Healing Environments:

Convergence of Biophilic Design and Patient Recovery

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Cover Image. Fig. 1. Healing Environments

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Image source: Landon Underwood

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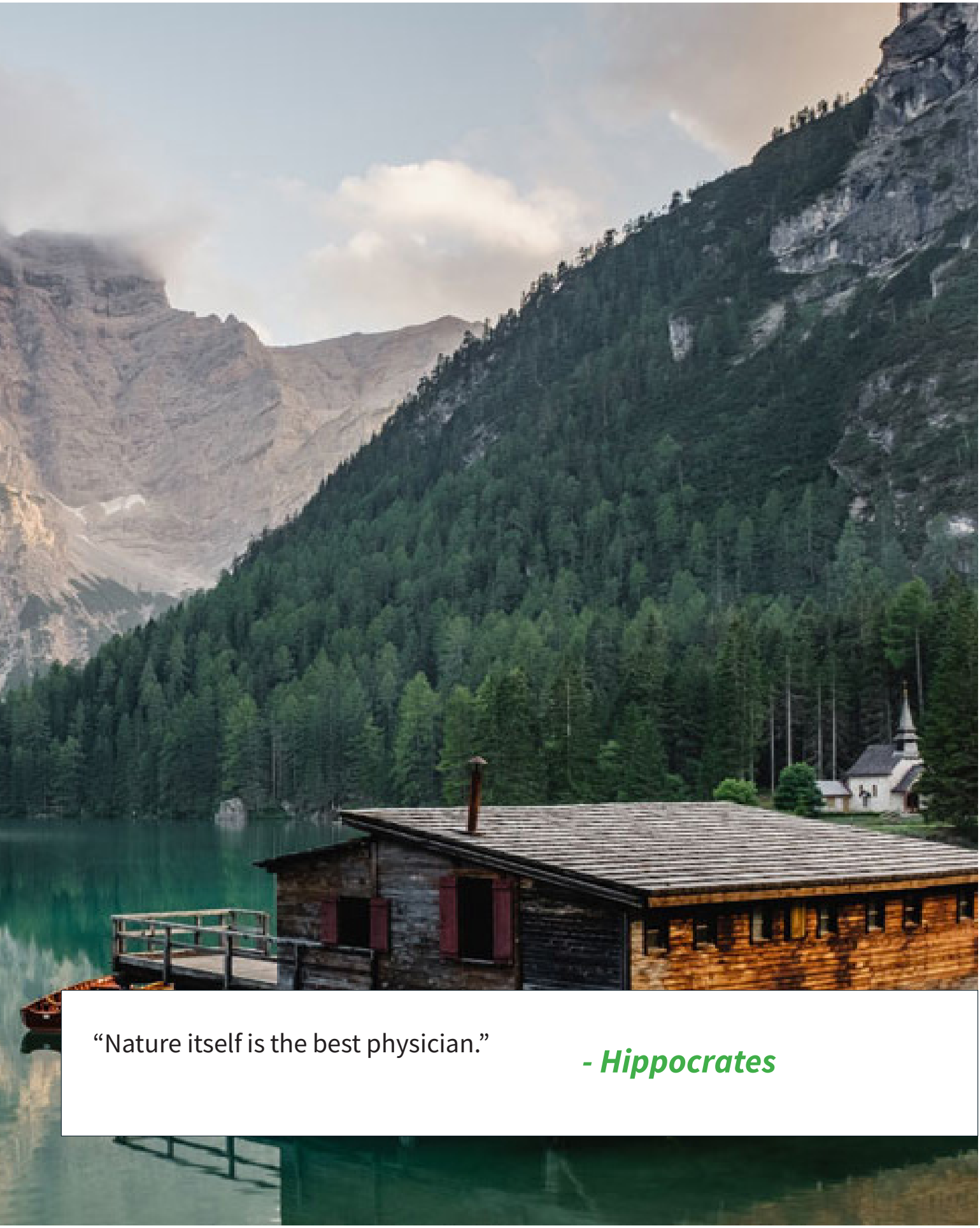
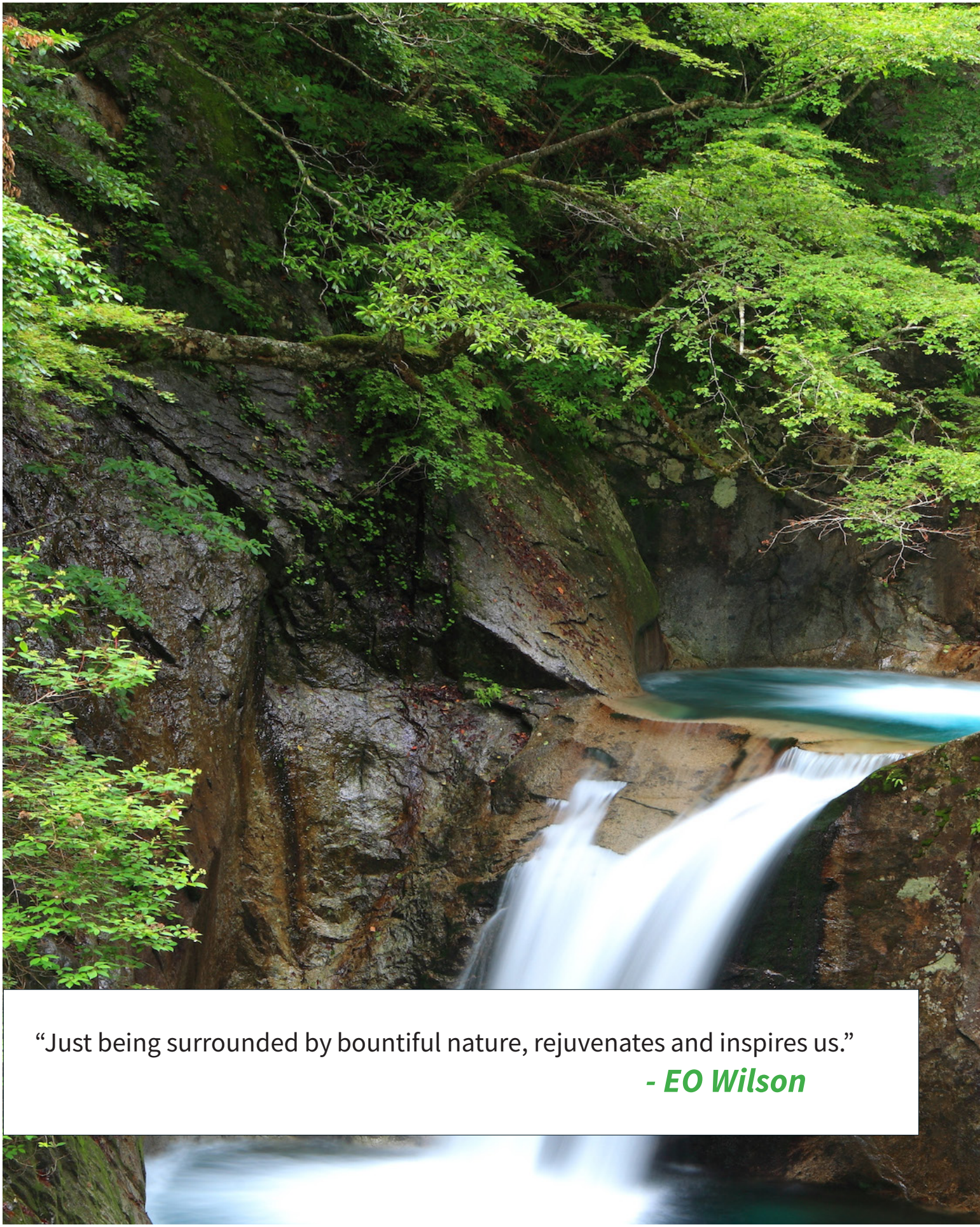
Image source: https://www.lifegate.com/app/uploads/montagna3.jpg



“Nature itself is the best physician.”

- Hippocrates



“Just being surrounded by bountiful nature, rejuvenates and inspires us.”

- EO Wilson

Fig. 3. Biophlic Design 2

Image source: https://media.mnn.com/assets/images/2018/10/forest-waterfall-nishizawa-valley-yamanashi-japan-02.jpg

Introduction

People crave nature. The connection to nature offers a people a relationship between their surroundings and their health. Over the course of the history of the human race, people used nature and the environment around us as cues for shelter, food, water, and other important needs that we have. As time has past and man has begun to take over the different realms of the world, there has been an evolution in this connection, with nature being taken away in order to develop large cities and infrastructure. But the connection to nature has never been completely diminished, as when people need to get away from the harsh realities and constant pressures of the real world, they turn to nature. When people go on vacations, travel around the world, and explore, popular destinations include beaches, lakes, woods, and other areas that act as a point of refuge - a place of healing. This desire to relocate to these locations offers great health benefits such as reducing heart rate, improving diastolic blood pressure levels, and calming the body and soul.

This connection makes it seem tough to want to go back to the built world. The reasoning behind that connection is because in places of large amounts of steel, concrete, and brick, our only connection to such environments occurs through the windows and plants located around the building. In some cases, there aren't even connections to nature available for our consumption. Instead, many of our environments have been wiped clean and sterilized, offering little benefits of maintaining or improving the health of the people that occupy those spaces. This is especially true of the places in which we need healing benefits the most - hospitals and healthcare facilities. Hospitals and other healthcare facilties are were humans can experience some of the most harmful and invasive surgeries and treatments, yet the only remedy that has been concocted to address human recovery and healing is the use of very addictive and dangerous opioids and narcotics. In order to combat this crisis, the architectural and medical professions are finally beginning to push towards a focus on creating healthier environments through the integration of biophilic design. Biophilic design offers the ability for our surrounding environments to reflect, mimic and even integrate nature back into our lifes, creating not only spaces that humans can perform well in but also spaces that offer a multitude of health benefits.

Fig. 5. Return to Nature

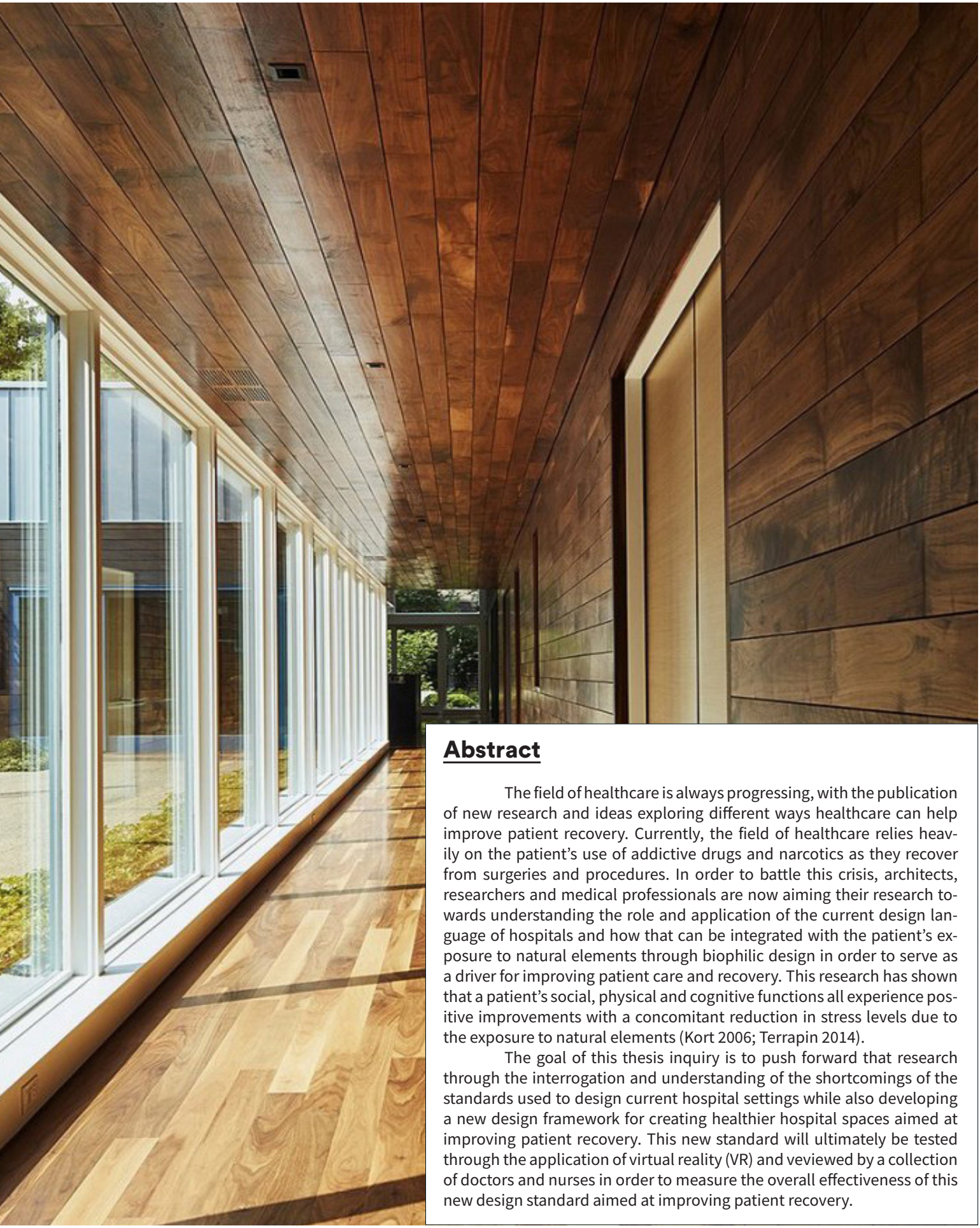
Image source: https://hoppetravel.com/wp-content/uploads/2016/11/Hawaii-Mountains.jpg

