for staff can reduce eye fatigue over long shifts, as well as eye strain with drastic lighting changes when entering and leaving patient rooms. Providing off-stage areas will allow staff to decompress mentally and emotionally from tragic or stressful events that may have occurred to the staff. These areas are often used to meditate, relax, or reflect on recent events. These off-stage areas are typically away from the public, quiet areas. Social support through proximity to other staff will strengthen the decision making and provide help when needed much quicker than with isolation. [34]

Healthcare environments can reduce or eliminate environmental stressors by:

Providing lighting that supports natural circadian rhythm; "Provide natural day lighting where possible or bright white lights (400-600nm) in the daytime are the typical methods of treating SAD. (J. Roberts, Ph.D.) Maintaining good indoor air
quality will also contribute to the health of the inhabitants.”[35] Stressors can also be mitigated by providing positive distractions such as views of nature from patient rooms and wherever possible in lobby, waiting, and other 'high stress' areas. [36]
The Architecture Potential for Green Healthcare Facilities

Green Healthcare Architecture and energy conservative building forms have potential for positive impacts on patient outcomes by harnessing healthier building practices, and integrating technological advances in mobility and communication. With this focus green healthcare architecture can prevent the design of sick buildings and create more therapeutic environments by creating environments that better promote healing.

Sustainable Design involves making architecture and urban design decisions that conserve natural and built resources, including culturally important buildings and sites, and creating healthful buildings and communities. [37] Air quality inside buildings is affected by many factors, these factors can be addressed through proper design and materials that respond to green architectural principles. Factors that can have a negative effect on health and comfort in buildings range from chemical and biological pollutants, to occupant perceptions of specific stresses such as temperature, humidity, artificial light, noise, and vibration. There is a growing effort to eliminate or decrease chemical and biological pollutants within the built environment in the
future. Significant sources of chemical indoor pollutants include the human body and human activities, emissions from building materials, furnishings and appliances, and the use of consumer products. These processes and sources are being studied to further the knowledge base of how green architecture can address those issues in the future. Microbial contamination is also a common contributor to the indoor air quality issue. It is mostly related to the presence of humidity and moisture, and is often linked to poor maintenance practices, that can in turn be changed by green building practices and techniques to reduce the possibility of moisture building up. [38]

**Health and Productivity Benefits:** Green healthcare architecture and building practices can improve health through minimizing potentially harmful elements within the built environment. Comfort can be achieved easier through the integration of nature with the building forms, allowing greater natural treatment of the environmental elements. Staff work rates and retention can be improved by creating
working environments that allow access to nature. Staff productivity can improve with appropriate lighting and views to nature. With healthier environments faster recovery times can be seen for illness and less transmission of illnesses. [39]

Environmentally responsive therapeutic designs of the future will incorporate connections to daylight, views to nature, natural ventilation, and positive distractions increasing the healing properties of the built environment.

Environmentally responsive "Green" design that incorporates daylight by increasing the glazing of a building without increasing heat gain, can allow greater opportunity for the human body to process vitamin D. “Six out of 10 adults of working age in the UK, and probably in other European countries too, are at risk of chronic disease because they do not get enough vitamin D. The diseases caused, at least in part, by insufficient vitamin D or insufficient sunlight include not only bone conditions such as osteoporosis and rickets but diabetes, multiple sclerosis and several different kinds of cancer, as well as high blood pressure and probably heart disease.” [40]
Views to nature and positive distraction through improved window placement and scene setting may increase the ability of nurses to function at the top of their abilities in healing the patient thus decreasing the length of stay. “Breaks from work and time in nature effect well being in distinct ways. Individuals who engage in nature-focused self care outside of work, such as gardening or observing wildlife, were significantly more focused. Results have implications for the structure of work days and patient care duties, nurse retention, patient care, and the physical design of health facilities.” [41]

Increasing natural ventilation within the healthcare environment can play a large positive health impact on the nurse working environment and patient healing environment. “The World Health Organization has assessed the contribution of a range of risk factors to the burden of disease and revealed indoor air pollution as the 8th most important risk factor and responsible for 2.7% of the global burden of disease. There is consistent evidence that exposure to indoor air pollution increases
the risk of pneumonia among children under five years, and chronic respiratory
disease and lung cancer (in relation to coal use) among adults over 30 years old.” [42]
Healthcare settings with increased natural ventilation would decrease the opportunity
for negative health effects by poor indoor air quality.

With the increase in staff shortages the need to improve staff satisfaction retention
and productivity has become a driving force for providing natural healing, stress
reducing environment within the healthcare settings of the future. Nurses as a whole
want to work in a stress reduced healing environment that will have a positive impact
on their day to day care activities.

