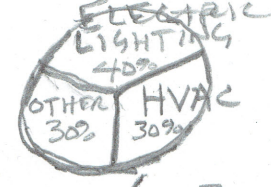


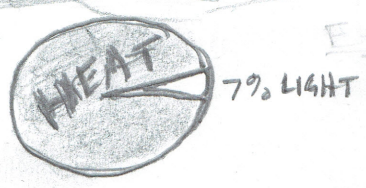
CH 12 "LIGHT"
 CH 13 "DAYLIGHTING"
 CH 14 "ELECTRIC LIGHTING"

U.S. ENERGY USE
 INDUSTRY, BULB, TRANSPORTATION, NGS



LUMEN (lm) = RATE SOURCE EMITS ENERGY (i.e. FLUX)

EFFICACY = $\frac{\text{LIGHT OUT}}{\text{ENERGY-IN}} = \frac{\text{LUMENS}}{\text{WATTS}} = \frac{(\text{lm})}{(\text{W})}$



EFFICACY = $\frac{1740 \text{ lm}}{100 \text{ W}} = 17.4$

INCANDESCENT (800-3000 HOURS OF LIFE)

WORST
 (BUT BEAUTIFUL LIGHT LIKE SUN)



EFFICACY = $\frac{7800 \text{ lm}}{100 \text{ W}} = 78$

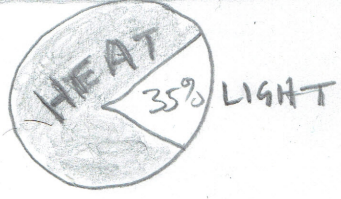
FLUORESCENT (10,000 TO 30,000 HOURS OF LIFE)

PROBLEMS → NOT SO NICE LIGHT:
 ① → PEAKS IN RED ("WARM") OR BLUE ("COOL")
 ② → FLICKER

MUCH RESEARCH TO MAKE THIS HAVE "NICER" SIMULATED DAYLIGHT LIKE THIS

① FIX: BUY "DAYLIGHT" BULB → LIKE SUN
 ② FIX: SWITCH FROM MAGNETIC TO ELECTRONIC BALLASTS

XXXXXXXXXX
 at 60HZ in U.S.
 at 50HZ in many other countries with different AC



EFFICACY = $\frac{9500 \text{ lm}}{100 \text{ W}} = 95$

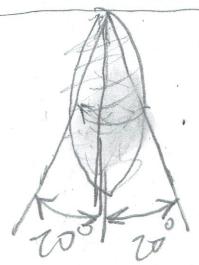
HIGH-PRESSURE SODIUM (24,000 TO 30,000 HOURS OF LIFE)

→ WIDE DIFFUSED LIGHT
 → USE IN GYMS
 → 5 MINUTES TO START

CANDLE POWER (CP), METRIC CANDELA (CA)

FOCUS ↑, CP ↑

CP DISTRIBUTION CURVE



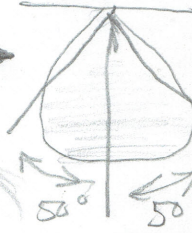
"SPOT" LIGHT



"FLOOD" LIGHT



CP DIST.



OTHER TYPES OF LIGHTS

GOOD SPOT LIGHTS ON PAINTINGS AND SCULPTURES

HALOGEN

2000 TO 5000 HOURS OF LIFE

EFFICACY = $12 \text{ TO } 24 \frac{\text{lm}}{\text{W}}$

CERAMIC METAL HALIDE

10,000 TO 20,000 HOURS OF LIFE

EFFICACY = $30 \text{ TO } 95 \frac{\text{lm}}{\text{W}}$

METAL HALIDE

EFFICACY = $50 \text{ TO } 115 \frac{\text{lm}}{\text{W}}$

→ WIDE DIFFUSED LIGHT

→ USE IN GYMS

→ 5 MINUTES TO START

NEW LIGHTING TECHNOLOGY

SOLID-STATE LED (DEF: NO MOVING PARTS)
 (Light Emitting Diode)

(10,000 TO 50,000 HOURS OF LIFE)

EFFICACY = **10 TO 208** LUMENS PER WATT

VARIABLE HEAT LOSS (BUT STILL HIGH)

NOT HOT TO TOUCH HOWEVER

GOOGLE: "LED EFFICIENCY"

