I, Danielle Caylor, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture (Master of).

It is entitled:

InHabit: Physiology and Architecture in Time

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inHABIT
Physiology and Architecture in Time

A thesis submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of Master of Architecture in the School of Architecture and Interior Design of the college of Design, Art, Architecture and Planning by

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abstract

Inherent in the discourse about energy and ecology is the pursuit of an optimal relationship between how we live and the resources we use to meet our needs. Organisms and species have evolved metabolic and behavioral strategies to optimize energy expenditure and food intake that are inextricably linked to the patterns and cycles of daily, lunar, and seasonal change. Current research in the fields of neuroscience and chronobiology reveal increasingly nuanced accounts of how our bodies have evolved to interpret these cyclical conditions. For example, the circadian clock tells our bodies not only when to wake up and fall asleep, but also when to digest certain nutrients, improve cardiovascular efficiency, as well as when to feel the most alert, energized, dexterous, or drowsy.

While many of these processes happen automatically within the body, they rely on external cues to stay synchronized. Multiple medical studies have demonstrated the altering effects of artificial lighting on hormonal cycles, and have linked continual disruptions of this kind to such prevalent diseases as cancer, insomnia, depression, diabetes, and obesity—
revealing a systemic inefficiency in the cultural expectations of human performance over time.

Architecture, then, as the choreography of physiological stimuli, plays a major role in determining the expression of these sensory signals through material choice, lighting design, and the construction of the thermal envelope. Americans now spend as much as 90% of our time indoors while we push for longer working hours and 24-hour services. Facilitating this cultural shift away from diurnal and seasonal schedules, building technology has become increasingly hermetic, as evidenced by the ubiquity of electric lighting and HVAC-controlled interior climates. While seeking to maintain constant conditions for human comfort, we have ignored the temporal dimension of design, and bypassed potentially synergetic strategies to optimize the performance of both body and building.

This thesis explores notions of habit and habitat by focusing on how human routines can be integrated with rhythmic variation. Beginning with environmental and physiological factors, this project presents an alternative design process that embraces variability in order to reassert the value of rhythm and ritual in current cultural practice.
contents

01 Inhabit

02 Body Building
How the body and architecture have looked to science and medicine to build healthy places.

03 Telling Time
How our body knows what time it is, and why this matters to architecture.
1. Light
2. Temperature
3. Social Patterns

04 Keep the Beat
How we can build habits and places that are in tune with the natural world.
illustrations


p.7 www.skiresort.infor/ski-resort/bormiocima-bianca/accomodations/b769.jpg

p.8 www.philipperahm.com/data/projects/winterbeach/index.html.jpgwbe1


p.11 www.flickr.com/photos/moritzberndtly/4888113657/sizes/o/in/photostream.jpg


p.28 "Herzog and de Meuron: Dominus Winery." Napa Valley, C.A. travelmodus.com/dominus-winery-napa.html


p.30 www.spc.rs/sr/svechano_bdenije_u_manastiru_visoki_dechani.jpg.


p.35 Harper, Sharon. From Above and Below. Santa Fe: Radius


p.53 www.telegraph.co.uk/health/healthnews/6413613/Bright-lights-at-night-making-us-more-depressed.html.jpg


p.71 Ditmeyer, Anne S. "Paris Marathon." www.4.bpblogspot.com/_QoYfiP-MPLk/T4sU1dIpoLAAAAAAAAAAAXg/0YqFWRwWXLY/s1600/pretavoyager-parismarathonband.

p.72 http://www.knowth.com/stonehenge.htm

p.72 http://www.greenmuseum.org/e/aen/ImagelEcology/Lankford/serpent.php


p.84 By Author

p.85 www.mcachicago.org/exhibitions/now/2012/201.jpg
p.88 www.artvisualdigest.blogspot.com.jpg
p.88 www.hokonouzemi.exblog.jp_nyyrmaki_chapel.jpg
p.97 Derome-Masse, Valerie (photographer). "St Exeter Library." http://www.flickr.com/groups/86873346@N00/pool/page2/?view=lg
p.99 www.virtualtourist.com/europe.italy/bologna/13/htm.jpg
we don't live this way anymore
we live like this:
inhabit\textsuperscript{1}

\textbf{a. trans.} To dwell in, occupy as an abode; to live permanently or habitually in (a region, element, etc.); to reside in (a country, town, dwelling, etc.). Said of men and animals.
habit²

8. The way in which a person is mentally or morally constituted; the sum of the mental and moral qualities; mental constitution, disposition, character.

9. a. A settled disposition or tendency to act in a certain way, esp. one acquired by frequent repetition of the same act until it becomes almost or quite involuntary; a settled practice, custom, usage; a customary way or manner of acting.

e. spec. in Psychol. An automatic, ‘mechanical’ reaction to a specific situation which usually has been acquired by learning and/or repetition.
For wherever there is an extraordinarily broad range of seasonal variations, where there is a very wide range of temperatures, there we find numerous differences in bodily habits, character and constitution. It is these causes that most profoundly modify human nature.  

-Hippocrates

This investigation began with the recognition of a simple truth: all human behavior, habits and customs are both influenced by the environment and act as a force of change on that environment. In fact, the words themselves, habit, habitat, inhabit, all come from the same Latin root word habere, also related to behavior, meaning the state or condition one is in, or ‘how one is?’ Embedded in this definition is the idea of regular and repeated actions related to not only what a person does, but when, why and how a person does it. The reasons behind why we behave the ways we do are inexhaustibly complex, but insight into the fundamentals of biology and psychology reveal relevant relationships between how we live and the environments that facilitate these lifestyles.
Architecture theorist Christian Norberg-Shulz, in his manifesto *Intentions in Architecture* poses the following questions: “What we need is a conscious clarification of our problems, that is, the definition of our building tasks, and the means to their solution… What purpose has architecture as a human product? How does architecture (the environment) influence us?”

In order to begin to find answers, he asks whether “particular forms ought to be correlated with particular tasks” and looks to history to uncover the relationship between architectural form and the traditional methods of providing solutions for specific temporal-spatial problems.

We know from everyday life that different activities, even the simplest acts of sleeping and eating require particular spaces to be carried out in a satisfactory way, yet the nature of these places is highly dependent on social, cultural and climatic conditions. For example, a church needs to have space and seats for people to gather. An office needs a desk and a chair. A bedroom needs a bed. But beyond these tangible items, there is the equally important character of the place, its mood and atmosphere: A church needs to inspire divine meditation. An office needs to allow for concentration and efficiency. A bedroom needs to invoke rest and relaxation. Each of these unique
atmospheres is comprised of a specific quality of light, air, space and time that distinguish a given place for a given purpose. In this way, “there are not different ‘kinds’ of architecture, but only different situations which require different solutions in order to satisfy man’s physical and psychic needs.”

Inherent in this sentiment is the notion that certain qualities of space are appropriate not only for the purpose of the activity, but also the health and well-being of the people using it. Throughout the history of architecture, what activities we do and the places where we perform these functions has always been tied to existing notions of health—whether formulated by religious beliefs, cultural taboos or the science of the day. This chapter covers ways architecture has used existing knowledge of biology and psychology to ‘build’ healthier and better ways of life—with important implications for the body.

“Whoever wishes to pursue properly the science of medicine must first proceed thus. First he ought to consider what effects each season of the year can produce; for the seasons are not all alike, but differ widely both in themselves and at their changes. The next point is the hot winds and the cold, especially those that are universal, but also those that are peculiar to each region… For knowing the changes of the seasons, and the rising and settings of the stars, with the circumstances of each of these phenomena, he will know beforehand the nature of the year that is coming… If it be thought that all this belongs to meteorology, he will find out, that the contribution of astronomy [calendar of the Greeks] to medicine is not a very small one but a very great one indeed. For with the seasons men’s diseases, like their organs, suffer change.”

-Hippocrates, Airs, Waters, Places

Ideas about how to live in a place in order to ensure healthy and happy lives are common to nearly every culture and can be traced back to some of our oldest ancestors. For example, Feng Shui is the Chinese art of arranging buildings and objects in space in order to achieve harmony and balance between the body and the environment. Evidence of this tradition may be
dated as far back as 6000 BC. It is widely believed that this practice “stemmed from ancient shaman who understood the vital importance of strategically placing a village. Areas that possessed mild winds would generate plentiful harvests while harsh winds would stunt crop growth or destroy the harvest altogether. In addition, the placement of a village in close proximity to flowing water and fresh springs would stimulate growth and ensure health, while stagnant water would foster disease and disharmony within the community. As the centuries passed, these shaman correlated their thoughts on wind and water with the teachings of Daoism, thus creating the practice of feng shui.”