**Environmental Benefits:** Green Healthcare Architecture decreases the amount of
CFCs and harmful off gassing from building materials typically used to build hospitals. This can minimize ozone depletion by decreasing pollutions contributed to poor construction. With the proper building techniques green healthcare architecture can reduce energy consumption and transporting materials by transporting from local
providers. By using local materials and energy, local and regional air pollution can be reduced by limiting the amount of waste produced by construction or improper building life cycle management. The reduction of urban heat islands by using more effective green parking areas to limit asphalt will have a positive impact on hospital heat gain throughout the day, thus limiting the need for increased air conditioning requirements. [43]
PRINCIPLES FOR ENVIRONMENTALLY RESPONSIVE AND MORE THERAPEUTIC HOSPITALS

The following strategies developed in this thesis are designed to facilitate the integration of day lighting, natural ventilation, and access to nature within healthcare settings. The application and integration of these design strategies will produce a more therapeutic and effective care environment for both patients and staff. These architectural strategies are intended to supplement or complement traditional functional adjacency requirements and efficiency standards required by the healthcare industry. These proposed architectural strategies range in scale from urban fabric to program placement and building circulation. Each individual strategy can be applied to a range of thick healthcare building typologies to improve access to natural elements. Collectively they can create more therapeutic healthcare environments that can have positive influences on both staff and patient health.
Chekerboard of Open Spaces

A checkerboard of open spaces is an urban fabric that consists of an alternating pattern of programmed and open non-programmed space such as courtyards, atria a or other public spaces arranged to provide access to day lighting, natural ventilation, and views to nature. The built fabric of cities and communities as well as healthcare campuses and facilities should incorporate green landscaped spaces in the design. The proportion of green and open space to built space should be 1 to 2. No building element in this checkerboard pattern should be thicker than is necessary to provide views to green planted spaces from 75% of all interior spaces.

These open spaces provide opportunities for inhabitants of the built environment to access planted areas that may be utilized for social gatherings, private reflection, or places for pause. Open space that is integrated within the built fabric allows inhabitants a place for respite and meditation, an area for mental and stress breaks.
This ability to view and access these nature spaces quickly will increase the ability for inhabitants to deal with day to day stresses and are conducive to stress relief.

Open spaces should be placed and designed in such a way that they allow sunlight to directly penetrate the building envelope. Open spaces should be sized according to the surrounding building heights to allow for at least 25% of the floor space or ground level to receive direct solar rays throughout the day.

Areas for decompression associated with nature have shown an increased ability for inhabitants to limit stresses influences. A study produced by Dr. Karstan Bruun has provided evidence that green spaces do impact the humans ability to cope with stress: 800 out of 1200 people agreed that green spaces allow them to cope better with stress, and 800 out of 1200 people agreed that green spaces affect their mood in a positive way. [44]
Administrative buildings in Wiesbaden, the capital of the regional state of Hessen in west-central Germany illustrate the integration of planted voids within a building fabric. This is an example of a building fabric that is massive but still integrates green planted spaces.
Perforated and Articulated Building Fabric

When larger building footprints are necessary, it becomes important to create perforated and articulated building fabrics. A perforated and articulated building fabric is distinct from the checkerboard of open spaces in that it involves the subtraction of built volume from a larger building volume. The overall building volume is understood as one complete form with open courtyards or other spatial features carved out creating areas for opportunity to connect with nature. It includes providing opportunities for light wells or smaller open areas that penetrate the building to provide light and air. This principle creates a perforated building form, a large block form perforated with open light wells and smaller courtyards that enable access to sunlight and natural ventilation within traditionally thicker diagnostic and treatment areas of the hospital.

This strategy is borrowed from traditional building typologies in a manner that provided greater opportunities for the inhabitants to access day lighting, naturally
ventilated spaces, and naturally planted areas. Within thicker building forms the ability to access daylight, naturally ventilated spaces is difficult; but by providing air and light wells, the proximity to sunlight and air can be increased giving a greater opportunity for inhabitants to lower stress and make a connection with nature. This technique of providing courtyards along with air and light wells should be implemented within close proximity to nursing stations, break areas, and major nodes of circulation for way-finding benefits.

Perforated and articulated building forms that promote the integration of nature within built hospital environments can be in three ways. They can be developed as large perforated blocks of Swiss Cheese, elongated bars or wings, and rectangular donut shapes with courtyards. By manipulating and combining all three forms, all areas of the typical hospital can be accommodated. The Swiss Cheese typology is accomplished by perforating thick building elements such as diagnostic and treatment areas with skylights, light wells, and courtyards. It enables the infiltration of natural
elements while maintaining functional adjacencies critical in diagnostic and treatment areas.

The elongated bar form is well suited for areas with high concentrations of patient care and work areas such as inpatient floors. Finally the donut form is produced by organizing multiple bar elements with complex and interconnected circulation loops to facilitate movement and functional relationships between units. Inpatient areas are more appropriate for the bar and donut typologies because of the number of small patient care and staff work spaces needing access to day light. The use of bar and donut forms optimizes access to natural elements in areas with many small spaces that require windows or benefit from direct access to natural light and views such as patient rooms and exam rooms.
Self Regulated Building Envelope

The treatment of each facade should be determined by the need to balance the response to the solar orientation, daylight and ventilation requirements and their ability to control heat gain (comfort) and life (health). This principle is focused on the design and development of a building facades that are responsive to the solar orientation of that facade and the response of that facade to regulate heat gain and sunlight infiltration effecting the comfort and use of interior spaces. Each facade, depending on its orientation, will inherently need different configurations of glazing and sun control to deal with heat gain and sunlight infiltration throughout the day.

Given that over the course of a day and year the exposure of a given facade varies continuously, Self Regulated Building Envelopes are important to mitigate heat gain and solar ray infiltration throughout the day, thus providing a comfortable healthy healing environment for extended periods of time.
The location, placement and orientation of the basic building forms will dictate the solar exposure. Therefore each building façade should be designed specifically to respond to its solar, regional and local environmental context. Examples of specifically designed facade treatments for a building in the northern hemisphere might suggest that the east elevation would be made of perforated panel system to provide views to nature through the glazing yet mitigate direct solar heat gain early in the day. Southern elevations require self regulating façades that would continuously adjust to the position of the sun throughout the day. These facades need to be designed with elements that automatically respond to day lighting and heating / cooling conditions required by the functional areas adjacent to the exterior wall. These wall systems should be comprised of a framework of individually adjusted perforated metallic panels. Each panel is directed to open or close through an integrated system of thermal sensors that measure the inside and outside temperature determining the appropriate aperture. The West façade should be comprised of a perforated panel system to mitigate the heat gain later in the day as the sun sets. The
Northern façade should be designed as a glass curtain wall system to provide as many views to nature and access to daylight.