EXPERIMENTAL

2011

"CREE'S XLamp XM-L" LED

100 lm/W @ 10 WATTS FULL POWER

208 lm/W @ 2 WATTS

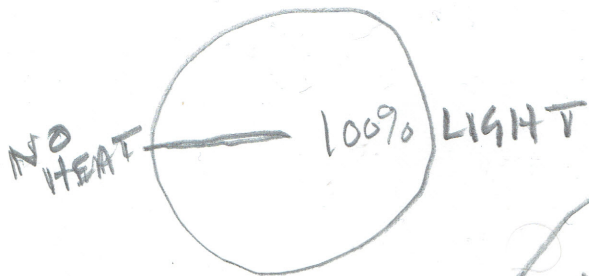
(I.E. DIMMER, BUT LESS UNIT-ENERGY USE)

BUT, AS OF 2012, BEST TO BE EXPECTED FOR EVERY DAY USE:

EFFICACY = **45**

→ GREAT CONTROL OF LIGHT QUALITIES

MAXIMUM POSSIBLE



EFFICACY = **680** LUMENS PER WATT

MONOCHROMATIC YELLOW-GREEN LIGHT

BUT, ONLY EFFICACY = **200** LUMENS PER WATT

YELLOW GREEN

"WHITE" LIGHT (ALL OF VISABLE SPECTRUM COMBINED)

SINCE HUMAN EYE MOST SENSITIVE TO

BUT, WE NEED WHITE LIGHT FOR BEST COLOR RENDITION

CH 13 DAY LIGHTING

→ RE-READ CH 7 NOTES (PASSIVE SOLAR)
CH 11 NOTES (JUST VERY LAST PART ON ROMAN ARCHITECTURE)

HISTORY

→ UNTIL 1800'S, NO ARTIFICIAL LIGHTING DURING DAY

→ WESTERN CIVILIZATION → 50AD, FIRST GLASS WINDOWS
→ SUNROOMS
→ PANTHEON OCCULUS GOOGLE IMG.

700BC-500AD

ROMAN

→ GROIN VAULT REPLACES BARREL VAULT

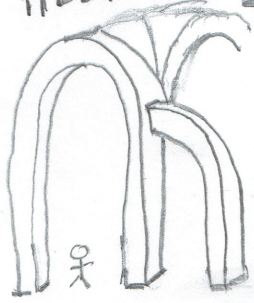


MORE LIGHT IN



~1300'S

GOTHIC ARCHITECTS USE GROIN VAULT AND MADE THEM HUGE, WITH THE HELP OF FLYING BUTTRESSES GOOGLE IMG.



~1400 TO ~1700AD

RENAISSANCE WINDOWS DOMINATE WALLS

GOOGLE IMG.
"HARDWICK HALL"

FLOOR PLANS (PRE-1900'S)

- HIGH SURFACE-AREA-TO-VOLUME
- CALLED ENVELOPE DOMINATED BUILDING (E.D. BUILDING)
- MAX LIGHT IN!!
- ALSO YIELDS GOOD VENTILATION

EX'S



~ 1860's
TO
PRESENT

INDUSTRIAL REVOLUTION
1860's +

→ "MODERNISM"
1900's

STEEL, MASS PRODUCTION

- CURTAIN WALLS OF GLASS
- SKYLIGHTS
- HUGE SUN-SPACES
- GLASS BLOCK

NON-WESTERN

ASIA FOR 1000'S OF YEARS

- SUN INTEGRATED INTO
WAY OF LIFE

CHINA:

GOOGLE IMG:

"FENG SHUI SUNLIGHT"

JAPAN:

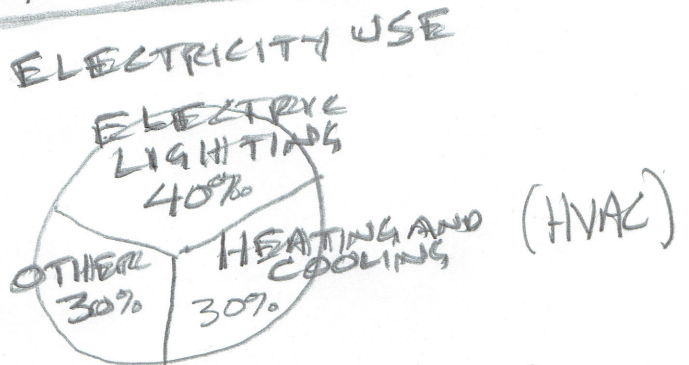
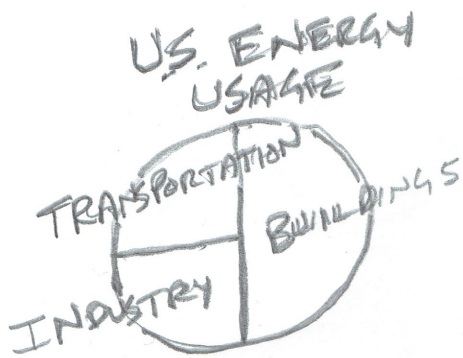
GOOGLE IMG:

"JAPANESE STEPPED
MOUNTAIN HOME"

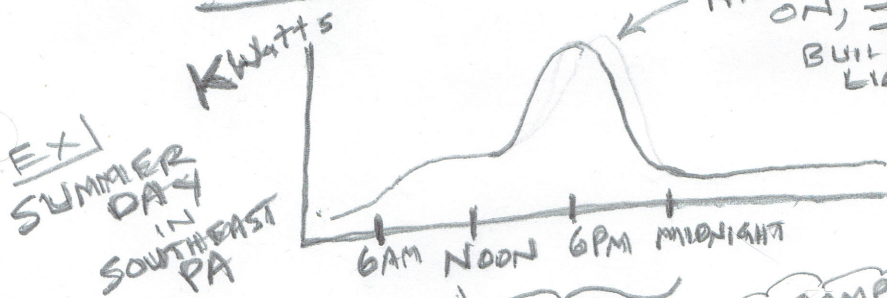
LAWS FOR SUNLIGHT

- TO 500 AD → ROMAN "SUN RIGHTS"
- ~1200 AD → ENGLAND DAYLIGHT-ACCESS LAWS
- 1900's → NEW YORK CITY ZONING MINIMUM-LEVELS OF DAYLIGHT
- PRESENT → MANY U.S. LOCAL ZONING LAWS FOR BUILDING HEIGHT RESTRICTIONS (∴ DON'T BLOCK SUNLIGHT TO ADJACENT PROPERTIES)

RATIONABLE FOR WHY WE MUST USE MORE DAYLIGHTING



DEMAND = \$ (TIME OF DAY)



PA. POWER COMPANY RATE STRUCTURES

- CHARGES MORE \$ FOR USAGE DURING PEAK TIMES

\$ MILLION IDEA

- COMPRESS GAS DURING OFF PEAK, USE IT TO GENERATE ELECTRICITY DURING PEAK

COMPANY **SUSTAIN X**
 FOUNDED BY ALUMNI CENGR DAX KESHIRE AND ETOWN ENGINEERING FACULTY MEMBER TROY McBRIDE

ONLY

3 FT x 3 FT

WINDOW

AND CAN ILLUMINATE A FLOOR AREA = 450 TO 2250 S.F.
(OVERCAST DAY) (SUNNY DAY)

= 100

60 WATT LAMPS

QUANTITY
EACH

LEED CREDITS FOR DAYLIGHTING

1	FOR 75% OF BUILDING DAYLIT
2	FOR 90% OF BUILDING DAYLIT
1 TO 10	FOR DAYLIGHT IMPROVING ENERGY EFFICIENCY OF BUILDING (ACTIVE AND PASSIVE)
1	FOR 90% OF OCCUPANTS HAVING GOOD VIEWS

REFLECTANCE

- CHANNEL LIGHT WHERE YOU WANT IT
 - INTO BUILDING
 - WHITE PATIO
- THROUGHOUT INTERIOR
 - LIGHT-COLORED WALLS

MATERIAL REFLECTANCE

ASPHALT	10
CONCRETE	30 TO 50
GRASS	10 TO 35
BLACK PAINT	4
WHITE PAINT	70-90

DAYLIGHT FACTOR %

↑ TYPICAL BEFORE ANY SPECIAL MEASURES DESIGNED

→ RATIO OF ILLUMINATION INDOORS TO ^{SUN} OUTDOORS ON OVERCAST DAY

GETTING

SPACE	DAYLIGHT FACTOR (%)
STUDIO	4-6%
FACTORY, LAB	3-5%
OFFICE, CLASSROOM GYM, KITCHEN	2%
LOBBY, LOUNGE LIVING ROOM, CHURCH	1%
HALLWAY, BEDROOM	0.5%

