EGR 343 "GREEN ARCHITECTURAL ENGINEERING" J. WUNDERLICH, PhD

CH9,10 SHADING AND PASSIVE COOLING

PORTICO, COLONADE, LOGGIA ⇒ PORCH ⇒ OVER HANG, ETC.

→ SHADE BUILDING & OUTDOOR LIVING SPACE

→ GREEK & ROMAN PORTICOES & COLONADES + LOGGIA

GOOGLE IMG "PORTICOES" THEN "PANTHEON"

DR. W PAGE, ITALY, ROME, THEN VENICE

THEN GOOGLE IMG "COLONADE", THEN "LOGGIA"

→ GREEK RIVIVAL

→ EX) U.S. SOUTH (HOT & HUMID)

GOOGLE IMG. "PLANTATION PORCHES"

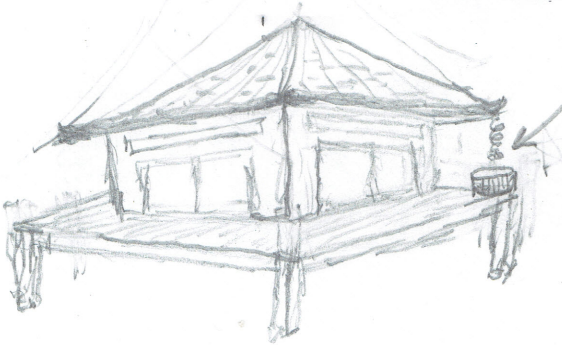
→ ALLOWED LARGE WINDOWS (FOR EVAPORATIVE COOLING)

WITHOUT OVERHEATING HOUSE WITH TOO MUCH SUN

→ OUTDOOR LIVING

→ BLOCKED RAIN

CHAIN FOR DOWNSPOUT; SEE J. WUNDERLICH -/OUTUBE CHANNEL



SIMILAR DESIGNS IN MOST OF SOUTHEAST ASIA (AND TROPICS)

ENGAWA GOOGLE IMG IT

(JAPANESE PORCH)

→ SLIDING WALL PANELS TO OPTIMIZE
1. LIGHT
2. VENTILATION
3. VIEW

→ CONTINUOUS TRANSLUCENT STRIP WINDOW ABOVE

→ HANGING CHAIN FOR RAINWATER FROM GUTTERS

GREAT AMERICAN ARCHITECTS INFLUENCED BY JAPANESE

★ (1) GREEN + GREEN (CALIFORNIA)

GOOGLE IMG "GREENE BROTHERS ARCHITECTURE"

★ (2) "FRANK LLOYD WRIGHT OVERHANGS" (A)

GOOGLE IMG IT

→ ALSO HIS:

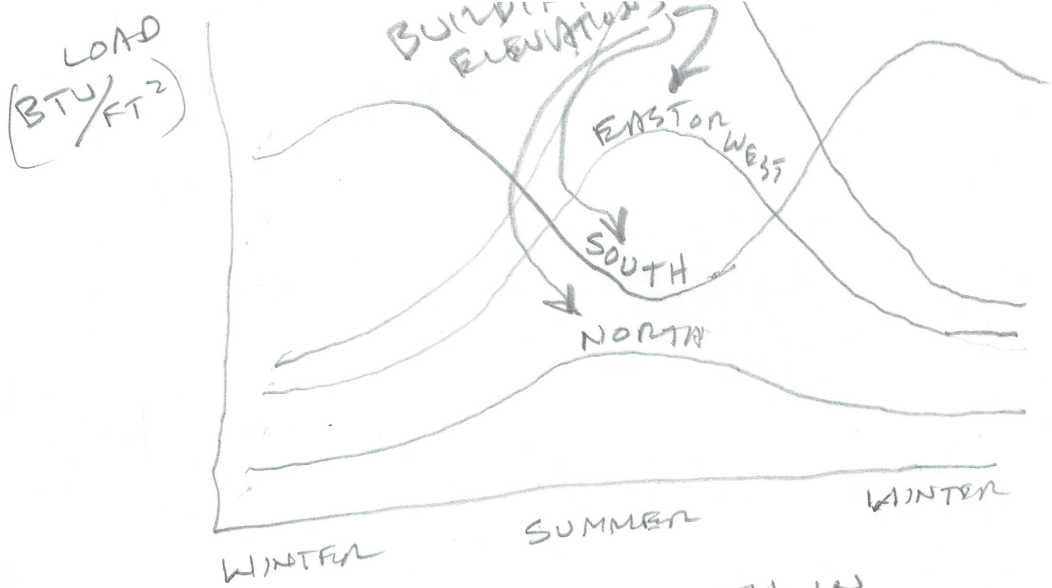
(B) USE OF LARGE AREAS OF OPERABLE WINDOWS FOR VENTILATION (EVAPORATIVE COOLING) FOR HOT, HUMID MIDWEST SUMMERS

(C) INSPIRED BY NATURE
(D) CONFORM TO NATURE
(E) LOW-PITCHED ROOFS

(F) CASCADED SMALL WINDOWS

(G) THICK STRUCTURAL MEMBERS
→ POST + BEAM
(H) VARIOUS WOOD DETAILS
(I) PLANTERS
LARGE + SMALL

(J) FINE ARTICULATION OF DETAILS
→ SMALL THIN BRICKS
(K) JAPANESE PRINTS ARTWORK
(L) JAPANESE STRAW MATS (TATAMI) INFLUENCE ON ROOM FLOOR PLAN



→ 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

SKYLIGHTS

→ DON'T FACE SOUTH

→ DON'T FACE WEST UNLESS LOW PITCH AND OPERABLE SHADES (THERMAL LAG WORST)

→ FACE EAST IS NOK BECAUSE THERMAL LAG MINIMAL

→ FACE NORTH OK FOR BEST ART OR ARCH. LIGHTING, BUT MUST MITIGATE COLD NORTHERN WIND

→ ALWAYS SPECIFY GOOD "FLASHING" AND "COUNTER-FLASHING" BECAUSE SKYLIGHTS OFTEN LEAK

→ 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 VERY COMMON IN U.S. SOUTHWEST)