With the design efforts focused on the building evolving to fit its environment throughout the day, interior environments can maintain their comfort levels with decreased mechanical heating and cooling needs because of the diminished climatic and solar impact.
Integrated Building System

The complexity of healthcare settings requires the use of large numbers of technologies and utilities to serve them. The building form should be developed to provide day lighting, natural ventilation, and access to nature, and the design and accommodation of building systems and technologies should not disrupt that ability. An integrated building system approach can accommodate the ever changing technologies and services required for healthcare environments over time and continue to provide access to nature. An integrated building systems approach provides all the mechanical, electrical and HVAC requirements above the inhabited floor either in an increased vertical floor to floor height or an additional interstitial floor level. This approach diminishes the impact of vertical visual barriers on occupied floors from mechanical, electrical, or HVAC chases. The resulting decrease in vertical chases and solid walls to accommodate mechanical distribution systems will increase the opportunities for views to nature and access to day light in interior spaces.
This integration of building systems in interstitial floors allows for greater flexibility in functional planning by decreasing the impact of mechanical space and chases that may potentially obstruct access and views to nature.

Integrated building systems also provide the ability to integrate and align building utilities with the structural system. The integration of the building systems with the structure will insure that the impact of structural and infrastructural elements on visual access to nature and day light will be minimal. By collocating all elements that create immovable vertical visual barriers the opportunities to create open visually connected spaces is increased. The library done by Mediatheque to the left was designed with structural light wells housing the mechanical and electrical distribution within. The two structural light wells (show light up at night) provide the opportunities for vertical elements that serve the building to travel to their designated locations, making open spaces possible.
Functional Orientation to Access Natural Elements

The placement and orientation of functional areas within the hospital is crucial to not only the operational efficiency of patient care and support activities but also the need for adequate access to natural elements for both staff and patients. This principle should be applied across the healthcare facility from diagnostic and treatment areas to patient care areas.

The stratification of public, staff, and treatment spaces should occur from east to west providing an opportunity for each zone to access direct solar rays over the cycle of a day. With each functional bar of public, staff, and treatment spaces touching a portion of the south façade, each functional areas is provided equal opportunity for connecting with day lighting. The range of more intensely controlled environments to the more open areas should be stratified from south to north with areas such as surgery and imaging on the southern facade. Surgery and Imaging being two large controlled departments that house many staff and patients involved in many complex
lengthy procedures that require the staff and patients to be at the peak of performance. Greater access to nature and day lighting can increase the ability to perform better.

Patient care spaces should be located having windows with views to nature, day lighting, and ideally, opportunities for natural ventilation. This should all be achieved by placing the care environments when possible with in a bar type building form thus maximizing the opportunity for views out.

Primary staff work areas should be located to allow direct or indirect access to daylight, and ideally, views to nature and natural ventilation. This is most important in areas where staff work for long periods of time and are involved in high stress activities. When windows to the exterior are not possible, work areas should be provided with light wells to provide greater opportunity for staff to access day light and natural ventilation during working hours. Waiting areas and way-finding nodes should also be placed to maximize day lighting, and views or direct access to nature.
Roof areas that can be viewed from above should be vegetative and whenever possible accessible to patients and staff.
SITE

Charleston, South Carolina is developed on a peninsula stretching out into the Atlantic Ocean. Charleston was originally a shipping port for the south eastern United States. The city now houses the state’s primary academic medical facility, The Medical University of South Carolina (MUSC). This will be the site of the thesis investigation because of its proximity for study, its surrounding urban fabric and well developed campus development. The MUSC recently developed an inpatient hospital replacement which produced a thorough program for the replacement portion of the campus. This provided an available, applicable and opportune site and project for this thesis investigation.
Selection Criteria

Site selection criteria were established to assure choosing a site that supports the ideals of the thesis investigation optimizing of day lighting, natural ventilation, and access to nature within a large academic medical center hospital. The site selection needed to identify a site in the northern hemisphere that would have seasonal changes yet limited day light and night darkness variation throughout the year. The site was to be limited to a size that could be investigated within the allotted academic calendar and would be easily accessible to visit and investigate during the design process. The criteria were to ensure that the scope of project was feasible with the time allotted for the investigation of this thesis.

The site and project needed to contain a 100 to 200 bed teaching hospital to allow for an adequate investigation of the design principles developed in this thesis. The site was to be located within an urban context so that the investigation of site limitations and constraints can occur. The site that was ultimately chosen provides a realistic
example of many of the issues and problems that architects are confronted with when dealing with the design of large urban healthcare facilities. A green field hospital project would not reveal valuable challenges that must be addressed in many hospital replacement or addition projects that occur today. The project was to be integrated within a larger healthcare system requiring a growth strategy within an integrated urban campus context. Given that any hospital will grow and change over time, an academic medical center campus provides an appropriate example of what is happening with these kinds of large medical center campuses today. The building strategies developed should be applicable to most healthcare facilities to create a viable investigation that will benefit healthcare design.
Site and Context

The selected site is bound by Courtenay Drive to the east, Charleston Center Drive to the south, McClennans Bank Court to the west and the MUSC Wellness Center to the north. The site is bisected by Doughty Street that is destined to become the MUSC green way through campus.