This type of thinking in relation to the healthy placement and orientation of cities is also evident in Vitruvius’ Ten Books on Architecture, from his essay on how to site a city: “First comes the choice of a very healthy site. Such a site will be high, neither misty nor frosty, and in a climate not too hot nor cold, but temperate; further, without marshes in the neighborhood. For when the morning breezes blow…if they bring with them mists from the marshes…to be wafted into the bodies of the inhabitants, they will make the site unhealthy.”

For people living in the late 1800s, the town of


3. Ibid .

Saxon in the Swiss Alps was famous for its therapeutic waters. People would travel from surrounding neighborhoods, and sometimes from surrounding countries, to bathe in these springs, though no one knew exactly why these waters had such a healing effect. Research carried out in the 19th century discovered that the presence of iodine in the Saxon waters was essential for the production of thyroid hormones. This was significant particularly because people who lived in this region, due to a lack of iodine in the soil, frequently suffered from goitre, (like Graves Disease or hypothyroidism). This disease is related to the thyroid which can lead to anxiety, weight loss, stunted growth and moodiness. Thus, by visiting these waters rich in iodine, these places were effectively treating a population with a chronic lack of an essential nutrient.\(^5\)
Iodine is also found in large quantities in the ocean, in both the seawater as well as everything living in it (algae, fish, crustaceans). With the knowledge that iodine is beneficial for health, the therapeutic advantages of sea bathing contributed to the widespread popularity of seaside resorts and the whole idea behind vacation at the beach, which before this time attracted little attention from international travelers. These traditions—now considered more recreational than therapeutic—persist to this day. The custom of drinking and bathing in mountainous mineral water is evident by the popularity of spas and baths throughout these regions of Europe, and the waters are sold in bottles all over the world.

Swiss architect and artist Phelippe Rahm demonstrates the physiological components of these places in an architectural installation titled *Winter Beach*. Built in a museum in France, Rahm re-creates the physiological functions of the beach and its therapeutic properties by using “just one or two phenomena, sun and spindrift, suntans and iodine: a certain radiation and its angle of incidence, an aerosol and a certain chemical composition, a few summer, seaside phenomena that are remade indoors, in midwinter.”6 By infusing the air with a marine aerosol, or iodine-rich spray, in addition to providing
the same electromagnetic frequency of UV-A rays present at a Mediterranean beach in summer and heating the space to around 82°F, the interior atmosphere starts to take on, not the appearance, but the atmosphere of being at the beach—where light, smell, taste and touch form the basis of an architectural experience.
The belief that places can have healing qualities was also common to the project of the early modernists, where health and hygiene were fundamental to the strategies architects and city planners employed to try to solve the problems of their day. The hygienic focus of this movement incorporated cross ventilation, white walls and hard surfaces, meant to ameliorate the squalid conditions of cities at that time. Within the machinic discourse of Modernism, incorporation of psychological and physiological factors, as seen in works by LeCorbusier and Alvar Aalto, points to a belief in architecture’s power to promote the efficient (and thereby healthy) functioning of the body. Echoing this sentiment, Alvar Aalto suggests that “the wrongness lies in the fact that the rationalization has not gone deep enough…the newest phase of Modern architecture tries to project rational methods from the technical field out to human and psychological fields.”

Most notably, the invention of the Sanatorium, invented to treat the Tuberculosis epidemic, evinces the influence of architecture as a healing force. The Paimio Sanatorium in Finland, designed by Alvar Aalto in 1929, demonstrates this conviction with its natural setting, efficient floor plan and thoughtful details. For Aalto, “the main purpose of the building
is to function as a medical instrument… One of the basic prerequisites for healing is to provide complete peace…. The room design is determined by the depleted strength of the patient, reclining in his bed. The colour of the ceiling is chosen for quietness, the light sources are outside the patient’s filed of vision, the heating is oriented towards the patient’s feet and the water runs soundlessly from the taps to make sure that no patient disturbs his neighbour.”

For this project, Aalto developed a host of technical solutions to consider the functional, psychological and physiological factors specific to the hospital, and considered it an essential function of architecture. Even the cheerful yellow floor of the hallway and stair were meant to the feeling of sunshine even in the winter months. Although the standard inclusion of balconies for patients to breathe fresh air was believed to be a major source of therapy, later scientific discoveries revealed that it was actually other factors that contributed to the healing of this condition: bright, therapeutic light un-shrouded by smog or the shadows of surrounding buildings, as well as the reduced oxygen content of the air in the high altitude mountains where many of these sanatoria were located.
Rahm’s project Hormonorium reproduces this kind of ‘healing’ mountainous environment in a technical exhibition of the effects of light intensity and oxygen levels on the body and psyche. The luminous floor of this all-white room is comprised of 528 fluorescent tubes creating an intensely bright space of greater than 7000 lux, typical of an alpine environment on a sunny day. Because the light is coming from the ground, as it would if snow were to reflect sunlight, the eyelids and eyelashes cannot filter the light—causing above normal suppression of the hormone Melatonin which may lead to feeling a decrease of fatigue, likely increase of sexual desire and regulation of mood.11

Philippe Rahm notes, “The sanatoriums of the early twentieth century, with their long windows facing south, their balconies, and their functional hygienic white architecture, are the basis for the modern architecture program of the 1920s. The problem, however, is that with the arrival of antibiotics this architecture lost and forgot the reason for its forms, forgot its origin in medical and therapeutic needs to combat the unhealthiness of nineteenth-century cities…. So we are trying to redefine these elements, but with the new knowledge available today about the internal and biological mechanisms of the human being.”12
Both UV-A and UV-B light rays are emitted, allowing for the tanning of the skin, and synthesis of Vitamin D, respectively. Moreover, the air is thin; increased levels of nitrogen reduce the amount of oxygen in the air from 21% to 14.5%, levels typically found in elevations of about 3000 meters. This induces a light state of hypoxia which may cause slight levels of dizziness, confusion, disorientation or bizarre behavior, and even maybe a slight euphoria due to the release of endorphins. When exposed to these conditions for longer than ten minutes, there is a noticeable increase of erythropoietin (EPO) and hemocrit levels, as well as an improved cardiovascular strength and respiratory function. As this project clearly demonstrates, the function of traditional architectural qualities such as light, temperature and air have significant implications for the behavior, emotions, and well being of the humans who inhabit these spaces.

If specific architectural qualities can truly affect our bodies, emotions and behaviors in the ways described above, we are no longer just designing rooms with walls and windows. We are designing behaviors, emotions, and moods. We are, in a sense, designing the body. In the words of chronobiologist Anna Wirz-Justice, “the environment bathes us in a

EPO, is produced by the kidneys and stimulates the production of red blood cells, thereby increasing the supply of oxygen to the muscles. It lead to the common practice of athletic training in high altitudes, as prolonged exposure to low levels of oxygen can “increase the capillary density of muscle tissue, increase the volume of mitochondria where oxygen is used to generate energy,” and thereby “allow the body to perform longer and harder before becoming fatigued.”

Aside from its benefits for athletic performance, high altitude has also been associated with weight loss, as well as anorexia. Hormones such as leptin, neuropeptide Y, and galanin, associated with the metabolism of food and nutrients, are altered at high altitude.

13. Philippe Rahm and Jean-Gilles Decosterd, "Hormonorium," in Decosterd & Rahm (see note 1, Chapter 1), 321.


15. Ibid.
fluctuating physical world of light, temperature, atmospheric pressure, humidity, ions, gases, radiation… The physical phenomena are encoded by the appropriate receptors of the brain and body, and translated into physiological signals.”

This creates a hidden dimension of space that constitutes the character or quality of place, and is experienced through the body. Embodied perception, therefore, is not just the experience of the world through sensory information, but is perceived with “the whole body all at once” with such a totality that it is impossible to isolate any one of the visual, auditory, olfactory, haptic or other senses from the overall perceptive experience.

On the premise that space could and should be experienced with the senses, “the function of the senses tends to expand. They are no longer limited to receiving information that would then be culturally or psychologically decoded by thought. Rather, they are becoming an interface in the transmission of biological, chemical, physical and electromagnetic information between the external and the internal environments, between the extra-corporeal space in which information is emitted by objects outside our body, and corporeal space that of the nervous and endocrine systems.”

Significantly, therefore, the
threshold between what we want to define as self (body), and other (environment), can no longer be drawn at the skin: Air penetrates our lungs; materials permeate our skin; light entrains our hormones. In the same way, the notion of what is considered architecture cannot be limited to tangible spatial dimensions; the design of place must also include the invisible qualities of air, light, humidity and sounds with much more care given to understanding how our bodies interpret these factors.

Architecture, then, as the choreography of physiological stimuli, plays a major role in determining the expression of these sensory signals through material choice, lighting design, and the construction of the thermal envelope. Philippe Rahm acknowledges “we are at the boundary of transformation of human nature and the human mind… The interior of the body is an architectural component. These are points in time positioned between hope and anxiety. These are utopias that are morally difficult.”

