Tim Frank

SIMULATING OUR FIRST-PRINCIPLES PREDECESSORS: *THERMAL ZONING IN DOMESTIC STRUCTURES FROM ANTIQUITY TO THE 19TH CENTURY*

Report
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ACKNOWLEDGEMENTS

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INTRODUCTION

Vernacular architecture is a designation for structures that contain engrained knowledge from centuries of experience built on the relationship between physical building constituents and the natural environment. These structures are based on a fundamental zero-energy response to dynamic climatic conditions, using construction strategies such as orientation, degree of enclosure, and material systems to intensively shape adequate thermal zones for human inhabitation. In vernacular structures located in hot temperate climates, thermal comfort is often achieved through natural ventilation and shading. Through extensive periods of development, early populations advanced their specific knowledge base about the most effective use of construction resources in providing improved levels of comfort within the built environment. Much work in this area was contributed by James Marston Fitch who articulated how distinct architectural attributes related specifically to their natural environment, countering the modern movement which utilized hermetically sealed building envelopes and steady-state interior environments which failed to make such a direct connection.

Today, with use of state-of-the-art computer simulation programs, much can be learned and demonstrated about the unique performance characteristics of historical structures and their connection to the immediate environment. Computer simulation platforms offer a highly interactive and diverse toolset to researchers, facilitating testing sequences which acutely disclose how a range of geometric building configurations intensively shape the behavior of light, heat, and airflow present within the extensive environment. The emergence of state-of-the-art computational fluid dynamics platforms provides an unprecedented understanding of how building boundaries shape fluid dynamics, inviting us to bridge the gap between the configuration of building enclosure systems and environmental factors. Knowledge of these strategies becomes crucial for those within the field of architecture as they expand our understanding of what constitutes significant historical precedents in design and construction.

To better understand the passive cooling potential of historical structures relative to variable inputs including prevailing wind and solar path, this study explores a series of chronologically and geographically distinct housing typologies which demonstrate a progression of knowledge about the most effective use of construction resources in providing improved levels of comfort within the built environment from classical European to pre-industrial American cultures. Classical European housing typologies investigated include the Insula Row House, the Peristyle House, and the Terraced Slope House. Pre-Industrial American vernacular typologies investigated include the Shotgun House, the Dogtrot House, the Bungalow House, and the Antebellum Mansion. Each housing type is digitally reconstructed and simulated using state-of-the-art computational fluid dynamics (CFD) and ray tracing algorithms to identify patterns of form and space demonstrating the potential for passive climatization. The aim of the study is to develop knowledge of ancient and vernacular thermal zoning measures that can be used to highlight the significance of high-performing historical structures and as the basis for contemporary development.

METHODOLOGY

Simulation supported case study analysis is comprised of four main constituents: computational modeling, multi-state simulation, output corroboration, and parametric analysis. The initial step in the analysis workflow involves the digital reconstruction of each historical structure to be studied using 3D geometric modeling software. Polygon meshes from photogrammetry surveys and background bitmaps representing each historical structure are scaled and located within the 3D modeling workspace, serving to generate the geometric armature of each reconstruction. Layer control dialogs are used to organize boundary surfaces by material assembly which are converted to polygonal mesh objects whose resolution and subsequent triangulation are set within the conversion process.

The next step in the analysis workflow involves the multi-state CFD and ray tracing simulation of each reconstruction. This process begins with the construction of a volumetric mesh that approximates building boundary conditions, inlets, and outlets, around and through which specified environmental states are simulated. The input values are established through the use of climate modelers. The modeler will establish a reliable climate profile for each region under investigation, accounting for changes in temperature, humidity, precipitation, and prevailing wind velocity across an annual cycle. These simulation platforms offer critical insight into the behavior of environmental factors relative to building boundary conditions and test the parametric relationship between boundaries and flow fields through the rapid adjustment of simulation states such as wind direction, velocity, and alternative boundary configurations.

The third step of the process involves output corroboration. Simulating multiple domains within the same model provides the opportunity to instill reciprocity protocols within the reiterative process. Using highly interoperable simulation platforms enables the system to attune itself, whereby one domain branch reinforces or critically examines the relative reliability of another. Instead of relying heavily upon computationally intensive simulation engines to corroborate results, the instilled reciprocity protocols allows us to compare and contrast the output from within the integrated system.

The final step of the process encompasses parametric analysis. As each historic structure is simulated and the results are corroborated using multiple states during critical time frames, variations to geometric models are introduced to gain a sense of how the built environment changes accordingly. This ‘flexing’ of the model measures the inextricable linkage that is present between the physical enclosure and the behavior of the built environment itself. Once this parametric relationship is established between the architectural assembly and the locally specific environment, these findings are compared to identify archetypal patterns of performance and space, highlighting underlying shifts and continuities in spatial organization across distinct periods and cultural traditions

METHODOLOGY

Each vernacular structure is analyzed using the methodology outlined above to determine how pre-industrial construction strategies modulated dynamic social and environmental factors within the built environment. Light, heat, wind, and view were larger factors considered in identifying optimal zones for inhabitation within each structure. This analysis accounted for three critical times of day; 9am, noon and 3pm while sampling three extreme periods across the annual cycle; winter solstice, fall or spring equinox and summer solstice.

The digital reconstructions and simulations were completed using the following software:

- Rhinoceros (three dimensional NURBS modeling)
- Grasshopper (graphic algorithmic editing)
- DIVA-for-Rhino (daylighting analysis)
- Ladybug (environmental analysis tool providing access to reliable simulation engines)
- Autodesk Ecotect (environmental analysis tool)
- Autodesk FlowDesign (virtual wind tunnel testing)
- Autodesk Simulation CFD (computational fluid dynamics and thermal simulation)

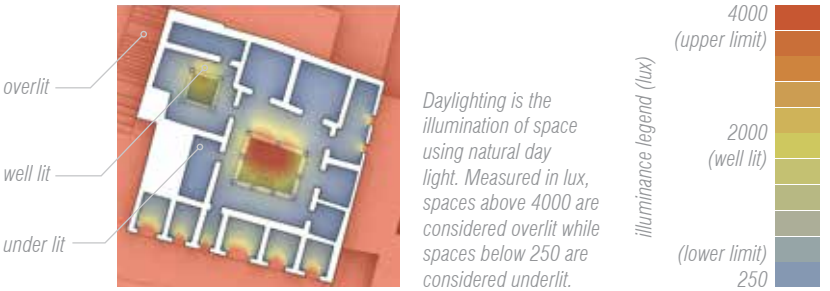
The analysis produced results that speak to the following environmental and social factors:

- Natural Daylighting (the amount of light energy falling on a given surface area)
- Solar Radiation (the amount of heat energy falling a given surface area)
- Solar Ray Tracing (the path of solar energy from the sun to a given surface)
- Air Velocity (the speed of air flow within a given unit volume)
- Air Flow (the path of wind within a given unit volume)
- Air Pressure (differentials in air density that shift in search for equilibrium)
- View Shed (volume of space visible from a given point)

READING THE RESULTS

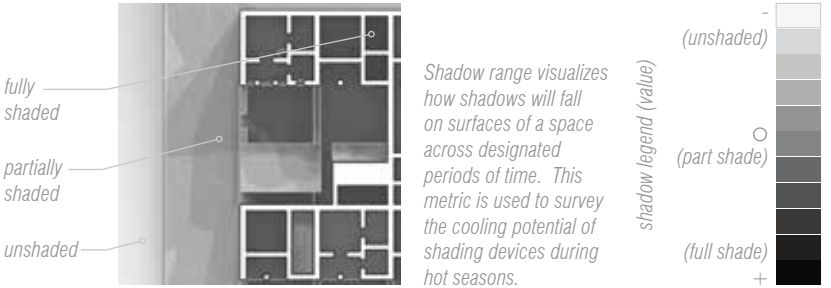
This report discloses how early populations organized space around environmental factors in order to provide thermal comfort within hot-temperate climate regions. It provides analysis of each project through the lenses of view, light, heat and air. While the report initially presents the content on a by-case basis, comparisons across the case study series are drawn at the end of the report. Cross cutting the case study catalog and areas of comparison are quantifiable results from simulation analysis which serve to substantiate conclusions drawn. In order to reinforce the legibility of results, the following guide expands upon the graphic notation used to represent each factor, expanding upon its significance in passively climatizing architectural space.

Natural Daylighting (the amount of light energy falling on a given surface area)



Daylighting is the illumination of space using natural day light. Measured in lux, spaces above 4000 are considered overlit while spaces below 250 are considered underlit.

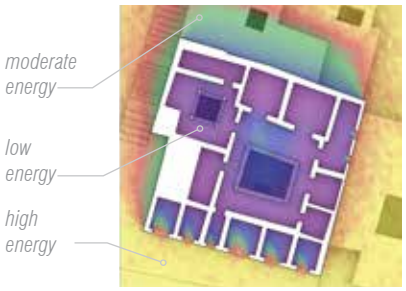
Shadow Range (the amount of shadow a surface receives during daylight hours)



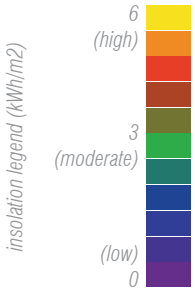
Shadow range visualizes how shadows will fall on surfaces of a space across designated periods of time. This metric is used to survey the cooling potential of shading devices during hot seasons.

READING THE RESULTS

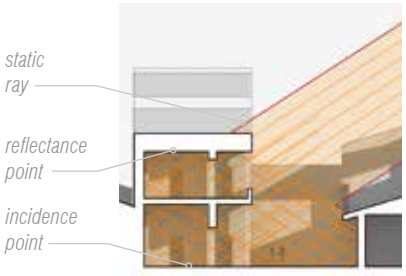
Solar Radiation (the amount of heat energy falling a given surface area)



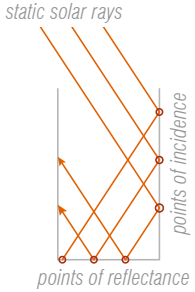
Insolation is the measure of solar radiation falling on a building surface over a period of time and is used to survey the passive solar heating potential of a structure.



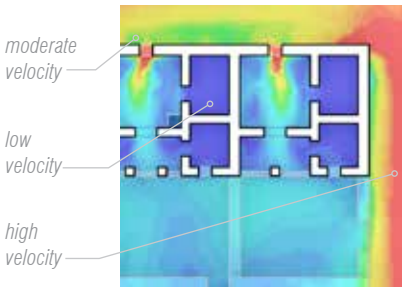
Solar Ray Tracing (the path of solar energy from the sun to a given surface)



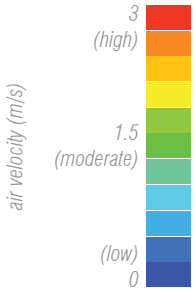
Solar ray tracing tracks the path of static rays, delineating points of incidence (initial strike), the number of subsequent reflections and the amount of light energy falling on critical building surfaces.



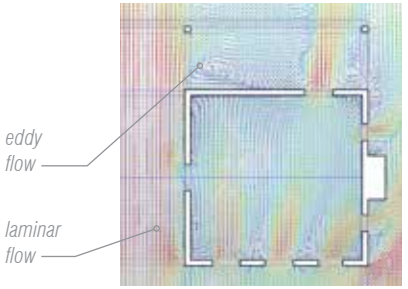
Air Velocity (the speed of air flow within a given unit volume)



Air velocity is the rate of air motion in a given direction usually represented in meters per second. Higher velocities provide evaporative cooling when experienced by building inhabitants.



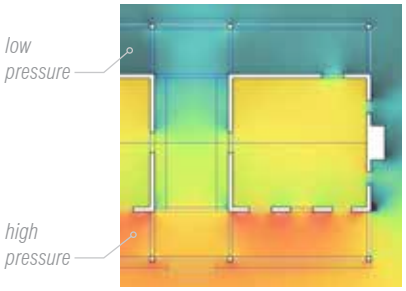
Air Flow (the path of wind within a given unit volume)



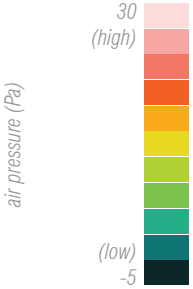
Air flow is the directional behavior of air in space whereby laminar flows run in parallel layers while eddy flows move in swirling directions with each offering different degrees of stimulation during evaporative cooling.

READING THE RESULTS

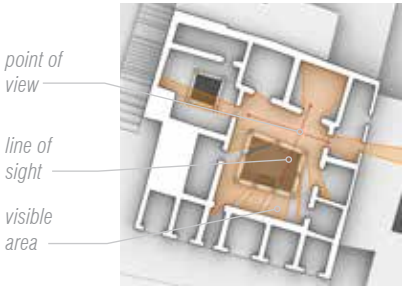
Air Pressure (differentials in air density that shift in search for equilibrium)



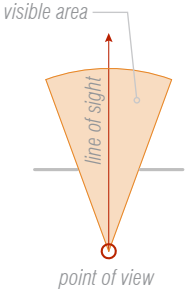
Air pressure is the amount of compression within a given volume of air. In order reach equilibrium, high pressure areas tend to migrate toward low pressure areas causing increases in velocity from the former to the latter.



View Shed (volume of space visible from a given point)



View shed or isovist analysis is the area of space visible from a defined vantage point which also incorporates lines of sight projected from the given point of view.



CASE STUDIES

To better understand the passive climatization potential of historical structures relative to variable inputs including prevailing wind and solar path, this study explores a series of chronologically and geographically distinct housing typologies which demonstrate a progression of knowledge about the most effective use of construction strategies in providing improved levels of comfort within the built environment from classical European to pre-industrial American cultures. Classical European housing typologies investigated include the Insula Row House, dating back to 400 BC located in the ancient Greek city of Priene; the Peristyle House, dating back to 200 BC located in the ancient Greek city of Pergamon; and the Terraced Slope House, dating back to the 1st century AD located in the Roman portion of Ephesus. The intensified development density of these settlements result in a unique model of collective living that establishes a spatial gradient from more to less enclosed. In each case, easing the transition from public to private zones produces a rich inventory of intermediate space types serving to moderate the daily and seasonal variations of the Anatolian climate.

In order to identify exemplary patterns of thermal zoning and spatial organization between housing typologies established in classical European architecture and those in the pre-industrial United States, formative vernacular housing types located within the southern U.S. are also examined to determine how systems of physical enclosure are put to task to achieve high performance outcomes. Four different pre-industrial housing typologies in the southern U.S. are analyzed using CFD simulation platforms to ascertain the principles of thermal zoning employed by each: an early shotgun style house dating back to the early 19th century located in central Mississippi; the Neal Family House, a dogtrot style house dating back to the mid-19th century located in northern Lousiana; the Charnley-Norwood House, a bungalow style house dating back to the late 19th century located along the Mississippi Gulf Coast; and the Waverly Mansion, an antebellum style mansion dating back to the early 19th century located in central Mississippi. Collectively, these vernacular housing types employ critical building attributes which provide thermal comfort for its inhabitants within hot and temperate climates. James Marston Fitch identified six attributes which maximized the shading and ventilation potential of these structures including a number of the following; the huge parasol roof, the deep southern porch, the ventilated attic, the operable perimeter enclosure, and the elevated floor plate.

FINDINGS

While both ancient and vernacular case studies discussed above supply ample evidence of the thermal zoning strategies employed by populations from antiquity to the 19th century, they also provide the opportunity to use state-of-the-art simulation tools to visualize and demonstrate the findings discussed by scholars such as James Marston Fitch. Looking at pre-industrial case studies as a source of insight, these models focus upon ecological relationships between the natural and constructed elements of a locale to understand how early cultures assimilated the building into the interworking of the local climate. These case studies provide evidence of how early populations leveraged natural resources toward the betterment of the built environment, offering added comfort and connection whereby spatial definition ceased to separate or isolate one from their surroundings but were used to extend, intensify and proliferate the characteristics of the natural world. Results from the analysis elucidate atmospheric dispositions within the built environment that reside well within established ranges for adequate interior comfort, demonstrating how quality of life and healthy living situations were achieved through construction strategies by early population groups.

This comparative survey discloses distinctions in atmospheric zoning strategies across traditions, underscoring our appreciation of the unique construction and material characteristics provided by each culture within their respective time period. These distinctive characteristics include organization, focus, and tectonics which are explicated below.

Organization

In ancient Anatolia, the overall composition of the housing block is customarily centralized around a courtyard volume while southern vernacular units are comprised of linear volumes that stretch out into the landscape. This difference can be attributed to both the population group served and the defensibility needed during periods of construction. The ancient Anatolian living blocks nest within systems of fortification and therefore require provisions for compact living within a highly constructed area. In the southern U.S., concentrating resources is also necessary for reasons to do with resource limitation in lieu of accommodating a maximum population within a well-defined perimeter area.

Focus

In ancient Anatolia, housing complexes are routinely focused inwardly toward a collective space, central to a building composition. As highlighted above, the space usually takes the form of the courtyard as the peristyle advances in popularity. This voided center offers access to natural resources for areas over constructed in response to the delimitation dictated by the settlement's fortified perimeter. In the southern U.S., vernacular housing compositions exhibit a prospect and retreat approach whereby view sheds emanating from enclosed interior areas extend horizontally out to the surrounding landscape in multiple directions.

FINDINGS

Tectonics
In ancient Anatolia, settlements are constructed with stone using stereotomic methods. Situated on promontories to satisfy the need for protection, these systems are constructed of earthen materials including brick and stone. The resultant load bearing structures are thick which provide a source of significant thermal massing. Mass-void juxtapositions also result, carving space out of terraced sites and constructed rooms perch just above the natural ground surface. In the southern United States, structures are constructed of wood using primarily tectonic systems. These woven systems frame space and in doing so provide ample opportunities for operability in concert with permeability. Due to their lightness, they also tend to float above the ground which suits the expansive and compressive clay ground below.

In light of these differences, we also find construction strategies bridging between the ancient European and vernacular American traditions. Thus, comparing patterns of thermal zoning between these two cultures we are able to highlight shared influences and progressive developments in spatial organization within hot temperate climates. These shared influences include construction strategies such as thinness, permeability, and symmetry which are further articulated below.

Thinness
Building widths corresponding with that of a single room, also known as singled loaded structures, are evident throughout the case study series. Even building widths containing a single room with adjoining porch or loggia are classified as thin due to the openness of the adjacent space. The narrow width of these building blocks prove useful in distributing natural light throughout inhabitable areas of the plan as the distance between light sourcing apertures and the central room areas is minimized. The alignment of apertures found in these thin floor plates also aids in ventilating these spaces.

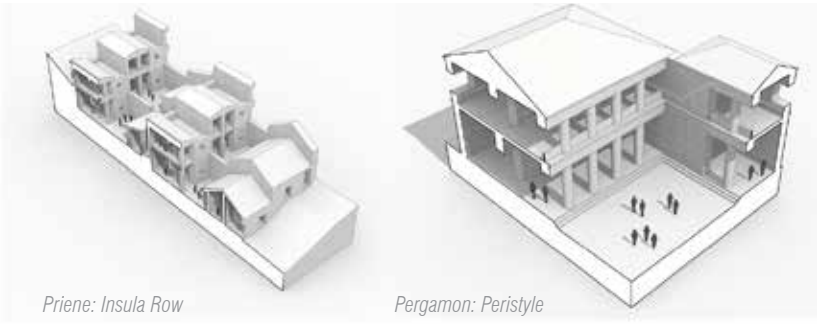
Permeability
Spaces with wide ranging degrees of enclosure, incorporating strategies of openness and closure are a prominent feature found within the case study series. Apertures within solid enclosing planes very from large, enabling physical passage from room to room; medium, for ease of light transmittance; and small, to facilitate visual connectivity. Displacements between enclosing elements create recesses and projections that offer a range of intermediary space types along the building perimeter to ease access to natural resources for inhabitants.

FINDINGS

Symmetry

Both symmetry along a single axis and bi-lateral symmetry are evident in abundance within the case study series. Whether single or double, these regulating axes approximate cardinal directions as the landforms upon which they reside permit. It is presumed that this symmetry and corresponding orientation along cardinal direction is largely due to the symmetry of solar path about a longitudinal axis. With prevailing winds stemming from both northerly and southerly directions, this correlation with building orientation and globalized symmetry can be understood. The neutrality of composition evident across the case studies only intensifies the eccentric natural conditions which dynamically pervade the structure across numerous timeframes.

ANCIENT ANATOLIAN HOUSING TYPOLOGIES

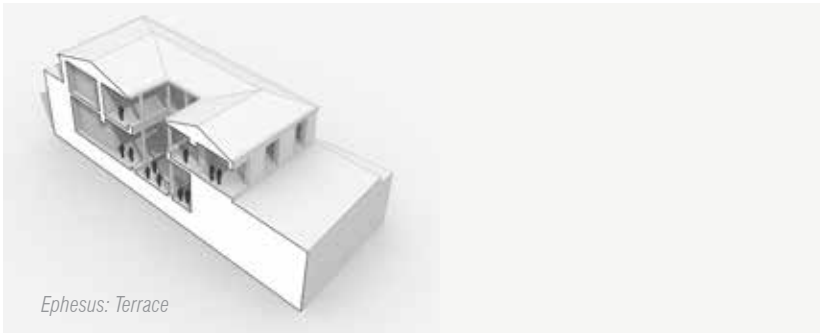


Priene: Insula Row

Pergamon: Peristyle

Strong examples of early urban planning are plentiful along the Aegean coastline in western Turkey, also known as ancient Asia Minor. Sites such as Priene, an Ionian settlement dating back to the 4th century BC, better known for its Hippodamian grid planning; Ephesus, an ancient Greek city dating back to the 10th century BC, best known for its housing complexes terracing from prominent urban promenades; and Pergamon, also an ancient Greek city dating back to the 4th century BC whose citadel is perched atop a prominent promontory all provide early examples of urban planning where space is organized around constraints dictated by both climate and the need for solid defenses from invading factions.

The compact composition of living units and the intensified development densities in these settlements adhere to their sloped terrains, creating terraced patterns that establish unique models of collective living, generating spatial gradients from more to least enclosed. In each case, these transitions from public to private zones establish a rich inventory of space types that serve to inflect the daily and seasonal variations of climate along the Aegean coastline. Furthermore, because these settlements were situated between Greece and Persia they were home to some of the most intense battles in ancient time, giving rise to sophisticated systems of fortification and the need to maximize space developed within the citadel. The spatial disposition within these settlements make them ideal models for passive climatization within high-density complexes as each space type engages the native region in a unique manner.



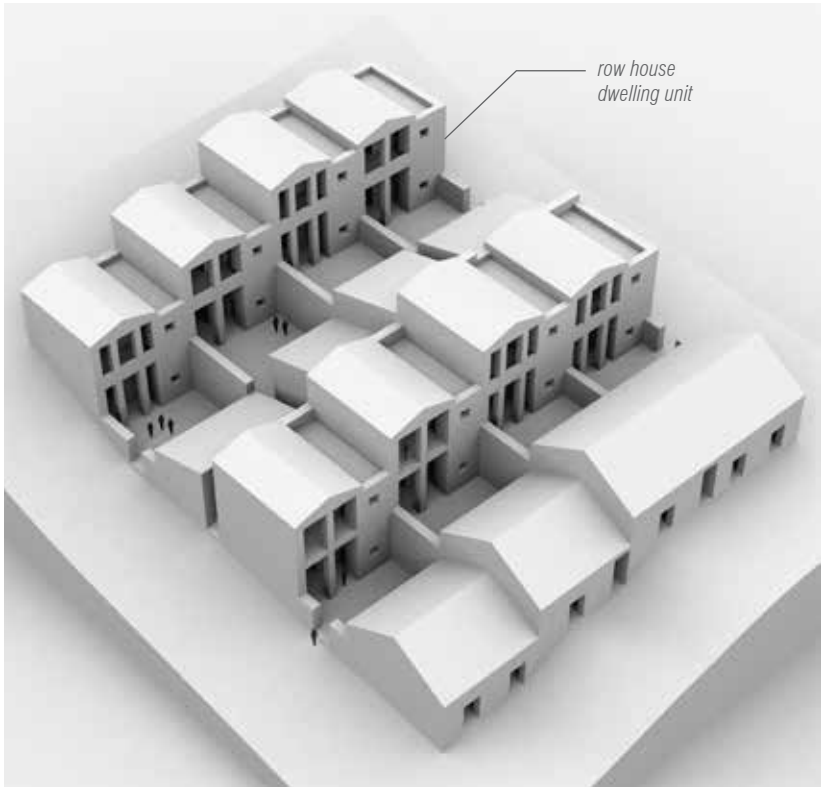
Ephesus: Terrace

Together, these parameters produce three distinct spatial zones: fully closed; fully open; and semi-open. Fully closed areas are typically bounded by earthen structures. Fully open areas provide nearly complete exposure to the surrounding elements, yet are still integral to settlement organization. Semi-open areas provide strategic access to shifting conditions of climate. Taken together, the three zones provide distinct forms of enclosure and can therefore be regarded as separate thermal zones that inhabitants occupied in accordance with comfort needs in relation to climatic situations.

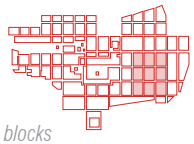
Western Anatolia is classified in the Köppen system as temperate with hot and dry summer seasons. This climatic region resides 39 degrees north of the equator and 28 degrees east of the prime meridian. Significant seasonal variation is present with daytime high-temperature averages in the winter at 7° C and in the summer at 28° C. Prevailing winds in the region generally come out of the north with year-round average speeds ranging from 4–6 m/s with peak velocities in the summer situated at 15 m/s. Additionally, from winter to summer solstice, the sun's elevation angle in the area shifts from 25–75° when measured at noon. The oblique relationship between solar inputs from the south and wind inputs from the north offer unique opportunities in passive climatization from summer to winter within Anatolia's temperate climate.

PRIENE

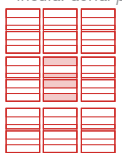
Overview



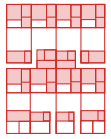
insula: aerial perspective (reconstruction after Hoepfner)



priene blocks



9 insulaes

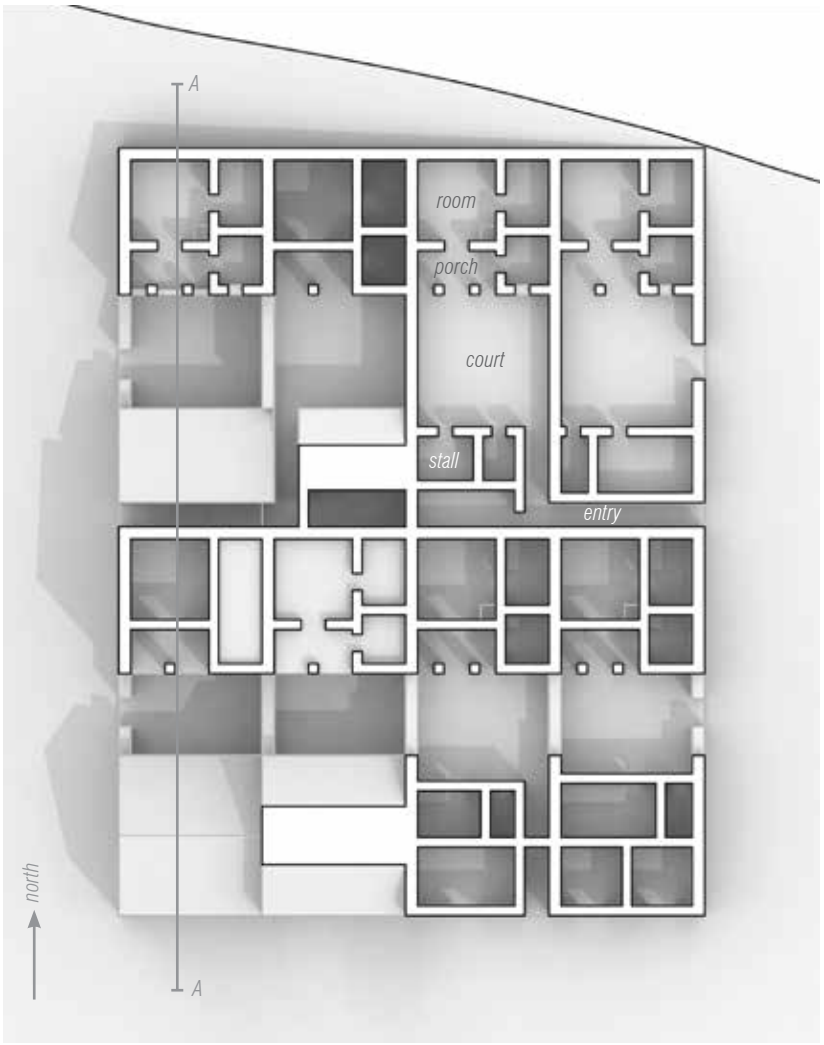


insula

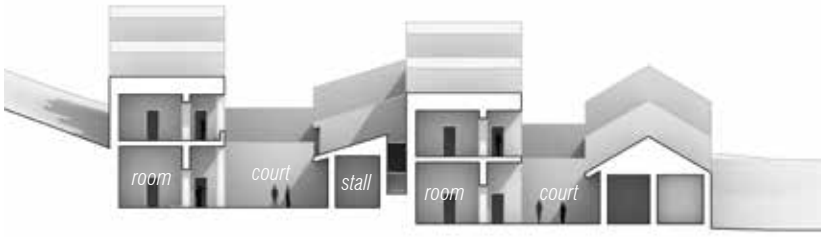
planning diagrams

5th Century Hellenistic Settlement

Priene, the ancient Hellenistic city of Ionia located along the western coast of Asia Minor dates back to the 5th century BC. Like nearby Miletus, Priene serves as one of the first examples of Hippodamian urban grid planning along cardinal axes. The city is comprised of 80 equally sized rectangular blocks (insulaes), each 120 feet by 160 feet. The standard insula contains 8 row house dwelling units, each orienting porches and internal courtyard toward the south. Aligning street networks serve to channel air and water providing equal access to resources while orienting dwelling units along the east-west axis with separating courtyards enables adequate solar access in the southern sky for all.



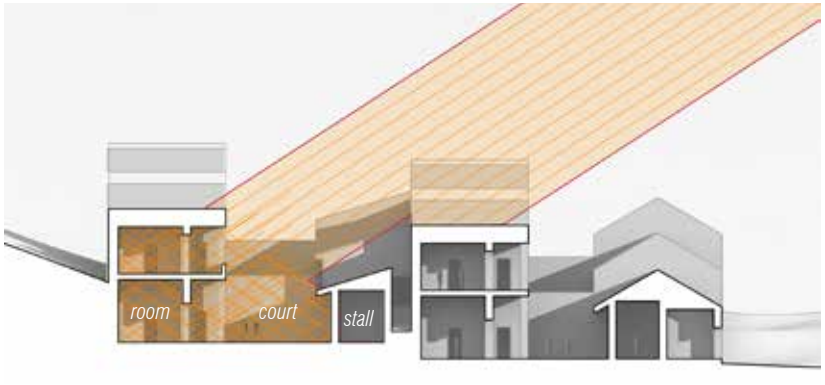
insula: floor plan



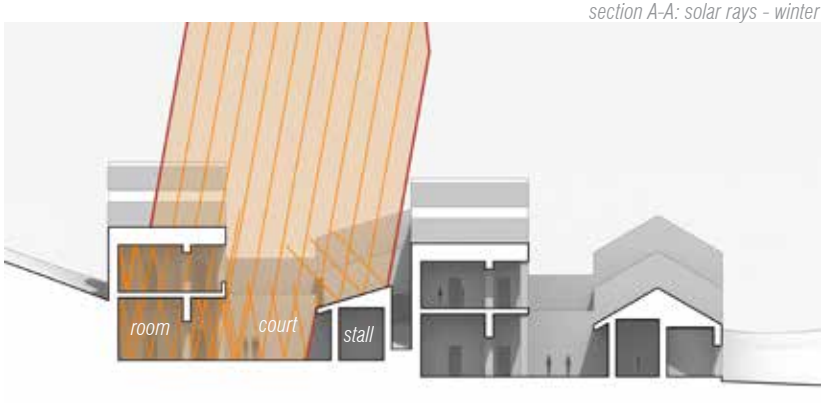
insula: section A-A

PRIENE

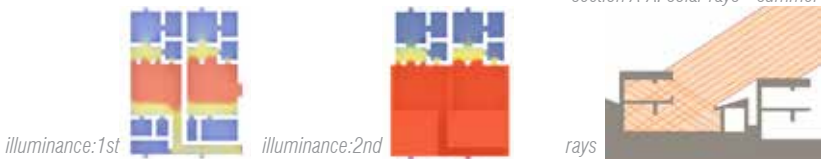
Daylighting



section A-A: solar rays - winter



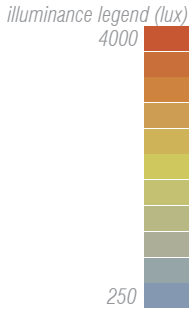
section A-A: solar rays - summer



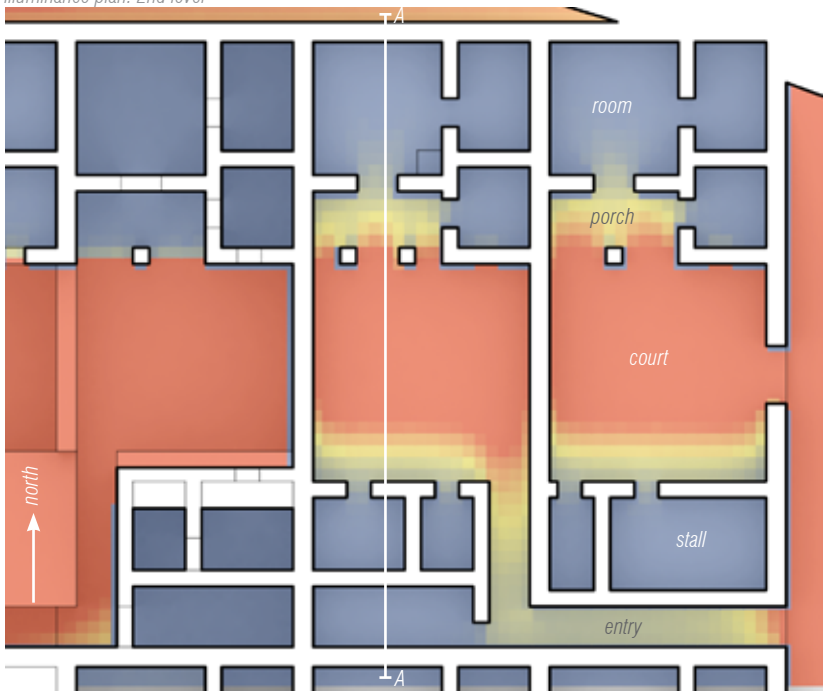
daylighting diagrams

Natural Daylighting Analysis

The court central of each insula serves as the primary source of natural light from the southern sky. Intermediary spaces (prostas/hall/porch) to the north of each court open to borrow and redirect natural daylight to interior spaces along the northernmost edge of each residence. Overhangs project out beyond vertical wall planes to harvest incident gains during winter months while protecting the interior from direct solar radiation in the summer.



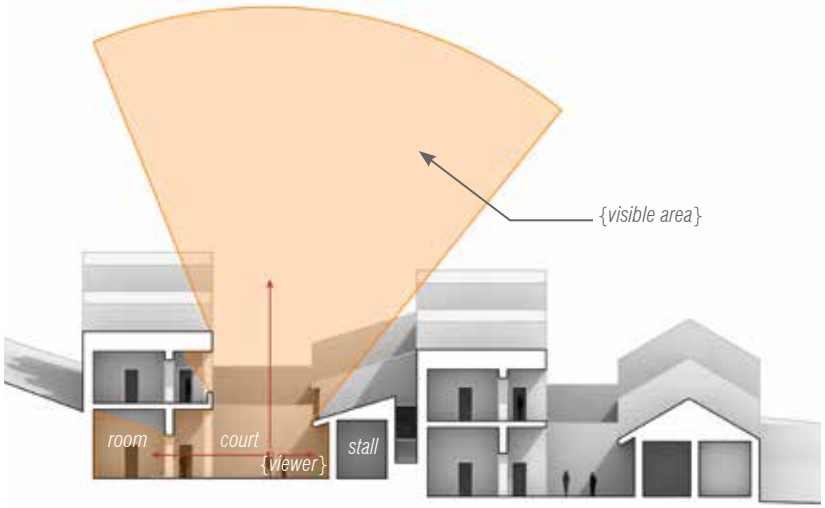
illuminance plan: 2nd level



illuminance plan: 1st level

PRIENE

Viewshed



viewshed section A-A

plan: 1st

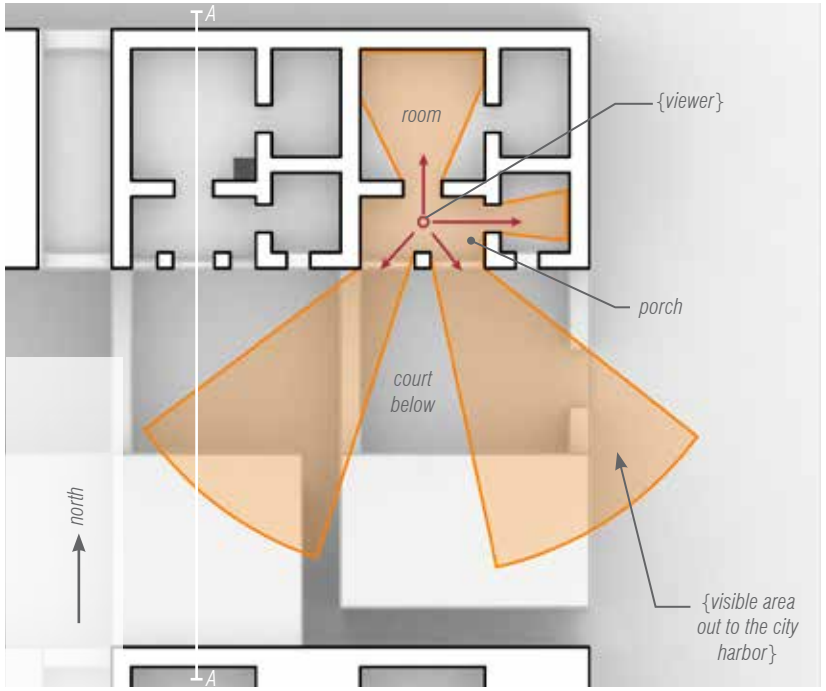
plan: 2nd

section

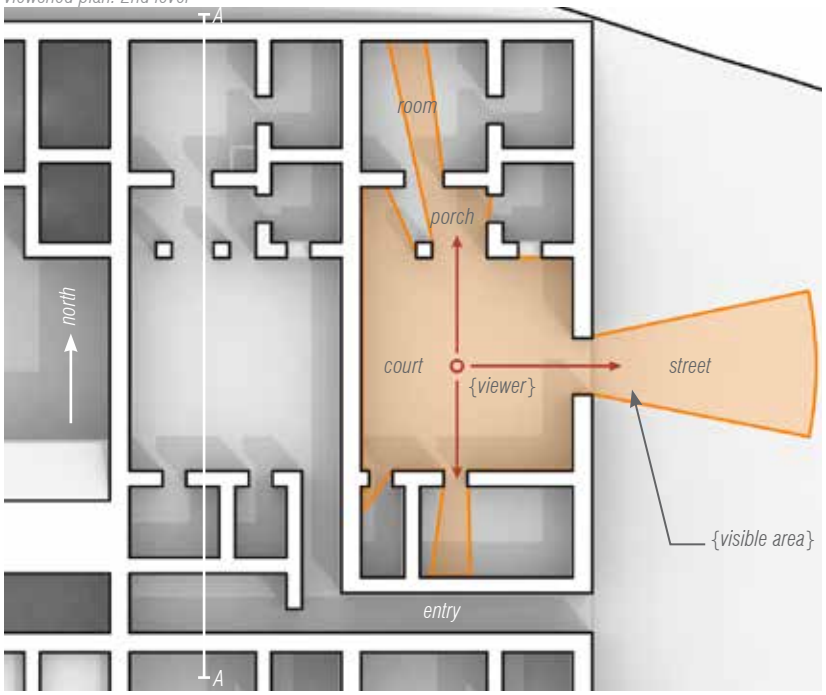
view diagrams

Viewshed Analysis

The insular block orientation deviates from standard urban planning whereby each unit addresses the street network in a similar manner. At Priene, each insula within a block orients to the same direction, to the south, for reasons associated with prevailing wind direction, solar path and viewsheds out to the city harbor. The terracing of the insula units along the southern slope of the city offer distinct views from the second level of each two story unit while views from the first level tend to focus on domestic activities central to each unit.