→ MAGNIFIED IN HIGH-DENSITY URBAN AREAS

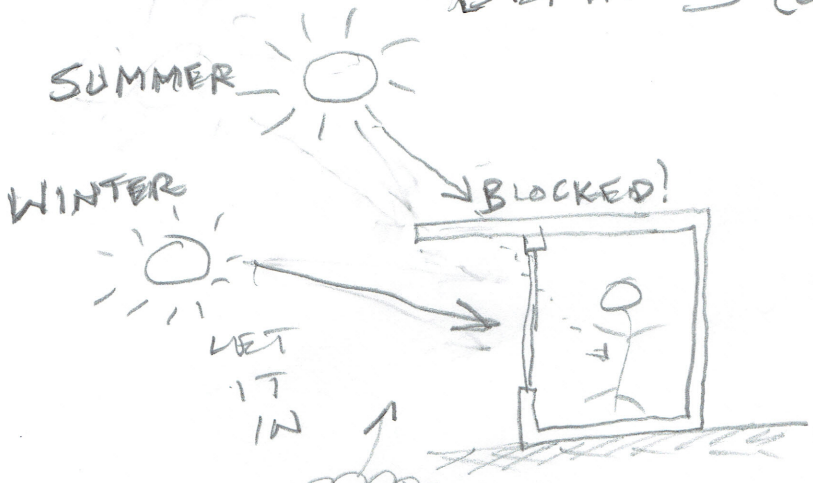
→ CONTROLLED BEST WITH OUTDOOR VERTICAL SHADING
→ TREES + SHRUBS

SHADING METHODS

★ ALL CAN ENHANCE THE ARCHITECTURAL AESTHETIC (UNLIKE MOST ACTIVE SOLAR)
→ BOTH THE ARCHITECTURAL ELEMENT AND THE SHADOWS

① OVERHANGS

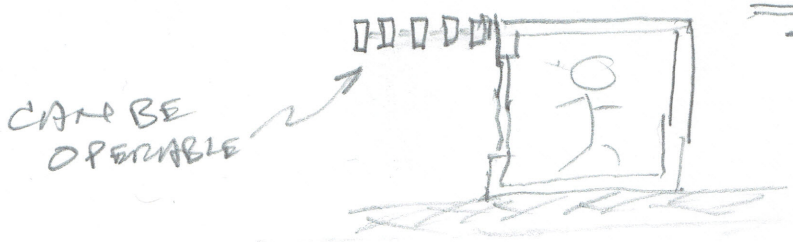
DEPTH = f(SUN ANGLE)
= f(SEASON)
= f(LATITUDE)



AND
= f(BUILDING ELEVATION)

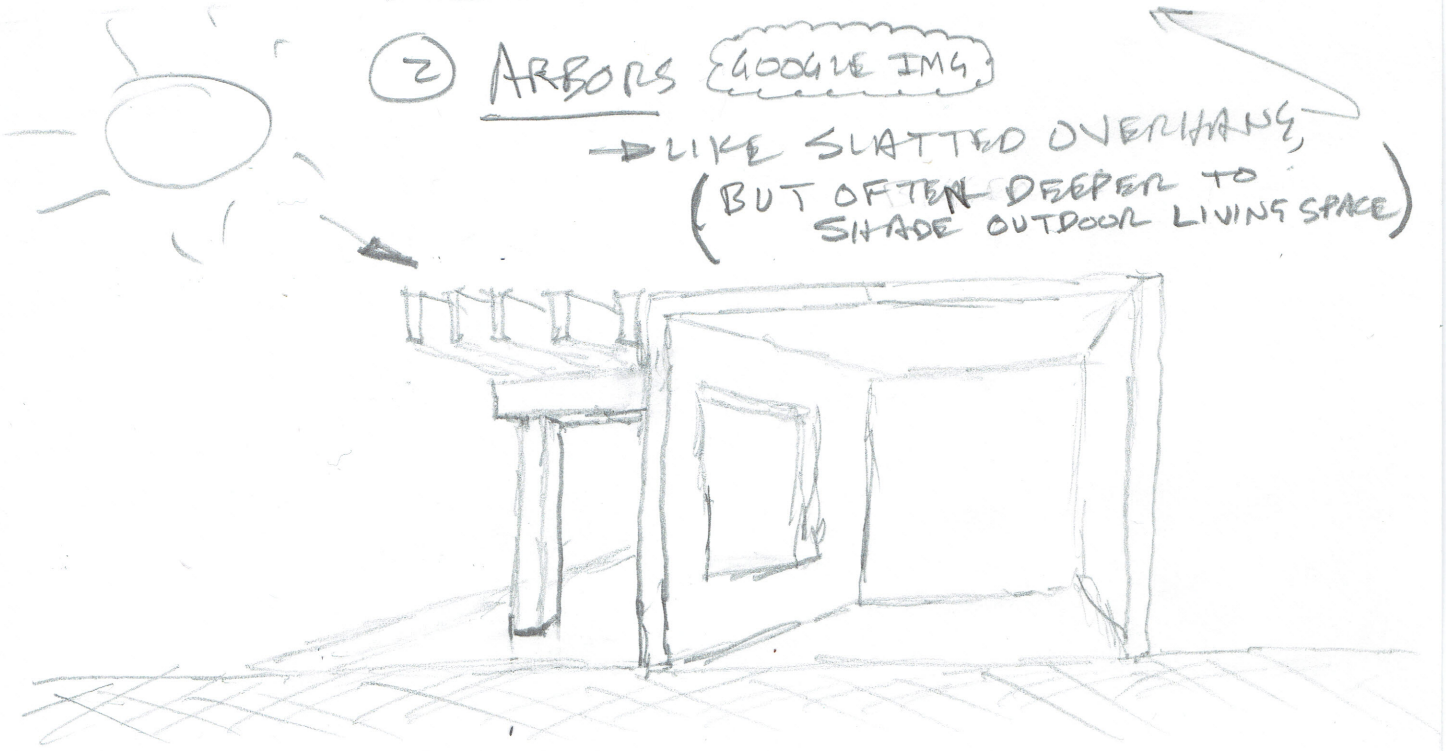
SOUTH BEST
→ ALSO EAST
+ WEST
DIFFICULT → (DEPTH!!!)