The site is located within the flood plain requiring the first occupied level to be 17 feet above sea level. With the close proximity to the ocean, tides and major storm surges become safety issues. The site is located near the shore of the Ashley River, and is prone to flooding. During major storm surges the site may contain up to 15 feet of water; this causes great concern for having habitable space below the 17 foot margin on site.
Site Assets

Pre-existing features within the urban context can help to inform the development of this site. Natural areas have been protected by the city of Charleston to mitigate environmental impact from the city as well as providing greater opportunity for areas of respite. These natural areas that have been established by the city of Charleston can be integrated with in the campus fabric to develop the beginnings of a checkerboard of green spaces throughout the urban fabric. Integration of the established green and natural spaces with the academic medical center campus will strengthen the impact of open landscaped spaces within the investigation of this thesis project.

**Natural Areas:** The Charleston peninsula provides an opportunity to connect to nature through access to the coastal environments bordering the peninsula. The city of Charleston has developed park and wetland areas to allow nature to be protected while continuing to allow people to view and interact with natural areas. Naturally occurring wetlands west of the MUSC campus will be able to be viewed from upper
floors of any building placed on this proposed site with orientations to the west, northwest and southwest.

**Public Space:** A greenway is proposed for Doughty Street, connecting the drop-off Horseshoe (existing green space) with the entire campus. The proposed greenway will bisect the site allowing the greenway to be integrated with the replacement hospital. This proposed greenway will help to begin to develop a checkerboard of open green planted spaces to provide public respite areas. Through the redevelopment of the campus over time the network of green spaces will increase improving the pattern of green spaces within the urban fabric that is Charleston.

**Pedestrian Circulation:** While Charleston is a pedestrian oriented city in the Lower Peninsula, the MUSC campus is not particularly pedestrian friendly. The proposed master plan for the campus envisions a more pedestrian oriented medical center campus. The placement of the hospital at the intersection of a major axis from the academic campus and the growth axis for clinical services make the proposed site a critical node in the overall medical district. Therefore, it is important to provide good
pedestrian access to the hospital from both nearby parking, the medical center academic campus and support pedestrian activity and movement at street level along Courtney Drive.

**Circulation Pathways:** Courtenay Drive serves as a public circulation corridor from north to south through the existing street fabric of MUSC. The main public and visitor vehicular traffic that will access this facility will primarily be focused along Courtenay Drive allowing for patient and visitor drop-off and pick-up. McClennans Bank Court provides existing service circulation to the west of the site. Limiting service vehicles to the McClennans Bank Court will decrease vehicular circulation along Courtenay Drive making it more pedestrian oriented.
PROGRAM PROPOSAL

Introduction

The program used for this thesis was developed as the first phase of the master planning of a replacement hospital for MUSC, which is an academic medical center. To adequately investigate day lighting, natural ventilation, and access to nature within a hospital setting, the program included all the components that make up a large contemporary academic medical center hospital. The program was only adjusted as need to successfully demonstrate the inclusion of day lighting, natural ventilation, and access to nature within a range of hospital components.

The program is derived from an existing project designed by NBBJ and LS3P. The project consists of phase one MUHA replacement hospital in Charleston S.C. Using the existing program and site for an actual hospital provided an element of credibility to study the feasibility of the design principles proposed by this thesis. This program provided the functional adjacencies and space requirements. These adjacencies and space requirements were maintained throughout the project. [45]
### Program Departmental Summary

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PROGRAM COMPONENTS

Arrival and Amenities

This area in the program is generally intended as an atrium space at the main public entry and major intersection of public elevators and circulation spines. It is used to orient and organize visitors and patients. Comprised of the Lobby, Entry and public restrooms this component also serves as the hospitality element when dealing with way-finding and information and directions. This areas is the first place most visitors come in contact with when arriving at this facility, therefore will the most accessible from the exterior. The gift shop and food services areas may be located directly off this major public space.

The Arrival and Amenities area will be the area most accessible to nature and natural ventilation. These areas are traditionally accessible to nature and function more effectively if they can be viewed from the exterior of the building allowing the public to know where to enter the hospital.
**Bedded Care**

The first phase of the replacement hospital has the capacity for 156 beds. The bedded care is programmed for all private patient rooms that need direct access to day lighting and views to nature. The private rooms are arranged in nursing units that require support space to address the care needs of the patients. These support spaces are comprised of medication, clean, soiled, equipment, conference, and mechanical spaces, all typically devoid from any access to nature through views or day lighting.

The spaces such as equipment, mechanical, soiled, clean rooms that do not require being centrally located should be located on the exterior of the building whenever possible. The remainder of the spaces should be investigated as to the required wall types that are needed to house the functions be performed within them. The areas that can be viewed by the public should be provided with glass or low walls allowing for greater visibility to staff as well as increased opportunity for views to nature and day lighting.
lighting. Spaces requiring full height walls should be located within the central portion of the unit as to decrease the visual obstructions to the exterior.

