Daylight & Architecture

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Daylighting

Daylighting

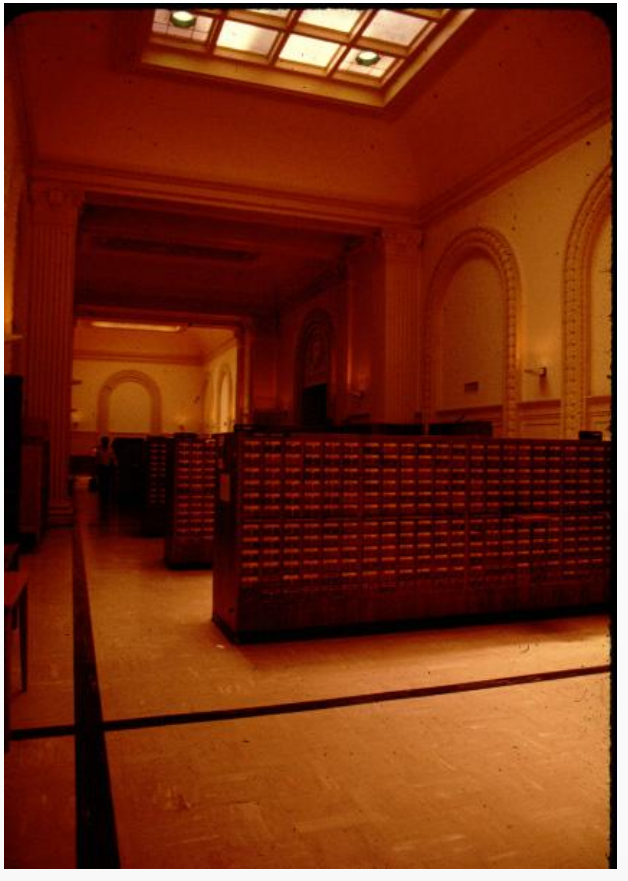
Outline

- Benefits of daylighting
- Climate & weather
- Source characteristics
- Design criteria
- Design strategies
- Energy savings
- Case studies
- Summary; Q&A

Benefits of Daylighting

Daylighting

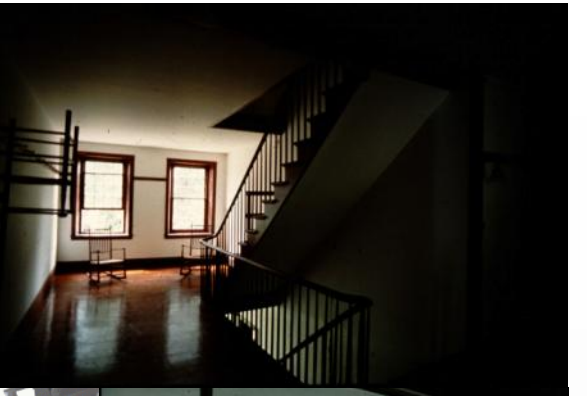
- **Energy savings**
  - Conservation by using daylight
  - Peak demand cost savings
- **Design & construction**
  - Integrate systems
  - Key element of architecture & interiors
  - Building form factor
  - Low or no cost additions



Benefits of Daylighting

Daylighting

- **Occupant issues**
  - Dynamic quality
  - Always changing intensity & color of light
  - View an important psychological element
  - Effect on impressions of activity setting & mood
  - People want daylight inside buildings
  - Architecture & space primarily experienced through vision



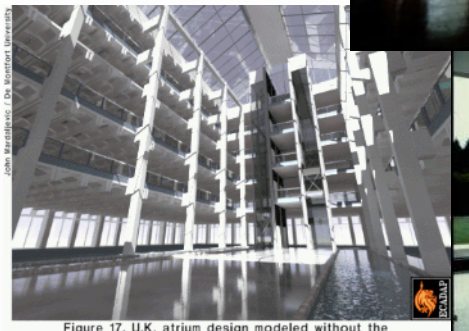
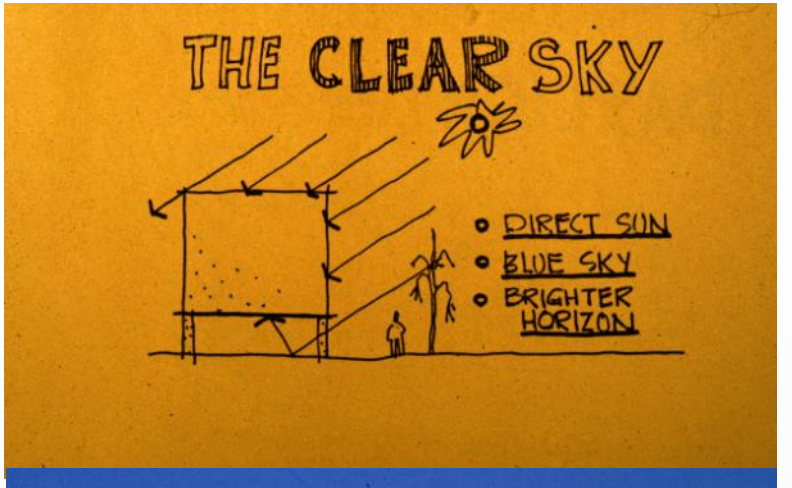


Figure 17. U.K. atrium design modeled without the benefit of a CAD system, using only Radiance scene description utilities.

