The Recovery Center: Light and Space in a Rooftop Inpatient Care Facility in South Lake Union"

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Committee

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Program Authorized to offer Degree:
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Abstract

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Architecture

Using a current facility in South Lake Union as a platform for developing a long-term recovery center, this project incorporates an inpatient care environment with ambulatory and acute care patient rooms, a clinic, healing gardens, and physical therapy and social support spaces.

This thesis examines the relationship between light and health, and employs an evidence- based design approach to treating cancer patients. This thesis proposes that architecture can also provide a healing mechanism but creating light and dark spaces that foster healthy circadian rhythms for cancer patients during their most difficult treatments and recovery. The design decisions are directly informed by medical research. Program activities focus on promoting patients healthy circadian rhythms with daylight, electric lighting, building organization and green open spaces. The relationship between body hormonal secretions and light dark cycle combined with the suggested light dark exposure time provide criteria for analyzing the performance of a particular design solution, and the design for this center comes as a result of an iterative process.

The goal of this project is to seek design solutions to support the treatment and healing process though an architectural intervention uses light, views, and connection to the outdoors as critical component of a healing environment based on the most current research into light and health.

Content

Chapter1: Introduction

Light is critical to human functioning in that it allows us to see things and perform activities. But it is also important because it affects human beings psychologically and physiologically. Several studies have documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyperbilirubinemia among infants[1] . Further, the presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment[2] Studies also show that adequate light levels are linked to reduced medication-dispensing errors in pharmacies. Thus, incorporating light into healthcare settings can be beneficial for patients as well as the staff who work there.

This thesis considers the mechanisms by which light impacts human health and performance and reviews the literature linking light (daylight and artificial light) with health outcomes in health-care settings. Studies conducted in other settings that are relevant to the discussion also are examined.

[1] Roger S. Ulrich, *The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-lifetime Opportunity* (Robert Wood Johnson Foundation, 2004).
[2]'The Benefits of Daylight through Windows; Boyce, Hunter, Howlett, 2003' <http://lighting.lrc.rpi.edu/programs/daylighting/pdf/DaylightBenefits.pdf> [accessed 3 March 2013].

1.1 Thesis Proposal

Every single cell in our body has its own clock and those clocks are managed and controlled by one master clock of the body, circadian rhythm. The circadian rhythm keeps the biochemical, behavioral and physiological processes of many organisms, including mice and humans, on a 24-hour cycle. It locates in a particular cluster of neurons in our brain ---- **the most powerful external stimulus for synchronizing (entraining) circadian rhythm to a 24 hour cyclic is exposure to the light of day and darkness at night.**

Human body cells grow, divide, and eventually die. Cancers start when cells in a part of body grow out of control. Cancer cell growth is different from normal cell growth and unfortunately, these abnormal cells invade other normal cells and tissues. Cancer is now a leading cause of death worldwide and more than 19 million people are suffering from this disease.

The best and most common treatment for cancer patients is Chemotherapy. It is basically a set of medication that is meant for killing, stopping, or slowing the cancer cells. However, Chemotherapy would take at least four to ten hours long and it has many side effects. Especially with a patients' body that is already weak, preparing them to be most healthy before receiving the treatment, stay ready when the treatment is operating, and help them recover after the treatment is done are necessary.

Since cancers are cells that grow abnormally. Encouraging circadian system, which is widely known that it keeps cells cycle work properly, to fight with those abnormal cells is a high potential assumption. Many researches about circadian rhythm and cancer have been conducted**. Most of them, by far, indicated and supported that the circadian rhythm could improve results and effectiveness of anticancer drugs. A shorter recovery time in patient after chemotherapy were stated. Some studies addressed most likely that chemotherapy should be given at a certain time and differently in a different type of cancer, according to circadian time.** Light is vital in circadian rhythm as mentioned.

Therefore, my proposal is to **study and also design lighting condition in a space that is most suit for those Chemo patients prior/ during/ and after the chemotherapy is given. Lighting concepts will base on a natural lighting condition that works cohesively with circadian rhythm and, or, special design considerations for Chemo patients.** This research is to suggest another way that might help those Chemo patients by circadian rhythm with lighting design.

Chapter2: Literature Review

2.1 Light and Life

Since life evolved under the influence of sunlight, it is not surprising that many mammals, including man, have developed a significant variety of both physical and physiological responses to the spectrum of light. For example, people in the North Temperate Zone will take an opportunity to darken their skin for the coming summer, even with the risk of being burned. Coincidently, those sunbathers expand their ability to store Vitamin D, which is a crucial substance for a proper metabolism of Calcium. [3] Or during winter time when sunlight and day time are limited, numbers of people who suffer with the seasonal affective disorder increase significantly. Even in animals, the amphibian camouflage is a good example. Pigmented cells in the tail of tadpoles darken under light, an adaptive response that helps to conceal the animal when it is exposed.[4]

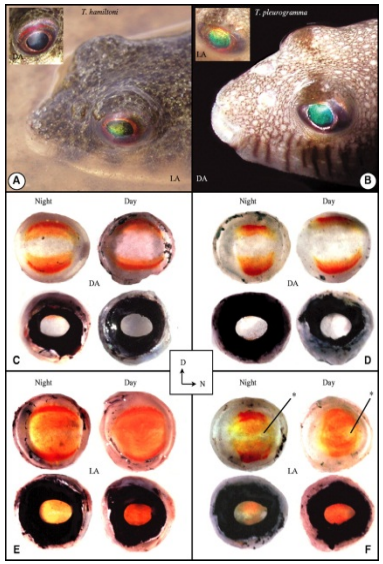


Figure1: a common toadfish that adapted the color in a different lighting condition. Not only their skin but also show a change on their cornea. Source: http://jeb.biologists.org/content/206/13/2177/F1.expansion.html

Figure2: sunbathing behavior in people in a North Temperate Zone. Source: http://beautytipforbeauties.blogspot.com/2012/06/treatment-for-tanned-skinhow-to-remove.html

Figure3: a changing of color in hibiscus flowers throughout a year. Source: http://artfulexpression.blogspot.com/2012/08/love-hibiscus-flowers.html

[3] 'The Effects of Light on the Human Body' <http://web.mit.edu/dick/www/pdf/286.pdf> [accessed 24 October 2012].
[4] 'Scientific American May2011.pdf'.

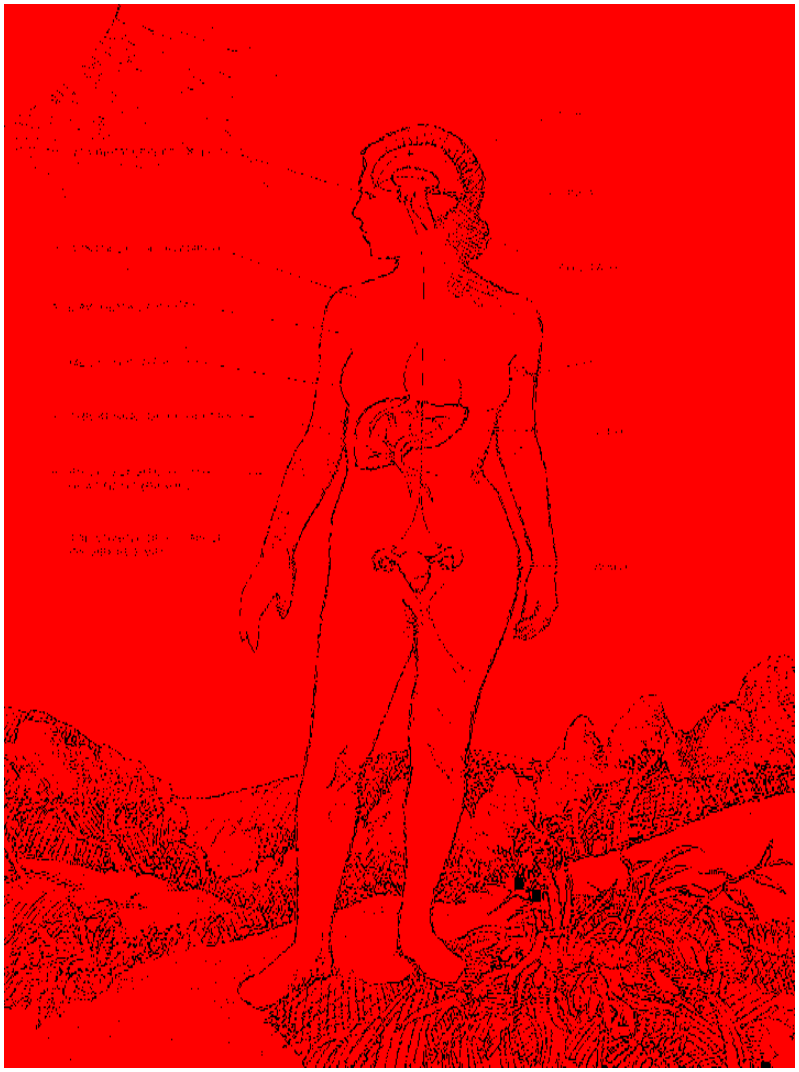


Figure4: A chart shows some effect of light with human body

2.2 Light and Human body

Some direct and indirect Effects of light on Human body are outlined in the drawing on the left. Indirect effects include the production of biological system or circadian rhythms. These effects are mediated by photoreceptors in the eye (1) with a novel receptor and involve the brain and neuroendocrine organs. (2). Erytheme, or reddening of the skin (3), is caused by ultra violet wavelength between 290- 320 nanometers. (4), a pigment that darkens the skin. Simultaneously the epidermis thickens (5), offering further protection. In some people the interaction of light with photo synthesizers circulating in the blood pressure caused a rash (6). In conjunction with selected photo synthesizers light can be used to treat psoriasis and other skin disorders (7). In infants light is also used to lower bilirubin in the blood until their liver is mature enough to secrete hormones. This bilirubin can damage the brain tissue if it is too much.[5]

[5] Richard J. Wurtman 'The Effects of Light on the Human Body'.

2.3 Light cycle in a day and Human's body

Human has a fundamental biochemical and hormonal rhythms that are synchronized directly to a daily cycle of light and dark. It is called 'circadian rhythm'. The circadian rhythm keeps the biochemical, behavioral and physiological processes of many organisms, including mice and humans, on a 24-hour cycle. It locates in a particular cluster of neurons in our brain ---- the most powerful external stimulus for synchronizing (entraining) circadian rhythm to a 24 hour cyclic is exposure to the light of day and darkness at night.

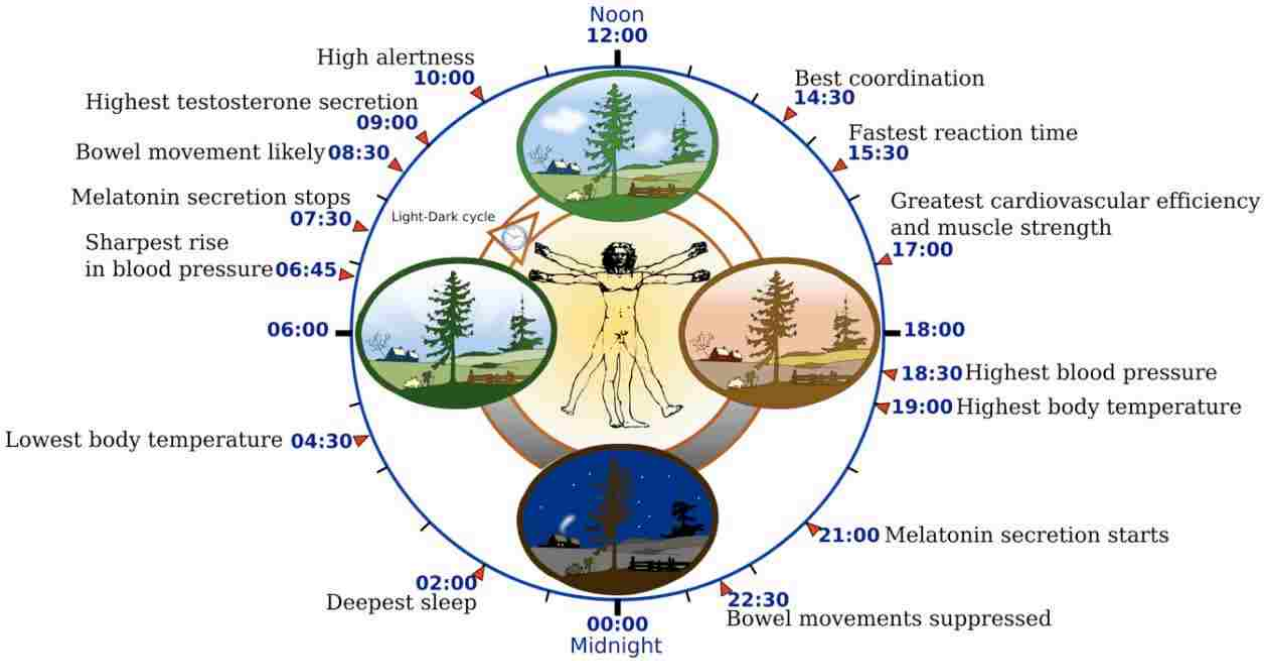


Figure5: Circadian Rhythms and body clock. Source: http://en.wikipedia.org/wiki/File:Biological_clock_human.svg

Figure6: Source: http://www.istockphoto.com/stock-photo-9922119-female-body-clock-young-woman-portrait.php

2.4 Biological Rhythms

Apart from the circadian rhythm that mentioned above, human body works always as a cycle. The circadian is the master clock that control 24hours directly related to light and dark cycle. In order to understand the circadian rhythm well, a basic knowledge of other biological rhythms in human body is necessary.

A biological rhythm is any cyclic that change in the level of a bodily chemical or function. It can be an internal (endogenous) or external (exogenous). The internal refers to the rhythm that controlled by the internal biological clock, a body temperature cycle is a good example. The external refers to the rhythm that is controlled by synchronizing internal cycle with external stimuli e.g. sleep/ wakefulness and day/ night. These stimuli include environmental time cues such as sunlight, food, noise, or social interaction. These stimuli help to reset the biological clock to a 24hour- day.

Biological rhythms can be categorized following these;[6]

Circadian rhythms -endogenously generated rhythms with a period close to 24hours.
Diurnal rhythms - a circadian rhythm that is synchronized with the day/ night cycle (e.g., sleep and wake cycle)
Ultradian rhythms - biological rhythms (e.g., feeding cycle) with a period much shorter but much more in frequency than circadian rhythm.
Infradian rhythms - biological rhythms with a cycle of more than 24hours (e.g., human menstrual cycle)

[6] Alan Hedge 'Biorhythms.pdf', p. 1 <http://ergo.human.cornell.edu/studentdownloads/DEA3250pdfs/biorhythms.pdf> [accessed 30 October 2012] Cornell University.

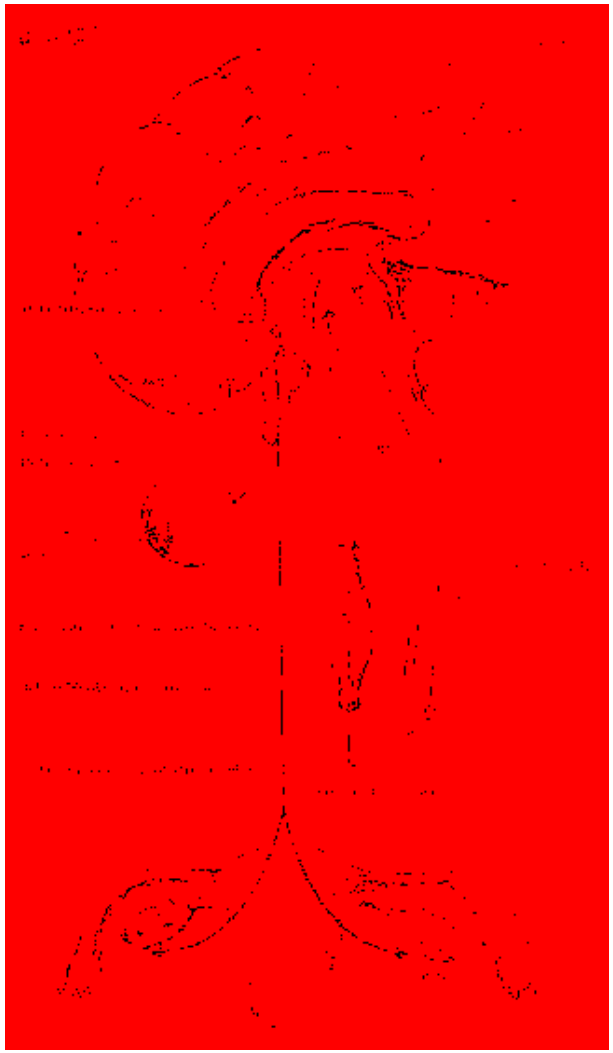


Figure7: Source: http://www.istockphoto.com/stock-photo-9922119-female-body-clock-young-woman-portrait.php

2.5 Circadian Rhythms

The circadian "clock" in humans is located mainly in the suprachiasmatic nucleus (SCN), which is a group of cells located in the hypothalamus (a portion of the brain). The circadian clock functions in a cycle that lasts a little longer than 24 hours. The circadian clock is “set” primarily by visual cues of light and darkness that are communicated along a pathway from the eyes to the SCN. This keeps the clock synchronized to the 24-hour day. Other time cues, known as *zeitgeber (in German meaning—time givers)*, also can influence the clock’s timing. These cues include meal and exercise schedules. Circadian rhythms and their sensitivity to time cues may change as a person ages. Circadian rhythm works and controls body systems as followed; [7]

Sleep and wakefulness cycle

The pattern of waking during the day when it is light and sleeping at night when it is dark is a natural part of human life. Only recently have scientists begun to understand the alternating cycle of sleep and waking, and how it is related to daylight and darkness.

A key factor in how human sleep is regulated is exposure to light or to darkness. Exposure to light stimulates a nerve pathway from the retina in the eye to an area in the brain called the hypothala-mus. There, a special center called the supra-chiasmatic nucleus (SCN) initiates signals to other parts of the brain that control hormones, body temperature and other functions that play a role in making us feel sleepy or wide awake.

The SCN works like a clock that sets off a regulated pattern of activities that affect the entire body. Once exposed to the first light each day, the clock in the SCN begins performing functions like raising body temperature and releasing stimulating hormones like cortisol. The SCN also delays the release of other hormones like melatonin, which is associated with sleep onset, until many hours later when darkness arrives.

Circadian rhythm controls two hormones that work directly with sleep and wakefulness cycle. They are cortisol and melatonin.

[7] ‘Biorhythms.pdf’.

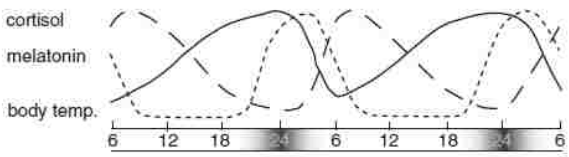


Figure8: Levels of hormonal balances affected by circadian rhythm. Source: Melatonin' <http://www.umm.edu/altmed/articles/melatonin-000315.htm> [accessed 5 November 2012].

Cortisol is a steroid and one of the primary stress hormones. Production is stimulated within the endocrine system's hypothalamic-pituitary-adrenal (HPA) axis. Secretion comes from the adrenal glands, which sit just above the kidneys. The lowest level being at night during sleep that gradually increases to when you need to wake up and get moving. The high cortisol levels present in early morning rapidly drop off and then continue to decline for the remainder of the day.

Melatonin is a hormone secreted by the pineal gland in the brain. During the day the pineal is inactive. It helps regulate other hormones and maintains the body's circadian rhythm. At night, or more exactly in darkness, human body produces more melatonin. Usually, this occurs around 9 pm. As a result, melatonin levels in the blood rise sharply and you begin to feel less alert. Sleep becomes more inviting. Melatonin levels in the blood stay elevated for about 12 hours - all through the night - before the light of a new day when they fall back to low daytime levels by about 9 am.[8] On the other hand, when it is light, the production of melatonin drops. Being exposed to bright lights in the evening or too little light during the day can disrupt the body's normal melatonin cycles. The exposure to light at night, even if it is a short-time exposure to light of low intensity, can cause the nocturnal melatonin peak to become either decreased or fully suppressed. Melatonin helps relief painfulness and stressfulness. It also helps control the timing and release of female reproductive hormones. It helps determine when a woman starts to menstruate, the frequency and duration of menstrual cycles, and when a woman stops menstruating (menopause).[9]

Melatonin also works with **Estrogen**-- a hormone that is necessary for the normal development and growth of the breasts and organs important for childbearing. It helps control a woman's menstrual cycles and is essential for reproduction. This particular hormone may increases a risk of breast cancer in women. When melatonin suppression occurs, estrogen will be founded in a high level and thereby higher risk.[10]

[8] National Sleep Foundation 'Melatonin and Sleep' <http://www.sleepfoundation.org/article/sleep-topics/melatonin-and-sleep> [accessed 25 November 2012].
[9] 'Melatonin' <http://www.umm.edu/altmed/articles/melatonin-000315.htm> [accessed 5 November 2012].
[10] '8Melatoninandmammarycancerashortreview.pdf' <http://www.unican.es/NR/rdonlyres/638265C7-36FF-4EBF-893B-150723B954AA/0/8Melatoninandmammarycancerashortreview.pdf> [accessed 25 November 2012].

Body Temperature

Body temperature fluctuates in warm-blooded animals throughout the day on a 24-hour, or circadian. SCN transforms that information into neural signals that set the body's temperature. Which mean that this body temperature is also sensitive to light and dark cycle/ sleep and awake cycle. However, recent researches indicated that even though the circadian rhythm controls body temperature within a day but a small change in body temperature can effect in circadian disruption as well.[11]

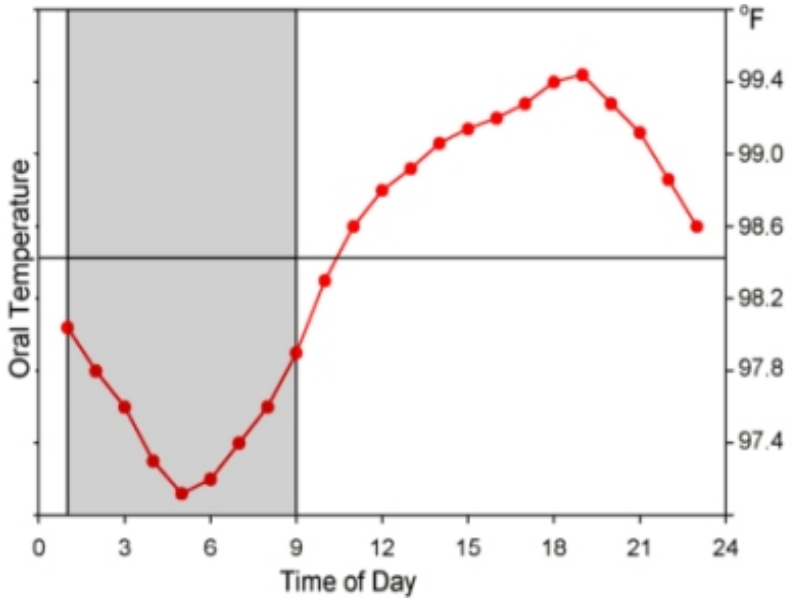


Figure9: Body temperature. Source: http://www.circadian.org/vital.html

[11] E. D. Buhr, S.-H. Yoo and J. S. Takahashi, 'Temperature as a Universal Resetting Cue for Mammalian Circadian Oscillators', *Science*, 330 (2010), 379–385 <doi:10.1126/science.1195262>.

Patterns of hormone secretion

Hormone is the most powerful chemical produced by the body that helps govern exercise recovery and tissue growth. It is the relationships between hormones and their specific secretion patterns that cause certain effects on the target tissue or tissues. Many hormones are governed by circadian, ultradian, and diurnal patterns. Entrainment of circadian and ultradian patterns of hormones can be modified by internal and external behaviors such as changes in the sleep-wake cycle, meal-timing, **light-dark cycles**, hypothalamic pacemaker effects, environmental temperature, and social cues.