**Ambulatory Care Clinics**

The Ambulatory Care Clinics serve as a triage area for the hospital. Exam and treatment rooms traditionally should be provided with access to nature given that they are typically on the ground floor with public access points. The area typically treats patients that after medical screening can be released under their own care. This limited acuity allows limits the controls applied to these areas in terms of lighting and climate control; this provides greater opportunity to open these areas up to more day lighting and views to nature. Open circulation spaces should have the greatest percentage of glazing because of patient confidentially and privacy issues when dealing with the exam and treatment rooms.
Diagnostic Imaging

Diagnostic imaging was programmed to consolidate the majority of the equipment needed to perform diagnostic examinations. The location of the diagnostic imaging area has always been closely associated with emergency medicine because of the need to access diagnostic information as quickly as possible, thus it is traditionally located adjacent to the emergency department.

Diagnostic imaging is very often closed off from the exterior elements because it houses very complex sophisticated instruments that require strict environmental control. The equipment requires very specific humidity and temperature control therefore the ability to provide natural ventilation is not possible. The ability to provide daylighting and views to nature is possible with respect to the treatment areas not affected by ultraviolet rays. This would allow for windows to be provided in CT Areas, X-Ray areas, and Nuclear Medicine areas, not traditionally provided with windows.
**Interventional Imaging**

Interventional imaging such as CATH and Cardiovascular services are areas that required limiting the amount natural light or views to nature that can be accessed in the procedure area. This area is becoming increasingly more outpatient driven, further reinforcing that these procedure areas should be more open to nature and access day light.

The possibility of day lighting and access to nature through views applies to interventional imaging but natural ventilation does not apply because of the much needed control of dust, humidity, and temperature. The integration of views to nature and accessibility of daylight within patient examination areas provide patients with a pleasant distraction to procedures that may become stressful. By locating these interventional imaging areas along the exterior of the building envelope and providing eye level glazing, when patients are awake and are able to look outside they will have the opportunity. Connections to nature can positively affect stress levels through these minimally invasive procedures.
Heart Center

The heart center collocates procedure areas and treatment spaces that are associated with cardiovascular complication. This area treats people who may have high stress, high blood pressure, or congenital heart or vascular defects. These are all a point of high concern for the people being treated, thus limiting the strain on the heart and lungs is positive. The treatment spaces are most often areas where patients must remain for an extended period of time to obtain vital information about heart or respiratory functions. These treatment spaces are mostly closed body procedures meaning that limited cutting in being performed. The integration of views to nature as well as day lighting is possible with in procedure rooms (EKG, EEG, Stress Lab, Respiratory Treatment, TEEP, etc. rooms). These are areas that prolonged testing is being performed that involve confining patients to one room. Providing the treatment and procedure rooms along the exterior wall of the building with glazing at eye level would provide increased opportunity for access to nature through views. The support spaces for the staff should be more centrally located within the department and proper wall types should be applied to their function (full wall, glass wall, half height, and
no wall). By developing the areas with limited walls or glass walls the opportunity for staff to access the views out is greatly increased.

**Digestive Disease Center**

The digestive disease center houses areas dealing with ailments that attack the digestive system. Patients often have extended treatments and prolonged procedures in this area.

Areas such as the Endoscopy and the Cytology are procedure areas that can have access to day light and views to nature because of the types of procedures that are being performed do not require total lighting control. Procedures consist of using scopes and tubes to enter an orifice to investigate and treat possible causes of disease. This can be a very messy and long procedure, patients that endure these procedures are most often awake, and thus providing a positive distraction with views to nature can benefit the outcome of the procedure allowing the physician to practice with less discomfort to the patient.
Surgical Services

Surgical services houses the general operating rooms. This area services the majority of the surgical cases performed within the hospital. Surgical services traditionally have required a large footprint because of the size of ORs and the support space needed to perform complex sterile procedures. This area houses sterile components that require controlled environmental spaces that function in the support of each operating room and have limited circulation and access points.

Surgical areas require complete environmental control; this is provided mechanically through HVAC systems. This will not change through this project, thus the primary features that will be integrated within the surgical department is day-lighting. This will be accomplished by the integration of structural light wells through the diagnostic and treatment block housing all surgical services. These light wells will provide redirected day light into the core of the surgical platform providing greater day light access to the staff.
Lab and Pharmacy Services

The lab is programmed to test specimens from patients and provide information to the physician in order to make a proper diagnosis. The lab houses a great number of scientific equipment needing various types of controls from vented hoods to open working space. Because of this variety natural ventilation is not possible. Access to nature through views and day lighting is possible with the provision that equipment and procedures that are affected by UV light not be compromised. Pharmacy is charged with dispensing and mixing medication or IV treatments. This area contains areas that require complete environmental controls, these areas should no be provided with natural ventilation or day lighting. The work areas and offices spaces often housed within the pharmacy can have access to nature through views as well as day lighting providing that these areas are not working with or containing medications that are affected by UV light.
Staff are the predominate users of this components and they spend a significant amount of time in these traditionally interior spaces, thus their long term health and well being can be improved with the integration of day lighting and access to nature through views in these spaces. Lab and pharmacy traditionally have been housed in the lower portions of the diagnostic block because of limited patient interaction, thus moving lab and pharmacy higher up within the hospital to an area with windows and access to planted areas would greatly benefit the health and productivity of the staff.

**Administrative and Faculty Offices**

The offices within this hospital have been programmed as a consolidated space. This provides the efficiency of collocation and these functions are often located within an office suite. The offices are typically programmed with common conference space and support functions.

The lack of demanding medical equipment and practices in these spaces allow for the integration of natural ventilation, day lighting, and views to nature. These areas do
not have to be in close proximity to patient care, thus providing the possibility of locating administrative and faculty offices in a different building type or off loading these areas from the main hospital facility entirely would allow for more environmentally responsive building forms.