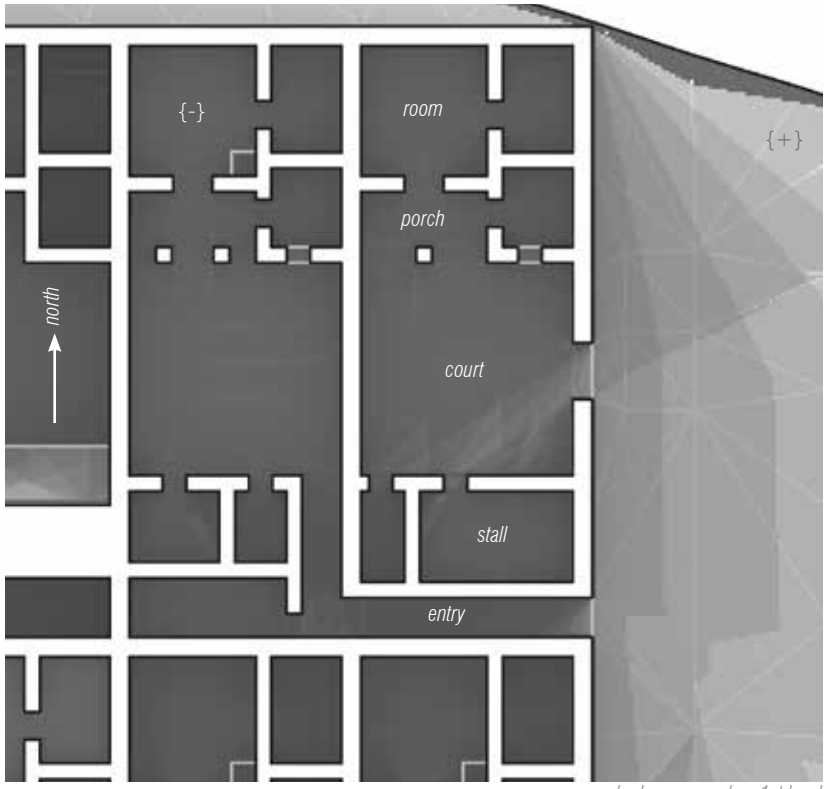
viewshed plan: 2nd level



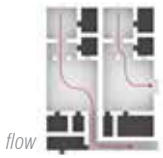
viewshed plan: 1st level

PRIENE

Cooling



shadow range plan: 1st level



flow

velocity

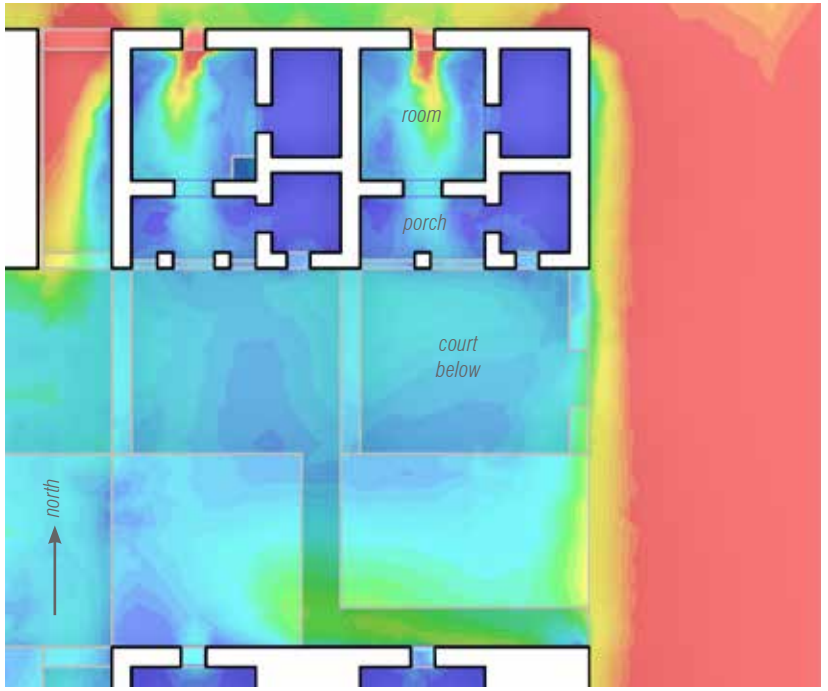
shadow

cooling diagrams

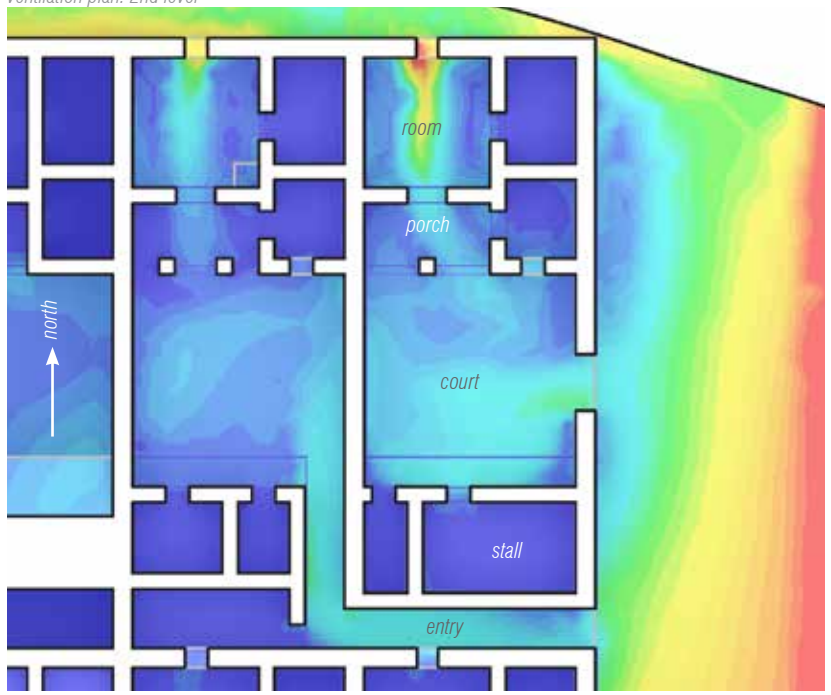
Shading and Ventilation Analysis

The Hippodamian urban grid planning along cardinal axes channels northern winds to each of the insular blocks. Thin east-west housing units sit perpendicular to the prevailing wind direction, supplying pressure differentials with high pressure building on the windward side and low pressure within the courtyard area. Ventilation through the housing unit is facilitated by small apertures on opposing ends while recessed room volumes and projecting overhangs contribute shading within inhabitable areas during hot summer months.

ventilation legend (m/s)



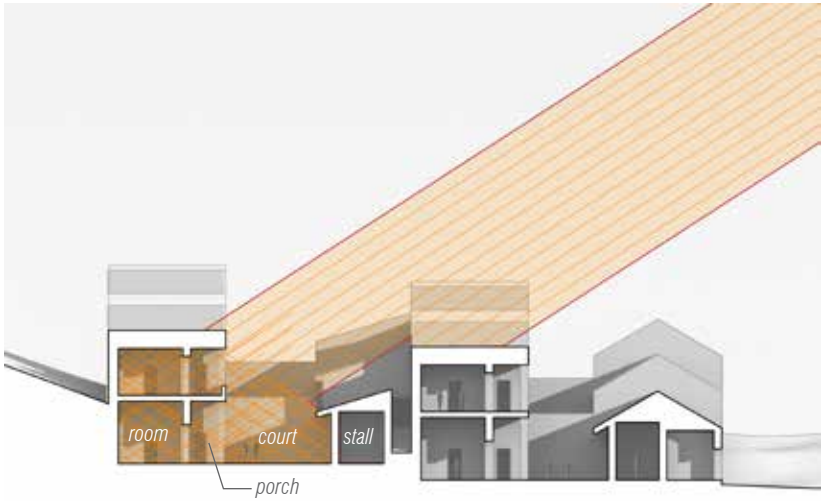
ventilation plan: 2nd level



ventilation plan: 1st level

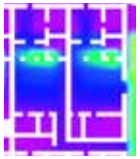
PRIENE

Heating



section A-A: solar rays - winter

incidence



insolation

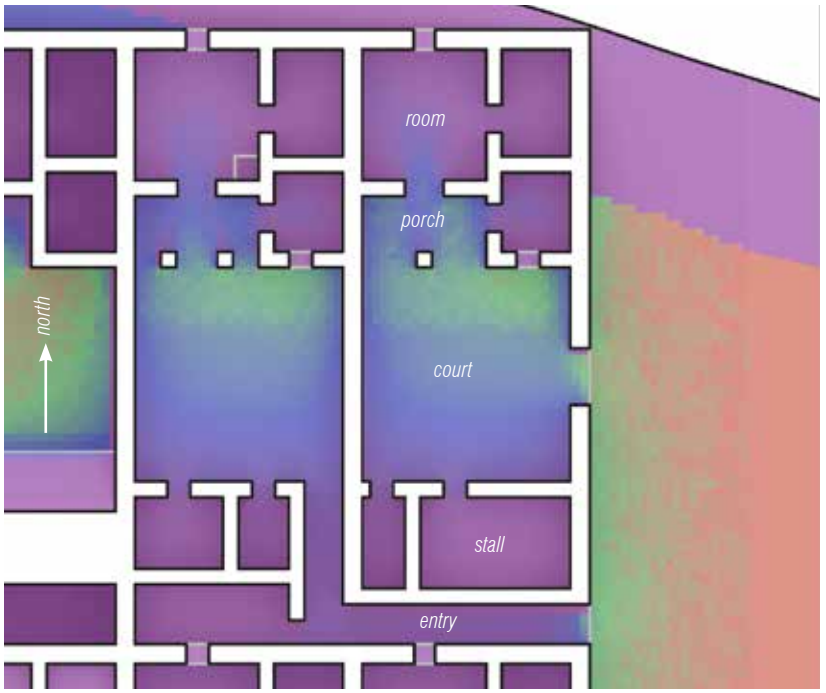
rays

heating diagrams

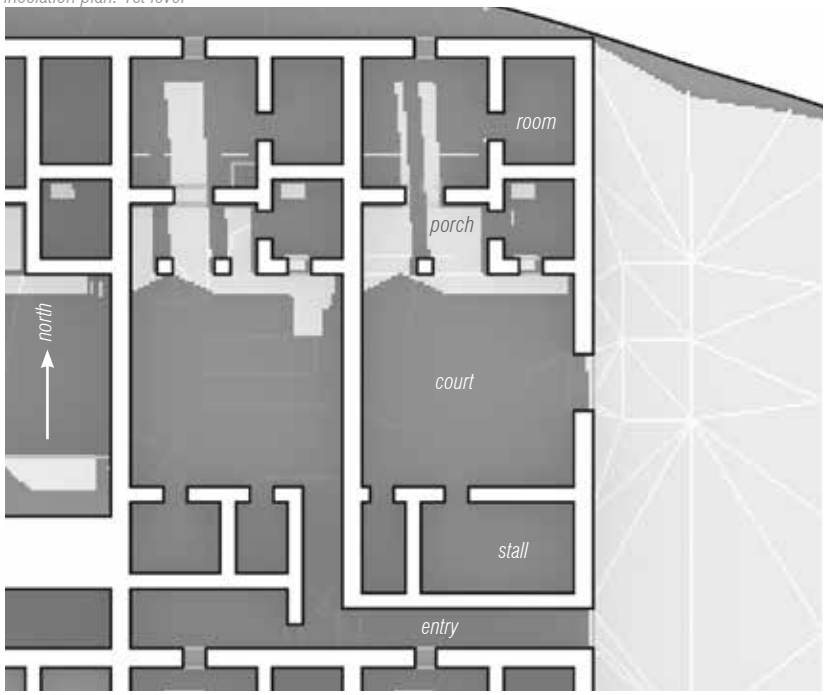
Solar Incidence and Insolation Analysis

The southern orientation of the east-west housing blocks maximizes the surface area exposed to direct solar gains. The recessed intermediary space types (prostas/hall/porch) further increase this surface area and draw these incident gains deeper into the building's composition. This configuration works well with the low solar angle during winter months. During this period, the courtyard is sunny and protected from the wind while the enclosed living areas adjacent to the north receive additional solar gains while still remaining buffered from northerly winds.

insolation legend (kWh/m2)



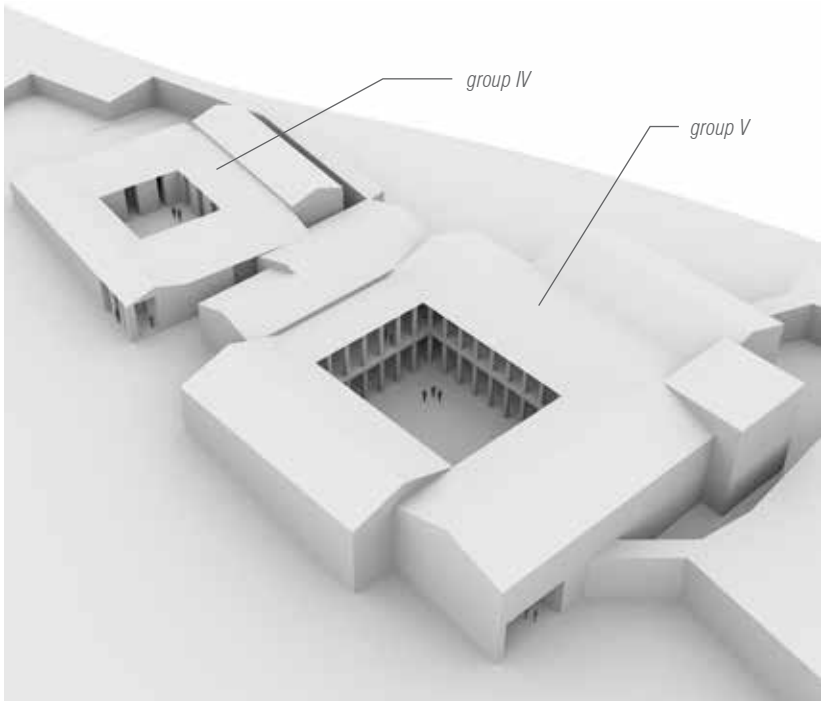
insolation plan: 1st level



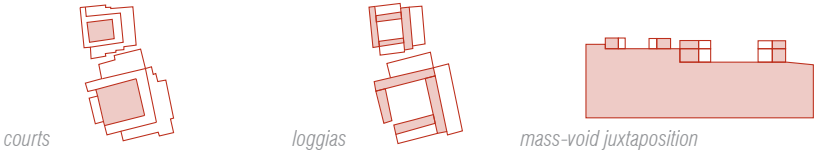
solar incidence plan at noon: 1st level

PERGAMON

Overview



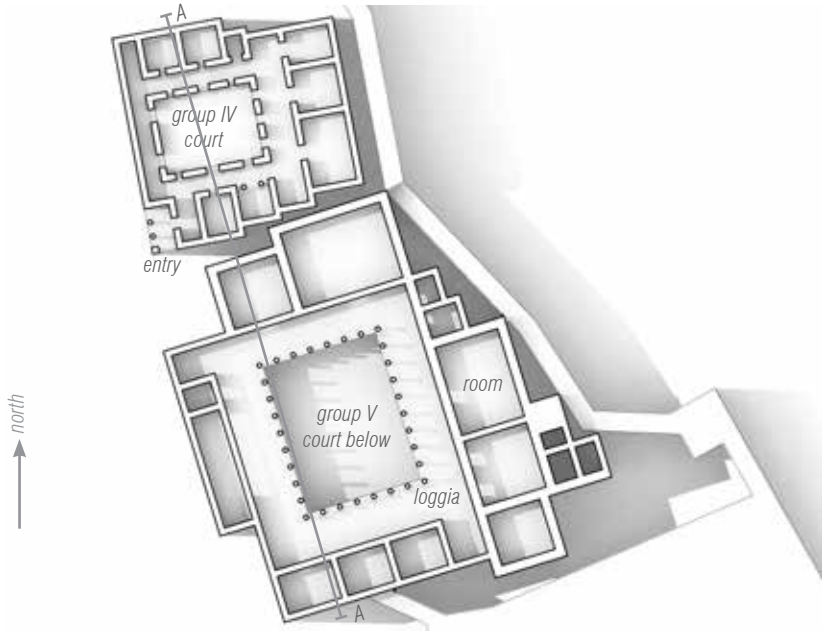
palace groups IV and V: aerial perspective (reconstruction after Radt)



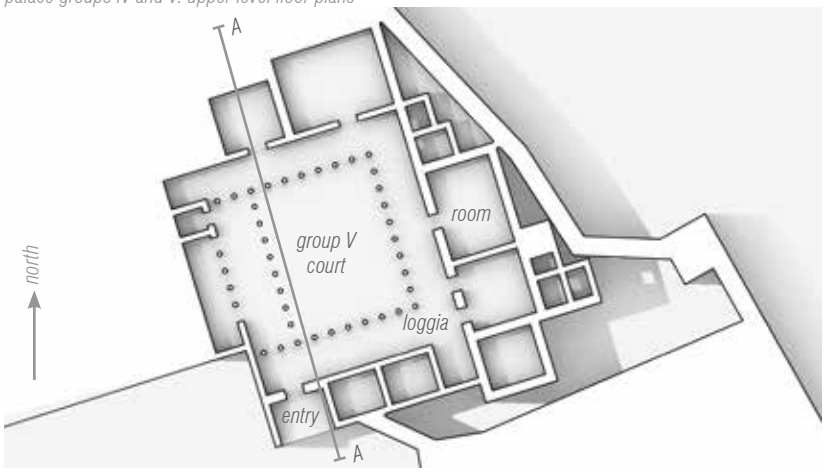
palace diagrams

3rd Century Greek Settlement

Pergamon, the ancient Greek city of Aeolis is located along the western coast of Asia Minor dates back to the 3rd century BC. The Upper Acropolis of Pergamon is perched high atop a prominent hill near the Aegean coastline. The terraced settlement concentrates along the southern face of the slope. Toward the eastern edge of the citadel sits the palace complex comprised of 6 palace houses. Each house is a peristyle whereby the rooms are organized around a central colonnaded courtyard open to the sky. This outdoor space provides access to water, light and air for interior rooms within the palace complex and offers a range of thermal zones for inhabitants to migrate their activities to and from.



palace groups IV and V: upper level floor plans

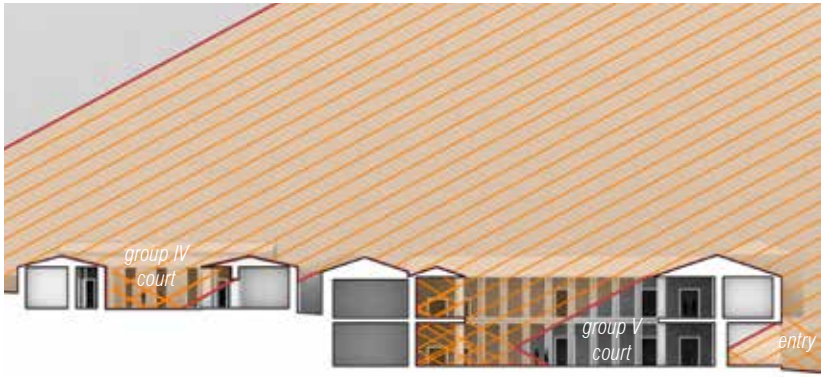


palace group V: lower level floor plan

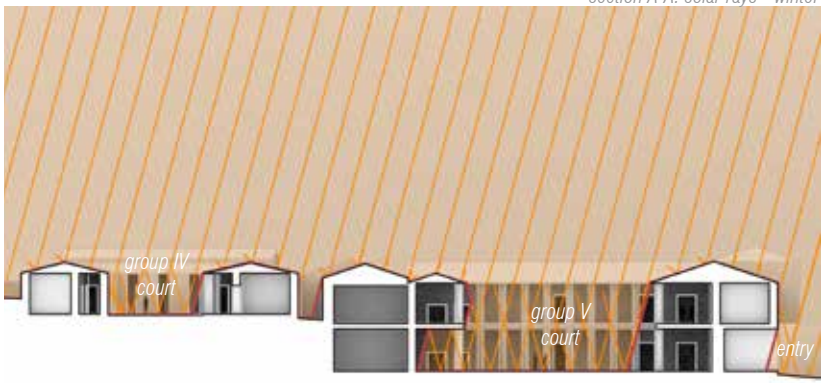
palace groups IV and V: section A-A

PERGAMON

Daylighting

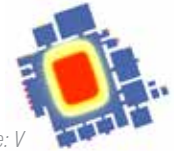


section A-A: solar rays - winter

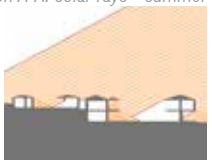


section A-A: solar rays - summer

illuminance: IV



illuminance: V



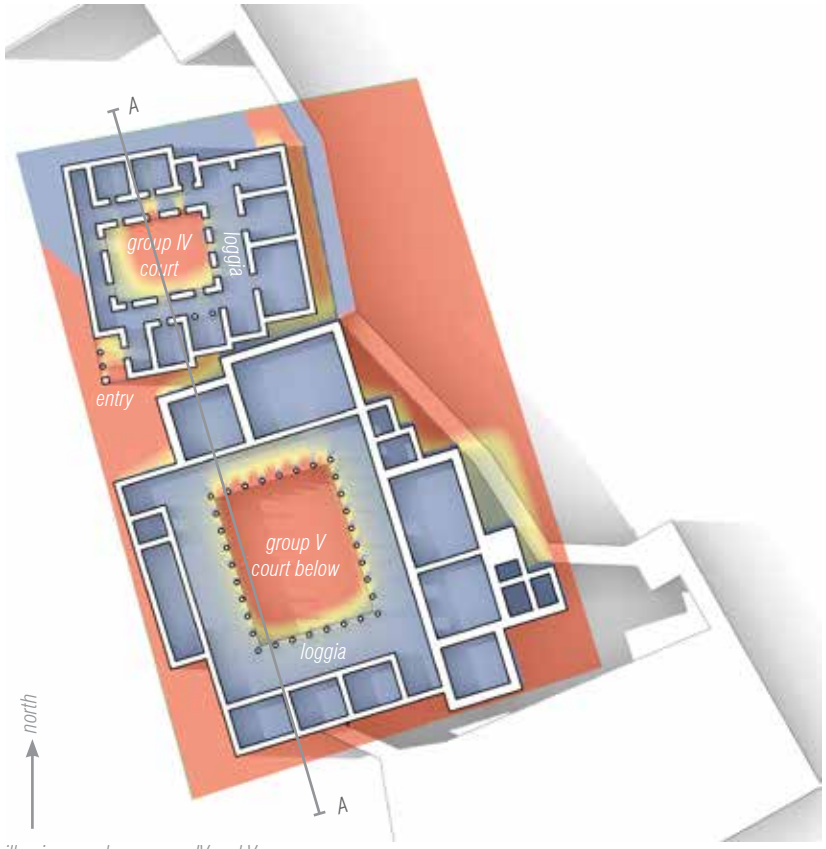
rays

daylighting diagrams

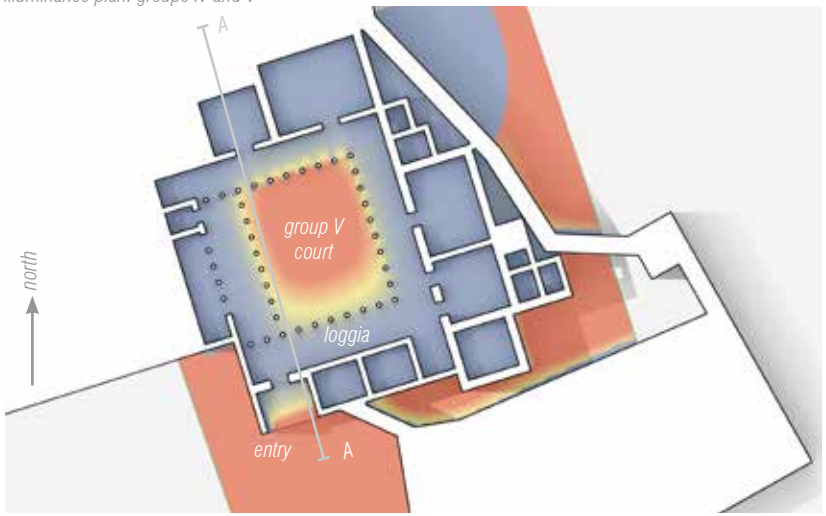
Natural Daylighting Analysis

The court central to each peristyle housing group serves as the primary source of natural light from the sky overhead. Intermediary spaces (loggia/arcade) that circumscribe each court redirect daylight for interior spaces around the outer perimeter of each housing group. The second level of Group V harvests the most natural light due to its size and degree of enclosure while the first level receives less light due to its proximity to the sun. Group IV interior spaces receive moderate light levels as a single story building with bearing walls.

illuminance legend (lux)



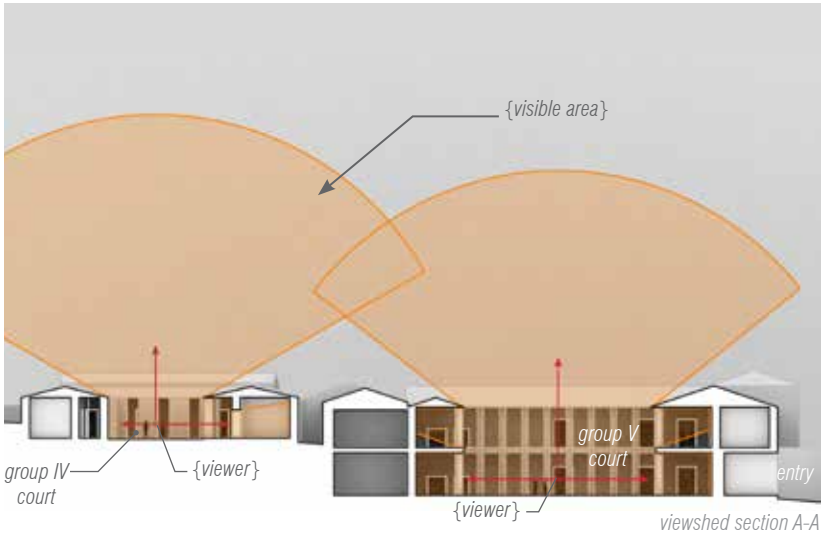
illuminance plan: groups IV and V



illuminance plan: group V 1st level

PERGAMON

Viewshed



viewshed section A-A

1st level: IV

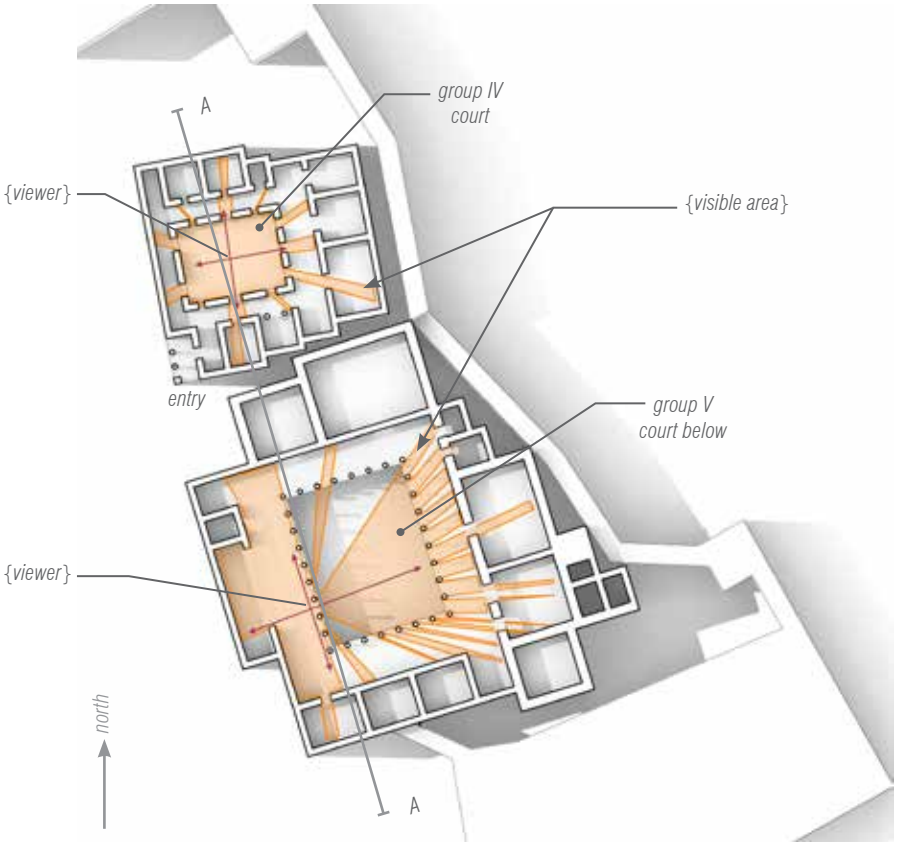
2nd level: V

1st level: V

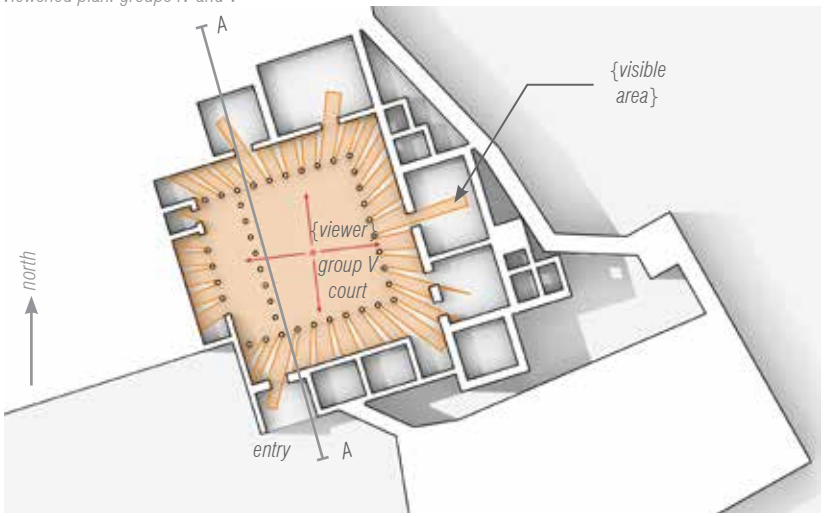
view diagrams

Viewshed Analysis

The open courtyard central to each peristyle building group offers abundant visual communication internal to the group and associated activities therein, especially in the court itself and surrounding loggia. Views out to the hinterland valley from the promontory of the upper citadel are facilitated by colonnaded arcades, open antechambers and aligned apertures within the peristyle housing block. However, views in to each building group from the street network are controlled through limited and tightly defined perimeter apertures.



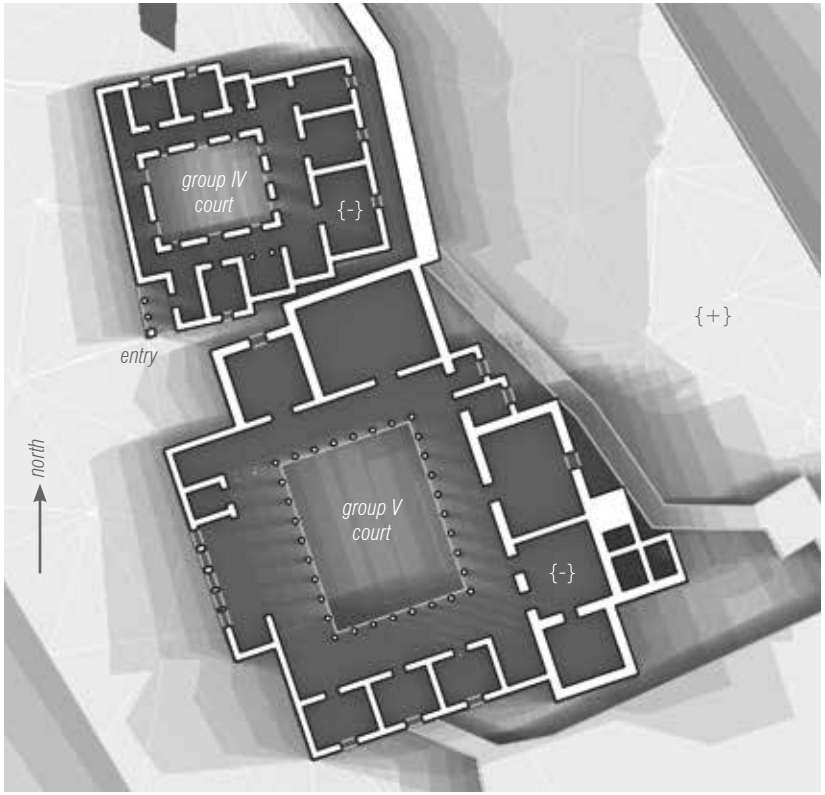
viewshed plan: groups IV and V



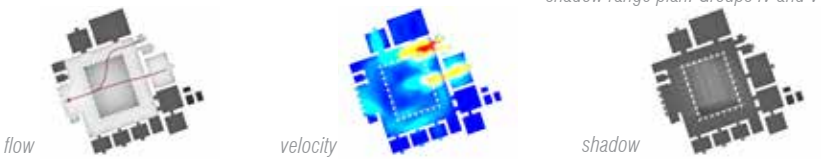
viewshed plan: group V 1st level

PERGAMON

Cooling



shadow range plan: Groups IV and V



cooling diagrams

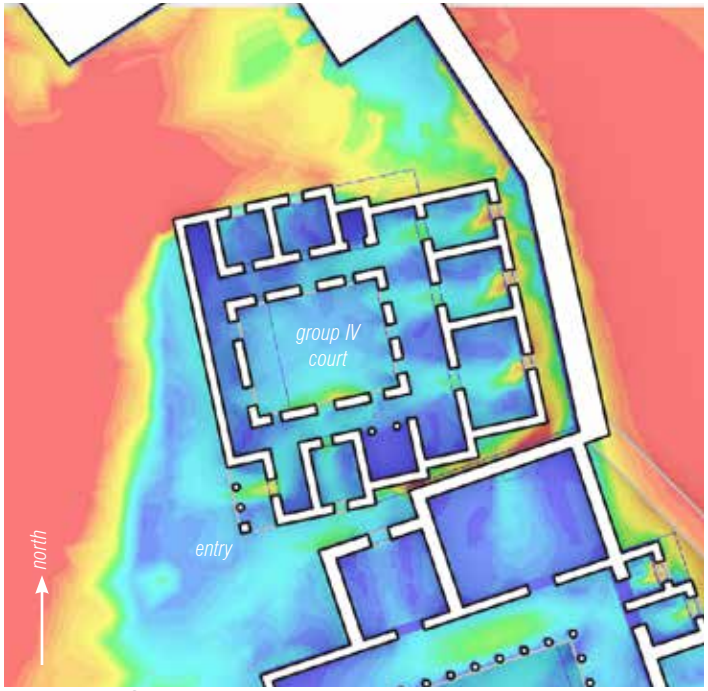
Shading and Ventilation Analysis

The peristyle configuration of both housing groups establishes a large void central to each group with a thin band of enclosed rooms around the perimeter. A number of small apertures around the perimeter block partnered with the communicating openings from the rooms to the open court offer opportunities for cross ventilation during hot summer months. A continuous overhead plane provides shading for these perimeter spaces while an opening above the court induces the ventilation potential of the complex.