SOLUTION: MAKE IT WITH SLATS:
"BRISE-SOLEIL" (GOOGLE IMG IT)
→ LIKE ON AMSTRONG LEED PLATINUM BUILDING TOUR



② ARBORS (GOOGLE IMG)

→ LIKE SLATTED OVERHANG, (BUT OFTEN DEEPER TO SHADE OUTDOOR LIVING SPACE)



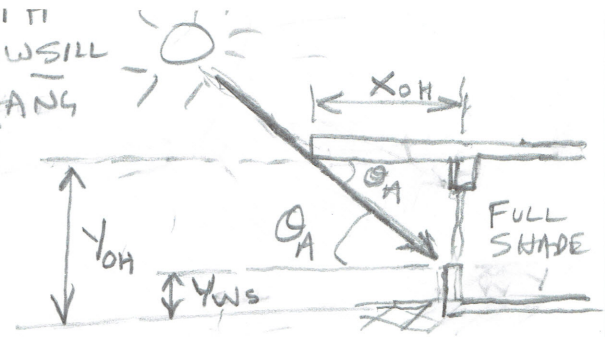
LET X_{OH} = OVERHANG DISTANCE

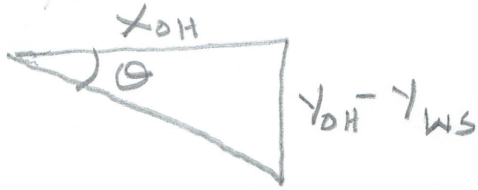
Y_{WS} = HEIGHT OF WINDOWSILL

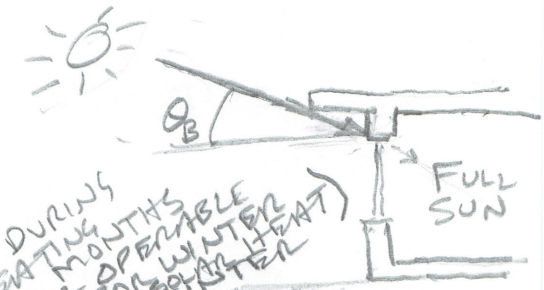
Y_{OH} = " " OVERHANG

θ_A = FULL-SHADE ANGLE

θ_B = " - SUN "







$$\tan\theta = \frac{Y_{OH} - Y_{WS}}{X}$$

$$X_{OH} = \frac{Y_{OH} - Y_{WS}}{\tan\theta_B}$$

FOR FULL SHADE DURING ON-HEATING MONTHS USE θ_B FOR OPERABLE OVERHANG (I.E. PASSIVE SOLAR)

FOR WINTER HEAT

$\theta = f$(FULL SHADE OR SUN, TYPE OF BUILDING)

- I.D. INTERNALLY DOMINATED (BIG BUILDING)
- E.D. ENVELOPE DOMINATED (HOUSE)

TEXT TABLES 9.9A, 9.9B, 9.12

U.S. CLIMATE REGION	SOUTHERN ELEVATION I.D. θ_A, θ_B	SOUTHERN ELEVATION E.D. θ_A, θ_B	EAST OR WEST ELEVATION I.D. θ_E	EAST OR WEST ELEVATION E.D. θ_B
★ 3 (SOUTHEAST PA)	53°, 47°	63°, 55°	25°	32°
11 (PHOENIX, AZ)	48°, NA	56°, 49°	19°, NA	24°, NA
16 (MIAMI, FL)	40°, NA	50°, NA	14°, NA	19°, NA

★ = FROM 8:00AM - 4:00PM DURING HOT MONTHS

NA. = NOT APPLICABLE

→ PASSIVE SOLAR BEST FOR E.D. SINCE NO DEEP INTERIORS

→ FOR COOLING, E.D. BEST BECAUSE HIGH SURFACE-AREA-TO-VOLUME RATIO (LESS VOLUME TO OVERHEAT)

→ FOR HEATING, I.D. BEST BECAUSE LOWER B.P.T. (BALANCE POINT TEMP)

→ ~ 50°F (VS. ~60°F FOR E.D.)

→ = TEMP. BELOW WHICH HEATING IS REQUIRED

→ LARGE VOLUME WITH SMALL SKIN HOLDS HEAT BETTER

→ IF THICK WALLS, DEEPLY SET WINDOWS CAN CREATE SOME OVERHANG AND VERTICAL SHADE

→ THICK ADOBE IN U.S. SOUTHWEST

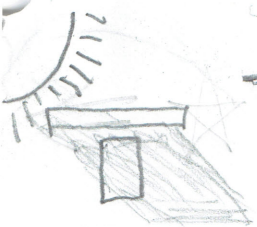
→ SHADOW MAY ENHANCE ARCHITECTURE

→ SEE WUNDERLICH XSRIBE PROJECT PARTICIPATION (SAN DIEGO, 1985)

→ WIDTH OF OVERHANG = $2 * (Y_{OH} - Y_{WS})$

SO WINDOW STAYS IN SHADOW DURING DAY

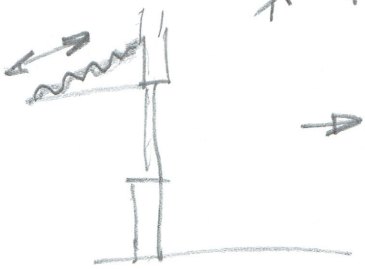
→ WON ANNUAL SAN DIEGO "ORCHID" ARCHITECTURAL AWARD



(GOOGLE IMG)

(3) AWNINGS (CANOPIES)

☆ → CHEAP



→ OFTEN OPERABLE

→ SMALL ONES FOR WINDOWS

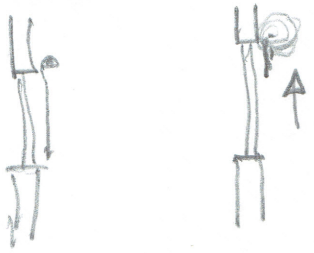
→ LARGE " " PORCHES AND OUTDOOR CAFE'S

☆ → BETTER THAN FIXED OVERHANGS FOR PASSIVE SOLAR HEATING

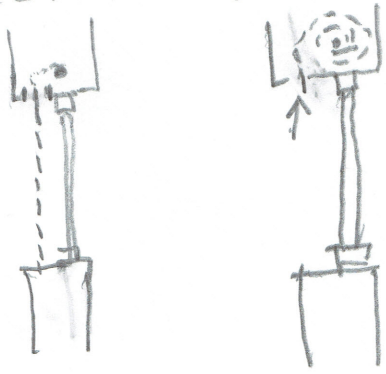
(GOOGLE IMG)