**Central Sterile Processing**

The central sterile processing functions as a sterilizing area for all the surgical equipment that is used within the hospital, this requires a great number of sophisticated pieces of equipment that will process and clean dirty instruments, then sterilize the equipment making it safe to use for the next procedure. This area typically houses decontamination, prep and pack, sterilizing, and sterile storage areas.

The ability to have natural ventilation is not possible because of the sterilization process that must occur within this space. The need to be connected to other support service or a transport dock typically requires the Central Sterile Processing to be in the lower portion of the building, thus limiting the amount of glazing and access to
These functional relationships make the ability to access nature possible only by exiting the building envelope. Consideration should be given to providing portions of the department with glazing on the exterior of the building and staff break areas where they can have access the outside.

**Circulation**

Circulation areas will be treated as an extension of the adjacent spaces and their requirements. Circulation areas such as staff corridors that occur in a patient unit will be treated as part of the support core allowing for greater connection of the core with the patient rooms. This treatment will be carried out by allowing for open spaces along the staff corridor to open to the support core along the interior of the unit. When the staff corridor has the opportunity to have contact with the exterior of the building should have visual access to nature through windows.

Public circulation areas should allow day lighting, natural ventilation, and access to nature. The public circulation areas have decreased requirements for privacy and
security and should be provided with greater opportunities for access and views to nature through expanded window areas and increased height spaces such as lobbies, atria and waiting areas located along the perimeter of the building footprint.

Service or back-of-the-house circulation should also be provided with day lighting and views to nature for staff. With the increased need for privacy and security dealing with patient transport and sterility, these circulation corridors should have access to nature through windows at points of egress, elevator lobbies, corridor terminations, and within patient holding areas.

**Mechanical**

Mechanical components housed within the building envelope should not be located in a manner that would limit the access to daylight or views to nature needed in other program areas. By locating major mechanical components on a central mechanical floor or within interstitial spaces, greater opportunity for connections to nature could
occur. Collocating mechanical equipment in a mechanical floor will decrease the impact of visual barriers throughout the hospital.
ARCHITECTURAL PROPOSAL

The architectural design proposal for the Medical University of South Carolina responds to and addresses the previously mentioned design strategies, site development issues, campus organization / growth identified in the campus master plan, and the functional requirements of the hospital programmatic components and organization. This proposal specifically explores ways to maximize opportunities for day lighting, natural ventilation, and access to nature within a large hospital building project.

Daylight

The strategy of maximizing day lighting is accomplished first through a perforated and articulated building form and fabric. This strategy will illustrate how a functionally proven diagnostic and treatment block borrowed from an existing hospital (Northwestern Memorial Hospital, Chicago) can be fractured providing a more articulated form that improves day lighting and views from more spaces within the building.
these functional areas than is typically provided in US hospitals. This perforated and articulated building form is also oriented with the long dimension running north-south for maximum solar access with limited solar heat gain. The second formal daylight elongated bar shaped tower oriented with the long axis running east-west. This form has a sun controlling façade on the southern exposure with deep slender room layouts limiting the amount of solar heat gain while continuing the opportunity for access for daylight. The room layout on the northern face provides longer façade access increasing views with increased glazing to provide greater opportunity for viewing nature.

**Natural Ventilation**

This proposal uses a strategy of building fabric perforations provided by structural light and ventilation wells. These structure light-ventilation elements are placed strategically throughout the building fabric in locations where public and staff circulation would be most prevalent in a variety of potential layouts. In addition to major circulation nodes, areas that will see the most critical patients or increased
detailed work would also be positioned with structural ventilation and light wells, though these would be much smaller in diameter due to the increase programmatic requirements for space. The structural light wells provide a “Swiss cheese” quality to the building fabric of the diagnostic and treatment portion of the hospital allowing day light and natural ventilation where traditionally access to these elements would not occur.

**Access to nature through views**

Accessing nature in a traditional diagnostic and treatment block is typically limited to when staff leaves or enters the building. The proposal provides opportunities for staff to access nature while working is typically limited. This proposal examines the introduction of vegetated spaces within the larger structural-ventilation-light wells, are more articulated building form and through specially designed façade treatments to mitigate solar heat gain and provide exterior retreat areas for staff to access with greater frequency. The expanded façade treatment provides a double skin with a
walkable surface between the two facades. These double skinned areas are located on the southern facades.

**Overall Design Concepts**

Additional significant areas of concern with this proposal include site-building fabric and potential for growth, building form, facade treatment, building system, and functional zoning. This proposal examines a strategy for each of the concerns that would typically be addressed by a hospital replacement project.

**Site Fabric and Growth:** The strategy applied in the proposal consisted of identifying and responding to existing and proposed critical campus and building access and movement for various forms of vehicular traffic (service, emergency, visitor, and staff) and pedestrian movement. This was achieved by continuing the contextual site fabric with similar street frequency and location. The building placement was also driven to mitigate solar heat gain, increase access to nature and allow for future grown corridors and growth directions. The growth strategy applied
to this proposal is a linear scheme that envisions continuing the future diagnostic and treatment growth to the south and repeating the nursing tower bar again to the south. The perforated and articulated building fabric of the diagnostic block allows the structural frame of additional bed towers to pass through to the ground limiting the disruption of adding a new structure above a previously existing. Utilities and support elements are carried through the supporting structural framework thus limiting the need to have supporting utilities being supplied from the diagnostic and treatment block making them independently supplied from or through ground fed utilities.