Fig. 6. Concrete Jungle

Image source: https://chrissygruninger.com/wp-content/uploads/2016/04/concrete-jungle.jpg

Fig. 4. Biophlic Design 3

Image source: https://cdnassets.hw.net/ed/d4/7034cec74ec095324a0268f307ee/marvin-apr2019-hero.jpg



Abstract

The field of healthcare is always progressing, with the publication of new research and ideas exploring different ways healthcare can help improve patient recovery. Currently, the field of healthcare relies heavily on the patient's use of addictive drugs and narcotics as they recover from surgeries and procedures. In order to battle this crisis, architects, researchers and medical professionals are now aiming their research towards understanding the role and application of the current design language of hospitals and how that can be integrated with the patient's exposure to natural elements through biophilic design in order to serve as a driver for improving patient care and recovery. This research has shown that a patient's social, physical and cognitive functions all experience positive improvements with a concomitant reduction in stress levels due to the exposure to natural elements (Kort 2006; Terrapin 2014).

The goal of this thesis inquiry is to push forward that research through the interrogation and understanding of the shortcomings of the standards used to design current hospital settings while also developing a new design framework for creating healthier hospital spaces aimed at improving patient recovery. This new standard will ultimately be tested through the application of virtual reality (VR) and veviewed by a collection of doctors and nurses in order to measure the overall effectiveness of this new design standard aimed at improving patient recovery.

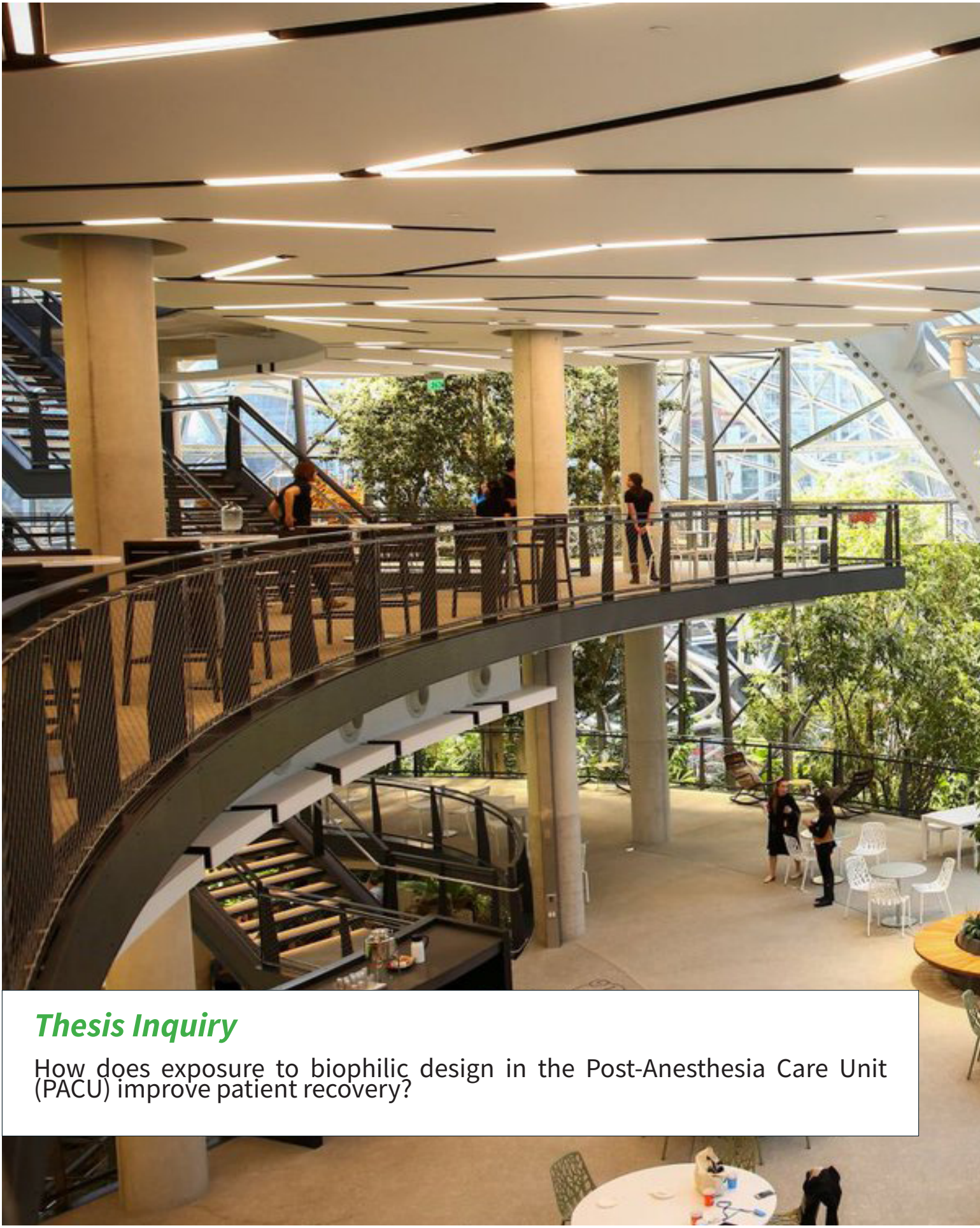


Fig. 7. Biophilic Design 4

Thesis Inquiry

How does exposure to biophilic design in the Post-Anesthesia Care Unit (PACU) improve patient recovery?

Image source: https://pbs.twimg.com/media/Dbi_2nkWsAIq5jX.jpg

Project Proposal

The proposed project of this thesis will test how a selection of the biophilic patterns can either influence or establish a new design for patient recovery spaces, such as the PACU, and how that design compares to the existing design criteria standard in healthcare facilities all across the country. The research methods uses over the course of this project includes:

1) a literature review of the three sections of the project (current hospital design language & performance, biophilic design, and the application of research and biophilia in healing spaces),

2) comparative case studies that will develop the design principles,

3) site research and documentation to select a hospital space that will serve as the location base of the project,

4) performance programming that will describe the scope of the work including goals, values, needs, programming strategy, performance metrics, and design evaluation and criteria, and

5) qualitative and quantitative research methods (such as interviews, surveys, questionnaires, observation of medical staff using Virtul Reality simulation tools) combined with data analysis methods (such as interview coding, survey quantification and graphical representation of the collected data) to measure the new design framework with the traditional design standards.

The timeline that will be followed to design recovery spaces and test those designs to current hospital settings will include:

- Take inventory of current hospital design language at Ball Memorial hospital. Use this inventory to bring into the computer a mock up of the existing conditions of the PACU at Ball Memorial or another local hospital.

- Meet with doctors, nurses, and architectural members of the healthcare industry to understand what the current existing conditions of patient recovery spaces are, how they perform where there are needed improvements, and how those can be addressed. This meeting will also allow the medical staff and architects to test the existing conditions (developed in the previous step) through Virtual Reality. The use of the virtual reality model will allow the medical staff to walk through the model and simulate the processes they follow to provide the necessary care a patient needs during the recovery process.

- Design a new patient recovery space that incoporates the design improvements of current design standards of the healthcare industry and also a combination of biophilic patterns .

- Meet with the medical staff, architectural professionals in the healthcare field and a selection of people that will serve as the “patients” to test different biophilic patterns and how they can effect the new design through the use of virtual reality software and hardware. The use of virtual reality will allow the caregiving staff to simulate how they use the space in order to measure the effectiveness of the design.

- Conduct interviews and questionnaires with the medical staff, architectural professionals in the healthcare field, and a selection of people that will serve as the “patients” to measure how they responded to the space. This will allow for an understanding of where the design is effective and where the design can be improved.

- Conduct another round of interviews and questionnaires with the medical staff, architectural professionals in the healthcare field, and a selection of people that will serve as the “patients” to measure how the second round of changes affect the performance and the perception of the space.

Image source: http://www.vedavimedical.com/wp-content/uploads/2016/05/2.jpg

Fig. 8. Medical Virtual Reality Simluation 1

Image source: https://www.devteam.space/wp-content/uploads/2019/07/VR-Simulator-For-Your-Healthcare-Business.jpg

Fig. 9. Medical Virtual Reality Simluation 2

Image source: http://55933-bcmed.s3.amazonaws.com/bcp/images/orlCMECourse/imgSource/istock-465539749.jpg

Fig. 10. Improve Patient Recovery

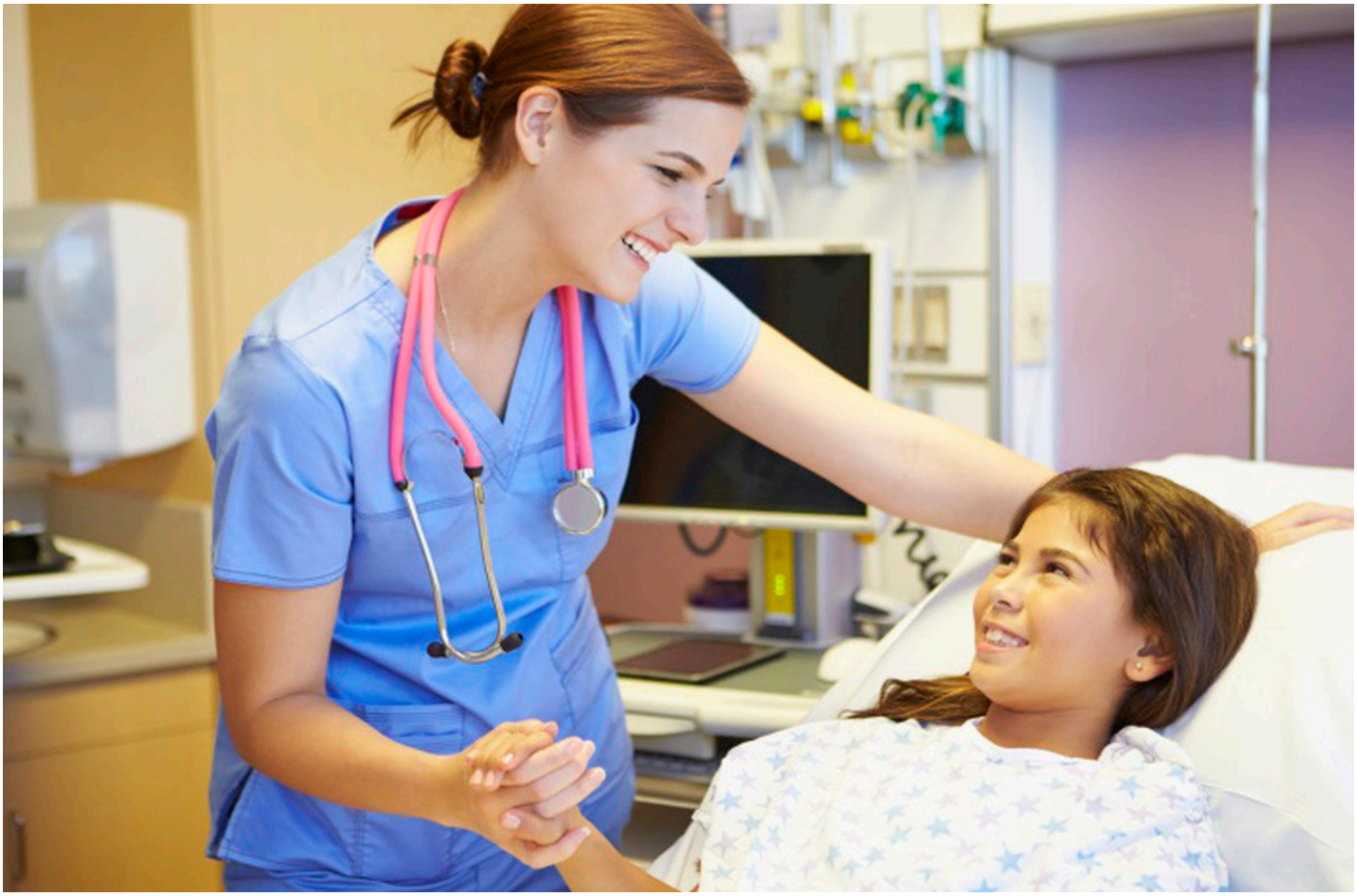


Image source: https://media.nurse.org/cache/bd/fc/bdfc3a2e49e0f7c7ca3253b33edb6a01@2x.jpg