(4) WINDOW SHADES

U.S. (CLOTH OR PLASTIC)



EUROPE (METAL)



☆ → MORE COSTLY

☆ → BUT:

- BETTER THERMODYNAMICS
- SECURITY

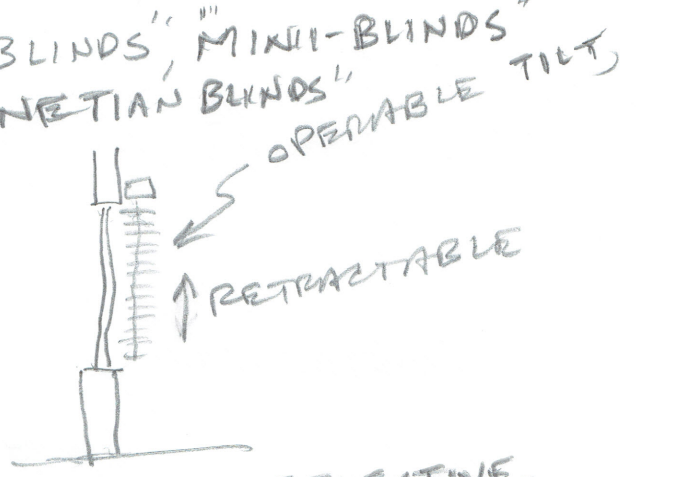
→ NEED THICKER WALLS

→ HOWEVER, IN U.S. WALLS NOW NEED TO BE THICKER FOR NEW INSULATION STANDARDS

(5) LOUVERS + BLINDS

(A) HORIZONTAL

"BLINDS", "MINI-BLINDS"
"VENETIAN BLINDS"



→ PUT REFLECTIVE COATING ON SUN-FACING SIDE OF EACH LOUVER

(B) VERTICLE

→ BLOCK VIEWS

→ ~ UGLY

→ BREAK EASILY

(6) GLAZING TREATMENTS

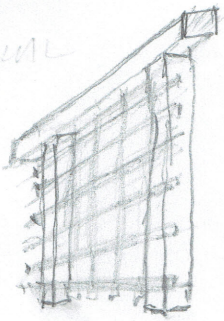
	SC SHADING COEFFICIENT	SHGC SOLAR HEAT GAIN COEFF
CLEAR GLASS	1.0	0.86
REFLECTIVE GLASS	0.4	0.4
BLINDS	0.4	N.A.
TREES	0.4	N.A
GLASS BLOCK	0.1 TO 0.7	~0.6

EX "REFLECTIVE GLASS"
- → BLUE, GOLD, BLACK, ETC
- → POPULAR IN U.S SOUTHWEST

(B) → GLASS BLOCK
- → CAN BE VERY ESTHETIC
- → PRIVACY

(7) TRELISES

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



(8) PLANTS

- → PLANT HIGH-CANOPY DECIDUOUS TREES NEAR BUILDING
  - → LEAVES BLOCK SUMMER SUN
- GOOGLE IMG. → "COLONNADE OF TREES" (SHADE PATHS, LONG PORCH, LOGGIA)
- → VINES
  - → ON TRELISES + BALCONIES
  - → COVER DARK WALLS
- → PLANTERS ON BALCONIES, WINDOW BOXES
- → $↓ IF PLANT YOUNG
- → LEAF TRANSPIRATION CAN COOL AIR
- → REDUCE GLARE
- → PRIVACY
- → ESTHETICS
- → FOOD

(9) ROOFS

GOOGLE IMG: "STANDING SEAM ROOFS"

POPULAR IN TEXAS

	REFLECTANCE
WHITE	85
STEEL	50
LIGHT GREY	30
BLACK	5

← BAD IDEA IN ALL BUT THE COLDEST CLIMATES; BUT PEOPLE LIKE THE WAY IT LOOKS; SO IT IS VERY COMMON

BALANCED CONTROL OF SUNLIGHT

THERMAL

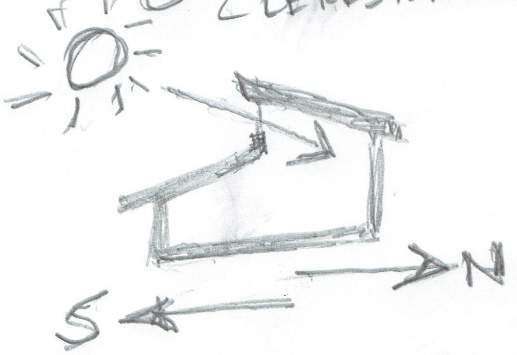
DESIGN GOALS:
- → MAX INTO BUILDING WHEN COLD
- → MIN INTO BUILDING WHEN HOT
- → MOVABLE SHADES DURING HOT MONTHS
- → OPTIMIZE DAYLIGHTING ALL YEAR