Climate & Weather

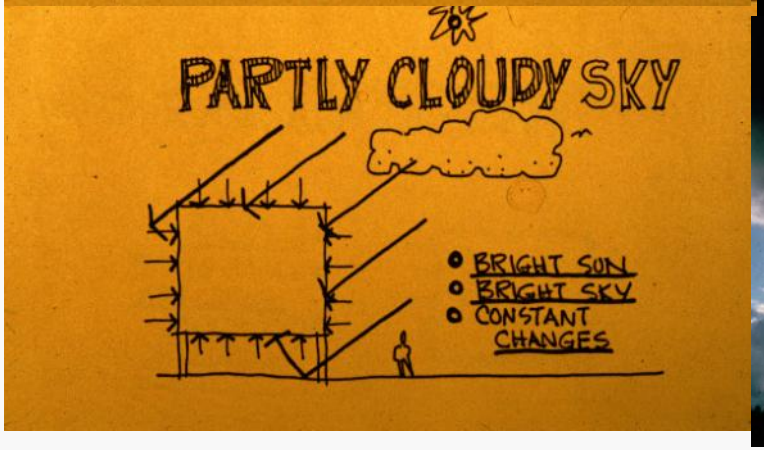
Daylighting

- **Sky conditions**
  - Clear sky
  - Overcast sky
  - Partly cloudy sky



Climate & Weather -- **Sky conditions**

Daylighting



Daylighting

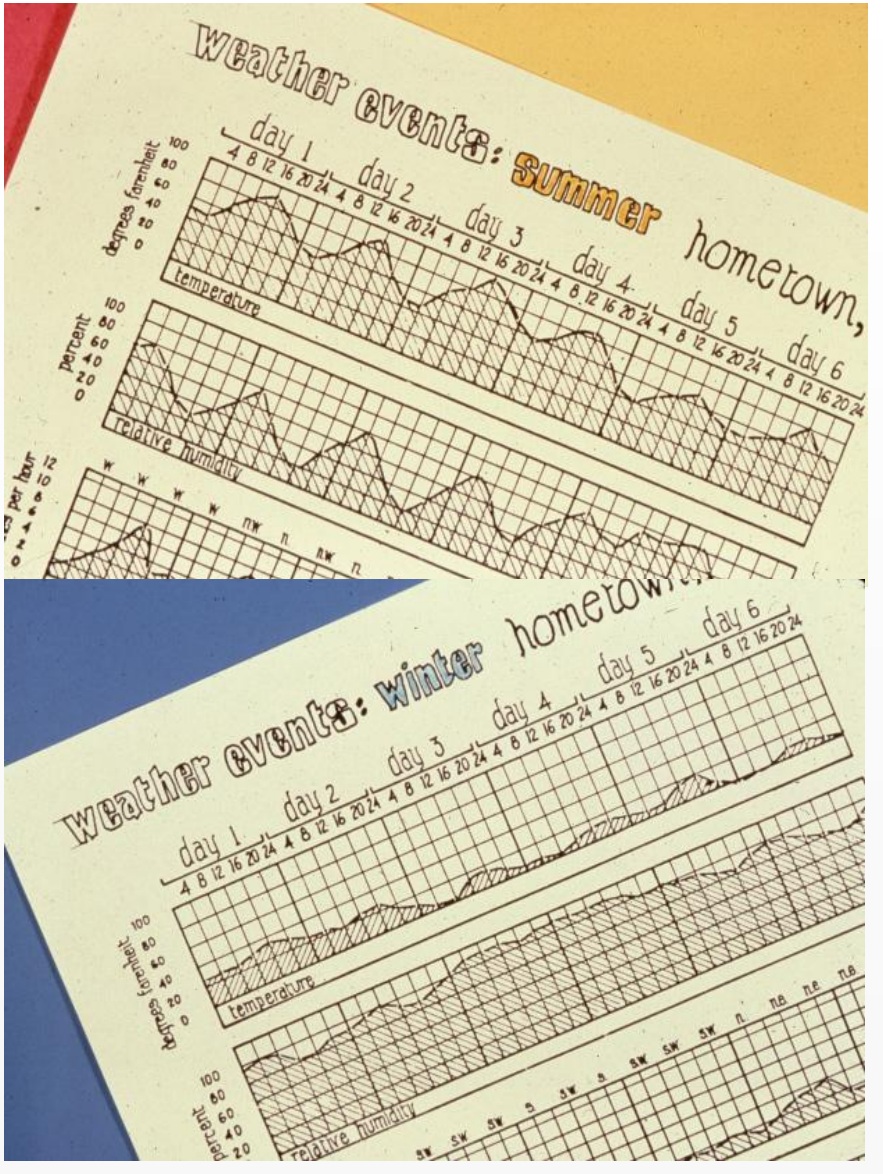
Climate & Weather

- **Climate types**
  - Hot, arid
  - Hot, humid
  - Cold
  - Temperate

Climate & Weather

Daylighting

- **Daylight availability**
  - Varies by climate type & cloud conditions
  - Impacted by pollution & emissions
  - Varies by solar altitude & azimuth
  - Varies by season
  - Directly impacted by geometry of space
  - Impacted by obstructions on adjacent site



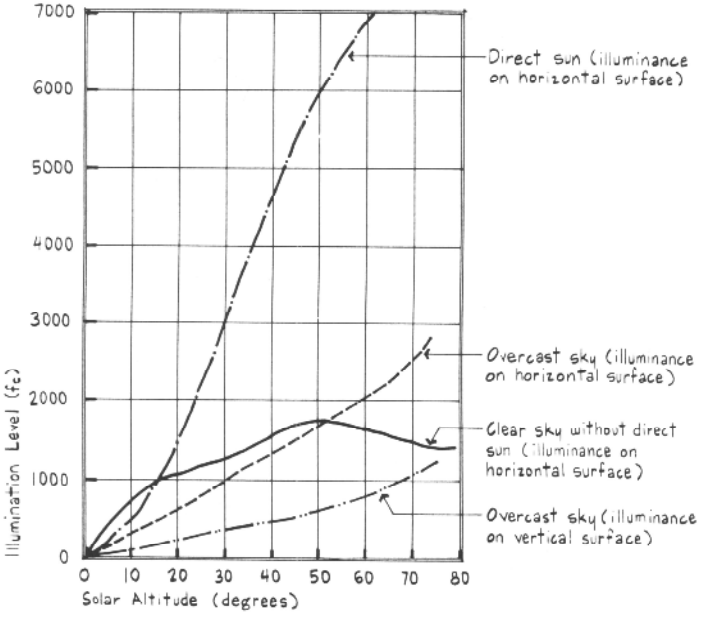
Source Characteristics

Daylighting

- **Sun**
  - High levels at higher solar altitude
- **Overcast sky**
  - Higher levels at higher solar altitude
- **Clear sky**
  - Higher levels at lower solar altitude when compared to overcast skies

DAYLIGHT ILLUMINANCE

The graph below presents average illuminance (in fc) for clear and overcast sky conditions. Actual levels may vary considerably due to changes in weather conditions.



Note: For additional illuminance data, refer to J. E. Kaufman (ed.), *IES Lighting Handbook* (1981 Reference Volume), p. 7-8. Maps of the United States showing available daylight in numbers of days and hours per year are also presented in Chapter 7 of the handbook.

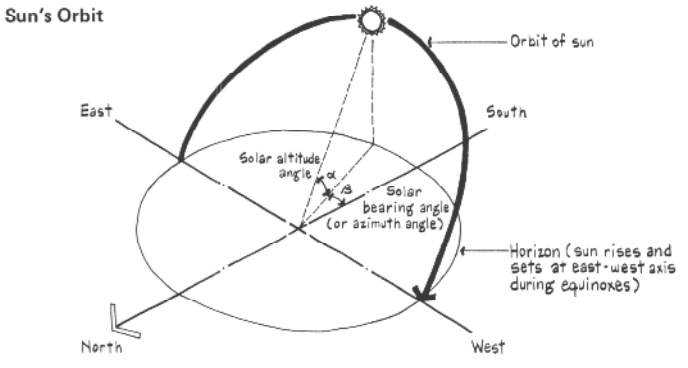
Source Characteristics

Daylighting

- Solar altitude & azimuth
- Winter & summer solstice; spring & fall equinox

SOLAR ANGLES

The position of the sun varies according to latitude (see map on preceding page), season, and time of day. As shown by the orbit sketch below, solar altitude angle ($\angle \alpha$) is measured between the horizon and the position of the sun above the horizon. Solar bearing angle ($\angle \beta$) is measured from the north-south axis to the vertical plane through the sun.



The table below presents solar altitude angle and bearing angle at various latitudes. Noon is the instant when the sun is at the highest point in its daily orbit.

North latitude	Solar angle (degrees)	Winter solstice (21 Dec.) 6 a.m. 6 p.m.	8 a.m. 4 p.m.	10 a.m. 2 p.m.	Noon	Spring equinox (21 Mar.) Fall equinox (21 Sep.) 6 a.m. 6 p.m.	8 a.m. 4 p.m.	10 a.m. 2 p.m.	Noon	Summer solstice (21 June) 6 a.m. 6 p.m.	8 a.m. 4 p.m.	10 a.m. 2 p.m.	Noon
46°	altitude (α)	–	2	15	21	–	20	37	44	17	37	57	67
	bearing (β)	–	52	28	0	90	67	39	0	107	88	58	0
42°	altitude (α)	–	4	19	25	–	22	40	48	16	38	60	71
	bearing (β)	–	53	29	0	90	69	41	0	108	89	63	0
38°	altitude (α)	–	7	23	28	–	23	43	52	14	37	61	75
	bearing (β)	–	54	30	0	90	71	43	0	109	90	70	0
34°	altitude (α)	–	9	26	33	–	25	46	56	13	37	62	79
	bearing (β)	–	54	30	0	90	72	46	0	110	95	78	0
30°	altitude (α)	–	12	29	37	–	26	49	60	12	37	63	83
	bearing (β)	–	54	32	0	90	74	49	0	111	99	84	0

Note: For comprehensive tables of solar angles at various latitudes, seasons, and times of day, refer to *ASHRAE Handbook* (1981 Fundamentals Volume), Atlanta, Ga., pp. 27.3 to 27.8, or J. E. Kaufman (ed.), *IES Lighting Handbook* (1981 Reference Volume), p. 7-4. For a graphic presentation of solar angles, sun angle calculators are available from Libbey-Owens-Ford Co., 811 Madison Avenue, Toledo, OH 43695.

Great site for sun angle & sun position caculations : http://www.susdesign.com/sunangle/index.html; http://www.susdesign.com/sunposition/index.html

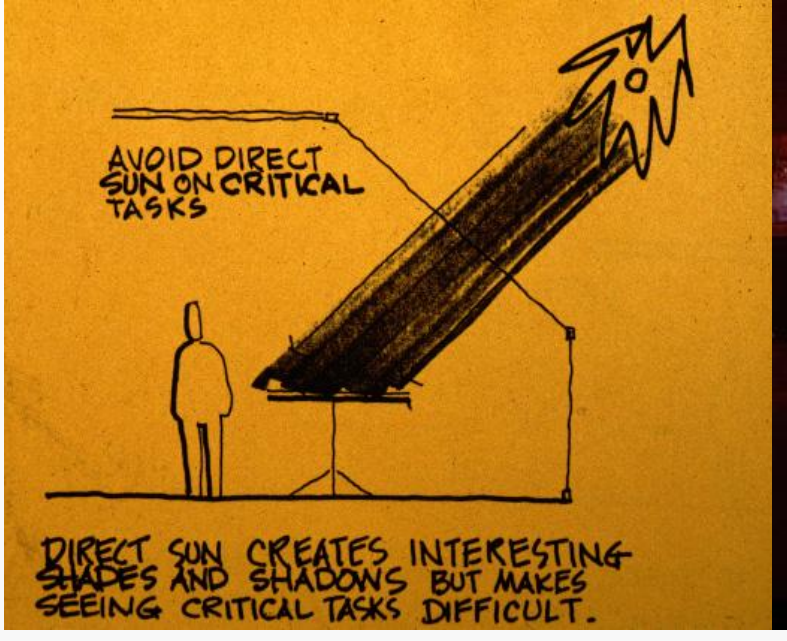
Design Criteria

- The following general design criteria, or rules of thumb, must be carefully assessed before using.
- Consider climate, location, site, specific building type, energy issues & human-centered needs before applying.
- What works in Phoenix may not work in Denver, Seattle, Miami or Bangkok!