Fig. 11. Improve Patient Care

Program Performance - Goals

The goal of this thesis inquiry is to introduce biophilic patterns into the design of patient recovery spaces and analyze how that influences and ultimately establish new design criteria, and how that compares to existing design criteria of the same spaces. In order to create a well-balanced design, this project will have two general areas with goals in each section. The first section is all about the patient and patient recovery. This section will include looking at the science and design strategies related to all things biophilia in the healthcare industry. The second section is all about the caregiving staff and the role they play in patient care. This section will look at understanding what the caregiving staff's tools, materials and processes are and how those can be improved through the integration with biophilic design principles. The goals of this project include:

1. Improve patient recovery
    i. Look at the current design methods used for the PACU and where the design is successful and fails
    ii. Research and evaluate the 14 patterns of biophilic design
    iii. Understand which biophilic patterns and design strategies would be most effective in improving patient recovery

2. Improve patient care
    i. How can the care provider's process of treating a patient be improved through better integration of tools, materials, and the tasks needed to treat the patients?
    ii. How can biophilic design improve the caregiving staff's working environment and performance levels?

Current Hospital Design Language Performance

One of the most talked about elements of the political dialogue in this country is the topic of healthcare. The field of healthcare plays a large role in the United States, not only as a system aimed to provide the necessary care to address health problems and risks but also as a business. Currently, the healthcare industry accounts of 18% of the Gross Domestic Product (GDP), which is valued at around $2.6 trillion dollars (Grunden, p 13). Because the healthcare industry accounts for such a large amount of business, there is constantly billions of dollars thrown at research and construction in order to develop the best medicine practices, equipment and treatments that can be given in some of the best performing buildings in the world. However, designs of new healthcare facilities and renovations of existing healthcare facilities continue to use hospital design language that creates waste in both the effeciency of the building but also the caregiving process, which ultimately poses a threat to the performance of both the facility and the healthcare system. In order to address this problem, there are ways that new design processes, such as LEAN led thinking, occupancy evaluations, and evidence-based design strategies can be implemented in order to reduce waste and improve patient safety, health and recovery. LEAN-led design thinking is a management philosophy based around two elements: continuous process improvement and respect for people (Grunden, p 5). LEAN is a way of continuously finding problems and addressing them in order to eliminate waste while increasing value to the patients. Within LEAN are three components – people, process and design (Grunden, p 6). People play a large role in the medical field, with patients being the recipients of the healthcare services, the frontline workers providing the service, and the hospital leadership as the drivers for the healthcare organizations. The process is the scientific method used to get things done while reducing waste in the system. Design is the process of developing a building that supports the constant transformation of processes through a building that is efficient in terms of the performance of the building's design, systems, equipment, technology and people.

Evidence-based design is a design metric that accounts for the ever-changing research of new methods and inquiries that change the practice of many professions, especially the medical field. Because this research occurs in order to support the demands of the industry that is always changing, there is a constant support to developing better designed systems and buildings that are not only functional but also positive to a patient's health. While evidence-based design is not a new design approach, until recently it has not been considered how much the design of the built environment plays a role in health and organizational outcomes (Cama, p 4). Evidence-based design is a process that can not only understand what design details are playing a role in the overall experience of a space but understanding the root of how that design detail effects the experience and how changing that detail can lead to more positive outcomes. This process leads the development of an interdisciplinary team that investigates these existing conditions in order to develop and design a new building or renovation project that can lead to improved outcomes through analyzing past design and facility performance intelligence, through supporting a proven design detail and innovating that concept, or using post-occupancy evaluation to reveal the successes or failures of such performance intelligence (Cama, p 8).

Facility evaluations are a great tool to understand the performative measures of a building's design and functionality. Because the healthcare industry is very complex, there are a few qualities of the industry that pose a different challenge for completing evaluations of the facilities: the role of evidence-based design, critical nature of information, complexity, potential impact on multiple buildings because of health systems, role relative to current political developments, number of stakeholders, and financial constraints (Shepley, p 8). Because of these constraints, these facility evaluations are a great tool to understand if design goals are addressed, lack any bias, and show how the end user is satisfied with the project. One of the most important cases for completing the facility evaluation is the business case and the return on investment of the evaluation. There are five important reasonings that support the business case of the evaluation: to support the decision process, to justify a change, to provide a record of the decision process, to evaluate decisions and to provide a framework for approving significant projects (Shepley, p 58). A rule of thumb is that a system that is included in the project cost ten times more to change while it is in development and one hundred times more once it has been released (Shepley, p 58). In order to make sure a system is developed correctly; it is very important to address it as early as possible in the design process. One of the biggest financial benefits of the return on investment is that the evaluation aims to understand the satisfaction of the patient, staff dissatisfaction, average patient stay and other performative measures that can be addressed in creating a more positive and effective work atmosphere for the caregivers and a healthier space for the patient that improves patient recovery.

Fig. 12. PACU Space Example 1

Image source: https://www.group2.ca/wp-content/uploads/2016/11/Foothills-Hospital-1350x900.jpg

Fig. 13. PACU Space Example 2

Image source: http://sites.georgetown.edu/anesthesiology/wp-content/uploads/sites/100/2019/04/recover-room.png

Program Performance - Facts about the PACU

(Retreived from UPMC <https://www.upmc.com/-/media/upmc/locations/hospitals/shadyside/services/surgical-services/post-anesthesia-care-unit/documents/pacu-brochure-upmc-shadyside.pdf >)

A. What to expect in the PACU (as a patient)

i. You will have monitors attached to you that take your vital signs every 5 to 15 minutes, unless your condition requires more attention.

ii. You may have an oxygen mask or nose prongs to

iii. help you breathe, as necessary.

iv. Your surgical site will be examined.

v. Intravenous fluids will be checked.

vi. A report will be taken by the anesthesia provider and the operating room nurse. This information is required in order to plan your care.

B. Comfort after surgery

i. It is common to experience a sore throat, aching muscles, or a feeling of being ill for up to 24 hours.

ii. You may experience shivering following surgery. Your PACU nurse will provide warmed blankets and, if necessary, a special blanket that circulates warm air. If shivering is extreme, you will be given medication.

iii. Nausea and vomiting may occur. If you have a history of motion sickness or nausea and vomiting following anesthesia, it is important to inform the anesthesiologist prior to surgery. It may be possible to give you medication before or during surgery to decrease the likelihood of this occurring. If you experience nausea or vomiting in the PACU, your nurse will administer medication through your IV line to alleviate your discomfort.

iv. Pain is common after surgery. It is important that you describe exactly how much pain you are feeling on a scale of zero to 10. Zero means no pain and 10 means the worst pain you can imagine. Based on your level of pain, we will give you pain medication to make you feel more comfortable.

C. Length of stay

i. Every patient's length of stay in the PACU is different, but on average it is usually one to three hours. This depends on factors such as type of surgery, the patient's response to surgery and anesthesia, and medical history. Most patients remember very little regarding their recovery room experience. If a patient has to stay longer than expected, family needn't worry. A longer stay may be necessary to ensure that the patient receives the best care possible and that they are comfortable before being discharged.

D. Discharge

i. Depending on their type of surgery or procedure, a patient is discharged from the PACU to an appropriate inpatient room (for an extended stay), or back to the Day of Surgery Unit (before discharge home). This decision is based on several conditions:

1. Recovery from anesthesia:

a. For general anesthesia, the patient should be awake and returned to a normal mental state.

b. For spinal anesthesia, the patient must be able to feel and move their legs the way they could before surgery.

2. Vital signs need to be stable.

3. Depending on the surgery and type of anesthesia, a patient may require medicines that help control heart rate, blood pressure, respiration, or disorders such as diabetes, which may require a longer stay in the PACU.

4. Pain should be under control and manageable.

5. If a patient is experiencing severe nausea or vomiting, a longer stay in the PACU is necessary.

6. Baseline temperature must be normal.

7. Excessive shivering and loss of body heat due to anesthesia may require a longer stay in the PACU.

ii. After all of the discharge criteria are met, a patient is discharged by their anesthesiologist to an inpatient room or to the Day of Surgery Unit (if you are going home).

E. Visiting the PACU

i. Visitors must be accompanied by a PACU staff member.

ii. Visit is limited to five minutes.

iii. Do not bring food or drink into the PACU.

iv. Do not bring cell phones or cameras into the PACU.

v. Visitors must be 14 years of age or older.

vi. Visitors must feel comfortable in a medical setting.

vii. Remain calm and supportive to the patient.

viii. Follow all directions of PACU staff.

ix. Utilize hand sanitizer at entrance to the PACU.

F. What to expect in the PACU (as a visitor)

i. The PACU is a large room where many patients recover at the same time. Bed areas are separated by curtains.

ii. The environment may be noisy, due to the large volume of patients, staff, machines, and activity.

iii. Every patient will have an intravenous catheter.

iv. Most patients will have oxygen for a period of time. They also may need to have oxygen when going to an inpatient room.

v. Each patient will be on a cardiac monitor that looks like a computer screen with many cables and wires attached to the patient. The monitor has alarms that alert the staff of any changes. Often the alarm goes off due to patient movement or interference. We will let you know if an alarm needs to be addressed.

vi. Some patients have tubes, drains, and medical equipment attached. These will be explained to you by the nurse.

vii. Patients often require x-rays immediately after surgery, or sometimes emergencies can occur in the PACU. In these instances, you may be asked to return to the Surgical Family Lounge.

viii. After having a surgical procedure and receiving anesthesia, patients may tell you they have a sore throat from a breathing tube, have nausea or discomfort, or complain of being cold. The PACU nurse is trained to address these issues.

ix. Anesthesia medications may cause changes in a patient's blood pressure, heart rate, respirations, and other levels, such as blood sugars. If you have been told your loved one is having one of these parameters treated, please understand that this is a normal occurrence in the PACU. The PACU nurse is trained to treat these occurrences as the patient recovers from anesthesia.

G. Other

i. Phone Calls into the PACU

1. Due to the busy nature of the PACU, phone calls are not allowed into the unit. If you are waiting for information on your loved one, the PACU nurse will contact the Surgical Family Lounge. You can expect a phone call from a PACU nurse within 90 minutes of your loved one's arrival in the PACU.