TO MINIMIZE ARTIFICIAL LIGHTING
- → WHICH IS VERY TASK-SPECIFIC
- → SEE CH 13

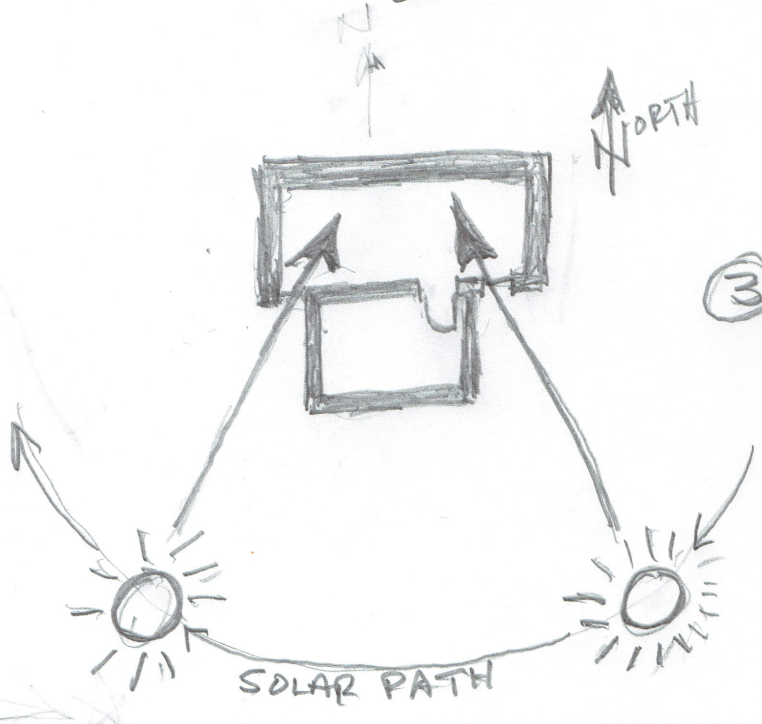
NATURAL DAYLIGHTING

- → 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 IMG.

④ MOVABLE SHADES + DRAPES

PASSIVE COOLING

① COOLING WITH VENTILATION
- → TALL CEILINGS
- → LARGE WINDOWS
- → PORCHES
- → SPACE UNDER BUILDING
- → LARGE ATTIC VENTS

GOOGLE IMG. → "JAPANESE MOVABLE WALL PANELS"

GOOGLE IMG.
- → "ROBIE HOUSE FLOOR PLAN" (ENTIRE WALLS OF DOORS AND WINDOWS)
- → SHUTTERS WITH ADJUSTABLE LOUVERS

GOOGLE IMG. → "ROOF BELVEDERE"

→ "STACK EFFECT" (CONVECTION UP AND OUT)
- → THERMODYNAMIC

AND
- → VENTILATION EFFECT
- → DUE TO AERODYNAMICS (FLUID MECHANICS)

NOTE: AIR OBEYS MOST FLUID-MECHANICS PRINCIPLES; HOWEVER IT ISN'T COMPRESSIBLE

✡ HUMANS COMFORTED BY EVAPORATIVE COOLING CAUSED BY AIR BLOWING ON SKIN, REMOVING MOISTURE AND HEAT FROM BODY

AIR $\vec{V}$ELOCITY (MPH)	EQUIVALENT TEMPERATURE REDUCTION (°F)	COMFORT
0.1	0	STAGNANT UNCOMFORTABLE AIR
1	~3	NOTICABLE
2 TO 5	5 TO 7	GOOD VENTILATION
10		GENTLE BREEZE

PHYSICS OF AIR MOVEMENT

→ AERODYNAMICS

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

FLOW (WIND)

→ CAUSED BY:

① ΔPRESSURE

OR

② CONVECTION CURRENTS $= f(\Delta T)$

→ TYPES:

① LAMINAR

② TURBULANT

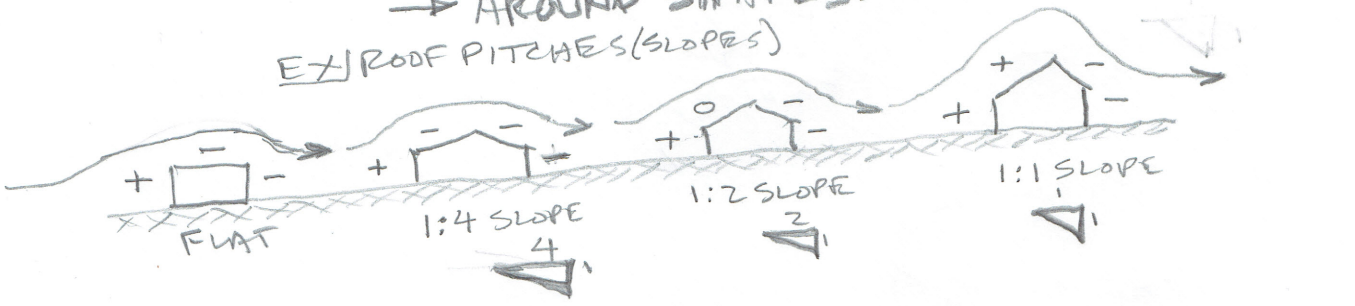
③ EDDY

④ SEPERATED (INDEPENDENT STREAMS)

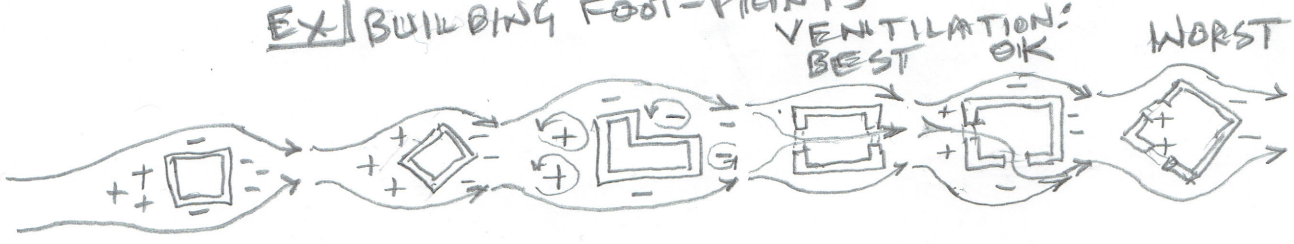
→ AROUND SHAPES:

+, − ARE PRESSURES

EX| ROOF PITCHES (SLOPES)



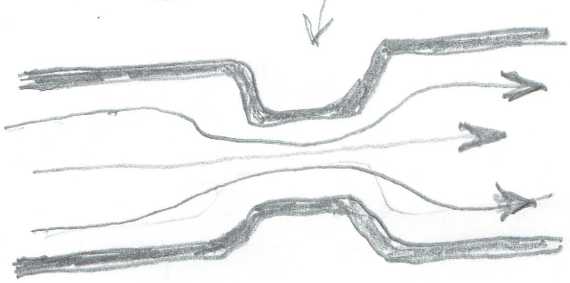
EX| BUILDING FOOT-PRINTS



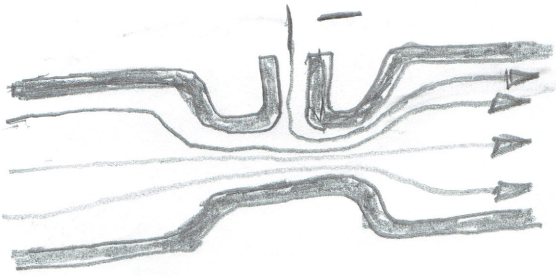
ALSO, FLOW $= f$ (ADJACENT BUILDINGS, TERRAIN, PREVAILING-WIND DIRECTION, WEATHER ANOMILIES)

