Daylighting a suburban house

Anders Sandli

Iowa State University
Daylighting a suburban house

by

Anders Sandli

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF ARCHITECTURE

Major: Architecture

Program of Study Committee:
Mikesch Muecke, Major Professor
    Joern Langhorst
    Cal Lewis

Iowa State University
Ames, Iowa
2003

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This is to certify that the master's thesis of
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CHAPTER 1. INTRODUCTION

Light and the Human Body

To begin understanding light and how light should be used, it is imperative to provide a base of knowledge about how light affects the human body. Current research results and knowledge in the field of photobiology (the study of light’s effect on living organisms) is still in its infancy. Nevertheless, according to George C. Brainerd, a professor of neurology and the director of the Light Research Program at Philadelphia’s Jefferson Medical College, there is no doubt that light is a powerful regulator of human physiology.¹ Light as a regulator has also been researched by Dr. John Ott and found that “light is a part of the body’s nutritional needs and can cause restlessness, irritability, depression, headaches and greater susceptibility to illness, including cancer.”² Being exposed the “right” kind of light contributes to a healthy light diet.

How light enters the body has long been a mystery for researchers. Photobiologists like Dr. Ott have found that light enters the body in many different ways, not just through the eye but also through the skin. The eye does, however, play an important role in being “open” to light penetration which in turn guides light exposure through neurochemical channels which stimulate the master gland - pineal and pituitary - which regulate the hormonal control of the body. Photobiologists also believe that light energy is the ignition system of all biological combustion - not just the visible light, but the whole spectrum of electromagnetic energy.³ Research by
Philip Salvatori shows that the human eye can detect non-visible light like ultraviolet light, thus making the point that light we can’t see has some importance to our bodies. Thus we shouldn’t limit ourselves to light that we can see, but broaden our ideas about light (somewhat like eating a variety of foods) to include the electromagnetic spectrum that surrounds us.

**Perceived Quality of Light & Lighting Design:**

Once we have a broad array of lighting solutions for different applications (windows, skylights, lightshelves, sun-tubes, remote-source lighting, and electric lighting), it is necessary to know how to use these solutions to best fit the problem. This may include where to place windows and skylights to offer the best application-specific lighting, and also where and when to use complementary electric lighting when sunlight is not sufficient.

People’s perception of their surroundings is greatly affected by the quality-level, type, and source - of lighting that is provided. As research shows, lighting can affect people’s moods or perceptions of spaces depending on an array of variables: color of light, where light is placed, which part of the space is lit and which space is not lit, etc. Thus, correctly arranging these variables to both fit the client’s taste and need is a vital part to making a building work.

**Thesis Focus**

This thesis is about applying fundamental daylighting techniques to a fairly common suburban house design. My goal is to demonstrate options for daylighting a single-family house, thus improving the quality of the space many call home. As I
have mentioned above, I will focus on integrating daylight into a generic type residence. As with many modern suburban homes, the popularity of the single-family residence has made them proliferate across the United States. With them, however, they bring both negative and positive aspects. One negative aspect is the lack of use of the power of daylight in creating pleasant spaces for mind, body and soul.
CHAPTER 2. HISTORY OF DAYLIGHTING

It is hard to deny the historical importance of daylight in shaping the form of buildings since collectively, with the effects of climate and location, daylight availability was basic to most plans. Conversely, with the launch of modern electric light source and or its rising efficiency since the Second World War, by the 1960s the desire to bring in daylight into buildings had begun to fade away. Many building types such as offices, shopping centers, factories, sports buildings, and schools were developed as “blind” or “semiblind” boxes on the belief that other environmental factors such as heating, cooling, and acoustics would be better served with the absence of windows.

That buildings would be better off without windows or any other method of letting in daylight, was never a sound argument and is even less so today. Architects have always recognized daylighting’s positive qualities, and have now taken a new interest in it because of the increased awareness of the world’s finite resources. They are becoming stewards of resources rather than consuming it blindly with the assumption that the world’s resources are unlimited.

Pre-industrial Architecture

Throughout most of architectural history, daylight has been the single most important source of light, supplemented by burned fuels. In addition to illumination, daylight symbolizes cleanliness, purity, knowledge, and heaven.⁷

To a great extent, pre-industrial architecture tended to let light enter only where it was desired. Generally, in climates where daylight is abundant and
predictably bright, architects have reacted by decreasing opening sizes or using diffusing mediums in the openings, like grilles and translucent or tinted glass. The presence of openings and brightly lit areas pointed toward special “events” like altars in churches. Windows and roof openings were given special consideration in the realm of structure. Therefore, there were vast changes in light levels inside buildings, also within the spaces of the buildings.

**Ancient Egypt**

In ancient Egypt, the presence of glaring and blinding sunlight called for exterior surfaces without vegetation and minimal size of walls and roof openings. Further limited by the restricting structural spanning possibilities of the large stone used for post-and-beam systems, the opening size became very small in the monumental temples of the period. Light was softened and diffused by the thick masonry walls, reflected in many directions. These walls doubled as thermal storage units to reduce the highly varying temperatures experienced in the region. Light was also brought in through clerestory openings fitted with large stone grilles to soften the sun’s rays. Other temples had roof slits and small windows and entrance doors that let light into spaces in very controlled ways. The quantity of light was purposely varied in the Great Temple of Ammon, to emphasize the axial sequence through the spaces from the Hypostyle Hall to the darkest inner sanctuary.