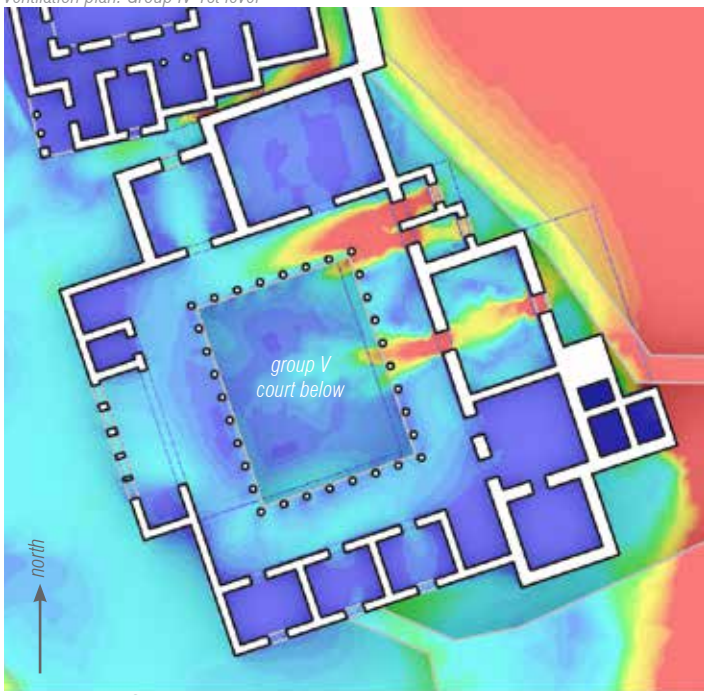
ventilation legend (m/s)

2

0



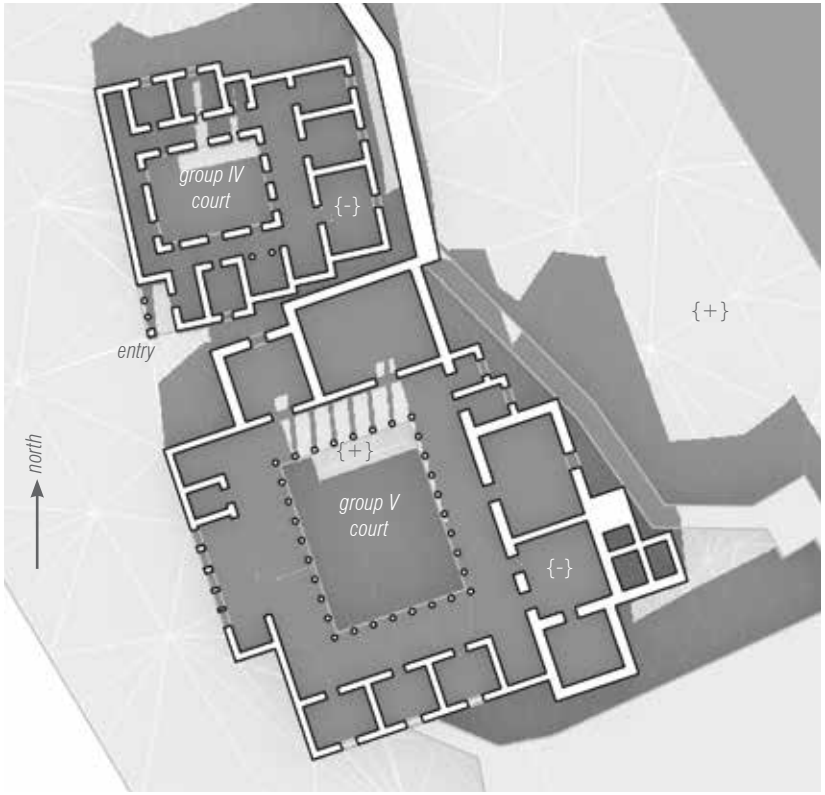
ventilation plan: Group IV 1st level



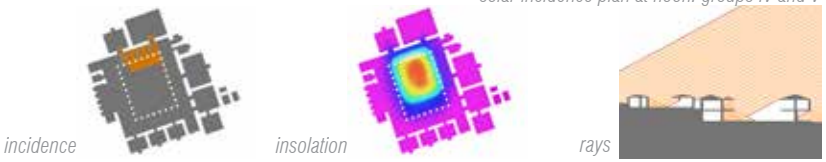
ventilation plan: Group V 2nd level

PERGAMON

Heating



solar incidence plan at noon: groups IV and V

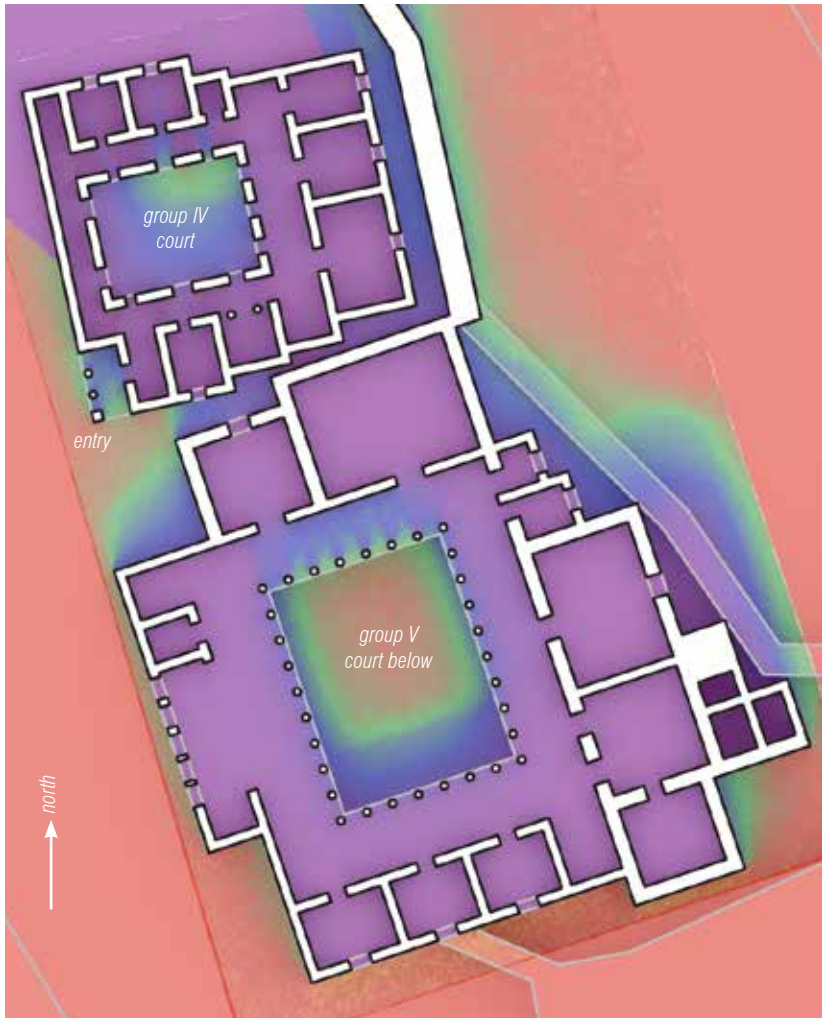


heating diagrams

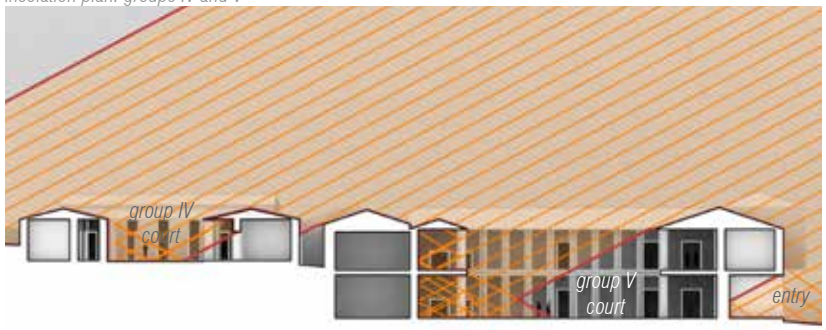
Solar Incidence and Insolation Analysis

Both building groups IV and V retain heat similarly. Enclosed courtyards create positive pressure, buffering all interior spaces from northerly winds when the perimeter is sealed. While protected from winter winds, the northern most areas of the courtyards and surrounding loggias receive incident solar gains and remain well illuminated throughout the day. This correlates with the radiation received and retained through the surfaces that make up the courtyard floors and walls. High insulating thermal masses aid in storing and releasing heat across daily cycles.

insolation legend (kWh/m2)



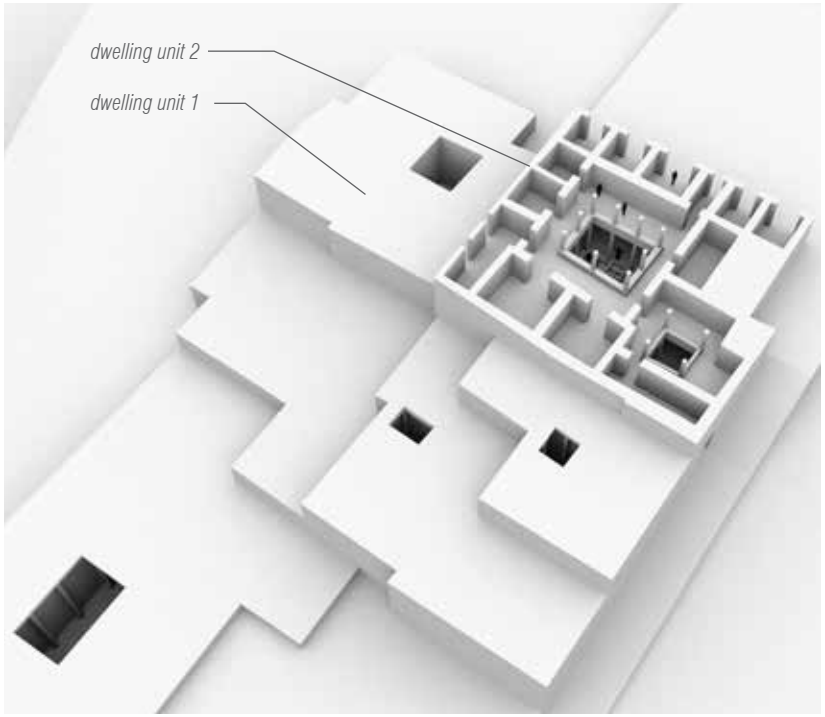
insolation plan: groups IV and V



section A-A: solar rays - winter

EPHESUS

Overview



aerial perspective, terrace house 2 (reconstruction after Osterreichisches)

terrace 2

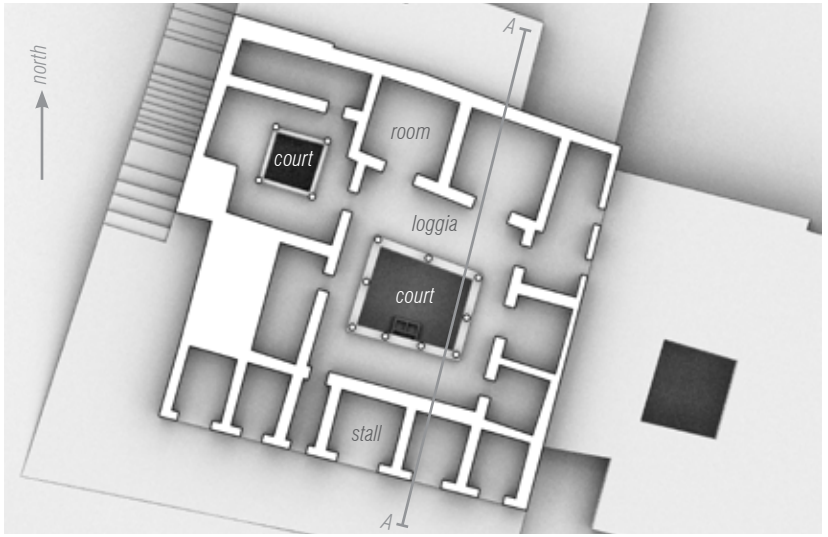
dwelling 2

mass-void juxtaposition

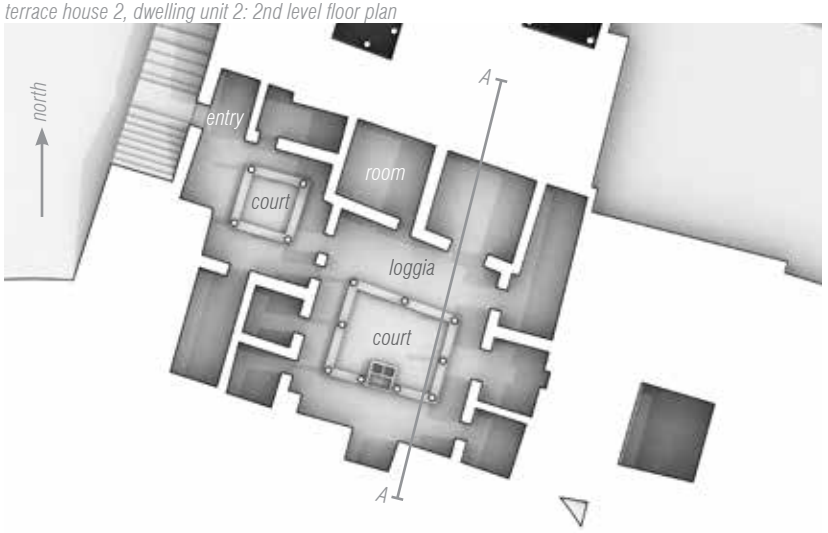
terrace house 2 diagrams

10th Century Greek Settlement

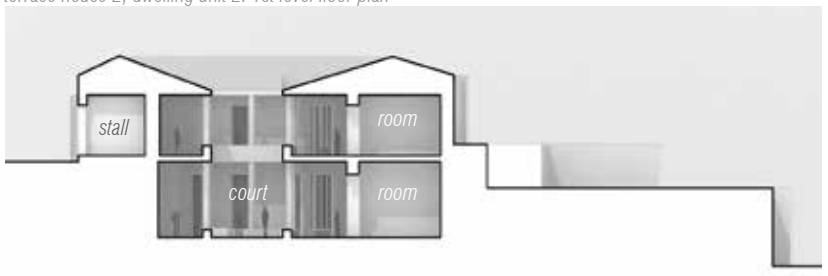
Ephesus, the ancient Greek city within the region of Ionia is located along the western coast of Asia Minor and dates back to the 10th century BC. Like nearby Priene, the Roman Period development of Ephesus is based upon the Hippodamian urban grid planning in which roads crossed at right angles. Along the southern edge of the prominent Curetes Street sits the Terrace Houses. Numerous dwelling units sit on three terraces on the northern slope of the Bulbul Mountain. Central to each dwelling unit is a shady courtyard, each double height with a narrow opening overhead. These courtyards facilitate the stratification of air for the surrounding spaces which are predominately subterranean.



terrace house 2, dwelling unit 2: 2nd level floor plan



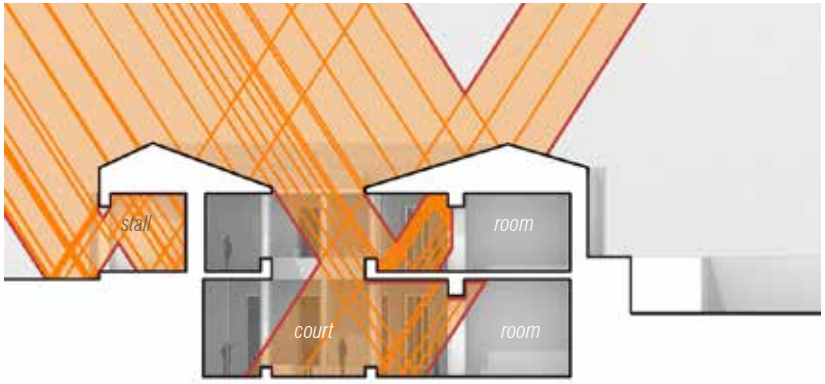
terrace house 2, dwelling unit 2: 1st level floor plan



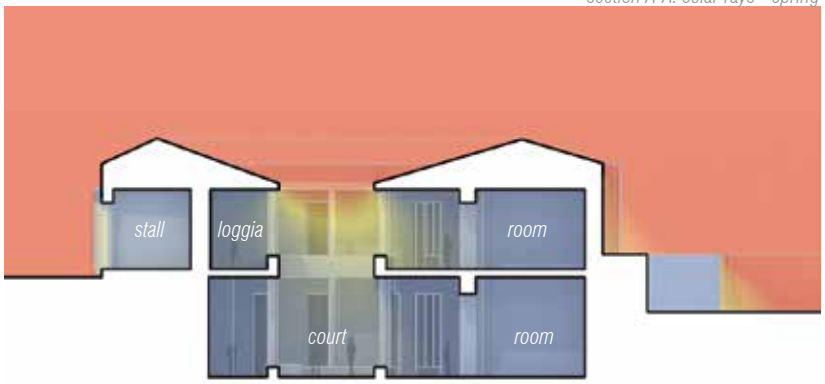
terrace house 2, dwelling unit 2: section A-A

EPHESUS

Daylighting



section A-A: solar rays - spring



illuminance section A-A

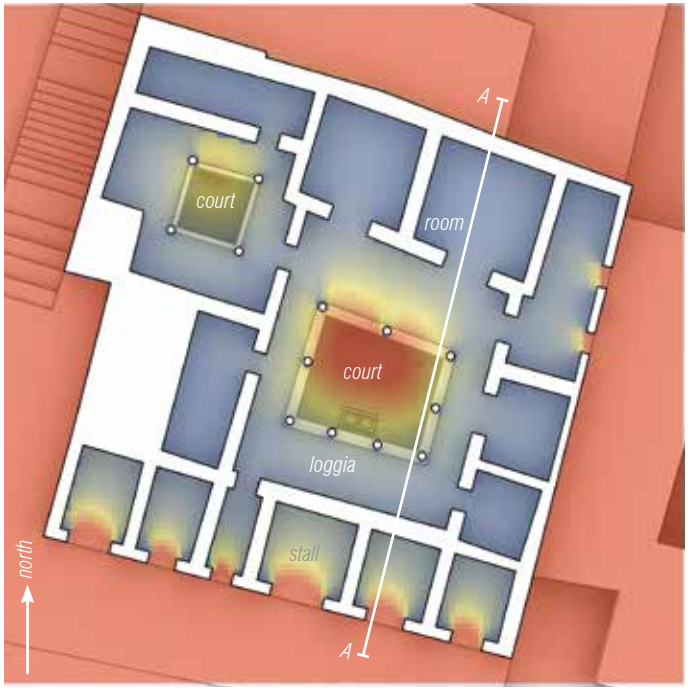
plan *section* *rays*

daylighting diagrams

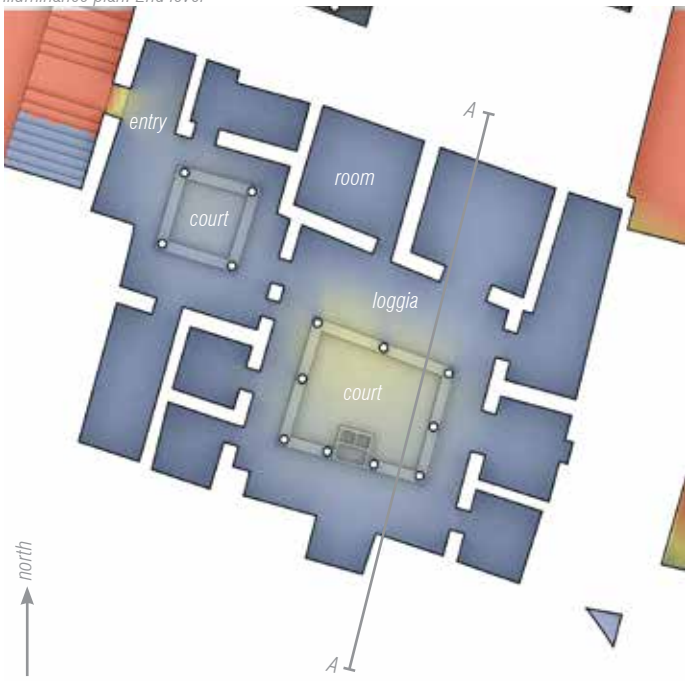
Natural Daylighting Analysis

The deep shady court central to the dwelling unit serves as the primary source of natural light from the sky overhead. Intermediary spaces (loggia/arcade) that circumscribe the court redirect daylight for interior spaces around the outer perimeter of each dwelling unit. The second level of Dwelling Unit II harvests the most natural light due to its proximity to the sun and degree of enclosure while the first level receives less light due to the aspect ratio of the courtyard space with respect to the floor to floor dimension of the terraces.

illuminance legend (lux)



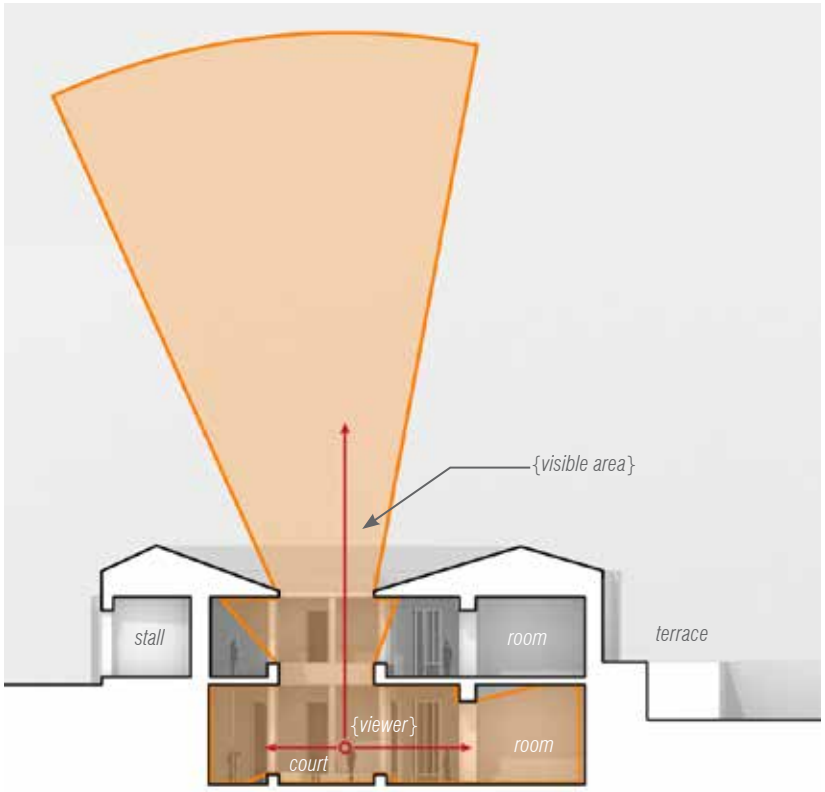
illuminance plan: 2nd level



illuminance plan: 1st level

EPHESUS

Viewshed



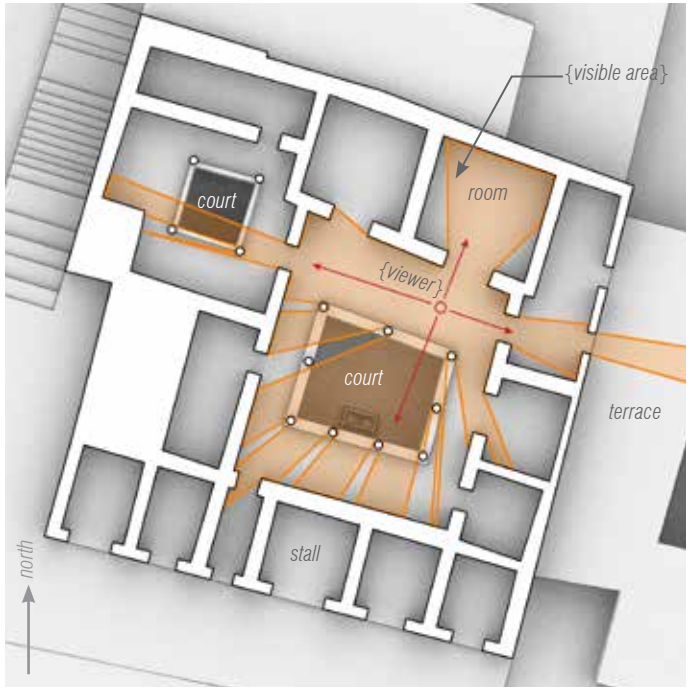
viewshed section A-A

plan: 1st plan: 2nd section

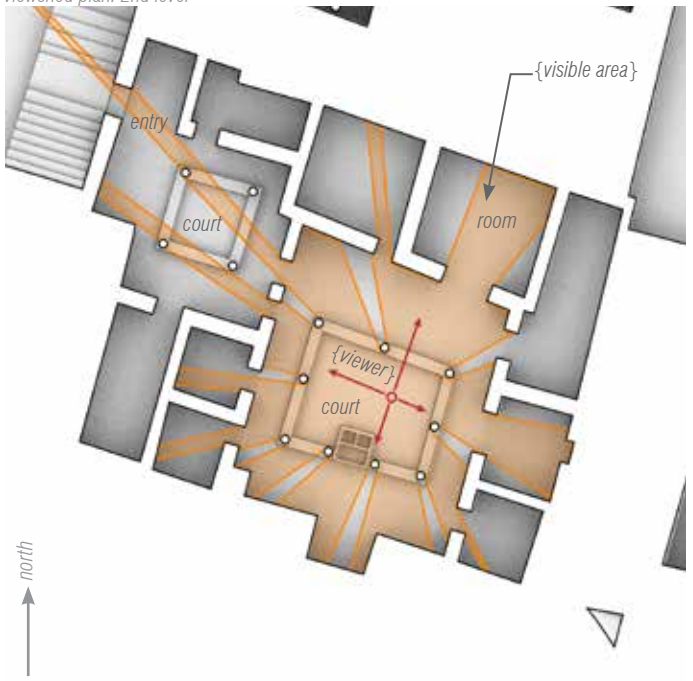
viewshed diagrams

Viewshed Analysis

The deep courtyard central to each dwelling unit offers abundant visual communication internal to the unit and associated activities therein. Internal view sheds and corresponding physical communication originate from the court itself, transitioning to the surrounding loggia and into the enclosed perimeter spaces. Viewsheds and physical communication extend beyond the unit perimeter to the neighboring rooftops which double as terraces. Stepping down the northward facing slope, the terrace house views concentrate down the prominent Curetes Street below and city center beyond.



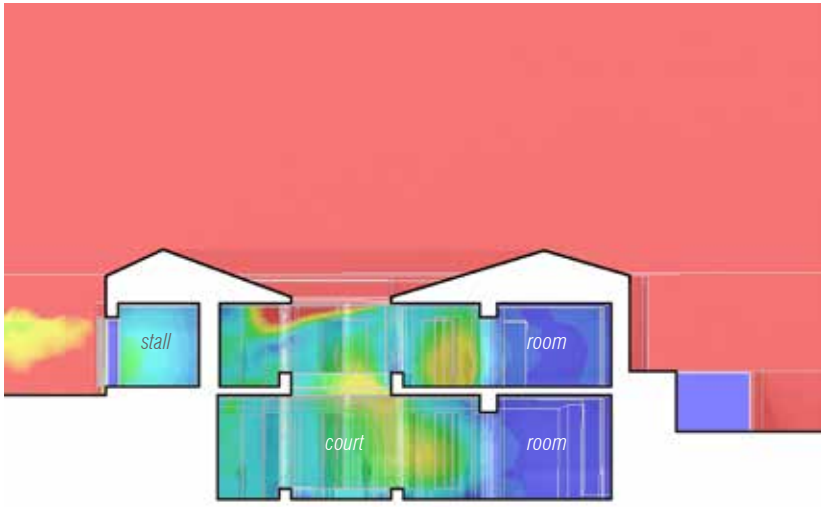
viewshed plan: 2nd level



viewshed plan: 1st level

EPHESUS

Cooling



ventilation section A-A

flow

velocity

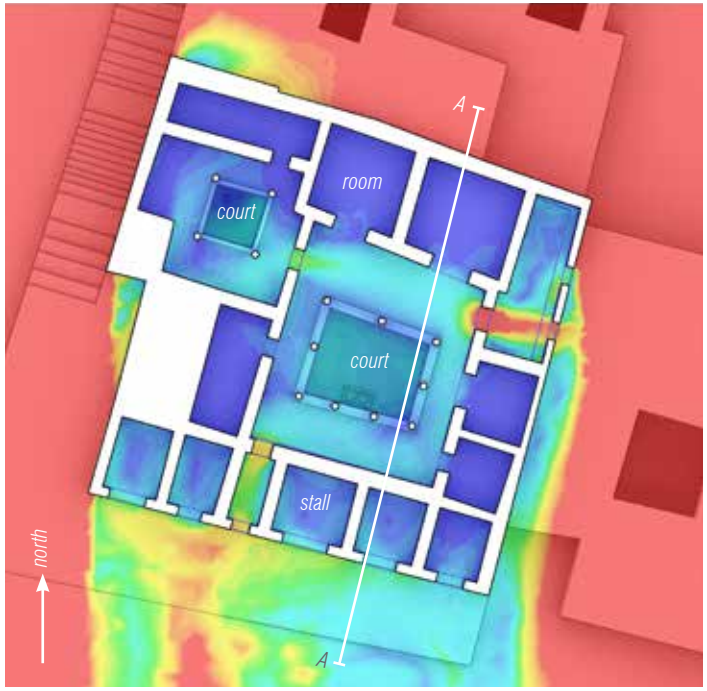
shadow

cooling diagrams

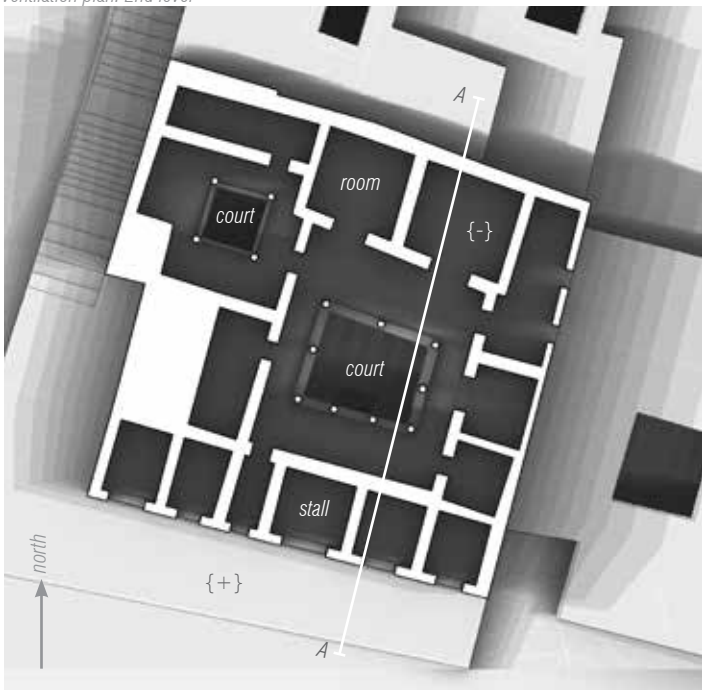
Shading and Ventilation Analysis

The deep shady court central to each dwelling unit is proportioned to minimize radiant heat gains during summer months. The depth of the court also provides enough verticality within the unit to promote air stratification whereby hot buoyant air rises and exits the top of the court while the earthen insulated lower level retains cooler, higher density air throughout the day. Low ventilation rates on the lower level combined with moderate levels on the second floor further promote this stack effect.

ventilation legend (m/s)



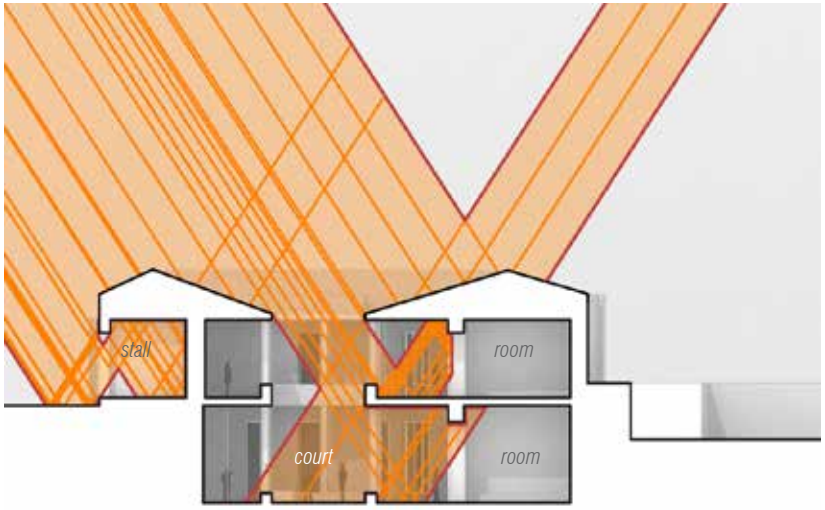
ventilation plan: 2nd level



shadow range plan: 2nd level

EPHESUS

Heating



section A-A: solar rays - spring

incidence

insulation

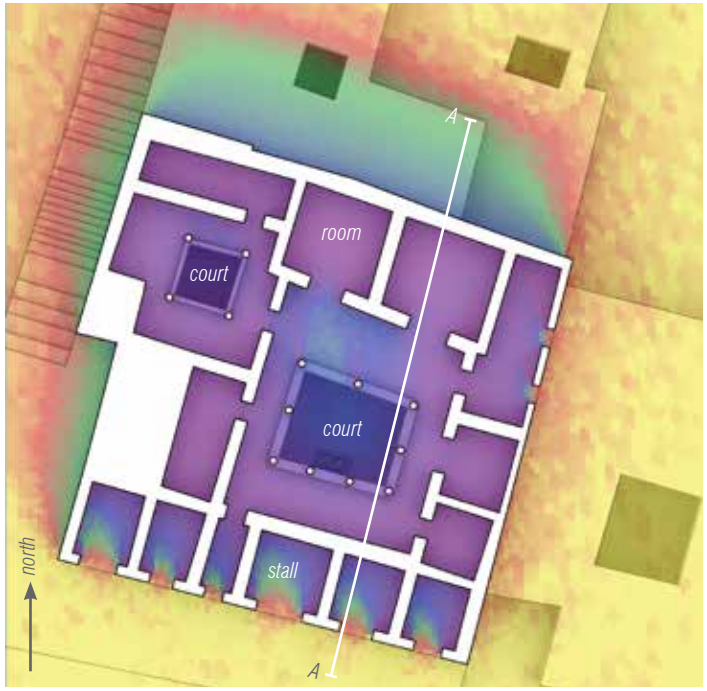
rays

heating diagrams

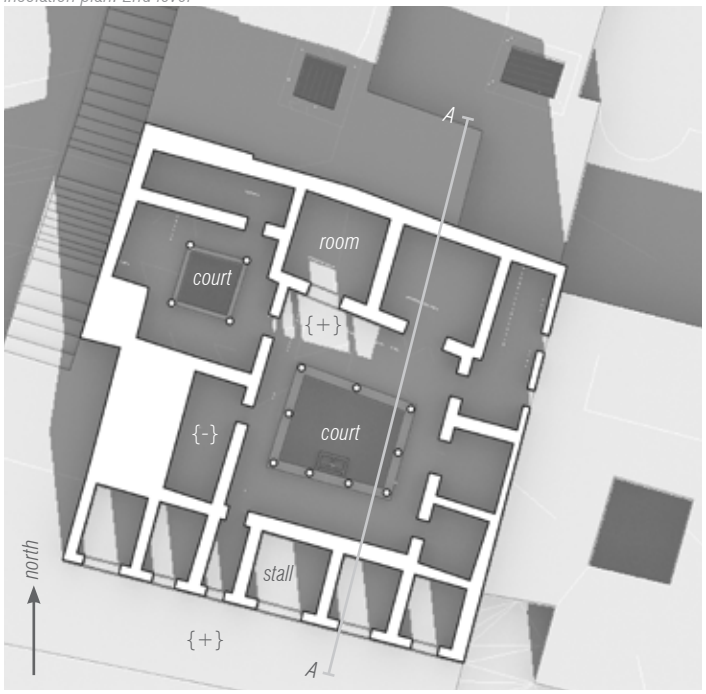
Solar Incidence and Insolation Analysis

Enclosed deep courtyards create positive pressure, buffering all interior spaces from northerly winds as the first level is earthen insulated while the second level perimeter with limited apertures can be closed. Protected from winter winds, the northern most areas of the courtyards and surrounding loggias receive incident solar gains, especially on the second level. Thick insulating thermal masses aid in storing and releasing heat across the winter season while the southernmost stalls optimize passive winter heating.

insolation legend (kWh/m2)

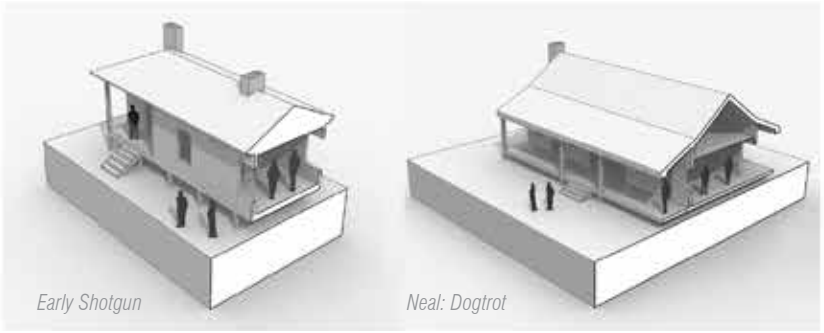


insolation plan: 2nd level



solar incidence plan at noon: 2nd level

VERNACULAR SOUTHERN U.S. HOUSING TYPOLOGIES



Early Shotgun *Neal: Dogtrot*

Formative vernacular building types located within the southern United States continue the strong traditions established by their early European predecessors. Southern housing typologies such as the Shotgun, a narrow structure whose spaces distribute along a single axis and whose width is that of a single space; the Dogtrot, a variation on the cabin motif whereby the programmatic core is divided into halves whereby a breezeway occupies their divided space; the Antebellum Mansion, a series of semi-enclosed rooms that revolve about an open central hall; and the Gulf Coast Bungalow, a hybrid of the Shotgun and Dogtrot types that compose multiple linear bars to provide a continuous flow of interior space while maximizing its connection to the immediate environment all demonstrate how systems of physical enclosure are put to task to achieve high performance outcomes even within the most severe extremes of climate.