Design Criteria

Daylighting

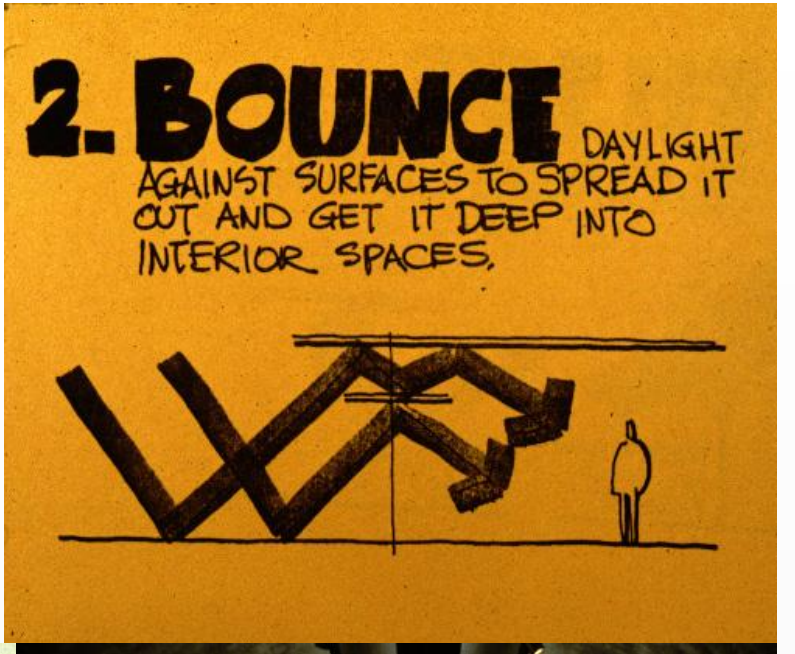
- Avoid direct skylight & sunlight on critical tasks

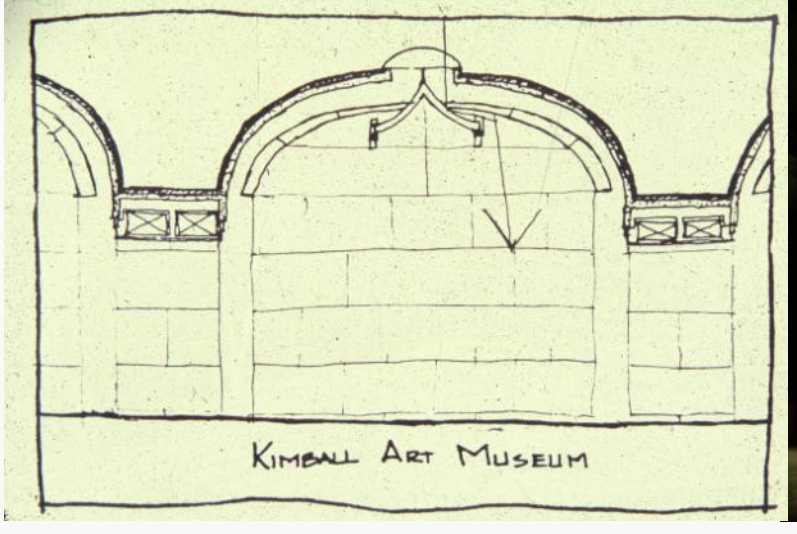


Design Criteria

Daylighting

- Bounce daylight off surrounding surfaces to diffuse light in more even brightness patterns

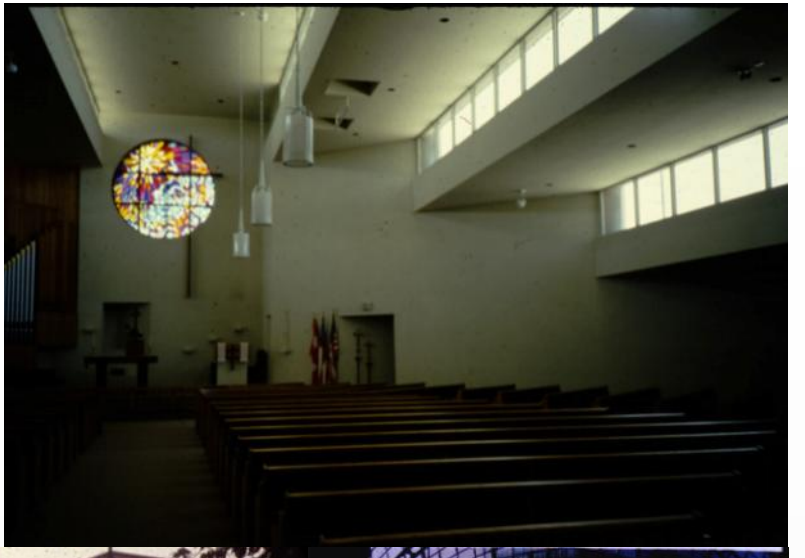




Daylighting

Design Criteria

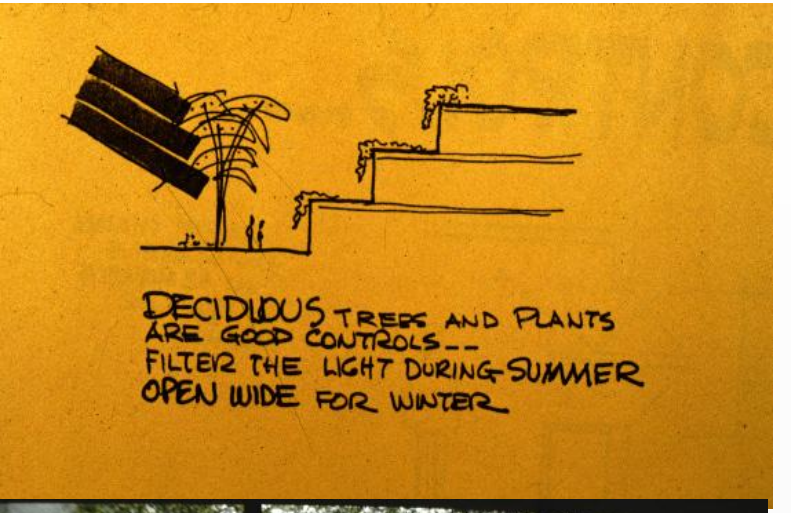
- Bring daylight in from above to obtain deeper penetration into space