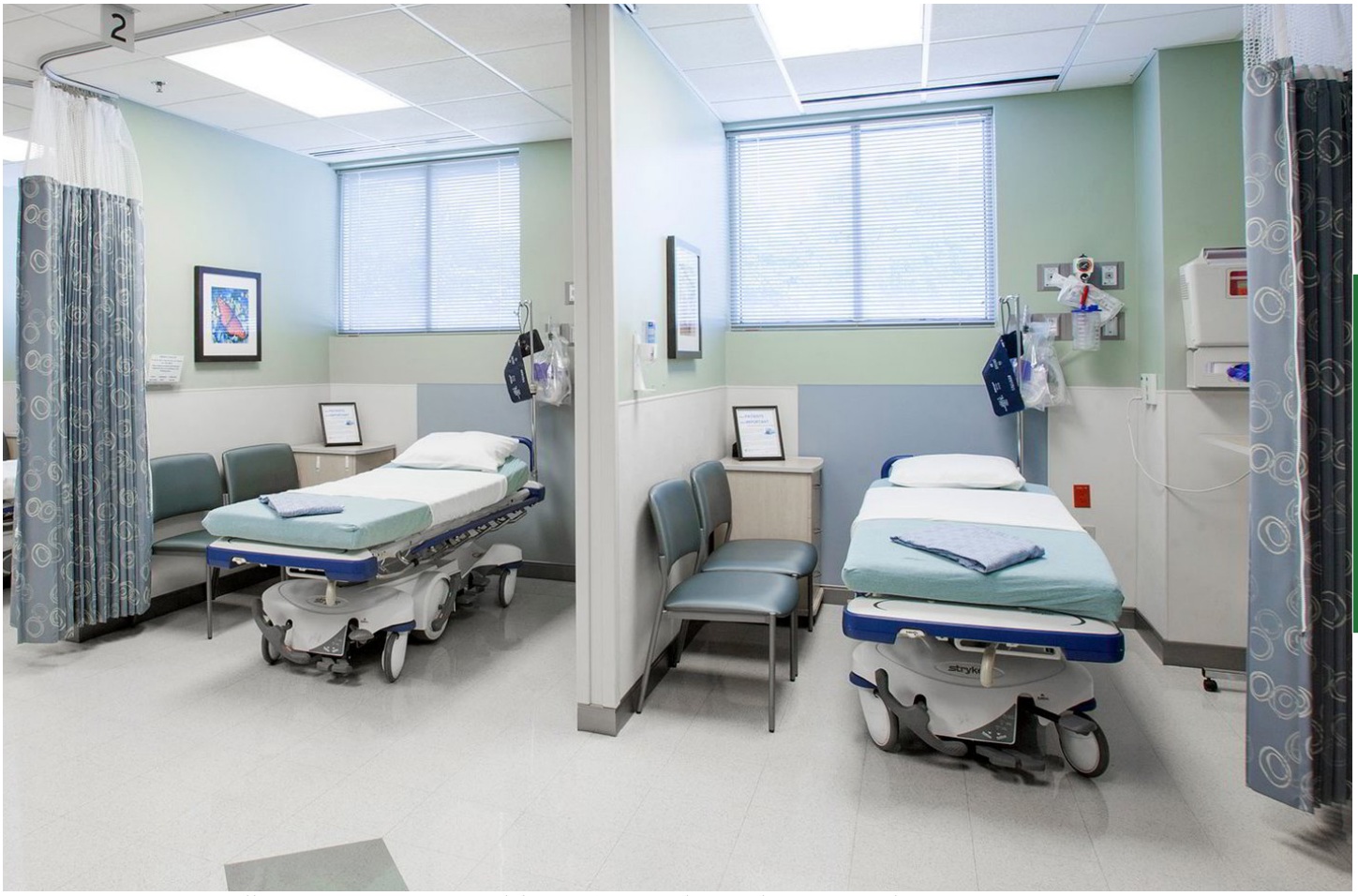


Fig. 14. PACU Space Example 3

Image source: https://content.web-repository.com/s/844222760519117l3/uploads/new-interiors/baylor-surgicare-north-garland2-3474531.jpg

Fig. 15. PACU Space Example 4

Image source: https://www.millerconstruction.com/wp-content/uploads/2019/02/8.10.5-ICU-PACU-web.jpg

Fig. 16. Ball Memorial Hospital PACU 1

Image source: https://www.thehagermangroup.com/projects/healthcare/iu-health-ball-memorial-north-tower/

Fig. 17. Ball Memorial Hospital PACU 2

Image source: https://www.thehagermangroup.com/projects/healthcare/iu-health-ball-memorial-north-tower/

Site 1

Site Name: Ball Memorial Hospital PACU

City Location: Muncie, IN

Location in the building: tbd

Healthcare Network: IU Health

Size: (at least 24 beds, tbd)

Site Features
- Headwall and all other equipment needed for each bed is located on north wall
- North wall features two colors: top half is navy, bottom half is tan
- Movable partition walls (wood material) are located on either side
- Curtain track located in ceiling toward opening on south side (no curtain is actually on the track)
- There is also a movable curtain that is located on the east side of each unit and can be moved to the south wall
- Each unit is along the north and south side of a long corridor
- This corridor has while laminate tile flooring, this acts as a wayfinding tool – showing how to travel through the space
- Each unit has a tan colored laminate tile
- Numbers are located on bulkhead above each unit to help wayfinding and management of each PACU unit/bed

Site context
- Located in (which patient tower) ((not sure, will be determined once visit is scheduled))
- Are there exterior views? (not sure, will be determined once visit is scheduled)

Site 1 Evaluation

Once the site has been visited and discussed with medical professions, this section of the page will include the evaluation of the site:

- describing the design details of the space

- the function of the space, the equipment used in the space

- the process it takes to bring a patient to and from the space

- how the patient uses the space

- the worker's experiences in the space

- where the space's design succeeds and fails

- how the space can be improved

The analysis of the site and the characteristics of the site with a team of medical professionals will allow for the assessment of the space and its history in order to begin to develop where the new design shall begin.

Site 2

Site Name: CRANE SURGERY SUITE, MERCY MEDICAL CENTER

City Location: Baltimore, MD

Location in the building: First Floor of the main building

Healthcare Network: Mercy Health

Size: 12 bed PACU with 2 isolation rooms

Site Features:

- Each unit has a “column” that serves as the headwall
- This column is located on the NW side of each unit and contains all of the necessary access points for power, CO2, O2, Vac, MedGas, workstation computer unit, etc.
- There is a sliding curtain located on each side of the unit
- The north wall is a light tan color and completely bare, except for a chair rail
- There is a cart located on the SW side of each bed
- There is a green LED sign that allows for wayfinding to each unit, this sign is also numbered
- The floor of the unit uses white laminate tile to denote how to get from one door to another, the nurses station has green laminate tile flooring, and the PACU units have a medium stain wood laminate tile.
- There is no direct light in each space or in the unit as a whole, but instead there is only access to diffused light

Site context:

- Located on the first floor of the main tower.
- Two towers are located on the site
- Located in downtown Baltimore, MD

Site 2 Evaluation

Because of how far away this project site is located, the medical staff of the Crane Surgery Suite will be contacted electronically to help discuss and submit information related to the same evaluation points used for the Site 1 Evaluation. These points include:

- describing the design details of the space

- the function of the space, the equipment used in the space

- the process it takes to bring a patient to and from the space

- how the patient uses the space

- the worker’s experiences in the space

- where the space’s design succeeds and fails

- how the space can be improved

The analysis of the site and the characteristics of the site with a team of medical professionals will allow for the assessment of the space and its history in order to begin to develop where the new design shall begin.

Fig. 18. Crane Surgery Suite PACU

Image source: https://www.hcm2.com/wp-content/uploads/2018/02/Mercy_Bunting_Surgery_PACU-1.jpg

Fig. 19. Biophilic Design Interior Application 1

Image source: https://elemental.green/wp-content/uploads/2017/05/Depositphotos_38061623_m-2015-1000x640.jpg

Fig. 20. Biophilic Design Interior Application 2

Image source: https://www.culturesouthwest.org.uk/wp-content/uploads/2018/07/cfb16238-013f-11e8-97df-295a7fd15d8d-1560x1272-760x510.jpg

Biophilic Design

Research has shown that the built environment plays a significant role in the performance of our health. This is a very important concept that needs to be addressed, especially in the field of healthcare. Because exposure to nature has a profound effect on the performance of a human's brain and body, there is a large amount of research that centered around biophilia – humankind's innate biological connection with nature (Terrapin Bright Green). Biophilic design is based around ways that architects and designers can create spaces that articulate the restorative, healing relationship between nature, satisfaction of a space, and the built environment. In order to address these relationships, Terrapin Bright Green has developed the 14 Patterns of Biophilic Design. These principles describe the different ways designers and architects can create a space that articulates healing and well-being through connection to nature. For example, the research of Terrapin Bright Green looks at the stress, visual acuity, hormone balance, creativity amongst other health measurables and found that architectural applications of biophilic design principles can reduce stress, improve cognitive function and creativity, improve our well-being and expedite healing; as the world population continues to urbanize, these qualities are ever more important (Terrapin Bright Green). A study conducted research of five different varying settings played a role in a patient's vitality levels. This research found that the patient's vitality levels increased as they were exposed to higher levels of nature (Ryan). This is very important to note because a patient's exposure to more and more levels of nature as they recover from a highly intensive surgery can lead to better recovery times. When natural elements are not readily available, there are also ways that look at how the simulation of nature through a screen affects performance in patient recovery. A study looked at how the manipulation of screen size of natural scenes can lead to different levels of performance of a patient's heart rate, skin conductance levels, etc. (Kort). When there is no opportunity for direct exposure to natural elements in the space from views of the exterior, there can be initial exposure to natural scenes through the implementation of nature via large screen sizes. Another study looked at how the exposure of biophilic designed space in virtual reality effects their body and mind. This study found that participants reported decreased negative emotions and an increase in positive emotions while also measuring blood pressure, galvanic skin response and heart rate. Those numbers were then compared to the same measuring points of participants that were exposed to a physical space of the same design quality (Yin). This can be very helpful in creating a space that can address the emotional levels, heart rate and blood pressure spikes that a patient might have pre- and post-operation.

Case Study 1

Khoo Teck Puat Hospital

Description

- Singapore
- Built in 2009
- 550 Bed Hospital
- 3.5 Hectare site

Project Goals

- Patients access to natural light, cooling breezes, and views without risk of solar glare or rain entry.
- Designed to be 'forest-like', it includes water features with aquatic species and plants that attract birds and butterflies.
- Greenery cascades to upper levels of the buildings and down into an open-to-sky basement
- Upper levels balconies that bring the experience to the patient's bedside

Performance

- 4x as much greenery as there is land
- 50% lower energy bills
- 400% increase in community engagement
- Evaluation (between hospital built in 1985 to KTPH)
- The presence of water and greenery led to higher awareness of nature, user well-being (stress levels, calm),
- 80% surveyed said they would pay higher costs for the older hospital to be designed like KTPH
- 15% of visitors come for social and recreational reasons
- 58% of visitors are from the local neighborhoods

Case Study 1

When it comes to biophilic design applications in the healthcare setting, Khoo Teck Puat Hospital is the standard for developing an elegant and effective combination of biophilia into a project. The reason this project was selected as a case study is due to the scale of the project. The size and scale of this hospital is just enormous, with the total scope of the hospital including 550 peds, whereas a typical PACU space includes 15-30 beds. Because this project addresses biophilia on such a large scale, this will be integral in the success of the thesis because the analysis of Khoo Teck Puat can understand how biophilia can be applied to a multitude of different spaces located in many different unique parts of a hospital. The analysis of the design of the hospital, the project goals and how the building performs will also be a great tool in designing and analyzing the performance of the thesis.

Fig. 21. Khoo Teck Puat Hospital Courtyard Aerial View

Image source: https://cdnassets.hw.net/dims4/GG/be72414/2147483647/resize/850x%3E/quality/90/?url=https%3A%2F%2Fcdnassets.