The southern U.S. is historically a region that demands affordable construction strategies that effectively perform within a fully humid climate marked by distinct seasonal and daily variations. Communities within this area have traditionally relied heavily upon the use of naturally renewable energy sources for provisions of indoor air quality, human comfort and adequate illumination within the built environment and their corresponding construction strategies have reflected this need. Unlike the massive stone stereotomic systems evident in western Anatolia, the vernacular structures in the southern U.S. utilize a lightweight tectonic approach where buildings are framed using available timber in the region. The lightness of construction lends itself to the six attributes outlined by James Marston Fitch in his 1961 essay entitled,

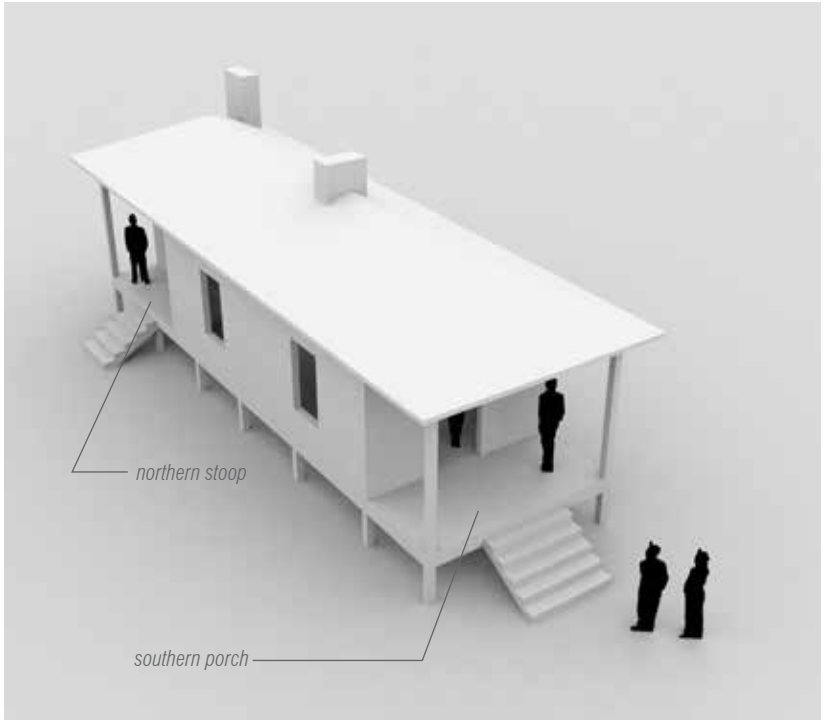
Waverly: Antebellum *Charnley Norwood: Bungalow*

'The Uses of History' located in *Architecture and the Esthetics of Plenty*. These attributes include elevated living floors, expansive parasol roof planes, continuous perimeter porches, large floor to ceiling distances, ventilated attic spaces and operable apertures to the exterior. Operating in concert, these attributes serve to admit prevailing breezes, evacuate concentrated interior hot air, shade inhabitable areas and prevent rainwater from entering the structure; all of which respond to the constraints dictated by the extreme southern summer climate.

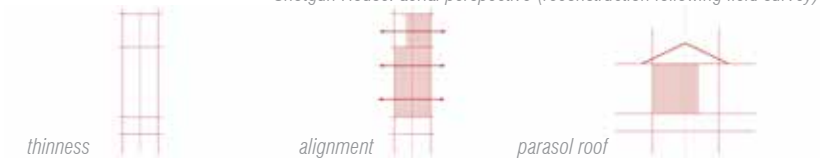
The southern United States is classified in the Köppen system as temperate with hot and humid summer seasons. This climatic region resides 30 degrees north of the equator and 90 degrees west of the prime meridian. Significant seasonal variation is present with daytime high-temperature averages in the winter at 14° C and in the summer at 33° C. Prevailing summer winds in the region generally come out of the south with average speeds at 4 m/s with peak velocities in the summer situated at 7 m/s. Prevailing winter winds in the region come of out of the north with average speeds from 7 m/s with peak velocities in the winter situated at 11 m/s. Additionally, from winter to summer solstice, the sun's elevation angle in the region shifts from 36–82° when measured at noon. The oblique relationship between solar inputs from the south and wind inputs from the north offer unique opportunities in passive climatization during winter months while sun and wind inputs from the south during summer months necessitate the need for expansive parasol elements.

EARLY SHOTGUN HOUSE

Overview



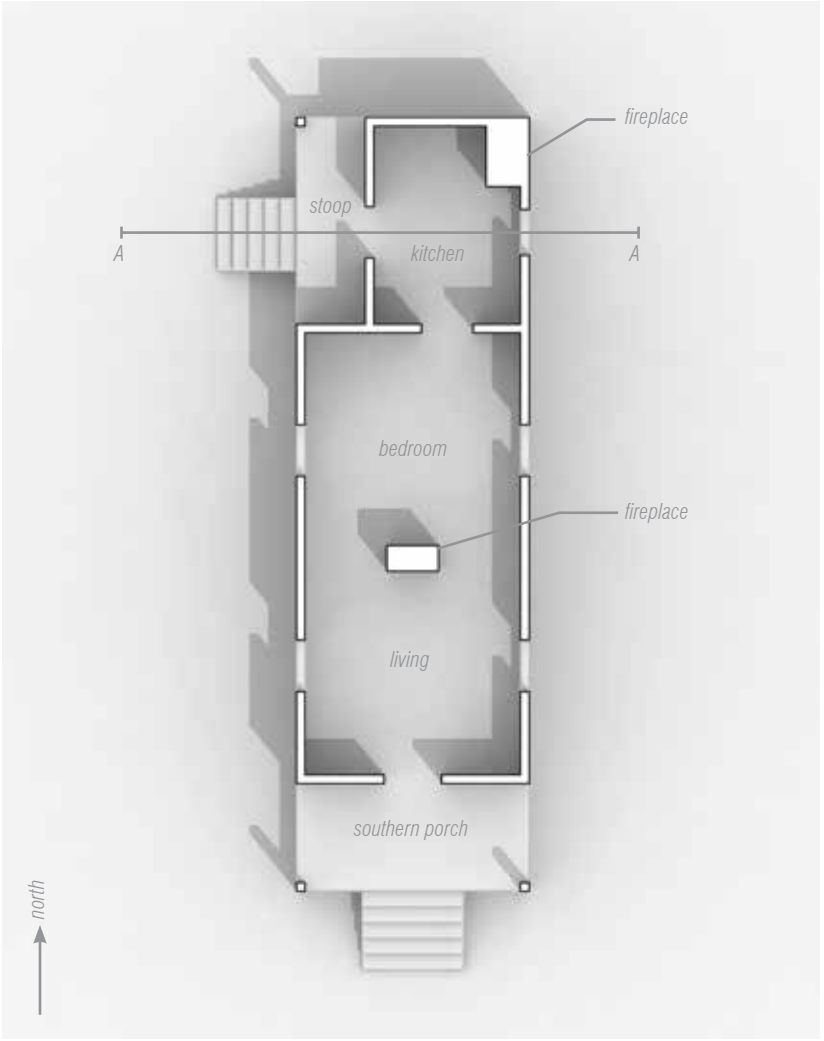
Shotgun House: aerial perspective (reconstruction following field survey)



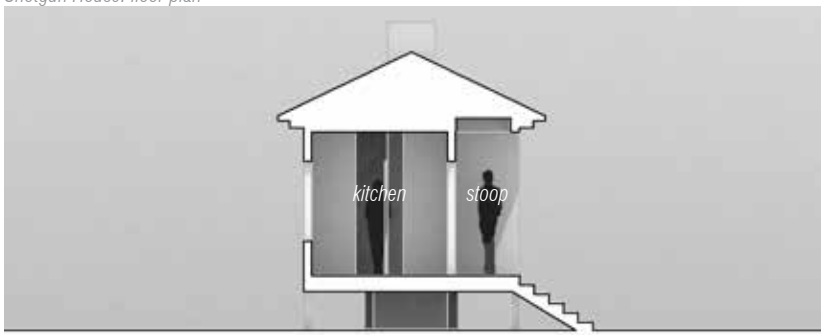
shotgun diagrams

Early 19th Century Southern Dogtrot House

The shotgun house organizes space in a linear manner, positioning the program elements from the entry to the rear of the home within a narrow 12 foot width. On the southern end of the linear block is a porch while a smaller scale stoop sits at the northern end adjacent to the kitchen. The distribution of aligned apertures across the transverse direction of the home aid in ventilating heat gains concentrating within the interior. The thinness of the building footprint also enables daylight to distribute evenly across most areas of the plan while the intermediate spaces on either end of the home provide areas for users to inhabit during extreme climate events.



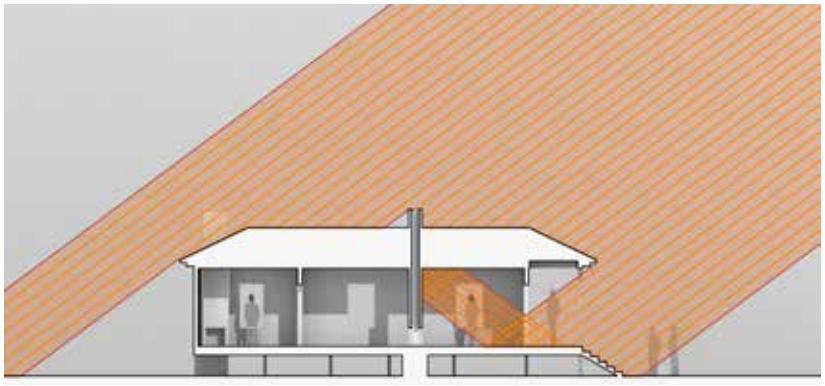
Shotgun House: floor plan



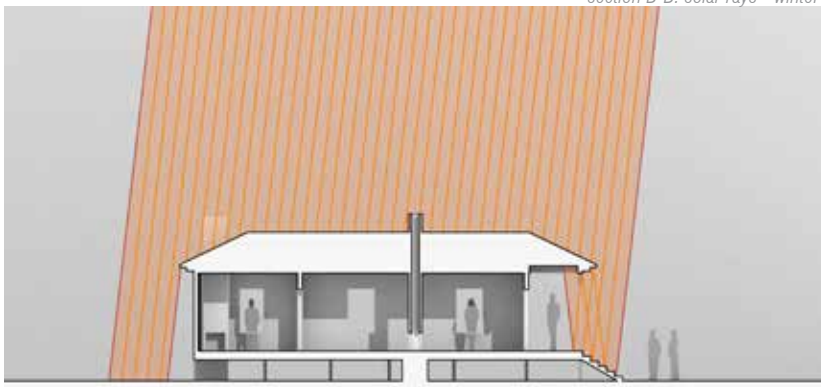
Shotgun House: section A-A

EARLY SHOTGUN HOUSE

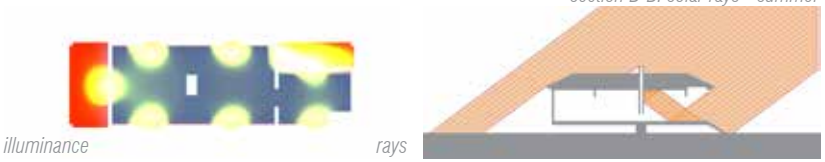
Daylighting



section B-B: solar rays - winter



section B-B: solar rays - summer



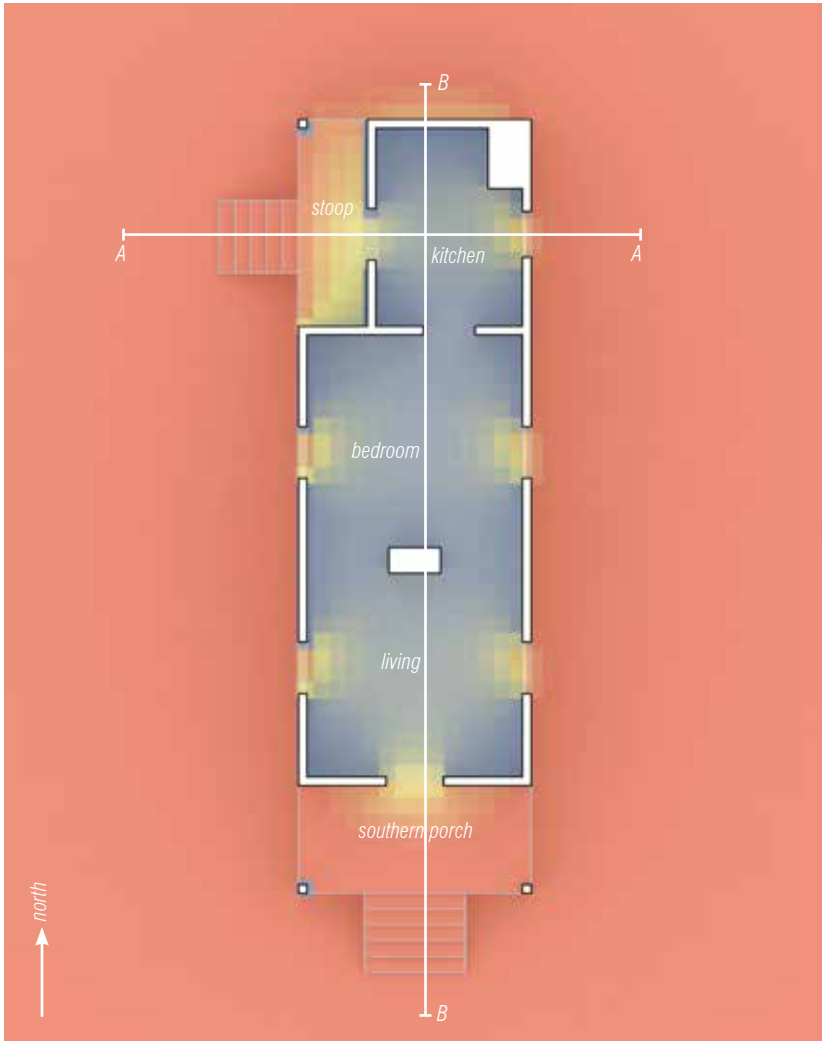
illuminance *rays*

daylighting diagrams

Natural Daylighting Analysis

The north-south linear bar principle to the building composition harvests the most natural light at its southern end. The southern porch at his point of the bar provides overhangs that redirect light entering the living area, aiding the supply of uniform daylight throughout the area. The core of the north-south linear bar receives natural light during early and late daytime hours with ample illuminance levels due to its narrow footprint and its abundance of aligned apertures. Diffusion within this bar is achieved through recessed perimeter walls and resulting stoop.

illuminance legend (lux)

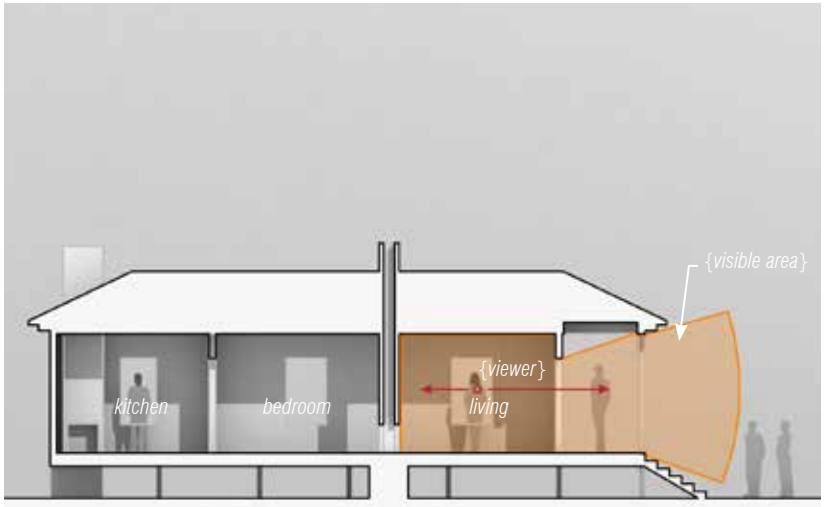


illuminance plan

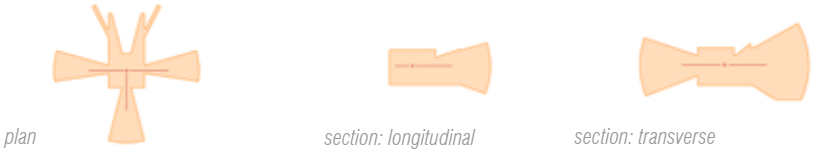
illuminance section A-A

EARLY SHOTGUN HOUSE

Viewshed



section B-B: solar rays - summer

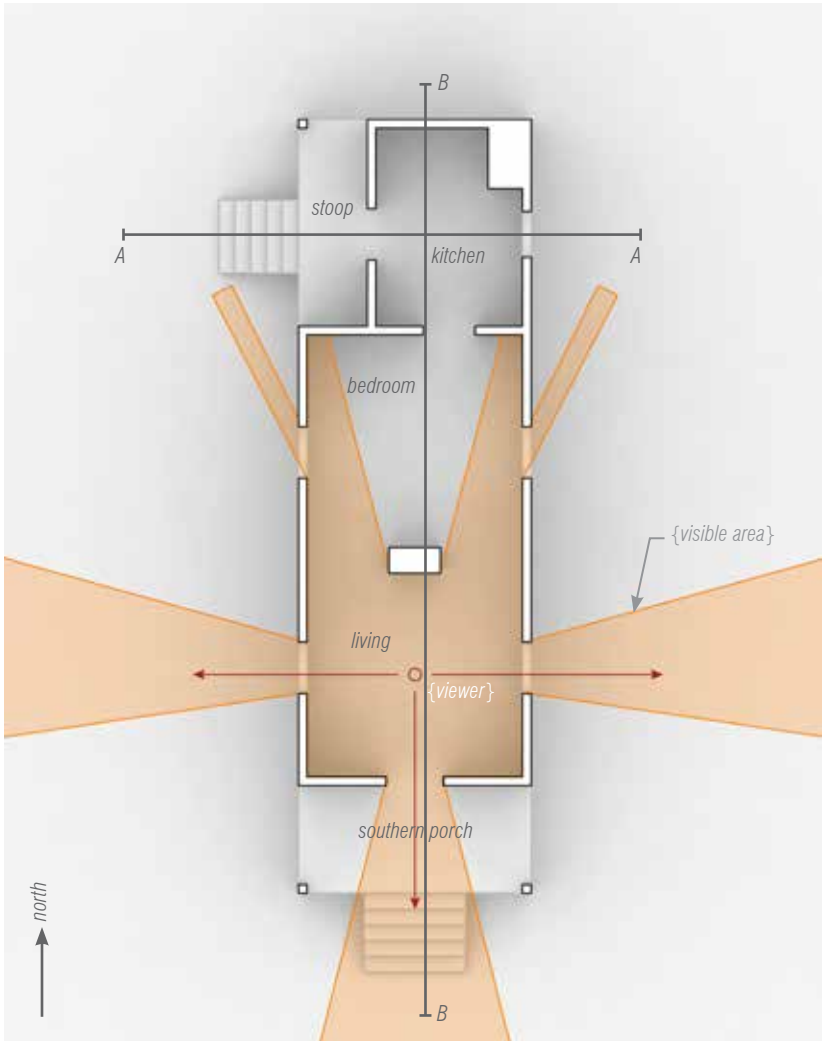


plan *section: longitudinal* *section: transverse*

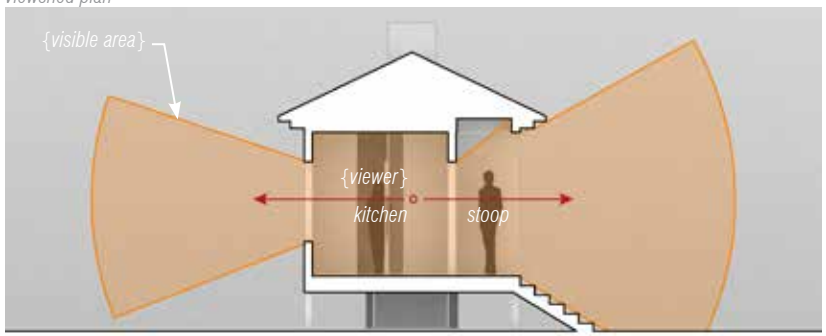
viewshed diagrams

Viewshed Analysis

Two small perimeter spaces including a southern porch and northern stoop offer extensive visual access to the surrounding landscape. From within the long and narrow structure, views out are facilitated by aligned apertures along eastern and western walls. From the most visually accessible interior living area, views extend out along three axes; east, west and south through the southern porch. Due to the lack of interior partitions, visual access to domestic activities internal to the building are unconstrained.



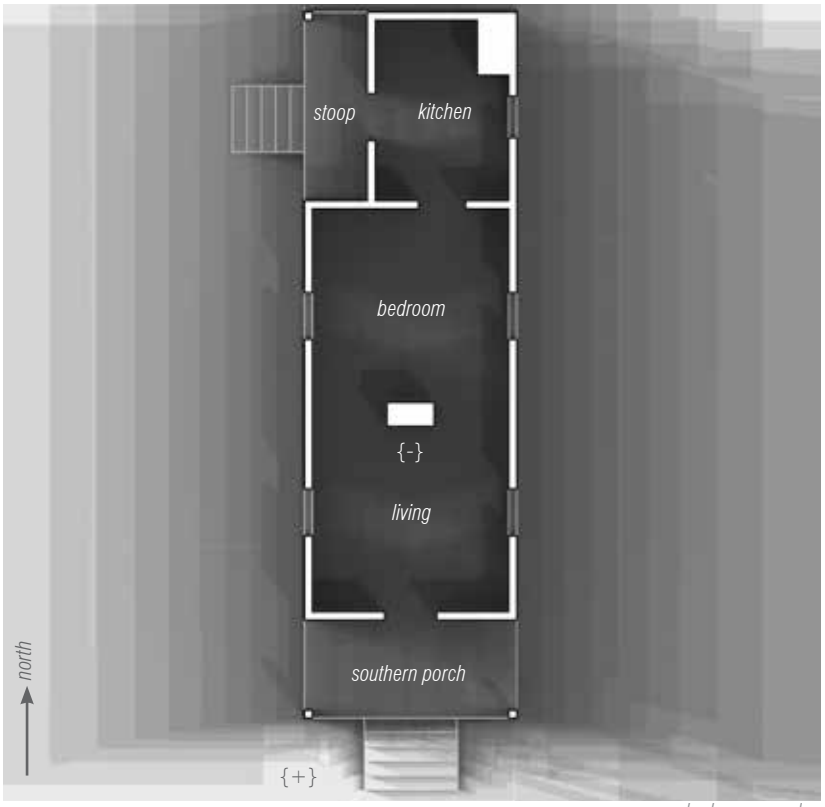
viewshed plan



viewshed section A-A

EARLY SHOTGUN HOUSE

Cooling



shadow range plan

cooling diagrams

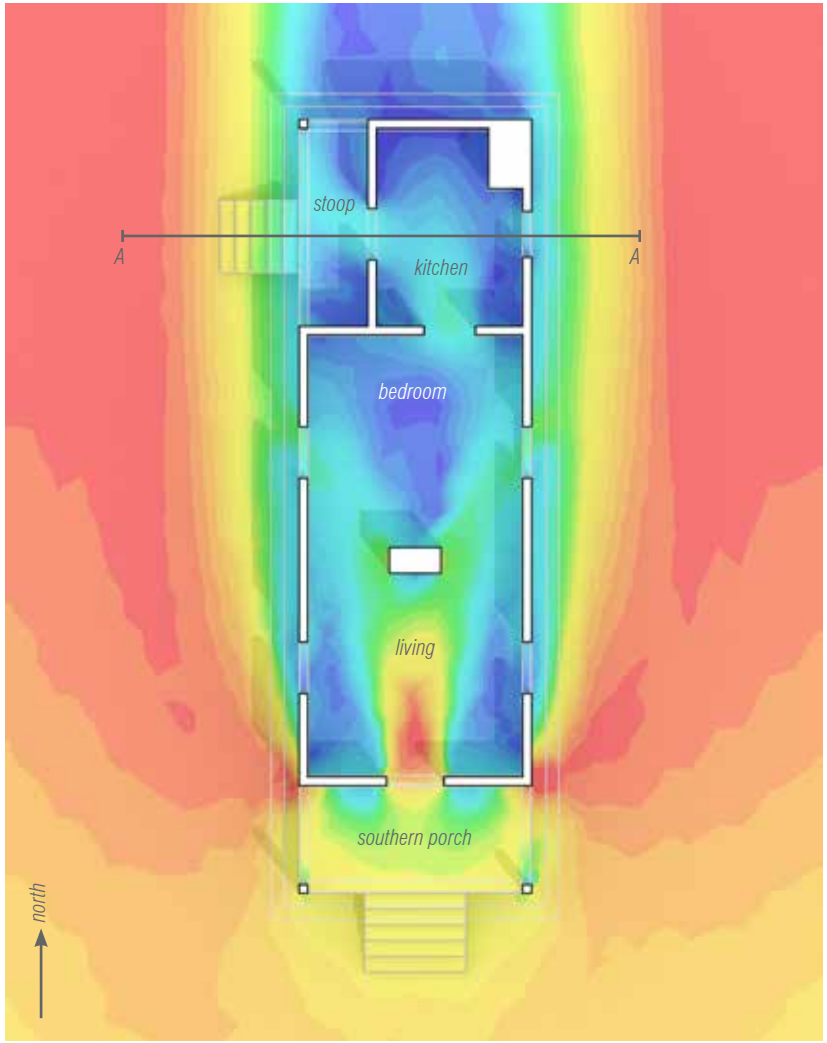
Shading and Ventilation Analysis

The north-south linear bar would be more effective in cooling if it were oriented along the east-west axis due to its narrow footprint and aligned apertures. However, the large communicating opening off the southern porch partnered with the numerous apertures spaced along the east and west surfaces provide increased ventilation rates within the living area. An unbroken parasol roof plane also shades the interior during midday periods when interior cooling is imperative.

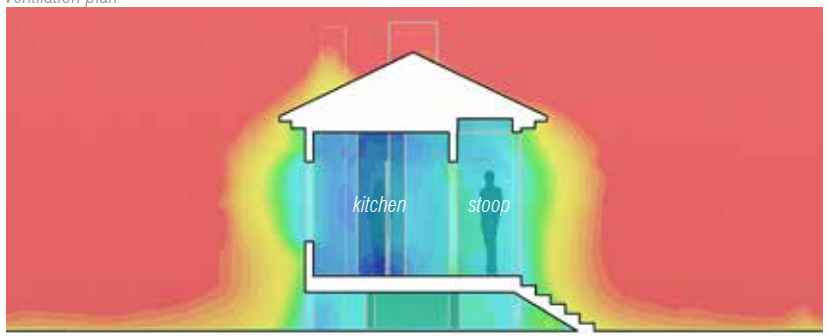
ventilation legend (m/s)

2

0



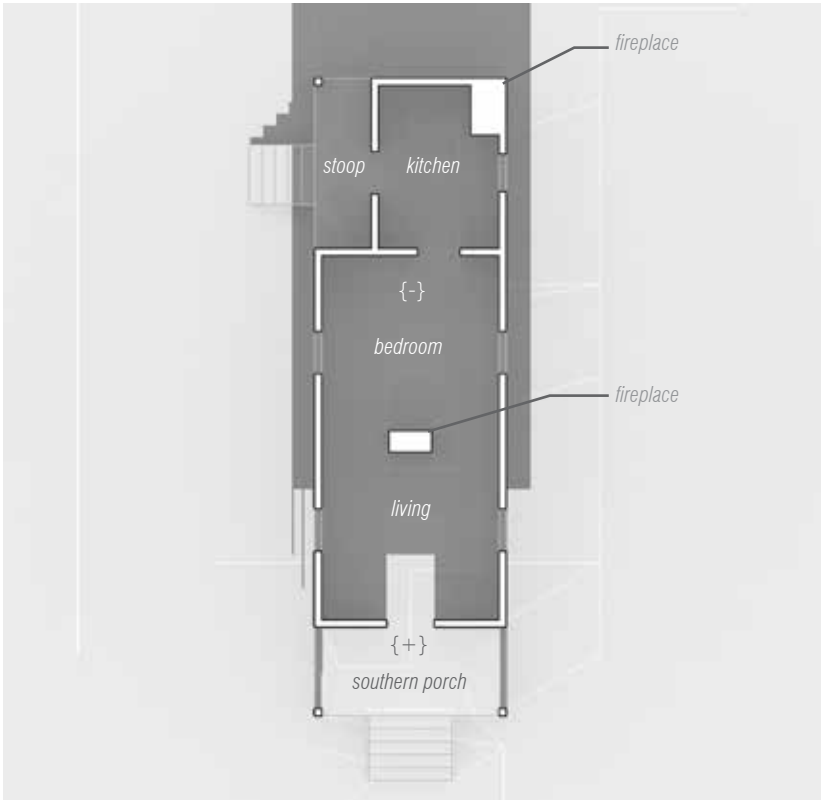
ventilation plan



ventilation section A-A

EARLY SHOTGUN HOUSE

Heating



solar incidence plan at noon

insolation

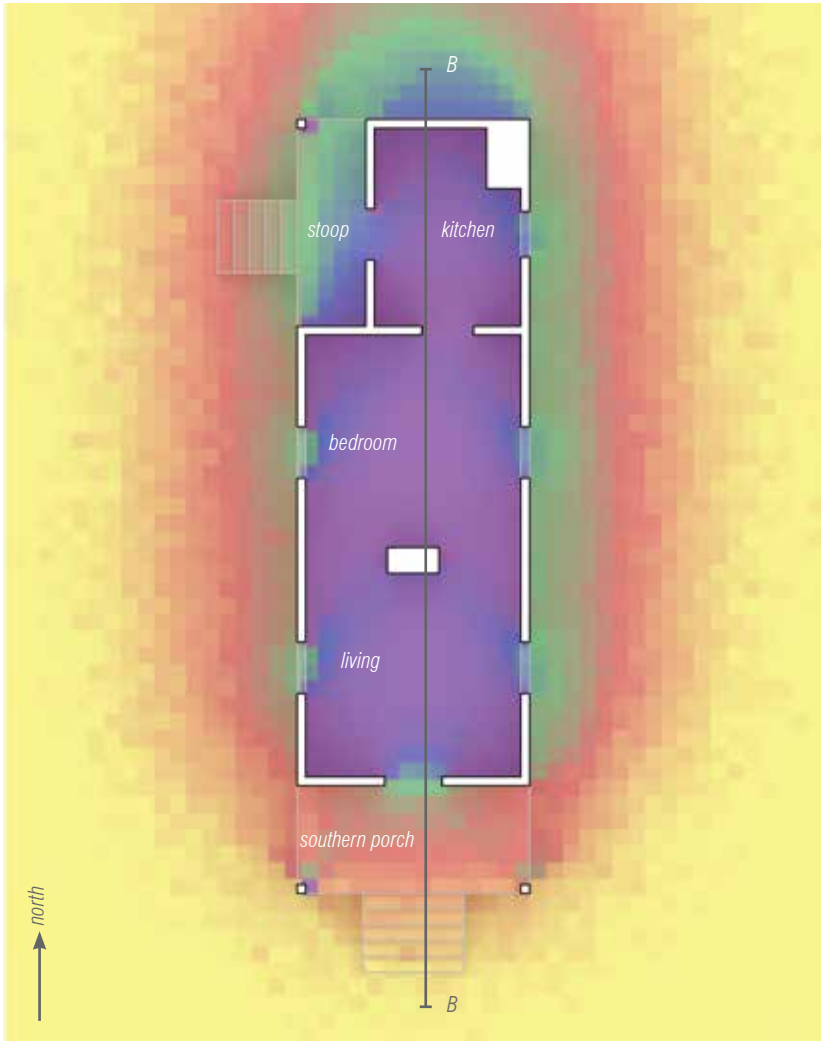
incidence

heating diagrams

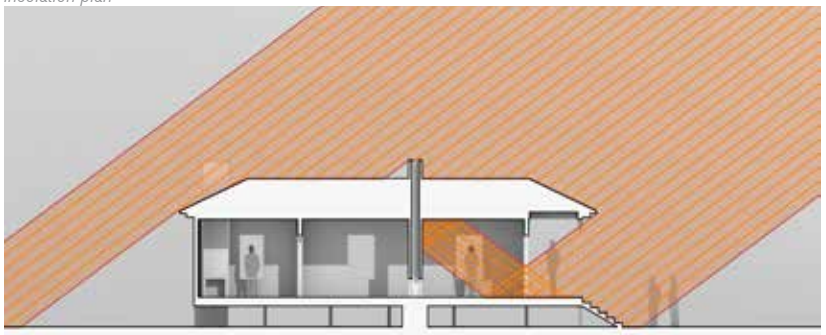
Solar Incidence and Insolation Analysis

Incident solar radiation is largely present in the porch that defines the southern end of the building. With prevailing winter winds from the north, the predominate area of the building mass buffers and protects the southernmost spaces from the cold northerly winds. Enclosed southern spaces like the living area, which communicate directly with the southern porch are optimal for winter inhabitation by being both wind buffered, sun exposed and further intensified by the fireplace which defines its northernmost edge.

insolation legend (kWh/m2)



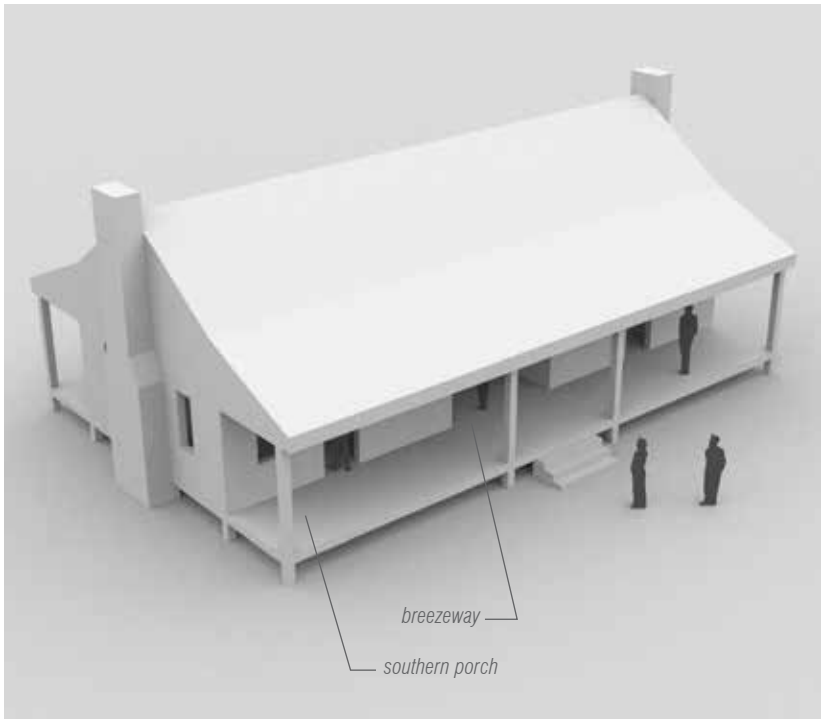
insolation plan



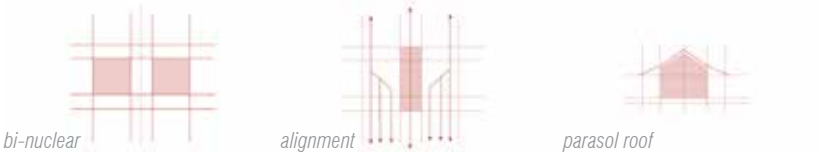
section B-B: solar rays - winter

NEAL DOGTROT HOUSE

Overview



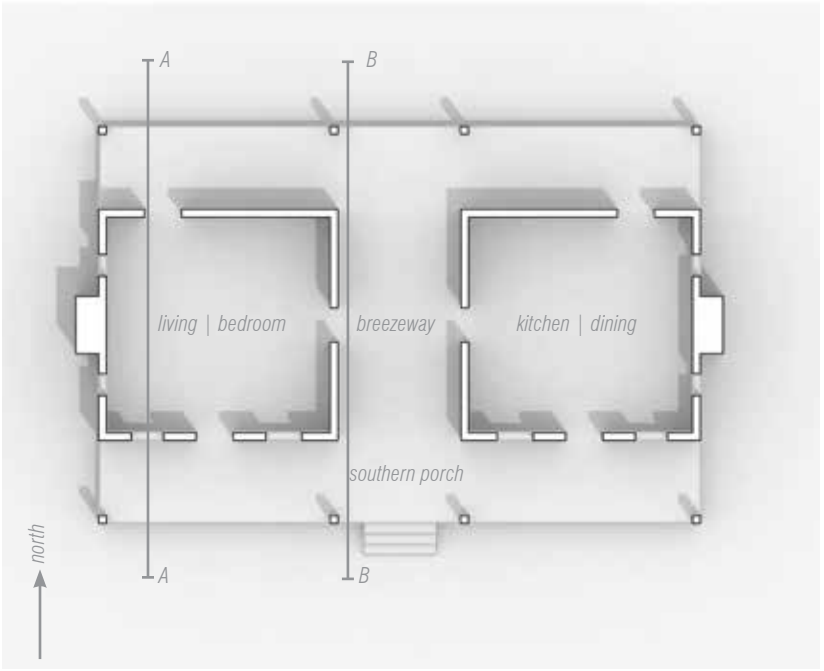
Neal Family House: aerial perspective (reconstruction following field survey)



dogtrot diagrams

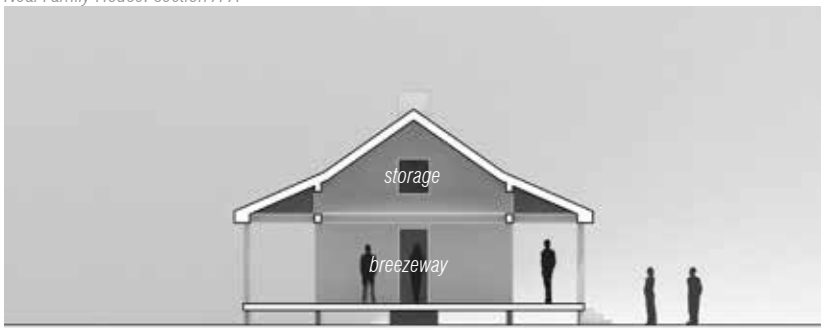
Mid 19th Century Southern Dogtrot House

The dogtrot house inflects the traditional southern cabin by being dividing into two equal units. The plan organization reflects a binuclear scheme, creating two dominate enclosed programmatic spaces connected by a central wind chamber, all of which are unified by a large parasol roof which extends beyond the footprint of the two enclosed spaces to create a deep perimeter porch. The organization of space intertwines the program with passive cooling strategies, an essential characteristic of structures located within a hot and humid climate. It modulates the harsh climate utilizing an inventory of well-crafted building design attributes including the central wind chamber, parasol roof and programmatic separation.