Housing for the people of Egypt used inner courtyards to give as many spaces within the structure access to daylight as possible. Since homes were
generally wall-to-wall in urban areas, the courtyard also functioned as a primary workspace, social area, and sleeping area for the family.\textsuperscript{10}

![Diagram of Great Temple of Ammon, Karnak. Section through Hypostyle Hall.\textsuperscript{11}](image)

**Figure 1. Great Temple of Ammon, Karnak. Section through Hypostyle Hall.\textsuperscript{11}**

**Ancient Greece**

Usually oriented toward the east, the Greek temples took advantage of the low morning sun penetrating the doorways to illuminate the statues within. Door openings are believed to have been the only light source for these spaces, but some argue that large room openings added light to the interior. Because of the relatively small door openings, the sunlight that reached into the temples was narrow and direct, creating sharp contrast with the interior darkness. During the remainder of the day, light would reflect off the ground into the building.\textsuperscript{12}
As with the Ancient Egyptian urban homes, Ancient Greek residences featured orientations maximizing solar access. This the Greeks achieved through the use of grid town plans, also referred to as the Hippodamian scheme, seen in figure 1-3, a city plan of Miletus after 479 B.C. The use of the sun was likely intentional, as the Greeks' use of the sundial indicated that they knew about the sun's movement. Homes were built for winter solar penetration through the "pastas", a long shallow room or portico that faced into the courtyard to the south. Some houses were two-storied around a courtyard. Others were one-storied on the south so as not to block sunlight to the two-storied north section.
Ancient Rome

Several Roman architectural improvements dramatically increased the use of daylighting and passive solar heating. In contrast to the Greeks who created public spaces and gatherings outside, the Romans built numerous monumental public buildings and developed a variety of strategies for daylight illumination. The development of the round arch, barrel vault, and dome permitted masonry materials to be used in compression for large spans. Allowing larger uncolumned interiors, arches created the promise for large wall openings that can admit great amounts of
light. In contrast, the Greek temples featured narrow shafts of light with sharp contrast between dark and light areas.

Romans also pioneered the development of glazing material. Available for the first time, it was primarily made up of small pieces of small glass sheets or thin pieces of transparent mica. Roman courtyard houses responded to the need of controlling heat and admitting light to the interior spaces. The atria or atrium at the center of the houses provided light to the surrounding rooms through large door openings. Rooms were also lit by windows facing a street or a garden.16

Illustrating the Roman inventions, the “Golden” house of the Emperor Nero engaged not only the occulus skylight to light the central octagonal hall, but also a string of hidden clerestories to light the adjoining rooms.

Figure 4. Nero’s Golden House, Rome, A.D. 64-68. Axonometric left, section right.17

The Pantheon in Rome, one of the most known buildings in Rome, features a central open skylight admitting the sun into the space below as seen in figures 5 and 6.
Figure 5. Dome, Pantheon, Rome.\textsuperscript{18}

Figure 6. Pantheon, Rome, A.D. 120-124. Section showing unglazed skylight.\textsuperscript{19}
The central locations of basilicas, halls of justice and commercial exchanges, indicated their importance to the Roman public life. Their plans were usually rectilinear, elongated east and west to maximize southern exposure. The roof over the center east-west nave was elevated above the flanking lower side aisles. The structure over these sides aisles consisted of concrete vaults running north-south covered by a flat roof. This flat side-aisle roof together with the raised center roof allowed the use of large clerestory openings to light up the vast interior, which typically exceeded 200 feet across the smallest dimension. These large expanses of daylight openings were not to be repeated until the Gothic period.

Figure 7. Basilica, Transverse section.\textsuperscript{20}

With the reduced availability of firewood on the Italian peninsula as early as first century B.C., Romans were forced to think of alternative methods of heating
their houses. Thus prompted the construction of solar tempered houses and public buildings. As Vitruvius argued,

"In the first place, the warmest possible situation must be selected; that is, one which faces away from the north and north-east. The rooms for the hot and tepid baths should be lighted from the southwest, or, if the nature of the situation prevents this, at all events from the south, because the set time for bathing is principally from midday to evening." 21

**Early Christian**

Used earlier for court and commercial trade functions, the basilica building type was adopted with few changes for religious services following the decline of imperial Rome. Timber trusses were used instead of the Roman concrete vaulting, resulting in sloped side-aisle roofs that reduced the wall area open for clerestory windows. Thus, clerestories and side-isle windows were reduced in size and increased in numbers.

*Figure 8. Old St. Peter's, Rome. (c. 333).* 22
The darker interiors nurtured the feeling of the mystical nature of the new religion. It also helped narrow the attention on the axial nature of the basilica rectilinear shape focusing on the altar. The apse with its typical semicircular shape was enhanced by windows directing light to the focal point of the church.

**Byzantine**

The single most influential development of daylighting in Byzantine architecture was the use of the dome supported at four points covering a rectangular plan. The extensive employment of domes is in stark contrast to the Roman use of vaulting and the Early Christian timber trusses to cover comparatively long, narrow plans. The Byzantine plan focused around a central dome surrounded by less important spaces covered with smaller half-domes intersecting below the main dome. Light entered through small stained-glass windows at the base of the central dome. As a result, the central dome appears to hover over the supporting structure. The most famous example of this is the Hagia Sophia in Constantinople (Istanbul).