In light of this increased responsibility, we are left asking, what then is moral architecture? With technology that can produce any type of climate, how do we know when to use it and what it should be like? Le Corbusier posits “the purpose of architecture is to
move us. Architectural emotion exists when the work rings within us in tune with a universe whose laws we obey, recognize and respect.”

In this sense, the role of architecture is to provide an opportunity for man to dwell within some kind of larger cosmic order, subject to the physical laws of nature which science perpetually uncovers.

By investigating the ways the body interprets the environment within the framework of circadian physiology, the following chapters present information pertinent to the problem of designing with, and not against, the natural rhythms of the earth. Instead of thinking merely about how we can make places that suit the way we live, it is also worth asking how we can develop ways of being that suit the places we live in. Hence, this thesis explores how architecture can promote human habits that work in harmony with the cycles and seasons of the natural world and help us to live healthier and more meaningful lives.

what *time* is it?
Time, finally, is the dimension of constancy and change, and makes space and character parts of a living reality, which at any moment is given as a particular place, as a genius loci.¹

Norberg Shulz

As demonstrated above, the character and mood of a place is also physiological—related as much to hormones within the body as to the environmental conditions outside it. In this way, it seems logical to conclude that the most appropriate design for a space would consider the needs of these three major factors: the program or activity, the atmosphere of the environment (its intangible qualities such as light, temperature, humidity) and the physiological condition of the body. One of the most important physical laws that ties these criteria together is time. Time is the underlying rhythm that structures all life and matter on Earth. As the globe turns on its axis and revolves around the sun, predictable patterns of day and night, summer and winter, rainfall and drought mark the landscape with the passing of time.

¹ Christian Norberg-Shulz, Genius Loci, 32.
EARTH’S TIME

DAY
The 24-hour cycle of light and darkness, which we know to be the day, is “the dominant natural synchronizer of natural rhythms.” One day represents the amount of time it takes the Earth to make one complete 360° rotation on its axis. If we divide 360° by 24, we come up the hour, or the time it takes the earth to rotate 15°. However, the precise duration for one complete solar day is 23 hours, 56 minutes and 4.09 seconds. Because the Earth is also rotating around the sun, the missing 4 minutes is due to the new location of the Earth relative to the Sun, about one degree different.2

MONTH
The calendar month is derived from the movements of the Moon. The Moon makes a complete 360° revolution around the Earth every 27.25 days, but because of the Earth’s orbit around the sun, the time it takes from one New Moon Phase to the next is about 29.5 days. This lunar movement not only influences the tides and is responsible for several biologic phenomena, but also serves as the basis for a number of calendars.3


3. Ibid, 71.
The year, made of approximately 365 days, is defined by the revolution of the Earth around the Sun in an elliptical pattern. Because the Earth’s axis is tilted 23.5° away from the Sun, at different points in the Earth’s orbit, the Northern and Southern Hemispheres are either tilted towards or away from the Sun. The point in the Earth’s orbit where the Northern Hemisphere is tilted towards the Sun, and therefore receives the most direct sunlight, is known as the Summer Solstice, which occurs near June 21. The opposite is true near December 22, or the Winter Solstice, when the Northern Hemisphere is tilted away from the Sun and receives the least direct sunlight. The two equinoxes, which occur near March 21 and September 23 mark the point in the Earth’s orbit in which the Northern and Southern Hemispheres receive the same duration of light. Our calendar year, therefore, is based on the number of days between one spring equinox to the next at the equator, which is measured to be 365 days, 5 hours and 49 minutes.\textsuperscript{4}
The Body Clock

All organisms and species have evolved biological and behavioral strategies to optimize energy expenditure and food intake that are inextricably linked to daily and seasonal changes. Current research in the fields of neuroscience and chronobiology reveal increasingly nuanced accounts of how our bodies know when, what and how to adapt to the environment. For example, the circadian clock tells our bodies not only when to wake up and fall asleep, but also when to digest certain nutrients, improve cardiovascular efficiency, as well as when to feel the most alert, energized, dexterous, or drowsy.

This clock is located in the brain, in Suprachiasmatic nucleus (SCN) of the hypothalamus to be exact, and it governs the timing of all other organs and processes in the body. These other organs also have their own smaller clocks that control when and what the different parts of the body do. Some processes, like the heartbeat, have short periods, taking mere seconds to complete a cycle. Other functions, like the 90-minute REM sleep cycle and the monthly menstrual cycle in women are longer. The SCN makes sure that all of these different rhythms
stay in beat with one another. This synchronization is critical to the health and well being of our bodies and our emotions; if these internal rhythms become out of synch with one another, this internal discord causes trouble for our health and well being.⁵

For anyone who has traveled overseas, the discomfort felt in the body, known as jet lag, is the body’s attempt to synchronize its schedule with the local time of the new location. Since there are many different cycles going on in the body, some may take more time than others to adjust, creating physical and mental health problems. Eventually, the body adapts to the new place and all goes back to normal, but this depends on the strength and consistency of external time cues, called zeitgebers, meaning time givers in German. This process of synchronization is referred to as entrainment, in which the internal body clock interprets cues such as light, temperature, diet, and even social patterns to estimate the time of the given location. Disjointed or conflicting zeitgebers may confuse the internal synchronization of biological rhythms and lead to disruptions in the proper cycling of the body’s essential functions.⁶
Unfortunately for the health and well being of both our body and the overall environment, current trends in architecture and lifestyle choice are becoming increasingly uncoupled from the patterns of the body and environment—sending mixed signals to the body’s clocks. Here are some of the most common ways the design of our spaces and the way we live are contributing to circadian disruption:

1. **LIGHT** High levels of artificial lighting at night coupled with low levels of light in the day. As Americans spend more and more time indoors—moving from the office to the car to the home—exposure to bright sunlight has greatly diminished.

2. **TEMPERATURE.** Constant, un-changing interior climates, made possible by air-conditioning and central-air cooling, do not allow for seasonal variations of temperature.

3. **DIET.** We expect to eat any food at any time. Whether breakfast for dinner or fresh tomatoes in January, the foods we eat and the times we eat them are out of synch.

4. **SOCIAL PATTERNS.** We are sleep deprived. The convenience of 24-hour services means more night-shift workers. Dancing all night at the club is just too fun.
These conditions, on which many of our habits and lifestyles are based, conflict with the timing of both the body as well as the environment. When these signals confuse the body’s ability to know what time it is, it causes “a breakdown of phasing internal biological systems appropriately relative to the external, i.e. environmental changes, which leads to chronobiological disorders.” These disorders include such pervasive conditions as insomnia, Seasonal Affective Disorder (SAD), anxiety and depression, diabetes, obesity and even cancer.

More simply, members of the scientific community place emphasis on conducting further research on circadian disruptors and the various possible interactions of to following issues related to cancer causation: “Light, melatonin, sleep, food, work and leisure activities, biological stress and ambient noise.” These factors have all been observed to function as chronodisruptors, or, “whatever allows the establishment of temporal organizational order in organisms [that is also] capable of disrupting such order or temporal programme when present or applied in excess or deficit and, most importantly, at unusual and inappropriate times, especially if combined with further agonistic or

In 2007, the International Agency for Research on Cancer (IARC) concluded that “there is sufficient evidence in experimental animals for CARCINOGENICITY OF LIGHT DURING THE DAILY DARK period (biological night)” but because of limited epidemiological evidence, it was concluded that “shiftwork that involves circadian disruption is probably carcinogenic to humans.”

Cancer research found that exposure of the retinas to artificial light at night stimulated the growth of breast tumors. The relationship between breast cancer and irregular cycles of light and dark was first discovered when breast cancer in night-shift nurses was found to be 30 % HIGHER than in the general population.
antagonist chronobiological effectors.” Additionally, much of the research dealing with seasonal and non-seasonal depression have focused on issues such as mood, sleep, core temperature, hormone secretion and other circadian rhythms and have found these rhythms to be shifted in phase, diminished in amplitude, or out of phase with each other. On the positive side, experts suggest that access to stronger external signals, or enhanced zeitgebers may increase the amplitude of physiological cycles and contribute to the maintenance of healthy rhythmic patterns. In other words, with a better understanding of how specific factors in the environment are affecting the circadian system, the design or our landscapes, buildings and schedules may help alleviate many of the diseases that plague us today.