Neal Family House: floor plan

Neal Family House: section A-A

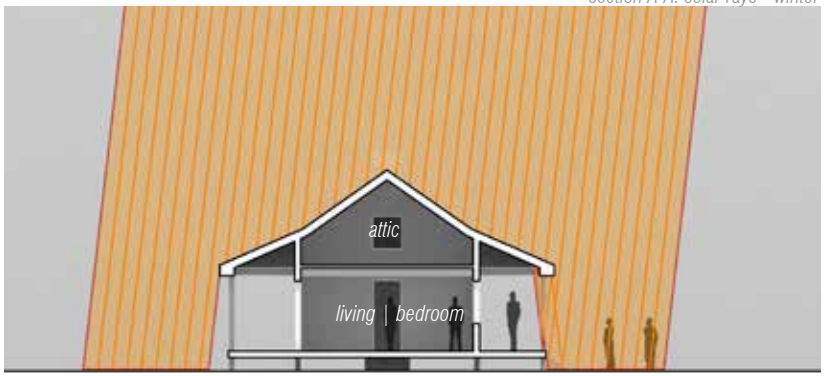


Neal Family House: section B-B

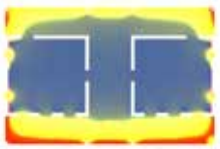
NEAL DOGTROT HOUSE

Daylighting

section A-A: solar rays - winter



section A-A: solar rays - summer



illuminance: plan

illuminance: section

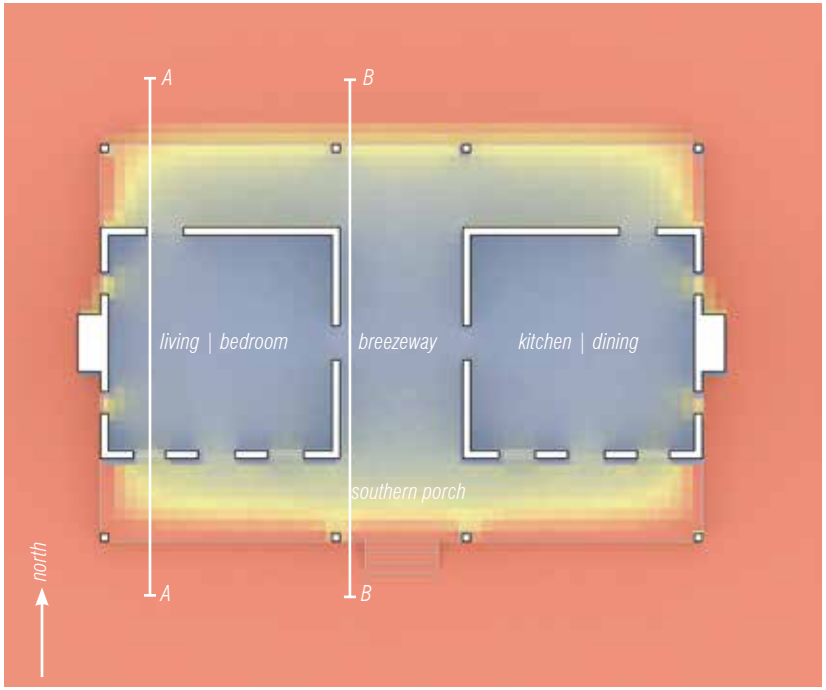
rays

daylighting diagrams

Natural Daylighting Analysis

The east-west linear orientation of the building harvests abundant natural light. The porch along the southern edge of the building provides overhangs that redirects light entering both enclosed rooms within the bi-nuclear scheme. The profusion of reflections encountered as solar rays track toward the interior supply uniform light levels of daylight inside. The thinness of these rooms in the north-south direction along with numerous apertures along the southern edge source adequate natural daylight for these interior zones.

illuminance legend (lux)



illuminance plan

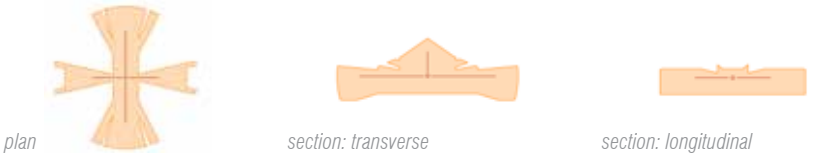
illuminance A-A

illuminance section B-B

NEAL DOGTROT HOUSE

Viewshed

viewshed section C-C

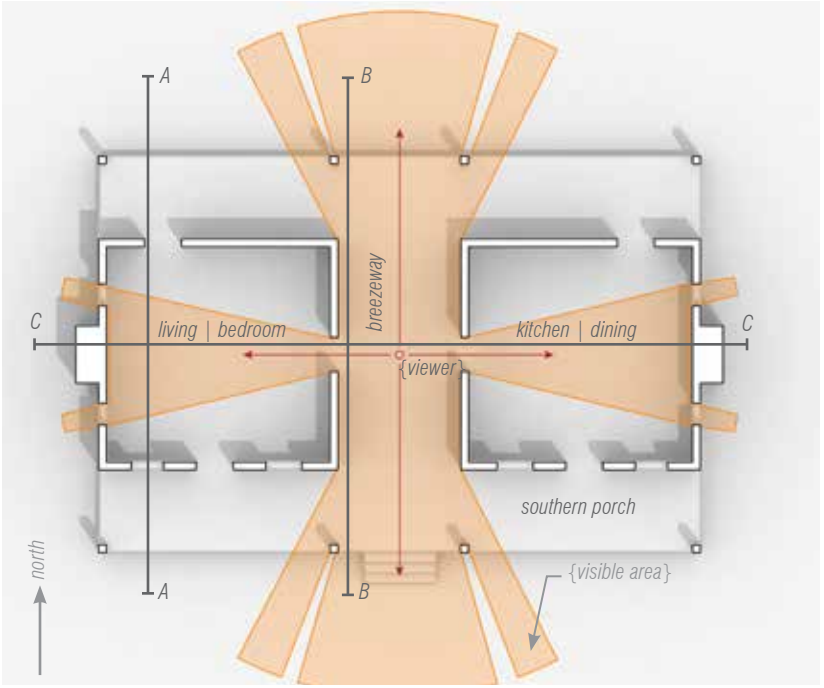


plan section: transverse section: longitudinal

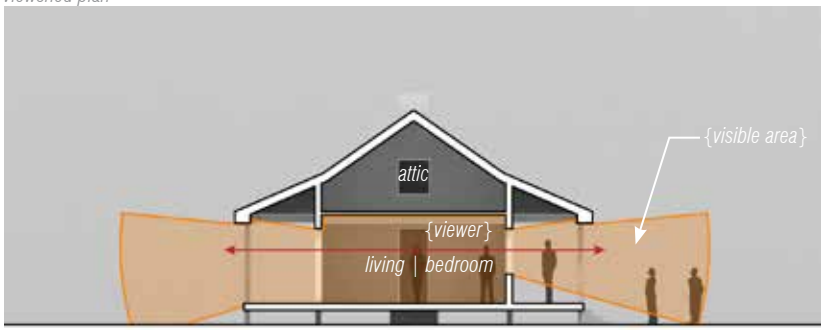
viewshed diagrams

Viewshed Analysis

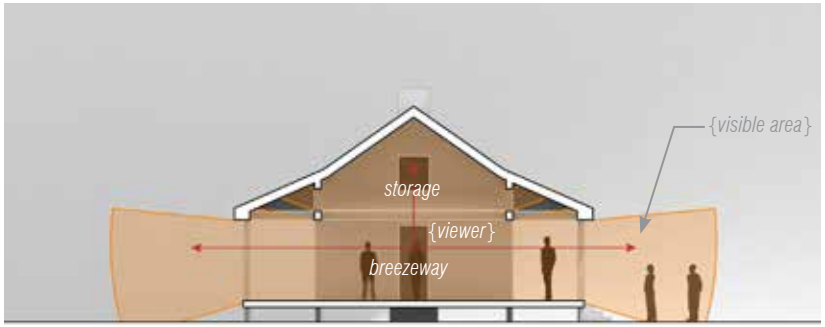
Long perimeter porches along the southern and northern edges of the building provide ample visual access to the surrounding landscape. The breezeway, central to the building composition, offers framed views out to the north and south while also providing a glimpse into each of the enclosed rooms that flank the breezeway to the east and west. Within each of the enclosed program spaces, views to immediate areas are framed through small operable apertures which allow each space to the opened and closed as dictated by social or environmental constraints.



viewshed plan



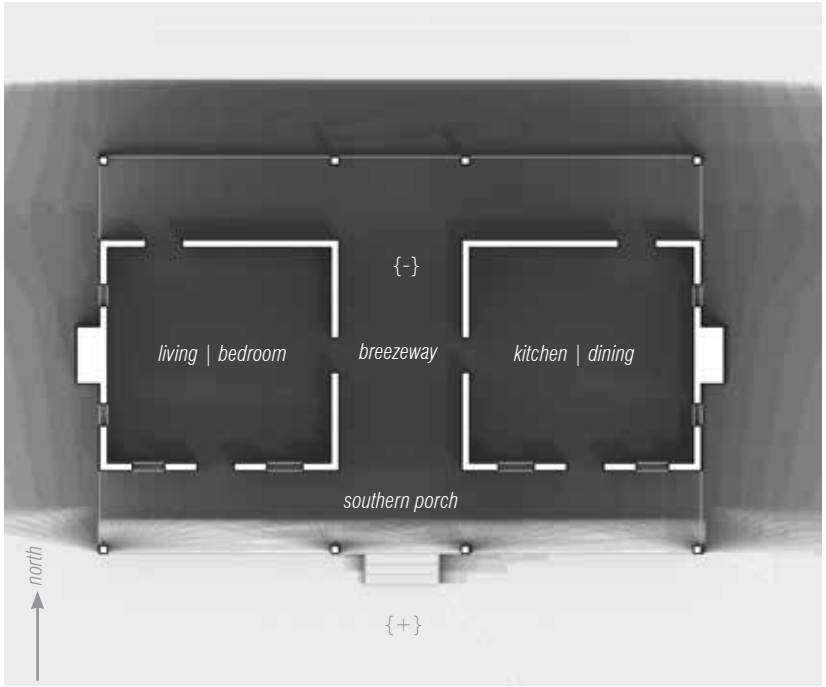
viewshed section A-A



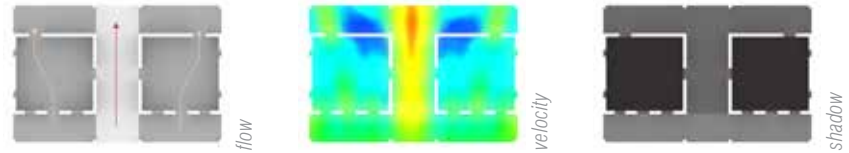
viewshed section B-B

NEAL DOGTROT HOUSE

Cooling



shadow range plan

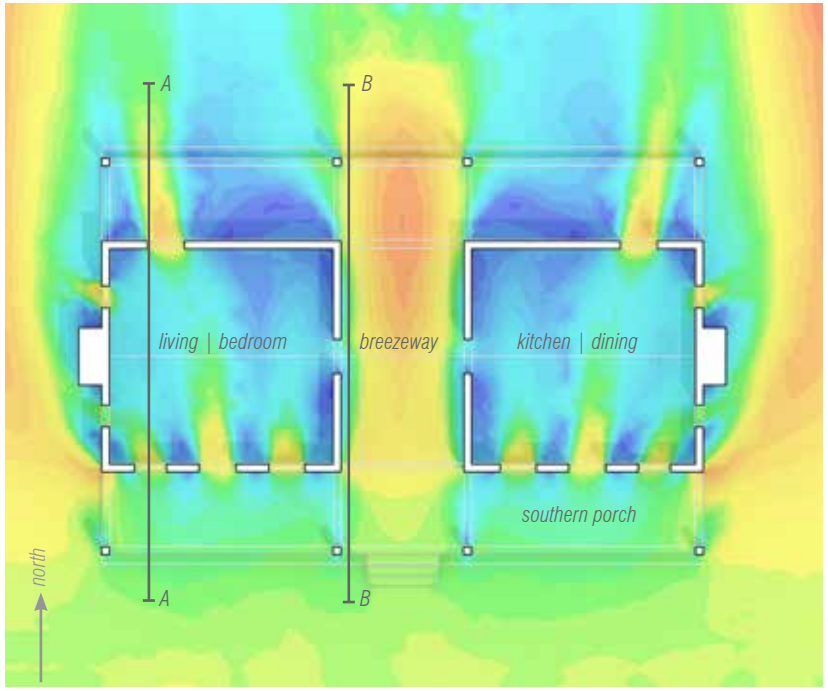


cooling diagrams

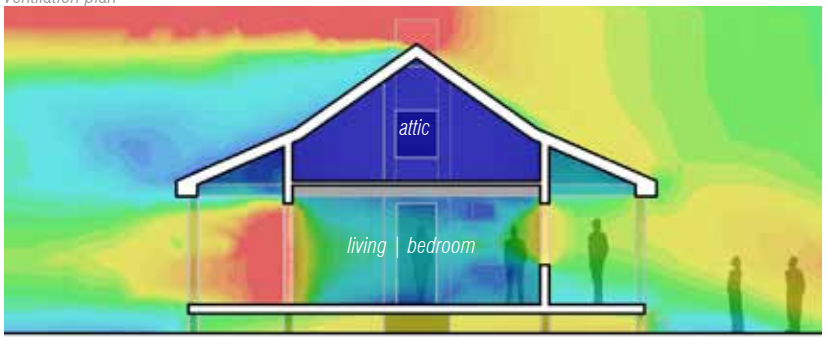
Shading and Ventilation Analysis

Renowned for its central breezeway, the dogtrot carves an intermediary space out of the building mass, providing the increased potential for cross ventilation in all zones of the building. The east-west orientation of the building mass establishes pressure differentials on opposing sides of the structure. This pressure differential combined with the narrow breezeway constricts airflow and increases air velocity through the structure. A large parasol roof also projects beyond enclosed interior rooms, shading all inhabitable living areas.

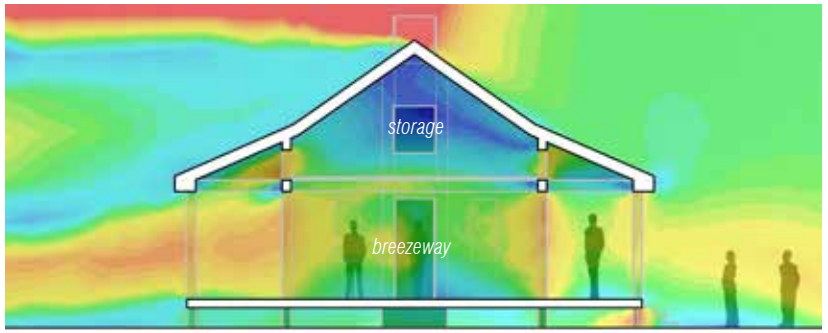
ventilation legend (m/s)



ventilation plan



ventilation section A-A



ventilation section B-B

NEAL DOGTROT HOUSE

Heating

section B-B: solar rays - winter

incidence

insolation

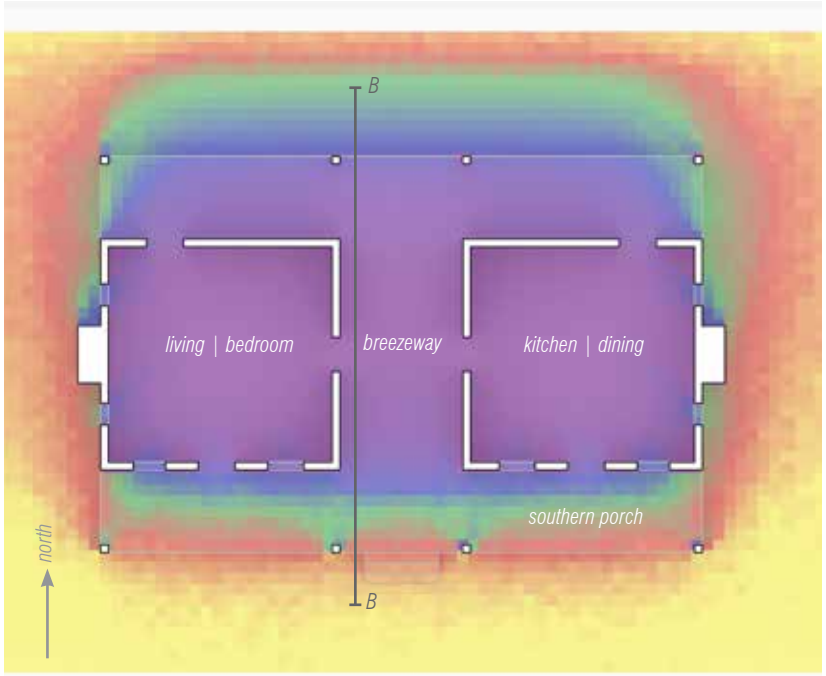
rays

heating diagrams

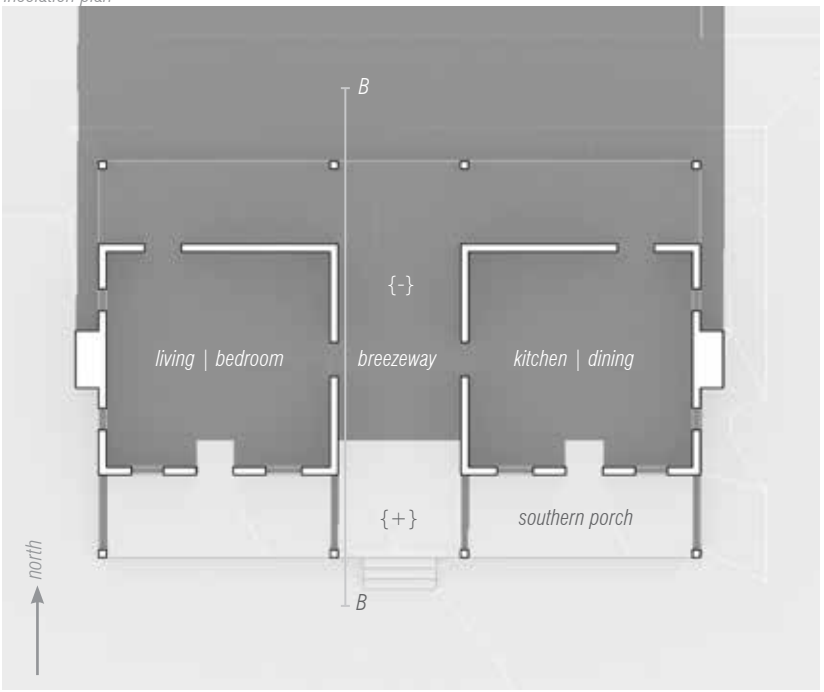
Solar Incidence and Insolation Analysis

Incident solar radiation is drawn largely from the porch that runs along the southern edge of the building composition. With prevailing winter winds emanating out of the north, the enclosed building mass, oriented along an east-west axis, buffer and protect the southernmost spaces from cold northerly winds. Enclosed spaces like the bi-nuclear program units, which communicate directly with the southern porch are optimal for winter inhabitation by being both wind buffered and sun exposed when operable perimeter elements are configured accordingly.

insolation legend (kWh/m2)



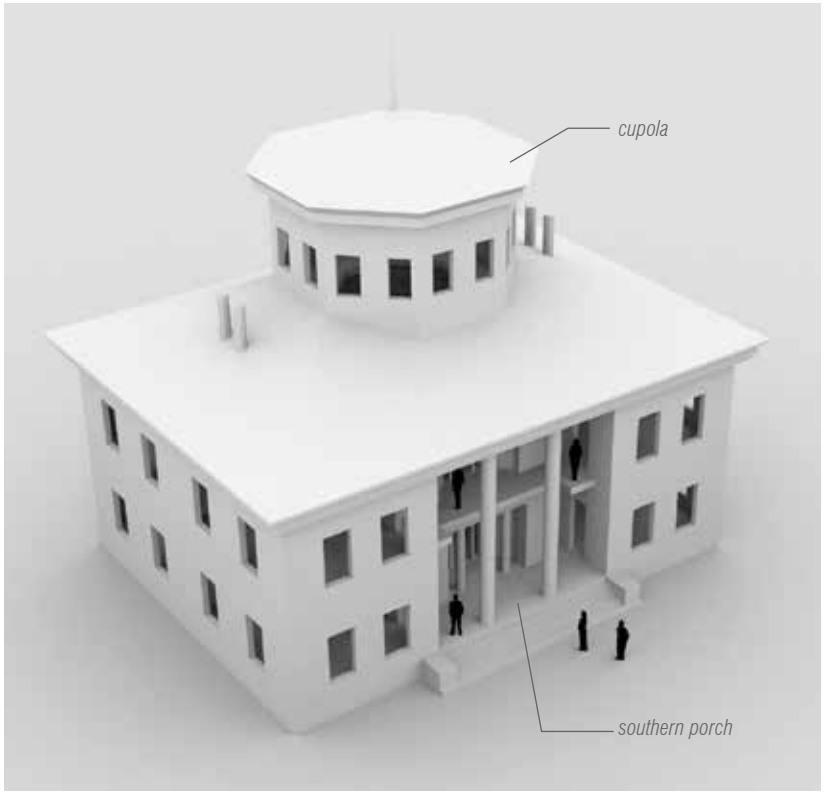
insolation plan



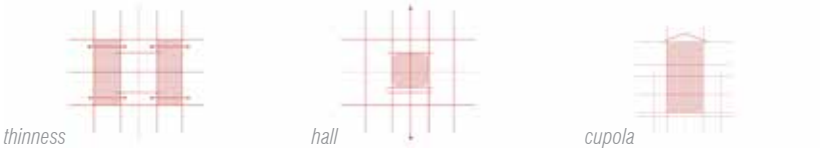
solar incidence plan at noon

WAVERLY MANSION

Overview



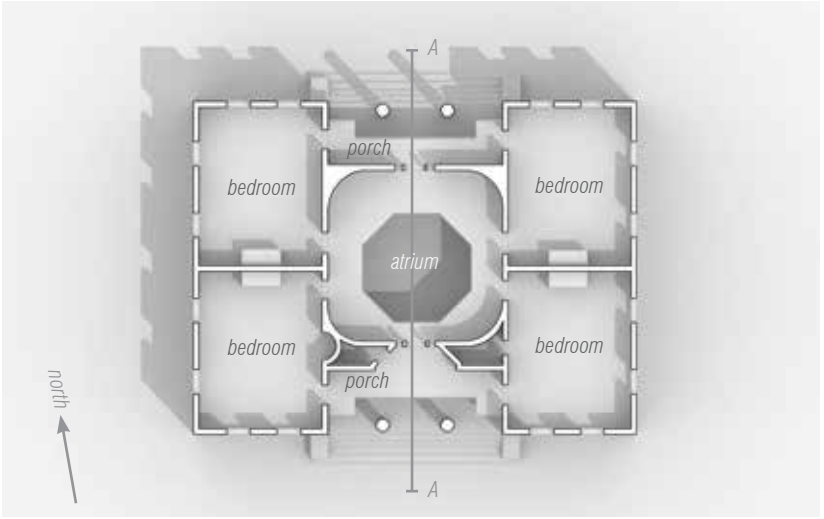
Waverly Mansion: aerial perspective (reconstruction following field survey)



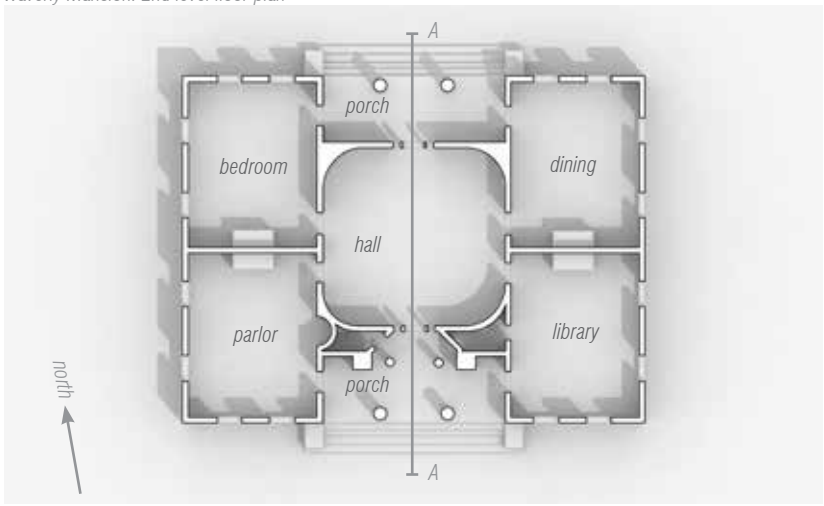
antebellum diagrams

Mid 19th Century Southern Antebellum Mansion

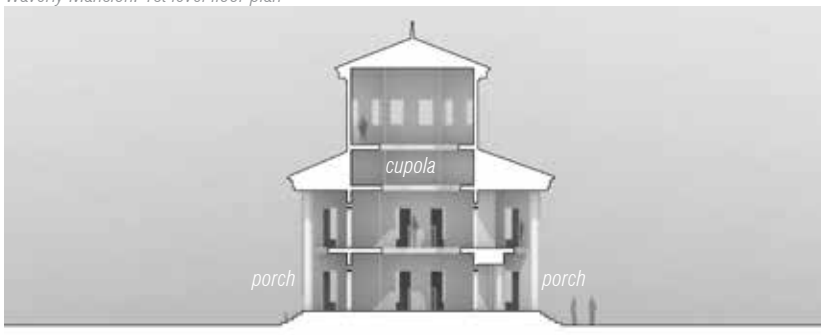
The antebellum mansion organizes space around a central octagonal atrium volume. With porch recesses that flank the central atrium on the northern and southern ends, the mass of the mansion is divided into two thin halves on the east and west sides. Each half opens directly to the exterior on two sides and to an exterior porch and atrium on a third side. These openings harvest abundant natural daylighting while enabling fresh air to move through each space into the central atrium. The verticality of the atrium with operable openings around the octagonal cupola allow hot air stratifying during hot summer months to evacuate the inhabitable interior spaces and exhaust out the top.



Waverly Mansion: 2nd level floor plan



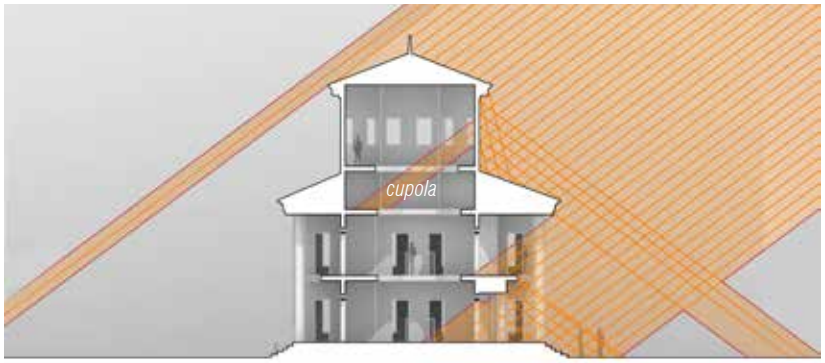
Waverly Mansion: 1st level floor plan



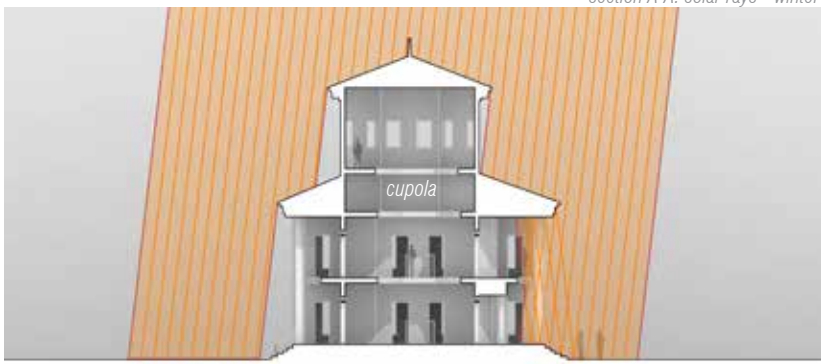
Waverly Mansion: section A-A

WAVERLY MANSION

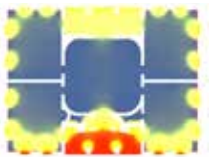
Daylighting



section A-A: solar rays - winter

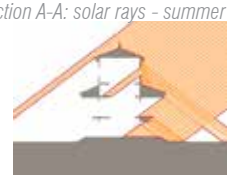


section A-A: solar rays - summer



illuminance: plan

illuminance: section



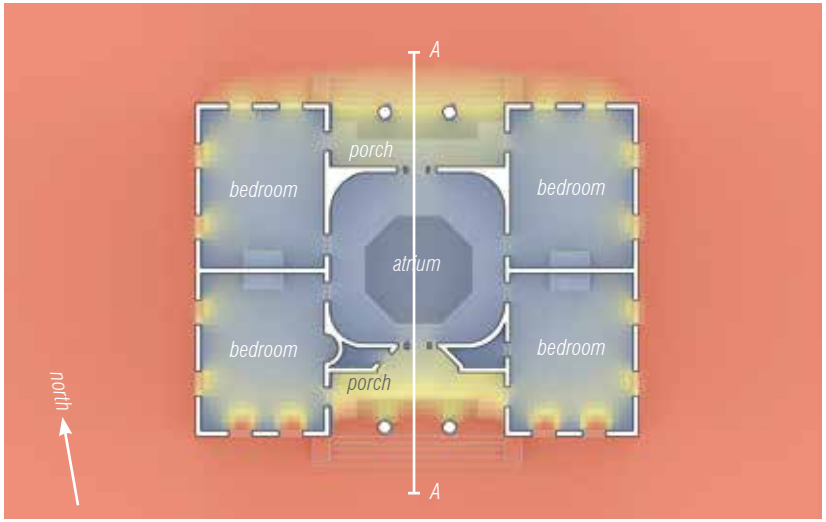
rays

daylighting diagrams

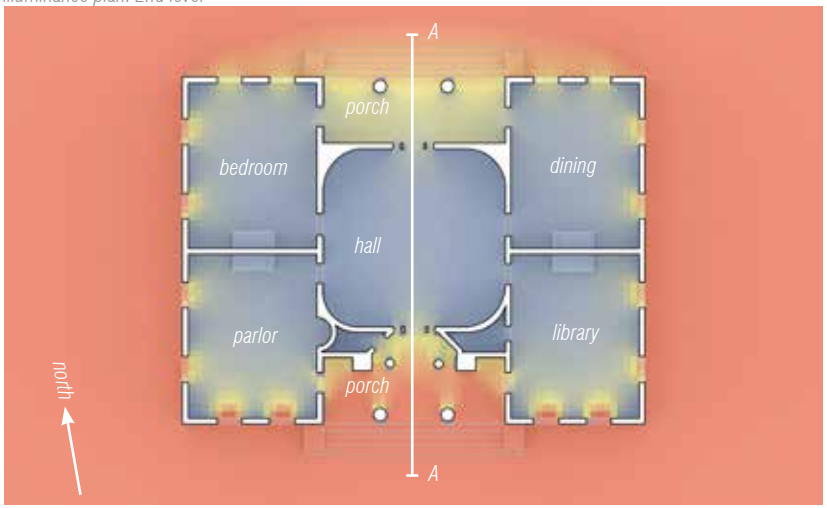
Natural Daylighting Analysis

With enclosed rooms encircling the four story atrium volume, natural daylight enters primarily through windows that circumscribe the cupola at its apex and a two story southern porch that extends along its central north-south axis. Recesses at the porch along with projecting overhangs supply diffuse natural daylight to the atrium itself. Enclosed rooms at the corners of the building subsequently project out to allow daylight to enter on three of four sides.

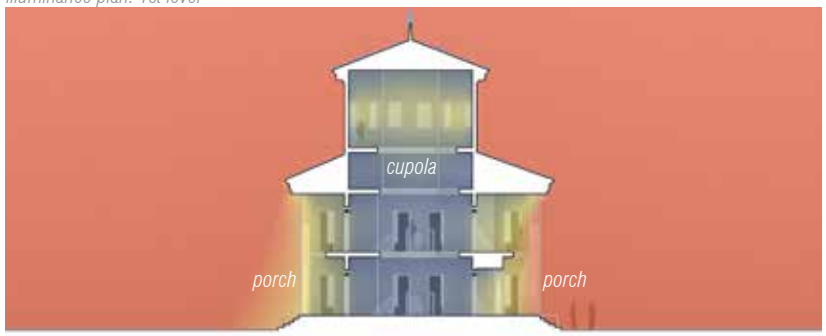
illuminance legend (lux)



illuminance plan: 2nd level



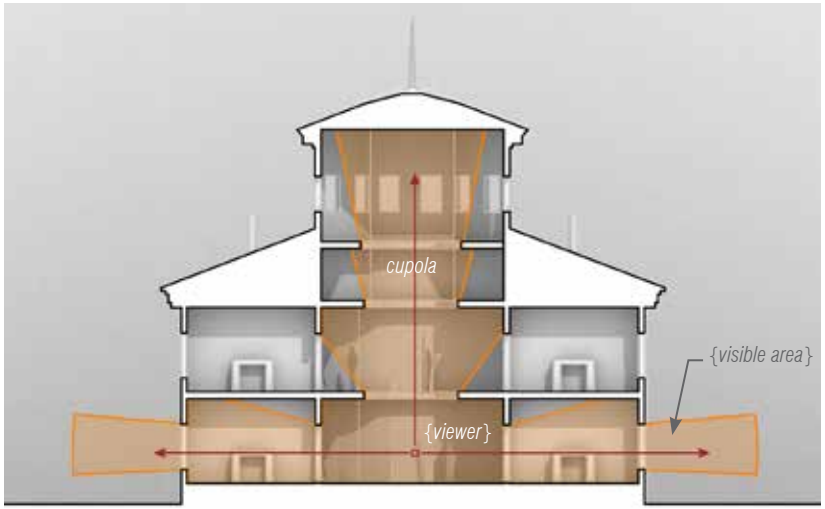
illuminance plan: 1st level



illuminance section A-A

WAVERLY MANSION

Viewsheds



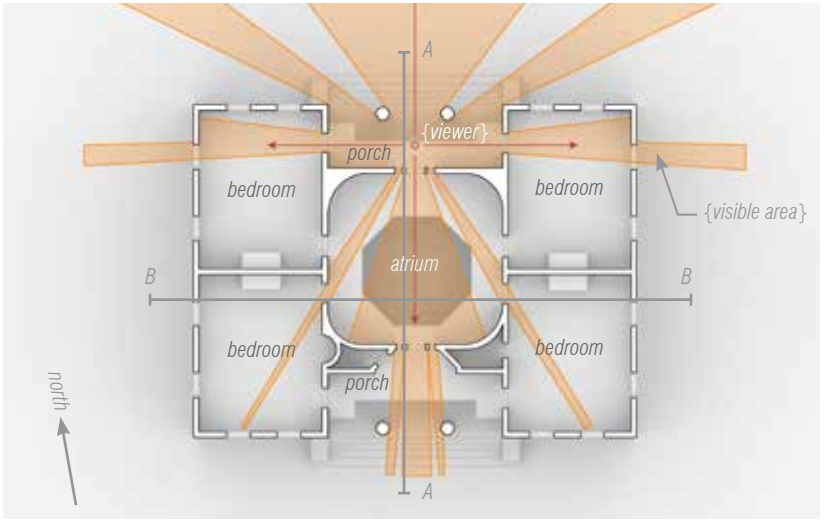
viewshed section B-B

plan: 1st plan: 2nd section

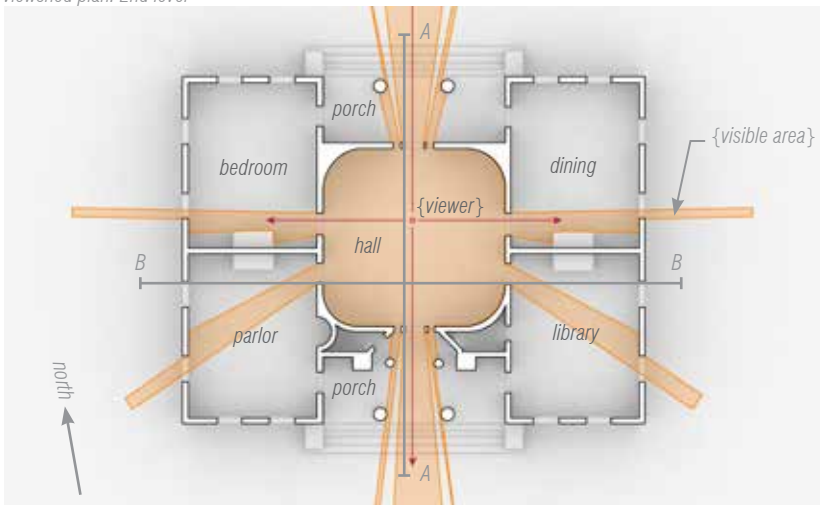
viewshed diagrams

Viewshed Analysis

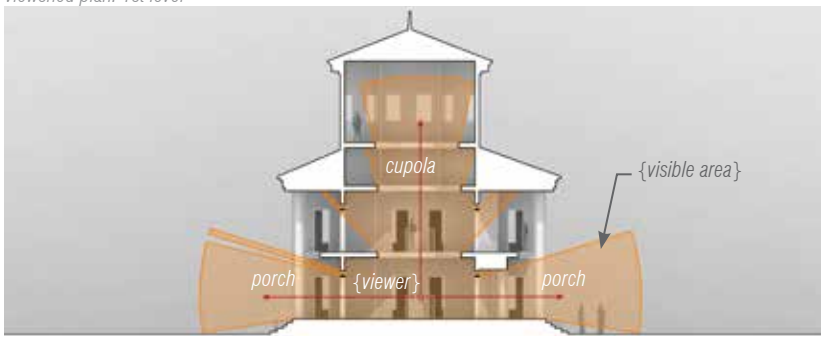
Small perimeter porches along the southern and northern edges of the central hall provide ample visual access to the surrounding landscape along their respective orientations. When within the structure, expansive viewsheds are provided within the central hall space; above to the upper reaches of the cupola, south and north through the aforementioned porches while penetrating the four semi-enclosed rooms that encircle the hall. From each of the rooms, apertures on three of the four sides offer full visual connections to the outside in addition to connections to the common hall space within.



viewshed plan: 2nd level



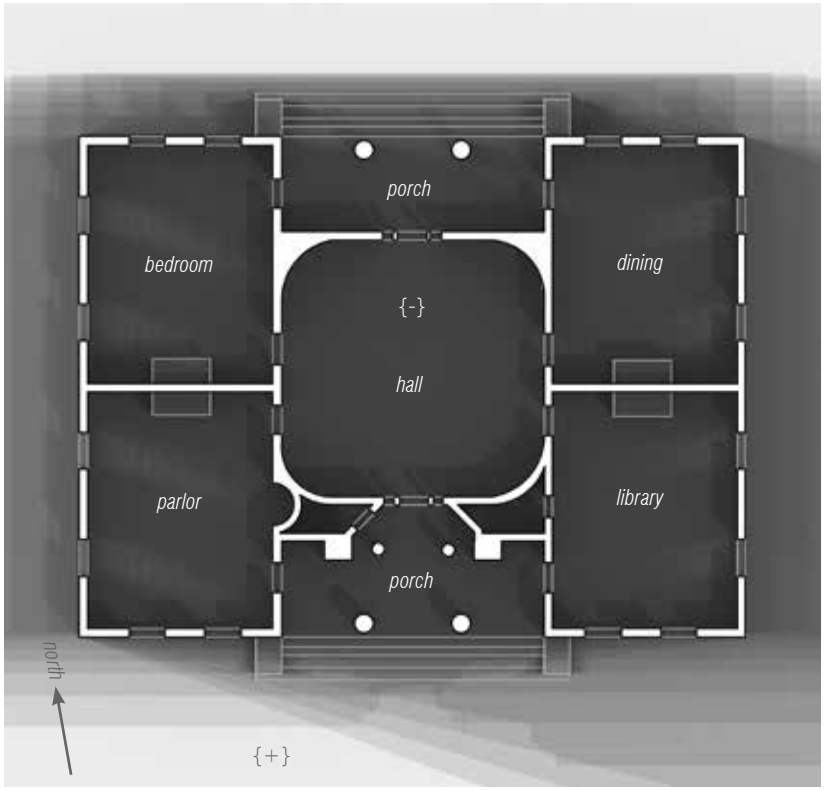
viewshed plan: 1st level



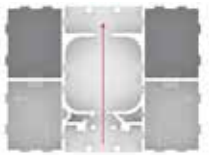
viewshed section A-A

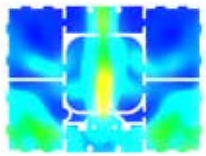
WAVERLY MANSION

Cooling



shadow range plan: 1st level


flow


velocity

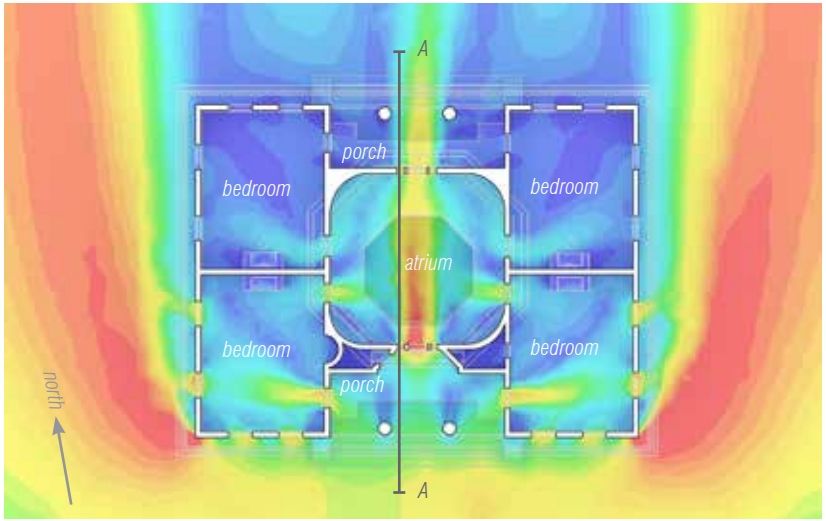

shadow

cooling diagrams

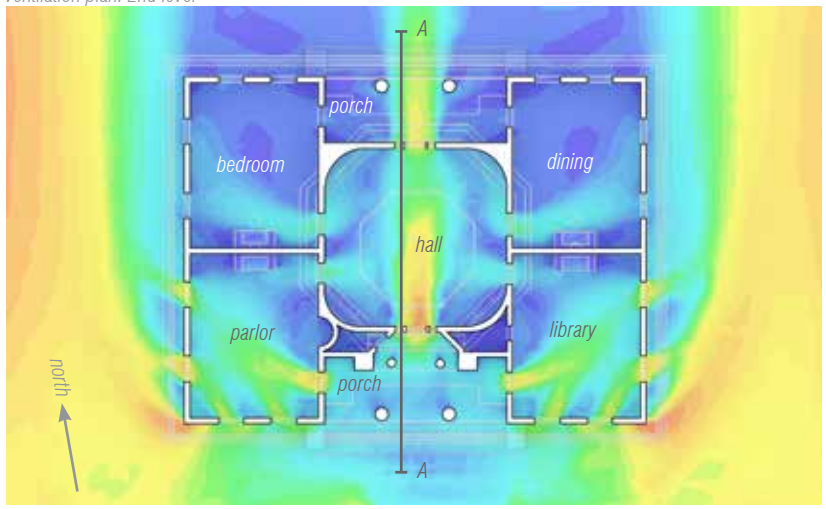
Shading and Ventilation Analysis

The four story hall with two story porch spaces flanking it to the north and south provide a highly permeable volume central to the building. With four semi-enclosed spaces surrounding this open center, constricted air increases its velocity when moving from the windward to leeward sides of the building. The height of the central hall also promotes air stratification in the vertical direction where it can exhaust in the cupola. Shading from the expansive roof volume is provided to both open and semi-enclosed areas of the interior during summer months.