VARIATIONS DUE TO TYPICAL FLOOR PLANS

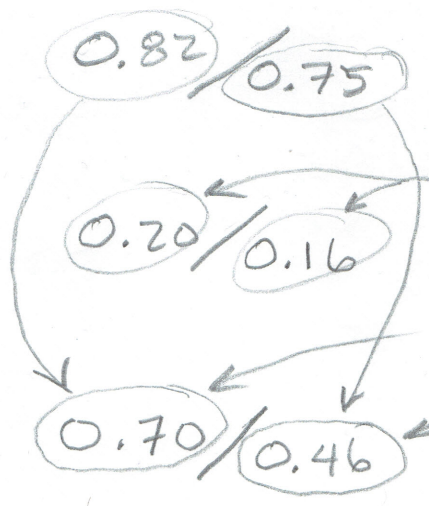
→ SO, NOT MUCH GETS IN ON OVERCAST DAYS
→ SO, MUST TAKE EXTRA MEASURES TO CHANNEL SUN INTO BUILDINGS!

BUT, CONSIDER A COST/BENEFIT TYPE RATIO:

BENEFIT SUNLIGHT-IN VS. HEAT FROM SUN-IN COST IF YOU DON'T WANT IT

$$L \frac{S}{G} \text{ RATIO} = \frac{V \text{ (VISIBLE TRANSMITTANCE)}}{SHGC \text{ (SOLAR HEAT AIR COEFFICIENT)}}$$