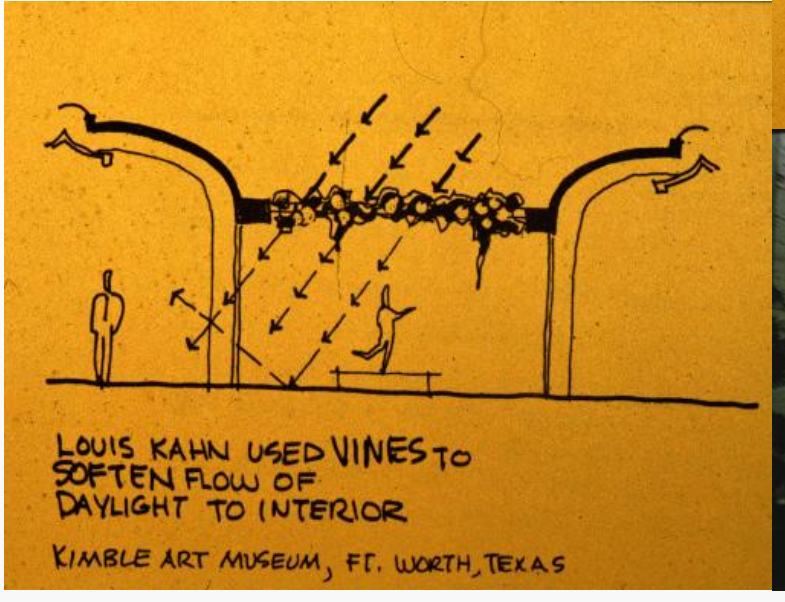


Design Criteria

Daylighting

- Filter daylight to avoid harshness of direct sun & sky light

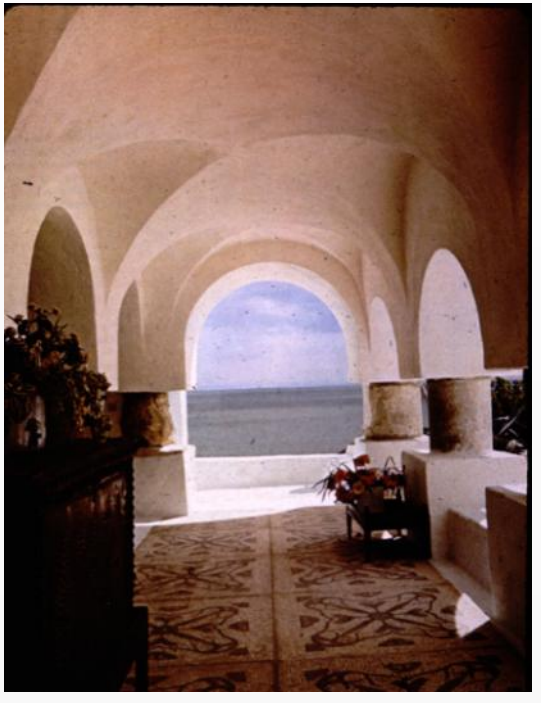




Design Criteria

Daylighting

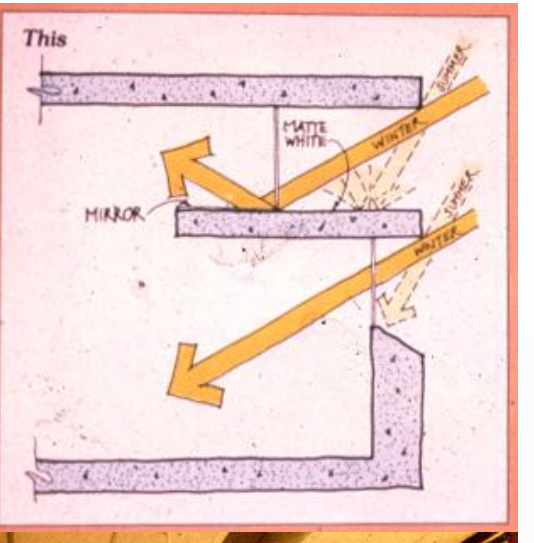
- Maximize ceiling heights to gain better light distribution

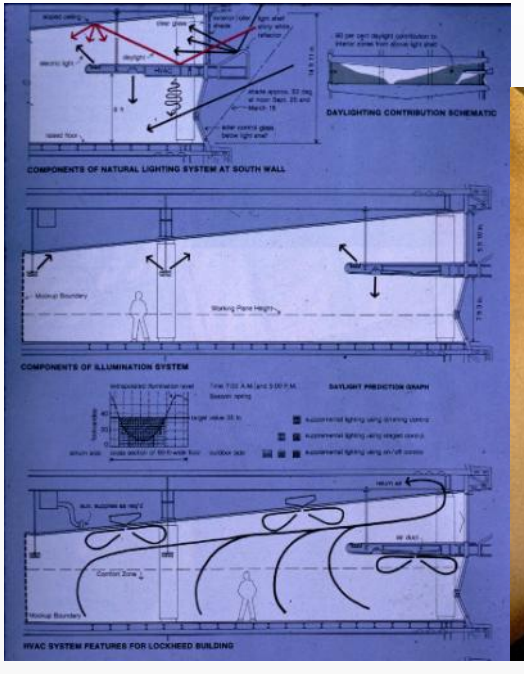


Design Criteria

Daylighting

- Use design strategies that separate view glass from daylight glass. Example - light shelf





Daylighting

Design Criteria

- Use ambient or task lighting to relieve visual gloom

Daylighting

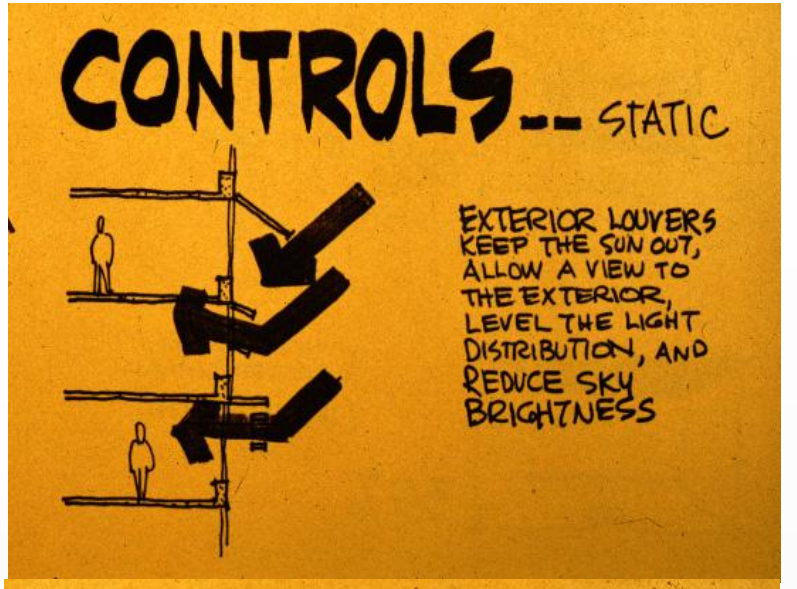
Design Criteria

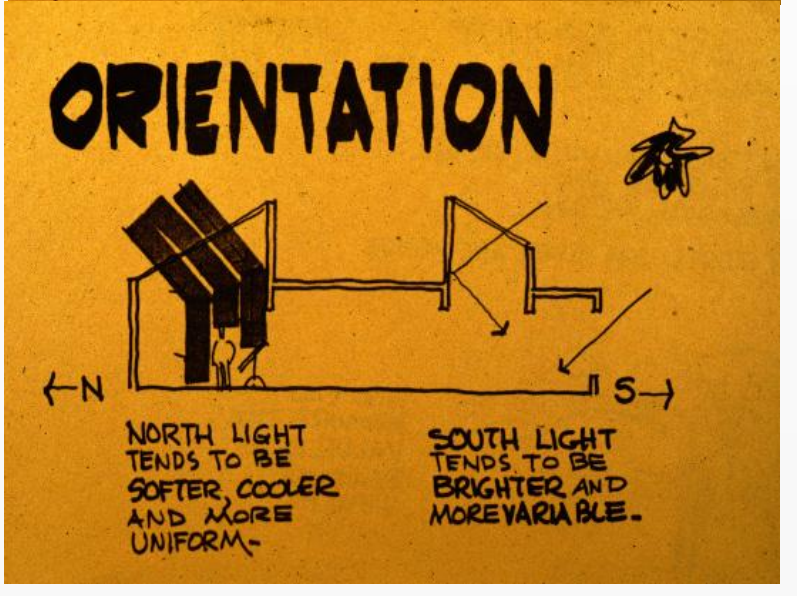
- Consider color of daylight combined with other sources

Daylighting

Design Criteria

- Develop appropriate control strategies
  - Glare
  - Thermal
  - View
  - Time of day at differing orientations
  - Nature of light due to controls and orientation
  - Climate type & sky conditions