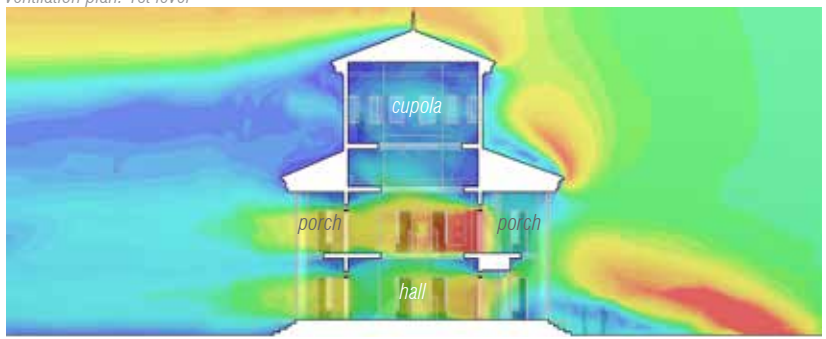
ventilation legend (m/s)



ventilation plan: 2nd level



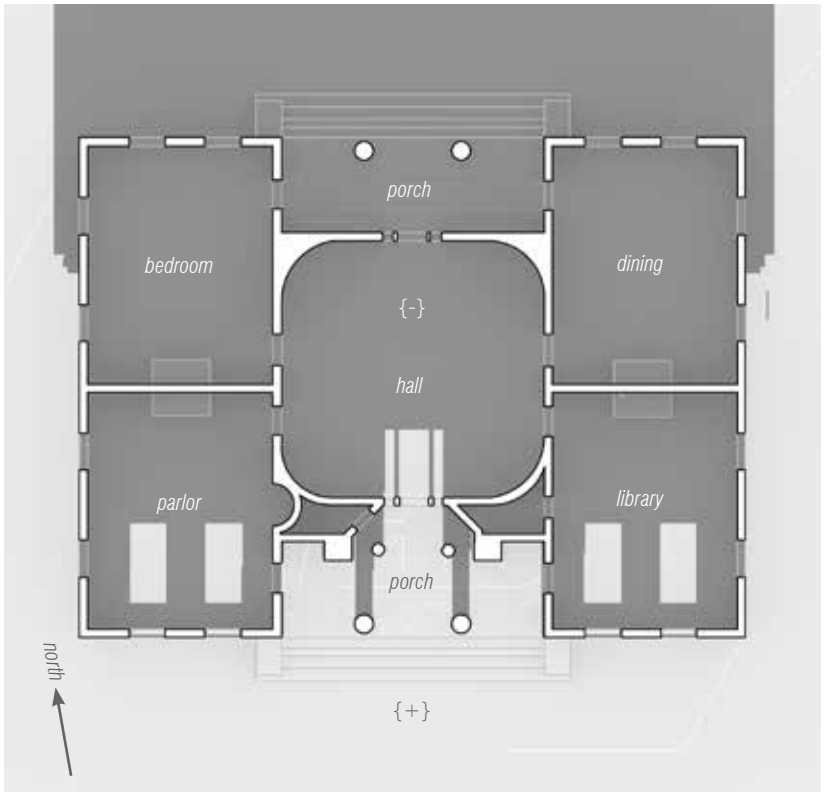
ventilation plan: 1st level



ventilation section A-A

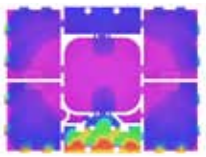
WAVERLY MANSION

Heating



solar incidence plan at noon: 1st level

incidence



insolation

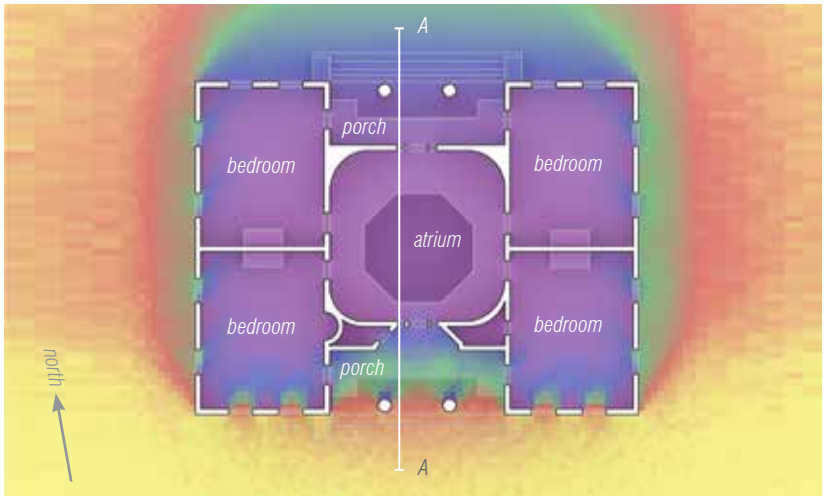
rays

heating diagrams

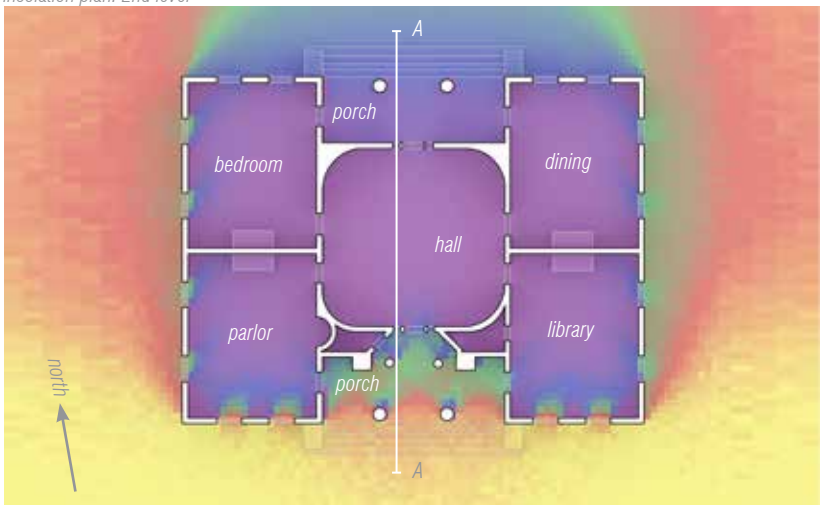
Solar Incidence and Insolation Analysis

Incident solar radiation concentrates largely in the porch that anchors the southern edge of the central hall. With prevailing winter winds emanating out of the north, the centralized building mass buffers and protects the southernmost spaces when the operable northernmost building apertures are closed. Enclosed rooms to the south which communicate directly with the southern porch are optimal for winter inhabitation by being both wind buffered and sun exposed especially with supplementary fireplaces.

insolation legend (kWh/m2)



insolation plan: 2nd level

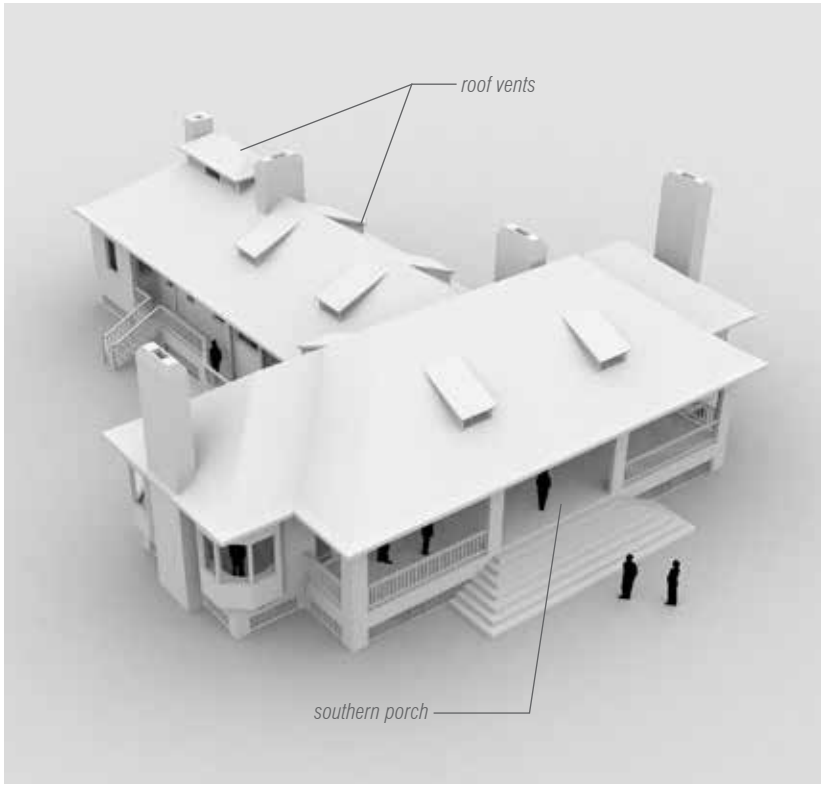


insolation plan: 1st level

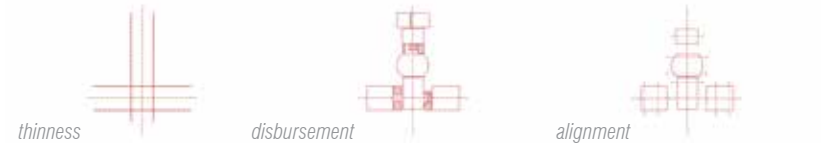
section A-A: solar rays - winter

CHARNLEY NORWOOD HOUSE

Overview



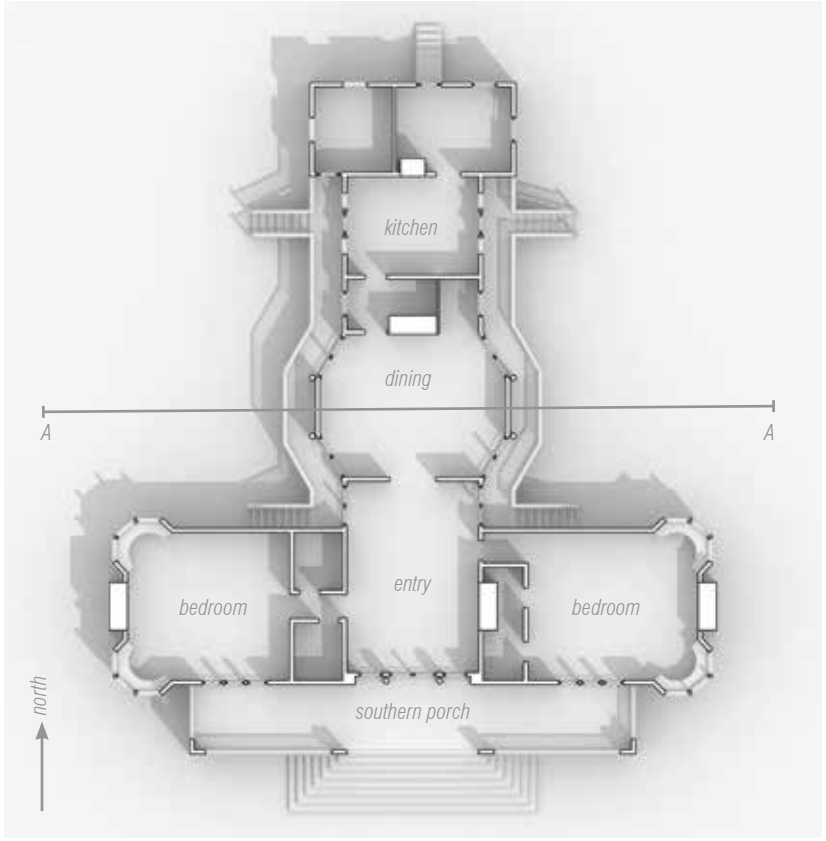
Charnley Norwood House: aerial perspective (reconstruction following field survey)



bungalow diagrams

Late 19th Century Gulf Coast Bungalow

The gulf coast bungalow uses linear units to generate an abundance of intermediary spaces between the structure's interior and its immediate context. While the plan organization follows its shotgun predecessor in its linearity, the repositioning of linear blocks create multiple exposures that alter the orientation of interior spaces to year-round climatic effects. The organization of space incorporates passive cooling control mechanisms, natural daylighting provisions, and cross ventilation strategies which include a deep perimeter porch, narrow building footprint, and vented attic volumes.



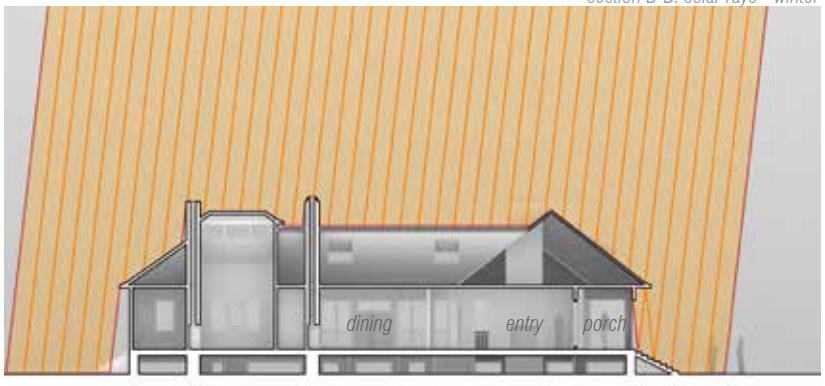
Charnley Norwood House: floor plan

Charnley Norwood House: section A-A

CHARNLEY NORWOOD HOUSE

Daylighting

section B-B: solar rays - winter



section B-B: solar rays - summer

illuminance: plan

illuminance: section

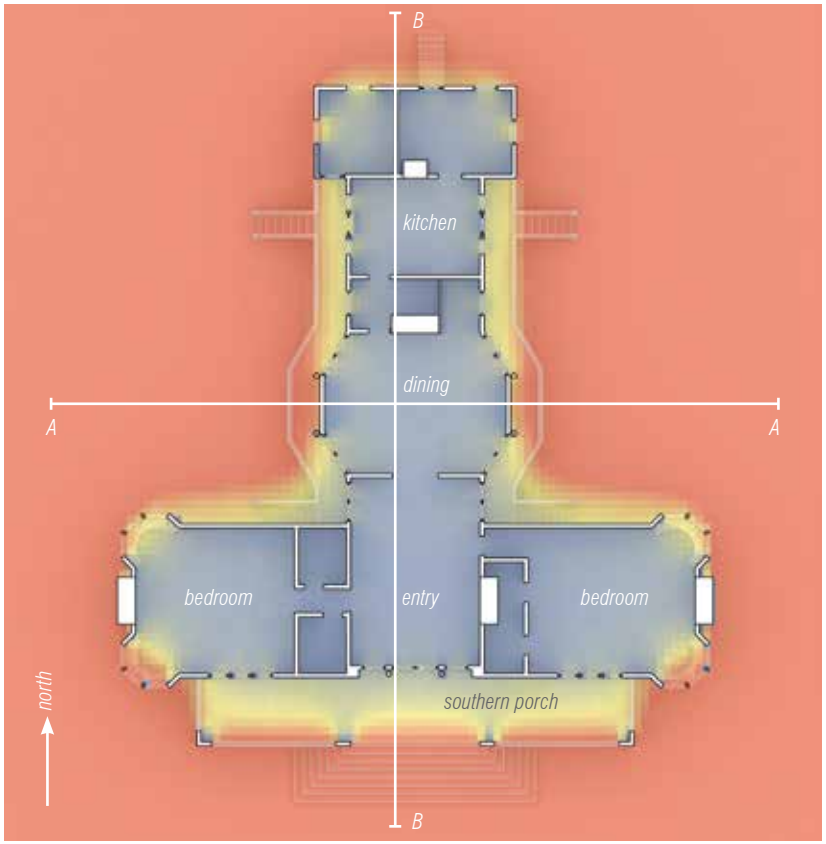
rays

daylighting diagrams

Natural Daylighting Analysis

The east-west linear bar that sits to the south of the building composition harvests the most natural light. The southern porch along the edge of this bar provides overhangs that redirect light entering the bedrooms and entry hall, supplying uniform daylight throughout those areas. The perpendicular north-south linear bar receives natural light during early and late daytime hours with ample illuminance levels due to its narrow footprint and its abundance of aligned apertures. Diffusion within this bar is achieved through the perimeter porch at each edge.

illuminance legend (lux)

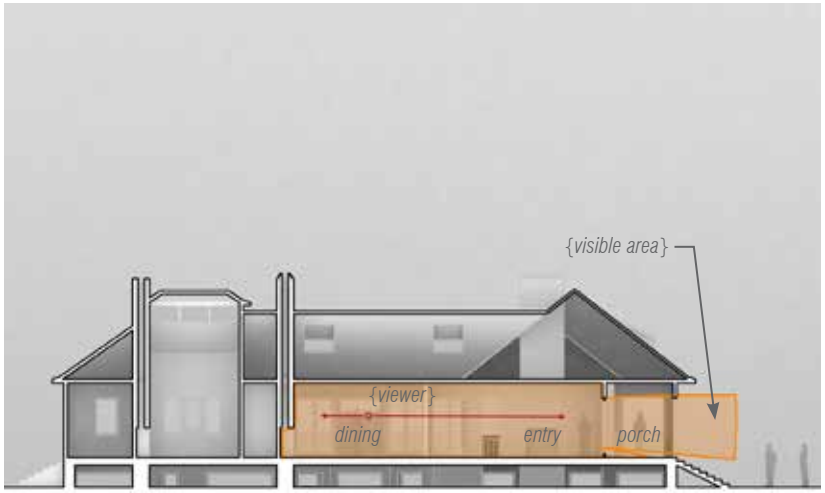


illuminance : 1st level

illuminance section A-A

CHARNLEY NORWOOD HOUSE

Viewshed



viewshed section B-B

plan

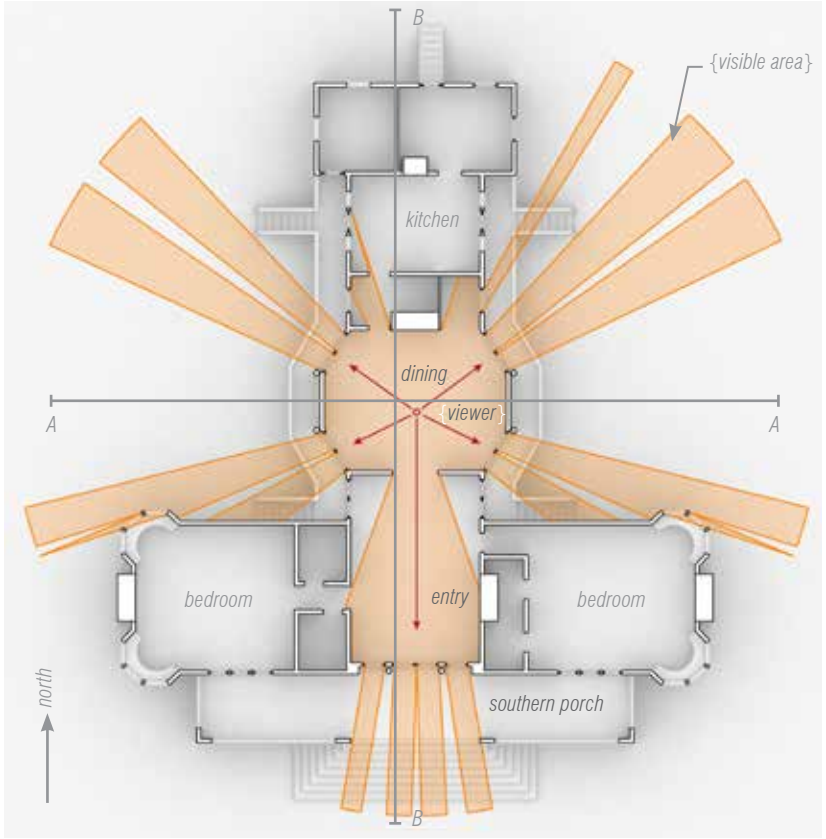
section: longitudinal

section: transverse

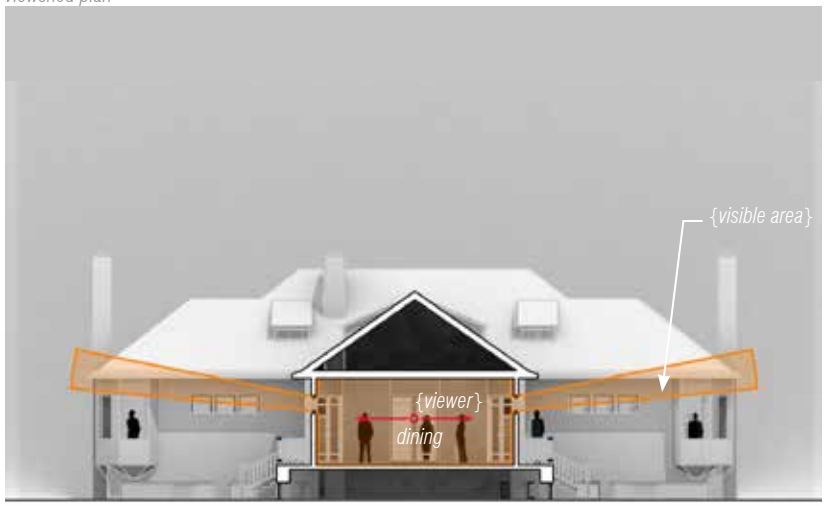
viewshed diagrams

Viewshed Analysis

Long perimeter porches along the southern, eastern and western edges of the building provide ample visual access to the surrounding landscape. When within the unit, expansive viewsheds are provided within the octagonal dining space. An axial view to the gulf penetrates southward through the entryway to the southern porch and is framed by the bedroom utility zones. From each of the bedroom spaces, corner window seats provide a place to inhabit the interior yet maintain full visual connections to the outside.



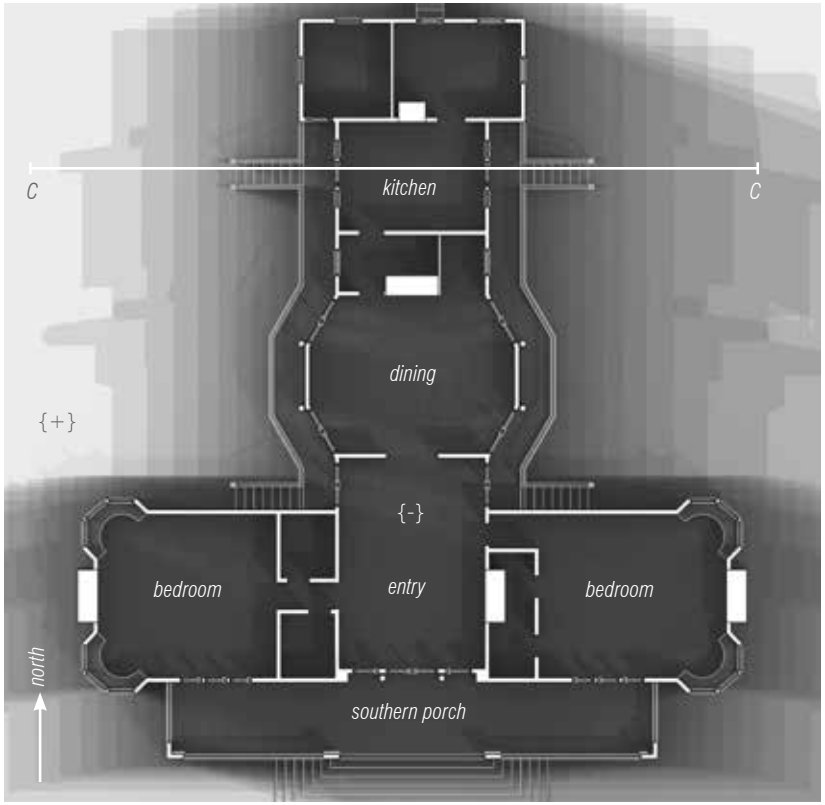
viewshed plan



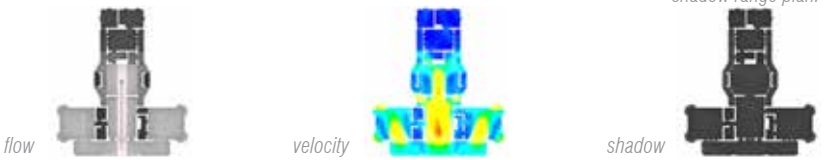
viewshed section A-A

CHARNLEY NORWOOD HOUSE

Cooling



shadow range plan:

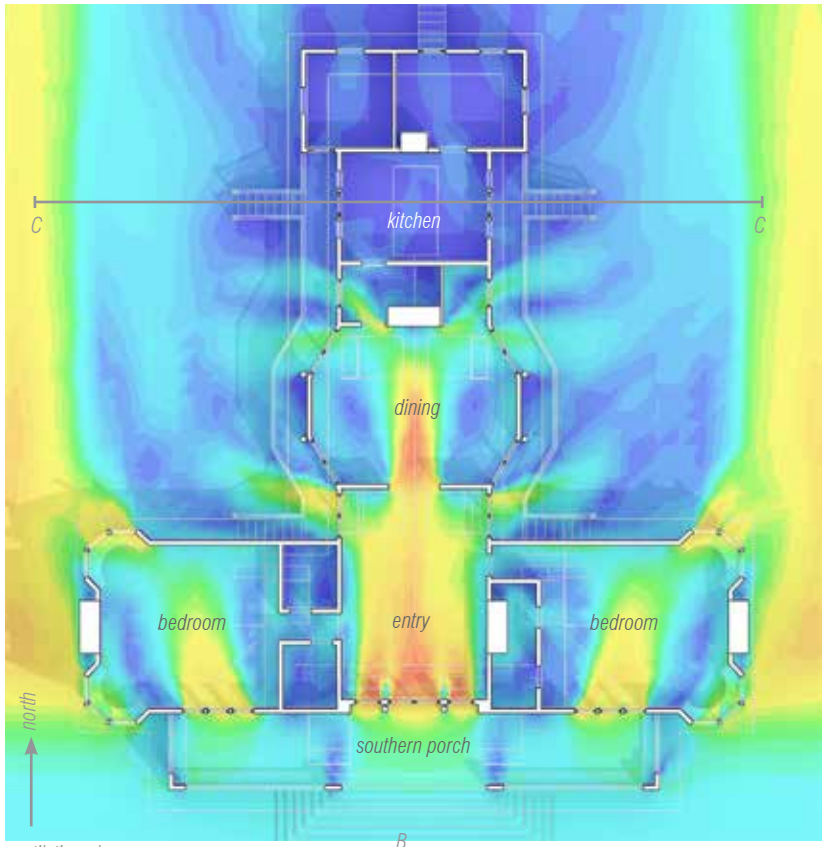


cooling diagrams

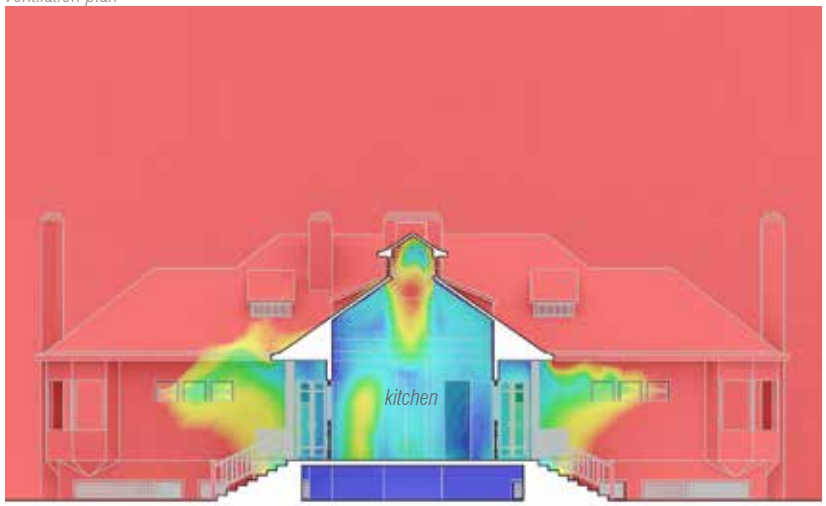
Shading and Ventilation Analysis

Intertwining attributes of the dogtrot and shotgun typologies, this bungalow uses an east-west linear bar oriented perpendicular to the southern prevailing wind direction to establish pressure differentials with high pressure building on the windward side and low pressure on the leeward side. Low pressure is created by the octagonal dining area with ample outlet area to draw air through the building. Furthermore, a continuous parasol roof that projects beyond the building footprint shades all inhabitable living areas during hot summer months.

ventilation legend (m/s)



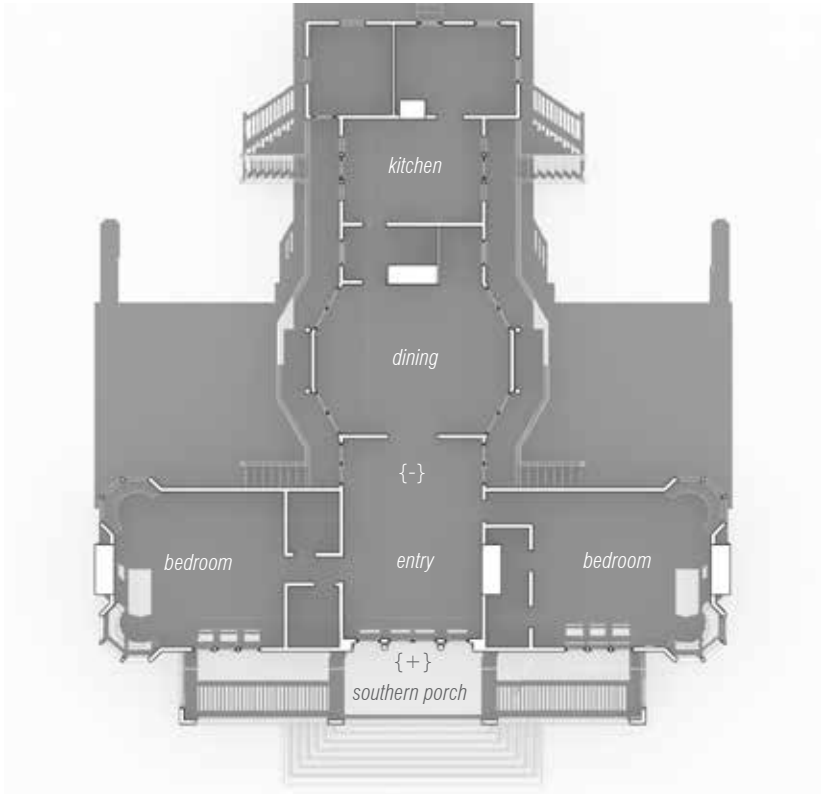
ventilation plan



ventilation section C-C

CHARNLEY NORWOOD HOUSE

Heating



solar incidence plan at noon

incidence *insulation* *rays*

heating diagrams

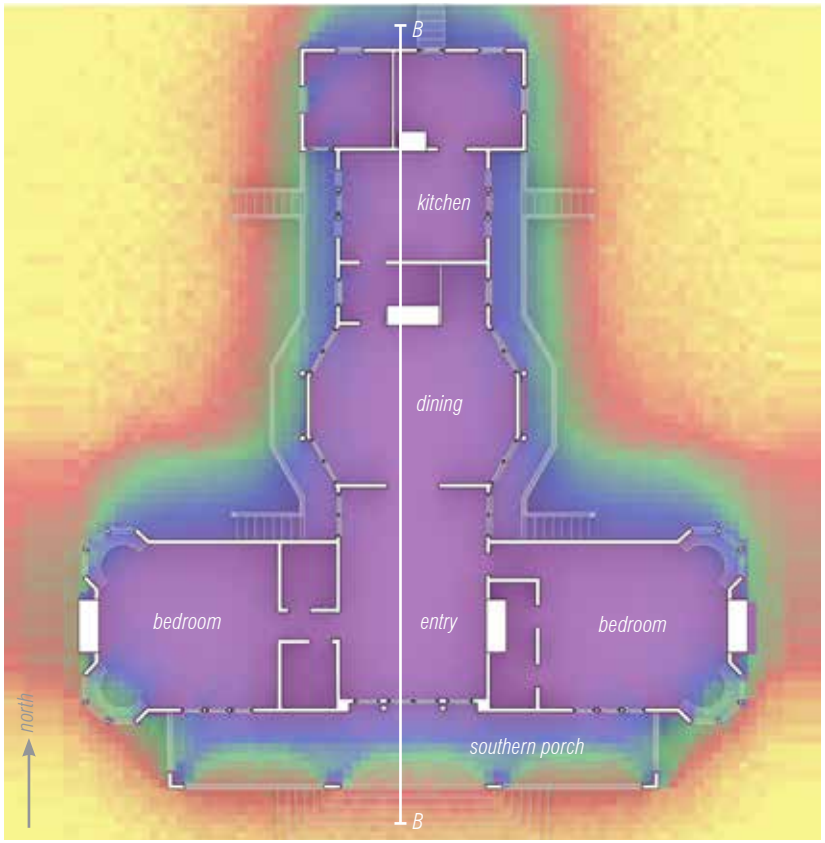
Solar Incidence and Insolation Analysis

Incident solar radiation is drawn largely from the porch that runs along the southern edge of the building composition. With prevailing winter winds emanating out of the north, the crossing east-west and north-south linear bars buffer and protect the southernmost spaces from the cold northerly winds. Spaces like the entry hall, which communicate directly with the southern porch are optimal for winter inhabitation by being both wind buffered and sun exposed, especially with its accompanying fireplace.