$\vec{V}$ VELOCITY

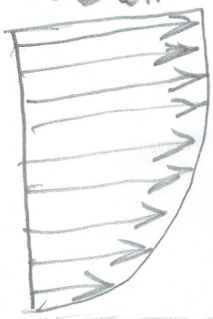
$\vec{V}\uparrow$ IF FLOW CONSTRICTED "BERNOULLI" EFFECT



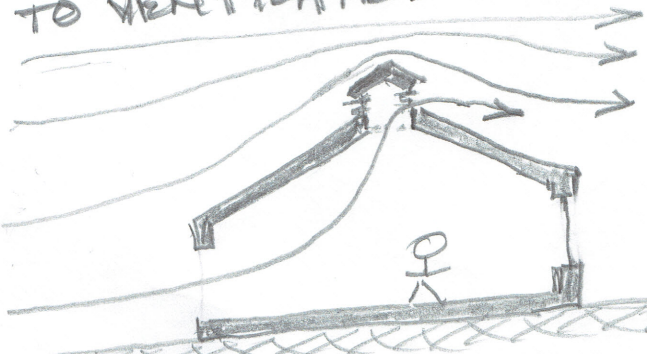
"VENTURI" EFFECT → SUCK IN AIR



TYPICAL $\vec{V}$ PROFILE = f(HEIGHT)

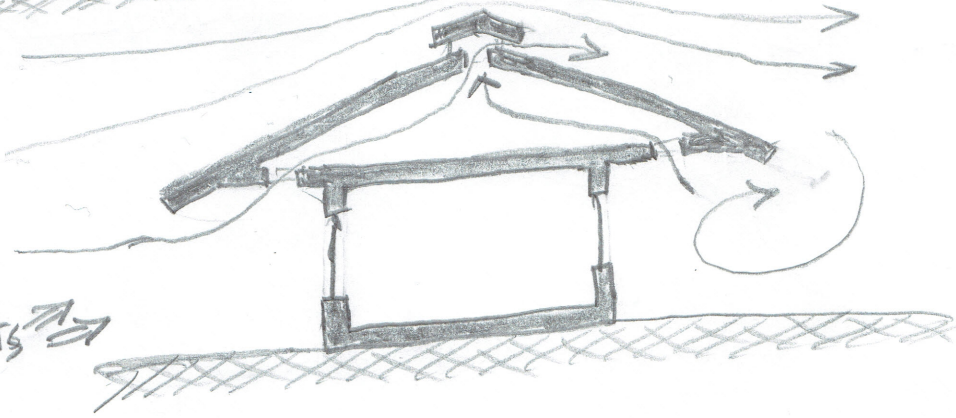


USE VENTURI EFFECT TO VENTILATE:



RIDGE VENT →

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 THE NIGHT SKY
  - CONCRETE
- "INDIRECT": NIGHT SKY COOLS A HEAT-TRANSFER FLUID, THEN BUILDING COOLED WITH IT
- BEST FOR HOT, DRY CLIMATE

(3) EVAPORATIVE COOLING

DIRECT

→ WATER PUT INTO AIR AS IT ENTERS BUILDING
→ SPRAY MIST
→ AIR THROUGH FOUNTIAN OR WATER FALL, OR ACROSS POND

BUT → HUMIDITY ↑

INDIRECT

TO GET T_{EMP} ↓ WITHOUT HUMIDITY ↑

→ SPRAY WATER ON ROOF OR RUN WATER THROUGH ATTIC
→ ROOF/CEILING THEN ACTS AS A HEAT-SINK

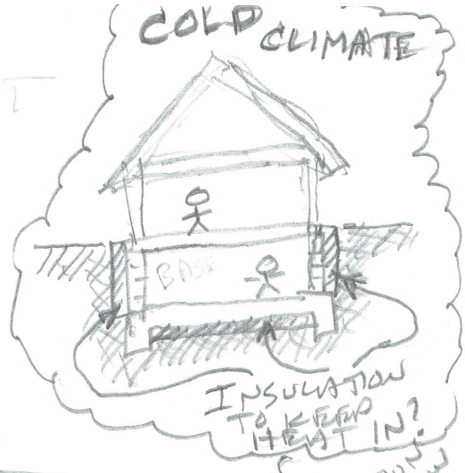
(4) EARTH COOLING ("DIRECT COUPLING")

HOT CLIMATES →

SLAB ON GRADE

→ COMMON IN THE SOUTH

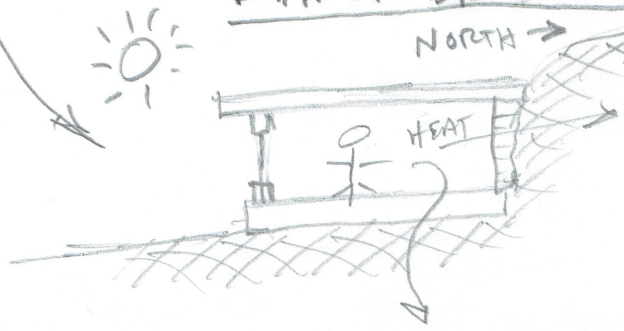
COLD CLIMATE



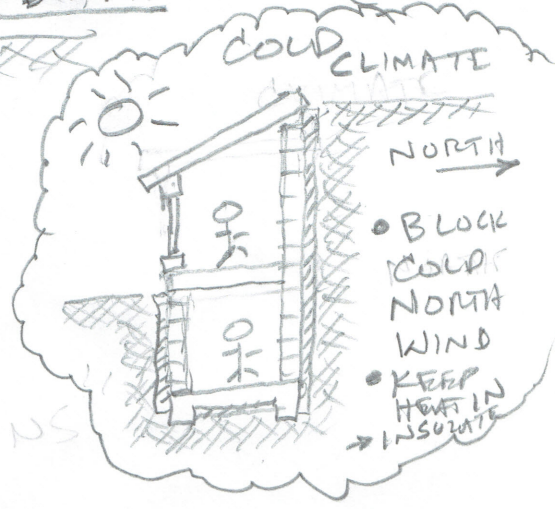
INSULATION TO KEEP HEAT IN?