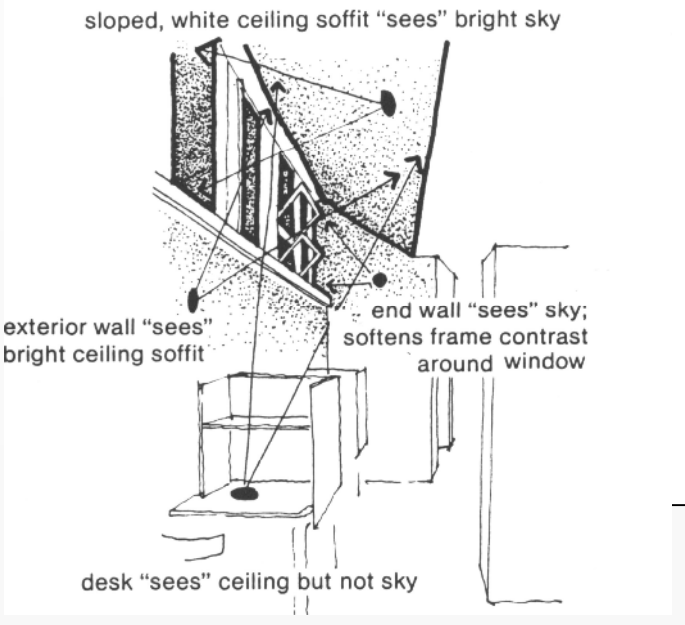




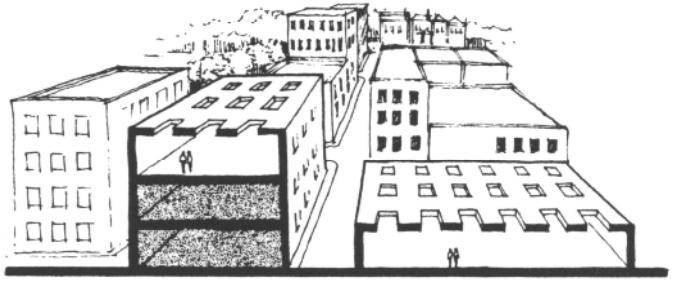
Design Criteria

Daylighting

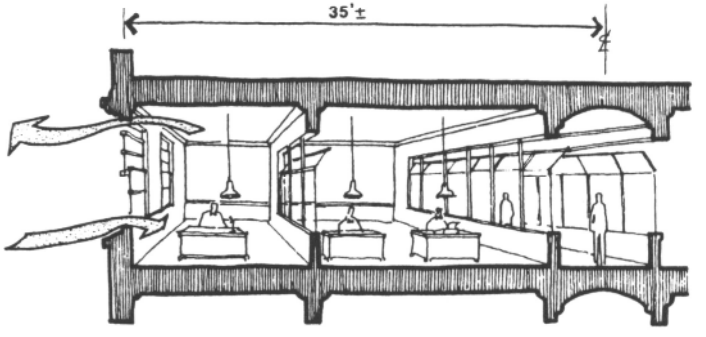
- Building geometry & spatial arrangement should promote, rather than preclude, distribution of daylight



Floor area available for top lighting is a function of roof area (and thus inversely of the number of floors).



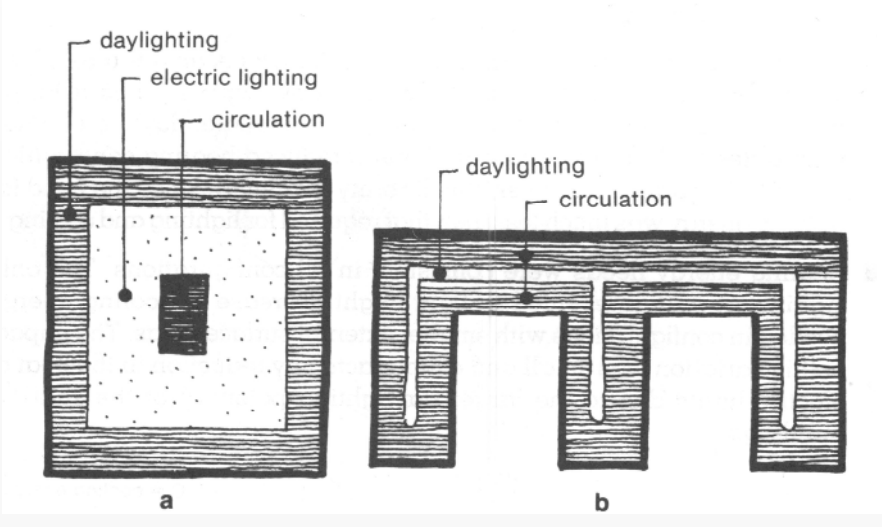
7-2. Typical pre-1950 office building (half section) allowed side light and ventilation penetration through transparent partitions and open transoms.



Design Criteria

Daylighting

- Buildings should be massed & configured so maximum # of spaces are near daylight



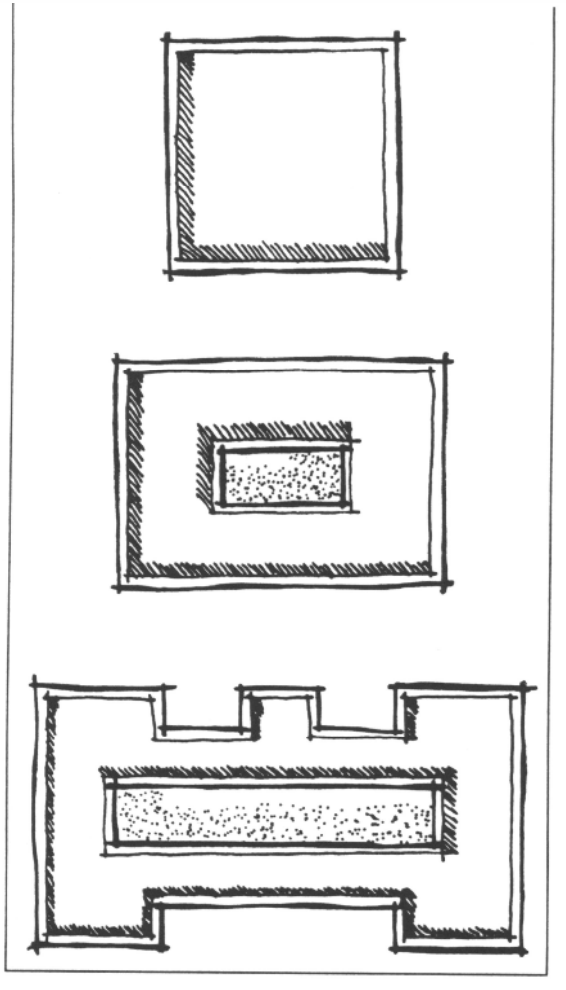


FIGURE 1.8
Articulated plans showing increased daylighting zones.

Room Geometry

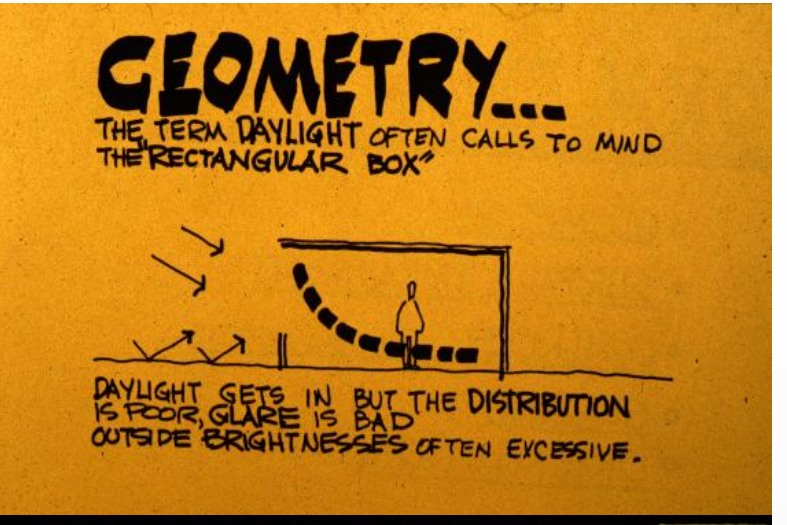
Daylighting

- The following room geometry rules of thumb may vary significantly with sky conditions, climate type or floor level.
- Site obstructions can have a major impact on light distribution & spread.
- Exterior & interior materials all effect reflected light within spaces.

Room Geometry

Daylighting

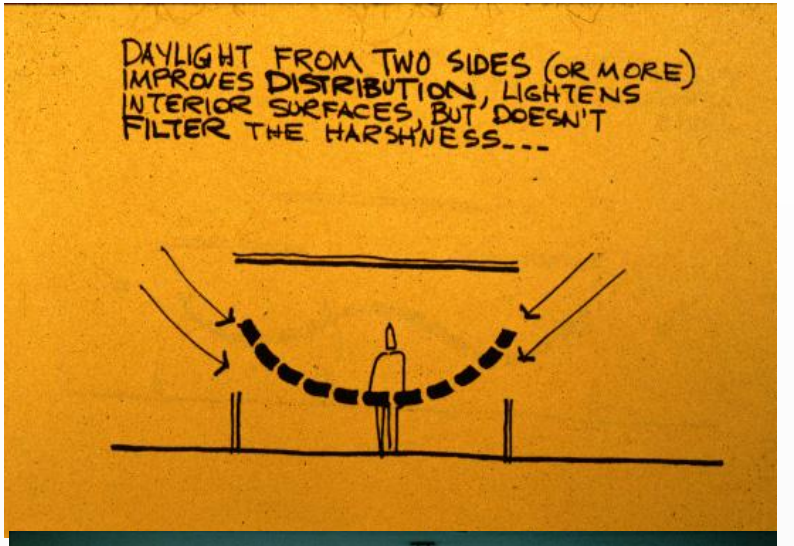
- **Single Sidelighting**
  - High E levels near window; low rear of room
  - 2.5 x Ht. To 10%