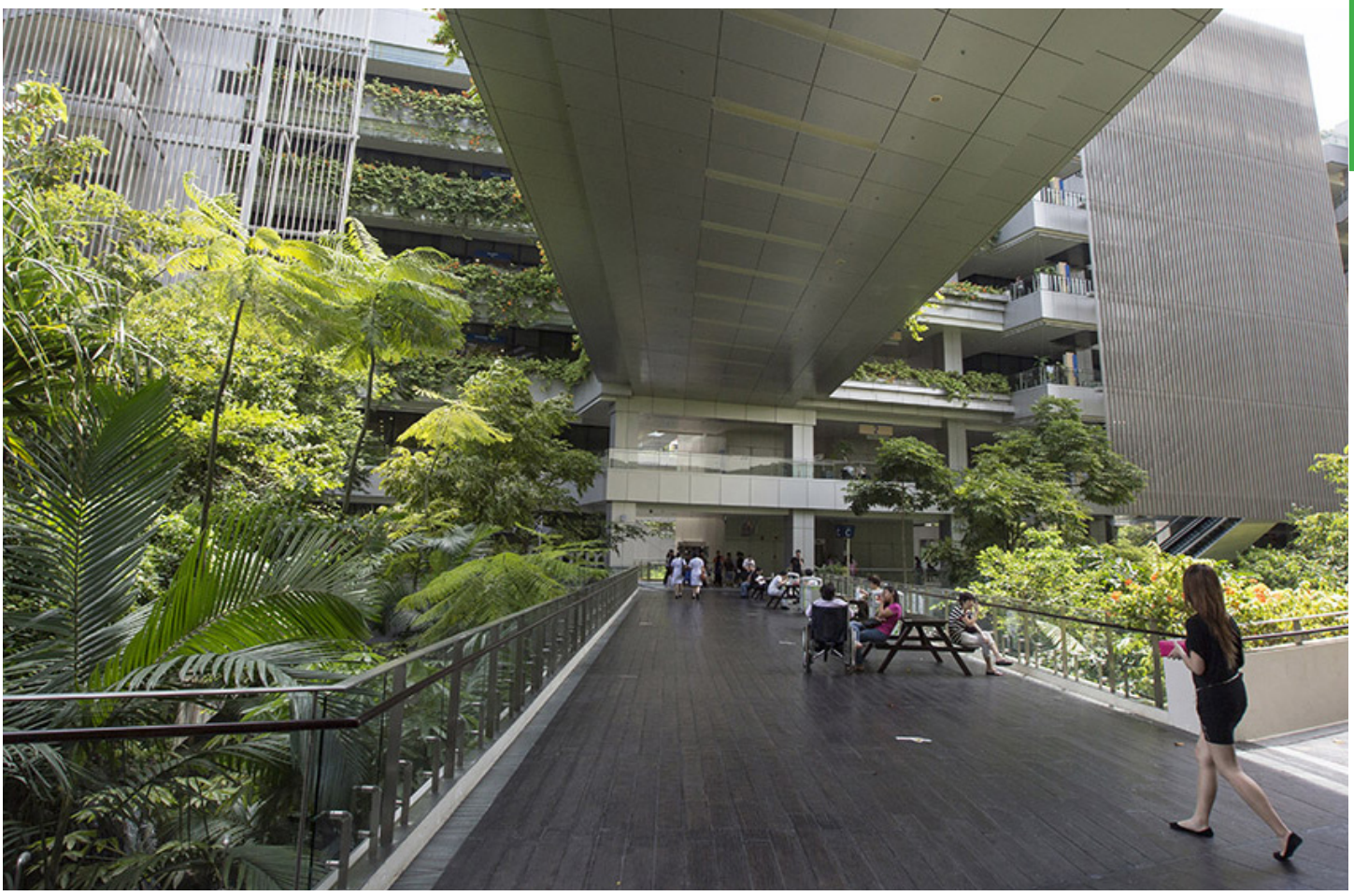


Fig. 22. Khoo Teck Puat Hospital Courtyard Walkway

Image source: https://living-future.org/biophilic/case-studies/award-winner-khoo-teck-puat-hospital/

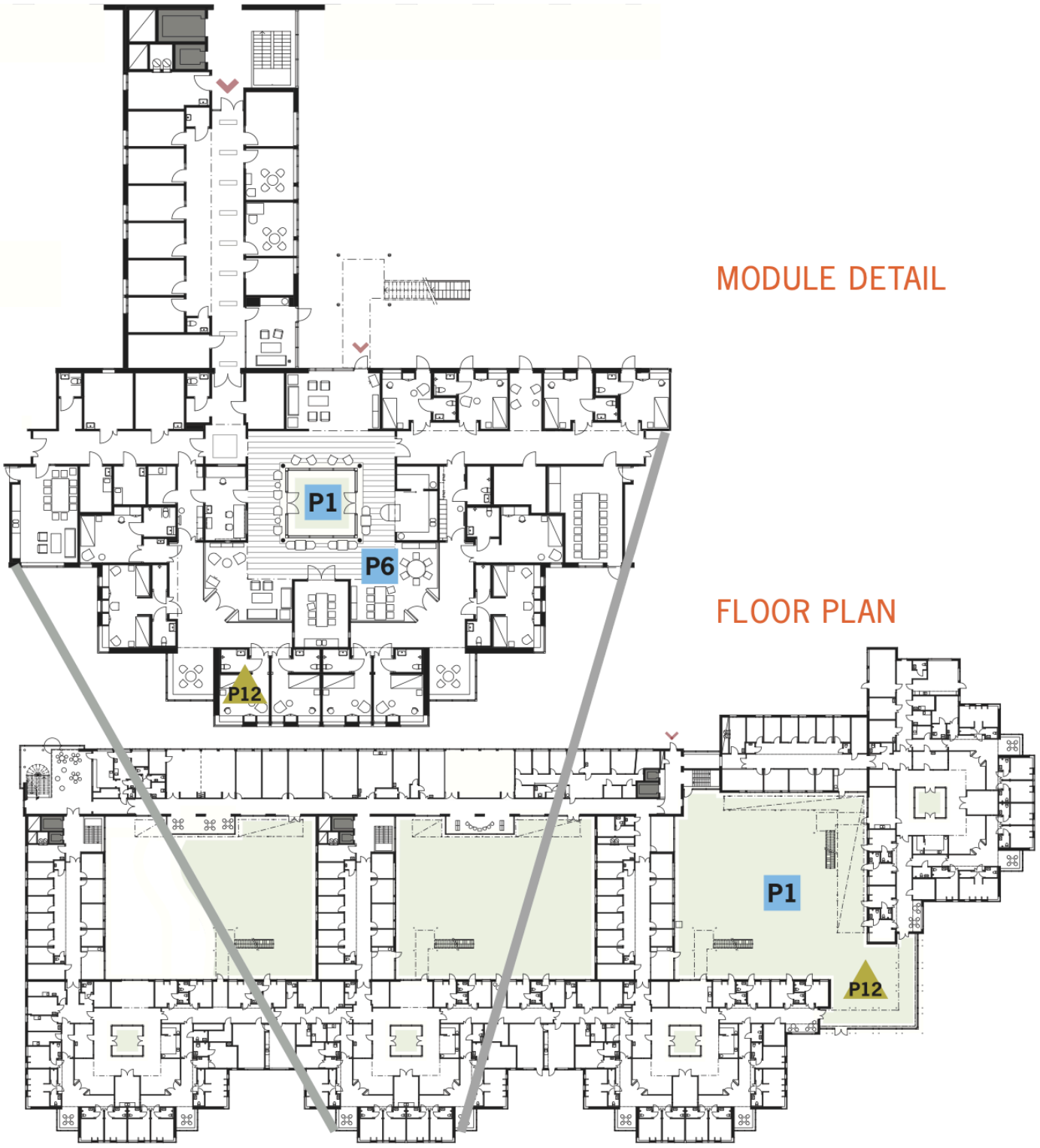


Fig. 23. Östra Hospital Floor Plan & Module Deisgn

Image source: https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Ostra-Psychiatry-Case-Study.pdf

Case Study 2

Östra Hospital

Description

- Göteborg, Sweden
- Psychiatric Medical Facility
- 193,750 SF
- Completed in 2006

Project Goals:

- Carefully consider patient experience throughout the entire building, from the building entrance, treatment rooms, amenities, and visitor experience
- Act as a healing environment through support of nature while meeting the unique safety and security needs of a psychiatric facility

Performance
- Patient stay is typically 19 days
- Design allows for patient to have ownership over their environments

Evaluation

- Reduction in the number of compulsory medications and restraints of patients
- Design of environment has led to calmer patients and fewer outbursts of aggression
- Reduction in staff becoming sick

Health Benefits
- Visual Connection with Nature. Lowered blood pressure and heart rate; improved mental engagement/attentiveness; positively impacted attitude and overall happiness.
- Dynamic and Diffuse Light. Positively impacted circadian system functioning; increased visual comfort.
- Complexity & Order. Positively impacted perceptual and physiological stress responses; observed view preference.
- Refuge. Improved concentration attention and perception of safety.

Case Study 2

Östra Hospital was selected as the next case study of the project due to the fact that this project includes different modules and discusses how those modules incorporate central courtyard spaces. This is important because typcial PACU and patient recovery spaces in a hospital operate at a unit, so the ability to understand how those modules operate before and after the integration of biophilic design will be effective in developing a new PACU/patient recovery spaces. Another reason this project was included as a case study is that it was recommeded by the team at Terrapin Bright Green. This project will also be important in understanding how Terrapin Bright Green evaluates biophilic design and its application to Östra Hospital and also how biophilic design applications have health benefits, such as calming patients.

Case Study 3

Kickstarter Commercial Headquarters

Description

- Brooklyn, New York
- 29,000 SF
- Class A Commercial Office Space
- Completed in 2014

Project Goals

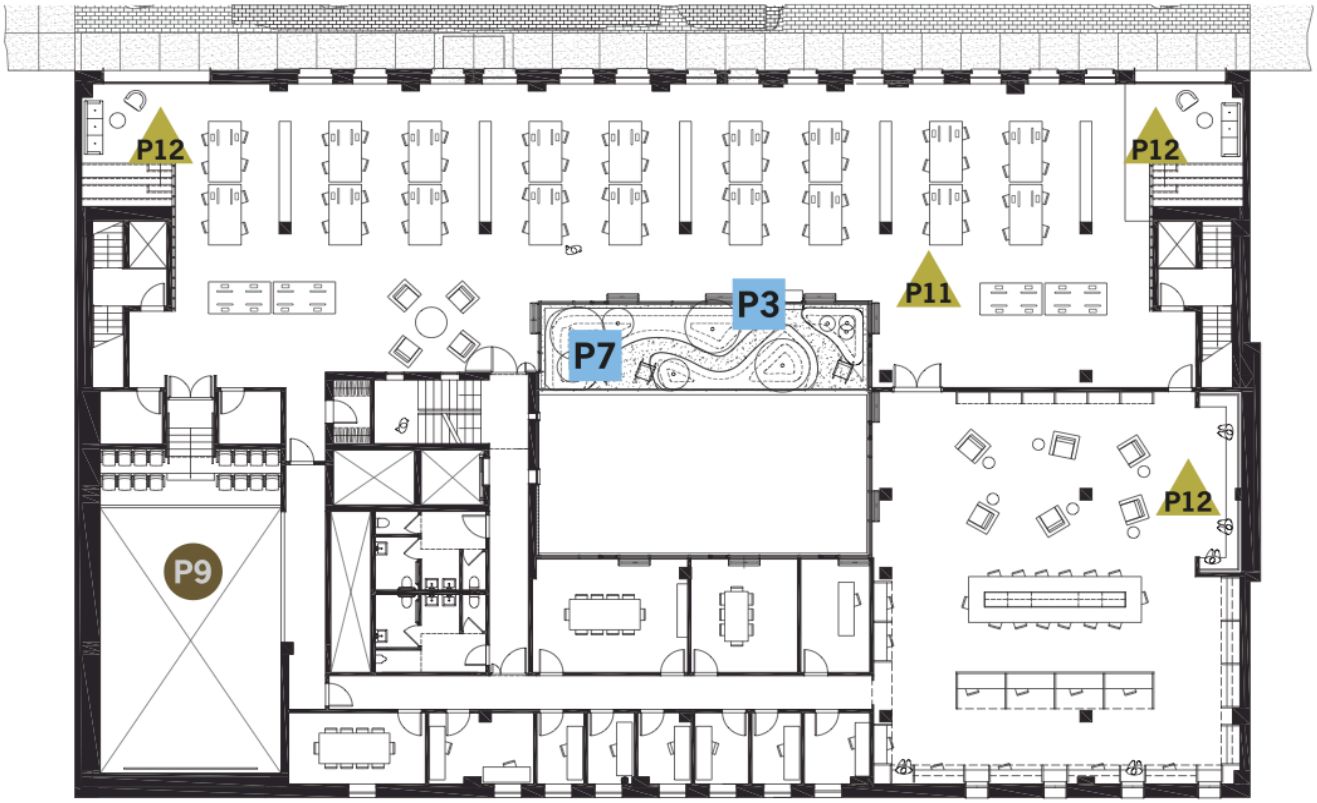
- Former pencil factory that had poor daylighting and fresh air qualities
- Use a renaissance palazzo to create interior relief to connect the user to the outside
- Create a dramatic, contextual office with daylight, natural materials and textures, and outdoor garden views
- Office space that is engaging, promotes creativity, productivity and well-being

Health Benefits

- Non-rhythmic sensory stimuli - Positive impact on heart rate, systolic blood pressure, and sympathetic nervous system activity; observed and quantified behavioral measures of attention and exploration.
- Connection w/ natural systems - Enhanced positive health response; shifted perception of environment.
- Material connection w/ nature - improved creative performance and improved comfort.
- Prospect - Reduced stress, boredom, irritation, and fatigue; improved comfort and perceived safety.
- Refuge - Improved concentration attention and perception of safety.