Here are some of the ways architecture can hurt or help.
LIGHT
“Light, thus, is intimately connected with the temporal rhythms of nature which form a fifth dimension of understanding. The phenomenon which distinguish a natural place cannot be separated from these rhythms.”¹¹

Christian Norberg-Schulz

Given that the daily light-dark cycle of the sun is the most consistent and reliable time cue, humans, as well as many other organisms, are most perceptive to the effects of light as an indication of external time. One of the most consistent and measurable indications of light’s effect on circadian timing is the daily cycle of the hormone melatonin. This hormone, associated with feelings of drowsiness, tells the body when to fall asleep, and has many other important functions to maintain the good health. Beyond just signaling sleep, melatonin has been associated with bolstering immune function, particularly in winter when increased hours of darkness trigger higher levels of melatonin. This hormone has also been found to have indirect anti-oxidant affects, and is used pharmacologically to treat conditions such as jet lag and insomnia, while reducing the toxicity of other drugs when used synergistically.¹⁴
While the natural rhythm of this hormone peaks at night and is at its lowest during the day, changes in light can alter this pattern. The first experiments found that when pulses of light were given to people earlier in the evening and before the body temperature minimum, light had the affect of keeping the individual awake longer. Similarly, when the light pulse occurred late in the night or early in the morning after the core temperature minimum, the melatonin cycle was advanced, signally the body to ‘wake up’ earlier.¹⁵

Diagram by Philippe Rahm showing how light is interpreted by the eyes and brain.
It was originally thought that only very bright light of around 1,500 to 2,500 lux was needed to stop the body from making melatonin, but research has demonstrated that night-time light levels as low as 250 lux (light from about one incandescent bulb) can also sufficiently suppress melatonin.\(^\text{16}\) In fact, exposure to artificial light of around 180 lux in the middle of the night has been shown to alter the cycle of both melatonin and cortisol by shifting the phase to start earlier or later than normal.

Underscoring the relevance of this research to architecture and environmental design, the architects and artists Decousterd and Rahm worked with several medical and scientific consultants to construct a space that would physically induce a feeling of tiredness akin to that of diurnal patterns. In their project *Diurnisme*, they contrived a set of environmental conditions that chemically and physiologically triggered systems in the body to respond in predicted ways, thereby producing a state of extreme drowsiness coupled with an intense feeling of being awake. Thus by manipulating light levels within a space, the architects spatially and chemically alter user behavior—affecting visitors of the space within minutes of entering the room.

\(^{16}\) Ibid, 410.
More recent studies are revealing the nuanced effect of not only light intensity (lux) but also wavelength (interpreted as color). Light in the range of 446 to 555 nm, seen as blue light, causes the most suppression of melatonin while lower frequencies (from incandescent bulbs or candle light) cause less disruption.17

The idea controlling the color (frequency or wavelength) of light, is explored in another work by Rahm. In his project *Split Time Café* Rahm designates three zones, or three “constructed temporalities.” The first zone, surrounded by clear glass, expresses in real time the natural course of the sun. The second temporality is that of circadian night, where yellow-tinted glass blocks the blue wavelengths that suppress the hormone melatonin, allowing the body to feel the physiological effects of night within a luminous space. The last temporality is formed by an envelope of blue colored glass, allowing only the wavelengths of light
Stevens and Itai Kloog, an environmental epidemiologist at the University of Haifa in Israel, looked at nighttime global-satellite images of 164 countries and noted that the incidence of prostate cancer was nearly double the average rate in areas exposed to the most light at night (LAN)."**18**

In evolutionary terms, this mechanism allowed human beings to stay in tune with the natural cycles of light and dark—with morning sunlight at dawn signaling the body to wake up and darkness at dusk triggering sleep. The time at which a certain quality of light is present is therefore critical to maintaining the proper timing of the cycle. The body is most sensitive to light during the hours right before dawn and right after dusk, thereby ensuring that the body can adapt to the seasonal changes in day length.**18**

Unfortunately, in today’s urban landscape, environmental light from sources other than the sun is the norm during all hours of the day and night—confusing the body’s ability to know what time of day or season it is. From flood lamps in parking lots, boulevards lined with lighting, to lamps, televisions and even computer screens, significant amounts of environmental light at night can be found in nearly every condition of our landscape. Light pollution, common to all the industrialized world, has been linked to disruptions in plant and animal species


19. Ibid.
natural photosynthesis, mating, and migration patterns with devastating effects. This lifestyle interferes “with the normal response of [humans] to seasonal changes in the photoperiod that otherwise would result in changes in the physiology of hormone secretions and other biological functions.”  

These changes have implications for every function of the body and have been associated with issues involving “puberty, psychiatric illness, stress-related disorders, immune responses, and carcinogenesis.”

In the same way that the melatonin cycle is sensitive to darkness at night, it also needs exposure to high levels of light during the day in order to achieve the optimal cycle. As Americans are estimated to spend more and more time indoors, access to natural daylight, as well as exposure to seasonal temperatures, has become increasingly limited. For a large portion of the population, daily routines take the individual from inside of their home, into a car and into the office where they spend most, if not all, their daytime hours—without ever being exposed to the external weather.

Lack of exposure to sufficient natural daylight
from windows was shown to disrupt normal circadian rhythms of cortisol in school children, a Swedish study found, with associative problems of distractibility and reduced cooperative behavior.\textsuperscript{22} The inverse is also true; exposure to high levels of bright light during the day is known to increase alertness and concentration, especially when coupled with slightly cooler temperatures.\textsuperscript{23} Because of this, many office designs incorporate these atmospheric qualities to promote perpetual productivity—making the body think it is perpetually sunrise and therefore time to be awake and alert. Unfortunately, this practice, which is common to nearly all modern-day


\textsuperscript{23} Karen Olson, “Light Rhythms,”\textit{Experience Life}. 
buildings, is sending mixed signals that may have costly consequences for our bodies.

Based upon this understanding, scientists studying circadian sensitivity to light have suggested better lighting practices that might include using full-spectrum lighting during the day inside homes, offices, and hospitals, and non-blue indoor and outdoor lighting at night (e.g. incandescent or low sodium vapor street lights). However, natural daylight and time spent outdoors, when possible, is widely considered the best way to ensure consistent entrainment to environmental time.
While light is currently believed to be the predominant zeitgeber, temperature plays a significant role in the homeostasis (internal balance) of the body. Because humans are warm-blooded, we need to keep our body at a relatively constant temperature, around 98.6°F, regardless of the temperatures going on outside. This means that in order to maintain this balance, called homeostasis, the body must either create heat if the outside air is cooler, or loose heat if the outside air is warmer. Heat is constantly being produced and lost within the body in the following ways:

HEAT PRODUCTION

1. **Cellular respiration** happens in every cell of the body as glucose from food energy is converted into the matter that makes up our body muscles, bones and tissue. More than half of the energy is given off as heat, similar to the way a light bulb converts electricity into both light and heat energy.

2. **Muscular activity** creates heat in the body by increasing cellular respiration as well as creating ‘frictional heat’ due to movement, like when you warm your hands by rubbing them together.
3. **Eating Food** generates heat through the process of metabolism. The process of digesting food and absorbing and processing the nutrients releases heat due to biochemical reactions. More heat is generated after eating meals high in protein and less after eating carbohydrates and lipids.  

**HEAT LOSS**

1. **Radiant Transfer** from the skin. Heat flows from an area that is warmer to an area that is colder. Since most of the time body temperature is hotter than the air around you (except for in very hot climates), heat leaves the body through the skin.

2. **Cutaneous Vasodilation.** By dilating the blood vessels near the skin, more heat can transfer into the air due to increased surface area and increased blood flow. This process is known as vasodilatation, and is also why your skin is redder when you are hot. Conversely, if you are too cold, the blood vessels near the skin constrict (vasoconstriction), minimizing the amount of blood flowing near the surface of the skin and therefore the amount of heat that would leave the body—this is why you look pale if you are cold.

3. **Sweating.** Through the latent heat of evaporation, heat energy is used to transform the
liquid (sweat) into a gas, effectively cooling the body. If the air around you is humid, it is harder for the sweat to evaporate, making it difficult to cool down.

4. **Breathing** releases warm humid air from inside the body out into the air. We loose about 20% of our heat through the process of exhalation.\(^{26}\)

Since temperature is related to both activity and food intake, the body evolved internal temperature rhythms to predict and prepare for regular occurring periods of activity and rest. Traditionally, humans are active during the day when there is more light, when air temperatures are higher, and when food is more easily available. Because of this, the circadian rhythm for internal body temperature is highest between 5 and 7pm, or at the end of a workday, and lowest a couple hours before waking up, usually between 4 and 6am.\(^{27}\) At this point, internal body temperature begins to increase, as the metabolism is preparing for the coming day and period of activity.

\(^{26}\) Ibid.