In order to keep this paper concise and simple, only hormones that related to body recovery time or cancer topics will be considered. Some of important hormones that will be mentioned in this research are following these;
Cortisol: Important for the sleep and wake cycle as mentioned in sleep and wakefulness cycle on page 12. Cortisol can be called a "stress" hormone.

Melatonin: Important for the sleep and wake cycle as mentioned in sleep and wakefulness cycle on page 12. Melatonin helps relief pain and stress. Maintain a regular sleep cycle.

Testosterone: Testosterone is an anabolic hormone that is produced in the testes in the male, the ovaries in the female, and the adrenal cortex of both sexes. Males have a higher testosterone than females which can account for their greater masculine physical traits and general increase in upper body muscle mass. Circadian rhythms and sleep patterns governing testosterone secretion are not fully understood.[12]Typically in a normal, male individual testosterone peak levels tended to occur between the morning hours of 5 AM to 9 AM and showed evidence of a circadian rhythm. However, an article by Touitou et al. in 1990 on the effects of shift work on night time secretory patterns of testosterone showed unpredictable times as well as an overall decrease in serum levels. This tends to support the theory that testosterone levels are not truly circadic in nature, but can be strongly influenced by external shifts in daily life patterns.

Growth hormone: GH exhibits a diurnal and weak circadian rhythm consisting of several ultradian pulses primarily during sleep.[13] These strong secretory pulses generally occur after the onset of sleep and are manifested during the third and fourth stages of sleep. However, GH pulses associated with sleep could occur during waking hours when sleep times

'Temperature Rhythms Keep Body Clocks in Sync' <http://www.sciencedaily.com/releases/2010/10/101014144314.htm> [accessed 27 November 2012].
[12] J. Takahashi and M Zatz, 'Regulation of Circadian Rhythmicity', *Science*, 217 (1982), 1104–1111 <doi:10.1126/science.6287576>.
[13] Gregory M. Brown, M.D., Ph.D., FRCP(C)'Light, Melatonin and the Sleep-Wake Cycle' <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1188623/pdf/jpn00057-0027.pdf> [accessed 25 November 2012].

were advanced by 5 hours.[14] GH levels peak during the stages of deep sleep (stages 3 and 4) and seem to follow an ultradian pattern throughout the night, generally decreasing in amplitude throughout sleep.[15] Additionally, GH release positively affects testosterone secretion which both interacts with necessary growth factors that also have a powerful effect on tissue growth and recovery. Alterations in the sleep-wake cycle can negatively affect testosterone levels. Therefore, an established daily pattern of sleep times is important.

Note about Growth Hormone

Meal timing and choice may also contribute to the diurnal pulse amplitudes of GH. GH is stimulated during low blood glucose levels. The information presented by Cooper in 1994 suggests that the amplitude of GH response from high intensity exercise was significantly inhibited by high fat and high glucose pre-exercise meals. When this idea is applied to daily life, the different types of meals chosen could affect the pulse amplitude of GH during normal diurnal and circadian rhythms.[16]

Other than sleep, exercise is the next most potent natural external condition that elicits an increase in GH pulses and amplitude during the diurnal rhythm. It could increase levels of cortisol, epinephrine and other hormones as well.

Growth Factors

Neurohumors or growth factors (GF) are some of the most important chemicals responsible for tissue growth and consequently, tissue recovery. They are primarily stored in the liver and pancreas and are synthesized by GH. There are circadian rhythms of IGF-I which are most likely due to the circadian variation of insulin. Since growth factors are usually reliant on other hormones such as testosterone and GH, it would be reasonable to assume the GF's would follow similar patterns. High resistance exercise is the most effective exercise method for stimulating increases in levels of growth factors throughout the body.

[14] E Van Cauter and others, 'Alterations of Circadian Rhythmicity and Sleep in Aging: Endocrine Consequences', *Hormone research*, 49 (1998), 147–152.
[15] E Van Cauter and others, 'Alterations of Circadian Rhythmicity and Sleep in Aging: Endocrine Consequences', *Hormone research*, 49 (1998), 147–152.
[16] 'Hormone Response' <http://www.myomaxfitness.com/Articles/hormones.htm> [accessed 25 November 2012].

	Circadian Light	Circadian Dark
Hormones	- Cortisol Stress - Serotonin Impulse Control - Dopamine Alert - Testosterone and Estrogen Alert	- Melatonin Sleep - Gaba Calm
Neuropeptides	- Follicle Stimulating Hormone Reproduction - Gastrin Releasing Peptide Hunger - Neuropeptide Y Hunger - Thyroid Stimulating Hormone Metabolism	- Vasoactive Intestinal Peptide Blood Pressure
Body Temperature	- Highest Body Temperature	- Lowest Body Temperature
Blood Pressure	- Highest	- Lowest

Table1: Hormonal balances. Source: Author

This chart concludes important hormones, neuropeptide, and other actions that work with light and circadian rhythms. This will impact recovery time of the patients. It is vital to maintain or adjust these levels to be normal and stable. The chart has two main categories; the first one is circadian light and the second is circadian dark.

The circadian light- Hormones that are activated during the daytime are mostly for helping ones active. Body needs them in order to have enough energy for activities. Those hormones are Cortisol, Serotonin, Dopamine, and sex hormones. Neuropeptides are Follicle Stimulating Hormone, Gastrin Releasing Peptide, Neuropeptide Y, and Thyroid Stimulating Hormone.

The circadian dark- Conversely, the circadian dark hormones help people feel more relax, prepare the body to rest at night. These hormones are melatonin and GABA. The neuropeptides is Vasoactive Intestinal Peptide; it helps relief blood pressure at night.

This chart was created to represent circadian rhythm and hormonal secretions. It will be a design tool throughout this project. To understand how hormones effect the body would help designer set lighting criteria that are proper with the circadian rhythms.

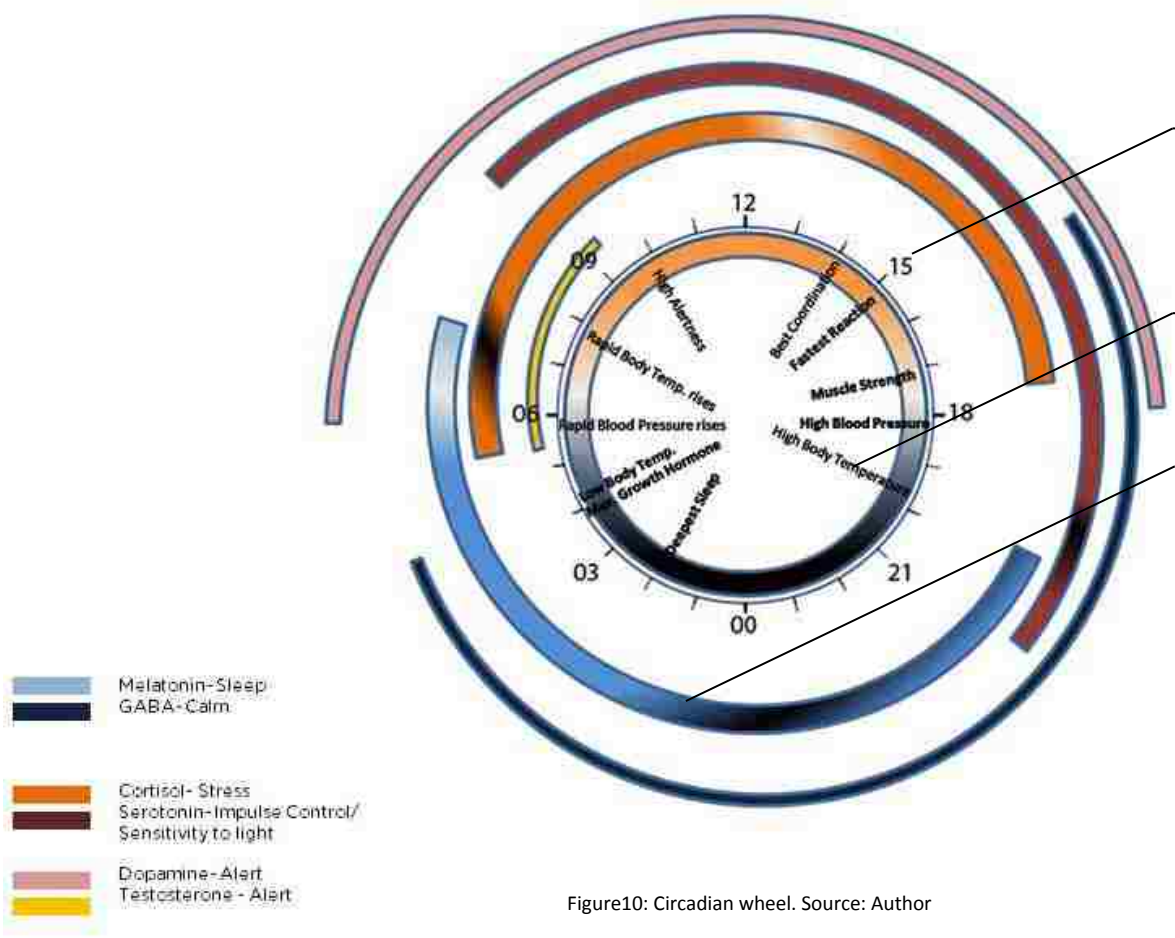


Figure10: Circadian wheel. Source: Author

1) The 24hours clock is indicated around the inner wheel. 6am is on the left side of the wheel and continuously clockwise 24hours. Color orange gradients to blue shows day to night time

2) A significant body activity levels in a day. These levels are results from circadian rhythms that shift throughout a day.

3) Hormonal levels. These curve lines represent all important hormonal levels in the body. The warm color represents hormones that are activated at day time and cool curve line indicates hormones that work at night. A darker (almost black) within those curves are addressed a peak rate of each hormones and a lighter color (almost white) is showed as a dropping point of each one. The day hormone; Cortisol (orange color), Serotonin (red), Dopamine (pink), and Testosterone (yellow) are mostly working as an active hormone. The body needs those in order to be ready to activities during the day time. They help us feeling alert, active, stress, and awake.

On the other hand, those curve lines that are represented in cool color addressed night time hormones. Melatonin (light blue) and GABA (dark blue), these night time hormones are helping the body to be relax, relief stress, claim, and sleep.

2.3 Cancers

2.3.1 What is Cancers?

Human body cells grow, divide, and eventually die. Cancers start when cells in a part of body grow out of control. Cancer cell growth is different from normal cell growth and unfortunately, these abnormal cells invade other normal cells and tissues. Cancer is now a leading cause of death worldwide and more than 19 million people are suffering from this disease.

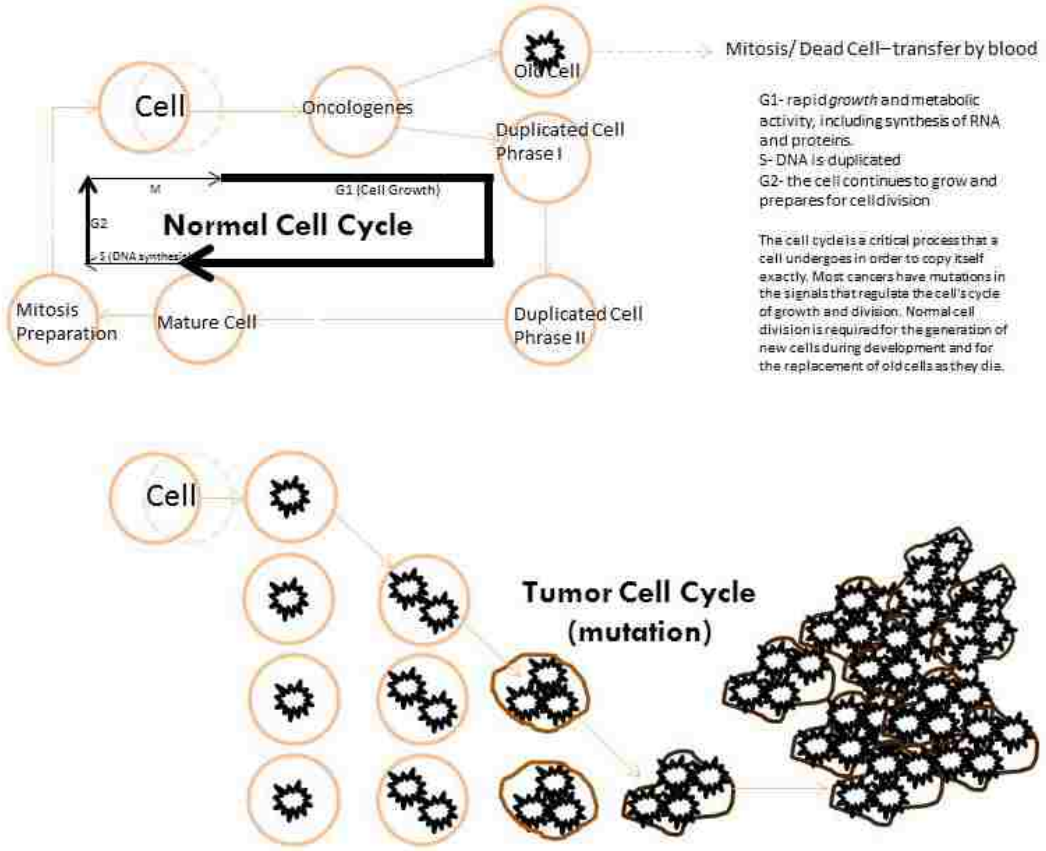


Figure11:Cancer cells. Source: Author

2.3.2 Cancer Treatment

Chemotherapy: Chemotherapy, or chemo, is medicine used to treat cancer such as AML. It works by killing cancer cells. Chemo can have many side effects. You may be more likely to get infections or have other problems. Caregivers will watch you closely and will work with you to decrease the side effects. Chemo may cure you or help you go into remission. Even if the chemo does not cure your cancer, it may help you feel better or live longer.

Blood transfusion: You will get whole or parts of blood through an IV during a transfusion. Blood is tested for diseases, such as hepatitis and HIV, to be sure it is safe.

Bone marrow transplant (BMT): This is when your diseased bone marrow is replaced with healthy marrow. You are usually given bone marrow from someone else (a donor). Sometimes your own marrow may be used if it is collected when your cancer is in remission (not active). The bone marrow transplant is given to you in an IV while you are in the hospital. A BMT may cure your illness, but it can cause other very serious health problems. You may be in the hospital for a month after your BMT.

Peripheral blood stem cell transplant (PBSCT): Bone marrow has many stem cells in it. The stem cells are the part of the bone marrow that make or change into blood cells. During a PBSCT, stem cells are put into your body. For this process, stem cells are removed from donated blood, and then put into your body through an IV. The stem cells should go into your bone marrow. Once in the bone marrow, stem cells can grow and become blood cells.

Radiation: This is a treatment using x-rays or gamma rays. It is used to kill cancer. This treatment may be given before you receive a bone marrow or stem cell transplant. You may need radiation if the AML has spread to your spine, brain or other parts of your body.

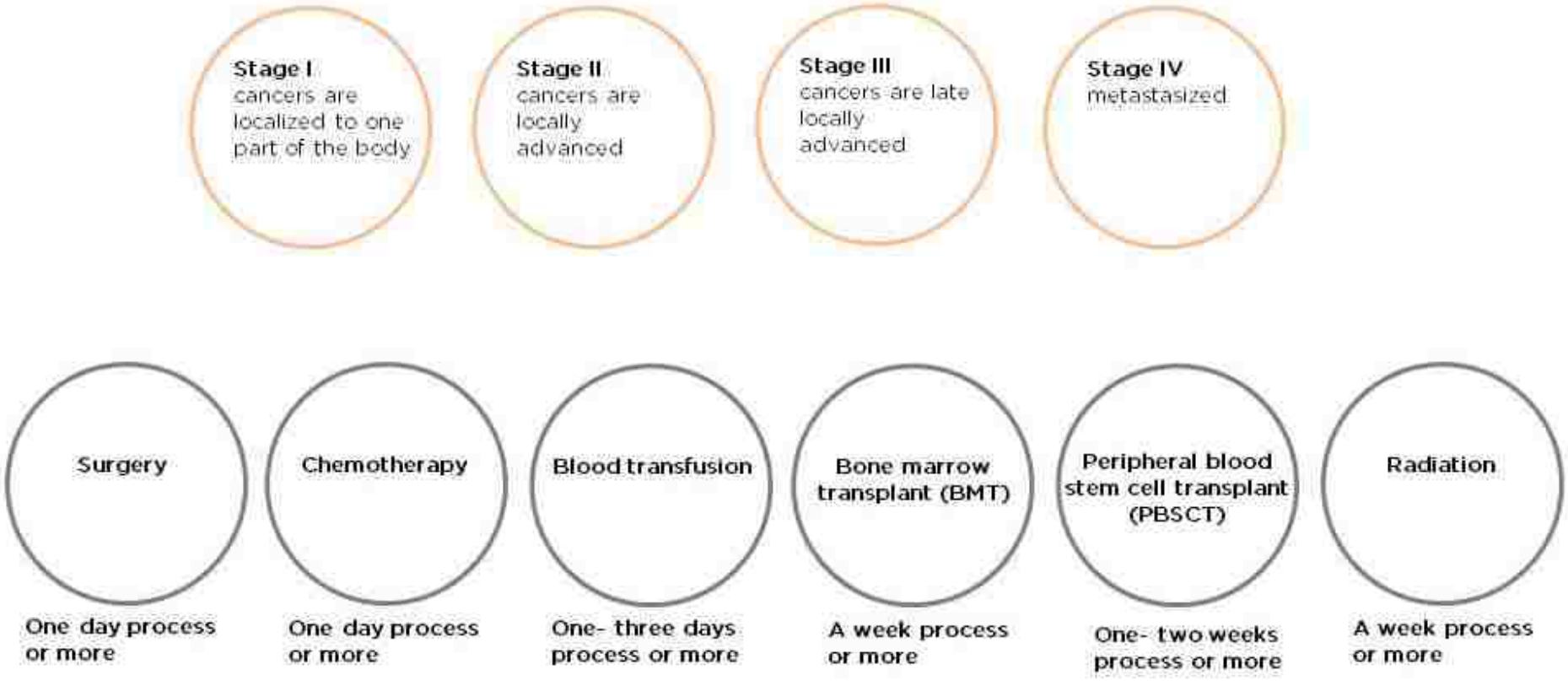


Figure12: Chart represents cancer treatment methods and durations. Source: Author

2.3.3 Cancer Treatment Procedure

Before starting treatment

1) first consultation with medical oncologist (cancer doctor). The oncologist will:

1a) take your medical history, do a physical exam, and review all your lab tests, mammography films, and biopsy results

1b) make a recommendation about which chemotherapy regimens would be best for you

1c) explain the benefits and side effects of each recommended chemotherapy regimen

Day of treatment

1) Meeting with the nurse or chemotherapy technician who will be giving you the medicine.

2) blood pressure, pulse, temperature, and respiration rate taken.

Your height and weight will be recorded so the appropriate dose of medicine can be calculated.

3) IV put in. The chemotherapy medicines are given through the IV.

4) Blood taken so number of red and white blood cells can be recorded "blood count".

5) Meeting with the medical oncologist (will examine, look at the results of the procedures and then calculate and order the amount of medicine needed).

6) "Pre-chemotherapy medicine" to prevent nausea or an allergic-like reaction.

7) Double check patient's information and dosage

8) Infusion

8a) preparing (hot pad for 1/2hr, or others)

8b) Saline

Dexamethasone (a steroid anti-sickness)
Saline
Piriton (antihistamine)
Saline
Tagamet (an antihistamine that controls acid reflux)
Saline
Ondansetron (anti-sickness)
Saline
Taxol
Saline
Carboplatin
Saline

Note:
Pre-meds: total time taken = 1 & 1/2 hours
Taxol: total time taken = 3 & 1/2 hours
Carboplatin: total time taken = 1+ hours

9) when chemotherapy session is done, the nurse or technician will take out the IV and make sure that patients vital signs. Give you further information and make sure patients acknowledge how to contact their doctors.

After the treatment

1-2 hrs after the treatment: drowsiness, nausea & vomiting, dehydration, body fatigue, joint pain, neuropathy (65up), etc.

Long term:

Pain, fatigue, nausea & vomiting, anemia, infection, blood clotting problems, mouth gum & throat problems, diarrhea & constipation, nerve and muscle effects, flu like symptoms, radiation recall, kidney & bladder, fluid retention, sexual organ & sexuality.

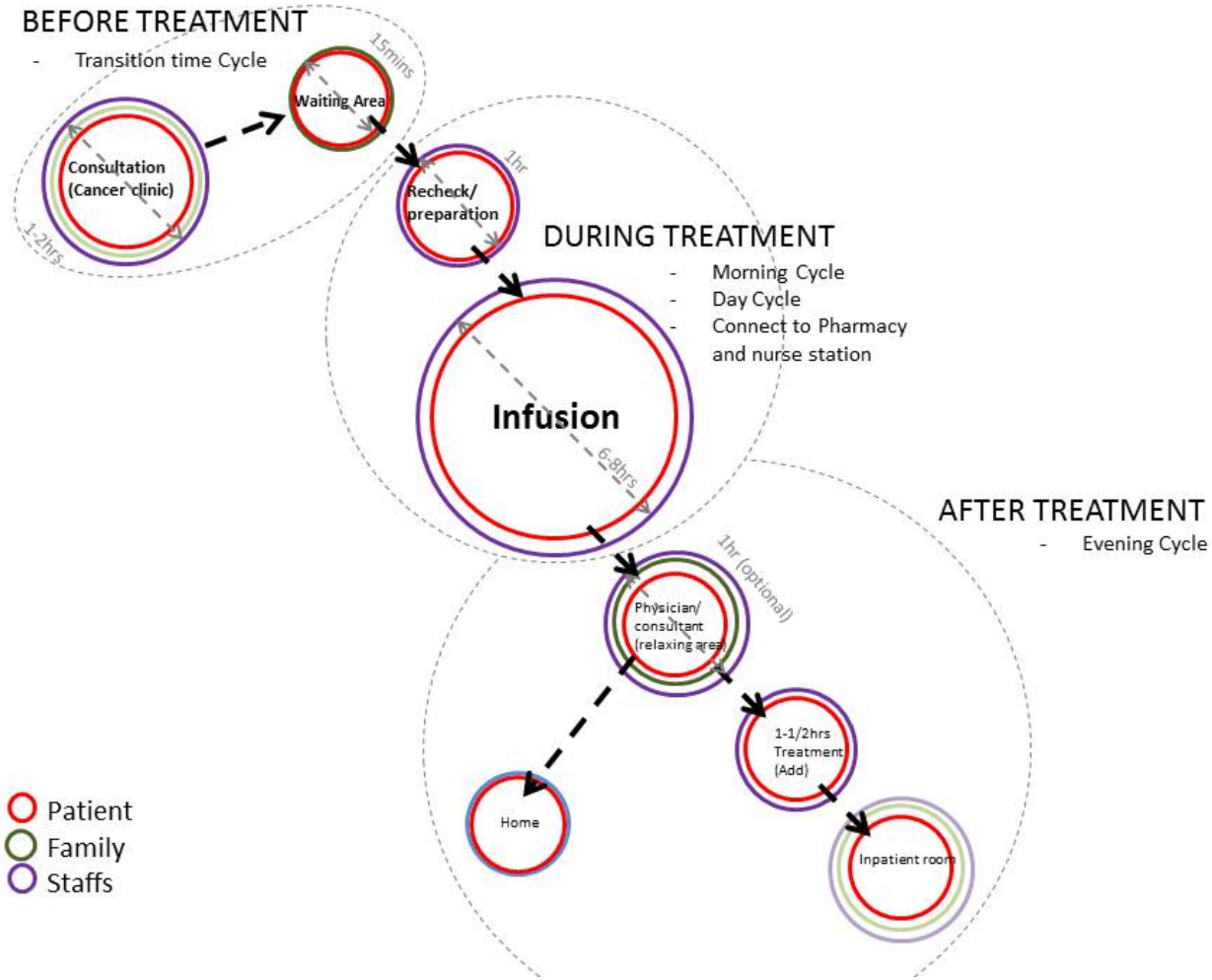


Figure13: Cancer procedure. Source: Author

Chapter3: Science of Light

3.1 Natural light and its spectrums

The natural source of light on earth is the sun. What we call 'Sunlight' is essentially an electromagnetic radiation form the sun. It is a member of a larger family of physical phenomenon. Figure 1 shows a little amount of Sun radiation that could penetrate onto the earth surface. The earth's atmosphere absorbs and reflects the radiation to protect the earth surface from receiving too much radiation that can be severely harmful for life. The radiation are measured and visualized by its wavelength and as the figure 2 demonstrates a widely range of all radiation from the sun, there is a tiny range between 330nanometer to 770nanometer that makes human see objects. That is a spectrum of visible light. Arrange from the shortest wavelength to the longest wavelength in sequence as violet, indigo, blue, green, yellow, orange, and red.