![Figure 9. Hagia Sophia, Constantinople. Longitudinal section.](image)
Romanesque

Characterized by a restoration of the round masonry vaults and arches of the Roman period, the Romanesque period replaced the lighter wood trusses of the Early Christian period. The linear basilican church plan evolved into a cross plan with a prominent dome at the connection. The groined vault developed as a result of two vaults intersecting, but was not as refined as that developed in the Gothic period which followed. Glazed window openings in the load bearing sidewalls remained relatively small in regions of Italy and southern France. Window openings became somewhat larger in northern Europe as the need for more light dominated. Emerging from this development came the non-bearing end wall that boasted larger openings and took form as the rose window.²⁵

Gothic

With its mystical shroud, the Gothic period elevated stone masonry to a higher level of structural refinement. Introducing the pointed arch and vault, intersection of roof vaults of different widths became a possibility. The ribs at the vault intersections diverted the roof loads laterally to point locations on the walls. With walls of unprecedented height, the flying buttress came about as a way to transmit the vertical loads to the ground while resisting the outward lateral loads resulting from the arch action. The wall was no longer the primary roof-bearing system, thus allowing for greater openings in the walls. These vast openings were decorated with large expanses of stained glass, which gave the walls a new feeling of lightness. Continuing the old tradition of orienting the basilican cruciform plan on
an east-west axis, almost every major Gothic cathedral utilized its south façade to maximize daylighting.\textsuperscript{26}

**Renaissance**

"The structural innovation and expression that characterized the Gothic period gave way, in the Renaissance period, to a revival of interest in visual harmony and proportion. Classical elements were introduced. Daylight illumination techniques became more subtle, sophisticated, and innovative. Daylight was typically used to emphasize architectural form and dramatize internal spaces." \textsuperscript{27} It formalized the window pattern within symmetrical facades, many times ignoring the interior spaces served by the glass. Long facades dominated palaces of merchant princes, giving a distinct impression of grandeur. The need for daylight dictated the depth of buildings, 50 to 65 feet, placing gardens and courtyards beyond.\textsuperscript{28}

An important advance of the Renaissance was the thick or pochè wall formed on each side of spaces directly in response to the spatial and decorative requirements of the particular rooms. The wall became what was left over after the room spaces were "carved out" – a significant change of earlier periods, particularly the Gothic period in which interior spaces were mostly determined by the structure. These thick walls became locations for servicing functions which servants would use. Also, the ceiling shapes responded equally in respect to the room below or above. Deeply recessed daylight openings were the result of the thick walls and ceilings. These openings were many times hidden from view, creating unprecedented quality of light. The Queen's House at Greenwich, designed by Inigo
Jones in the 17th century, pioneered the use of top-lit internal rooms which allowed for deeper plans.

Figure 10. Queen's House, Greenwich (1616-35).

Domes of this period were usually supported on "drums" with a large number of window openings. A new method of structuring domes developed, with the exterior and interior domes as separate structures, resulting in a complex path for letting daylight in to the upper part of the dome.
Industrial Architecture

The building envelope was the primary mediator between the outside and the inside prior to the 1800s. Architects used daylighting as the primary lighting source, which was determined by the window size and placement, climate, activity, and location within a building. Any extra lighting was supplied with candles and oil lamps. Thus, activities in need of light were limited to daylight hours. With the building envelope as the primary controlling factor of the inside environment, architects were forced to use existing conditions of the site.

With the advent of the industrial revolution, all that changed. Innovations were developed that offered the designer other ways to control the thermal and light properties of the inside environment. To most architects, this was a freeing development in which they could freely express and develop new concepts in architecture. Thus, the way buildings were designed came to an abrupt change of direction.
The Modern Movement

The modern movement was pioneered by architects who reacted to the ornamental extremes of the late Renaissance. They used the new freedom aided by new technologies of the industrial revolution to invent new building forms. A few architects like Frank Lloyd Wright, Le Corbusier, and Alvar Aalto continued to use historical principles of building orientation, shape, natural ventilation, and daylighting while creatively incorporating a plethora of new technologies.

On the opposite side, architects began ignoring climate and developed buildings completely isolated from its surroundings by mechanically moving air and illuminating spaces. Unfortunately, this direction came to dominate professions like architecture and engineering during the rebuilding of post-World War I in Europe.

Due to the immigration of prominent architects like Walter Gropius, Eliel Saarinen, and Ludwig Mies van der Rohe to the United States, the movement quickly took root. As these architects became involved with the teaching and practice of architecture, they created the foundation for the movement. As a result, simple geometric buildings were developed.

Influenced by Cubists and de Stijl, they reacted to the excessive ornamentation of earlier centuries. But as seen in the 1930s house by Ward & Lucas and Maxwell Fry’s house in Chipperfield, new structural inventions allowed for more daylight to enter buildings, thus creating well-lit spaces (figure12).
Figure 12. The 1930s house by Connell Ward and Lucas illustrates how new developments in structure allowed wraparound windows to increase daylight. Photo: Derek Philips.

Figure 13. Maxwell Fry designed this house in Chipperfield for both daylight and view. Photo: Derek Phillips.
As students of these early advocates graduated and entered the profession, these technical relationships developed to become mainstream ways of designing buildings. A style that was energy-dependent emerged, fundamentally altered from previous shelter-oriented styles.³²

**Postindustrial Architecture**

With energy as a seemingly unlimited resource, the large consumption of the energy-oriented buildings of the international style was ignored. But with the realization of the vulnerability of such designs during the 1970s and the energy crunch, attitudes have begun changing little by little. Concerns for the environment were not enough to change attitudes, but with the glooming economic impact of possible scarce fossil fuels did prompt a change in direction.

