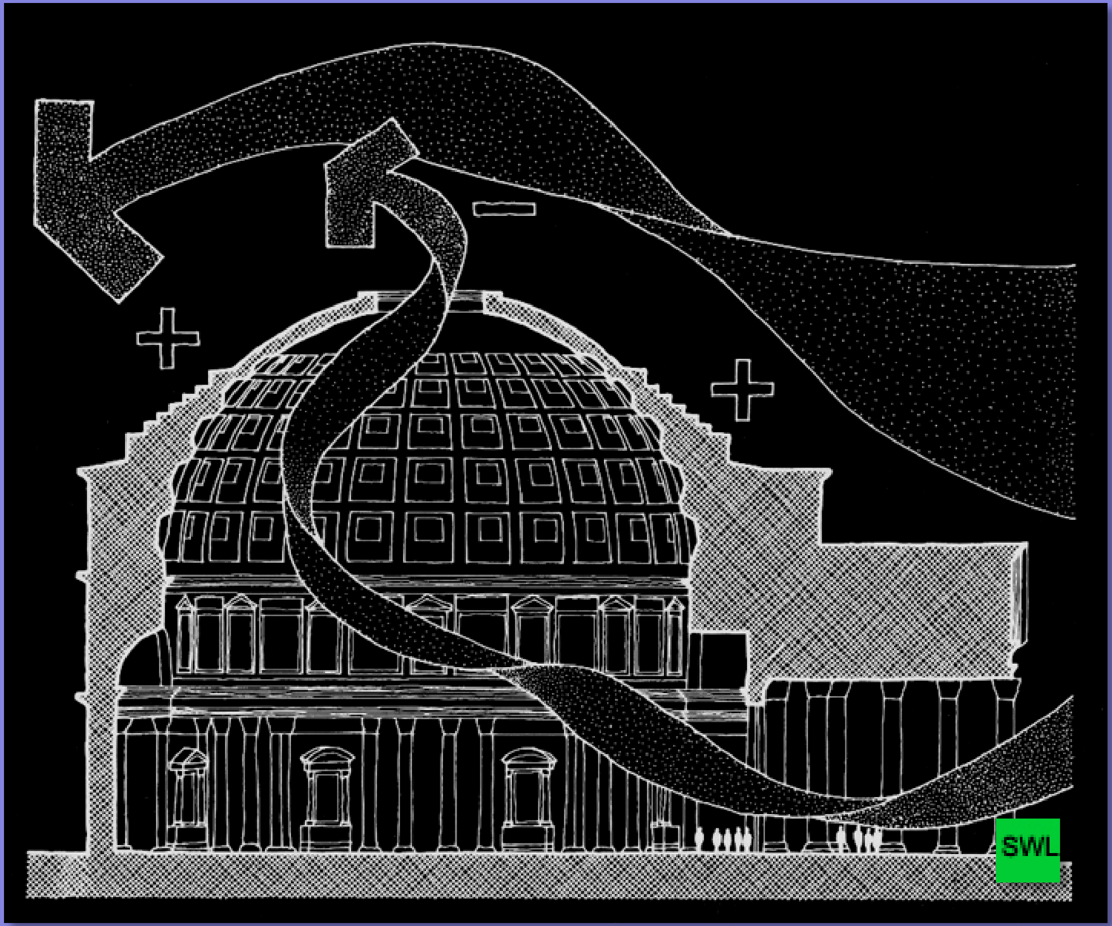
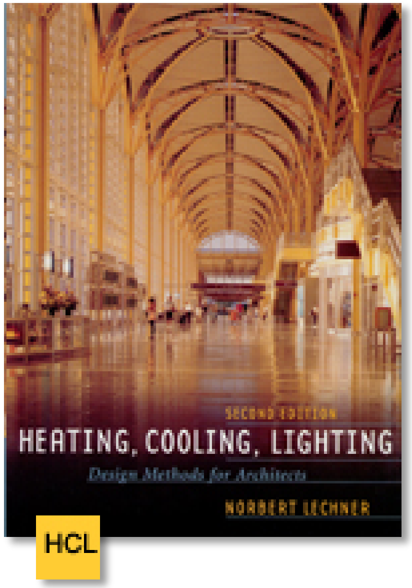
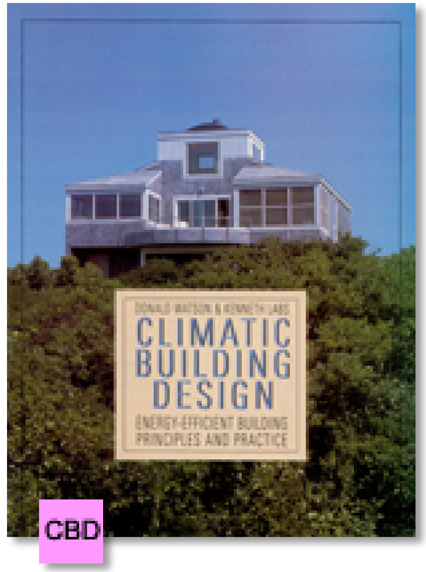
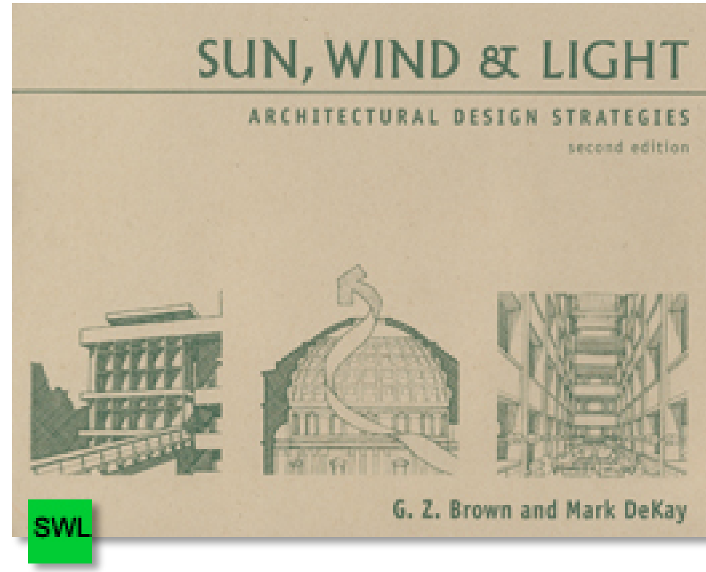