FOUNDATION MUST BE BELOW FROST LINE! ∴ BASEMENTS!

EARTH-SHELTERED BUILDING

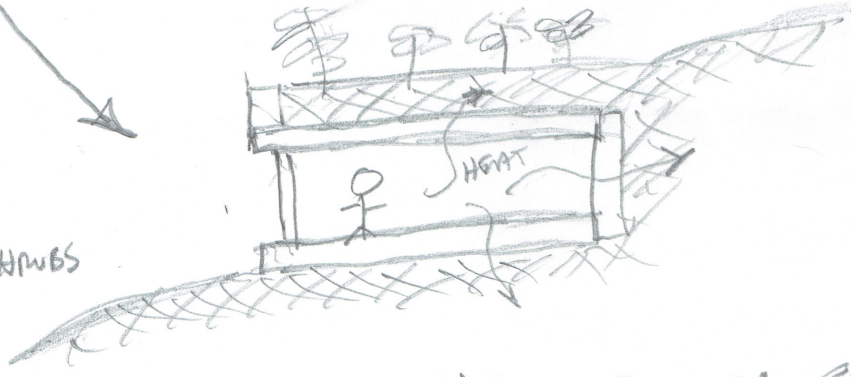


COLD CLIMATE



- BLOCK COLD NORTH WIND
- KEEP HEAT IN → INSULATE

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 → KEEP HEAT IN
- → INSULATE AT DIRT
- → EARTH IN GARDEN CAN ADD INSLIATING VALUE

(5) "INDIRECT COUPLING"

→ AIR ENTERS BUILDING THROUGH EARTH TUBES

JT Wunderlich PhD

6 COMBINE CONDUCTION, CONVECTION, AND RADIATION

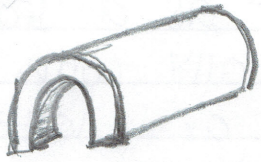
☆ HEATSINK THEN

EX: ROMAN VAULTS & DOMES

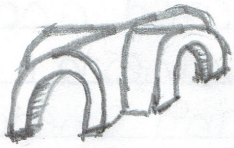
→ MOST MADE FROM MASONRY

VAULTS:

"BARREL" (OR "TUNNEL") VAULT



"GROIN" (OR "CROSS") VAULT



"CLOISTER" VAULT ("CLOISTER DOME")

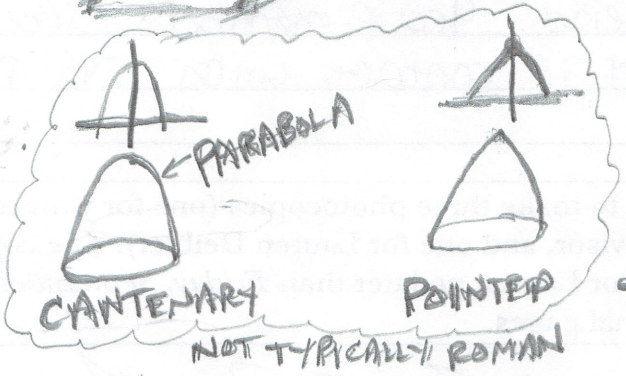
← SQUARE BASE

DOMES:

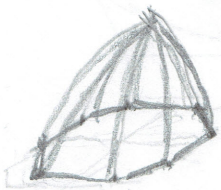
MATH:

ART:

HEMISPHERICAL



NOT TYPICALLY ROMAN



8 SIDED → OCTAGON

POLYGON BASE

ALSO 5 PENTAGON, 10 DECAGON, 12 DODECAGON

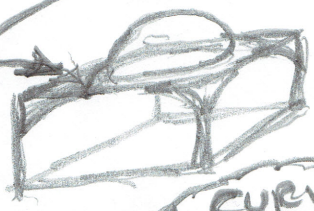
BASE - STRUCTURES:

ROTUNDA

ROUND ROOM UNDER A DOME

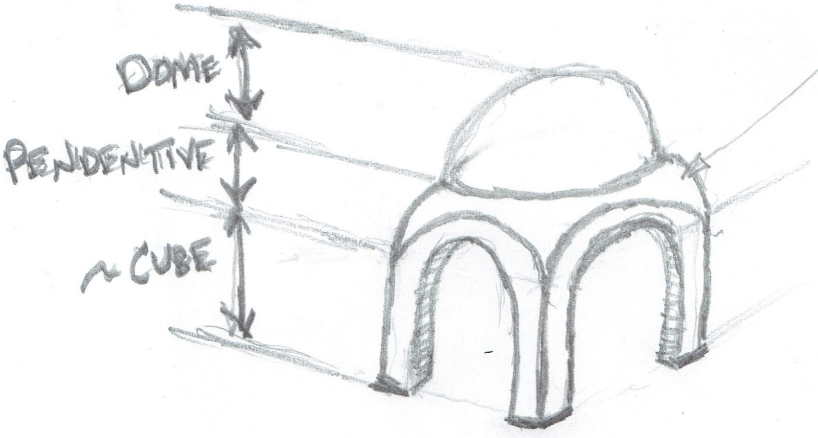
SQUARE BASE WITH "SQUINCHES"

← INTERIOR VIEW



SQUARE BASE + "PENDENTIVES"