The financial community could easily adapt to new ways of thinking ahead, but for architects the challenge was much more daunting. Rethinking previous mechanically oriented designs and strategies required a return to the fundamental knowledge of architecture and reclaiming the position of the integral designer.
CHAPTER 3. DAYLIGHTING DESIGN CONCEPTS

Daylighting Design

This chapter serves as a guide to some of the most useful daylighting techniques. It also serves to inform about the advantages and disadvantages of daylighting and how to maximize those advantages while minimizing the disadvantages.

Fundamental Components of Daylighting

_Treat the building as a luminaire._

A goal of all daylight design is to create even and consistent interior illumination. As with most lighting fixtures, internal and external geometries and finishes impact the way light is distributed within a space. The architecture does more than just dictate the way light comes into a building; it can help light reach interior spaces by redirecting it, thus effectively reducing glare associated with high contrast ratios.

_Separate the vision and daylight glazing._

A common misconception is to think of the standard curtain wall and punctured windows in buildings as a method of daylighting. These types of windows do have some potential for illuminating adjacent spaces. A designer must be aware of the fact that glazing has two purposes: providing a view out and letting daylight in. Also called "vision glass", it creates a connection between the outside and the inside. Therefore, glass that is used to daylight spaces is inherently different from
the "vision glass", providing spaces with light from other areas of the building, which are not in the line of vision of the occupants.

<table>
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<th>Color</th>
<th>Purpose</th>
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<th>( \tau_{\text{solar}} )</th>
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<th>Summer U</th>
<th>SHGC</th>
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<td>46%</td>
<td>.31</td>
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<td>60%</td>
<td>25%</td>
<td>.29</td>
<td>.30</td>
<td>.31</td>
</tr>
</tbody>
</table>

Notes:
1. \( \tau_{\text{vis}} \) is the visible light transmittance.
2. \( \tau_{\text{solar}} \) is the total solar transmittance.
3. Winter U-value is the center-of-glass thermal conductance under standard winter conditions in Btu/hr·°F·ft².
4. Summer U-value is the center-of-glass thermal conductance under standard summer conditions in Btu/hr·°F·ft².
5. Solar heat gain coefficient (SHGC) is the fraction of the incident solar radiation that becomes a cooling load.

Figure 14. Typical Glazing Selections for Daylighting and Vision Glass.

Position the daylight aperture to create mood and visual focus.

As with artificial light, daylight can be used to create visual focus. With careful attention to aperture location and detailing, one can influence the direction and
placement of daylight, thus affecting occupants' mood. Directing daylight to areas of importance within a structure can bring emphasis to specific activities in a building. A great advantage to daylighting is the psychological connection to the outdoors that is created with its subtle lighting color and intensity changes occurring throughout the day.

Address the requirements of the visual task.

The human activities within a space must be carefully understood to provide adequate light to specific visual tasks. A good source for standard lighting design can be found in Illuminating Engineering Society of America's Handbook.  

Integrate the daylighting system with the architecture.

Complimenting and playing along with the architecture is what daylighting should do. It should help direct the overall form of a building without overly controlling it. It can provide a unifying theme to the creativity of the architect. Daylighting should be placed with careful consideration of the differing nature of the vision and daylighting apertures.

Integrate the daylighting system with other building systems.

Realizing that today our society and peoples' lifestyles are engaged in a variety of activities after the sun has set. The need for artificial light is an important factor when considering a daylight system, but should be considered a secondary option during hours with plenty of daylight. Thus incorporating lighting control systems that can ensure energy savings should be realized. Recognizing the importance of the energy aspect of daylighting, however, this thesis has its focus on
the application of daylighting techniques within the area of standard suburban housing.

Design Issues

"Architects and designers who are sensitive to basic daylighting fundamentals can achieve an aesthetically pleasing space without sacrificing cost or creativity. An awareness of certain issues that occur when daylighting is employed will assist in the success of an effective design." Gregg D. Ander, AIA

Design Variables

Site Context

The sun is a very dependable source of fairly constant light. Sky conditions affect the amount and quality of sunlight entering buildings. There are three types of sky conditions that are used when estimating illumination levels within a space:

Overcast sky. A very uniform type of sky which tends to move and change very slowly. It is defined as such when 80% or more of the sky is covered in clouds. The illumination produced on the Earth's surface can vary between several hundred footcandles to several thousand, depending on the density of the clouds.

Clear sky. It is brighter than the overcast sky, and has fairly stable illumination levels. It is defined as up to 30% of sky is covered with clouds. The illumination levels it produces vary between 5,000 and 12,000 footcandles.

Cloudy sky. The remaining amount of clear sky is considered to be within the definition of a cloudy day. Clouds covering between 30% and 80% of the sky. It features widely varying luminance levels from one place to the next.
External obstructions adjacent to a building affects the amount of daylight entering the spaces in a building. Trees, topography, and other structures, are examples of common external obstructions.

**Design Strategies**

*Increase Perimeter Daylight Zone.*

One of the simplest methods of increasing the possibility of daylight entering a building is to increase the perimeter daylight zone. Elongated plans or courtyard-style buildings are favored over deep buildings. In essence, the exterior envelope of the building is increased to maximize exposure to daylight.