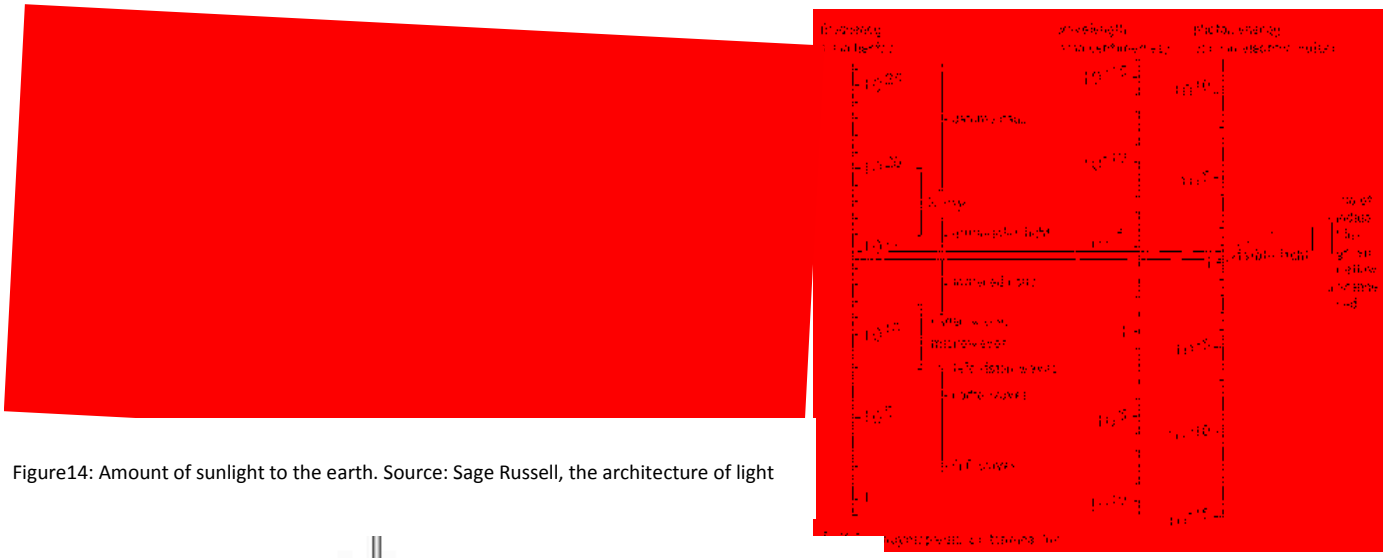


Figure14: Amount of sunlight to the earth. Source: Sage Russell, the architecture of light

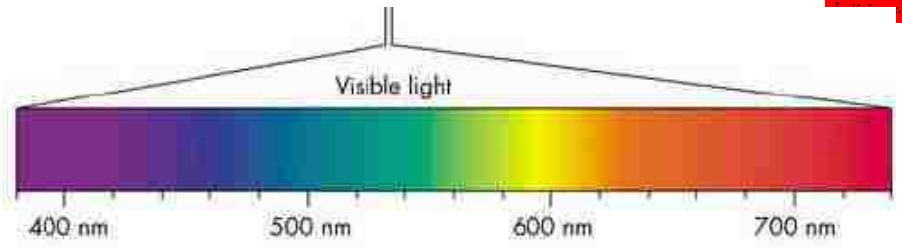


Figure15/ 16: Visible light wavelength. Source: http://science-edu.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

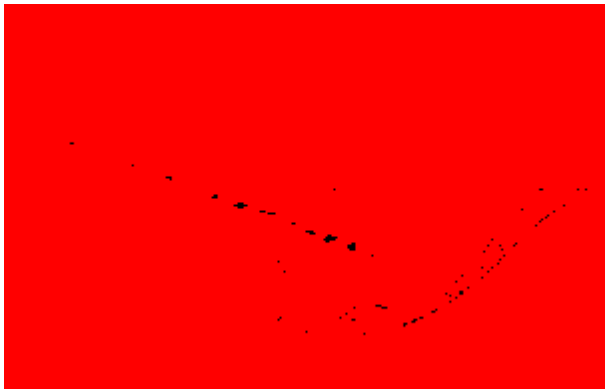
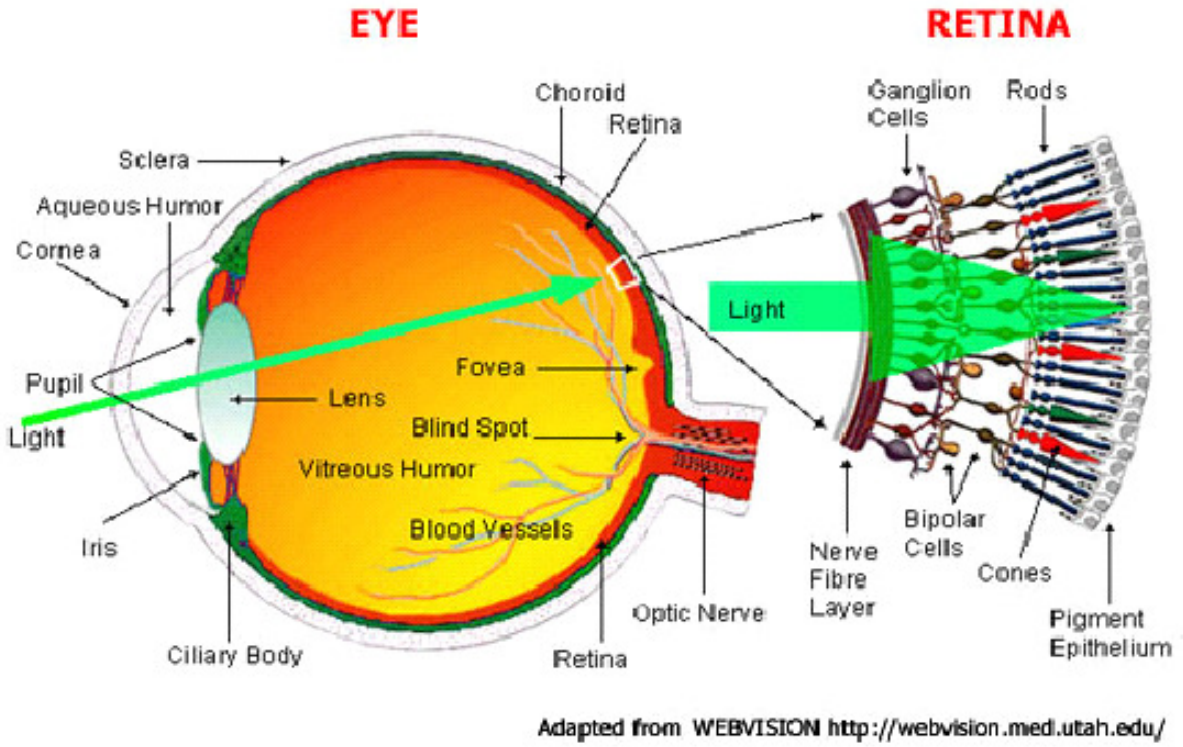


Figure17: Reflective light. Source: http://ceipntrasradelapiedad.wordpress.com/2010/03/30/light/

3.2 How do we perceive light?

Everything human see is a reflected light. Meaning that we actually would not see light itself, but luminance from any surface that light has fell onto. With the full spectrum of sunlight with a various range of wavelength (visualize as colors), when falls onto object, the object absorbs all wavelength that it does not contain, then reflect all wavelength that it has out. For example in figure 3, the green leaf contains pigments that people agree that is 'green' in it, when the full spectrum ray falls on it, other wave lengths except 'green' (500-580nm.) were absorbed and only the 'green' reflected to human's eyes. This is an explanation of how human could see, by seeing a reflected light.



3.3 The Third Photo receptor

Human perceives light through the eyes. Absorb them by photoreceptors in retina area. Rods cells are activated when a little amount of luminance value is given and Cones work when a higher luminance value come and take place. For more than 150years, scientists considered rods and cones to be the only two photoreceptors in the eye. However, the recent research in 2002 revealed the third photoreceptor that can detect the non- visible light[17]. It locates in retina of mammals which is a very far back in the eye ball. This newer recovered receptor regulates non- visual biological effect such as circadian rhythm, body temperature, cortisol production, melatonin production, alertness, and many more.

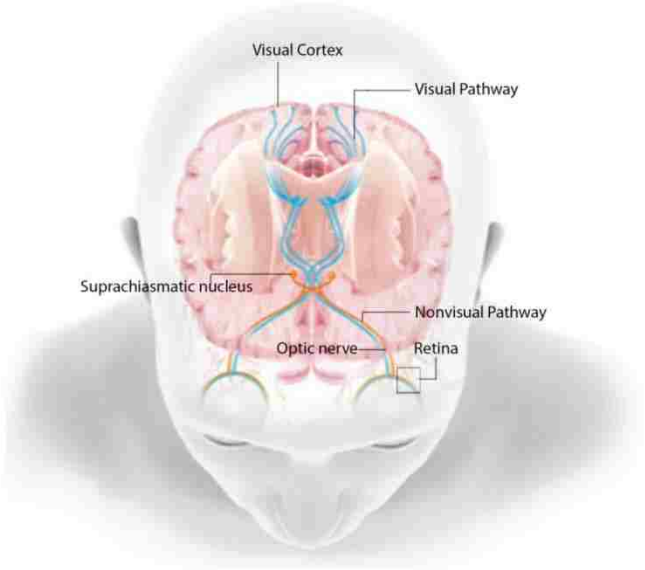


Figure19: Picture shows two light pathways in human's brain. Source: Scientific America. May 2011

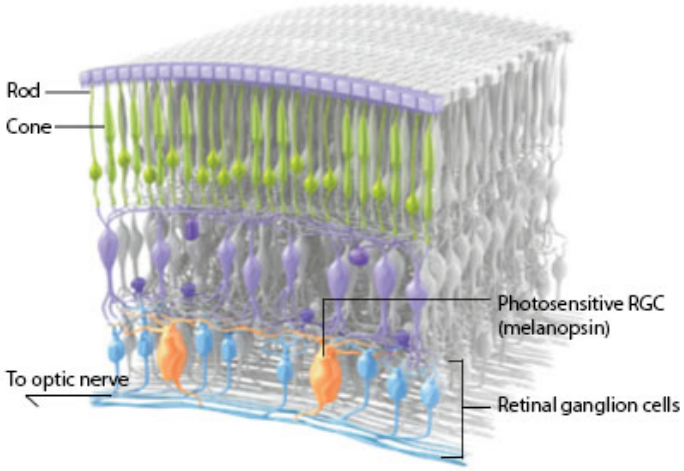


Figure20: Retina photoreceptor cell close up. Source: Scientific America. May 2011

[17] 'Melanopsin, Ganglion-Cell Photoreceptors, and Mammalian Photoentrainment' <http://www.ifc.unam.mx/pages/curso_ritmos/capitulo10/Rollag.pdf> [accessed 30 October 2012].

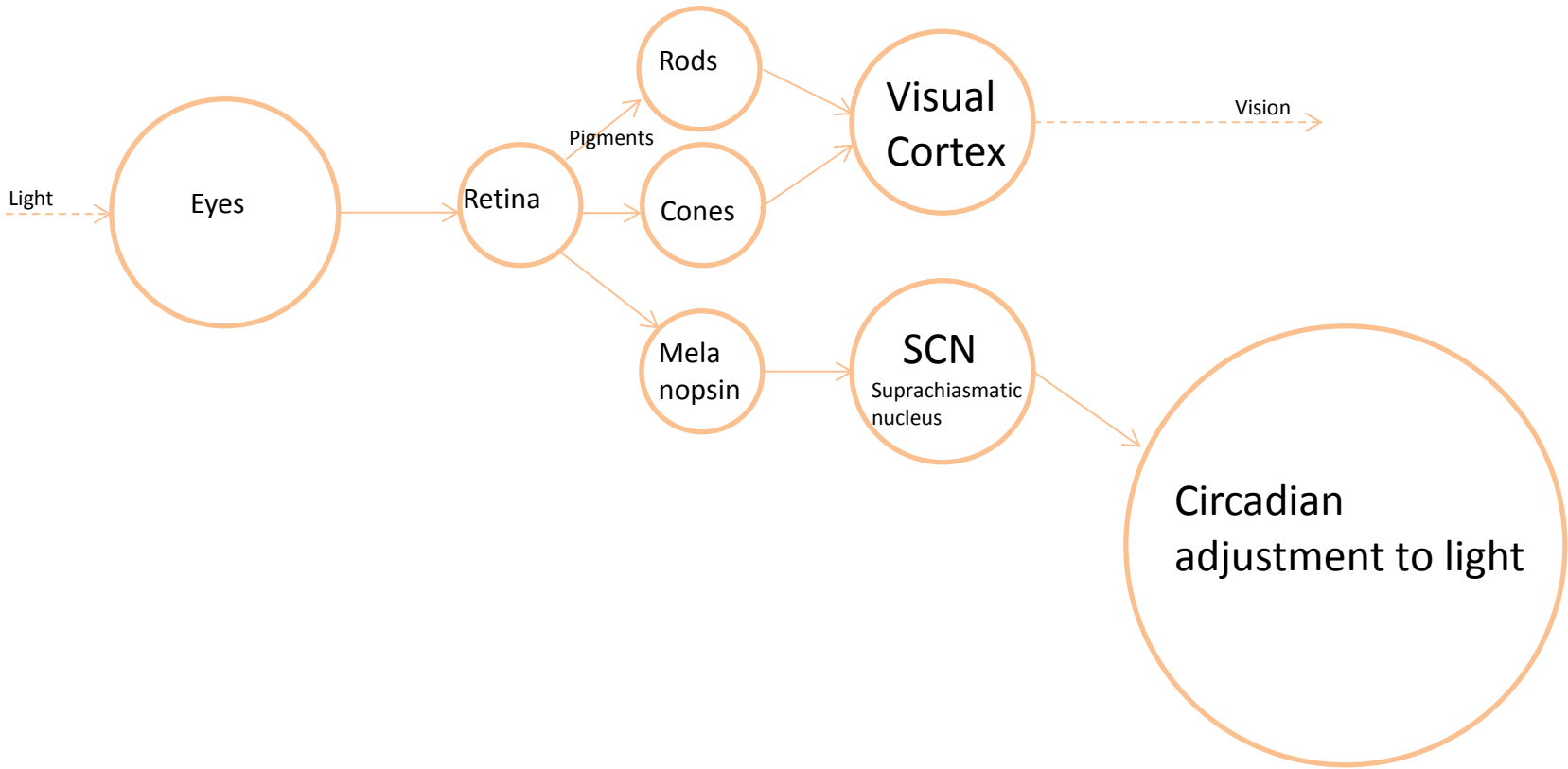


Figure 21: The chart represents the system of the eyes receiving lights and sends those signals into different paths. Visual pathway receives light and interprets as a vision from visual cortex. On the other hand, with the light that would regulate the circadian rhythms is going into a different part of the brain which is Suprachiasmatic nucleus as mention. Source: Author

Figure22: Circadian disruption. Source: http://sweetremedyfilm.blogspot.com/2012/01/disruption-of-body-clock-causes-neuro.html

Figure23: Circadian disruption. Source: http://ummentalhealth.info/2012/11/02/time-change-leads-to-sleep-disruption-for-many/

3.4 Circadian Disruption—Natural Light vs. Artificial Light

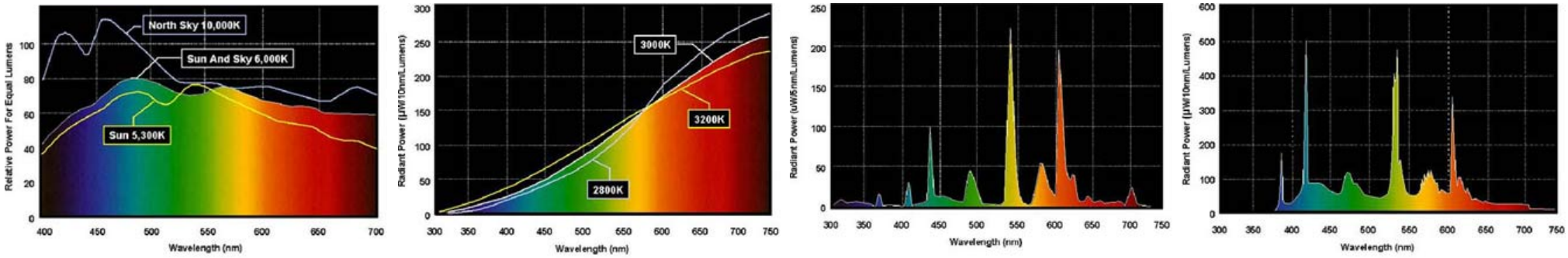
In our modern industrialized society, the disruption of our individual circadian rhythms has become commonplace, from shift work, jet lag to sleep disorder or even could lead to a serious illnesses like diabetes[18] or cancers if the disruption has developed chronically. High risks of cancer in shift worker were reported[19][20] one of the reasons was because the disruption suppressed Melatonin at night and that confused other hormones in the body. For example; estrogen—higher and cause more risk of breast/ ovary cancer in women, changing in metabolism rate could be resulted in diabetes.

Because circadian rhythm works directly with light and dark cycle, a healthy circadian rhythm may persist when ones receive a complete cycle of natural light. Cool color of sunrise when it is at low angle, bright light at noon, or warm color of the sun when it is about to set—these are what our ancestor had experienced for ages. An emerging of electrical lighting may be the most important impact on circadian disruption. A 24 hour lit up environment makes people nowadays stay up later at night and wake up later in the morning when the sun light is necessary.

Most healthcare settings, as well as other buildings, are lit by a combination of daylight entering through windows and skylights and electric-light sources. It is important to understand how these two types of light sources differ to understand their relative impacts on human health and performance. Sunlight is electromagnetic radiation in the wavelength range that can be absorbed by the photoreceptors of the eye. Sunlight provides a balanced spectrum of colors with elements in all parts of the visible wavelength range. The actual wavelengths present in daylight vary over the day with latitude, meteorological conditions, and seasons (Boyce, Hunter, & Howlett, 2003; Edwards & Torcellini, 2002).

[18] G. Boden, X. Chen and M. Polansky, 'Disruption of Circadian Insulin Secretion Is Associated with Reduced Glucose Uptake in First-degree Relatives of Patients with Type 2 Diabetes.', *Diabetes*, 48 (1999), 2182–2188 <doi:10.2337/diabetes.48.11.2182>.
[19] Eva S. Schernhammer and others, 'Night-Shift Work and Risk of Colorectal Cancer in the Nurses' Health Study', *Journal of the National Cancer Institute*, 95 (2003), 825–828 <doi:10.1093/jnci/95.11.825>.
[20] Scott Davis, Dana K. Mirick and Richard G. Stevens, 'Night Shift Work, Light at Night, and Risk of Breast Cancer', *Journal of the National Cancer Institute*, 93 (2001), 1557–1562 <doi:10.1093/jnci/93.20.1557>.

In contrast, light from most artificial electric-light sources, such as cool white fluorescent light and incandescent lights, are composed of wavelengths of lights that are concentrated in limited areas of the visible light spectrum, for example, yellow to red end or orange to red end of the spectrum (Edwards & Torcellini, 2002). Full-spectrum electric-light sources, such as xenon lamps and some filtered incandescent lights that have a spectral content similar to daylight, though their spectral content does not vary over time, are now available. Studies suggest that daylight is not inherently superior to artificial lighting for perform• Wavelengths of light consonance of most visual tasks (Boyce, Hunter, & Howlett, traded in limited areas of 2003). However, natural light has benefits over electric-spectrum (except full-spec light sources in regulating circadian rhythms and maintrum fluorescent lighting)



Natural Daylight 5500K | Incandescent Lamp | LED White 3000K | LED White 4000k

Figure24: Different wavelength that electric light produced. Source: Osram.com

Chapter4: Design

4.1 Methodology

1. Data Gathering
    a. Literature Review
2. Understand cancers and methods of treatment.
3. Explore the relationship between light and health
4. Understand circadian rhythm and natural light
5. Identify traditional methods for treating and explore an alternative treatment options
6. Broaden perspective by looking for other needs that may encourage a superior environment for Chemo patients.
    a. Site Investigation, Field Study, and case study analysis
7. Questionnaires to patients, oncologists/ nurses, family members.
8. Follow process and side effects of Chemotherapy with example cases
9. Site visiting; Seattle Cancer Care Alliance
10. Conceptual Design
11. Programming+ site selection- select and use an existing building in Seattle area and propose a new design. Creating a prototype treatment/ inpatient's room with educated design decisions.
12. Develop Architectural Design Criteria
13. Develop Lighting Design Criteria -Use both Literature and survey information to create design criteria.
14. Set both lighting and scene sequence design criteria integrate with an alternative treatment options and suggest a new space / experience to patients according to circadian rhythm needs.
15. Design Solution
16. Employ an iterative lighting design/ sequences approach to openings, views, comfort, environment, circadian rhythm.

4.2 Tools

4.2.1 Surveys

The questionnaires had been online for easily accessible. The purpose of this is for a better understanding of how the process and situation of patients along the treatment processes. With 43 cancer survivors
2 from California, 29 from Seattle area, 1 from North Carolina, 1 from New York, 10 from Thailand
26 of Female and 17 of Male participants

Figure25: Survey questions. Source: Author

Figure26: Survey questions (cont.). Source: Author

The Results

1. Type of Cancers and Genders

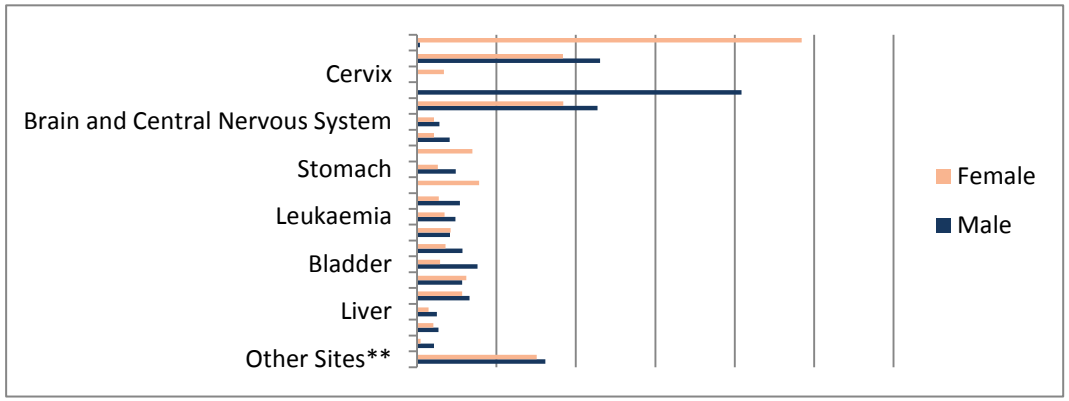


Figure26: Result from survey; type of cancers and genders. Source: Author

The survey indicated that breast cancer is a number one cancer type for women. For men, a bowel cancer held the majority. The design should be able to focus and respond to this fact.