CURVED TRANSITION BETWEEN CUBE AND DOME



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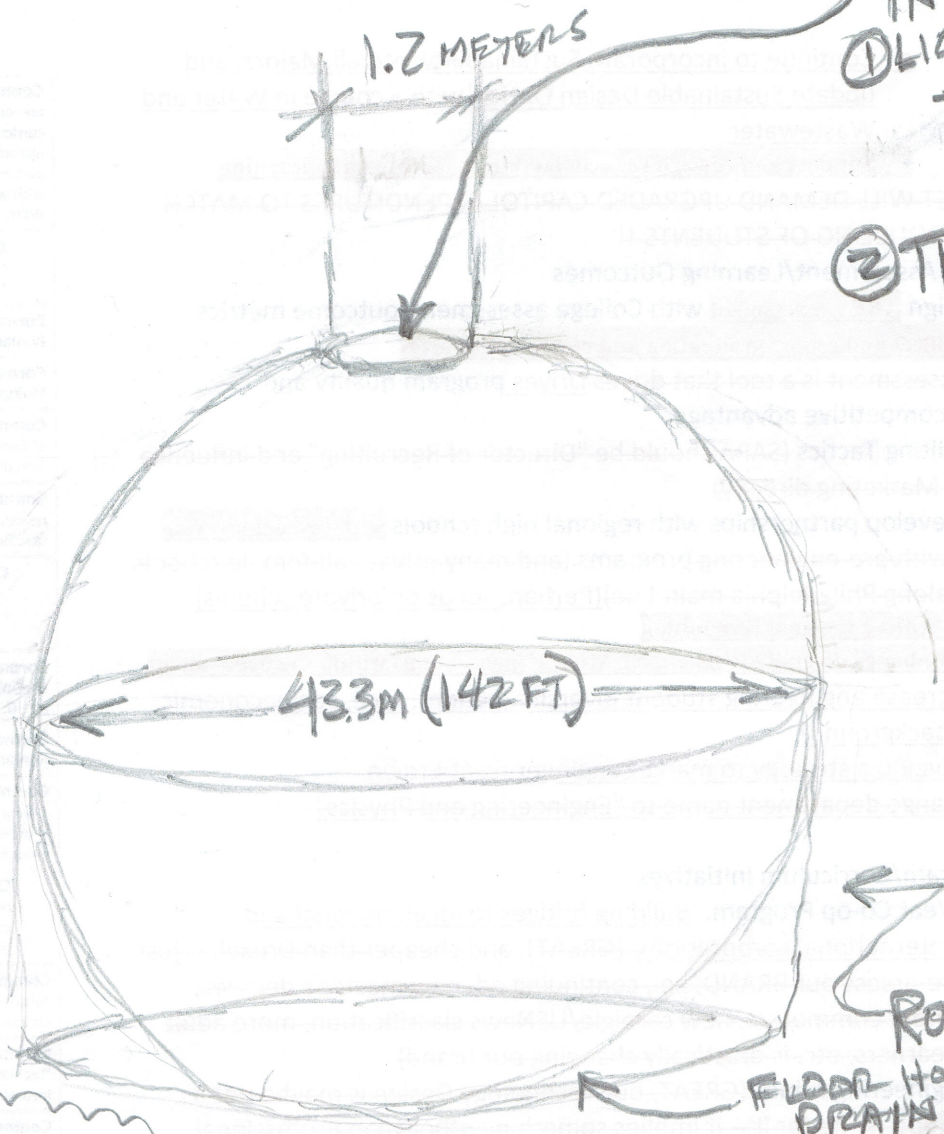
PANTHEON

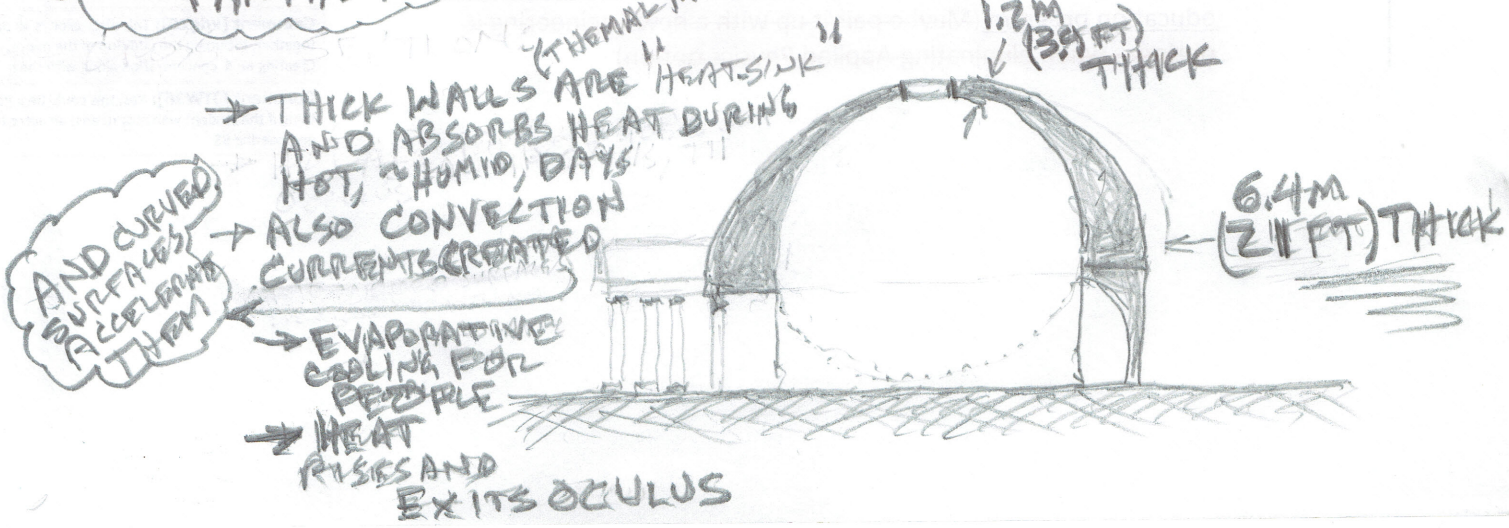
BUILT IN 27 B.C. (REBUILT ~126 AD)
IN ROME
→ LARGEST DOME FOR ~1400 YEARS, UNTIL BRUNELLESCHI'S DOME IN FLORENCE #36

- BUILT AROUND A "SPHERE"

"OCULUS"
CIRCULAR HOLE IN CEILING FOR
① LIGHTING
→ ONLY OTHER LIGHT SOURCE IS LARGE FRONT DOOR
② THERMODYNAMICS



GOOGLE IMAGES "PANTHEON"



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(7) 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