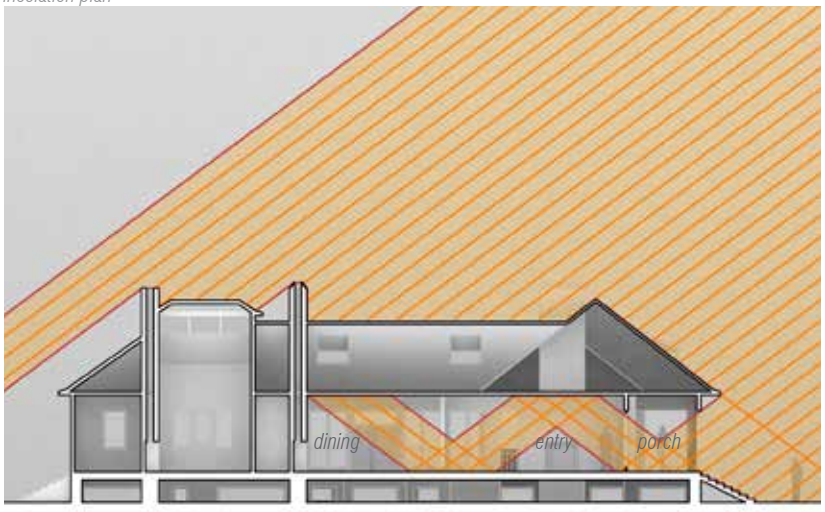
insolation legend (kWh/m2)

4

0

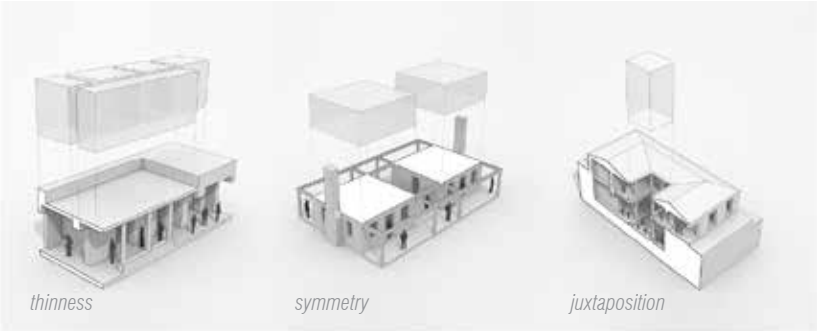


insolation plan



section B-B: solar rays - winter

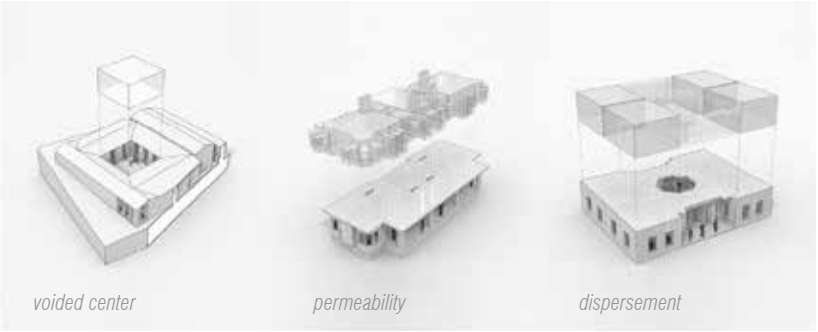
TAXONOMY OF CONSTRUCTION STRATEGIES



From the analysis of seven case studies in the former section of the report, a taxonomy of construction strategies is identified. Patterns in spatial disposition are noted across case studies of similar era and region in addition to those of both markedly different time period and location. The similarities across the series can be classified into distinct strategies which are conceived with particular performance characteristics in mind.

The syntactical strategies outlined in this section are considered hallmarks or signatures of construction utilized by pre-industrial societies shared across the case study series. These approaches shed light on how space was organized in concert with the dictates of the natural environment in order to provide suitable constructed environments for inhabitants. The shared characteristics across time and culture demonstrate the fundamentals of first principles approaches toward design and the importance of progressive development that adheres to factors both social and environmental.

Highlighted in this section are a series of construction strategies that connect ancient European and vernacular American architecture. Each strategy is briefly defined and unpacked using performance modeling and simulation platforms. While each strategy operates at multiple scales and in many environmental states, each strategy is demonstrated through a domain considered to be most indicative to the approach



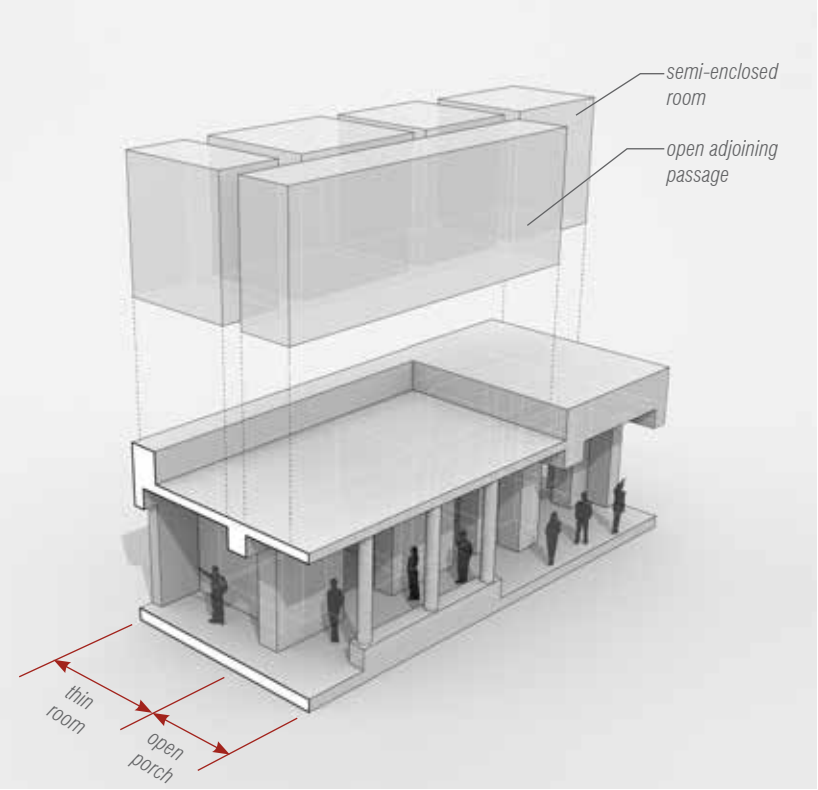
utilized. While this taxonomy is not complete, it does shed valuable light on how the American decedents of ancient European culture adapted valuable lessons of first principles design within their modest structures suited for distinctive populations, materials and sites.

The strategies highlighted in the following pages include:

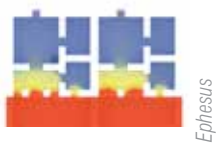
-Thinness
-Linearity
-Symmetry
-Voided Center
-Mass-Void Juxtaposition
-Permeability
-Intermediate Spaces
-Aligned Apertures
-Dispersed Volumes

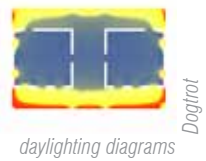
THINNESS

Daylighting



oblique: thin unit block

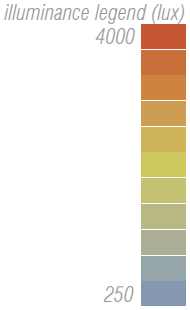


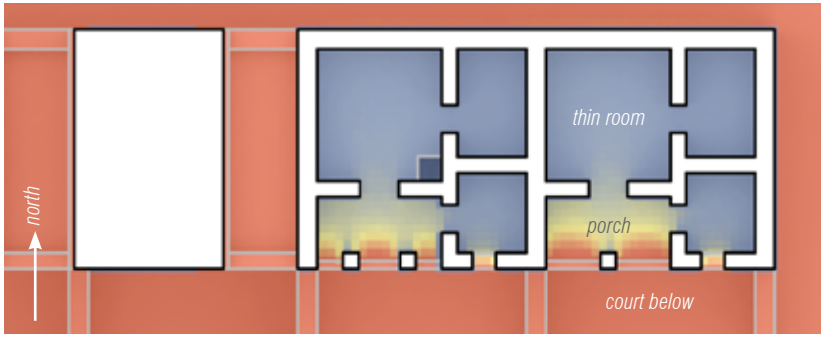


daylighting diagrams

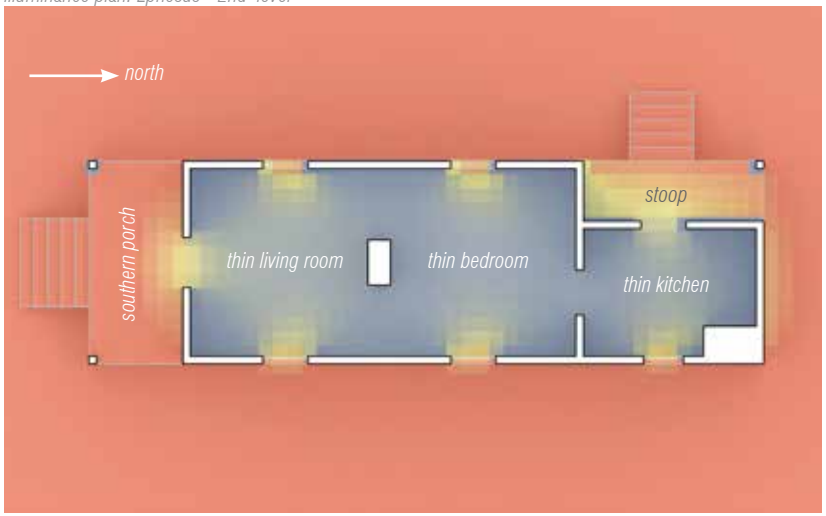
Thinness - Daylighting

Thin unit blocks are typically one to two rooms wide with direct connections to the natural environment. The thinness of the plan and the loose definition of the southern-most edge provide daylight uniformity and ample illuminance levels within interior rooms. The reduced dimension between the daylight sourcing apertures and the central areas of the room volume contribute to high levels of natural illuminance while adjacent intermediate volumes like porches provide surfaces to reflect light entering thin rooms.

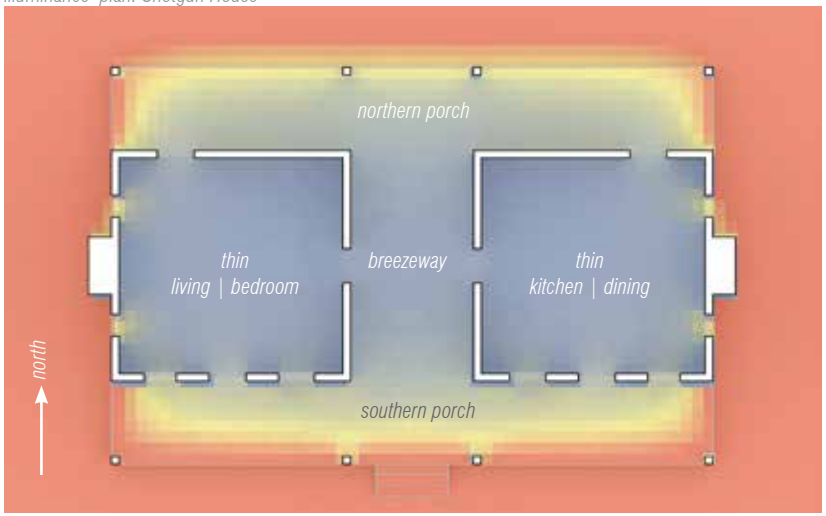




illuminance plan: Ephesus - 2nd level



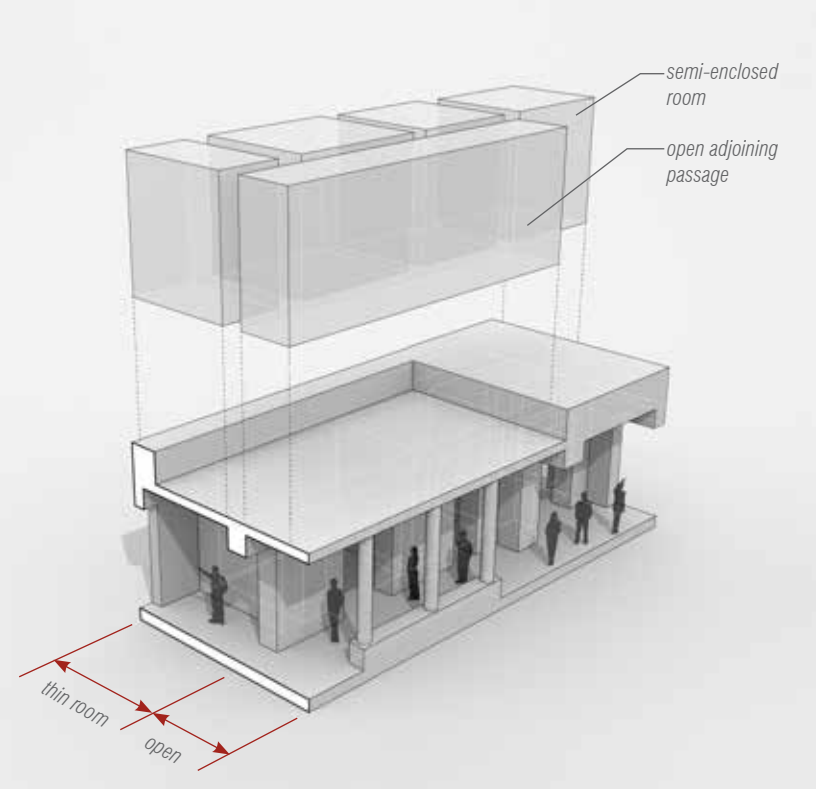
illuminance plan: Shotgun House



illuminance plan: Dogtrot House

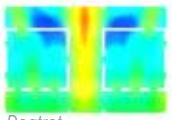
THINNESS

Ventilation



oblique: thin unit block

Ephesus



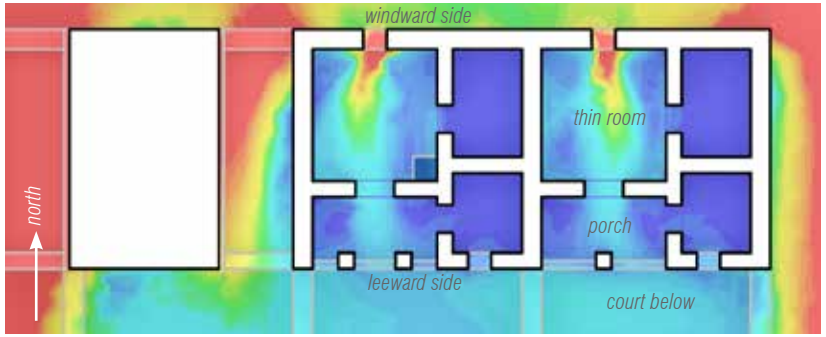
Dogtrot

Charnely Norwood

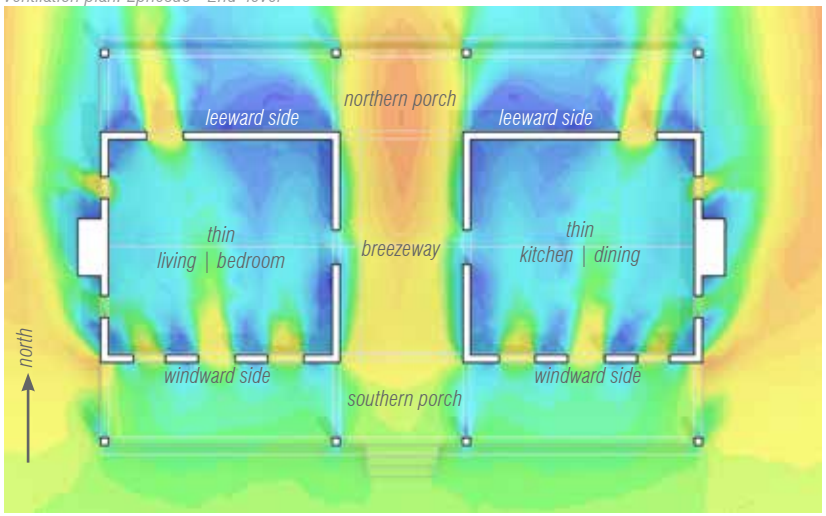
ventilation diagrams

Thinness - Ventilation

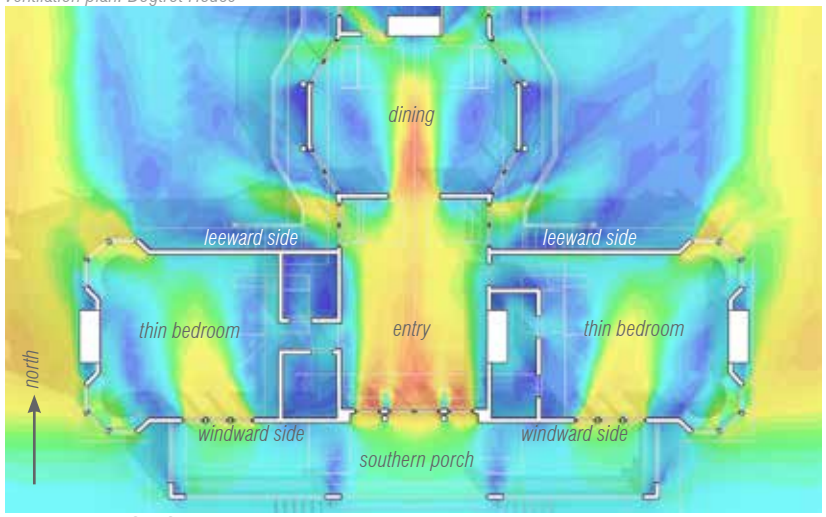
Thin unit blocks are typically one to two rooms wide with apertures on opposite sides to promote cross ventilation within the space. The long axis of these rooms is typically oriented perpendicular to the prevailing wind direction during hot seasons to generate pressure differentials between the windward and leeward faces. With the aim of achieving equilibrium, air increases velocity as it moves from high to low pressure zones. Thin, single room building widths assist this transition and provide rapid air change within these areas



ventilation plan: Ephesus - 2nd level



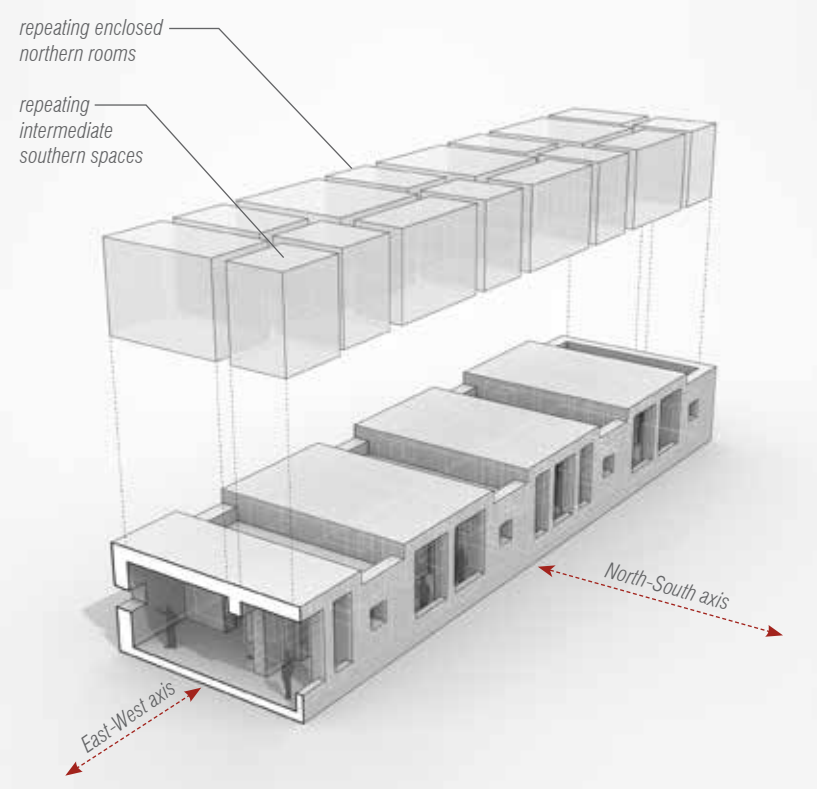
ventilation plan: Dogtrot House



ventilation plan: Gulf Coast Bungalow

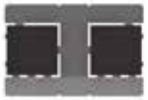
LINEARITY

Shadow Range



oblique: linear unit block

Ephesus



Dogtrot

Charnley Norwood

shadow diagrams

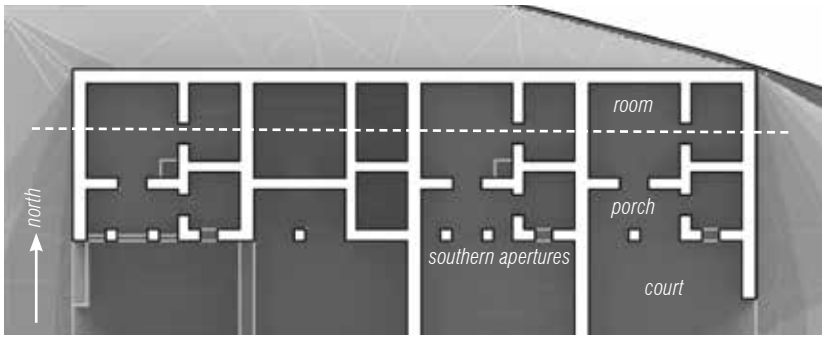
Linearity - Shadow Range

Linear organizations are comprised of repeating spaces along an elongated east-west axis to maximize exposure to solar and wind resources. Southern edges of these linear organizations open to harvest maximum sunlight and intermediate spatial zones along these same edges diffuse natural light to provide uniformity in daylighting. Eastern ends are stimulated by solar gains in the morning while western ends are stimulated in the evening. Apertures along the northern edges complement those along the south and offer cross ventilation.

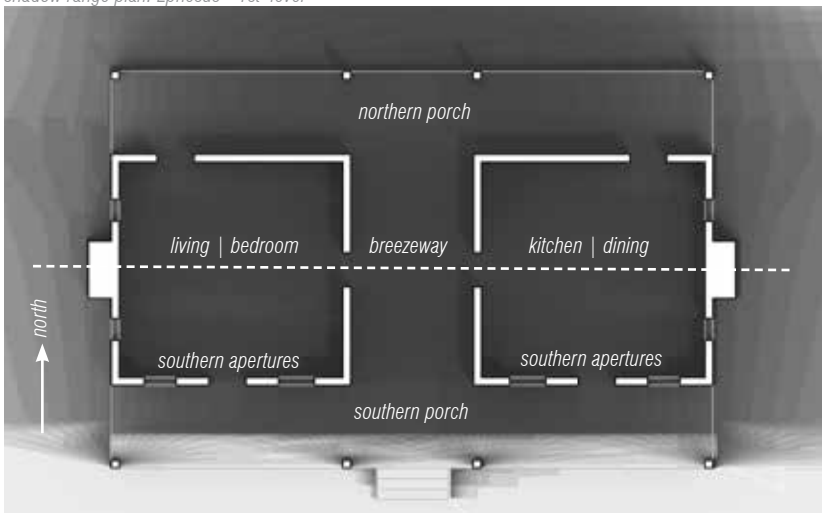
shadow legend (value)

(-)

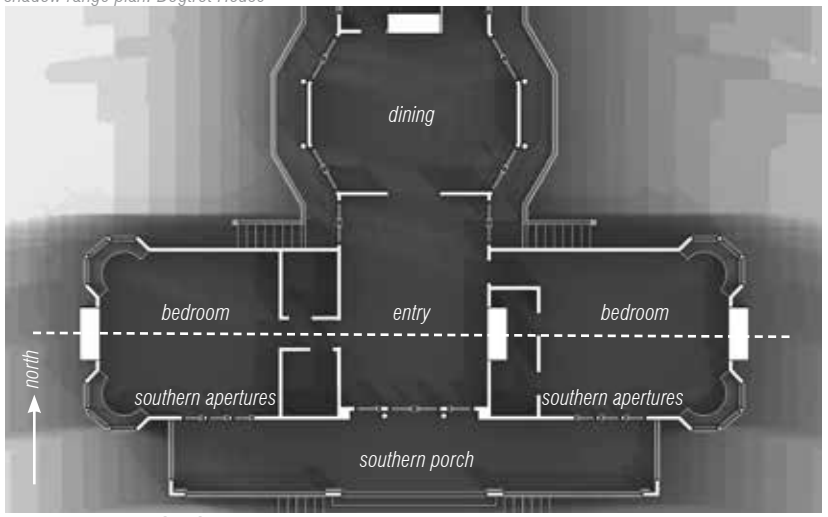
(+)



shadow range plan: Ephesus - 1st level



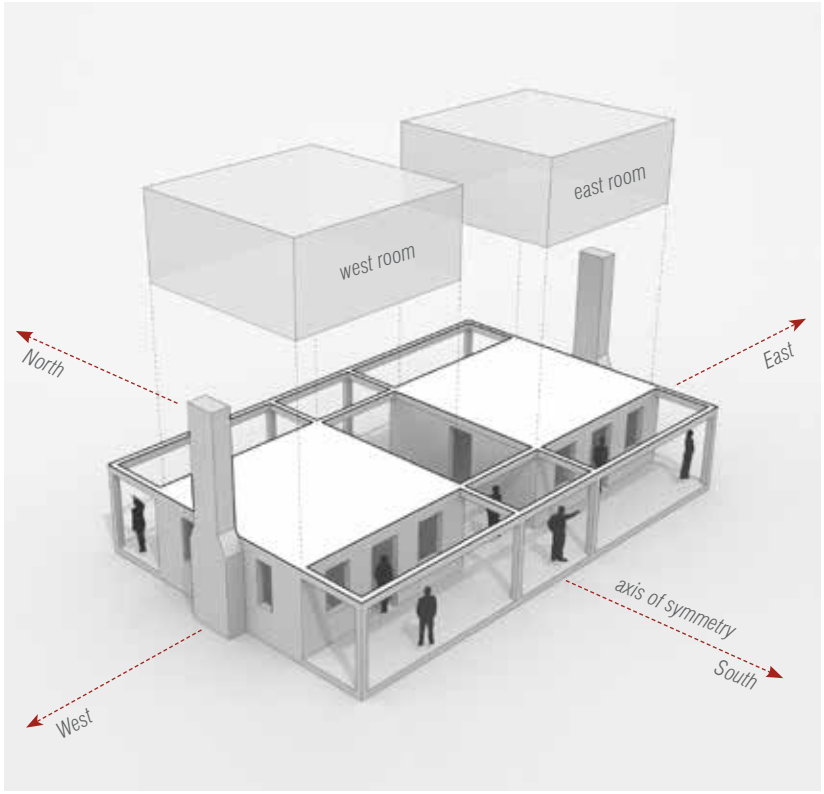
shadow range plan: Dogtrot House



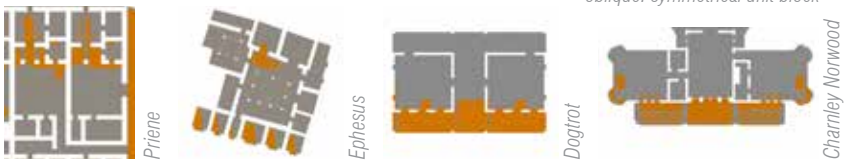
shadow range plan: Gulf Coast Bungalow

SYMMETRY

Shading



oblique: symmetrical unit block

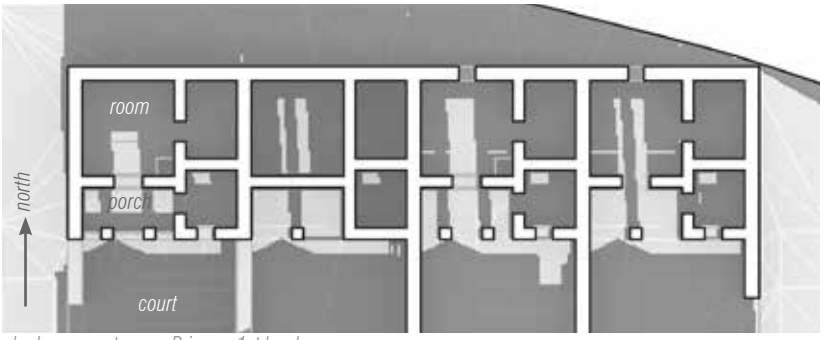


incidence diagrams

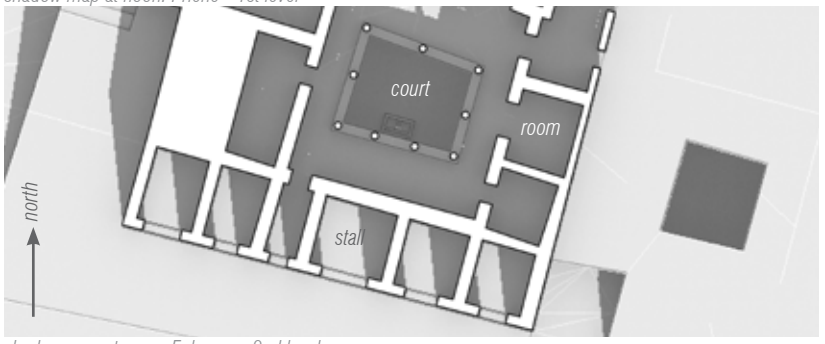
Symmetry & Orientation - Shading

Symmetry is a type of spatial organization whereby similar spatial zones are equally distributed about strong regulating axes. In these examples, symmetry happens about axes that run along cardinal directions whereby spaces can be classified as north-south-east-west. This neutrality in spatial disposition takes advantage of the eccentricity of environmental factors and offers a wide variety of thermal zones. These variations allow users to migrate activities based upon the desired activity set in concert with prevailing climate characteristics.

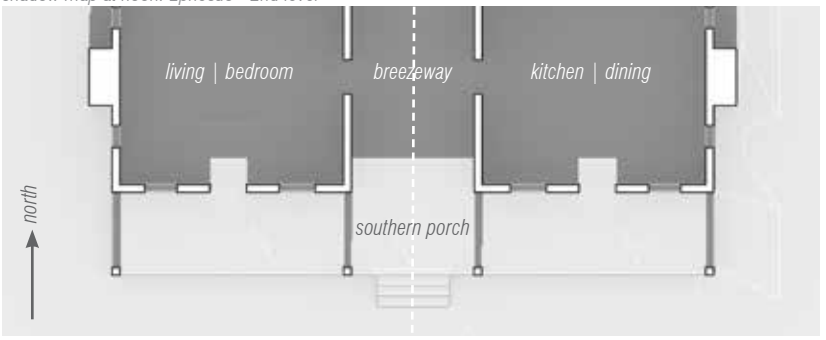
shadow legend (value)



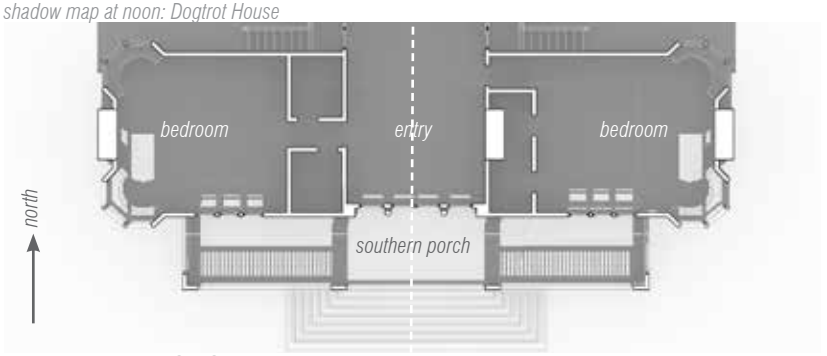
shadow map at noon: Priene - 1st level



shadow map at noon: Ephesus - 2nd level



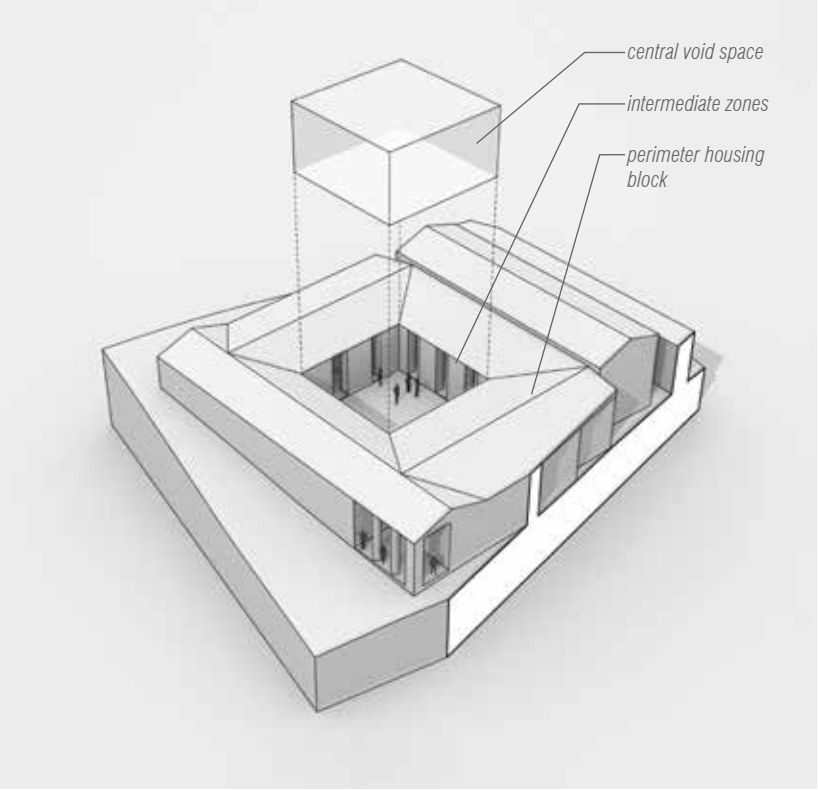
shadow map at noon: Dogtrot House



shadow map at noon: Gulf Coast Bungalow

VOIDED CENTER

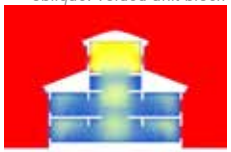
Daylighting



oblique: voided unit block

Pergamon

Ephesus

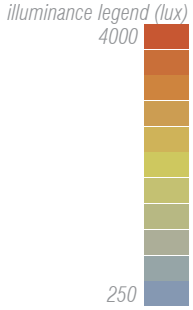


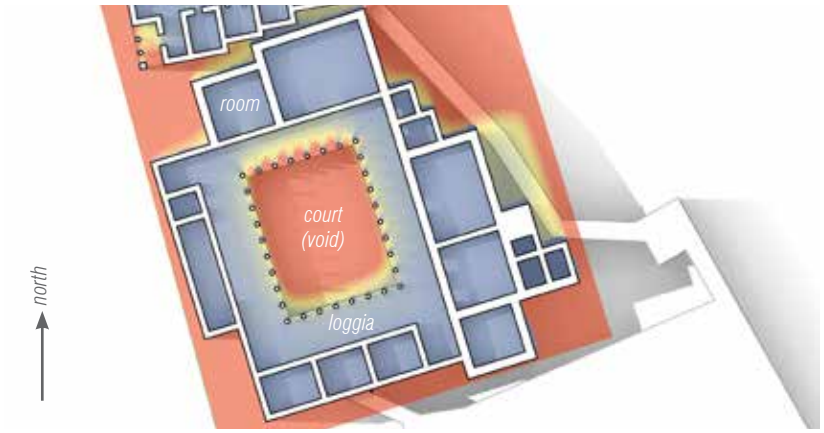
Waverly

daylighting diagrams

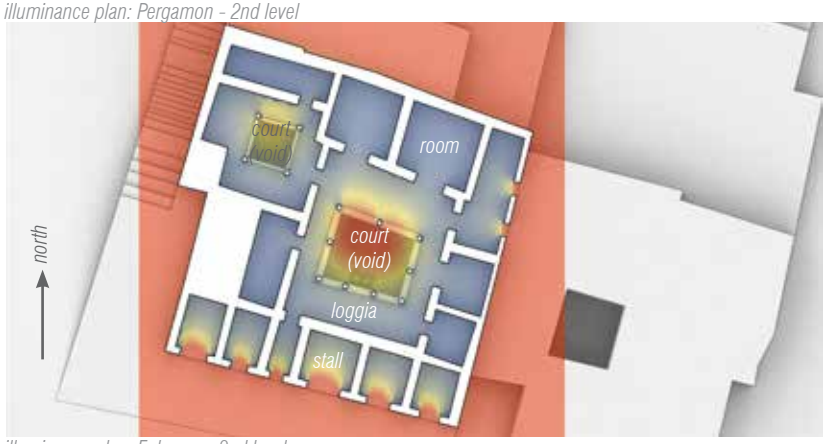
Voided Center - Daylighting

Building masses with large scale void spaces central to their composition result in a series of linear perimeter room blocks that have access to natural resources from at least two sides. This access is provided either directly in the form of apertures within enclosing planes or indirectly in the form of semi-open intermediate spaces like loggias. Open at the apex, these void spaces serve as a significant source of daylight for perimeter blocks, diffused by intermediate zones. These voids also allow buoyant hot air to exhaust upon stratification.