\(^{27}\) Ibid.
Temperature is controlled in the Thermoregulatory Reflex Center, located in the hypothalamus of the brain, which compares the actual body temperature to the desired temperature and adjusts accordingly. If the body is too cold, the TRC sends signals to the body to effectors such as cutaneous blood vessels (to keep blood from circulating near the skin), skeletal muscles (shivering), and glands (to produce hormones that change the cellular respiration and metabolic rate of the body). 28

Since it takes time for the body to respond to changes in temperature, anticipating these changes and preparing for them ahead of time can greatly reduce how uncomfortable we feel. For example, if we know that it will get very cold as soon as it gets dark, we may choose to put on a sweater before it gets dark and we actually feel cold, instead of waiting until we start shivering to adapt to the change in temperature. If putting on a coat is still not warm enough, we might choose to drink hot tea, sit by the fire, turn up the thermostat, or move around. These are all relatively quick responses to thermal changes. If the body senses that it is cold for longer periods of time, it will send hormones like thyroxin (from the thyroid gland) and adrenalin (from the adrenal gland)
to increase cellular respiration in order to generate more heat. These hormones, as well as others, make us crave certain foods, and follow circadian and circannual (yearly) rhythms.\textsuperscript{29}

As mentioned above, eating foods that are high in proteins produce more heat energy than foods that are not as heavy. This is why, if you live in a someplace very cold like Minnesota or Norway, you might want to eat heavier meals (like meat and potatoes) to keep up with the winter-time increase in metabolism. As temperatures start to warm up over the long term, the metabolic rate slows down so that we generate less heat. Hence, in hot summer months, we generally don’t feel like heating heavy meals and may opt for lighter foods like salad, which don’t make the metabolism work as hard to burn.

**ENTRAINMENT BY TEMPERATURE**

Similar to the studies done with light, temperature has been shown to affect the timing of some circadian functions by advancing or delaying the cycle. In humans and other warm-blooded animals, the cycles of body and skin temperature can cue the timing of other peripheral organs in the body. Moreover, “when combined with a light-dark cycle, a
temperature cycle usually enhances the amplitude when applied in phase with the light dark cycle, i.e., warm phase during light and cold phase during night."\textsuperscript{30} In people and animals that are completely blind, temperature has been shown to entrain circadian rhythms, which “result in the optimal adaptation of the organism to the day/night changes of the environment.”\textsuperscript{31} It would follow, then, that exposure to the external temperatures at some point during the day would tell the body how to adapt to the particular thermal needs of that environment. If we are constantly indoors and infrequently exposed to this thermal information, the body may not be able to adequately adapt.

This phenomena may in part explain why different cultures respond differently to the extreme temperatures of their environments. For example, in much of Scandinavia, it is common practice to take children outside in sub-zero temperatures for their afternoon nap. It is believed that exposure to fresh air keeps the kids healthier, and “in some studies they found pre-schoolers who spent many hours outside generally - not just for naps - took fewer days off than those who spent most of their time indoors.”\textsuperscript{32}

Similarly, the effect of acclimatization can be seen in

\begin{itemize}
\item \textsuperscript{31} Ibid.
In the winter they often go out completely naked and roll themselves in the snow, while the temperature is 40 or 50 degrees below zero. They wander naked into the open air, talking to each other and even with a chance passerby. If the traveler in search of help happens to arrive in a remote village at the time when all the inhabitants are in the sauna, they will leave the bathhouse in order to harness or unharness a horse, to fetch hay, or do anything else without ever thinking of putting any clothes on. Meanwhile, the traveler, although enveloped in a fur coat, is stiff with cold, and does not dare to take off his gloves. What astonished the people of our climate the most is that no ill effects ensue from this sudden change of temperature. People who live in warmer climates are liable to get rheumatism even when the most gentle wind blows.  

THE COMFORT ZONE

Relatively new and pervasive technologies such as central air heating and air conditioning allow us to create homogenous indoor environments independent of temporal or climatic conditions. Building upon 19th century experiments with air cooling, air conditioning gained momentum with the technological and promotional contributions of Willis H.J. Viherjüuri, Sauna: The Finnish Bath (Brattleboro VT: Stephen Green Press, 1972) reproduced in Lisa Heschong, Thermal Delight in Architecture (Cambridge: MIT Press, 1979), 22.
Haviland Carrier, also known as the “Father of Air Conditioning.” In 1952, the Carrier Corporation demonstrated the totality of their vision for the architectural implications of this new air-conditioning system:

“This house started a revolution. It need not depend on natural ventilation. Ells and wings wouldn’t be necessary. Only a few windows need have a movable sash. The bathrooms needn’t require a window. Windows, doors, and even the rooms themselves could be placed to suit the convenience of the owner, not to catch the breeze.”

As this quote clearly describes, the implications of air-conditioning, while technically sophisticated, placed a perhaps unreasonable emphasis on the issues of temperature and humidity and fail to acknowledge other factors of human comfort. With functional requirements for the design of passive ventilation brushed aside, many traditional architectural forms seemed to be no longer necessary. Issues of programming and spatial organization, seemingly no longer restricted by orientation to prevailing winds, could now be explored with limitless implications for social and cultural behaviors tied to building organization before air-conditioning. Moreover,
homes in climates with cool winters designed rooms with doors not just for privacy, but also to keep the heat from escaping to other unoccupied rooms. As we now heat all rooms in a building evenly, the thermal need for doors has vanished, and the preference for open floor plans demonstrates the desire for easy movement between spaces—in fact fundamentally altering how we think and conceive of ‘rooms’ and architectural space. The preference for openness, and indeed also transparency, reveals a cultural shift in notions about privacy and community as defined by spatial boundaries and zones.

Without private rooms with individual thermal climates, people must now be expected to all share the same thermal preferences. Yet people are not all alike and come with different cultural and physiological definitions of comfort. Due to changes in circadian cycles in the body, a temperature that was comfortable in the morning might be too cold in the afternoon—and these circadian cycles also vary amongst individuals. Since there is now one large space housing more people, the interior climate must somehow now provide a standard level of comfort for everyone—ultimately leading the near universal adoption of the idea of the ‘comfort zone.’ It is a
relatively new American idea to expect the temperature of our rooms and bodies to remain at a constant state of comfort. This expectation is in fundamental opposition to the reality that temperature is constantly changing both inside the body and in the climate outside.

The idea that all interior space should be maintained at a constant temperature at all times of use—a condition with had never before been expected or maintained—is just now beginning to be refuted by research into acceptable environmental fluctuations. As Kiel Moe points out in his book *Thermally Active Surfaces in Architecture*, “in the last century, nearly all approaches to human comfort in buildings relied upon the psychometric chart as the core technique for determining human comfort.”

The reliance of this chart on only humidity and temperature exposes the fallacy of such a simplistic notion of comfort and dismantles centuries-old patterns of life within architectural forms.

Coupled with the ubiquity of electric lighting and inexpensive and abundant fuel sources, buildings become hermetic enclosures with “thin layers of dropped ceilings, think curtain walls, deep floor

The environment can be understood as “all of the natural (physical, chemical, biological) and cultural (sociological) conditions capable of affecting living organisms and human activities.”

(D&R, 71).

plates” which “play a major role in the crisis of resources in contemporary architecture.” Moreover, these ways of building make it “possible to fill larger areas with people and the equipment they use to work, but the people, the lights, and equipment all produce heat, which requires even more conditioning. As heat removal becomes ever more important, windows are sealed and were designed to exclude as much sunlight as possible, making the interior environment more efficient, but less and less pleasant.”

Lisa Heschong in her book *Thermal Delight in Architecture* lamented the often-homogenizing effect of modern heating and cooling technology as well as the sensory discord that can result from the disassociation of building form and building function.

*A picture of a mosque in Isfahan, for example, with its polished marble floors and heavy masonry walls, its airy vaults and deeply shaded recesses, looks invitingly cool and refreshing. Of course, we imagine it to be in the hot desert sun of Iran. With almost the same set of visual clues—heavy masonry, smooth polished surfaces, high airy colonnades—a building in Germany, such as one of the neoclassical government buildings of the twenties and thirties, comes across forbiddingly cold and inhospitable.*

37. Ibid, 51.

Our visual perceptions might mislead us completely. Both places could conceivably be heated by a hidden radiant system. With our current technology the temperature of a place need not be associated with the form of the building or the materials used or the region where it is located. But how unsatisfying is this dissociation of warmth and coolness from all our other senses!  

While seeking to maintain constant conditions for human comfort, we have ignored the temporal dimension of design, and bypassed potentially synergetic strategies to optimize the performance of both body and building by working with the specific climatic conditions of the site. We must embrace ways of building that allow for these changes to happen. We must realign our expectations of thermal comfort with the changes that are already happening in the body and climate.
SOCIAL PATTERNS
Finally, and not least importantly, social patterns are a major organizer of what we do and when we do it, and also serve as an essential zeitgeber for our bodies. From the near complete darkness of winter in the higher latitudes to the heavy rains that characterize tropical forests, patterns of nature govern how we are able to live in a place. In traditional societies these cycles set the tempo for when we sleep, eat, work and rest and were intimately tied to the specific qualities of the natural environment. Everything from how we dressed to what we ate was closely tied to the cycles of the sun and seasons. Over time, cultures developed increasingly sophisticated and precise ways of keeping track of time, based on astrological observations, in order to ensure that everyone was ‘in time’ with one another.