*Allow Daylight Penetration High in a Space.*

Letting light penetrate high in a space allows for deeper penetration of daylight into spaces. Entering above the field of view of the occupants, excessive brightness is avoided and the light will reflect and scatter around the space before it reaches the task level.


As the area of an aperture increases, the amount of daylight received in a space also increases. If the glazing of an opening is perfectly transparent, the “effective aperture” size would equal the area of the opening. The “effective aperture” is in essence the potential of a glazing system to admit light. By calculating this potential one can effectively evaluate the daylighting potential of a schematic building configuration.\(^{36}\)
Bounce Daylight Off Surrounding Surfaces.

Surfaces inside a space can be used to help daylight areas that would otherwise not get enough natural light, leveling out the differences between the dark and the brighter areas.

Slope Ceilings to Direct More Light into a Space.

When used high in a space and towards the core of a building, sloped ceilings are great at directing light into the center. Equipping the sloping ceiling with a highly reflective surface and a diffusing system, it should perform effectively according Ander.37 But as Evans points out in the calculations investigating a sloped ceiling, there was no significant effect on daylight in the space.

Figure 15. Sloping ceilings: Sloping ceilings have no significant effect on daylight on the task.38
Avoid Direct Beam Daylight on Critical Visual Tasks.

Most people have experienced excessive light on a task at some point in their lives. It is discomforting to work under such conditions, thus more control of the incoming light must be achieved. Fenestration control should be considered.

Figure 16. Building section showing fenestration treatments to control direct beam.\textsuperscript{39}

Use Direct Sun Cautiously in Areas Where Non-critical Tasks Occur.

When using direct sunlight, patterns of light and shadow can add a dynamic dimension to a space. Letting the sun play through a space creates a sense of well-being, time, and orientation.
Filter Daylight

Filtered daylight can create an exciting space within a building. It can be achieved by using vegetation, louvers, or curtains. Filtering the light aids in softening the light and distributes light more evenly throughout space.

Figure 17. Section showing vegetation and lattice to filter daylight.40

Figure 18. Drapes can be effective and attractive daylight controls.41
Figure 19. Types of reflectors and shades.⁴²
Interior Elements

Interior Shading Controls

Venetian blinds can be very effective in blocking out direct sunlight and can be adjusted to reflect light away from the field of view. Draperies are also very effective in diffusing light. Draperies can provide total darkness with the proper textiles, or can diffuse light through sheer fabrics, allowing for a limited view out. As with other forms of interior shading controls, roller shades can provide a variety of shading options with varying degrees of opaqueness. The strength of interior shading devices is that they can easily be removed when not needed, thus creating a more dynamic space.

Design Options

Sidelighting.

This is most common form of lighting spaces today. Sidelighting refers to window openings that are located on walls. Their popularity stems from the ease of installment and the views they provide for the occupants. Again, there is a possibility of glare if not shaded properly. Spaces can be daylit with windows unilaterally, bilaterally, and multilaterally with a variety of results. Unilaterally lit spaces are lit through windows on one wall only. Bilaterally lit spaces let light in through non opposing apertures, and multilaterally lit areas receive light from at least two non-opposing apertures.43
Clearstories.

The difference between clearstories and skylights is that they are placed vertically, not horizontally or at an angle like skylights. They can be shaded effectively to control direct sunlight. Clearstories are great for use high in a space, admitting light into parts of the building the sidelighting cannot reach. The George Gund Hall on the Harvard campus shows how clearstories can be used effectively.

Figure 20. Celestories can bounce great quantities of daylight and can control direct sun and vision to the exterior.44
Figure 21. Harvard's Gund Hall uses clerestories over the studio areas for ambient and task lighting.  

Skylights

When a large quantity of light is wanted, a skylight is an excellent option. It provides large amounts of light with minimum-sized openings. Generally the skylights are oriented horizontally, thus taking advantage of the proportionally larger amount of light than with vertical glazing systems.
CHAPTER 4. DESIGN PROPOSAL

In this thesis I have set forth a goal to design a commonly used house layout to demonstrate daylighting techniques on a smaller scale than with commercial and other types of larger-scale buildings.

The site for the Daylit Suburban House is located in Ames, Iowa. (more accurately, in the far southeastern corner of the city, in a neighborhood called Kate Mitchell named after the Kate Mitchell Elementary School). The city of Ames boasts a population of about 50,000. Of that, a large percentage are students at Iowa State University. The Kate Mitchell neighborhood began in the early 1970s as a small out-of-the-way part of Ames. It has continually grown with new homes of varying sizes.

Located at the corner of Ken Merill Rd. and 550th Ave., the site features tall grasses and a small row of trees on the southern edge, see Appendix D for photographs of site. The topography is somewhat sloped towards the north east (figure 24). To the west is a row of smaller houses built almost at the same time in the mid 1980s (Appendix C). These homes are predominantly single family, with a few duplexes mixed in. To the north is an old farm that has withstood the expansion of the neighborhood. To the east and south are fields and a small farmstead. The farm to the south is located a few hundred feet to the southward, thus not an obstruction to privacy nor sunlight for the house designed in this thesis. The southern exposure of the site makes it an ideal site for locating a daylit house
(Appendix C). Also, with very little vegetation obstructing the sun from entering the east side of the house.

