Shading and Passive Cooling

Portico, Colonnade, Loggia \(\Rightarrow\) Porch \(\Rightarrow\) Overhang

→ Shade building + outdoor living space etc.

→ Greek + Roman Porticoes + Colonnades + Loggia

→ Greek Revival

→ Ex U.S. South (Hot + Humid)

→ Plantation Porches

→ Allowed large windows; for evaporative cooling

→ Without overheating, house with too much sun

→ Outdoor living + blocked rain

Engawa (Japanese Porch)

→ Sliding wall panels to optimize
  1. Light
  2. Ventilation
  3. View
→ Continuous translucent strip window above

→ Hanging chain for rainwater from gutters

Similar designs in most of Southeast Asia (and tropics)

JT Wunderlich PhD
GREAT AMERICAN ARCHITECTS INFLUENCED BY JAPANESE

1. GREEN + GREEN (CALIFORNIA) [Google Image]
   "GREEN BROTHERS ARCHITECTURE"

2. "FRANK LLOYD WRIGHT OVERHANGS" [Google Image]
   "ALSO, HIS"

   B. USE OF LARGE AREAS OF OPERABLE WINDOWS FOR VENTILATION (EVAPORATIVE COOLING) FOR HOT, HUMID MIDWEST SUMMERS

   C. INSPIRED BY NATURE, CONFORM TO NATURE

   D. LOW-PITCHED ROOFS

   E. CASCADING SMALL WINDOWS

   F. THICK STRUCTURAL MEMBERS

   G. POST & BEAM

   H. VARIOUS WOOD DETAILS

   I. PLANTERS

   J. LARGE & SMALL

   K. FINE ARTICULATION OF DETAILS

   L. SMALL THIN BRICKS

   M. JAPANESE PRINTS ARTWORK

   N. JAPANESE STRAW MATS (TATAMI) INFLUENCE ON ROOM FLOOR PLAN

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- **Big Dip for South in Summer Because Sun Directly Overhead Mid-Day**
  - But Must Shade South Just Before and After Mid-Day

- **Horizontal (i.e., Roof and Skylights)**
  - Overheated in Summer
  - Don't Face South
  - Don't Face West Unless Low Pitch and Operable Shades (Thermal Lag Worst)
  - Face East is Ok Because Thermal Lag Minimal
  - Face North Ok for Best Art or Arch. Lighting, but Most Mitigate Cold Northern Wind

- **Direct Sunlight Controlled Best with Horizontal + Some Vertical External Architectural Elements**

- **JT Wunderlich PhD**
2. Diffuse Sunlight

- Given: Max in humid and polluted-air places.

- Design Goal: Controlled best with indoor shading because sunlight coming from everywhere.

3. Reflected Sunlight

- Given: Max in non-humid and non-polluted places.

- Design Goals:
  - Magnified by highly reflective surfaces on adjacent buildings (e.g., reflective glass is very common in U.S. Southwest).
  - Magnified in high-density urban areas.

- Controlled best with outdoor vertical shading.
  - Trees & shrubs.

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SHADING METHODS

1. OVERHANGS
   DEPTH = f(SUN ANGLE)
   = f(SEASON)
   = f(LATITUDE)

   SUMMER
   WINTER
   LET IT IN
   BLOCKED!