Ancient civilizations erected monuments that tracked the precise movements of the sun, moon and stars that organized the timing of agriculture, religious festivals and social activities. Almost all major civilizations from ages past built monuments and earthworks to acknowledge the importance of daily and seasonal changes to their way of being. Examples include Stonehenge in England marking the summer solstice, the Sun Dagger in New Mexico, ancient
burial mounds in Ohio, Macchu Picchu in Peru, as well as the Mayan Temples, which marked the number of days of the year with steps scaling the four sides of the pyramid. These elaborate constructions were not merely calendars and clocks, but instead were manifestations of what each culture believed their place within the larger cosmos to be. Norberg-Schulz explains the significance of this concept: “In mythopeotic thought time is just as qualitative and concrete as other natural phenomena, and is experienced in the periodicity and rhythm of man’s own life as well as in the life of nature. Man’s participation in the natural totality is concretized in rituals, in the ‘cosmic events’, such as creation, death and resurrection are re-enacted.”

Many ancient celebrations and festivals were centered on significant events, following daily, weekly and yearly cycles. The summer and winter solstices mark two of the most important astrological events of the year and are observed in religious and cultural celebrations all over the world. Midsummer, celebrated throughout Europe up until the nineteenth century and currently in Scandinavia, marks the longest day of the year, or the summer solstice, by burning huge bonfires. Similarly, the western
Christmas holiday marks the shortest day of the year and celebrates the coming of longer days:

“Certain it is that the winter solstice, which the ancients erroneously assigned to the twenty-fifth of December, was celebrated in antiquity as the Birthday of the Sun, and that festal lights or fires were kindled on this joyful occasion. Our Christmas festival is nothing but a continuation under a Christian name of this old solar festivity; for the ecclesiastical authorities saw fit, about the end of the third or beginning of the fourth century, arbitrarily to transfer the nativity of Christ from the sixth of January to the twenty-fifth of December, for the purpose of diverting to the Lord the worship which the heathen had hitherto paid on that day to the sun.” (Frazer in Thermal Delight, 52)

In the Islamic tradition, daily calls to worship occur according to solar time: just before sunrise, at solar noon, in the late afternoon, at sunset, and before going to sleep. In ancient times, people referred to the position of the sun to know when to pray. In predominantly Muslim countries, the hauntingly beautiful call to prayer is performed aloud—signaling to the community when it is time to pray. Today, more precise times are derived from the specific solar charts based on location throughout the world.
Weekly cycles are similarly adhered to by most cultures and religiously. Notably the Jewish Sabbath commands that after six days of work, the seventh would be consecrated as a day of rest. In North America, most work schedules also follow Monday to Friday patterns, with the weekend (Saturday and Sunday) devoted more to leisure activities and religious services. This pattern of work and rest has significant implications for the ways we spend our money, use our cities, and cultivate relationships.

Beside the physiological ways the body tells time through daylight and temperature, there are other options for interpreting what to do and when. For example, for the majority of city dwellers, the vibration of engines, honking of horns and glare of headlights from the daily traffic patterns provide a very clear indication of whether it is morning or evening rush hour. The sounds, smells and sights of the street and the reverberations felt within the walls of the surrounding buildings are expressly different at 8:00am on a Monday than they are at 8:00am on a Sunday. While walking down the street in Milan, for example, an individual can tell what time it is by the types of stores and businesses that are open or closed; there are more coffee bars and bakeries open in the
morning, businesses and retail stores are open during the day and frequently closed during the lunch break when people still go home or to sandwich shops to eat, and restaurants and bars open as it gets dark. Church bells may signal the time on Sunday or other religious holidays. The use of electricity, when people use the most water to shower, even programming of television and radio shows all follow daily, weekly and seasonal cycles. In fact, social cues regarding the time are so ubiquitous, that they often go unnoticed, though they shape every aspect of our lives.

Today, our predominant experience of time is just as pervasive as ever, though increasingly disassociated with the solar cycle. Instead of judging by the position of the sun or setting our watches to the central clock tower, as was the practice in many early European villages, we rely on technology (like our phones, computers, and other appliances) to automatically synch with international time. We are obsessed with making schedules and filling out calendars, and we tell our software to send us reminders and messages to make sure we don’t miss important meetings or events. We set alarms to wake us up in the morning, usually based on what time we have to be at work or school instead of when the sun
rises or the body is fully rested—leading to a potential disconnect between the rhythms of the body and the rhythms of society.

While the popular 9am-5pm workday persists as a remnant of daylight rhythms, increasingly mobile technology allow us to work later into the evening and from a variety of different locations. This new pressure to work at all hours is creating a cultural crisis for our sleep habits. Studies show that Americans are seriously sleep deprived. A recent poll done by the National Sleep Foundation found that more than one in four, or 27% or Americans, report trouble sleeping at night due to anxieties about personal finances, the economy or job-related stressors and many are treating the troubled sleep with medications.\textsuperscript{42} Additionally, a poll among college students found that the average amount of sleep students get is around 7.02 hours, with 25% reporting less than 6.5 hours. This means that over 70% of college students are not getting the recommended minimum 8 hours of sleep their bodies need.\textsuperscript{43}

These sleep habits have significant influence on the physiological function of the body. As mentioned before, hormones are genetically programmed to tell


you when to go to sleep at the best time for your body, and they follow predictable daily schedules. But our intentions to just get one more thing done or to get up extra early in order to get more work done may actually be undermining our ability to perform emotionally, cognitively, as well as physiologically. Additionally, going to sleep at different times each night (i.e. staying out until 3am on the weekends and sleeping in late), is essentially subjecting the body to weekly bouts of jet lag as the body struggles to figure out when it should be sleeping or not. Exacerbated by staying up even later on weekends, college students “classified as poor-sleep quality sleepers reported significantly more problems with physical and psychological health than did good-quality sleepers.”

This is because sleep plays a dramatic role in regulating the restoration, healing and health of the body. While we sleep, the body is performing hundreds of complex tasks and is “vital for sustaining peak mental performance, stabilizing mood, bolstering immunity, coping with stress, repairing our tissues, rebalancing our biochemistry and maintaining a healthy metabolism.” Without enough sleep, we are more likely to feel grumpy, short-tempered, easily frustrated, unmotivated, and sluggish, emotions

44. Ibid.

possible caused by dampened nerve function. For example, “during sleep, levels of the stress hormone cortisol decrease and we secrete more growth hormone (a key tissue-repair substance). Without enough sleep, our cortisol level can remain elevated, keeping the body in a state of alertness and driving up blood pressure, which increase the risk of heart attack and stroke.”

In this way, by ignoring the physiological need the body has to sleep, we are disrupting the restorative power our body has to promote health, as well as happiness. Moreover, it is not just sleep, but the underlying cultural disregard for environmental cycles that seems to be contributing to the epidemic of chronic and preventable disease that is sweeping through the country. As modern technology has allowed us to come up with new ways of living, no longer so intimately tied to the patterns of nature, we have to ask whether the benefits of our lifestyle outweigh the costs. We are tasked with understanding how our bodies and environment work, as presented to us through traditional knowledge and scientific advances, and to imagine ways of living that work in harmony with these factors.

46. Ibid.
Space has no room, time not a moment for man. He is excluded. In order to 'include' him—help his homecoming—he must be gathered into their meaning...
Whatever space and time mean, place and occasion mean more.

Is he able to find the right place for the right occasion?

*Aldo Van Eyck*
Time is not a phenomenon, but the order of phenomenal succession and change. Buildings and settlements, however, are static, apart from certain mobile elements of secondary importance. Nonetheless man has succeeded in ‘building’ time, by translating basic temporal structures into spatial properties. Primary life is ‘movement’, and as such it possesses ‘direction’ and ‘rhythm’. The path is therefore a fundamental existential symbol which concretizes the dimension of time.”

Christian Norberg-Shulz

There are a number of ways we can 'build time' into the designs of our buildings, which in turn effects both our bodies' habits and our routines.

1. ENHANCE THE EXPERIENCE OF THE ZEITGEBERS.
Let Dark be Dark and Light be Light.

By focusing on the ways the building makes itself manifest to the various senses and cycles of the body, perhaps architecture can help in enhancing these zeitgebers. Thus by celebrating daily and seasonal changes in our buildings we can contribute to
healthier, more meaningful ways to inhabit our homes and cities.

Historical precedents provide many beautiful examples of ways design can enhance or control the particular character of light at any given time to accentuate the sensory perception of that condition. In places near the equator where the light is direct and intense, blocking the light is essential not only to protect the eyes from over-stimulating glare, but also to keep out the heat from direct solar radiation. These cultures developed methods of building solid thick walls, and where some light was necessary, they employed elaborated methods of screening the light, creating ephemeral patterns that dance across the walls and floor as the sun moves throughout the day.