CLEAR GLASS 1.20 =
REFLECTIVE GLASS 1.25 =
SPECTRALLY SELECTIVE LOW-e GLASS 1.52 =

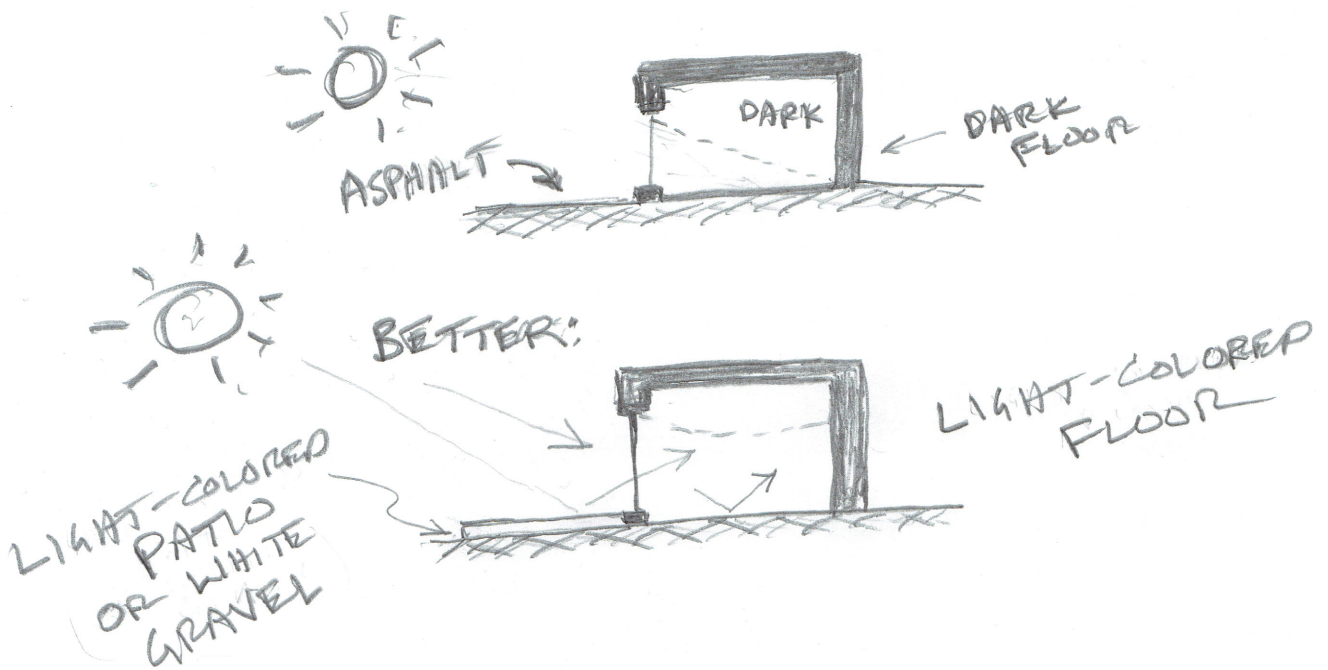


ALL LIGHT AND HEAT GETTING IN

EVERYTHING BLOCKED

LET MOST LIGHT IN BUT BLOCK MOST HEAT

ILLUMINATION GRADIENT



BUILDING ORIENTATIONS

- SOUTH:** INTENSE, MAX LIGHT, EASIEST TO CHANNEL
- NORTH:** BEST ALL-YEAR, ALL-DAY EVEN LIGHTING, BUT LOW INTENSITY
- EAST:** NICE MORNING SUN, BUT ~ DARK REST OF DAY
- WEST:** NICE SUNSET, BUT CAN SERIOUSLY OVERHEAT HOUSE

SKYLIGHTS: PROBLEMS: IC

- Δ SUN INTENSITY $\uparrow\uparrow$
- LEAK IN PATH

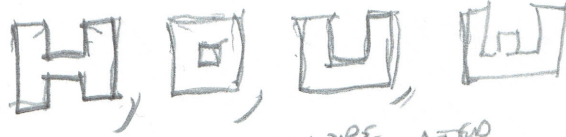
BUT IF PROPERLY DESIGNED

\rightarrow SOLUTION: BLINDS

LEAKS ARE VERY MUCH LIGHT

HOW TO GET LIGHT DEEP INTO BUILDING

- ① MAX SURFACE AREA SHAPES (BUILDING FOOTPRINTS)



FOR E. D. ^{ENVELOPE DOMINATED} BUILDINGS AND I. D.

- ② FOR I. D. ^{INTERNALLY DOMINATED} BUILDINGS, USE

• EVENLY DISTRIBUTED ON TALL CEILINGS
• CHANNEL LIGHT WITH REFLECTORS AND CEILING/WALLS

- SKYLIGHTS
- LIGHT-TUBES
- CLEAR-STORY WINDOWS
- LIGHT "SCOOPS"
- CURTAIN WALLS

- ③ TALL CEILINGS, TALL WINDOWS

- ④ DISTRIBUTE WINDOWS EVENLY

- ⑤ LIGHT-COLORED WALLS CLOSE TO WINDOWS TO CHANNEL LIGHT

- ⑥ TRANSLUCENT DRAPES

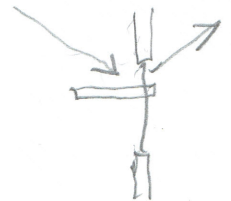
- ⑦ CHANNEL LIGHT WITH OPERABLE LOUVERS (ON WINDOWS, ETC.)

→ VENETIAN BLINDS

- ⑧ CHANNEL LIGHT IN WITH REFLECTIVE WINDOW SILLS (OR EVEN "LIGHT SHELVES")

- ⑨ GLASS FLOORS

- ⑩ HELIOSTAT
→ BIG DISH COLLECTS LIGHT



DISTRIBUTE LIGHT WITH FIBRE OPTICS

⑪ TRANSLUCENT WALLS + WINDOWS

→ LIKE TENTS

EX LANCASTER, PA MALL

"PARK CITY"

TABLE 14.2

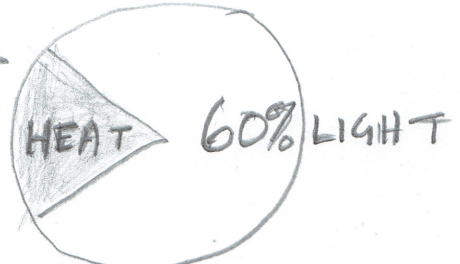
EFFICIENCY

DIFFERENT THAN EFFICIENCY (LUMENS PER WATT)

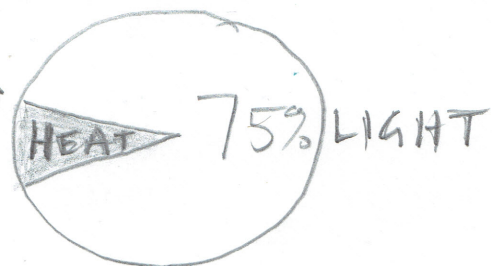
= MAX WATTS PER SQUARE FOOT OF BUILDING
 → A STANDARD DESIGN GOAL

BAD

5	BEFORE ANY CODES OR STANDARDS
1.2	AMERICAN SOCIETY OF HEATING AND REFRIGERATION ENGINEERS STANDARD
0.9	LEED
0.45	BEST MAX POSSIBLE DURING DAY IF DAYLIGHTING USED