**Building Form:** The building form is based on a diagnostic and treatment block that is first fractured in the direction of the most solar access, in the case the south, then perforated with large structural light wells allowing for greater day lighting in the interior portions of the diagnostic and treatment block. The building fabric is thought of as a “Swiss cheese” building form with an elongated patient tower with a slim profile creating greater access of interior spaces to access nature through views.
The patient tower (bar) and the diagnostic and treatment block (Swiss Cheese) have independent structural systems, further reinforcing the two different building typologies as previously noted.

**Structural System:** The structural building system incorporated in this proposal consists of the diagnostic and treatment block being supported by structural light wells supporting a coffered steel floor system welded into place limiting the need for column support. Column support was only added where the distance of the interior structural light wells surpassed an assumed safe distance from the exterior skin.

The patient tower was structured using a steel system of support adapted from the structural typology of an oil rig. The main body of the patient tower is then supported by large structural footings that elevate the tower above the diagnostic and treatment block independent of its structure. The utilities of the patient tower are transferred through the inner portions of the structural footings designed as umbilical cords to the ground fed utilities.
Functional Zoning: The zoning applied was a linear scheme of filtering the public functions through a progression of the more exclusive functional zones. A band of public spaces lines the east portion of the building form, and then follows a semi public transitional space where the public must begin to gain access through a point of control. The next zone serves as a staff and patient care zone, this provides an area that begins to limit the public circulation and serves as the boundary for public traffic within the diagnostic and treatment areas. These two transitional zones function as a filtering system for the public entering the facility.

All of the zones are designed to grow in a linear fashion providing an opportunity to expand the diagnostic portion of the facility and maintain the current design strategy. Vertical circulation access is associated with the functional zone in which it is located; public circulation is housed to the east and progressively become staff accessed to the west.
URBAN PLAN

Site fabric and growth: The site located on the peninsula of Charleston South Carolina has a pre-defined street grid and general circulation orientation that is 27 degrees of east / west orientation, and the ideal orientation is 27.5 degrees of east / west. The benefit of this established grid orientation is its relationship to ideal solar orientation for limiting heat gain and coastal breezes. The current site was identified in the proposed master plan by the architects for MUSC (NBBJ and LS3P) to house the replacement hospital with potential growth, this is crucial to the development of this proposed hospital replacement and establishing a growth direction for future development and growth of the academic medical center.

The location of the replacement hospital is along the proposed MUSC greenway (Doughty Street). The site then will be integrated within a network of open / green spaces that will be integrated within the MUSC campus. The open / green spaces will be adjacent to and integrated within the building form of the replacement hospital
A vegetative roof provides the opportunity for staff and patients to access nature as well as creating an open / green space within the urban fabric.

The replacement hospital because of its integration within the MUSC campus must accommodate a systematic growth strategy. The phasing growth strategy for the next 15 years is predominantly along Courtenay Street. The linear growth pattern will translate to the overall circulation and service patterns of the phase one replacement as well as future growth, thus providing a positive growth and circulation strategy for an urban fabric that promotes the integration of nature. The future phases two through five will follow the design strategy allowing for a checkerboard of built with open / green space.
BUILDING DESIGN CONCEPT

The building design concept is based on a perforated and articulated building fabric applied to an existing and critically recognized yet functionally driven hospital plan for a comparable urban academic medical center. This plan is re-contextualized through the manipulation of the building form and orientation. The manipulated building fabric is then integrated with a structural system that facilitates limited visual disruption of views to nature, increases day light access through light wells and allows for the capability of growth and functional efficiency.

Building Form: The perforated and articulated building fabric was developed through the process of manipulating a case study urban hospital plan to optimize access to day lighting, natural ventilation, and nature. The diagnostic and treatment block of Northwestern Memorial Hospital in Chicago was chosen because, like MUSC it is an urban academic medical center with comparable programmatic components and its clarity of programmed spaces and circulation pathways.
The resulting diagnostic block was fractured on the southern portion of the building plan allowing increased solar access to traditionally interior portions of the diagnostic and treatment block. The fracturing occurred in the public, staff, and treatment areas providing equal opportunities for access to nature and day lighting. The plan was stratified by functional circulation zones, public, public/staff, and staff only. The plan was then fractured along the zone separation lines, spacing the zones and allowing for a more articulated building form. This increased the exterior skin expanding the opportunity for views to nature.

The fractured form is then perforated to allow day lighting and opportunities to access nature within the core of the diagnostic block. The entry is placed within the solar fracture.

Each perforation is sized according to the interior functions that occur adjacent to the perforations. Public areas receive the larger perforations due to the lower requirement
for climate control and visual privacy; staff areas receive the smaller diameter perforations due to climate and temperature control needs as well as patient privacy restrictions. The perforations that occur in more public areas also have a larger diameter because of the flexibility of functional need required by waiting areas and circulation spaces. The perforations that occur within a treatment area such as Phase I Recovery are approximately sixty feet in diameter and are positioned adjacent to the nurse station or semi-public areas and staff work areas.

The functional area that contains the largest concentration of diagnostic and treatment equipment such as imaging and surgery have a regimented array of perforations with a diameter of approximately twenty-five feet. The diameter of the perforations allow for the concentration of equipment to be integrated with the perforations. The 25ft diameter is large enough to place the ducting, electrical conduit, and data cables within the structured light wells, thus bringing light and mechanical needs to intensive areas. The functional requirements of the intensive diagnostic and treatment areas dictate the regulated smaller diameter perforations.
Façade Treatment: Each façade of the perforated and articulated building form is then treated individually. The northern façade consists of a curtain glazing and wall system. The western and eastern facades are divided into thirds consisting of a curtain glazing system (northern third), a double skinned glazing and perforated wall system (middle third), and a regulated perforated panel system (southern third).