Room Geometry

Daylighting

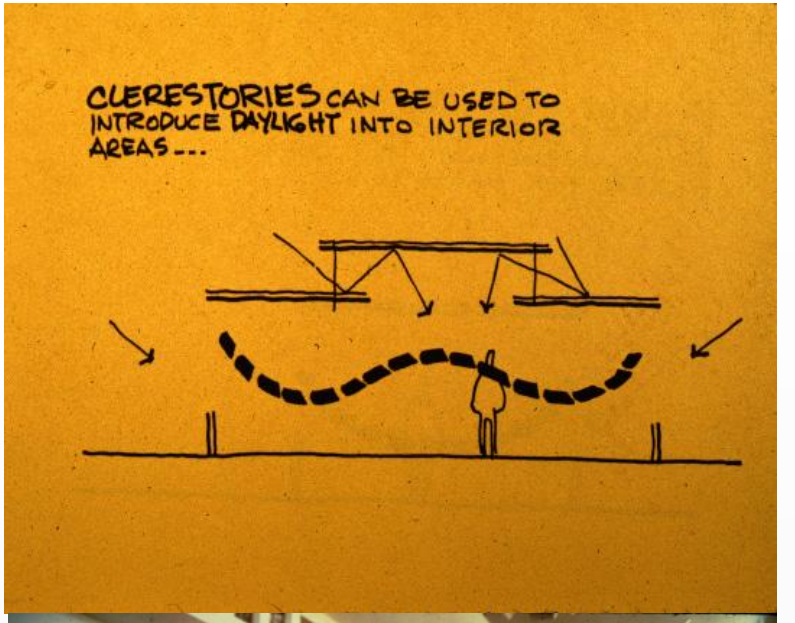
- **Bilateral lighting**
  - Better distribution balance
  - Less glare than single side lighting
  - Glare can still be a problem without filtering or bouncing light



Daylighting

Room Geometry

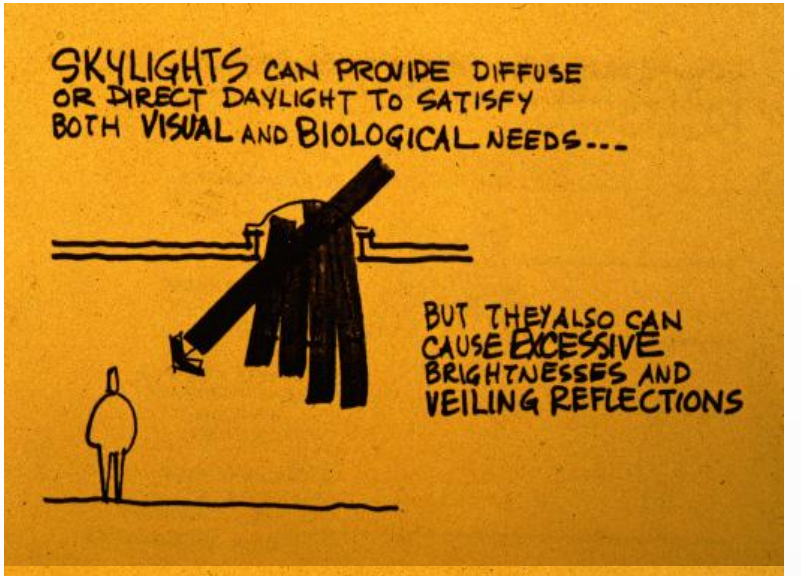
- Multilateral lighting
  - Light from multiple directions
  - Better brightness balance
  - Glare control still needed
  - Less use of artificial lighting during daylight hours
  - Controls by zone

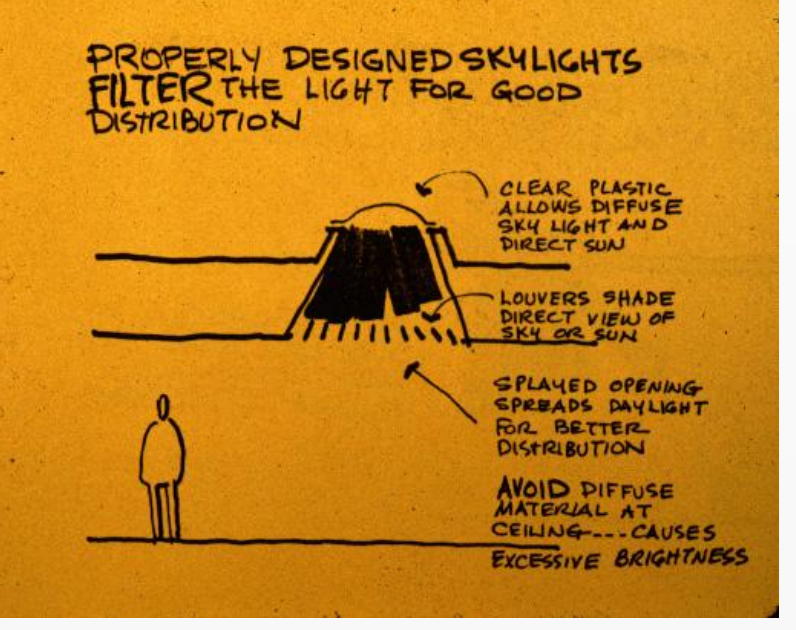


Room Geometry

Daylighting

- Top lighting
  - Atria & lightcourts
  - Skylights
  - Sunscoops (south)
  - Lightscoops (north)

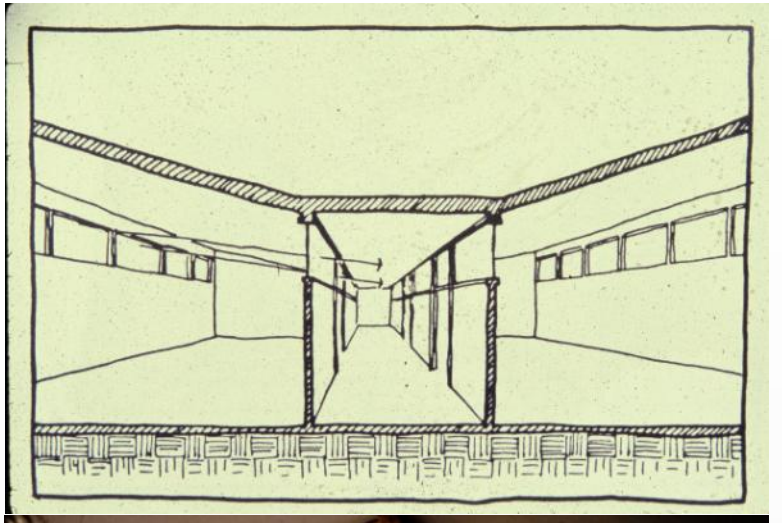




Daylighting

Room Geometry

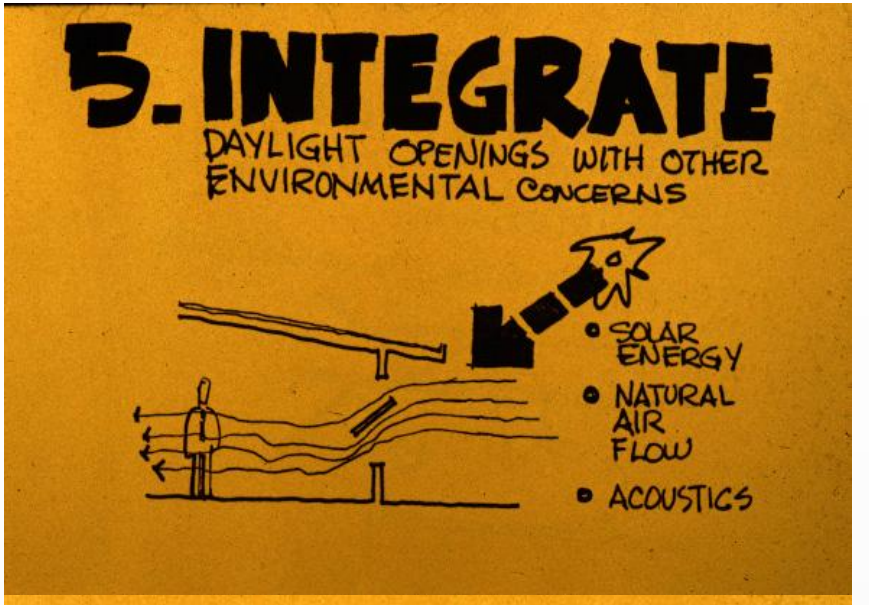
- **Borrowed light**
  - With acceptable depths, light can be shared to hallways & other spaces
  - Interior partitions must have glass or open space to share lighting
  - Noise/security concerns
  - Usually uses clerestories or glass located high in the exterior wall for best distribution.
  - Ceiling is a secondary light source!