Case Study 3

The reason this project was selected as a case study is due to the combination of biophilic design and a traditional work/office space. This will be important in understanding how biophilic design principles can affect the space people work in and what those health benefits are. This will be important because while the project goals are aimed at improving patient recovery, they are also aimed at improving patient care. In order to improve patient care, this means creating a work space that provides health and performance benefits to the medical staff that is in charge of the caregiving process to the patients. The ability to include both the patient and caregiving staff in the design will ultimately create a more wholistic and better performing space.



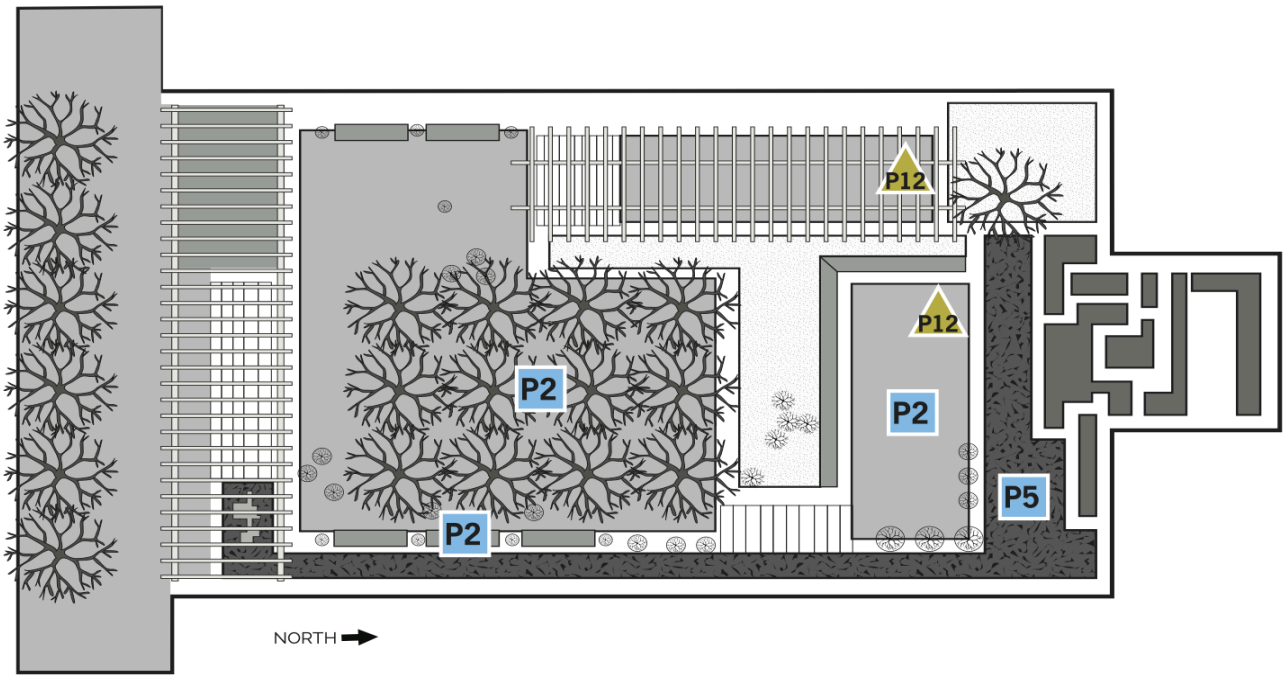
:COND FLOOR PLAN

Image source: https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Kickstarter-Spring-16F.pdf

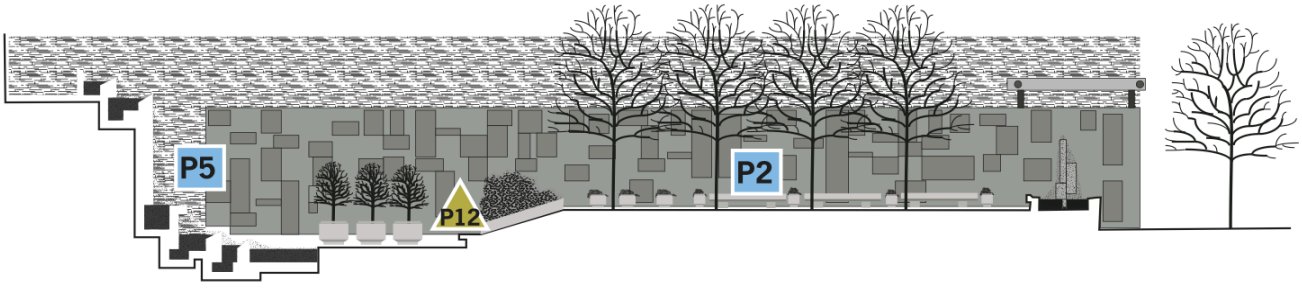
Fig. 24. Kickstarter Headquarters Second Floor Plan

Fig. 25. Kickstarter Headquarters Courtyard View

Image source: https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Kickstarter-Spring-16F.pdf



SITE PLAN



SECTION

Fig. 26. Greenacre Park Site Plan & Section Detail

Image source: https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Greenacre-Park-Fall16.pdf

Case Study 4

Greenacre Park

Description

- New York, New York
- Publicly accessible private park
- 6,000 SF
- Completed in 1971

Project Goals

- Small-scale biophilic intervention
- Serve as refuge in an overstimulating urban environment
- Use three distinct levels to provide users several choices of environmental conditions

Design

- Ivy covered west wall, relief sculpture east wall, and a northern wall with ivy and a waterfall
- Visual complexity creates an immersive environment

Evaluation

- Common complaint is that the park is overcrowded due to the high demand for the park
- Improved air quality
- Reduction in urban heat island effect
- Strong social benefits and accessibility

Health benefits

- Non-visual Connection with Nature - Reduced systolic blood pressure and stress hormones; Positively impacted cognitive performance; Perceived improvements in mental health and tranquility.
- Presence of Water - Reduced stress, increased feelings of tranquility, lower heart rate, and blood pressure; Improved concentration and memory restoration; Enhanced perception and psychological responsiveness; Observed preferences and positive emotional responses.
- Refuge - Improved concentration, attention, and perception of safety.
- Mystery - Induced strong pleasure response.

Case Study 4

The reason this project was selected as a case study for the project is due to the project being a garden and park. One of the more popular applications of biophilc design in a hospital setting is the use of a healing garden. Because of the case study's site is located in New York, New York, this case study will be a great way in understanding how people respond to biophilc design in an overstimulating environment. Taking key design elements and strategies from this project and understanding their health benefits will act as a great tool in not only the design of a potential healing garden or courtyard used in the project's design but also how to address biophilic materials that can be used in the space.

Application of Research and Biophilia in Healing Spaces

In order to understand how the thesis inquiry can be addressed, it is important to understand how biophilia research and biophilic design principles are being applied to healing spaces in the healthcare industry. For example, one study looked at how the number of elements in different hospital rooms contributed to the perceived control, social support and positive distraction of a patient and how that played a role in the stress levels the patient experienced in each space (Andrade). Another study looked at understanding how the end existing condition of a healing garden space at the Lady Cilento Children's Hospital in Brisbane, Australia, plays a role in the healing process of the patient's and their families. This study collected user feedback and devised different categories and functions of the gardens in order to measure the success of the space (Reeve). They look at the reasons for which the garden was used, the perceived benefits of the space, and different features and aspects that they most appreciated. Reeve concluded that the reasons that the gardens were enjoyed were because of the emotional respite to the visitors, appreciation of the views, the ability to have time away from the hospital setting, being in natural environments, restorative experiences in the garden setting and access to fresh outdoor air. Gardens can play a key role in allowing the patients to only get away from being in their recovery room, but to also physically interact with nature rather than have views from their windows. Another study addressed global health challenges of the 21st century and understand how a new approach of creating humanized healthcare spaces (Totaforti). The study looks at the history of what biophilic design is and understanding the foundation it sets on creating healthier spaces. It then looks at the abilities of surgical patients to recover when exposed to biophilic designed spaces and how that can drive creating a new, more humanized hospital that is focused on creating healthier and better performing spaces for the patient. Understanding the psychology of different elements of biophilic design can play a role in measuring the performance of current hospital spaces and how the implementation of the 14 Patterns of Biophilic Design can lead to a better performing design language. A study by Locklear entitled *"Guidelines and Considerations for Biophilic Interios Design in Healthcare Environments"* looked at how different design considerations and guidelines can create sensory-rich and physically accommodating spaces in a hospital setting while creating a space that offers healing and restorative benefits related to the cognitive, physical and social functions of a patient (Locklear). This study not only looks at the exterior functionality of a human-environmental response to exterior applications of biophilic design in a hospital, but also the interior applications driven from research based around environmental psychology. Understanding interior applications with direct access to exterior elements of nature is very important in providing biophilic design to all patients, especially those who might be early in the recovery process and can't leave their recovery unit.

The built environment is fundamental in shaping our health and well-being; it is important to design hospital facilities in a way that can improve patient recovery. Because the medical industry is going through a constant process of conducting research and testing aimed to improve a patient's experience, the ability to create a new design typology aimed towards the better healing and well-being of patients can lead to less reliance on the use of addictive drugs and narcotics and higher patient satisfaction with the healthcare system. Biophilic design has shown that direct and indirect exposure to natural elements and scenes plays a direct role in our stress levels, blood pressure, heart rate, vitality levels and many other important physical and emotional attributes that contribute to social, physical and cognitive functions of our bodies. Because of this, architects and designers have the ability and the responsibility to not only create more positive and higher-performing buildings and spaces, but also create a healthier more sustainable future.

Fig. 27. Khoo Teck Puat Hospital Perspective View

Image source: https://www.3blmedia.com/sites/www.3blmedia.com/files/images/KhooTeckPuatHospital.jpg

Fig. 28. Hospital REcovery Room w/ Exterior Garden View

Image source: https://www.carolehyder.com/is-a-hospital-room-with-a-view-enough-of-a-connection-to-nature/

Values

The values of this project are integral in maintaining the integrity of both the project and also the profession. These values shall be followed at all times and meet or exceed the standards and level of detail used in both the profession of architecture and also healthcare. Following these values will also create a design that is highly functional, effective at meeting the goals of the project and also reinforce that the patient is the central focus of the project.