2. Activities during treatments

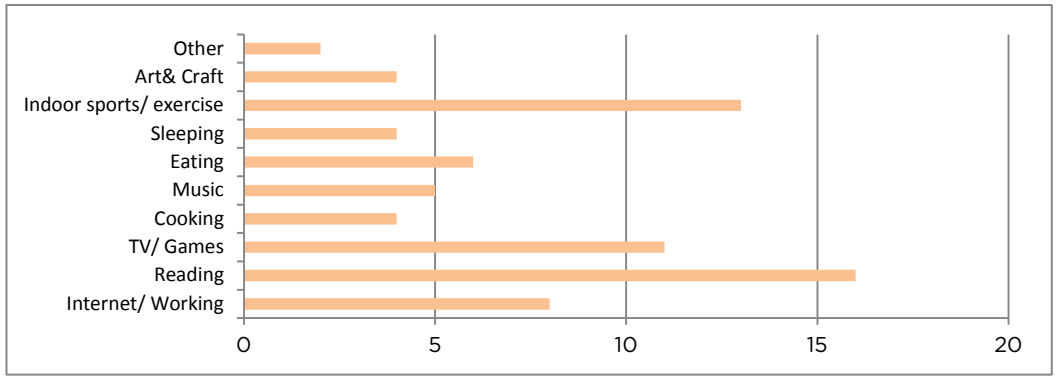


Figure27: Result from survey; patient activities. Source: Author

These are activities that patients liked to do when they were being treated in a hospital. The most popular activity is reading, then exercising, working, and others.

3. Comfort during treatments

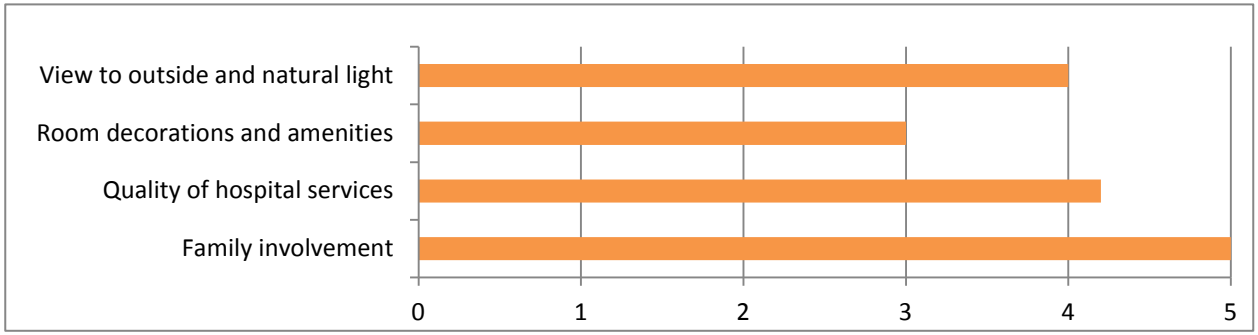


Figure28: Result from survey; Comfort during treatment time. Source: Author

4. Time of self-illumination devices

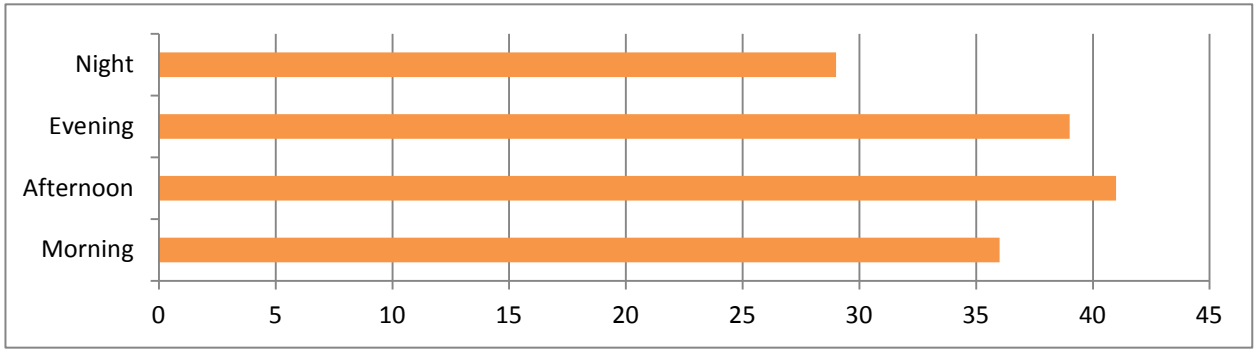


Figure29: Result from survey; Time of self- illumination devices. Source: Author

4.2.3 Computer Simulations

4.2.3.1 Ecotect and Radiance

Use Ecotect as a tool to create building model in order to run daylighting simulations. Ecotect is a user- friendly program and provide the accurate sky condition and other data. Ecotect tends to calculate more accurate than other daylighting simulation program. Materials are categorized by zones. Form Ecotect, we can export to another simulation programs easily.

Radiance is an external program that works with Ecotect. Radiance uses TMY3 data which gives a superior calculation results. Radiance- Ecotect was used in the project for finding illuminance and luminance data.

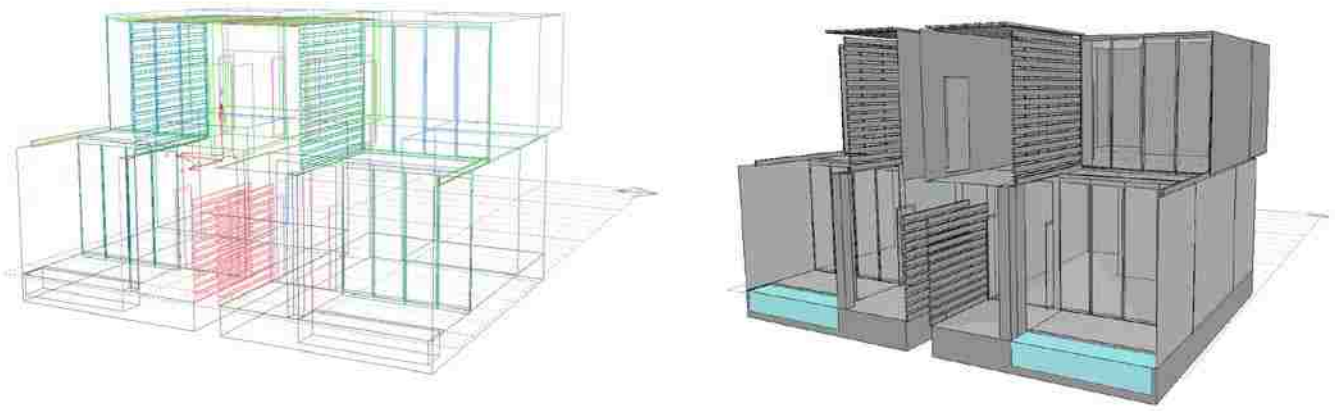


Figure30: Example of Ecotect work. Source: Author

4.2.3.2 Photosphere

Photosphere is a program that helps create HDR images from Jpeg pictures. This is very helpful for lighting designer to study luminance data which usually is a difficult thing to achieve. The process of creating HDR images from photosphere is

1) Take pictures with different shutter speed with the same exposure. Try to get one that is over exposure and one that is under exposure
2) Use photosphere(Macintosh) to create HDR image.

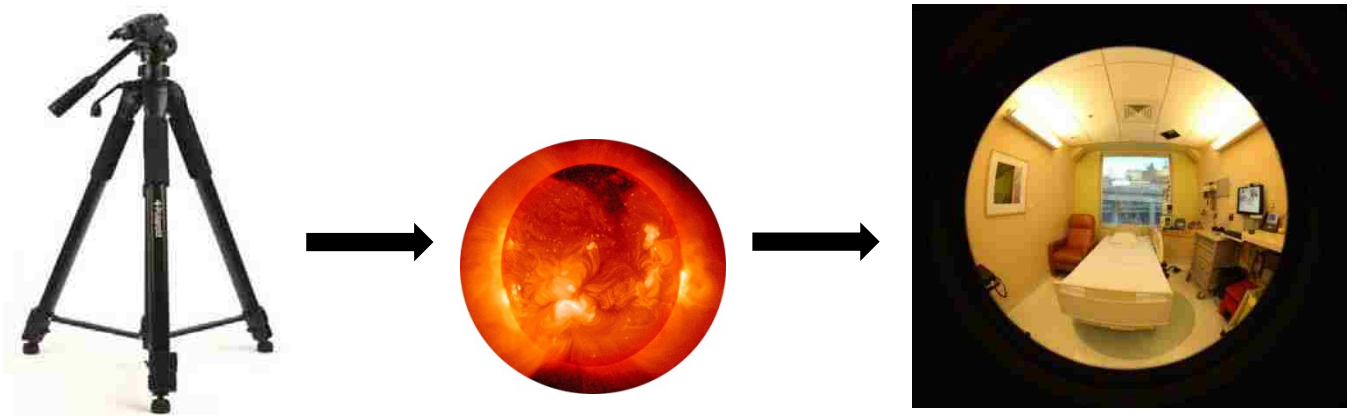
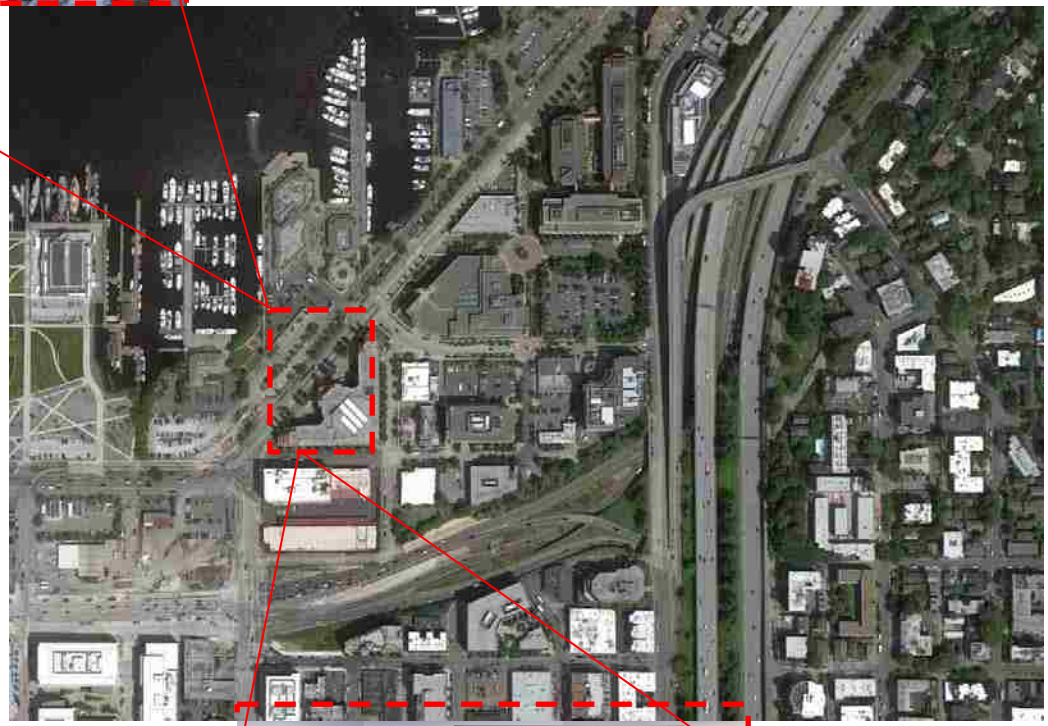


Figure31: process of making HDR images from photosphere program. Source: Author

4.3 Site Selection

South Lake Union:
This is a good view to the North side of the building.

Figure32: View of South Lake Union area.
Source: http://www.traceres.com/Waterfront-Properties



Downtown Seattle:
South side of the building provides a good view of Down town Seattle.

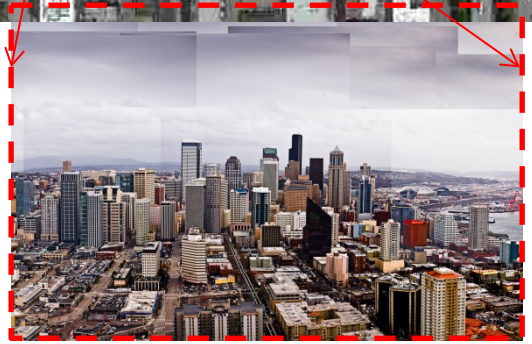
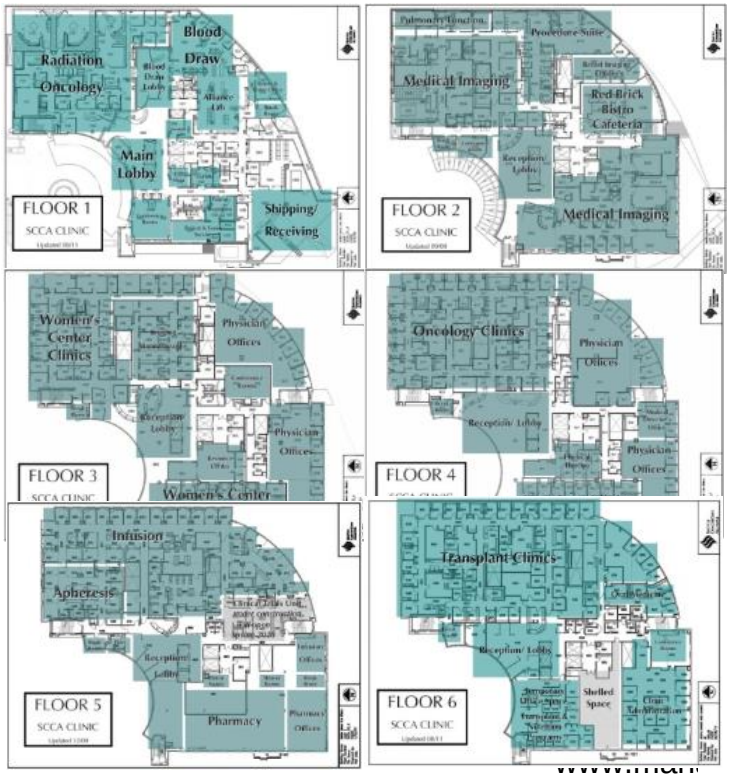


Figure33: View of Downtown Seattle.
Source:http://www.tomhawkins.com/photocollages2010/photos/Downtown_Seattle.jpg

Seattle Cancer Care Alliance



Seattle Cancer Care Alliance (SCCA) is a cancer treatment center that unites doctors from Fred Hutchinson Cancer Research Center, UW Medicine, and Seattle Children's. Our goal, every day, is to turn cancer patients into cancer survivors. Our purpose is to lead the world in the prevention and treatment of cancer.

SCCA patients may be seen at the SCCA outpatient clinic on Lake Union, UW Medical Center, Evergreen Health, and Northwest Hospital. Pediatric patients may be seen at the SCCA outpatient clinic and Seattle Children's. If overnight hospital stays are necessary, adult patients go to UWMC and pediatric patients go to Seattle Children's.

Existing Programing

1st Floor

-Main Lobby, Radiation Oncology, Blood Draw, Main Lobby, Alliance Lab

2nd Floor

-Medical Imaging, Cafeteria, Procedure Suite

3rd Floor

-Women's Center Clinics, Physician office

4th Floor

-Oncology Clinics, Physical Therapy

5th Floor

-Infusion, Apheresis, Clinical Trials, Pharmacy

6th Floor

-Transplant Clinics, Oral Medicine

Figure34: Seattle Cancer Care Alliance facilities.
Source: SCCA manual 2009.

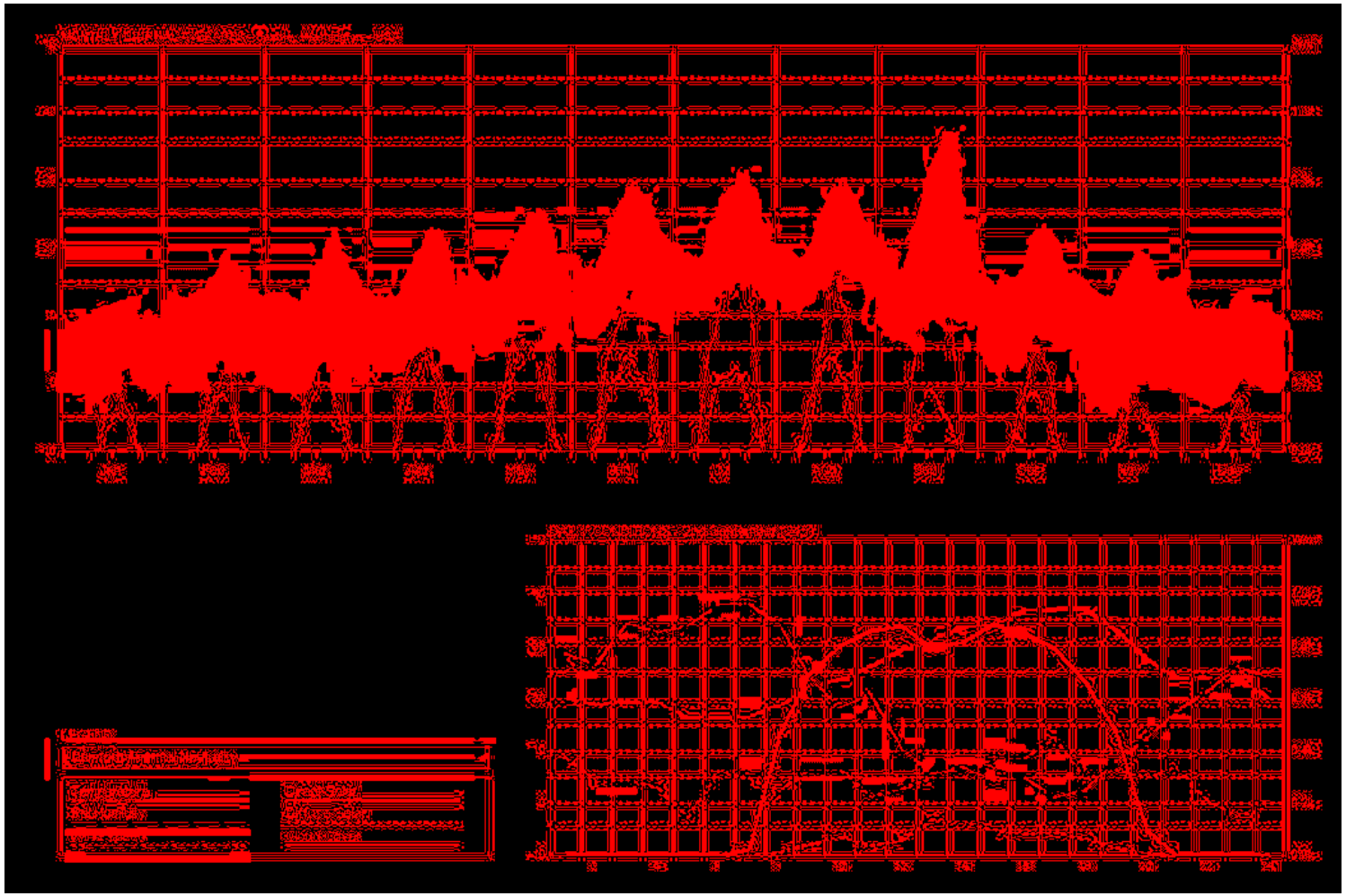
North Elevation

East Elevation

West Elevation

South Elevation

4.3.1 Seattle Weather Data



Monthly Average

Temperature:
Most of the time below comfort zone. Varies between -0 to 20C
Highest at 36C Lowest at -5C

Direct Solar:
Highest in July. Varies between 0.1K- 0.6K W/m2

Diffuse Solar:
Highest in May. The highest values vary between 0.1K- 0.3K W/m2. In the graph shows consistency- graph does not swing much.

Daily Condition

Temperature:
Highest at 17:00pm,34C Lowest at 5:00am, 15C.

Direct Solar:
Up to 0.9k W/ m2 from 6am- 11am. Little drop in the afternoon. Then drops back in the evening.- see graph.

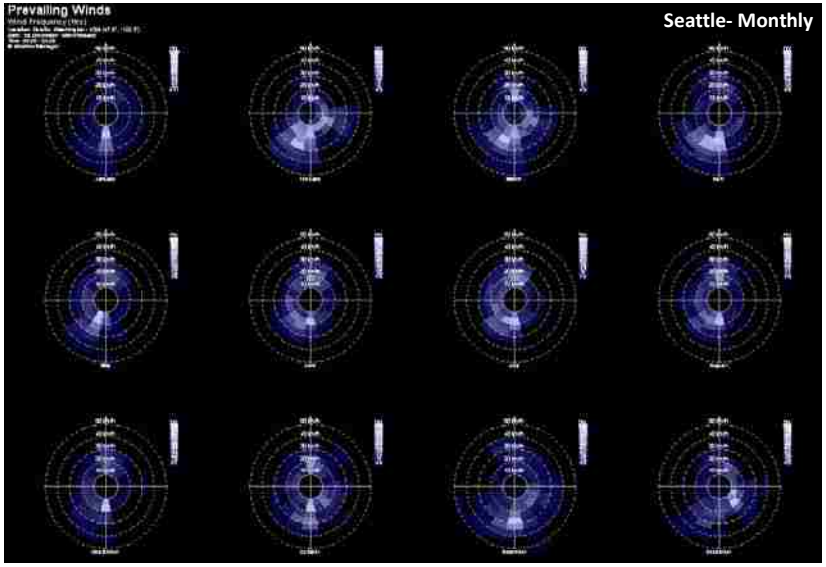
Diffuse Solar:
Highest at 13pm. Varies between 0k- 0.15k W/ m2

Rel.Humidity:
Maximum in the morning
Minimum around 13pm- 18pm.

Wind Speed:
Varies between -5k to 0.45k W/ m2 throughout the day

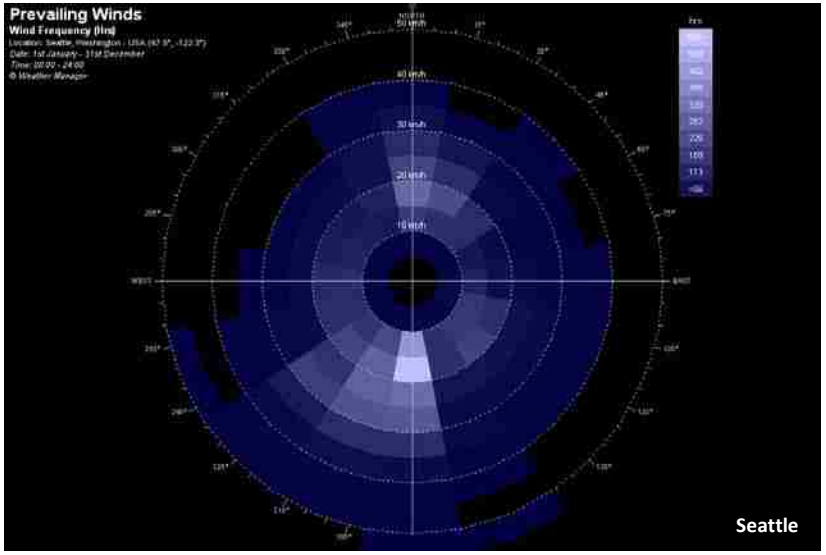
Figure35: Seattle Weather Data. Source: Author

Wind



Mostly wind comes from the south- west direction and becomes more directions in October to December. Wind speed varies between 0- 40km/ hr

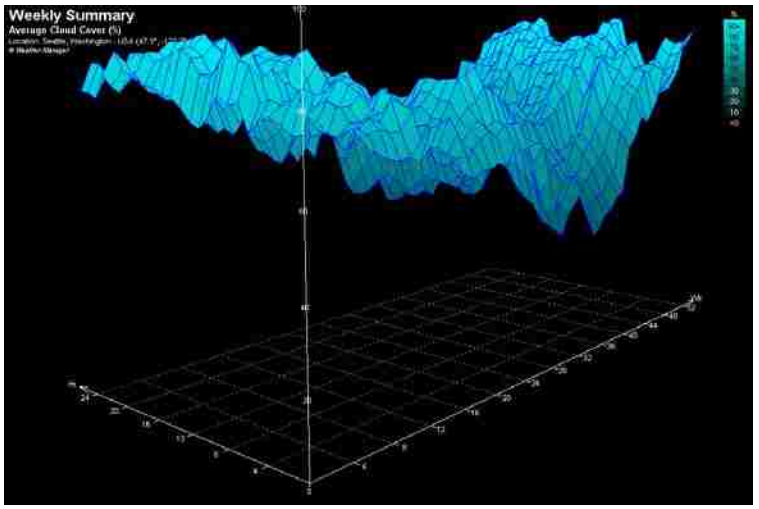
Figure36: Seattle Weather Data; monthly wind data.
Source: Author



Wind comes from the south and south-west direction. South- west wind is the strong one and can have a maximum speed up to 50km/ hr.