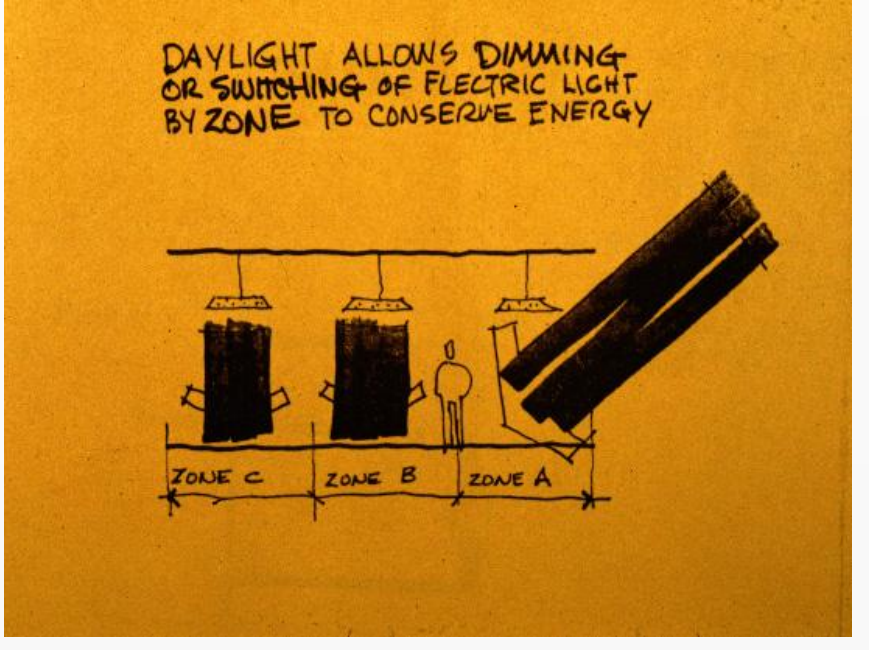


Daylighting

Energy Savings

- Integrate with other systems: lighting, mechanical, electrical, communications & others





Energy Savings

Daylighting

- Integration with electric lighting through differing control strategies:
  - Stepped
  - Dimming
  - Load shedding
  - Occupancy scheduling

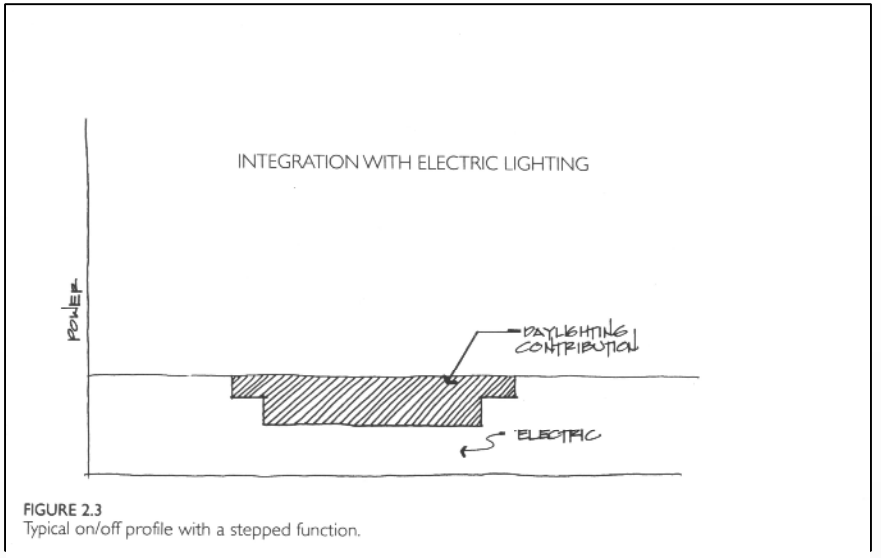


FIGURE 2.3
Typical on/off profile with a stepped function.

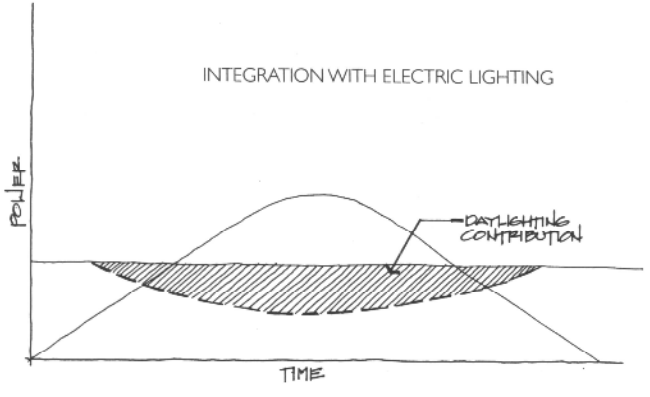


FIGURE 2.4
Typical dimming control profile.

Energy Savings

Daylighting

- Daylight is the most efficient source of light
- 1 watt of light equals 3.4 BTU of heat
- Efficacy & control strategies result in energy savings

4-1. Efficacy of various forms of daylight and electric lamps (sources: (a) Hopkinson et al., 1966; (b) I.E.S., 1981).

LIGHT SOURCE	EFFICACY (lumens/watt)	SOURCE
Sun (altitude = 7.5 degrees)	90 lm/w	(a)
Sun (altitude > 25 degrees)	117 lm/w	(a)
Sun (suggested mean altitude)	100 lm/w	(a)
Sky (clear)	150 lm/w	(a)
Sky (average)	125 lm/w	(a)
Global (average of sky and sun)	115 lm/w	(a)
Incandescent (150 w)	16–40 lm/w	(b)
Fluorescent (40 w, CWX)	50–80 lm/w	(b)
High Pressure Sodium	40–140 lm/w	(b)

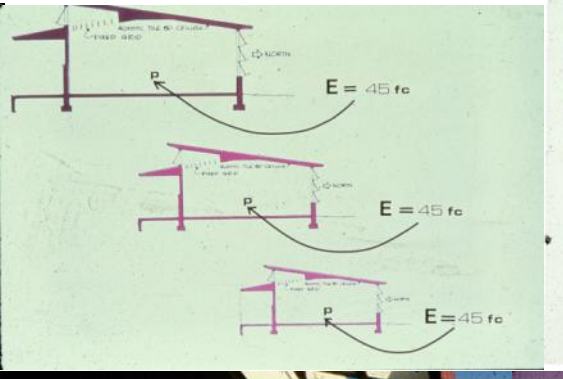
COMPARISON OF EFFICIENCIES OF DIFFERENT ILLUMINATION SOURCES

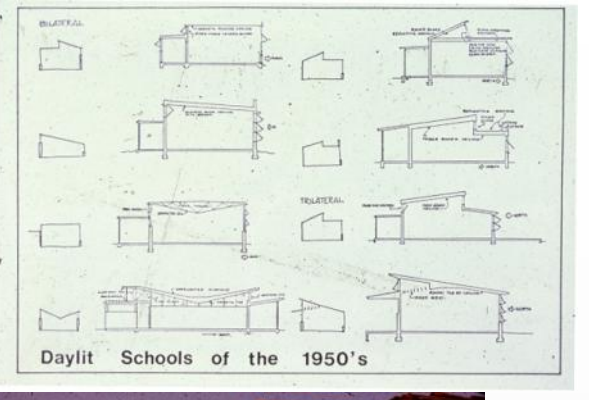
Illuminating Engineering Society, 1979

Source of Illumination	**Efficacy** lm/w	**AC Load** (tons/10,000 lm)
Daylight	106	0.27
Incandescent light	20	1.9
Fluorescent light	60	0.63

Case Study: CA Schools

Daylighting



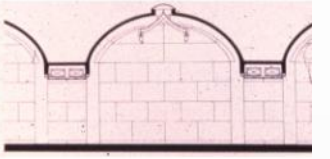
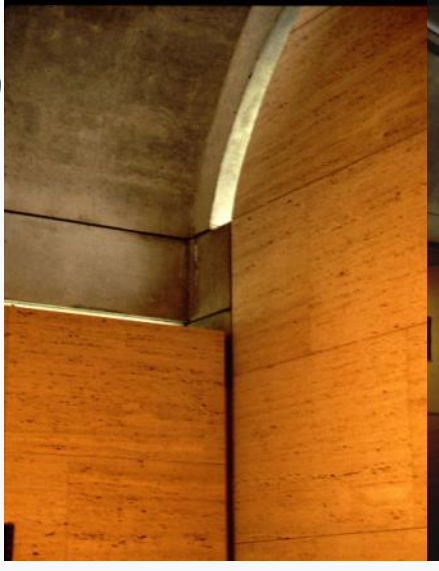