The orientation of most suburban houses is towards the street. As this is very convenient for today’s automobile-centered culture, I am continuing this theme and locating the house with its front towards the street providing access to the garage via the driveway (figure 24). The north side of the house is nestled into the ground by help of earth berms (figure 27). This provides some protection from the winter winds from the northeast (Appendix E). The garage is located to the northeast of the house, also providing a buffer for the potentially harsh winter weather. Fast growing coniferous trees are planted on the western, northwestern, and northern sides of the house (figures 28, 29, 30, 31). The north and northwestern trees break up the winds from the north. The western trees, planted at a size of between 12 and 14 feet in height, will grow more than a foot a year, thus providing shade for the western side of the house as they age. The southern line of trees are great for shading the south facade of the house (figure 30).

The shape of this house allows for a majority of the space within it to have some contact with the outer perimeter of the house. Rooms are located on the outer edge of the house while circulation is located in the center areas (figures 24, 22). Placing rooms near illumination sources are critical for maximizing the potential for daylighting solutions. In this design I have incorporated at least two sources of light in each space. This approach allows for softer light and the light is blended in with the darker areas of each space, effectively reducing glare. Figures 25 and 26 are detailed plans of where all windows and other openings are located.
Here is a summary of the luminaries in each space in the house. The living room has large south facing windows that open up to the back porch. Light also comes in from the above skylight and adjacent spaces (figures 25, 26). The kitchen has large clearstory windows facing east and windows facing south (figure 23). The dining room has windows facing east and north. The library has windows facing south and clearstory windows facing west. The powder room on the first floor has a large window fitted with frosted glass on the west side. The laundry is fitted with clearstory windows on the west and tall windows facing north. The 2nd floor has a similar
arrangement with daylight entering from multiple sides. The bedrooms have conventional windows facing east and west respectively, and are fitted with skylights on the north side of the roof. The den has windows facing south and west. The bathroom has windows on the east side, south, and west. The west side window in the bathroom, borrows light from the central space. The central space of the house has two skylights: one continuous from east to west at the peak of the roof, the second in the center of the north section of the roof.

Figure 23. East Elevation. 10 a.m. June 21. Not to scale.

On the east side of the house there are multiple windows, clearstories, lightshelves, glass blocks, and glass doors. These are all specific to the needs of the spaces beyond. In figure 23 one can see these features of the east wall at 10 a.m. on June 21.
Figure 24. Site Plan. 1' contour lines and vegetation. Not to scale.
Allow Daylight Penetration High in a Space.

The most occupied spaces in most houses are the kitchen, bedroom, and living room. Lighting these spaces with large amounts of light from high on the exterior walls improve the lighting of these spaces and promises improved health according to Dr. John Ott. Skylights, clearstories, and light-shelves help daylight enter high in spaces, directing light further into the space.

Bounce Daylight Off Surrounding Surfaces.

Using lightly colored materials for the walls aids in the spreading of daylight into areas of the house that otherwise may be dark. The hallway on the first floor has been outfitted with lightly colored materials that have a fairly high reflectance rate, effectively directing the light coming from multiple directions (figures 32, 33). The floors throughout the house are mostly tile, with a few exceptions in the library and bedrooms. Tiles have a high reflectivity but can easily be controlled with area rugs or applying patterns imbedded in the tile. It is also important to consider the surfaces surrounding the exterior of the house. Smooth and lightly colored stones pave the exterior patio and paths leading around the house. These surfaces reflect light that does not directly hit the windows, thus providing more diffuse lighting (figure 42).

Avoid Direct Beam Daylight on Critical Visual Tasks.

All windows in the house that are subject to direct sunlight at any point during the day are outfitted with venetian blinds. These devices can block sunlight or redirect it upward towards the ceiling of a space. Their flexible nature allows for maximum usage as the sun is constantly shifting position in the sky and the lighting
needs also change continuously throughout the day (figure 31). Overhangs are also an important part of the daylighting concept (figure 42). If positioned correctly, overhangs block unwanted hot and bright sunlight. Overhangs should shade windows during the time the sun is located between 71 and 48 degrees off the horizon. This means from about mid-spring to mid-fall (Appendix A).

**Filter Daylight.**

Louvers placed on the south side of the house filter sunlight as it shines on the porch and south façade of the house (figure 42). The louvers create an exciting play of light and shadow as the sun moves through the day. Venetian blinds on the windows also help diffuse the light coming in. Vegetation surrounding the house is an excellent way to filter sunlight (figure 30). The trees to the south of the house break up direct sunlight as it passes through the tree. Placed on the west side of the house are coniferous trees that have dense foliage all year round; this is great for diffusing low-angle sunlight from the east, but most effective in the west when the sun is at its hottest during late afternoon (figure 31).
Figure 25. First Floor Light Penetration Plan.
Figure 26. Second Floor Light Penetration Plan.
With some soil bermed up on the north and north west sides of the house, harsh winter winds are directed over the house. Vegetation on these berms also help diffuse winds. The roof of the house is fitted with turf. Turf roofing has many advantages and disadvantages, but in this thesis it is merely a roofing material and I have not explored this avenue and it does not have anything to do with the daylighting focus of this thesis (figure 27).