For the great cathedrals of Europe, stained glass accentuates the directionality of the light. When the windows are lit from the outside, beams of colored light draw, together with the uplifting of the structural vaults, draw the viewer’s gaze and attention heavenward. The use of colored or patterned glass also provides a sense of warmth in many of Frank Lloyd Wright’s interiors and qualitatively changes the connection between the world inside the home and the world outside the window. For many modern artists, such as James Carpenter, and Olafur Eliasson,
light is a medium whose specific physical properties, when combined with glass, water or other materials, has the power to completely transform a surface or one’s surroundings—creating an ephemeral dialogue between time and materiality.
Similarly, for the Japanese, controlling natural daylight was not merely about letting in as much light as possible, but rather enhancing the more subtle ways light can dance within a space—even to the point of celebrating darkness. Jun’ichuro Tanizaki poetically describes this phenomena in his book *In Praise of Shadows*, "in the darkness of the innermost rooms of these huge buildings, to which the sunlight never penetrates, how the gold leaf of a sliding door or screen will pick up a distant glimmer from the garden, then suddenly send forth an ethereal glow, a faint golden light cast into the enveloping darkness, like the glow upon the horizon at sunset. ...Their use of gold leaf and gold dust was not mere extravagance. Its reflective properties were put to use as a source of illumination.”

In northern latitudes, the character and quality of light is marked by drastic contrasts. With months of the year in near total darkness, there are also times where the sun never seems to set. These cultures have developed ways to celebrate these dramatic shifts in character. Light takes on its own personality: bright and cheerful during the day. Cozy and warm at night. By creating environments that are comfortable and inspiring within the constraints of long hours of darkness, traditional Scandinavian design has

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**HYGGE** is the Danish word meaning something close to cozy in English. However, this term encompasses more than just warm flickering candlelight on a dark rainy winter evening. Hygge also means the gathering of friends and family for a hearty meal, a warm beer, in essence, it is the way of being together, taking advantage of each other’s warmth and company.
embraced the difficulties of their environment and found ways to celebrate both the brightness of the day, and the darkness of night.

As these examples begin to illustrate, powerful and inspiring places not only allow for the ephemeral transformations brought about by the movement of the sun, but also incorporate other senses to enhance the whole body’s experience of space in time.
2. LAYERED MEANINGS. *Use the different senses to reinforce the zeitgebers, not mixed signals.*

Often the strategy for dealing with one factor overlaps with the strategy for another—allowing for synergetic responses to these time sensitive characteristics. Lisa Heschong, in her book *Thermal Delight in Architecture*, describes some of the nuances that contribute to our thermal sense of comfort (and pleasure!). She explains, “Since our thermal sensors are not distance receptors, that is, they cannot warn us that a place will be cold before it starts to chill our body, we have to rely on other senses to give advance clues. We look for qualities that have been associated with warmth or coolness in our past experience...”

Drafts and breezes can change the perceived temperature as perceived by the skin. Colors and lights may either enhance or oppose the perception of temperature as determined by the thermometer—as simple as the linguistic reference to warm colors (red, orange and yellow) as well as cool colors (blue, green, violet). For example, in the hot and humid summers in Japan, “people like to hang a lantern or wind chime under the rood of the veranda. The lightly swaying lantern or the ringing of the bell gives a suggestion of refreshing wind and coolness.”

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These factors allow for a complex and multi-sensory experience of comfort, and often “such clues from other senses can become so strongly associated with a sense of coolness or warmth that they can occasionally substitute for the thermal experience itself. For example, the taste of mint in drink or food seems refreshing and cool regardless of what temperature it is.”

In a project done for the Royal Danish Academy of Fine Arts, School of Architecture, Decousterd and Rahm re-examine architecture as just one of the layers we use to control our body’s perception of comfort. The architects blur the boundaries between the physiological reactions (like shivering), active responses (like putting on a sweater), and architectural strategies (like insulation). In their exploration termed “More Warm,” the intention is to address the issue of adding ‘heat’ to a space, inasmuch as the body perceives itself to be warm. One installation consists of a metal grate under which hot chili peppers are grown as well as a warm tea with hot peppers. Rahm describes the physiological function of the following means of ‘feeling warm’:

Hot peppers stimulate Ionic channel and neurotransmitter TRPV1, the one that detects temperature sup to 44°C and also bustles in presence of «capsaicin», a molecule we find in red hot pepper. The «capsaicin» and temperatures up to 44°C stimulate the TRPV1 which activates the sensation of strong heat.

Additionally, music with a techno rhythm at 120 beats per minute plays out of a speaker, helping increase the heart rate, thereby increasing metabolism and muscular activity to generate heat. Another malady often associated with cold climates is the deficiency of Vitamin D and Vitamin A, associated with the sleep hormone melatonin, all related to the decrease of light levels in the short days of winter in northern latitudes. Their response to this problem was to provide “a horizon” of ultraviolet light, allowing the synthesis of vitamin D; an

Vitamin D
Sunlight helps create Vitamin D, a fat-soluble vitamin that “works with the parathyroid hormone to balance calcium in the blood and build strong bones. It also maintains healthy cellular growth and regulates the immune system, which prevents excessive inflammation that can lead to autoimmune diseases like rheumatoid arthritis, diabetes, periodontal disease, multiple sclerosis and irritable-bowel diseases.”

7. Olson, “Light Rythms.”
indoor carrot field providing the source of vitamin A, also improving night vision; an electromagnetic radiance of 470 nanometers to block the secretion of melatonin which increases with the absence of light; and a table for a feast full of oily fishes like salmon, trout, halibut which are foods contribute to healthy vitamin D levels.8

While this project raises our awareness of these processes and body-climate relationships, these clever interventions portray an atmosphere of artificiality, while highlighting relationships between food, space, culture and climate that have traditionally existed for centuries. For example, eating carrots and fish in Denmark, before the inundation of foods from other climates in super markets, was commonly done and necessary, since these foods were simply what their northern climate provided in cold, dark winters. This raises the fundamental problem for human health: while our bodies and nature provide the problems and solutions for human comfort, we must know how to both identify these problems and know what the solutions are in order to benefit from them.

3. ENCOURAGE FLEXIBILITY TO RESPOND TO VARIATION. This can happen in two major ways: Mobility and Adaptability.

MOBILITY: Provide different places for different purposes
One of the most basic ways to adapt to changes in environmental conditions is to move to a different environment. This is evident in the long distance migrations of many kinds of birds, as well as for several species of fish as well as animals. When the climate becomes inhospitable or when the source of food is no longer sufficient, an organism may choose to travel to a more suitable location. These types of migrations frequently occur on an annual basis following the noticeable, and often extreme, variation of the seasons as well as on a daily basis.

In desert climates, for example, where the temperature can swing from extremely high temperatures during the day to freezing conditions at night, lizards and snakes can be seen basking on a sunny rock to warm up in the morning or hiding underground to escape the midday heat. In the same way, humans have also evolved patterns of seasonal and daily migration to cope with fluctuations in temperature and weather.
Nomadic people groups from all over the world have developed different strategies for their built environment to facilitate moving from place to place. Whether travelling long distances or just a few feet, the homes constructed reflect the wide range of ways architecture can be designed for migration. On one end of the spectrum, consistent movement between two or more places has lead to the construction of more permanent or semi-permanent dwellings in each location. This movement can seen in Paiute tribe of southern California, as well as in the seasonal cities used by the English in India who “simply packed up during the hottest months and moved business, the colonial government, and all social life up to hill stations, towns in the Himalayan foothills where the air was cooler”\(^9\)

In fact, this type of long distance migration can still be seen in Florida and other Sunbelt states that attract Northerners, or snow birds, who live for half of the year in the cooler northern summer and then spend the second half of the year at their second home in the south to escape the cold winter weather. While most of the population who can afford this complete relocation twice a year are retired, there is an understood connection between this way of living and the health benefits afforded by friendlier climates.
INTERNAL MIGRATION

When climatic seasonal changes are not as drastic, or long distance migration is not possible, moving from room to room, or from inside to outside at different times for different activities can be an enjoyable way to move around space. It is human nature to seek out a spot in a sunbeam on a cold winter day or to relax under the cool shade of a tree to escape the hot summer sun, and this type of simple movement can be seen in a variety of the spaces we include in the modern home.

In his Ten Books on Architecture, Vitruvius explains what the orientation, lighting and temperature of individual spaces should be as related to the climatic conditions of his region:

Winter dining rooms and bathrooms should have a southwestern exposure, for the reason that they need the evening light, and also because the setting sun, facing them in all its splendour but with abated heat, lends a gentler warmth to that quarter in the evening.