   SNOW AND WIND LOAD CONCERNS

   SOLUTION: MAKE IT WITH SLATS:
   "BRISE-SOLEIL" GOOGLED IT.
   LIKE ON ARMSTRONG LEED PLATINUM BUILDING TOUR

2. ARBORS
   GOOGLE IMG
   LIKE SLATTED OVERHANG,
   BUT OFTEN DEEPER TO
   SHADE OUTDOOR LIVING SPACE

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\[
\begin{align*}
X_{oh} &= \text{OVERHANG WIDTH} \\
Y_{oh} &= \text{HEIGHT OF WINDOWSILL} \\
\frac{Y_{oh}}{Y_{ws}} &= \text{FULL SHADY OVERHANG} \\
\theta_a &= \text{FULL SHADE ANGLE} \\
\theta_b &= \text{"- SUN"} \\
T\tan \theta &= \frac{Y_{oh} - Y_{ws}}{X_{oh}} \\
X_{oh} &= \frac{Y_{oh} - Y_{ws}}{\tan \theta} \\
\theta &= 5(\text{FULL SHADE OR SUN}) \\
\text{TYPE OF BUILDING:} \\
\text{ENVELOPE DOMINATED (BIG BUILDING)} \\
\text{INTERIORITY DOMINATED (HOUSE)} \\
\text{U.S. CLIMATE REGION} & \quad \text{SOUTHERN ELEVATION} & \quad \text{EAST OR WEST ELEVATION} \\
3 \ (\text{SOUTHEAST PA}) & \quad \theta_a, \theta_b & \quad \theta_a, \theta_b \\
11 \ (\text{PHOENIX, AZ}) & \quad 53^\circ, 47^\circ, 63^\circ, 55^\circ & \quad 25^\circ, 32^\circ \\
16 \ (\text{MIAMI, FL}) & \quad 48^\circ, \text{NA} \quad 56^\circ, 49^\circ & \quad 19^\circ, 24^\circ \\
16 \ (\text{MIAMI, FL}) & \quad 48^\circ, \text{NA} \quad 56^\circ, 49^\circ & \quad 14^\circ, 19^\circ \\
\text{NA. = NOT APPLICABLE} \\
\rightarrow \text{PASSIVE SOLAR BEST FOR E.D.} \\
\rightarrow \text{FOR COOLING, E.D. BEST BECAUSE OF HIGH SURFACE-TO-VOLUME RATIO (LESS VOLUME, OVERHEAT)} \\
\rightarrow \text{FOR HEATING, E.D. BEST BECAUSE OF B.P.T. (BALANCE POINT TEMP.)} \\
\rightarrow \text{IF THICK WALLS, DEEP-LY SET WINDOWS CAN CREATE THICK ADOBE IN U.S. SOUTHWEST} \\
\rightarrow \text{SHADOW MAY ENHANCE ARCHITECTURE} \\
\rightarrow \text{SEE WUNDERLICH XSRIBE PROJECT PARTICIPATION (SAN DIEGO, 1985)} \\
\rightarrow \text{LION ANNUAL SAN DIEGO "ORCHID" ARCHITECTURAL AWARD}
\end{align*}
\]
3. **Awnings (Canopies)**
   - **Cheap**
   - Often operable
   - Small ones for windows
   - Larger for porches and outdoor cafes
   - Better than fixed overhangs for passive solar heating

4. **Window Shades**
   - U.S. (cloth or plastic)
   - More costly
   - But:
     - Better thermodynamics
     - Security
   - Need thicker walls

   **However, in U.S., walls now need to be thicker for new insulation standards**

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LOUVERS + BLINDS

A) Horizontal
   - "Blinds"; "Mini-Blinds"
   - "Venetian Blinds"
   - Operable tilt
   - Retractable
   - Put reflective coating on sun-facing side of each louver

B) Vertical
   - Block views
   - Ugly
   - Break easily

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**GLAZING TREATMENTS**

- REFLECTIVE GLASS
  - BLUE, GOLD, BLACK, etc.
  - POPULAR IN U.S. SOUTHWEST

- GLASS BLOCK
  - CAN BE VERY ESTHETIC
  - PRIVACY

**TRELLISES**

- VERTICAL AND HORIZONTAL ("PERGOLA")
  - ADD VINES TO ENHANCE SHADING WHEN NEEDED (SINCE DECIDUOUS)
  - AND GREAT ESTHETIC

**PLANTS**

- PLANT HIGH-CANOPY DEciduous TREES NEAR BUILDING
  - LEAVES BLOCK SUMMER SUN

- COLONNADE OF TREES" (SHADE PATHS, LOUNGE PORCH, LOGGIA)

- VINES
  - ON TRELLISES + BALCONIES
  - COVER PARK WALLS
  - PLANTERS ON BALCONIES, WINDOW BOXES

- $↓ / IF PLANT YOUNG
- LEAF TRANSPIRATION CAN COOL AIR
- REDUCE GLARE
- PRIVACY
- ESTHETICS
- FOOD
**Balanced Control of Sunlight**

**Thermal**
- Design goals:
  - Max into building when cold
  - Min into building when hot
  - Movable shades during hot months
  - Optimize daylighting all year
- To minimize artificial lighting
- Which is very task-specific
- See ch 13

**Natural Daylighting**
- Always optimize windows
- Don't avoid east + west windows
- Sunrise with breakfast, sunsets
- Use creative placement of windows, and various floor plans to let light in

1. Clerestories:

2. Floor plans:

3. Light-tubes
   - Google inc.

4. Movable shades + drapes

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PASSIVE COOLING

1. Cooling with ventilation
   - Tall ceilings
   - Large windows
   - Low porches
   - Space under building
   - Large attic vents

   **Google Image:** "Japanese movable wall panels" (Entire walls of doors, and windows)
   **Google Image:** "Robie House floor plan" (Shutters with adjustable louvers)
   **Google Image:** "Roof Belvedere"

   **Note:** Air flow (most fluid mechanics principles), it is non-compressible

   **Stack Effect** (Convection up and out) and ventilation effect due to aero-dynamics (fluid mechanics)

   *Humans comforted by evaporative cooling caused by air blowing on skin, removing moisture and heat from body.*