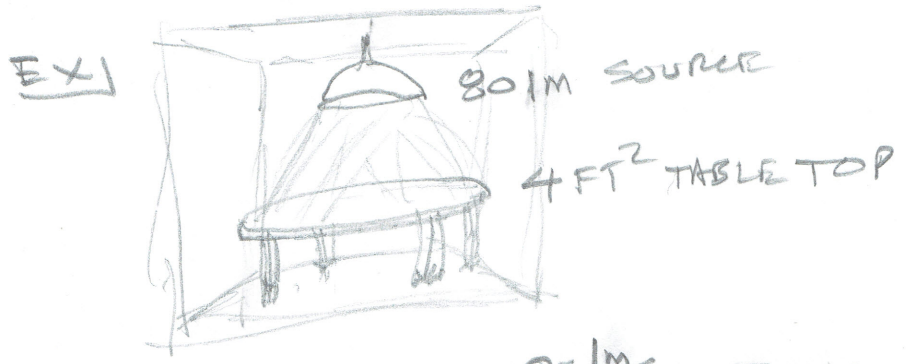
SUNLIGHT THROUGH CLEAR GLASS



SUNLIGHT THROUGH SPECTRALLY-SELECTIVE LOW-E GLAZING (GLASS)

ILLUMINANCE / FOOTCANDLE (LUX) METRIC

LIGHT INCIDENT ON A UNIT AREA



$\frac{80lm}{4ft^2} = 20 \text{ FOOTCANDLES OF ILLUMINATION}$

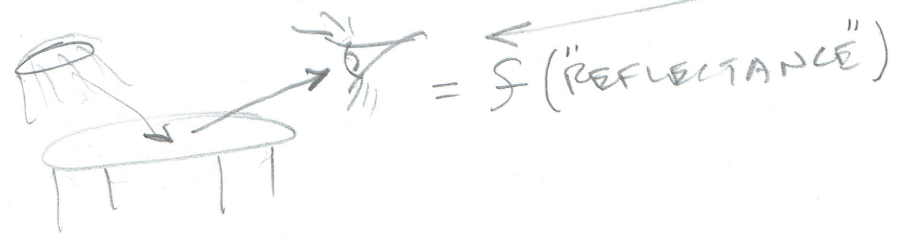
BRIGHTNESS VS. **LUMINANCE**

PERCEIVED
= f (EYE'S ADAPTATION)
= f (PSYCHOLOGY)

VIA LIGHT METER (OR EYE)

- EX) BRIGHT LIGHT AT NIGHT
- EX) GLARE

★ DESIGN FOR BOTH



LUMINANCE NEEDED = f (① TASK, ② EYE PERFORMANCE, ③ PSYCHOLOGY, ④ CONTRAST NEEDED)

TASK	FOOTCANDLES NEEDED
RESIDENTIAL (NO-work)	8
RESIDENTIAL (work)	30
CLASSROOM	75

★ REDUCE GLARE WITH "DIFFUSERS" AND LAMP SHADES AND WALL & CEILING COLORS/TEXTURES

BRIGHTNESS RATIO

VARIATION IN BRIGHTNESS BETWEEN AREAS

AREAS	MAX RATIO
BOOK TO DESK	3:1
" " NEARBY	5:1
" " FAR "	10:1
WINDOW TO ADJACENT WALL	20:1

PSYCHOLOGICAL CONSIDERATIONS

- ① SPACIAL ORIENTATION
- ② TIME "
- ③ FORM IDENTIFICATION (EDGES) → DETECTION
- ④ ACTIVITY ENHANCEMENT
- ⑤ DEFINE PERSONAL SPACE
- ⑥ HAPPINESS (WE NEED DAYLIGHT) REAL OR SIMULATED
- ⑦ VISUAL DIVERSITY NEEDS
- ⑧ ORDER "
- ⑨ SECURITY "
- ⑩ LIGHT POETRY
 - SUNSET / SUNRISE
 - SUNLIGHT ON A STREAM
 - FOUNTAINS
 - WATER FALLS
 - CRY POUNDS
 - UPLIGHTING ON STATUES + BLDGS
 - SPOTS ON PAINTINGS + TREES
- ⑪ COMBINING SOURCE-TYPES WITH WALL / CEILING / FLOOR COLORS + TEXTURES
- ⑫ MAXIMUM NATURAL DAY LIGHT