Bedrooms and libraries ought to have an eastern exposure, because their purposes require the morning light...
Dining rooms for Spring and Autumn to the east; for when the windows face that quarter, the sun, as he goes on his career from over against them to the west, leaves such rooms at the proper temperature at the time when it is customary to use them. Summer dining rooms to the north, because that quarter is not, like the others, burning with heat during the solstice, for the reason that it is unexposed to the sun’s course, and hence it always keeps cool, and makes the use of the rooms both healthy and agreeable. Similarly with picture galleries, embroiderers’ work rooms, and painters’ studios, in order that the fixed light may permit the colors used in their work to last with qualities unchanged.  

Many houses have separate dining spaces for breakfast in the morning and more formal dining rooms typically used only for dinner or special occasions. The breakfast is different from the formal dining hall largely because it is used in the morning, when the body is hungry for a quick meal and the light is most spectacular to the East, where a breakfast room should be located. Moreover, formal dining rooms are more commonly to the south or west for the evening light, which is also when we are hungry for dinner. These rooms are most commonly used during the fall and winter when families are kept inside and the heat from the afternoon sun keeps...
these spaces warm and inviting. Nor are specific rooms and times of day restricted only to dining. As the research reveals, mental performance is at its best in the mid morning, lending to the conclusion that a study or library with access to bright morning light and cool temperatures would enhance the performance of the body at the time.

Demonstrating the role of this kind of physiological preference in the way we use space, Louis Kahn, while designing of the Exeter Library, stated, “You get the book and move toward the light.” This simple statement assumes the connection between the design of the physical environment, the needs and preferences of the body’s sensory systems, and the way we make decisions to participate in this architectural dance. In this example, it is clear to see how Kahn, instead of providing equal amounts of lighting throughout the library, intended the space to be used; a person is not meant to spend hours reading in the stacks, but to move toward the windows, where, in fact desks and chairs are provided for this purpose. In this way, users of the library receive at least who signals from the environment that inform them of how to use the space: the first being the placement of the furniture, and the second being the superior quality of light at the desired location.

Nor do we only move to different places because of the climate outside. The internal climate of the body can cause significantly different experiences of comfort based on whether or not we are moving or sitting still. As described earlier, body temperature varies over the course of the day as we perform different activities. A gym can be kept cooler, since the bodies exercising in it will produce heat. A staircase or hallway does not need to be as warm as the library, nor does the kitchen, as it will generate its own heat as we cook. The body’s thermal needs while sleeping may be remarkably different than our idea of comfort while dancing, and the air quality, including humidity, need to be considered when designing these different places.

**SPEND TIME OUTSIDE**

Since the body is interpreting cues from the outside environment, what better way to enhance the experience of zeitgebers than by going outside? Being outdoors gives our bodies access to the full range of sights, smells and sounds and temperature as they change throughout the day and the seasons. Beyond just being able to sense changes in light and temperature, being outside exposes us to a whole other host of enjoyable and reinforcing time clues.
Bird songs in the morning, the haunting hoot of an owl at night, the sound of summer rain and rumbling thunder, the rush of a creek after a spring rain all provide beautiful reminders of nature’s sense of time. Similarly, the scent of garden flowers carried by a summer breeze, sweet odor of decaying autumn leaves, and the taste of fresh summer fruit remind us of the changes taking place in the world around us. The ability for Nature to communicate and inspire us with her never-ending dance of transformation is perhaps one of the most enjoyable ways we can enhance the embodied experience of time.

Here are some ways architecture and landscape can encourage us to spend more time outside.

1. *Build it in to the commute.* You have to go outside in order to get somewhere you need to go. If you have to go outside to walk to work or to buy groceries, the path you take can provide quality time spent outdoors.

   On days that are raining and dreary, covered patios and passageways allow people to walk from place to place without getting wet, while still able to smell and hear the rain. Bologna, Italy, arcades and porticoes allow for people to move freely through the city outdoors without hardly ever needing an umbrella.
2. *Make it comfortable, and fun.* Historically in America, the home has incorporated this type of movement depending on the climate. For example, the generous front porch of the Southern home is ubiquitous in the region characterized by hot, humid summers. Its overhanging roof and open sides provides protection from the heat of the sun. Sitting on the front porch in the evening has as much to do with enjoying the cool evening breezes as it does with socializing with family and neighbors who might be passing by on the street. Similar in function is the Spanish custom of the Paseo. In cultures where the cool evening air brings refreshing relief to hot, blindingly bright days, it is a popular pastime to walk up and down a central street, where you are sure to run into friends. In the winter when it may seem far to chilly to be outdoors, a south-facing or west-facing sunroom, greenhouse or terrace can soak up the sun while blocking cold winds.

Activities for recreation and exercise can also be an appealing enticement to move outside. Ice skating and skiing are some activities that help to make snowy winters more fun. Swimming in pools, lakes or rivers is refreshing and invigorating. These elements can be built in, like in the case of the pools built in the Turkish summer home and the reflections ponds and playful fountains of Arabic palace gardens.
**ADAPTABILITY.** *Changing the space to meet changing needs.*

Aside from moving every time a space becomes thermally inhospitable, architecture has developed ways of adapting a space to make it more habitable or comfortable. The means for altering space are abundant and can be seen from actions as simple as opening and closing a window, drawing blinds or curtains to filter direct sunlight, or hanging thicker curtains over windows or openings to protect against cold drafts. Historically, in the stone or brick castles and buildings of medieval Europe, tapestries or heavy fabrics were hung on the walls to soften the cold, hard surfaces. These tapestries, now known mainly for their elaborate designs and woven illustrations, were primarily instruments for human comfort, and could be seen, at times, completely covering these interior rooms.

Shutters and storm windows are another example of adaptive strategies to help insulate buildings from cool winter temperatures and harsh winter winds. As the Turkish tradition of vernacular construction demonstrate, windows and other openings could often include several layers: thick winter curtains, thin curtains of lace or light linen, two layers of operable glass windows, a shade screen, and solid shutters.
In this way, the amount and quality of sunlight and natural ventilation could be modified to meet the changing needs for comfort over time.

Perhaps one of the best examples of this kind of flexibility can be seen in the traditional Japanese Tea House. Sliding panel walls can be opened to expose views and access of the gardens outside, or closed to create a peaceful retreat. This kind of change allow us to “appreciate the thermal function of a place or object is variability. We are more likely to notice the function of something if there are times when it is not in operation, to notice the significance of something if there are times when it is not there.”

CONCLUSION

Much of the work and ideas present in this thesis present potentially startling critiques of the role of science in architecture; as our knowledge and ability to control and manipulate the environment has increased, we have simultaneously become more and more aware of our seeming subjection to it. The implications of designing with increased control over the physiology of the body may tend to argue for a “total management of biological life” and the use of “technology to take charge of our biological animal aspect in order to manage it.” 13 On the other hand, as Henri Atlan in *La Science est-elle Inhumaine?* (Is Science Inhuman?) observes, we are “trying to reconstruct morality and responsibility within a biological determinism that is apparently becoming more credible every day through advances in scientific knowledge.” 14

As we face such ethical and moral dilemmas as genetic engineering, smart technology, and global warming, we must critically examine our role as the designers of not only our habitats, but also of our bodies. Landscape architect Gilles Clement writes, “The role of humans in the environment is to understand how it functions, and to promote its continued functioning. Since man is just one species
among the great diversity of species in nature, he cannot hope to intervene and to exploit this diversity without jeopardizing the mechanisms of interaction among the many forms of life on the planet.”

In the age of ecological sustainability, we are faced with a greater responsibility to understand how our actions may contribute to or take away from the wealth of the resources we depend on for our survival. Within the context of scarcity, economic, ecological, social and political conditions have mandated a change in the way we conceive of and consume natural and human resources—challenging architects and designers to find ways of creating environments that could not only use resources and energy more efficiently, but to invent ways that architecture could also add value to the inhabitants and ecosystems for which and in which buildings exist.

What we once understood as tradition and mythologies may actually reveal the same body-environment relationships we now treat with modern medicine. As we ship the produce of our lands across the globe, as we migrate to different countries, landscapes, languages and societies, we confuse, obscure and forget the reasons we do the things we do, eat what we eat, and feel the way we feel. Now, as we face the potential to reconnect

these fractured foundations through science and technology, we must re-familiarize ourselves with the necessity to identifying the problems presented to us through our environment and act with awareness of how our bodies work in the context of the physical world. The garden of Eden, before the harmony of ecosystems was thrown off-balance, was never real for us, therefore we remember it as it was told to us by others who were also just remembering—all the while rendering our hearts in conflict for a world again in healthy balance. The provoking work presented in this thesis becomes, if nothing else, a powerful tool for the discussion, appreciation and contemplation of what it means to live and make decisions in a complex, interconnected, ‘physiological’ world.
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