The southern facade consists of automatically regulated panel system and curtain wall glazing system. This system using solar and heat sensors will activate motorized building panels that adjust their angle addressing the movement of the sun throughout the day. The southern façade is periodically interrupted by a fracturing of the building form that is clad using a curtain glazing system allowing the maximum amount of daylight to enter interior circulation spines. The regulated panels are mounted on a scaffolding system that creates a double skin along the southern facades to promote convective cooling of the thermal envelope. The scaffolding is implemented on the southern facade connecting the public, staff and treatment areas.
thus creating the ability to access the exterior of the building envelope in intense, stressful situations.
93. Façade treatments for each solar orientation
94. Self Regulated Façade throughout the day
The use of the scaffolding along the southern side of the building increases the ability to access nature and day lighting (life), while tempering the effects of solar rays to create heat gain (comfort).

The façade scaffolding is designed to extend from the exterior columns through the floor plate cantilevering a small structural system on the exterior of the building envelope. This system then is integrated with each occupied floor. The scaffolding is a fully enclosed by a perforated mesh that is articulated with temperature controlled panels to temper solar heat gain and allows access for maintenance. The scaffolding will have adequate safety features limiting the possibilities for falls to occur and will comply with the national and state building codes.
Building System: An integrated building system (building system that collocates structure and mechanical systems to increase the functional floor space and to limit vertical interruptions throughout the building form) similar to that of Mediatheque library designed by Toyo Ito was used in this thesis and employed the use of light wells that were implemented within the building form as both perforations and structural elements. Each structural light well consists of a triangulated steel tube structure that is placed according to the perforation size and location. The structure of the light well works in tandem with the structural floor plate to carry the load of the equipment and occupancy that the building requires. This partnership creates a column free floor space that increases access to daylight and opportunities for natural ventilation and views to nature where functional uses permit (public / semi-public).

The light wells located in the most intensive diagnostic and treatment areas do not allow for natural ventilation and in turn are not appropriate for vegetative growth. The integration of the cooling tower intake with the light wells in the diagnostic and treatment areas will aid in the infiltration of daylighting and continue to perform as a
cooling tower for HVAC loads to maintain environmental control needs. The structural steel tubing provides opportunity to distribute and change or maintain utilities vertically while continuing to provide access to nature. This integration of utilities, structure, and nature will ensure that these access portals do not become areas of infill as the building life cycle progresses and the hospital must grow.

Throughout the life cycle of the hospital structure the implementation of newer technologies must occur. The use of an interstitial floor system will allow newer technology to be implemented without creating visual obstructions for occupants. One interstitial floor was placed for every two occupied floors; this was to minimize the building height and maximize the ability to provide day lighting to the lower levels.
**Functional Orientation:** The functional spaces are oriented to allow the public, staff, and treatment areas to better access direct sunlight without heat gain and to allow an organized and efficient functional lay-out. The public zone is positioned on the eastern side of the building form along Courtenay Street. The placement of the public zone allows its connection to the public circulation network that exists on campus as well as the MUSC greenway. The staff/service zone bisects the building form from north to south providing possibility for linear growth along Courtenay Street. The diagnostic and treatment zone is placed along the western portion of the building form providing connection to the staff/service circulation network that exists on McClennans Bank Court. All three zones have access to direct solar rays throughout each daily cycle. The patient nursing tower that exists above the diagnostic block has access to direct sunlight along the western, southern, and eastern facades and ambient day lighting within the northern facing patient rooms.
Conclusions

This thesis has analyzed how the development of healthcare architecture was influenced by social and cultural forces and how this eventually led to the contemporary thick building form, common today in the modern hospital. The proposal presented employs Green and healthy design strategies focused on maximizing day lighting, natural ventilation, and access to nature within hospitals in order to improve therapeutic outcomes, patient and staff satisfaction, and operational effectiveness. Further study is required into the development and construction techniques needed to create structural light wells within healthcare facilities. The specific differences in the construction requirements must take into account increased structural load and increased mechanical and ventilation needed required with in a healthcare facility. Further study into day lighting and the effects of the natural antibiotic potential of UV rays. This may play a factor in diminishing the number of hospital born bacterial infections that are resistant to antibiotics. Further investigation into the effects of day light on staff efficiency and medical errors should be developed possibly showing the positive impacts of day light that we intuitively know to be true.
This thesis proposal was developed to begin the process of addressing the needs of peoples living and working within large healthcare facilities, to create and environments for healthcare that are truly healthy care giving environments. This thesis was developed to provide techniques to address, day lighting, natural ventilation, and access to nature through views within an architecture of tomorrow. These techniques can also be applied to all architecture as a whole but is primarily directed to the development of healthcare environments.

These techniques previously discussed can all be applied to the building form as presented within this thesis project, or can be applied in many different combinations. This thesis has developed strategies for healthcare architecture to become environments that provide greater day lighting, natural ventilation, and access to nature through view, thus creating an environment that heals.
103. Thesis proposal site plan
105. Entry diagram for visitors

106. View to hospital entrance ramp through campus
107. Regulated Building Façade / Southern
108. Integrated mechanical column
109. Section through public structural light well
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