Case Study: Kimball Art Museum

Daylighting

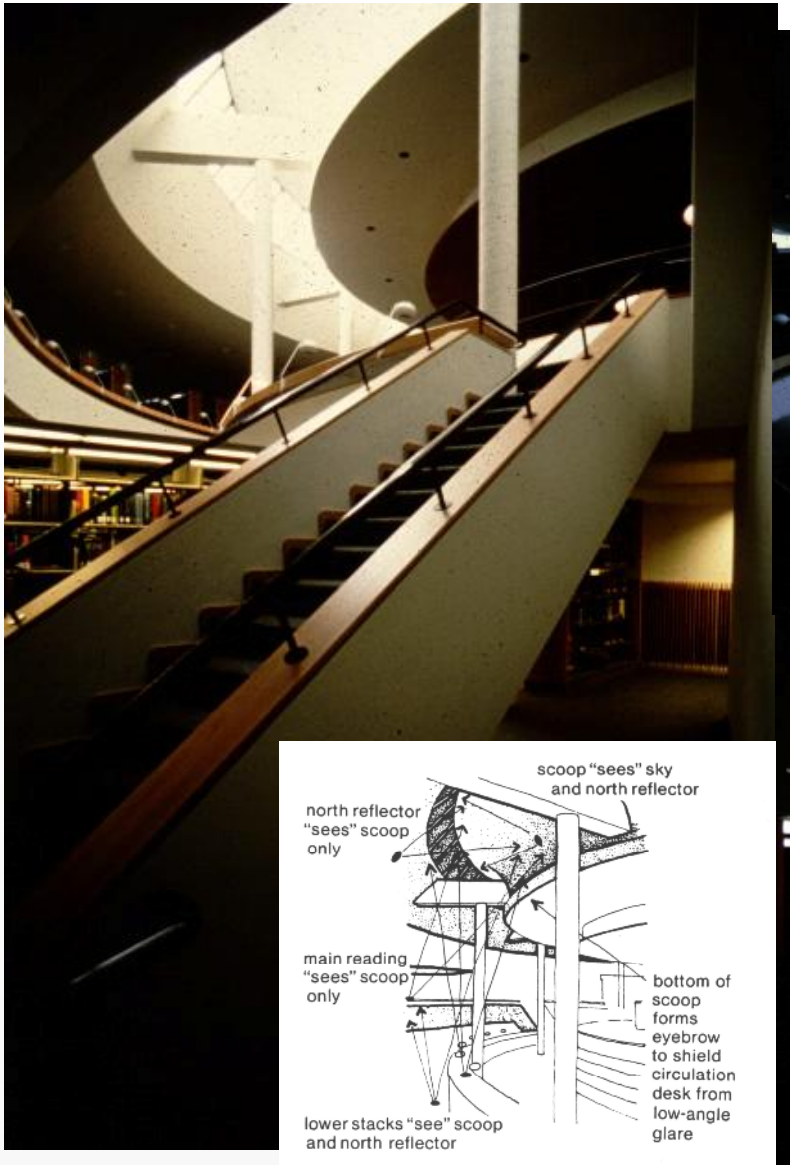


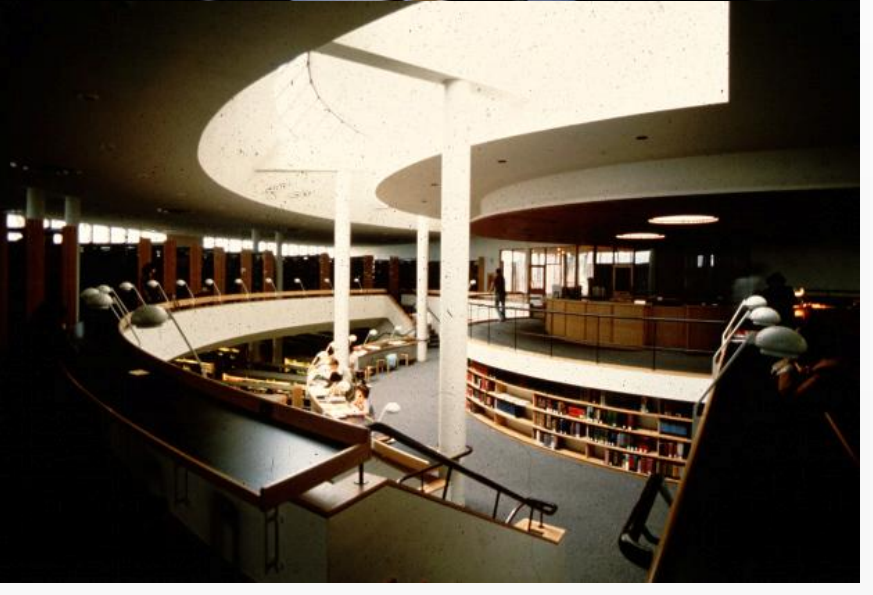



Case Study: Mt: Angel Abby Library

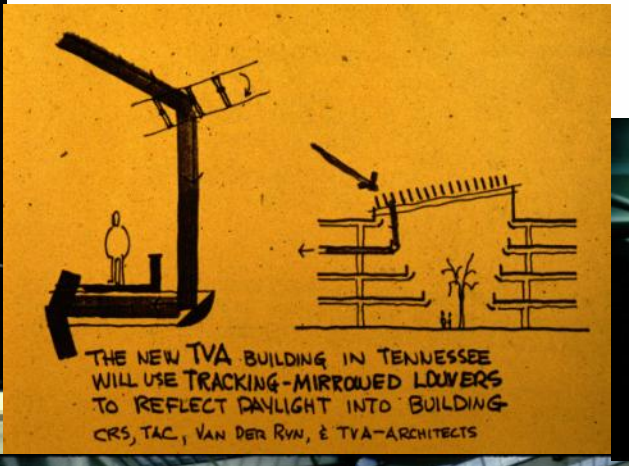
Daylighting





Case Study: TVA Building

Daylighting



Case Study: High Museum of Art

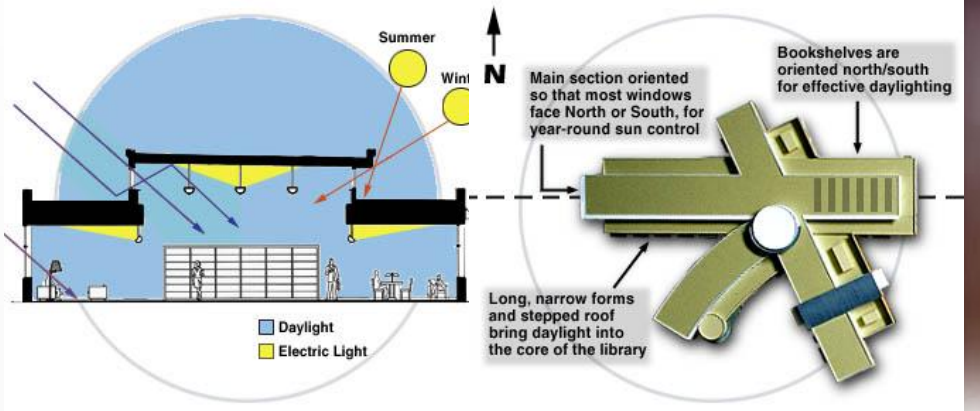
Daylighting

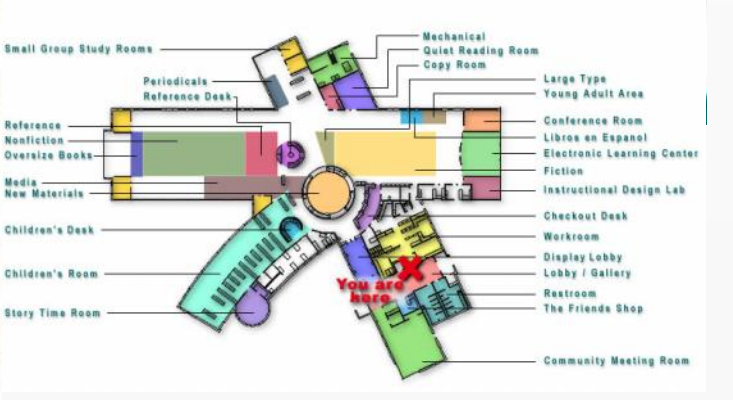
Case Study: Denver Airport

Daylighting

Case Study: Harmony Library

Daylighting





Summary & Discussion

Daylighting

- Integration is key