Figure37: Seattle Weather Data; hourly wind data.
Source: Author

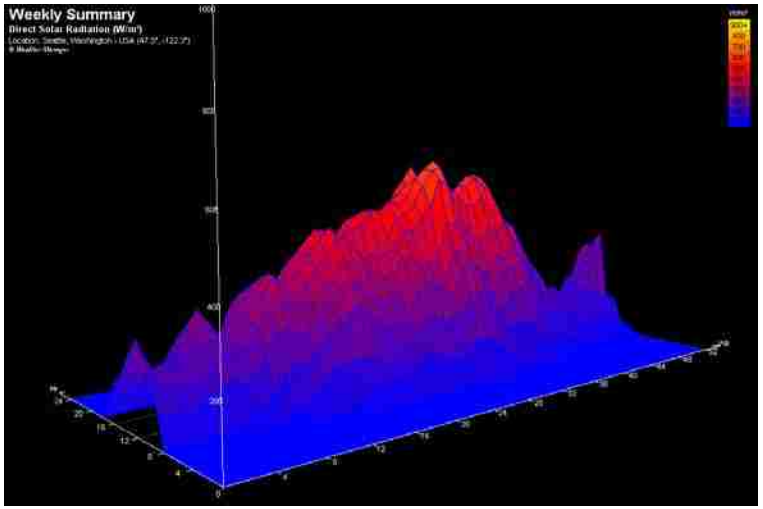
Cloud Coverage



Cloud coverage in Seattle varies between 30- 90+%. Means there are a lot of overcast sky days in a year.

Figure38: Seattle Weather Data; weekly cloud coverage data. Source: Author

Solar Radiation



Will be highest in Summer around noon. The direct solar varies from 0-700W/m2. There are limited in winter. The passive heating does not make sense to use during Winter.

Figure39: Seattle Weather Data; solar radiation. Source: Author

4.4 Programing

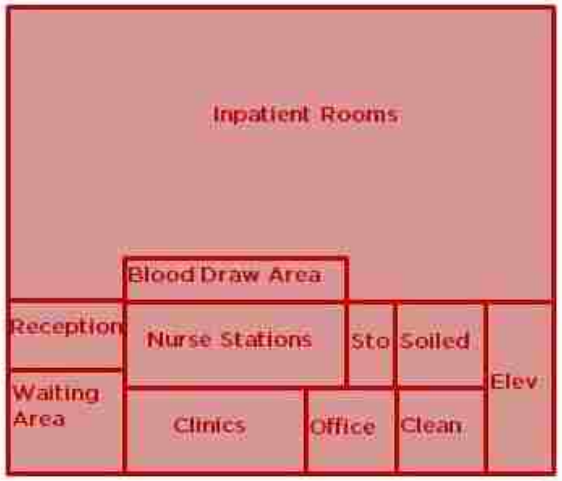


Figure40: Primary function block diagram. Source: Author

Primary Functions (sq. ft.)

-	Inpatient rooms	25,000
-	Intensive care rooms	7,000
-	Blood draw/ small injection area	150
-	Nurse stations	1,200
-	Storage	800
-	Clean utilities room	400
-	Soiled utilities room	400
-	Clinics	6,000
-	Reception	200
-	Check in+ Waiting area	500

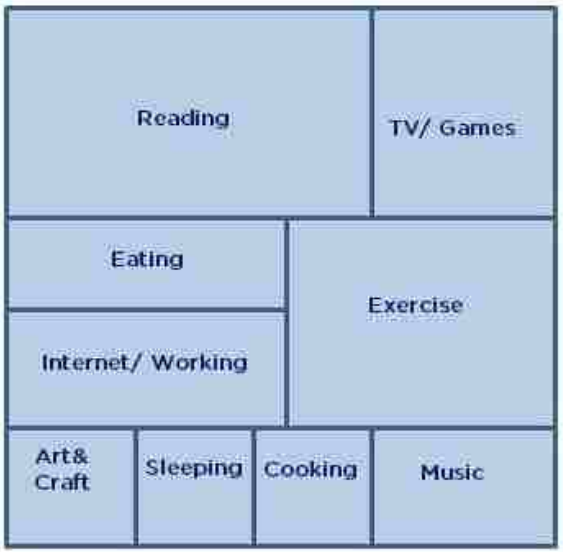
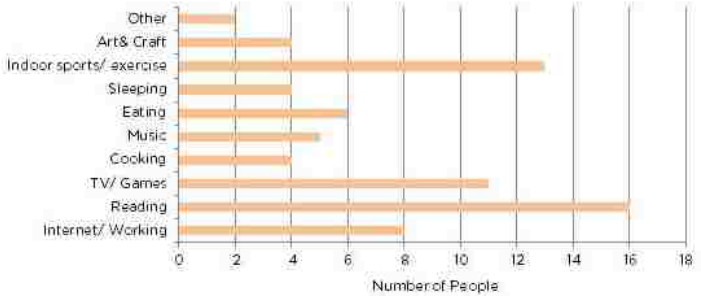


Figure41: Additional patient activities block diagram. Source: Author

Additional Patient Activities (sq. ft.)

-	Physical Therapy	1,200
-	Reading+ Coffee Shop	1,000
-	Lunch Area	800
-	Pool and Sundeck	1,200
-	Healing Garden	15,000



4.5 Architectural Design

Figure42: Program on site diagram. Source: Author

4.5.1 Conceptual Design

Start off with laying down all programs as mentioned onto the compass to find the best orientation of each space according to daylight time exposure.

East - suitable for areas that require bright light in the morning

Inpatient rooms: East morning sunlight
Nurse stations/: Morning activities for patients- morning sunlight
Blood draw area

South - suitable for areas that require bright light at noon till afternoon

Lunch area: Brightness illumination at noon

Physical Therapy: Brightness illumination in the afternoon

West - areas that patients are not using/ can be closed in the afternoon

Clinics: can be enclosed/ no patients activities response to light

North - suitable for openings to receive ambient illumination and areas that providing comfort is crucial

Nurse stations: facing North to avoid glare

Process1: circadian rhythms chart

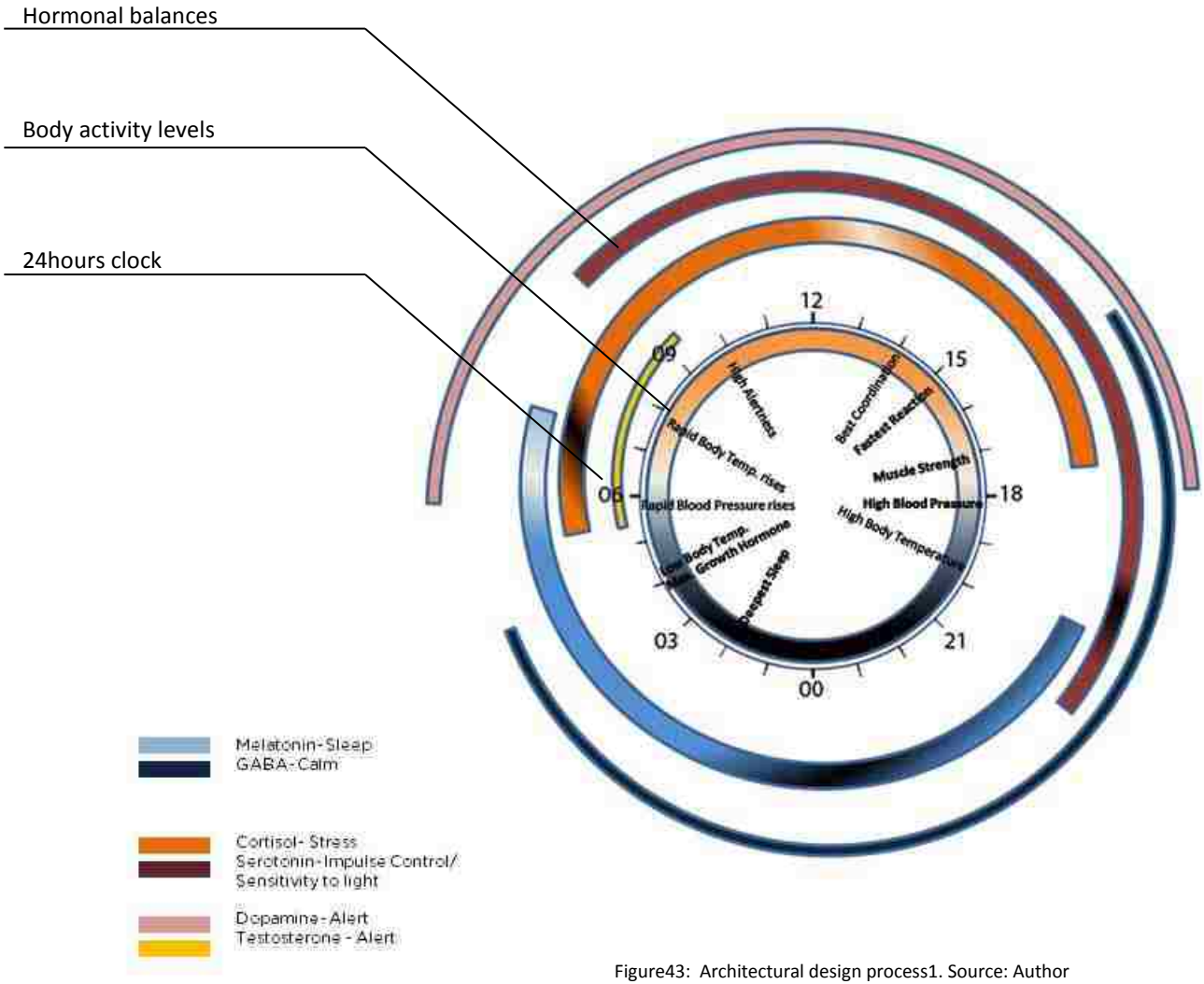
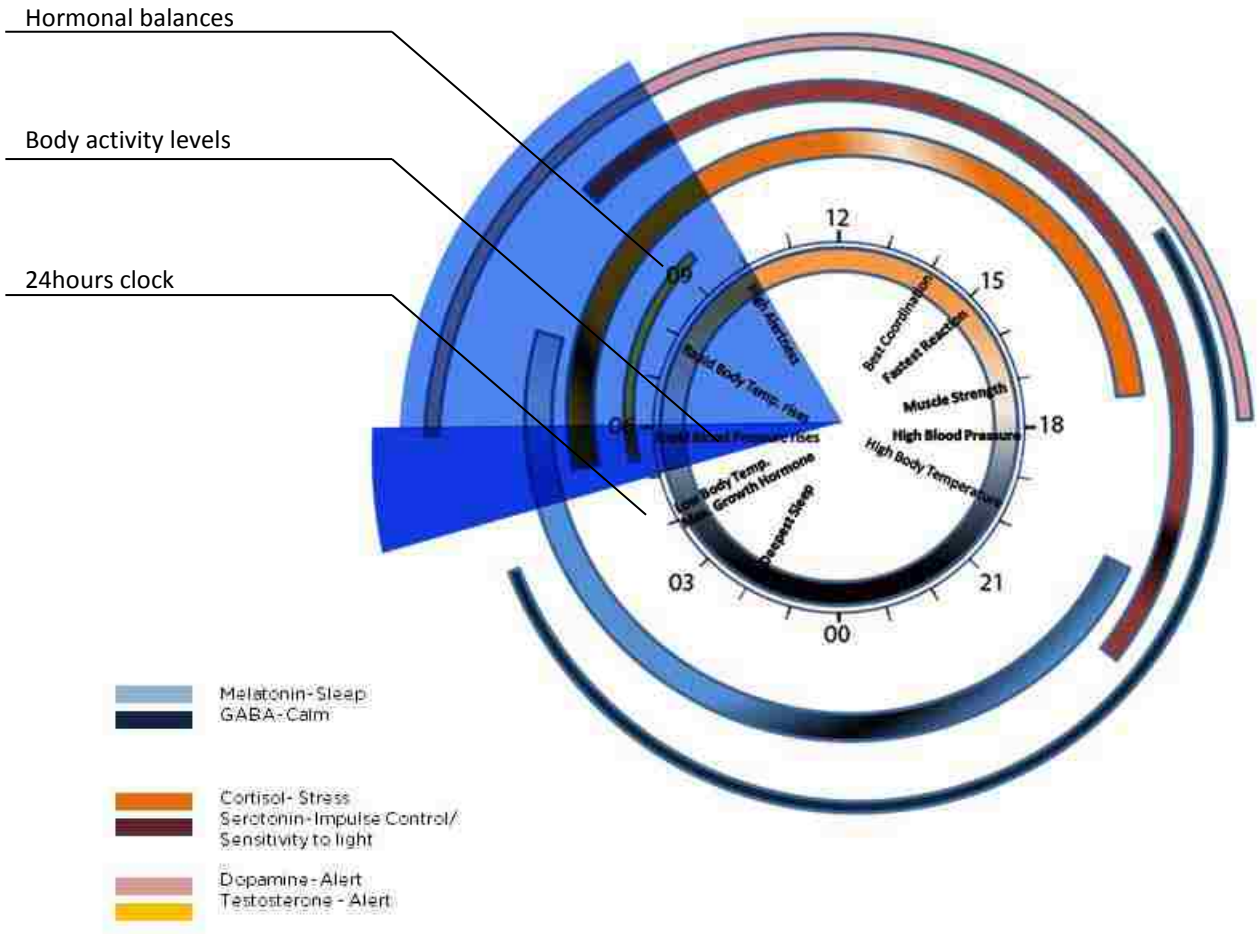
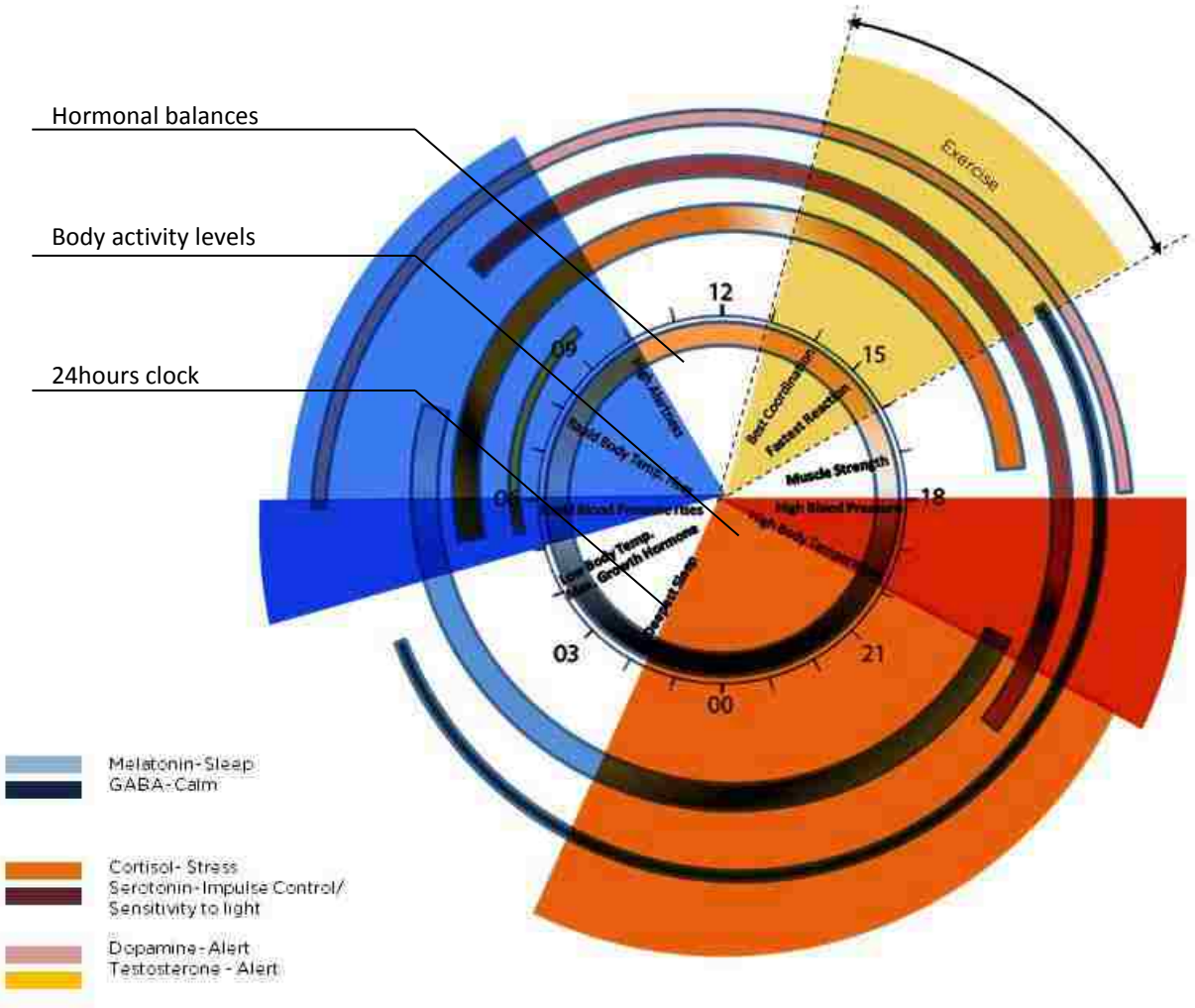


Figure43: Architectural design process1. Source: Author



Process2: Focusing on the morning light. Receiving bright blue light in the morning is crucial for circadian rhythm to work effectively, especially, 30-60minutes after one wakes. This high intensity light will help increases cortisol [stress], serotonin [impulse control], gaba [calm] and dopamine [alertness] levels, modifies the synthesis of follicle stimulating hormone (FSH) [reproduction], gastrin releasing peptide (GRP) and neuropeptide Y (NPY) [hunger], and TSH (metabolism)

Figure44: Architectural design process2. Source: Author



Process3: On the opposite side, at night, low Intensity and avoid Blue light (1-2hrs before sleep) allows for the production of melatonin [sleep], vasointestinal peptide [lowers blood pressure] and growth hormone [metabolism and repair]

Figure45: Architectural design process3. Source: Author

Process4: Concluded time of light exposure.

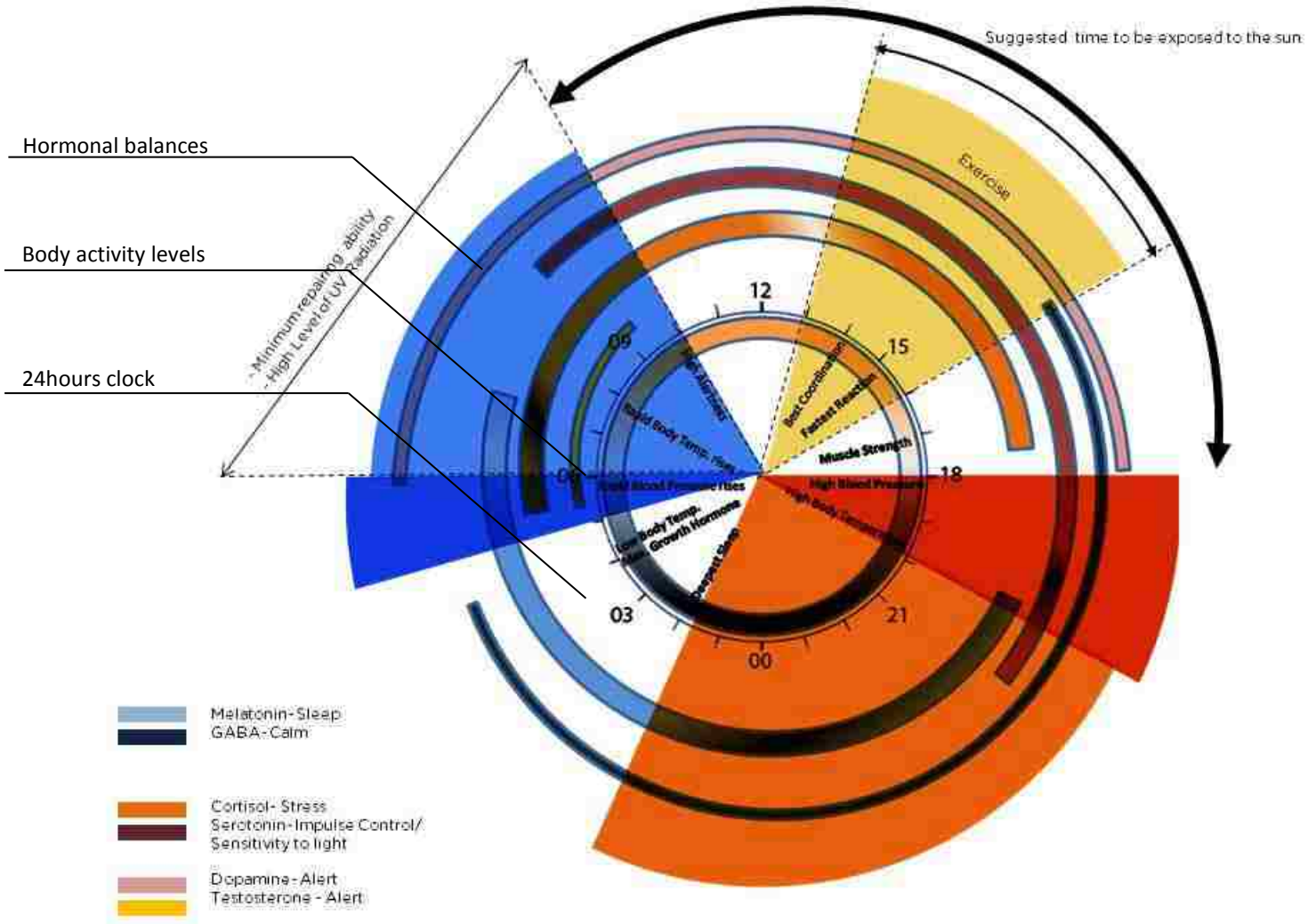
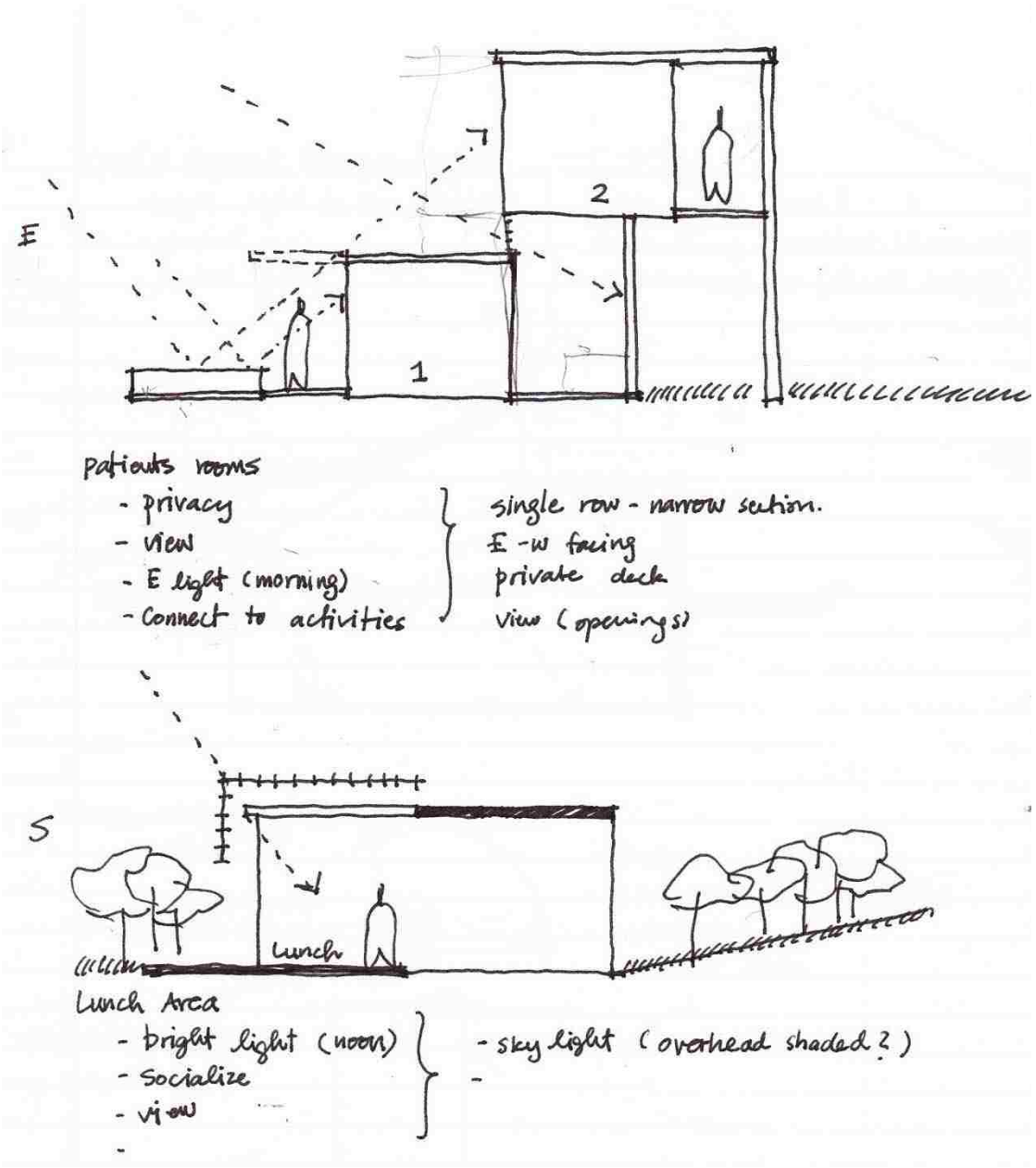
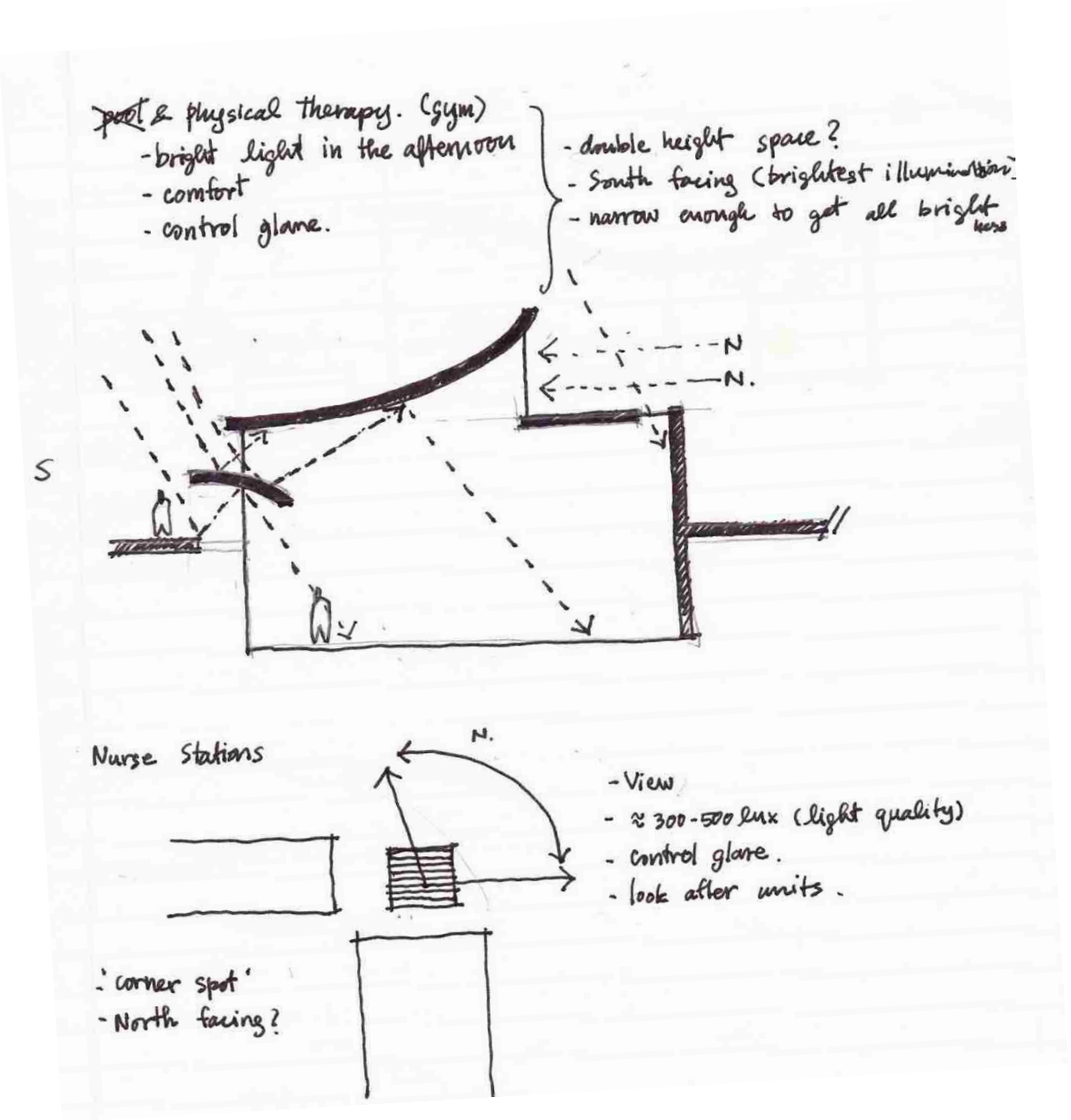