The windows on the north side provide diffuse light to spaces needing only some light. The dining room, entry, stairs, and laundry are spaces that are not occupied for long periods of time, thus they are great buffer rooms on the north. The bedrooms are located on the second floor, on the north side of the house. Skylights (figure 27, 43) provide light into these spaces from above.
Figure 28. Front Elevation with Vegetation. Not to scale.
Figure 30. South Elevation with Vegetation. Not to scale.
Figure 32. First Floor Hallway. View from West. 6 p.m. June 21.

Figure 33. First Floor Hallway & Dining Room. View from East. 7 a.m. June 21.
The library is a quiet place to retire in after a long day. Creating a relaxing atmosphere in this space is appropriate for its function. Located in the south west corner of the house, it needs good fenestration control from the hot afternoon sun. The south windows are fitted with venetian blinds and lightshelves that bounce light up into the ceiling. On the west wall are clearstory windows minimizing the amount of sunlight penetrating the room in the afternoons. A perfect spot for reading in bright light is the window seat located below the south windows. One can enter the library through two french doors, from the hallway and from the living room. Fitted with glass, these doors let light through, lending it to the adjacent living room or borrowing from the living room (figures 34, 35).
Figure 35. View of Library from Southwest Corner. 8 a.m. June 21.

Figure 36. Living Room at 11 a.m. March 21.
The living room faces south with its large floor-to-ceiling windows (figure 36, 37). The windows have incorporated doors which open up out onto the south patio. With its two-story space, the living room flows up into the upper hallway and den, from which one can look down (figure 40). The walls are painted a light yellow color and the floor is tiled to facilitate light to move about the space.

Figure 37. Living Room at 8 a.m. June 21.

The master bedroom is located on the north east side of the house. Up on the second floor it receives early morning light through its large east windows. Flooding the room with morning light, the windows are ideally placed on the east side for maximum privacy. The view east is that of fields located in the floodplain. Two skylights provide diffuse light and a possibility of stargazing at night (figure 38).
Figure 38. Master Bedroom at 8 a.m. March 21.

Entering a bright room early in the morning is not very welcome by some people. By exposing your body to bright morning light, one can reap health benefits and a better mood to start the day with. The kitchen is fitted with large clearstory windows on the east wall. These windows light up the ceiling with sunlight that gives the room a brighter feel. Door leading to the east patio provide a link to the outside and possibilities of enjoying food or a relaxing moment under the sun or the stars (figure 39).
Figure 39. Kitchen at 8 a.m. March 21.

Figure 40. View of Living Room from Balcony. 4 p.m. June 21.
Figure 41. West Façade at 3 p.m. June 21.

Figure 42. South Façade at Noon, June 21.
Figure 43. View of Skylights Facing North.
## APPENDIX A: SOLAR ALTITUDE AND AZIMUTH.

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**TIMES** are solar times, not necessarily clock time.

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<td>127.2</td>
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<td>131.8</td>
<td>-15.0</td>
<td>136.7</td>
<td>-12.5</td>
<td>138.4</td>
</tr>
<tr>
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<td>145.9</td>
<td>-21.7</td>
<td>149.7</td>
<td>-18.9</td>
<td>151.0</td>
</tr>
<tr>
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<td>-34.2</td>
<td>162.2</td>
<td>-26.1</td>
<td>164.3</td>
<td>-23.1</td>
<td>165.0</td>
</tr>
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<td>-36.0</td>
<td>180.0</td>
<td>-27.6</td>
<td>180.0</td>
<td>-24.6</td>
<td>180.0</td>
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</tbody>
</table>

**TIMES** are solar times, not necessarily clock time.

**ALTITUDES** are expressed in degrees above the horizon.

- **+** means the sun is above the horizon
- **-** means the sun is below the horizon

**AZIMUTHS** are expressed in degrees from due south:

- 0 corresponds to due south
- **+** corresponds to compass directions west of south
- **-** corresponds to compass directions east of south
- north is either +180 or -180
APPENDIX B. PRECEDENT SUBURBAN HOUSES

Figure 44. "The Pineville" by LifeStyle HomeDesign.

Figure 45. "The Greenwood" by Breland & Farmer Designers, Inc.
APPENDIX C: AERIAL PHOTOGRAPHS OF AMES SITE

Figure 46. Kate Mitchell neighborhood.
Source: http://www.amesassessor.org/
Figure 47. Aerial Photograph of site.
Source: http://www.amesassesor.org/
Figure 48. Aerial Photograph Close Up.
Source: http://www.amesassesor.org/
Figure 49. Aerial Photograph Close Up of Site.
Source: http://www.amesassessor.org/
APPENDIX D. PHOTOGRAPHS OF AMES SITE.

Figure 50. West Side of Site. August 2002.
Figure 51. South East View. August 2002.
Figure 52. South East View. August 2002.
Figure 53. Looking South. August 2002.
Figure 54. Looking South Along 550th Ave. August 2002.
Figure 55. Looking South West. August 2002.
Figure 56. Looking North West. August 2002.
Figure 57. Looking North West Toward Farm. August 2002.
Figure 58. Looking North. August 2002.
APPENDIX E: IOWA’S CLIMATE


Iowa’s climate, because of latitude and interior continental location, is characterized by marked seasonal variations. During the six warm months of the year the prevailing moist, southerly flow from the Gulf of Mexico produces a summer rainfall maximum. The prevailing northwesterly flow of dry Canadian air in the winter causes this season to be cold and relatively dry. At intervals throughout the year, air masses from the Pacific Ocean moving across the western United States reach Iowa, producing comparatively mild and dry weather. The autumnal “Indian summers” are a result of the dominance of these modified Pacific air masses. Hot, dry winds, originating in the desert southwest United States, occasionally sweep into Iowa during the summer producing unusually high temperatures and desiccating crops.