1. Design a space that keeps the patient's care, comfort and safety as the top priority

2. Provide a connection to nature through the integration of materials, views, and a number of the 14 patterns of biophilic design

3. Maintain privacy for the patient

4. Allow for the patients to have control over their environment

5. Create a positive, effective and efficient work environment for the caregiving staff

Needs

In order to create a project that is effective in following both the goals of the project and the values behind the project, it is important to create a concept map. This concept map will lead to the development of the different areas of the project and the needs that come from each section. The structure of the concept map found in Fig. 24. shows that healing spaces, services, patients, and the architectural requirements will be the main points focused on in this project. Healing spaces will focus the role Biophilic Design Principles will play on the project. Services will discuss the role the medical staff and their equipment will play in shaping the projects form due to the nature of their roles they play in the recovery process. The Architectural Requirements will be important in addressing the building codes, programs of hospitals, and the rules & regulations of different laws and agencies in the healthcare industry. Finally, the patient will be the fourth section, with the focus of how the psychological and physiological experiences a patient might have during the recovery process need to be addressed. From this concept map the following needs of the project will be addressed:

1. Healing Spaces
    - Provide the patient with multiple connections to nature
2. Services
    - Maintain a high standard of patient care & safety
3. Architectural Requirements
    - Integrate biophilic design principles in a way that meets building code and medical standards
4. Patients
    - Improve patient recovery by designing a space that allows for the use of less opioids and other harmful narcotics

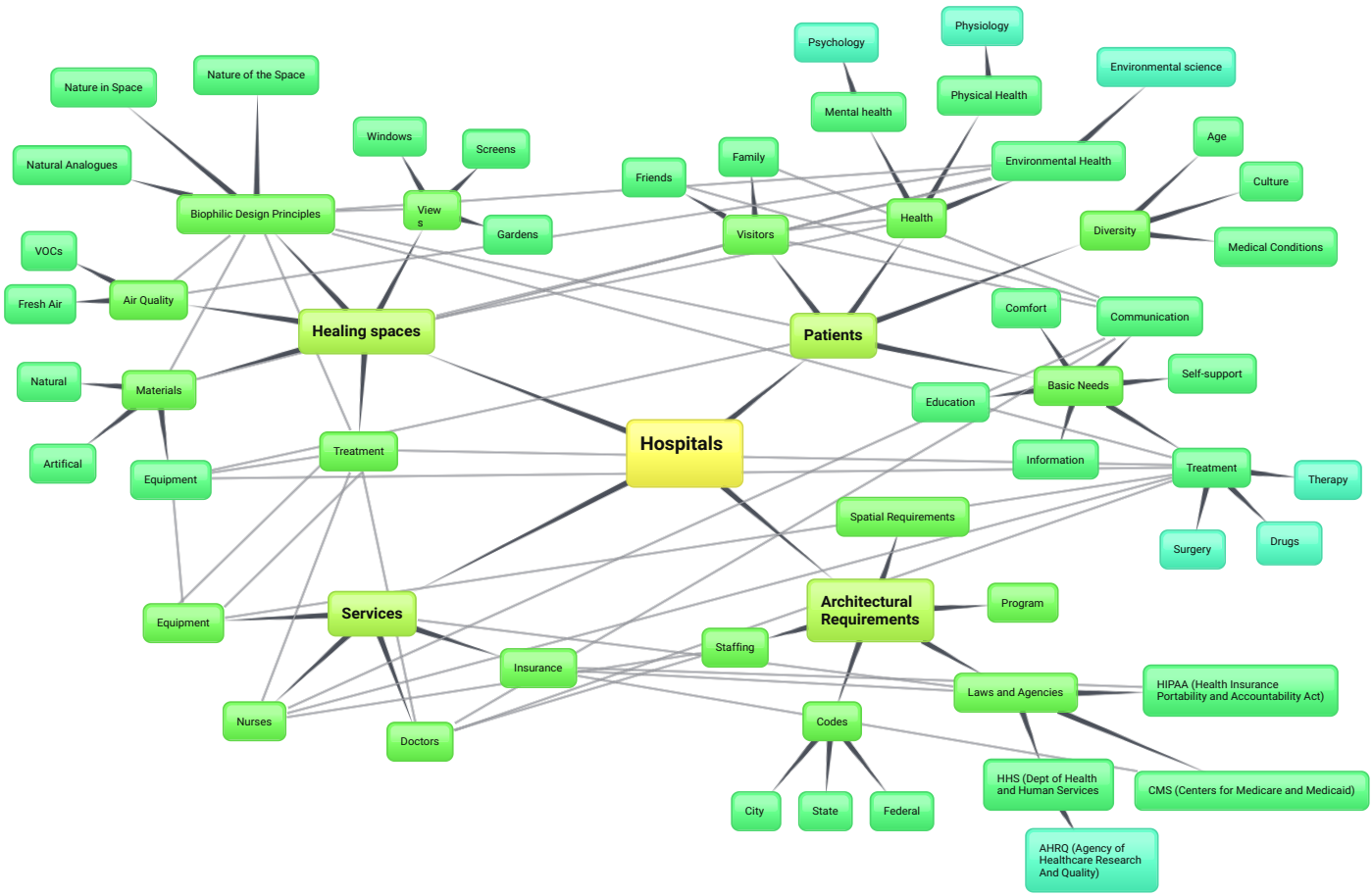


Fig. 29. Concept Map

Image source: Landon Underwood

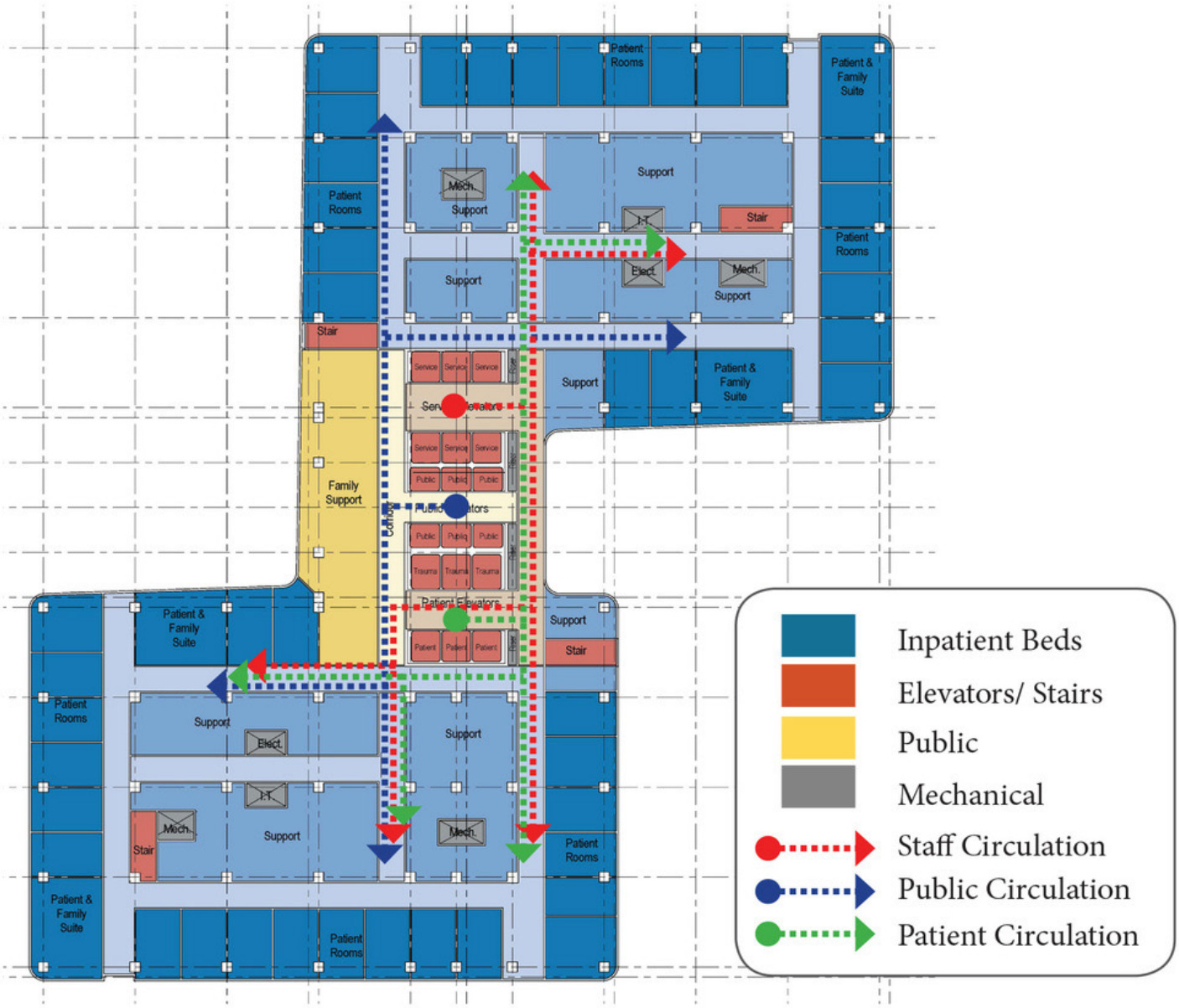


Fig. 30. Hospital Programming Design Strategy

Image source: https://www.kmdarchitects.com/design-efficiency-in-healthcare

Programming Strategy

In order to begin to redesign the PACU and other areas of the hospital used for patient recovery, it is important to understand the nature of the space - meaning the characteristics of the design and the performantive measures that occur in the space. This knowledge can come from beginning to ask the following questions:

a. Understand patient flows/ how a patient travels through a hospital

i. What are the steps a patient follows in order to pass through the PACU?

1. From entering the site, entering the building, filling out paperwork, pre- and -post surgery, the PACU, post-operation recovery, and through leaving the hospital

b. Understand the surgery process and the needs of the patient

i. What is the necessary items, equipment and spacing needs and requirements for all of these items?

c. Understand where the PACU needs to be located in the hospital

i. Does it have to be located in the center of the building?

ii. Are there multiple PACU units in a hospital?

d. What is the typical sizing of a PACU

i. Can there be multiple PACU units in a hospital?

ii. How many beds are typically used?

iii. What is the typical amount of nursing staff, equipment, etc. needed for the space

e. What role does OSHA and other medical governing bodies and jurisdiction play in the design and planning of a hospital and a hospital space, such as the PACU?

Performance Metrics

In order to understand how the new design of the patient recovery space compares to the design of current medical facilities, there will be a set of performative metrics used. These metrics will be used throughout the complete timeline of the project in order to ensure that the testing of the project is both thorough and consistent. The performance metrics that have been developed to measure the designs of the patient recovery spaces include:

a. Compare the effectiveness of the design to the previous design through

i. The amount of time a patient spent in the PACU

ii. Patient turnover

iii. Performance of a patient's vitals including blood pressure, heart rate, etc.

iv. The amount of medication, drugs, opioids, etc. needed for pain control

v. The amount of time staff spends attending to the patient

vi. Staff performance levels, including:

1. response to the environment
2. number of sick days
3. mistakes made

Image source: https://www.sdglobaltech.com/blog/the-role-of-business-analytics-in-improving-your-hospital-performance

Fig. 31. Hospital Performance Metrics

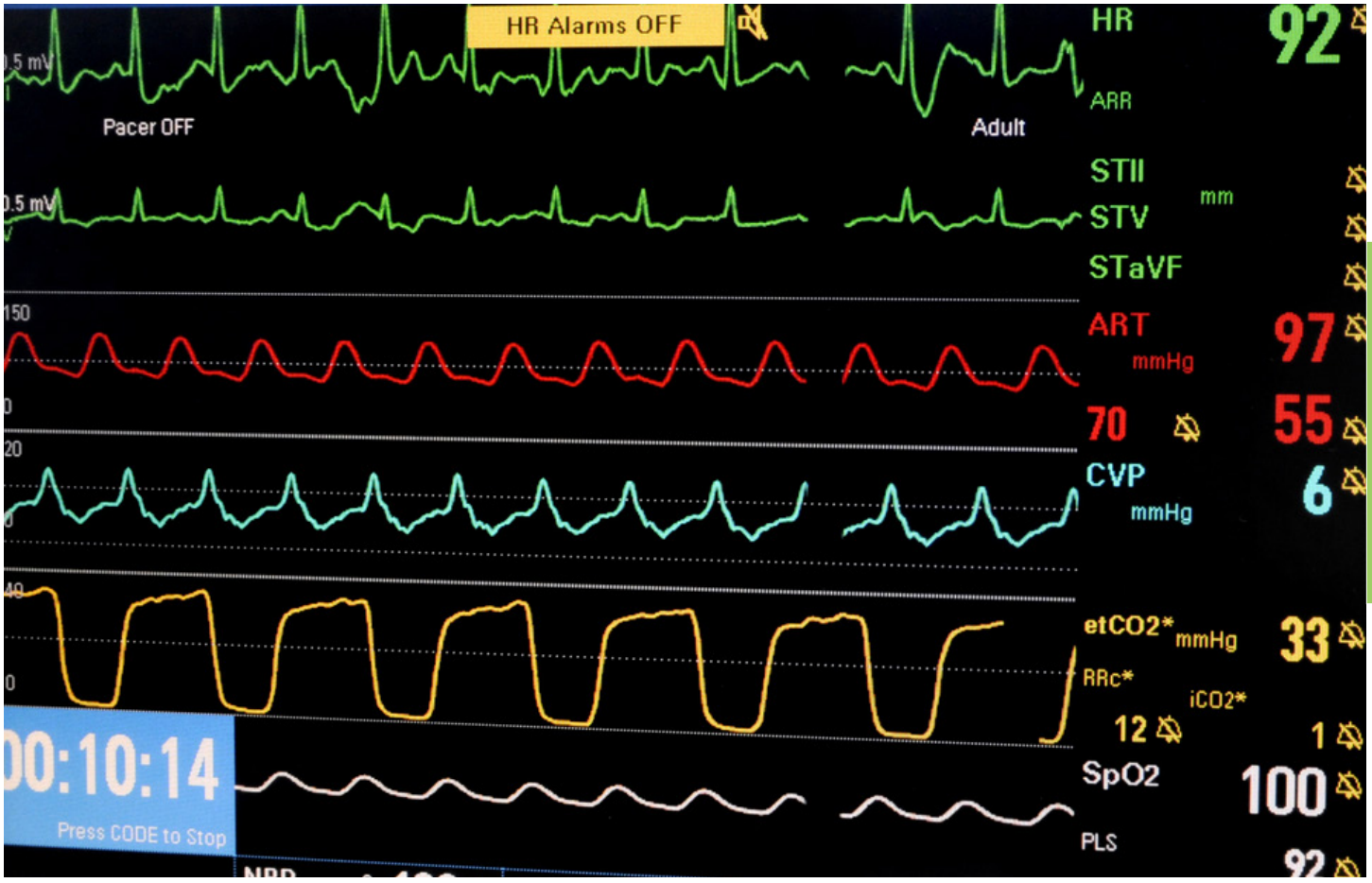


Image source: https://www.israel21c.org/wp-content/uploads/2017/06/shutterstock_210626443.jpg