Figure46: Architectural design process4. Source: Author

Sketches





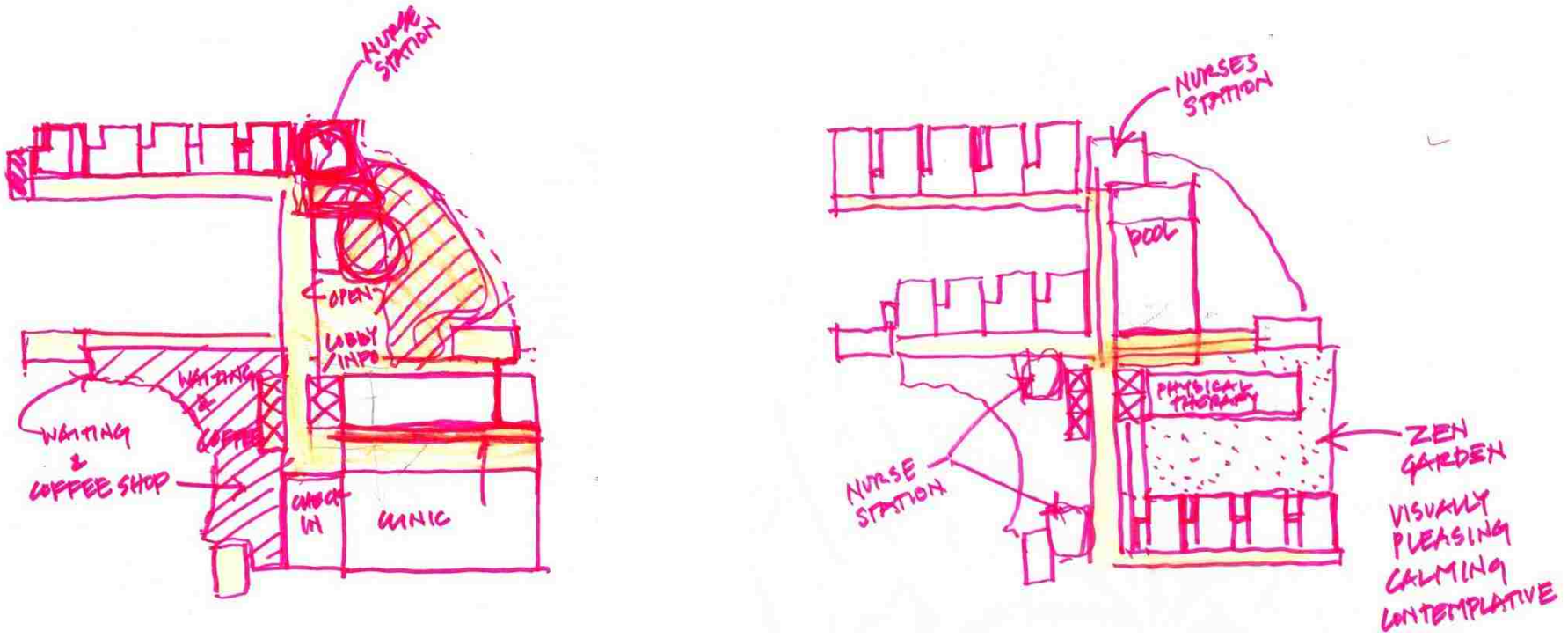
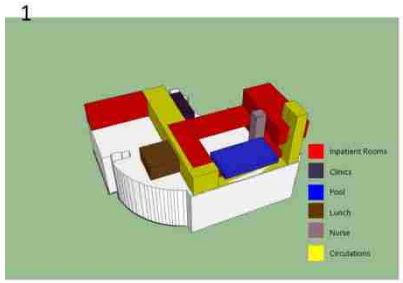
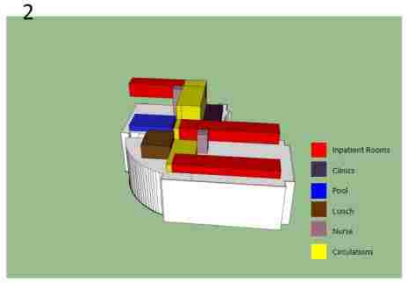


Figure49: Design diagram sketches. Source: Author

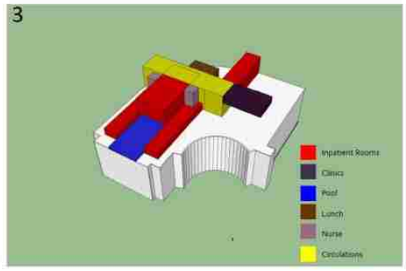
Schematic Model



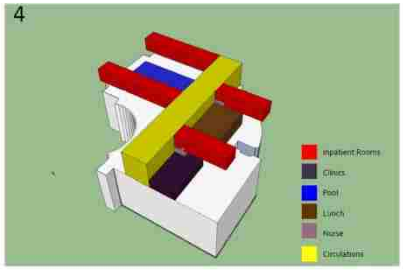
1. Open spaces in a center of the building. Enclosed with inpatient units. Other additional programs are close to open space as well.



2. Open spaces are still in a center of the building. However, patient units are higher in sequences from East side of the building to provide a maximum East morning light. Other programs are mostly on the South side to receive as much sun as possible in the afternoon.



3. Open spaces are in a North side to reduce glare problems when they are being used. Inpatient units are mostly on the West side of the building. Then on the East side provides more open space on the first floor so those inpatient rooms are not blocked from the East morning light.



4. All open spaces and other additional programs are on the first floor and inpatient rooms are in a higher level. A single row design has applied to inpatient rooms in this scheme.

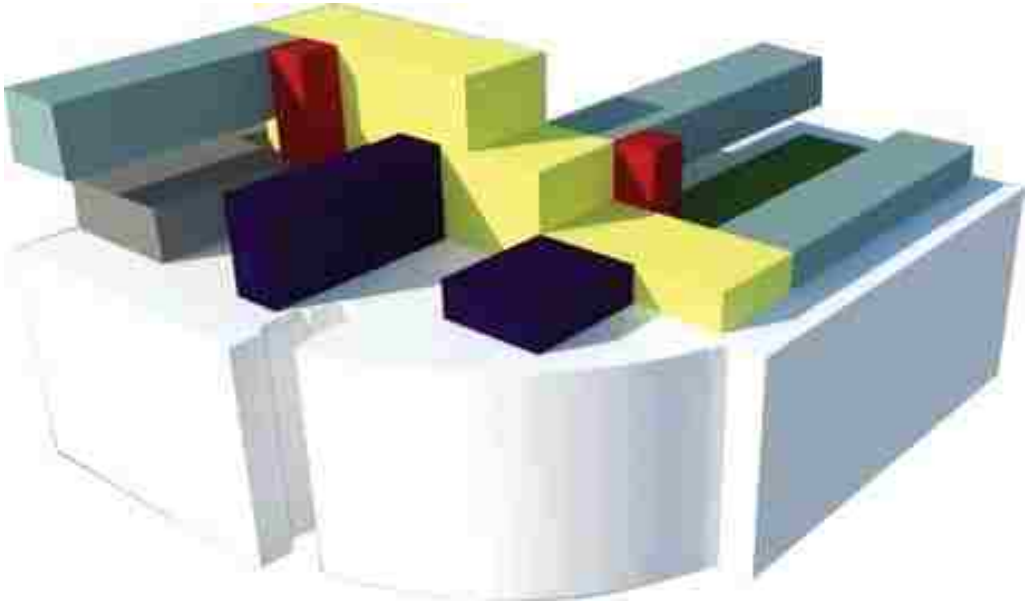


Figure50: Final schematic design. Source: Author

Main Circulation
Inpatient Units
Physical Therapy / Lunch Area
Nurse Stations
Healing Garden
Clinics

The final schematic model is a development from the 2nd scheme. Having inpatient rooms (light blue) in a single row design helps units to receive daylight in all directions. Other programs such as; swimming pool, physical therapy, and lunch area where need brightest light in the afternoon, these area are in the South side of the building.

Open spaces (healing gardens) are set to be in the center of the building, create new courtyards. These courtyards help improve daylight quality within spaces. Moreover, these gardens provide good natural view and deliver to users.

Nurse stations are located at the areas where easily accessible to patients (corner spot). These nurse stations are facing to North direction which will reduce glare problems. While ambient light for their task is still provided. Accessible to view outside is also a consideration for the nurse stations.

Clinic is on the first floor with an easy accessible from the main circulation (elevator hall). This space is facing to the West side of the building

The main circulation of the building is located in the center area of the building and lie from West to East. Other areas are connected to this main circulation.

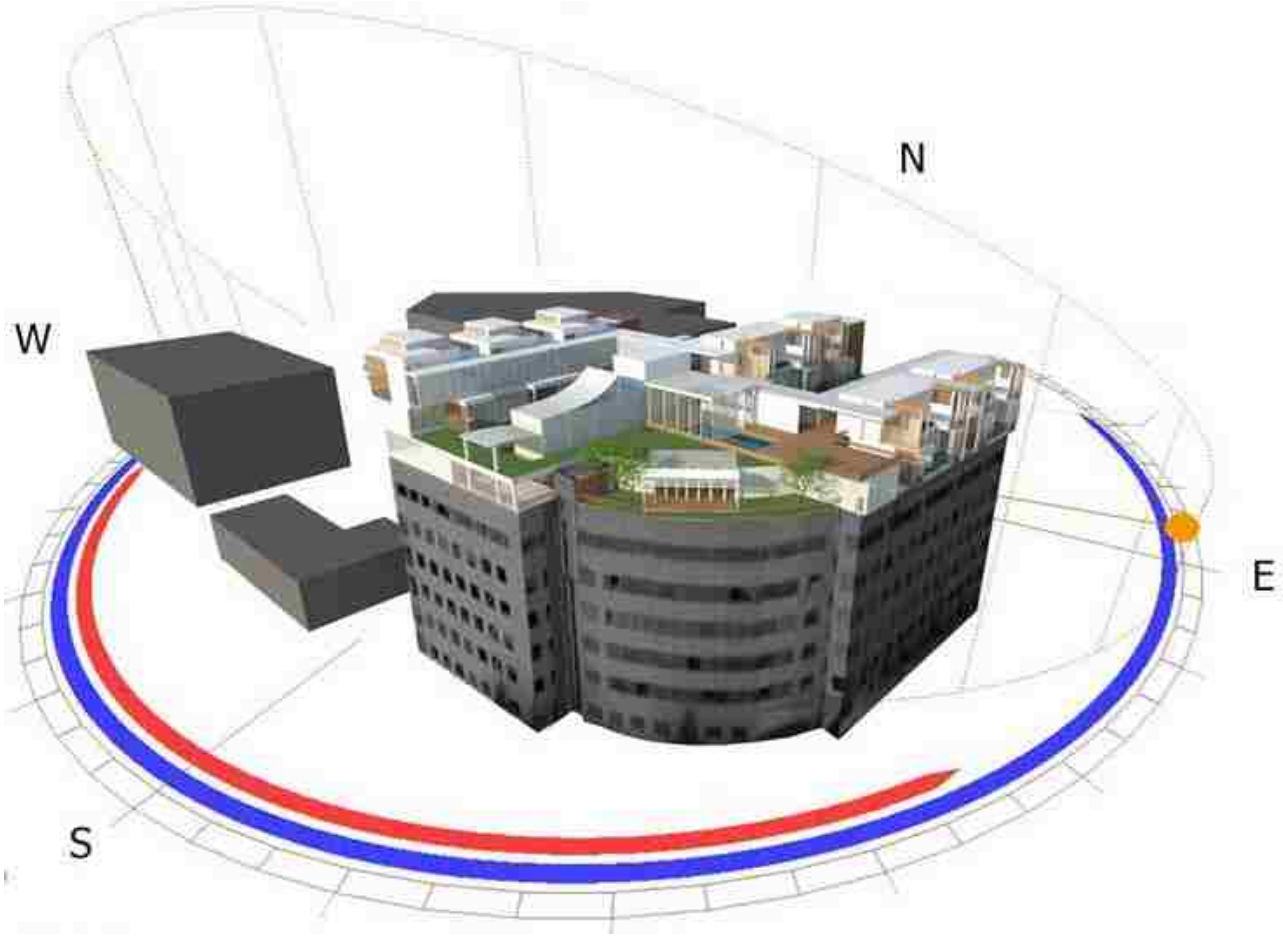


Figure51: shows a developed building from the schematic model. Source: Author

1. Inpatient Units
2. Acute Inpatient Units
3. Reception Area
4. Nurse Stations
5. Physical Therapy
6. Coffee Shop
7. Check-In/ Consultant
8. Pool
9. Sundeck
10. Clinic
11. Shop
12. Storage
13. Elevator
14. Stair
15. Restrooms
16. Blood Draw/ Injection Area
17. Healing Garden
18. Lunch Area

Main Circulation
Inpatient Units
Physical Therapy / Lunch Area
Nurse Stations
Healing Garden
Clinics

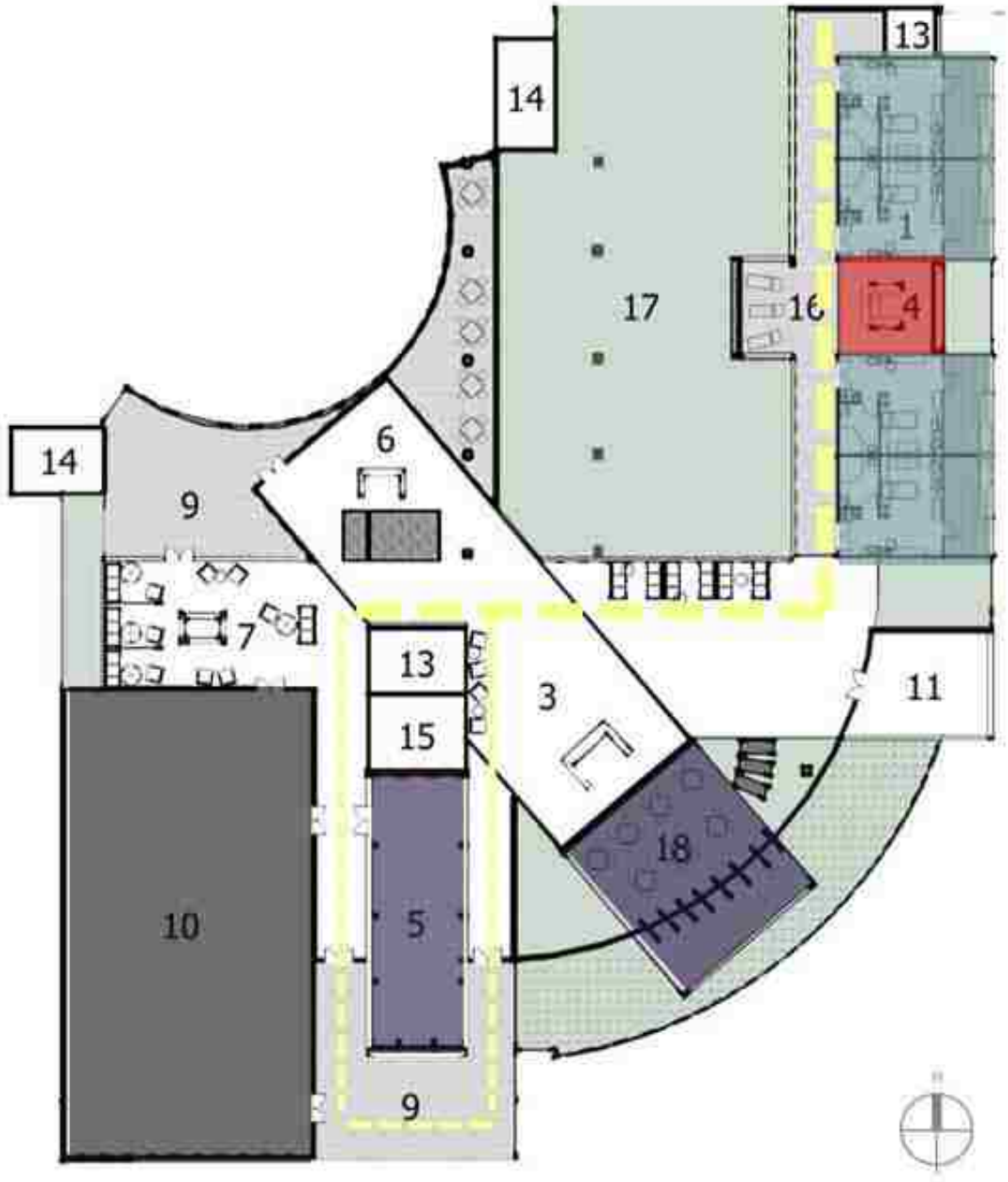


Figure 52: 7 Floor Plan

1. Inpatient Units
2. Acute Inpatient Units
3. Reception Area
4. Nurse Stations
5. Physical Therapy
6. Coffee Shop
7. Check-In/ Consultant
8. Pool
9. Sundeck
10. Clinic
11. Shop
12. Storage
13. Elevator
14. Stair
15. Restrooms
16. Blood Draw/ Injection Area
17. Healing Garden
18. Lunch Area

Main Circulation
Inpatient Units
Physical Therapy / Lunch Area
Nurse Stations
Healing Garden
Clinics