TEMPERATURES

The average annual temperatures range from 46° F in the northern counties to 52° F in the southeastern counties.

In July, the hottest month, the average daily maximum is around 85°F and the daily low are mostly in the lower 60s.

In January, daily highs range from 24°F to 34°F, north to south, and the lows from 4° F to 14° F.

Extreme temperatures have varied from 118°F at Keokuk on July 20, 1934, to -47°F at Washta on January 12, 1912.

In almost every year, somewhere in Iowa, there is a maximum above 100°F and a minimum under -20° F. In half the years there is a maximum above 104° F and a minimum below -31°F. The average number of days with temperatures 90°F or higher range from 47 at Shenandoah to 6 at Waukon and Saratoga. The number of days with zero or lower temperatures range from about 10 per year in the south to 30 in the north.

PRECIPITATION

Precipitation averages around 31 inches per year for Iowa, ranging from 25 inches in the extreme northwest to about 34 inches in the east central and southeast parts of the state. However, annual totals vary widely from year to year and from place to place. Annual totals for individual localities have varied from as little as 12.1 inches to as much as 74.5 inches, the latter occurring in 1851 at Muscatine. During the period of reliable records (since 1873), the wettest year in Iowa was 1881, although 1858 was probably wetter, and 1910 was the driest year.
Nearly two-thirds of the annual precipitation is measured during the six crop months of April through September. Measurable rain occurs on about 100 days per year; the frequency of a tenth of an inch or more increases southeastward across the state from 44 days per year at Inwood, James, and Merrill to 69 days at Maquoketa. Half an inch or more per day varies from 15 days in the extreme northwest to near 25 in the southeast. The heaviest daily rainfall of record is 12.99 inches at Larrabee on June 24, 1891. Amounts to 17 or 18 inches have probably fallen in a day or less.

**DROUGHT**

Drought occurs periodically in Iowa, the most severe in recent decades occurring in the 1930s. Hot dry summers were also reported in the mid-1950s, 1918, 1916, 1910, 1901, 1894, and 1886. Extended summer drought periods occurred in 1977 and 1983.

**SNOWFALL**

The average seasonal snowfall varies from near 20 inches at Keokuk to 35-45 inches over northern counties. The season normally extends from October or November to April, but measurable snow has fallen as late in the season as May 28 (in 1947) and as early as September 25 (in 1942). The average number of days with snow cover one inch or deeper per season varies from about 40 days along the southern border to around 90 in the northernmost counties. The average date of the first one-inch snowfall varies from November 25 in the north to December 10 in the southeast. The first trace of snow occurs about one month earlier. In about half the years a daily snowfall of 5 inches or more occurs over southern Iowa, 6 or more over central counties, and 7 or 8 over northern counties. Late winter snowstorms have produced as much as 31 inches of snow in a single storm and 24-hour amounts have exceeded 20 inches. The snowiest winters have almost twice the seasonal average.

**STORMS**

Around 80 percent of the 40 to 50 thunderstorms per year occur in the spring and summer. Occasionally hail, high winds, heavy rains, and even tornadoes, are associated with thunderstorms. The probability of occurrence is highest in late spring and early summer. Tornado frequency is highest in May and June in the afternoon and early evening. Tornado occurrences average about 15 per year on 8 days. Damaging hailstorms, reaching a maximum in early summer, average 58 per year and destroy about 1 or 2 percent of the major crops. Severe hailstorms are slightly more frequent over northwestern counties. In any locality hail usually occurs from two to six times a year.
FLOODS
Floods are most frequent in June at the normal maximum rainfall period but also occur near the end of March, usually as a consequence of rain on frozen ground or rain and rapid snowmelt. Ice jams often contribute to the spring flooding.

WINDS
High winds at 15 feet above the ground (housetop level) reach 50 miles per hour in about half the years. Winds to 75 miles per hour at the 15-foot level, excluding gusts, may be expected once in 50 years.

SUNSHINE
Sunshine increases from northeast to southwest. The percent of possible sunshine varies from 40 to 52 in December, the cloudiest month, to 72 to 76 in July, the sunniest month.

GROWING SEASON
The growing season for warm weather crops extends from mid-May to early October. The spring growing season, suitable for hardy crops, lasts approximately 6 weeks and the autumn season about 7 weeks. The dormant season, averaging 19 weeks, extends from mid-November to late March.
ENDNOTES


3 “Light and Life.” American Society for Photobiology.


8 Moore, 3.

9 Moore, 4.


12 Moore, 6.

13 Fletcher, 110


15 Moore, 6

16 Philips, 1

17 Moore, 7

18 Trachtenberg, 137

19 Fletcher, 235

20 Moore, 7

22 Trachtenberg, 161

23 Moore, 8.

24 Fletcher, 289

25 Moore, 9

26 Trachtenberg, 225

27 Moore, 11.

28 Phillips, 2

29 Fletcher, 1024

30 Fletcher, 812

31 Fletcher, 1031

32 Moore, 14.


34 Southern California Edison, 3


37 Ander, 8


39 Ander, 8

40 Ander, 9

41 Evans, 79

42 Evans, 88

43 Ander, 16.

44 Evans, 71

45 Evans, 72
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