Fig. 32. Hospital Patient Vitals Monitor

Fig. 33. Medical Staff Virtual Reality Training 1

Image source: https://sciencenode.org/feature/Preparing%20for%20real%20life%20with%20VR.php

Fig. 34. Medical Staff Virtual Reality Training 2

Image source: https://sciencenode.org/feature/Preparing%20for%20real%20life%20with%20VR.php

Design & Evaluation Criteria

Following the same standards used for the performance metrics of the project, the project propsoal will also include a standard set of design and evaluation criteria that will be used throughout the virtual reality testing of the model, surveys, questionnaires and interviews conducted over the course of the timeline of the projecct. These design and evaluation criteria include:

a. Post-occupancy evaluations of a typical PACU environment compared to the new PACU environment

i. This evaluation process will use the following data sets as a way to measure the performance metrics stated above:

1. Interviews with patients, doctors and nursing staff

2. Questionnaires and surveys

3. Evaluation of patient turnover and other data sets that are found in the business side of the hospital

4. Evaluation of the patient's vitals and other elements that are measured during the caregiving process

5. Evaluation of the requests and needs of the patient that are addressed by the caregiving staff.

6. Performance of the caregiving staff

Research Methodologies

The investigation, collection and analysis of the information collected throughout the project will include both qualitative and quantitave methods. This investigative analysis of the data will include the use of interviews, questionnaires and surverys collected from a range of medical staff such as doctors and nurses, architectural professionals in the healthcare industry and a group of people that will serve as the role of the patient. Some examples of both the qualitative and quantitative methods used in the project include:

Qualitative Method

Ethnography is the means of collecting qualitative data that I will be using because interviews will be a great way to understand the what the experiences, thoughts, and feelings both the patients and healthcare providers have throughout the patient's recovery process. These interviews and observations can allow for a better understanding how the space actually performs and use that information to drive the research forward through defining the experiences of both the patient and the healthcare providers, how the spaces perform, and how those two parties perform as well. The submersion into this setting allows for this approach to capture some information that wouldn't be captured in the quantitative method.
Interview questions:

1. Patients:

a. Have you had any surgeries or operations at a hospital? If so, what was that experience like?

b. After the surgery, where were you taken in the hospital? Please describe the room setting you were in.

c. Were you given any medication or drugs to combat any pain you had?

d. Did you feel the room you were in provided any comfort or reduction in the pain you were feeling? Why or why not?

e. Did you have any family, friends or other guests come and visit you? How did that make you feel?

f. Roughly how long were you in the space? 30 minutes-3 days?

g. What was the experience like leaving the hospital after you were cleared to leave?

h. Where did you go once you left the hospital? Please describe in detail the room setting.

i. Do you feel that the space you went to one you left the hospital had any elements that helped improve your comfort and/or manage the pain you were experiencing? Why or why not?

j. Did you have any family, friends or other guests come and visit you? How did that make you feel?

k. How would you feel the hospital's recovery spaces would perform if some of these elements were added to the space?

l. Are there a combination of places or experiences that you feel help you recover or heal? These places or experiences can be found in a home, spa, garden, vacation destination and other similar settings.

m. Overall, how would you improve your experiences at a hospital post-surgery?

2. Healthcare providers:

a. What is the process you experience when a patient comes in for a surgery or operation?

b. Please describe the physical environment that the patient is taken to.

c. How do you feel the patient performs in those spaces post-operation?

d. What elements of the spaces and of the care-giving process could be improved to better patient care and recovery?

e. How do you feel you perform in those spaces?

i. What helps or hinders your ability to deliver high quality services to the patient in this environment?

ii. Do you feel that you make more or less mistakes?

iii. Do you feel that you enjoy the space more or less?

iv. Do you experience more or less sick days compared to other settings you might have been?

f. Are there spaces in a hospital setting that you feel you perform better in compared to the spaces used for patient recovery post-operation? If so, please describe those environments.

g. Are there spaces in a hospital setting that you feel the patient performs better in compared to the spaces used for patient recovery post-operation? If so, please describe those environments.

Quantitative Method

1. Questionnaire for Patients:

Scale: Strongly Disagree Disgree Neutral Agree Strongly Agree

1. Having a safe and speedy recovery from a surgery is important to me.
2. The use of heavy addictive drugs and similar medication should be avoided.
3. The use of any medication or drugs should be avoided.
4. The environment I am placed in post-operation should have some positive effects on my healing and recovery process.
5. The recovery environment was clean.
6. The recovery environment was quiet.
7. The caregiving staff took a proactive approach to addressing my needs.
8. The doctors/caregiving staff provided clear instructions and answers that were easy to understand to any questions or concerns I had.
9. The caregiving staff explained what medications were for and any potential side effects.
10. My pain and comfort levels were controlled.
11. My condition was stable and at a level that I felt comfortable at when I was cleared to be discharged from the hospital.
12. I would recommend the hospital staff/facility/experience to others.
13. My experience at the hospital was positive.

On a scale of 1-10, how would you rate your experience at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how would you rate the caregiving staff at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how would you rate recovery spaces at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how much would you recommend this facility to someone else?
1 2 3 4 5 6 7 8 9 10

What recommendations do you have to improve your experience at this facility?

What changes would you make to the recovery spaces in order to improve patient recovery and comfort?

What were the positive aspects of your time at the facility?

What were the negative aspects of your time at the facility?

2. Questionnaire for Caregiving Staff:

Scale: Strongly Disagree Disgree Neutral Agree Strongly Agree

1. Having a positive work environment is important to me.

2. The environment I work in should have some positive healing effects, creating a more comfortable, better performing work environment.

3. The work environment is aesthetically pleasing.

4. The caregiving staff took a proactive approach to helping each other.

5. The doctors/caregiving staff/patient provided feedback on the quality and performance of my work.

6. The caregiving staff and supervisors provided me with the right amount of training.

7. The caregiving staff and supervisors encouraged any suggestions of potential improvements I had.

8. The management made changes based off of my feedback.

9. I would recommend the hospital staff/facility/experience to others.

10. My experience at the hospital was positive.

On a scale of 1-10, how would you rate your experience at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how would you rate the caregiving staff at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how would you rate recovery spaces at this facility?
1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how much would you recommend the work environment as a good place to work?
1 2 3 4 5 6 7 8 9 10

How would you improve your experience at this facility?

What changes would you make to the recovery spaces in order to improve patient recovery and comfort?

What were the positive aspects of your time at the facility?

What were the negative aspects of your time at the facility?

Conclusion

Fig. 35. Caption

Image source: https://cdnassets.hw.net/ed/d4/7034cec74ec095324a0268f307ee/marvin-apr2019-hero.jpg

Fig. 36. Caption

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Fig. 37. Caption

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Fig. 38. Caption

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Fig. 40. Caption

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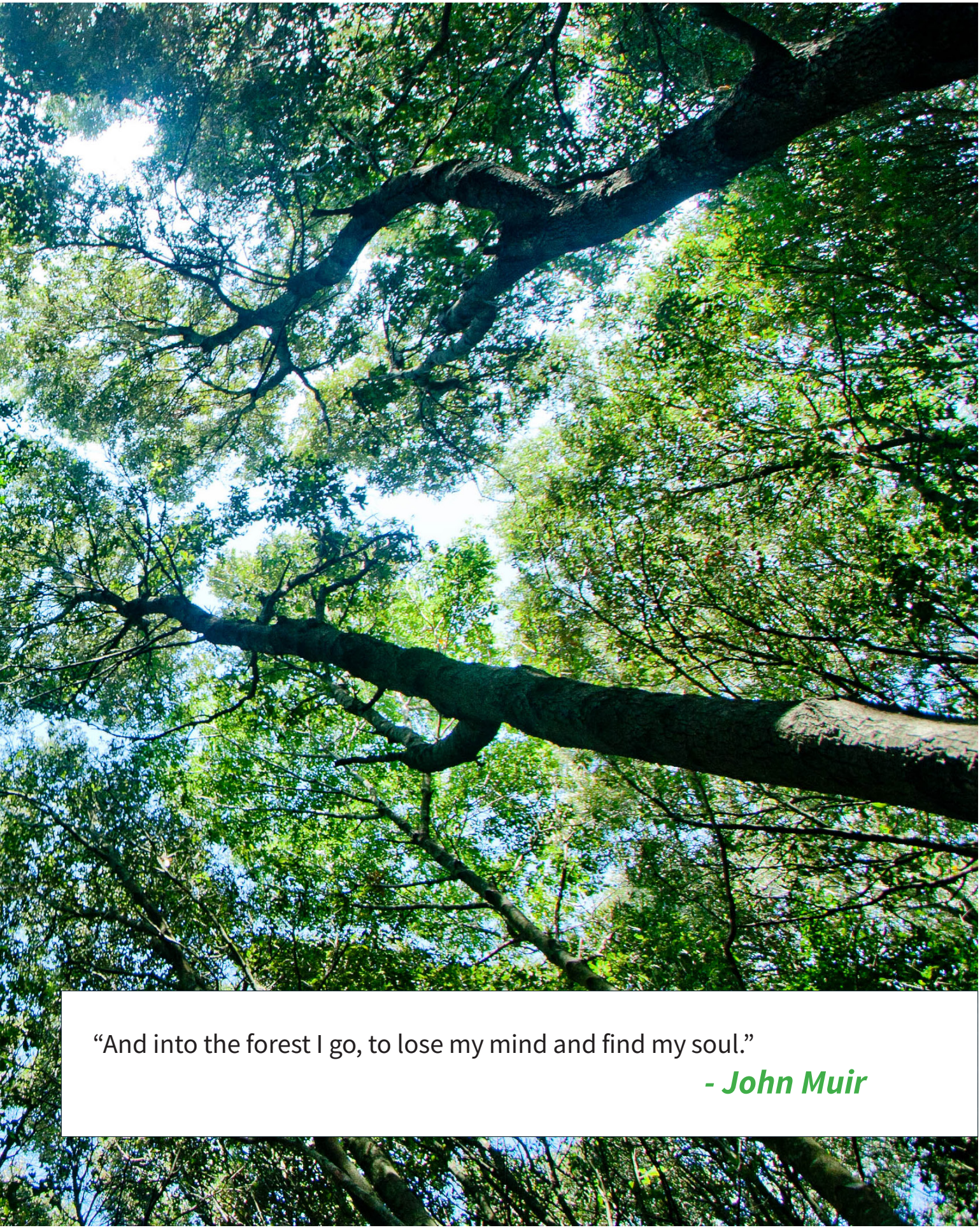
Fig. 41. Biophlic Design

Image source: https://media.mnn.com/assets/images/2015/07/forest-canopy.jpg



"And into the forest I go, to lose my mind and find my soul."

- John Muir

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