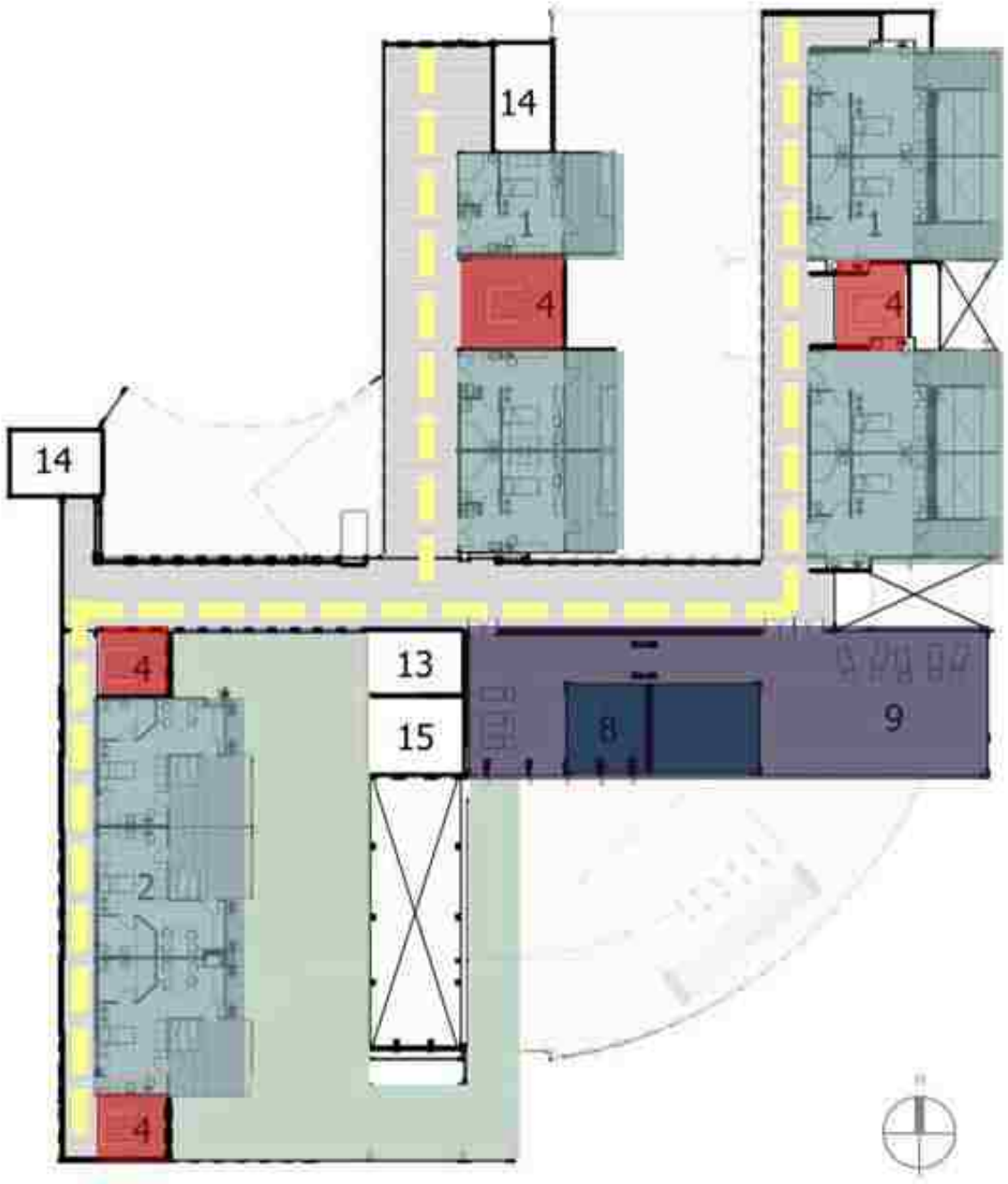


Figure 53: 8 Floor Plan

1. Inpatient Units
2. Acute Inpatient Units
3. Reception Area
4. Nurse Stations
5. Physical Therapy
6. Coffee Shop
7. Check-In/ Consultant
8. Pool
9. Sundeck
10. Clinic
11. Shop
12. Storage
13. Elevator
14. Stair
15. Restrooms
16. Blood Draw/ Injection Area
17. Healing Garden
18. Lunch Area

Figure 54: 9 Floor Plan

Figure 55: Section A

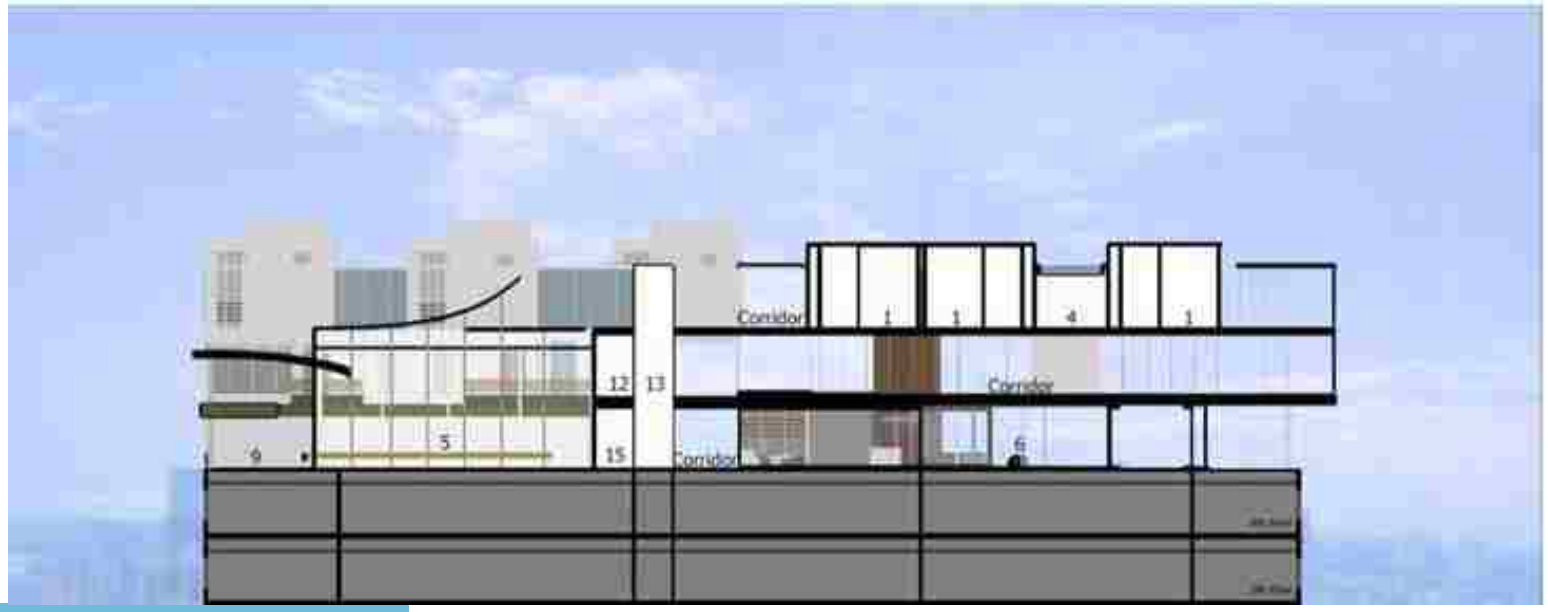


Figure 56: Section B

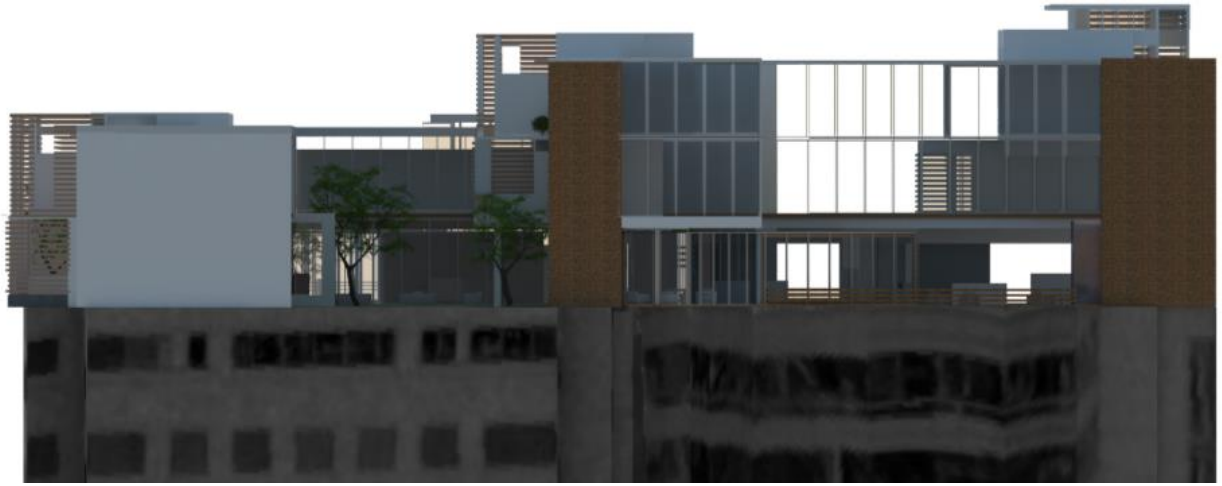
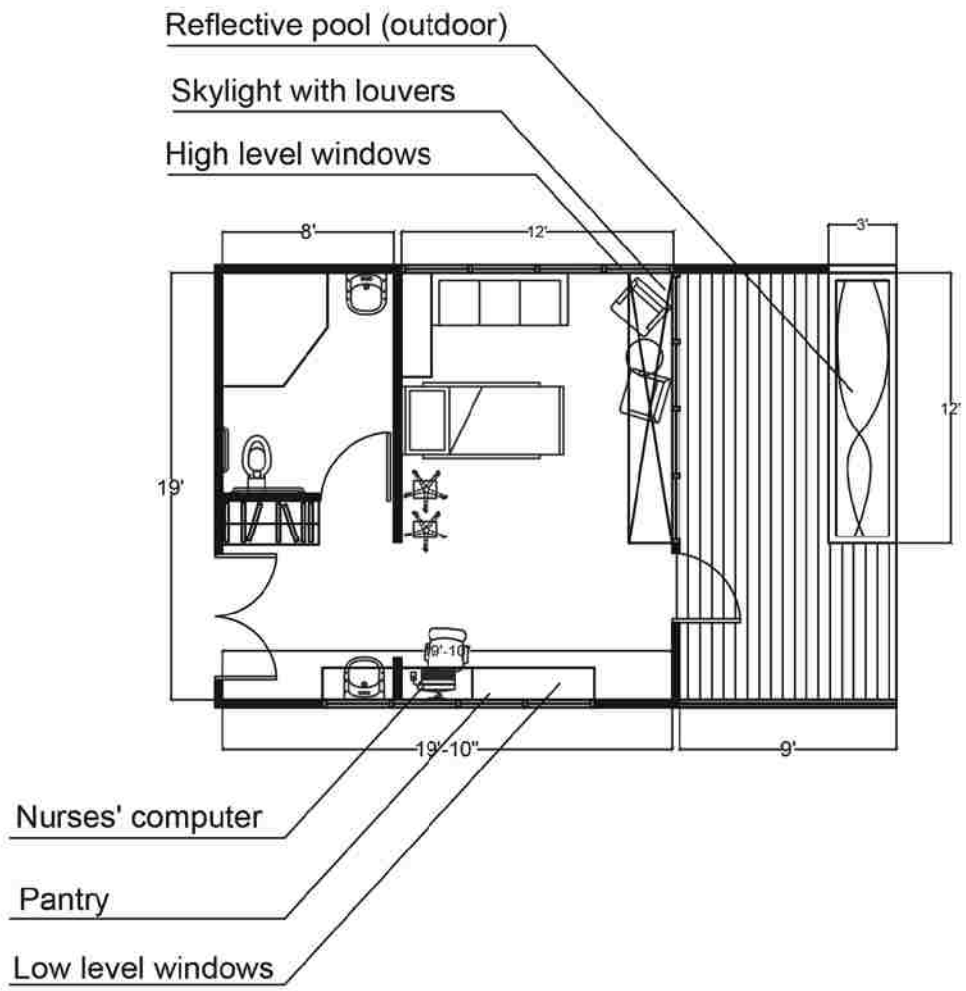


Figure 57: North Elevation

Figure 58: South Elevation

Figure59: East Elevation

Figure 60: West Elevation



The type A room:

East- West facing with reflective pool on the East helps reflect blue light in the morning into the room on both floors (skylight over the deck to provide reflected light to upper units). The pool also acts as a natural feature for the room.

The room provides a small living area for family members and patient activities. Openings are designed to receive an optimum brightness and view from outside. Other amenities as described.

Figure 61: Type A Room Layout. Source: Author

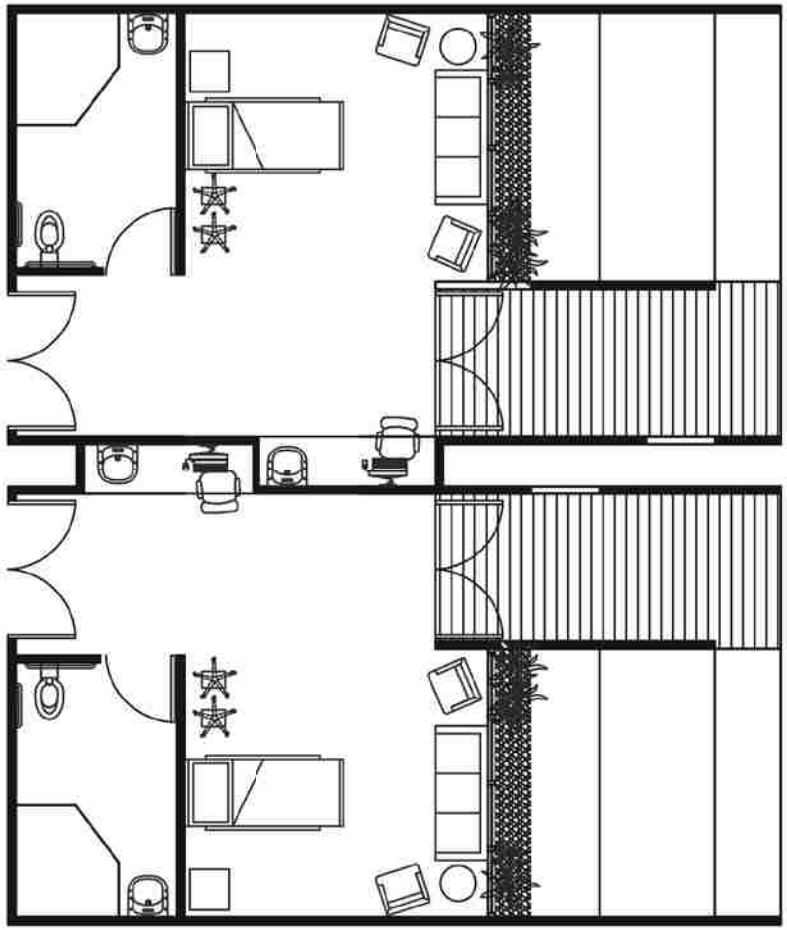


Figure 62: Type B Room Layout. Source: Author

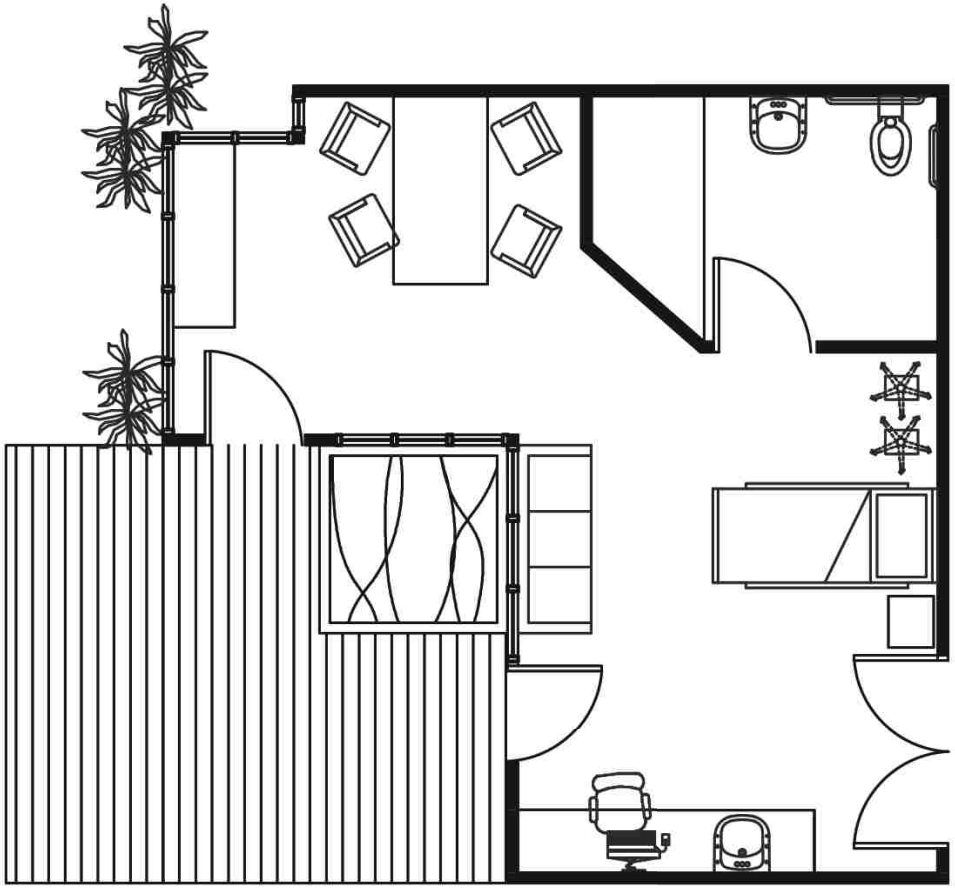


Figure 63: Type C Room Layout l acute units with private Jacuzzi. Source: Author

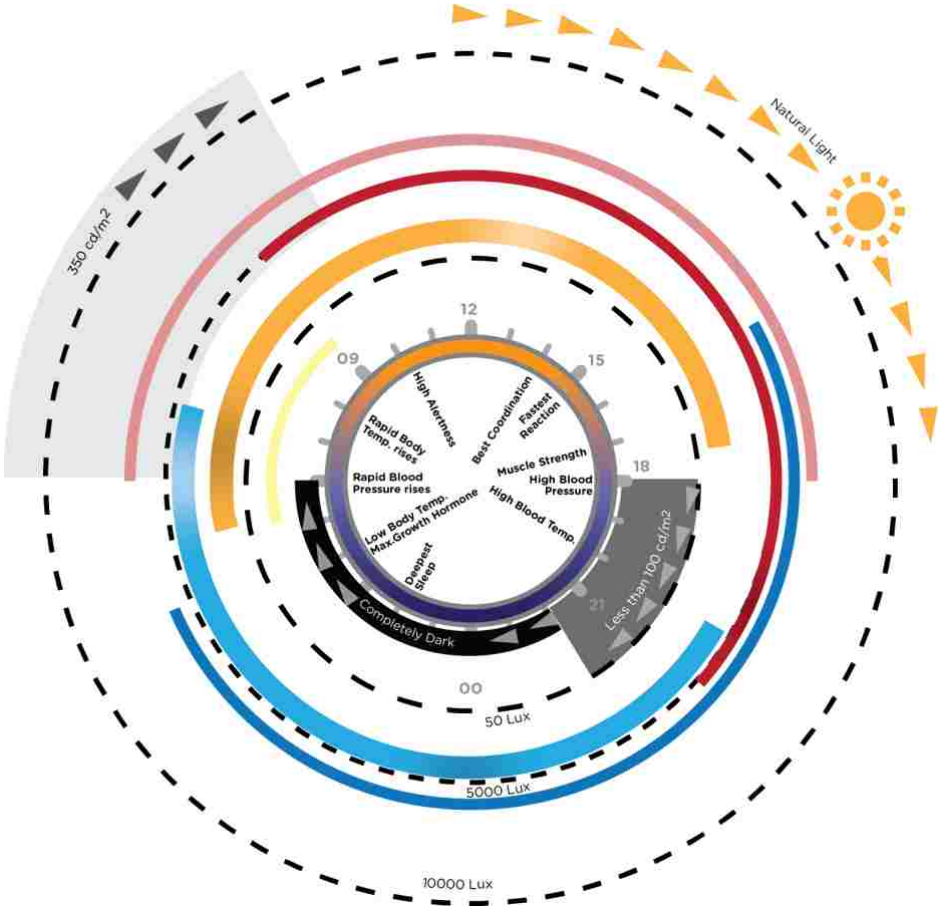


Figure 64: Lighting design criteria based on the circadian wheel. Source: Author

4.6 Lighting Design

4.6.1 Conceptual Design

Light and Dark therapy has been incorporated and adapted into the project's lighting design concept.

Traditional light therapy: By using a 24"x 24" light box. The main idea of the light box is to provide 10,000 lux. With the situation that daylight is provided, the less Illumination can be considered. In this case the illumination is set to less than 5,000lux because of bigger openings to daylight atmosphere outside. This therapy will take around 1- 1 ½ hours a day.

Traditional dark therapy: Ideally situation is to have patients stay in a completely dark space at night. However, that idea is not practical. Therefore, creating a close to dark space situation has taken place. This can be achieved by blocking blue light that would regulate circadian light and keep atmosphere dim with a low illumination (50lux). However, higher illumination task lighting task light is provided to patients.

Morning Hours	Luminance Level : >350cd/ m2 Illuminance Level : 10,000<5,000 lux Color Temperature: 4,000- 5,000K
Noon/ Afternoon	Day lit spaces
Evening Hours (6-8 pm)	Luminance Level : <350cd/ m2 Illuminance Level : 50 lux (general) Color Temperature: 2,800K

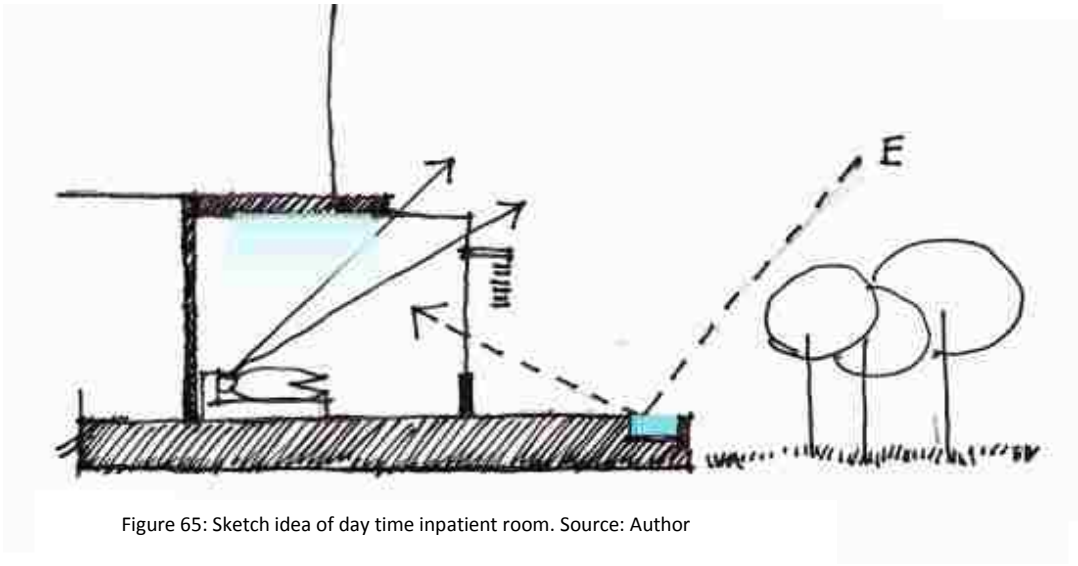


Figure 65: Sketch idea of day time inpatient room. Source: Author

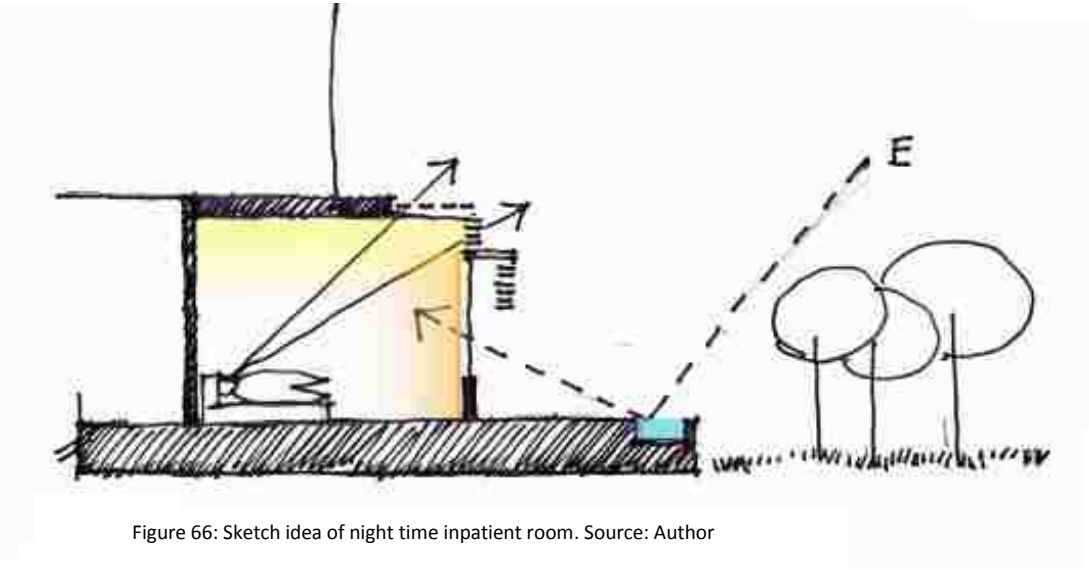


Figure 66: Sketch idea of night time inpatient room. Source: Author

4.6.2 Lighting Design Strategies

Daytime

Daylighting: Lighting design strategies for the day time in inpatient room is focusing on receiving a bright morning blue light of the East. Adding a reflecting pool that is going to reflect the blue wavelength into the inpatient units help achieve what the circadian rhythms need.