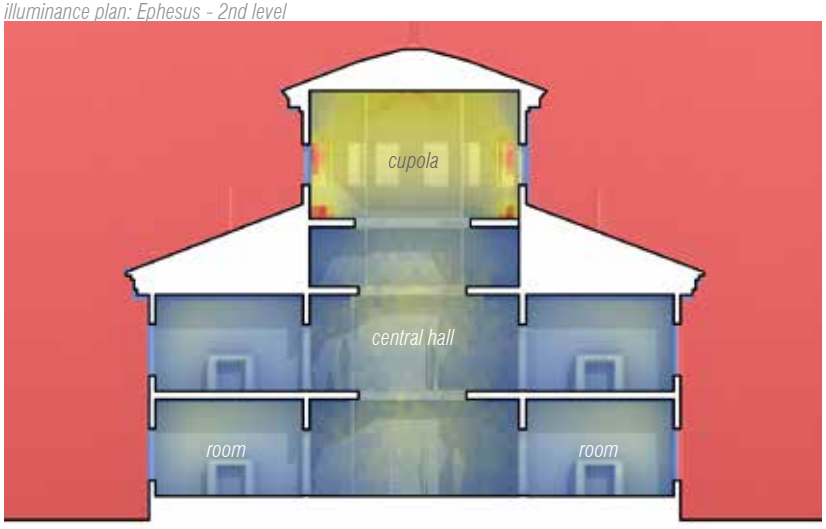




illuminance plan: Pergamon - 2nd level



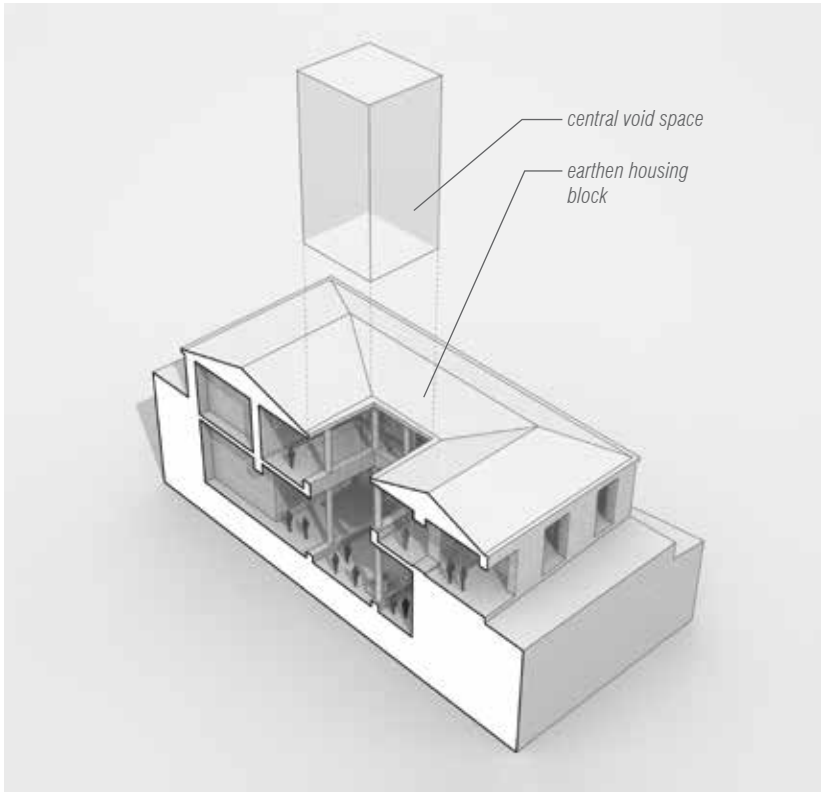
illuminance plan: Ephesus - 2nd level



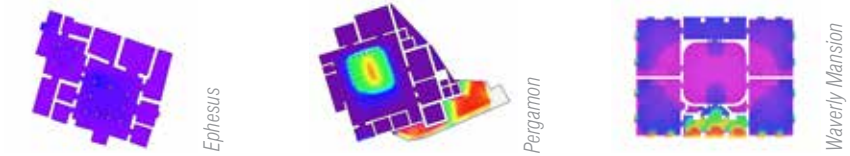
illuminance section: Antebellum Mansion

MASS-VOID JUXTAPOSITION

Thermal Control



oblique: juxtaposed unit block

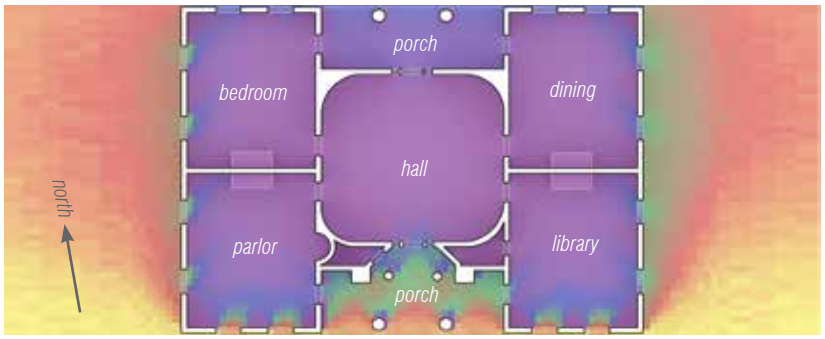


thermal diagrams

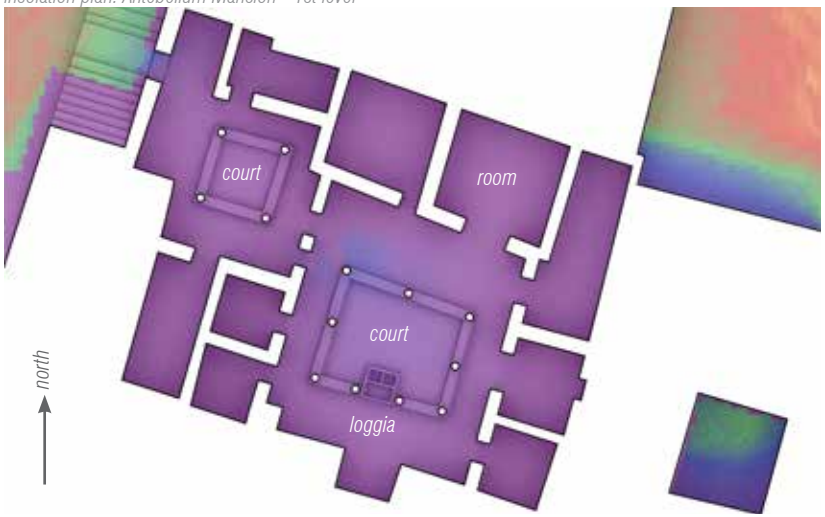
Mass-Void Juxtaposition - Thermal Control

Mass-void juxtaposition is a type of spatial organization that places open space central to well enclosed volumes and sets loosely enclosed spaces above. These mass-void juxtapositions happen through deep central voids that provide light and air access to enclosed spaces while allowing air and heat to stratify from lower to upper levels of a complex. This approach creates two distinct zones within a composition, an upper zone where light and air velocity levels are more variable and a lower zone where there is a much tighter light and velocity range.

insolation legend (kWh/m2)



insolation plan: Antebellum Mansion - 1st level

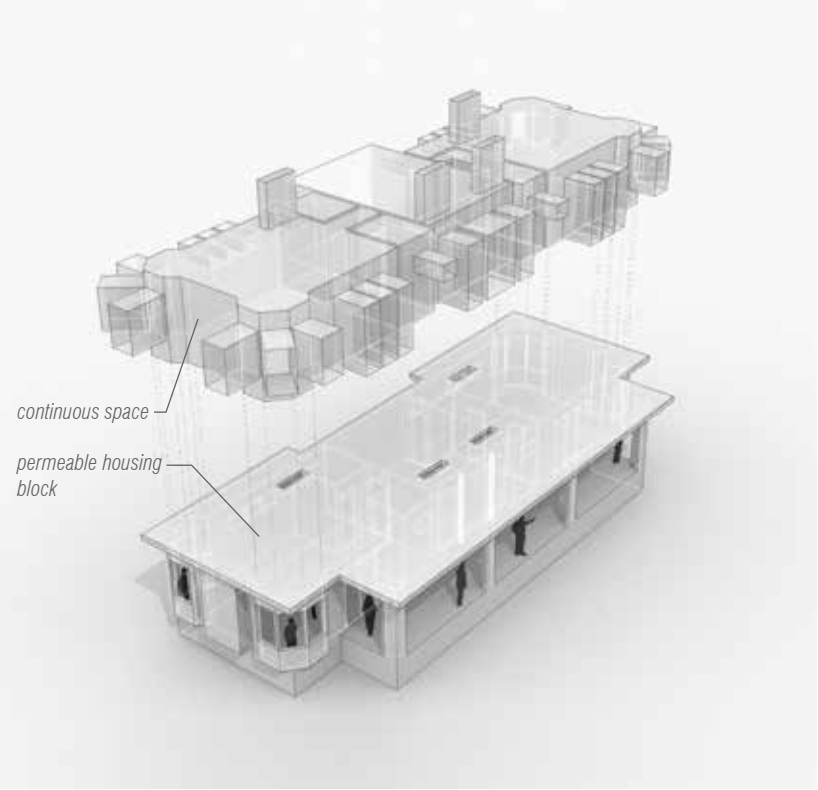


insolation plan: Ephesus - 1st level

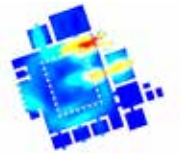
insolation plan: Pergamon - 1st level

PERMEABILITY

Ventilation



oblique: permeable unit block



Pergamon

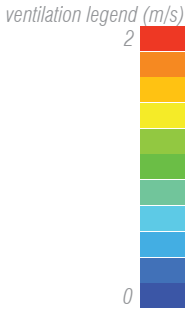
Ephesus

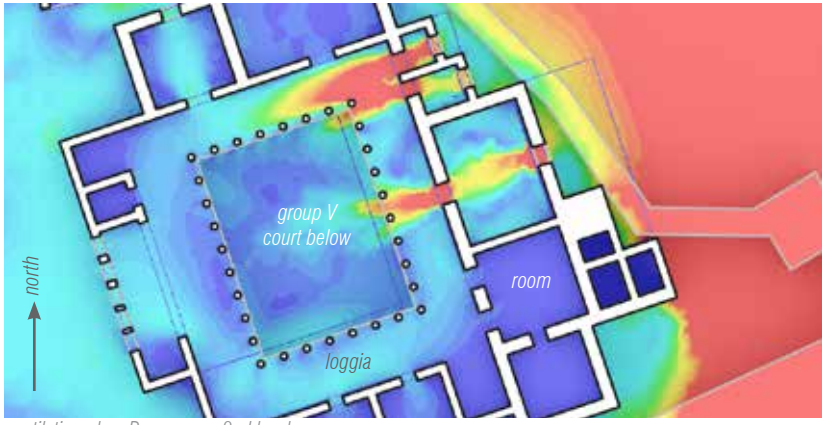
Charnley Norwood

cooling diagrams

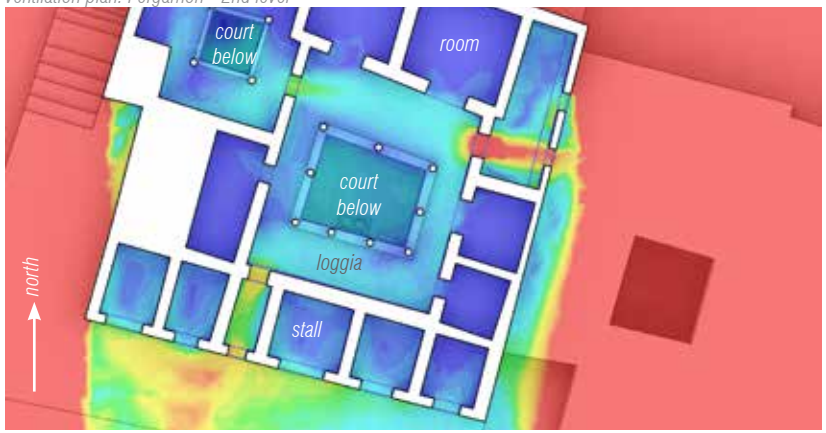
Permeability - Ventilation

Permeability includes the design of apertures and open spaces within a defined building block which harvest natural resources like wind and daylight while also framing views out to the immediate context. Permeability is achieved through construction strategies including perimeter porches, open intermediate spaces and aligned apertures within housing blocks. These strategies produce moderate ventilation rates on the interior; create daylight levels situated within today's comfort range; and offer framed visual connections out to the surrounding landscape.

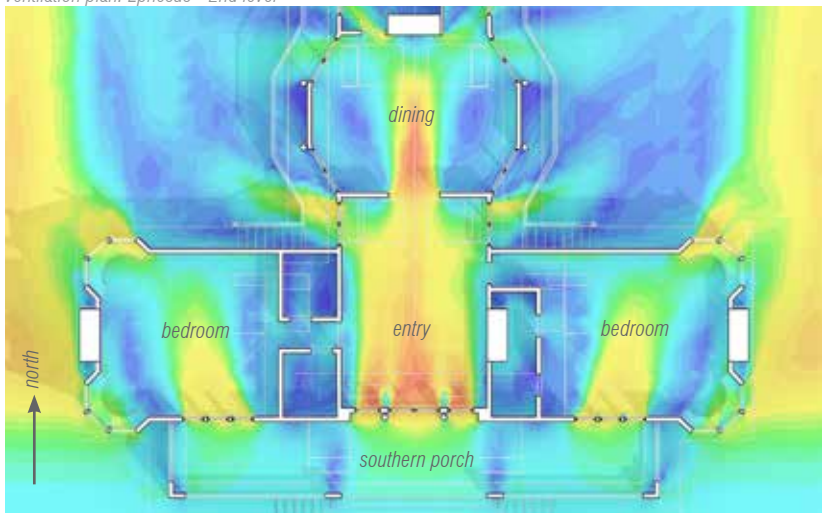




ventilation plan: Pergamon - 2nd level



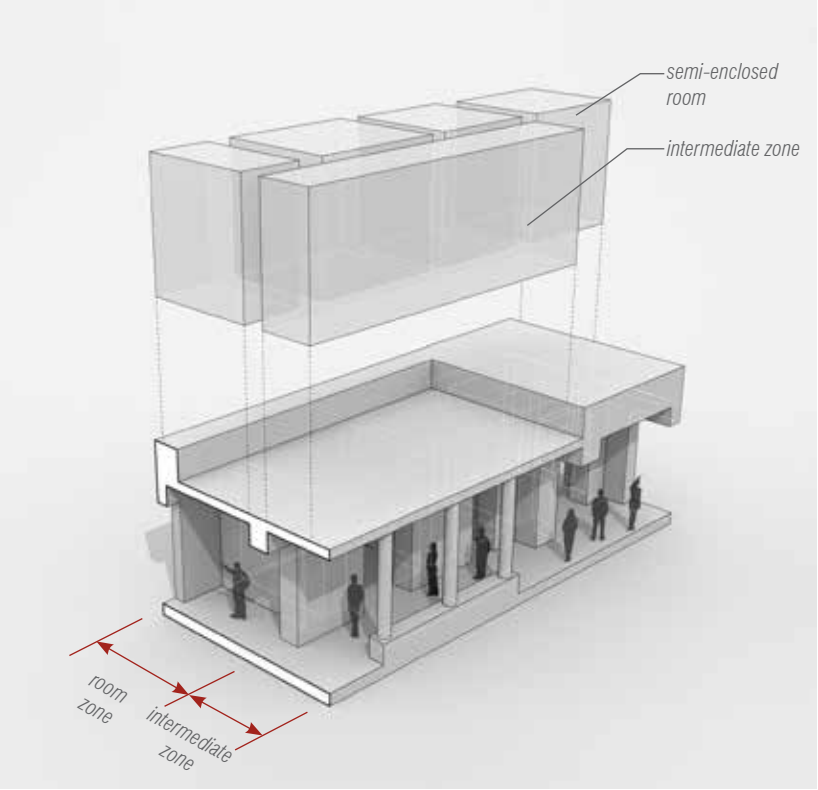
ventilation plan: Ephesus - 2nd level



ventilation plan: Gulf Coast Bungalow

INTERMEDIATE ZONES

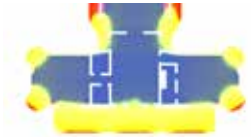
Daylighting



oblique: intermediate zones

Priene

Ephesus



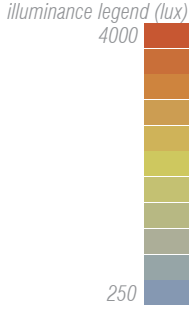
Charnley Norwood

daylighting diagrams

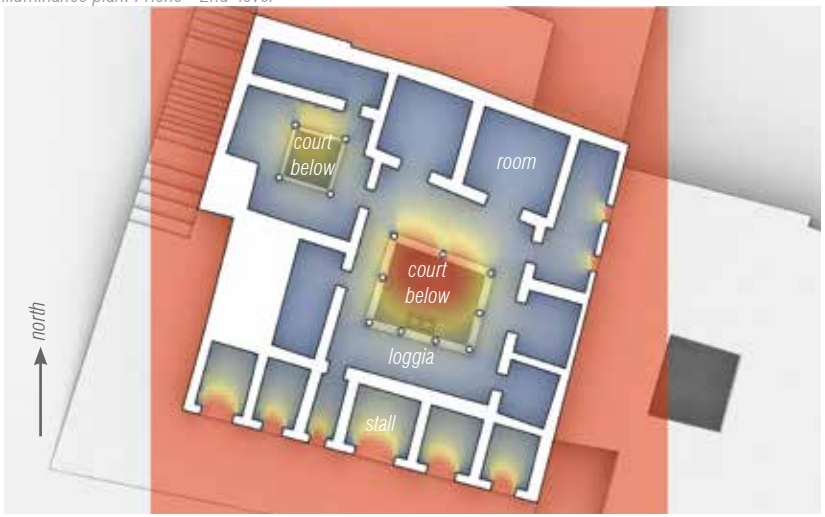
Intermediate Zones - Daylighting

These intermediate space types typically lie adjacent to both fully and semi-enclosed rooms in addition to areas fully exposed to natural resources. In the case of daylighting, these spaces offer varying degrees of light penetration into enclosed room volumes through reflective surfaces that redirect ample daylight into all areas of the plan and provide daylight uniformity to semi-enclosed rooms. Due to the added exposure of these space types, they serve as optimal thermal zones when additional access to natural air, light and heat is desired.

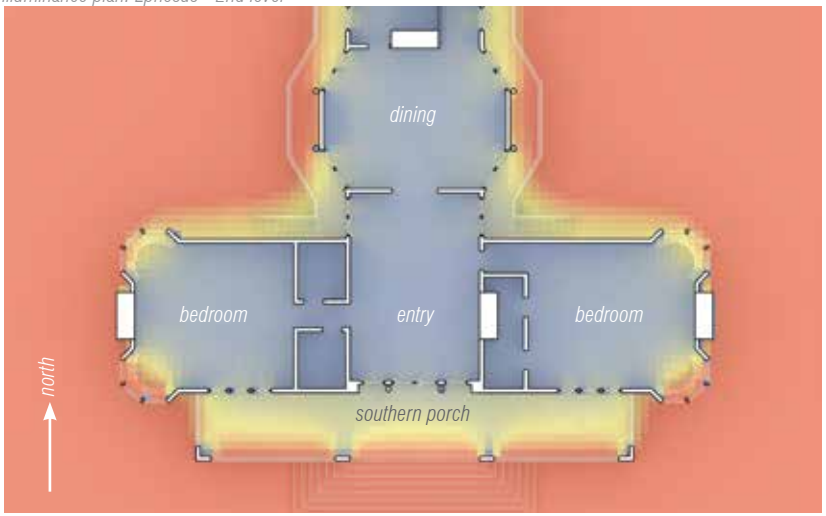
illuminance legend (lux)



illuminance plan: Priene - 2nd level



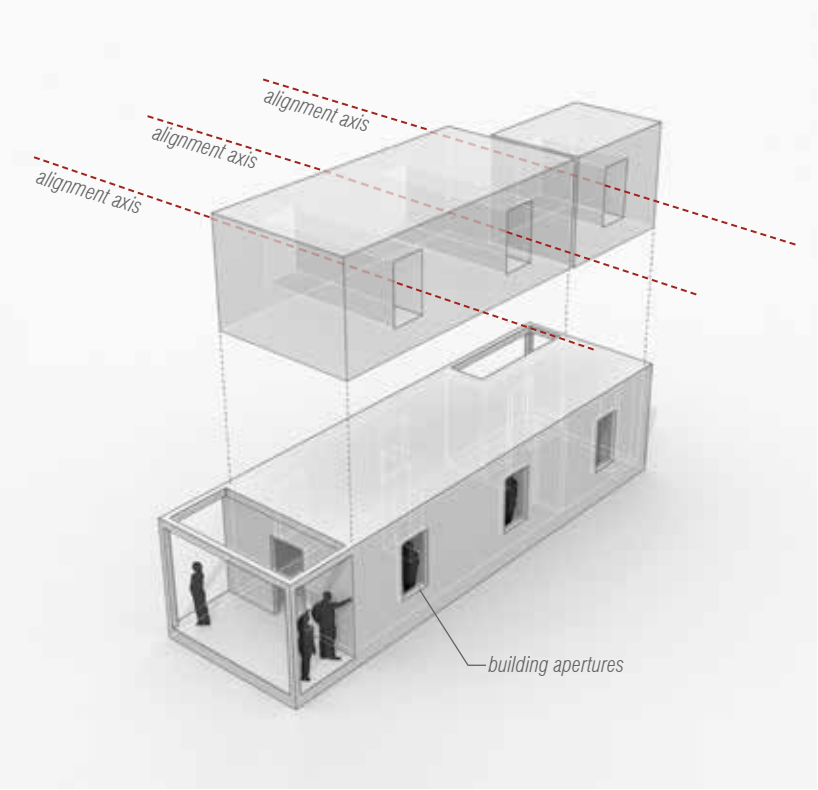
illuminance plan: Ephesus - 2nd level



illuminance plan: Gulf Coast Bungalow

ALIGNED APERTURES

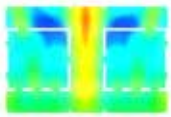
Ventilation



oblique: aligned apertures

Priene

Shotgun



Dogtrot

cooling diagrams

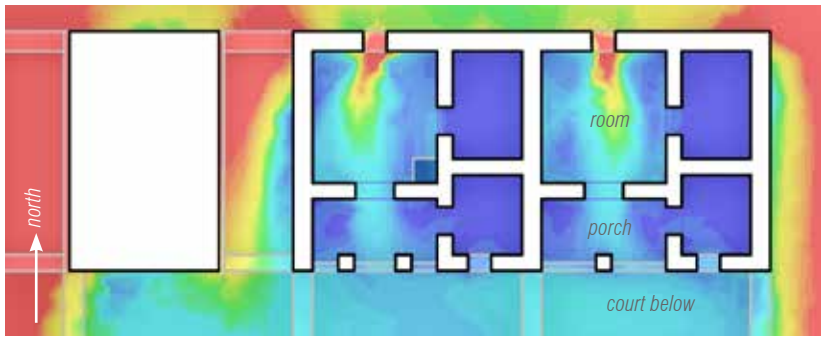
ventilation legend (m/s)

2

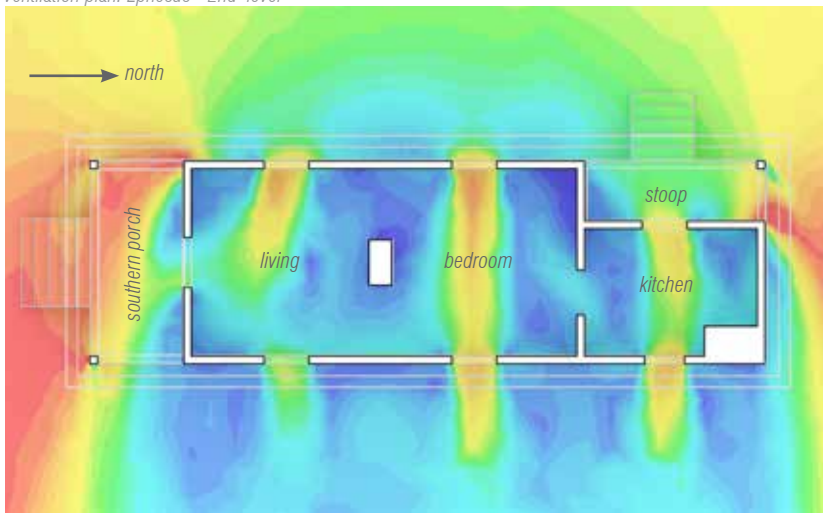
0

Aligned Apertures - Ventilation

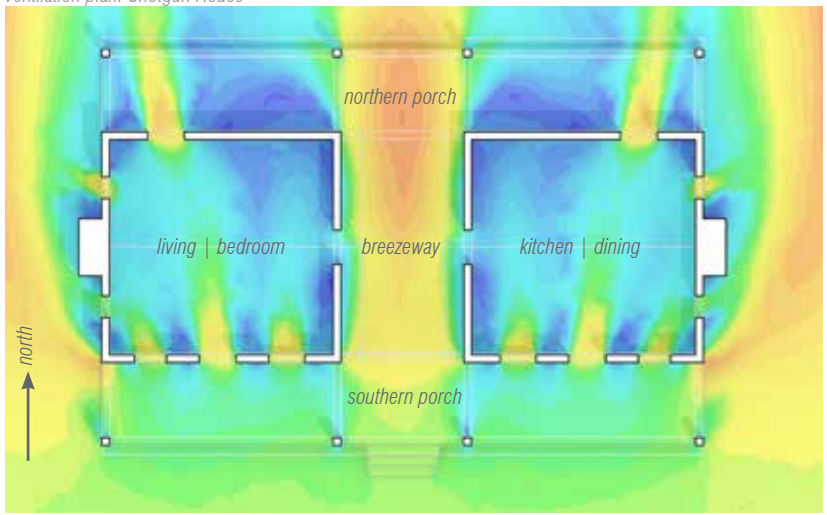
Aligned openings on opposing ends of a space or through of series of spaces offer unobstructed paths for light, air and view. When opposing ends of a chain of aligned apertures contain an air inlet and an air outlet, cross ventilation presents itself within the sequence of spaces connected. Therefore, alignment enables spatial layering, lending equable access of natural resources to each layer within a composition. When aligned apertures are present within a narrow space, environmental intensities are present at intervals consistent with aperture



ventilation plan: Ephesus - 2nd level



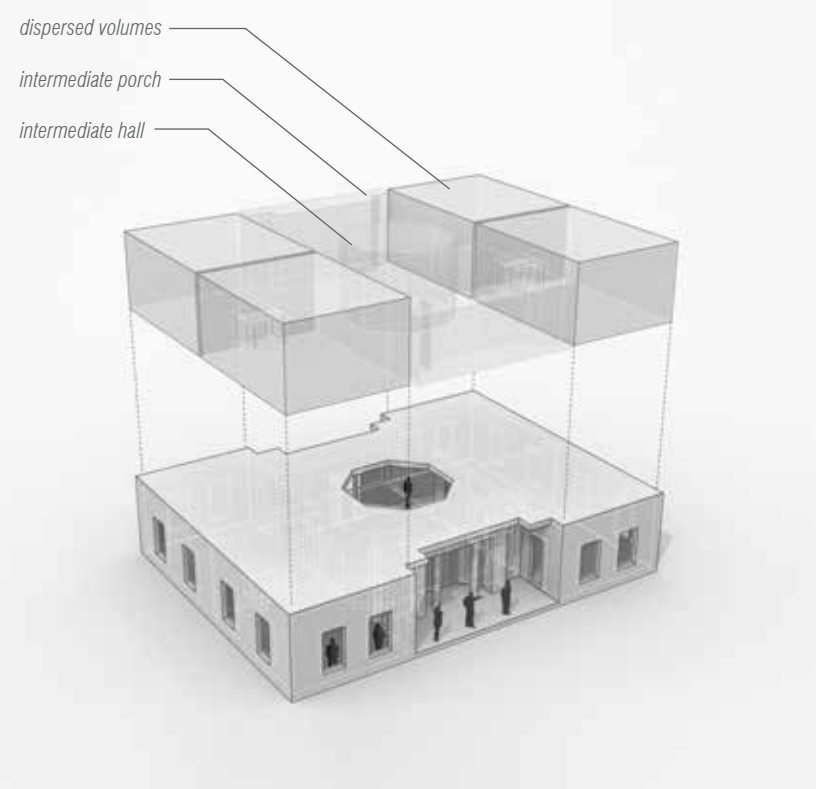
ventilation plan: Shotgun House



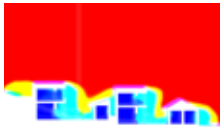
ventilation plan: Dogtrot House

DISPERSED VOLUMES

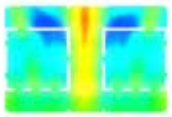
Ventilation



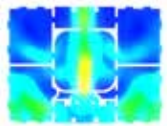
oblique: dispersed volumes



Priene



Dogtrot



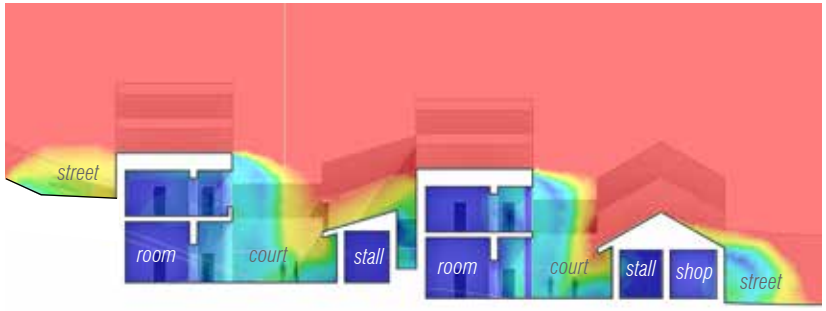
Waverly

cooling diagrams

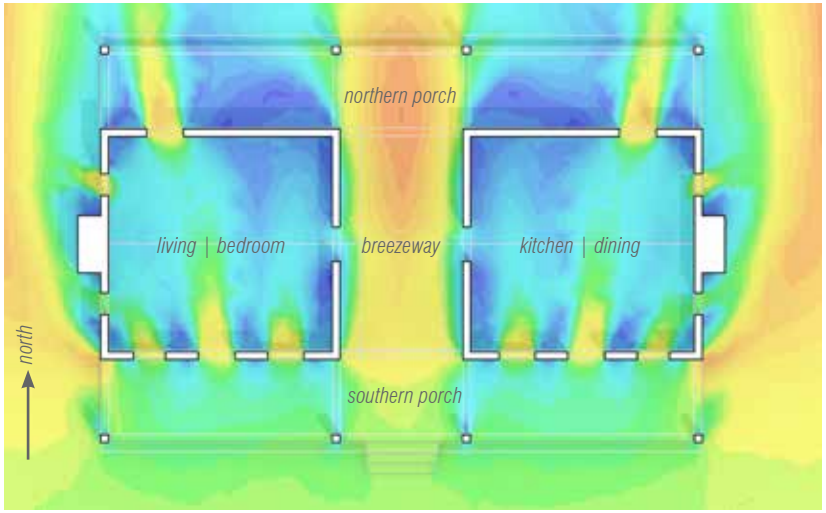
Dispersed Volumes - Ventilation

Dispersed volumes are spaced at intervals from one another to allow the continuous flow of intermediate space between. Because of the open nature of intermediate space types, they source natural resources including light and air to more enclosed dispersed room volumes through functions of distance and openness. Due to the exposure of these intermediate spaces, they offer intensified access to natural conditions for users to migrate their activities toward should the conditions of climate permit.

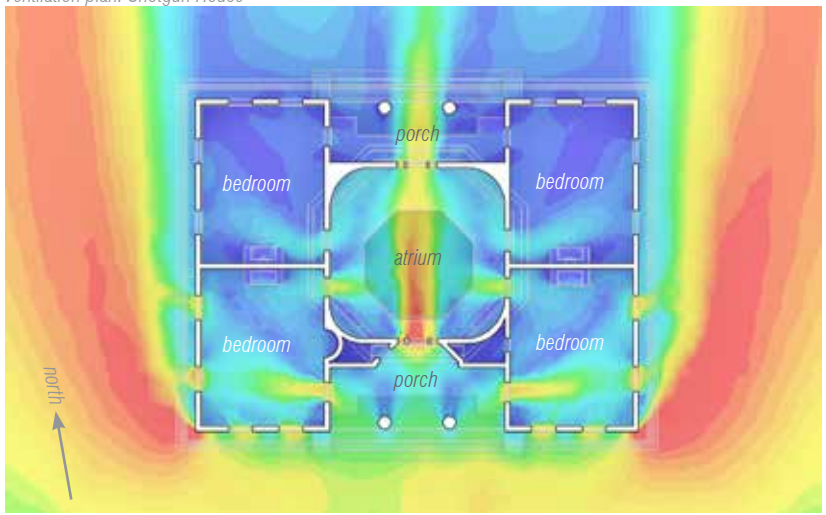
ventilation legend (m/s)



ventilation section: Priene



ventilation plan: Shotgun House



ventilation plan: Antebellum Mansion

CONCLUSION

Throughout the series of case studies presented in this report, three dominant characteristics develop that inform the spatial composition of the built environment from classical European collective housing groups to detached American vernacular structures – the *integrated*, the *principled*, and the *multifarious*. The first of these characteristics, the *integrated*, can be best understood as the propensity to intertwine the natural and built environments instead of deploying defensive strategies where the building isolates itself from its surrounding milieu through sealed boundaries used to maintain steady state conditions regardless of an ever-changing climate. The second characteristic, the *principled*, builds from the integrated approach as it develops space from a network of fundamental relationships that exist between the material enclosure and the climate profile, offering comfort for inhabitants in full accordance with the dictates of environment. This relationship-based approach toward spatial organization extends to the third characteristic, the *multifarious*, in which the delicate assessment between constituents conjoin building and ecological systems to create a wide range of intermediary spaces types, offsetting the homogeneous approach to space making which is reduced to internationally presumed absolutes.

In *Vernacular Paradigms for Post-Industrial Architecture* of 1982, James Marston Fitch advocates for *integrated* spatial dispositions, warning that with the rapid industrialization of the Western world, the propensity to ignore the significance of the natural environment when developing inhabitable space has increased to the point where climatic factors seem inconsequential. The result is the adoption of defensive design strategies anchored by hermitically sealed building envelopes and steady-state conditioned interiors. One of the impacts of this approach, as articulated by Dr. Fitch, is the unprecedented abuse of high-grade energy sources to supply interior conditioning systems which continues to plague designed environments today. The alternative approach is one that integrates natural forces within the spatial composition of the built environment, leading to various degrees of spatial enclosure resulting in an array of thermal zones. The research findings elaborate upon this integrated condition through gradual transitions of environment from exterior to interior. These transitions are mediated by elements such as overhanging, recessed, layered and operable boundary conditions with resulting intermediary space types such as loggias, balconies, terraces and courts. Taken together, these strategies as employed by pre-industrial populations softly modulate extremes of climate to create comfortable zones of inhabitation, leveraging rapidly renewable resources instead of defending against them as diametrically opposed nuisances. The strategies embedded within the case study series, as evoked by the research, offer valuable lessons to the contemporary developers in offsetting high grade energy sources when acclimatizing space for human inhabitation.

In *Architecture and the Esthetics of Plenty* from 1961, James Marston Fitch elaborates upon the uses of history, arguing for a *principled* approach to spatial organization

distilled from centuries of indigenous experience about how to configure material enclosures in response to prevailing climate regimes. This approach distinguishes itself from purely visual replications of historical motifs in which building elements are detached from their native domains and merely copied without regard for how they are in-formed by patterned cultural and environmental contexts. The effect of interpreting architectural history as an esthetic concern alone is the general lack of understanding about how spaces are organized around the principled operation of place within which it is situated. In order to perpetuate a principled understanding of building heritage, we must acknowledge that historical building artifacts are fundamentally comprised of factors that modulate human action and a changing climate using readily available local building materials. Traditions of craft in this sense largely pertain to how material assemblages are shaped to reflect, redirect, filter, absorb and buffer the most basic factors that constitute our atmosphere. The research findings in this report clearly indicate patterns of building configuration and resulting performance characteristics that span both time and place. While most of these patterns are outlined in the Taxonomy of Construction Strategies, one reoccurring motif that is highly influential across the series is the voided center. One of the most significant findings from the research indicates that the formal composition of the voided center does not parallel its ambient disposition. While the voided center is typically organized using compositional devices such as biaxial symmetry, geometric equilibrium and centrality; the ambient disposition of this space is distinctly eccentric. The analysis reveals at least three different thermal zones present within the voided center migrated through by inhabitants year-round; all of which is made possible by the characteristics of a temperate climate located in the northern hemisphere. With the use of simulation tools and corresponding analysis routines, we can elicit crucial knowledge from vernacular structures, using historical artifacts more effectively as lessons for contemporary development.

In his updated 1966 text, *American Building: The Environmental Forces That Shape It*, James Marston Fitch argues that a new type of environmental zoning is urgently needed in the built environment, one that denies the standardization and homogenization of space found in industrialized cultures, favoring instead a *multifarious* assortment of space types. According to Fitch, the conformance of spatial dispositions to a handful of standardized international stereotypes fails to represent truly scientific methods whereby organizational alternatives are measured within a domain shared by prevailing environmental factors. On the other hand, an architecture comprised of a wide range of responsive space types is considered satisfying as it stems directly from the dynamic terrestrial environment. Such a rich inventory of spatial strategies derived to mediate the behavior of local climatic conditions offers economies in both capital and operational costs as material enclosures are tasked to supply comfort from rapidly renewable local resources. While the research offers numerous examples of multifarious spatial zoning; the

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Shotgun House supplies the widest array to space types with the most modest material palette. The building's orientation partnered with the symmetry about the north-south axis creates five distinct spatial zones from only two enclosed rooms. Each zone acquires a distinctive character from a unique collection of exposures to solar and wind resources across various time frames. With winds prevailing from the north, the sun located in the southern sky, eastern light in the cool mornings and western light in the warm evenings each zone harvests this array of environmental resources offer differentiated thermal zones for inhabitation. The development of mixed microclimates from site to building scales highlight the potential influences that historical structures can have on contemporary development strategies, improving their capacity to integrate natural and constructed environments through a multitude of space types, maximizing eco-social synergies and shared economies.

The dominant characteristics evident across the case study series share the propensity to dissolve the built environment into the complex entanglement of its locale. As the research in this report demonstrates, when taken together, these characteristics offer the potential to radically redefine established paradigms for building climatization. The intertwining of these design characteristics, namely the *integrated*, the *principled*, and the *multifarious*, are operational from classical to pre-industrial periods of development through intermediary space types and techniques of building enclosure that seek to maximize natural resources central to our existence. While the interaction of these principles is provoked in the case study findings through organizational strategies such as the central court, their ramifications in contemporary practice is acknowledged through evidence of acceptable interior comfort ranges suitable in light of today's standards. This account of building culture where differentiated spatial dispositions imply shifts toward heterogeneous thermal zoning due to their proven instrumentality serve as strong reminders that new paradigms are needed to curtail excess high-grade energy use. This account also provides ample evidence of the potential of state-of-the-art simulation tools as they bridge the gap between traditional knowledge and our on-going struggle to shape our built environment in the most responsive and efficacious ways possible.

CONCLUSION

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