<table>
<thead>
<tr>
<th>Air Velocity (MPH)</th>
<th>Equivalent Temperature Reduction (°F)</th>
<th>Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0</td>
<td>Stagnant uncomfortable air</td>
</tr>
<tr>
<td>1</td>
<td>~3.</td>
<td>Noticeable</td>
</tr>
<tr>
<td>2 to 5</td>
<td>5 to 7</td>
<td>Good ventilation</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Gentle Breeze</td>
</tr>
</tbody>
</table>

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PHYSICS OF AIR MOVEMENT

AERODYNAMICS

SAME AS FLUID MECHANICS
EXCEPT AIR IS COMPRESSABLE
(LIQUID WATER IS NOT)

FLOW (WIND)

CAUSED BY:
1. \( \Delta \text{PRESSURE} \)
2. CONVECTION CURRENTS = \( f(\Delta t) \)

TYPES:
1. LAMINAR
2. TURBULENT
3. EDDY
4. SEPARATED (INDEPENDENT STREAMS)

AROUND SHAPES:
EX/ROOF PITCHES/ SLOPES

EX/ BUILDING FOOTPRINTS
VENTILATION:
BEST
OK
WORST

 Also, flow = \( f(\text{ADJACENT BUILDINGS, TERRAIN, PREVAILING-WIND DIRECTION, WEATHER, ANOMALIES)} \)

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△ Velocity

\[ \vec{V} \uparrow \text{IF FLOW CONSTRUCTED} \]

"Bernoulli" Effect

"Venturi" Effect

↓Suck in Air

Typical V Profile = V(Height)

Use Venturi Effect to Ventilate:

Ridge Vents

Soffit Vents

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**Types of Cooling**

1. **Night Flush Cooling**
   - Pre-cool building at night
   - Let in cool night air
   - Thermal mass cools
   - Heat sink sinks heat during day
   - Best for hot, dry climate

2. **Radiant Cooling**
   - "Direct": Roof structure cooled by night
     - Imaged the night sky
     - Concrete
   - "Indirect": Night sky cools a heat-transfer fluid, then building cooled with it
   - Best for hot, dry climate

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**3. Evaporative Cooling**

**Direct**
- Water put into air as it enters building
- Spray mist
- Air through fountain or water fall or across pond

But: Humidity↑

**Indirect**
- To get T<sub>emp</sub> without humidity↑
- Spray water on roof or run water through attic
  - Roof/ceiling then acts as a heat-sink

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4 Earth Cooling ("Direct Coupling")

Hot Climates
- Slab on Grade
  - Common in the South

Earth-Sheltered Building
- North

Cold Climate
- Insulation to keep in?
- Foundation must be below frost line
- Basements

Roof Garden
- Can wet soil with sprinklers to increase heat transfer
- Also use trees & shrubs to shade soil
- Can also cover with gravel (white)
  - Shades soil
  - Allows evaporation from soil

Need extra structure
- Drainage
  - Can do in cold climates but
    - Insulate at dirt
    - Earth in garden can add insulating value

5 "Indirect Coupling"
- Air enters building through earth tubes

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Passive Cooling

6 Combine Conduction and Convection and Radiation
Then

External Roman Vaults + Domes

Most made from masonry

Vaults:

"Barrel" (or "Tunnel") Vault

"Grown" (or "Cross") Vault

"Cloister" Vault ("Cloister Dome")

Domes:

Math:

Art:

Hemispherical

Cryptal
Not typically Roman

Parabolic

 pointed

Segmented

Octagon

Polygon Base

8 sides

Also Pentagon, Decagon

12 DD Decagon

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BASE - STRUCTURES:

**Rotunda**
Round room under dome

Square base with squinches

Interior view

Square base + pendentives

Dome

Pendentive

≈ Cube

Curved transition between cube and dome
**PANTHEON**

BUILT IN 27 BC (REBUILT ~126 AD) IN ROME

- LARGEST DOME FOR ~1400 YEARS
- BUILT AROUND A "SPHERE" "OCULUS"
- CIRCULAR HOLE IN CEILING FOR LIGHTING
  - ONLY OTHER LIGHT SOURCE IS LARGE FRONT DOOR
- THERMODYNAMICS

1.2 METERS

43.3 M (142 FT)

**ROTUNDA**

FLOOR HOLES DRAIN RAIN

GOOGLE IMAGES "PANTHEON"

- THICK WALLS ARE "HEAT-SUCK" AND ABSORB HEAT DURING HOT, HUMID DAYS
- ALSO CONVECTION CURRENTS CREATED
- EVAPORATIVE COOLING FOR PEOPLE
- HEAT RISES AND EXITS OCULUS

6.4 M (21 FT) THICK

1.2 M (4 FT) THICK

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Natural (passive) dehumidification

- Best in humid climate

- Desiccant (drying agent)
  - Silica gel
  - Natural zeolite
  - Activated alumina
  - Calcium chloride

Still in development

- Chemicals above give off heat as they work

- They also saturate