Electric lighting: Electric lighting has been provided with a cool color temperature for creating a high illumination space when it needs (overcast sky days). Back lit lighting at the ceiling act as a big light box for patient on cloudy days. Cove lighting with 2color temperatures that could supplement ambient illumination. At day time this cove is in a cooler color temperature (4,000K). These two lighting options are dimmable.

Night time

Daylighting: Instead of having the blue light in the inpatient units, warm light is more needed. Amber curtain is used in order to screen blue lights out. Shading devices have been applied to openings to block other light pollutions from outside.

Electric lighting: Electric lighting has been provided with a very warm color temperature with a low illumination for ambient lighting (50lux). Back lit lighting at the ceiling could be turned off or leave it very low. Cove lighting plays more important role at night. It will provide a warm atmosphere to the units. The two options are also dimmable.

Figure 67: Mood images of daytime electric lighting design. Source: Barissol.com, http://farm9.staticflickr.com/8201/8164653051_f4552a2c8a_c.jpg

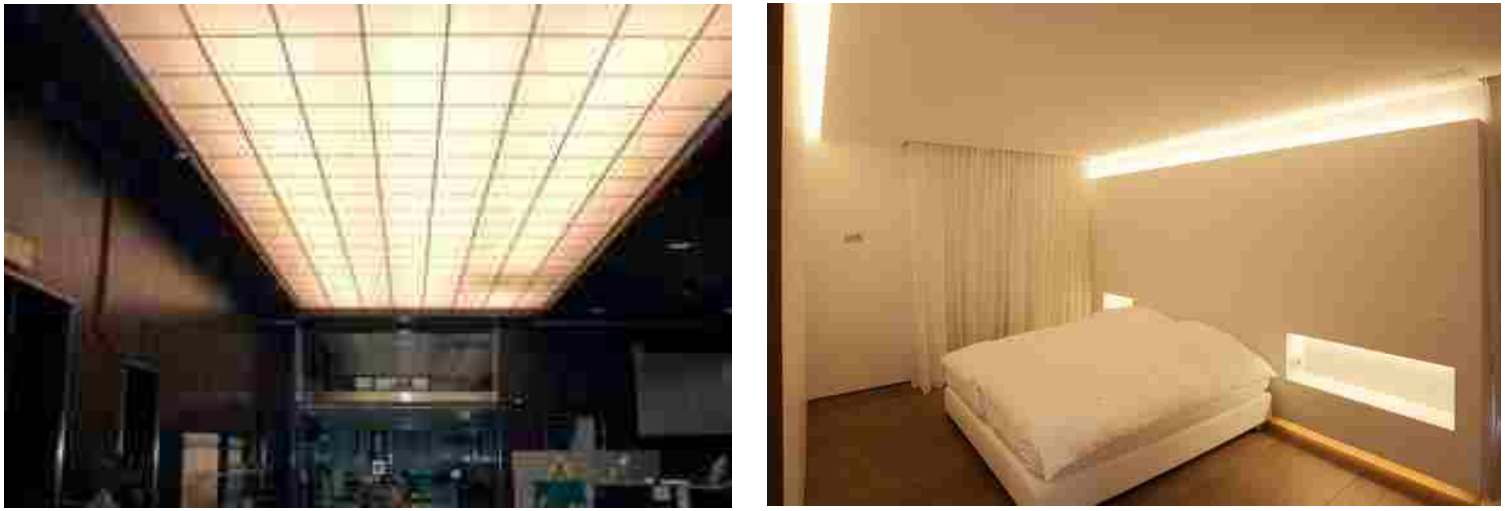


Figure 68: Mood images of nighttime electric lighting design. Source: http://www.lumco.eu/en/lumcove-200.htm, Barissol.com

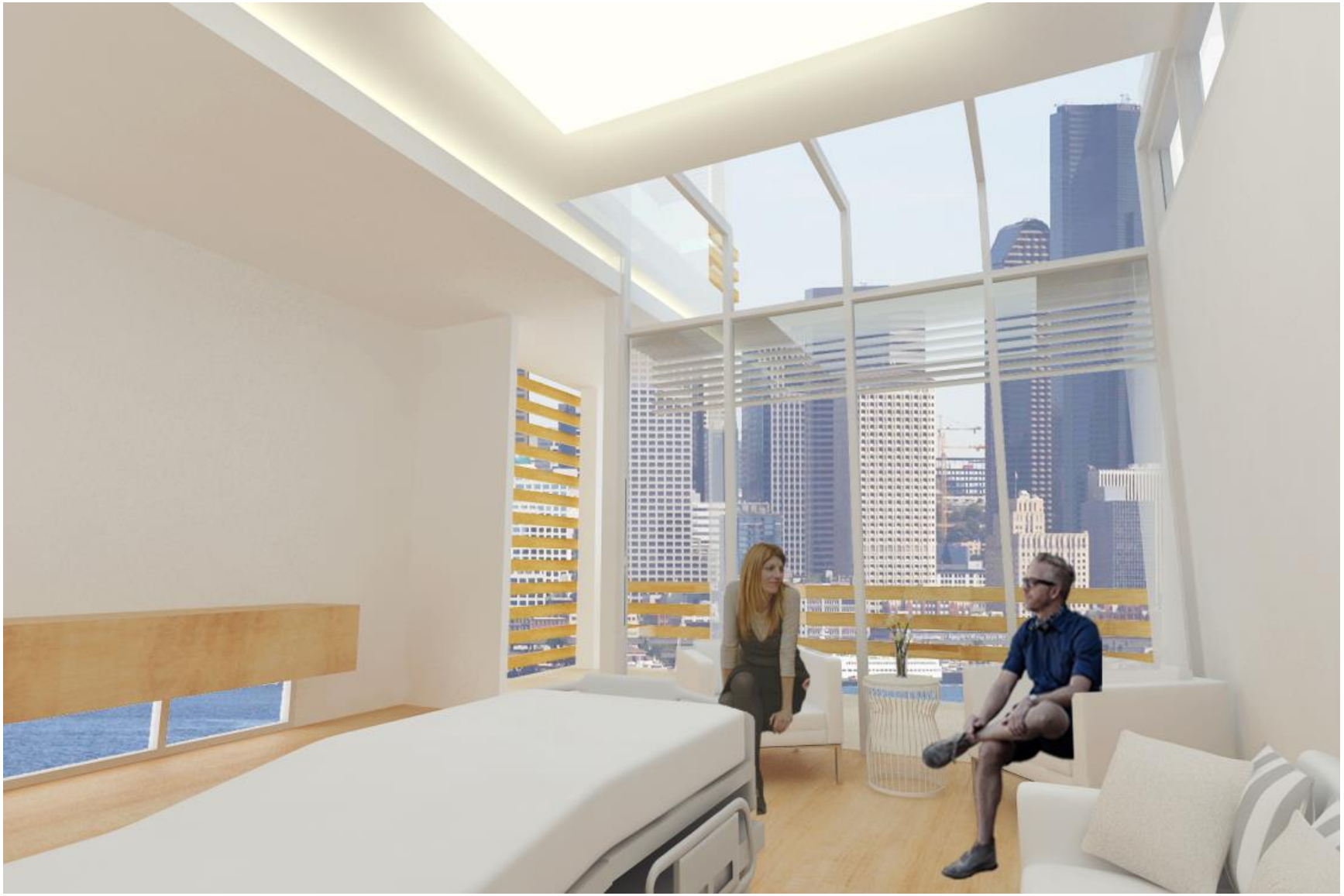


Figure 69: Day time inpatient unit. Source: Author

Figure 70: Night time inpatient unit. Source: Author

Day time luminance level.

The criteria are set at 350cd/ m2 and this calculation has proved that this value could be achieved with the design. At the windows where patient will look at is 360 or above. This high luminance value will help improve better circadian rhythms in patients.

Night time luminance level.

The criteria are set at less than 50cd/ m2 and this calculation has also proved that this value could be achieved with the design. At the windows where patient will look at are not exceed 50cd/ m2. This low luminance value will help the body relax with a better sleep.

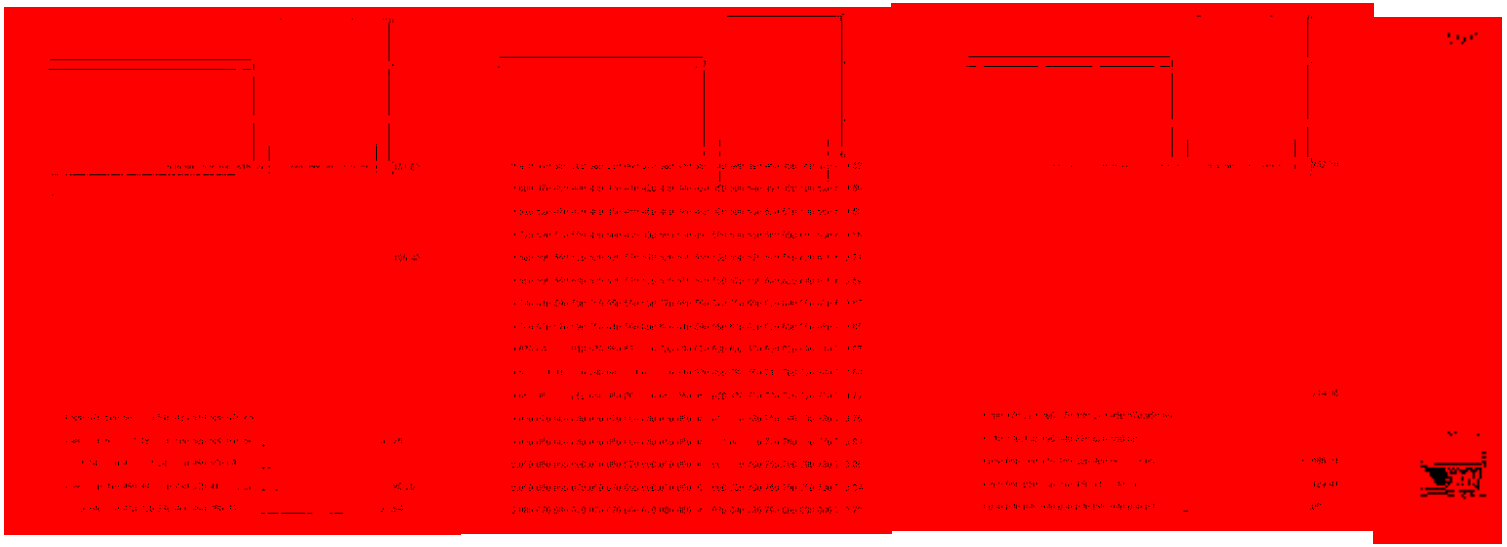
Figure 71: A comparison between day and night luminance maps. Source: Author

Figure 72: Day time illumination at 9:00am. Source: Author

Day time illuminance level

Illuminanace level has set to Scale 500- 5,000 lux as day time criteria set. The calculations were done in Seattle under clear sky and overcast conditions in 3 months; March, December, and June. The results from these calculations suggest a supplementary lighting from electric light sources. There are no absolute ways of achieving what we were expecting for.

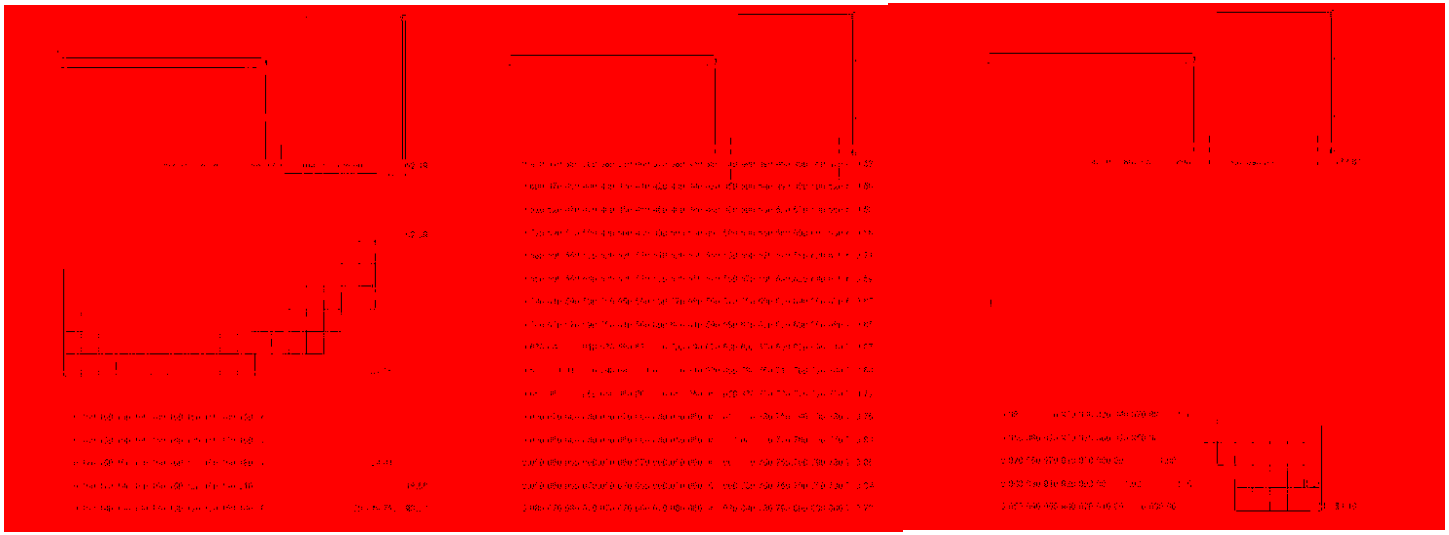
Focusing only in the area that patient will use regularly (bed), March and June are achieving illuminance level of 5000lux or more. In December, illumination is a little less than the criteria therefore, electric lighting needed.



type A l March 21st 6:00pm Clear sky

type A l December21st 6:00pm Clear sky

type A l June21st 6:00pm Clear sky



type A l March 21st 6:00pm Overcast sky

type A l December21st 6:00pm Overcast sky

type A l June21st 6:00pm Overcast sky

Night time illuminance level

The illumination criteria for night time were set at under 50lux. These calculations were done also done in Seattle under clear sky and overcast conditions in 3 months; March, December, and June. Sunset time is important and effect directly with these calculations. Notice that in December when the sun set very soon, illuminance values are less than 50lux which achieves the criteria. For another two months; March and June, curtain and other shading devices have to be applied.

Figure 73: Night time illumination at 6:00pm. Source: Author

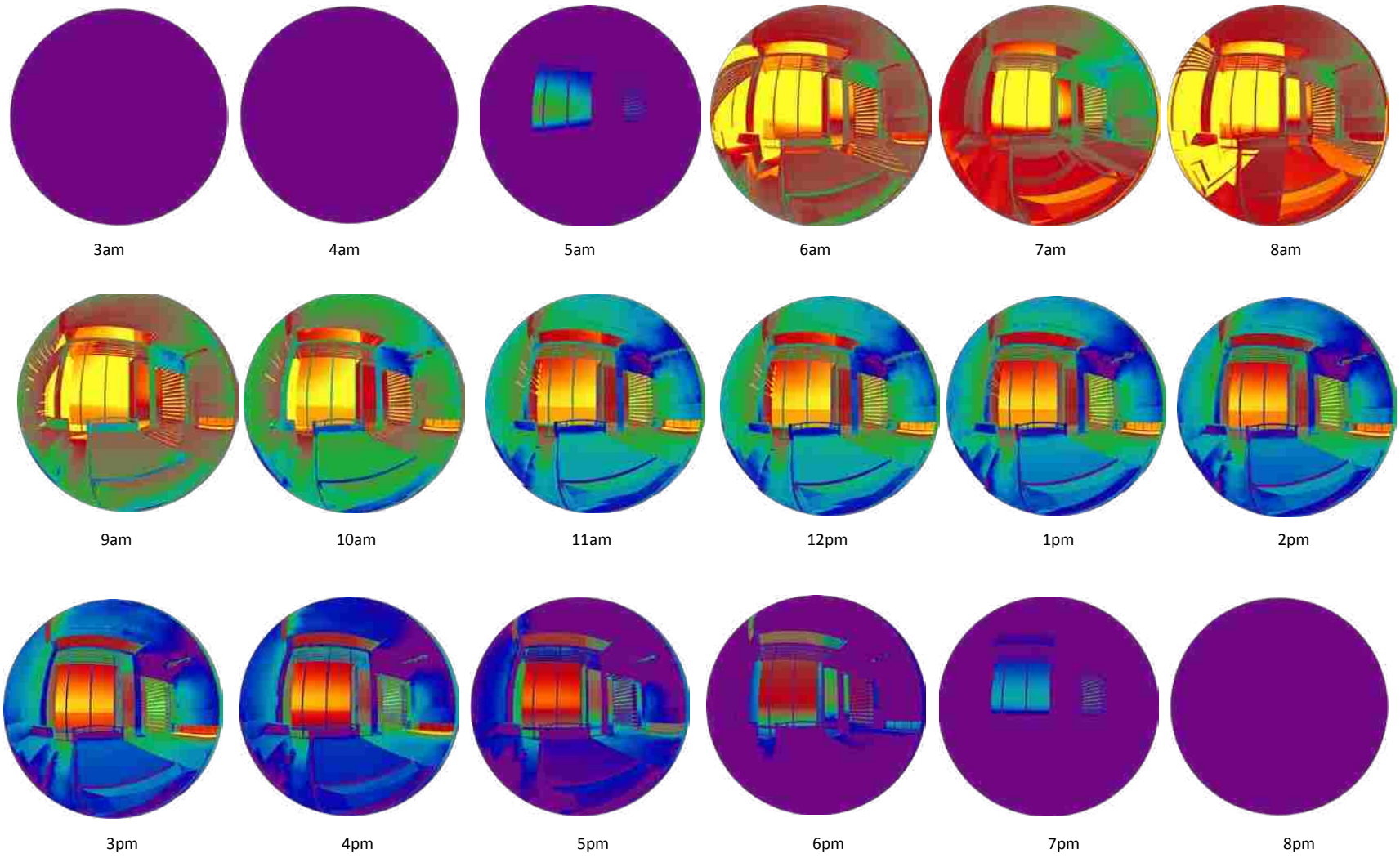


Figure 74: Luminance false color map calculated on a Sunny day; March 21. Source: Author

Figure 75: Exterior view l healing garden. Source: Author

Figure 76: Reception area. Source: Author

Figure 77: Walkway. Source: Author

Figure 78: Nurse station. Source: Author

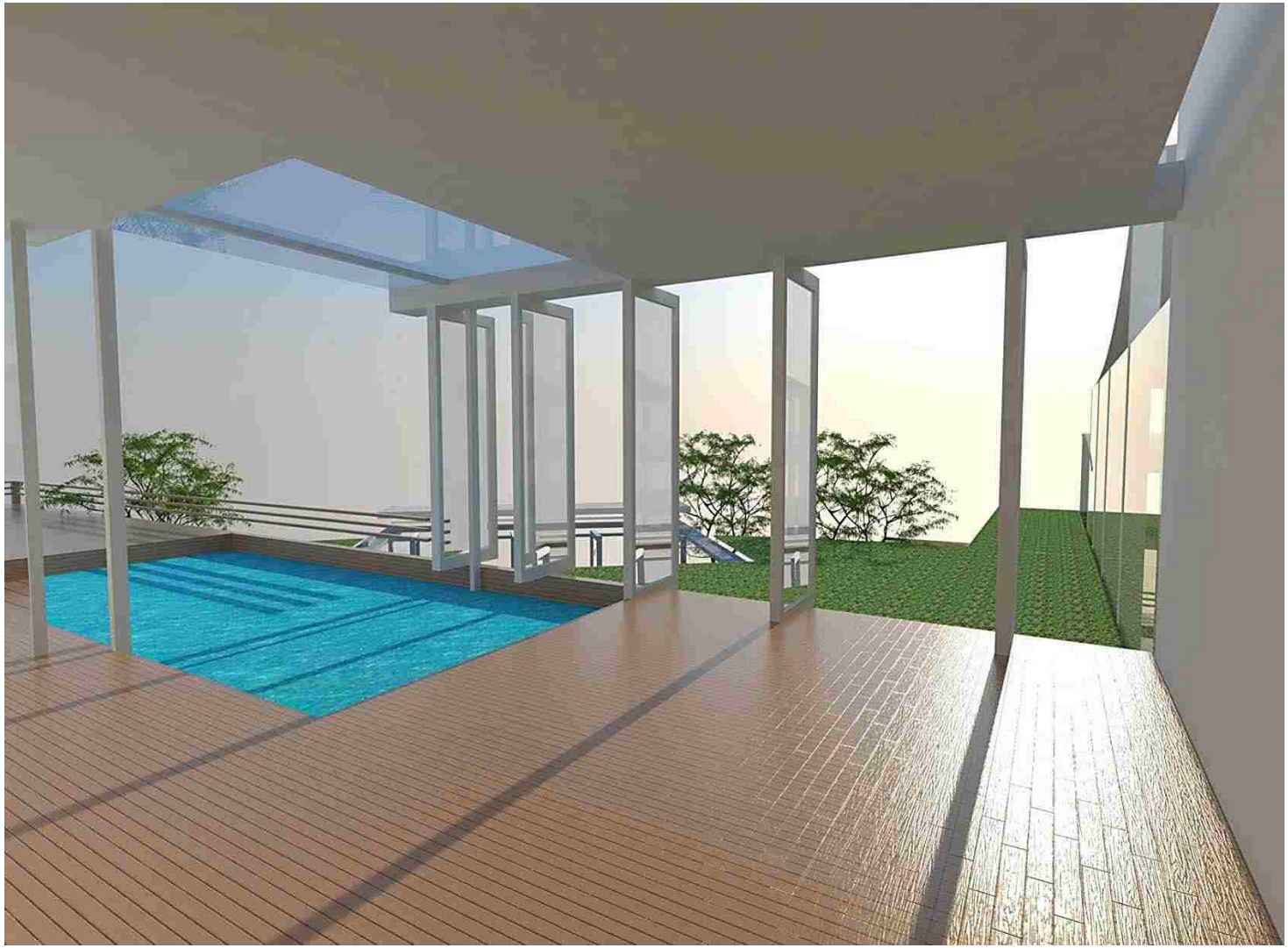


Figure 79: Swimming pool. Source: Author

Chapter5: Conclusion

Based on research, the ideal lighting condition for human's body is daylight. To design lighting in health care setting, the most important thing is to understand daylight and how it works with the body, especially with the circadian rhythm. In some climate zones that may not have adequate daylight time, an artificial daylight may be considered. Quality of brightness, color temperature, and variation throughout a day of daylight should be the heart of the design for patients to be able to recover better.

The time exposure to daylight is very important. In the morning between the time one wakes to 10 Am., the eyes should be exposed to a good amount of blue wavelength zone. This will help regulate better hormones that will result in a healthier circadian rhythm. At noon and afternoon, being outside and enjoying the sun is best. The evening is when the body needs to relax; exposure to warm dimmed light is preferred.

Orientation of each space is also critical. Not only orienting the building to receive much daylight but also have to think about where to avoid light at a certain time. For example, orienting inpatient rooms to East and West would benefit from daylight in the morning and dimmed light at night. On the other hand, the nurse station does not require that.

Therefore, understanding daylight and circadian rhythm, time exposure, and orientation are the three main concepts of creating a good and healthy inpatient care facility.

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