Arch 126: Environmental Building Design

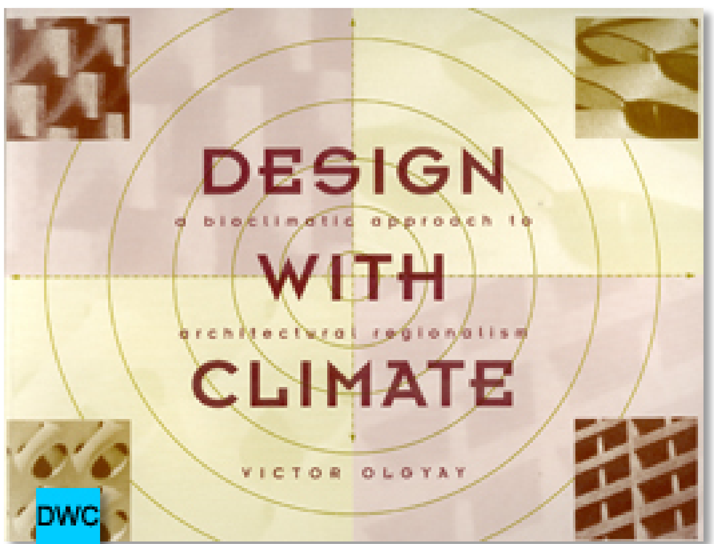
Passive Design (Cooling)











Texts used in the preparation of this presentation.

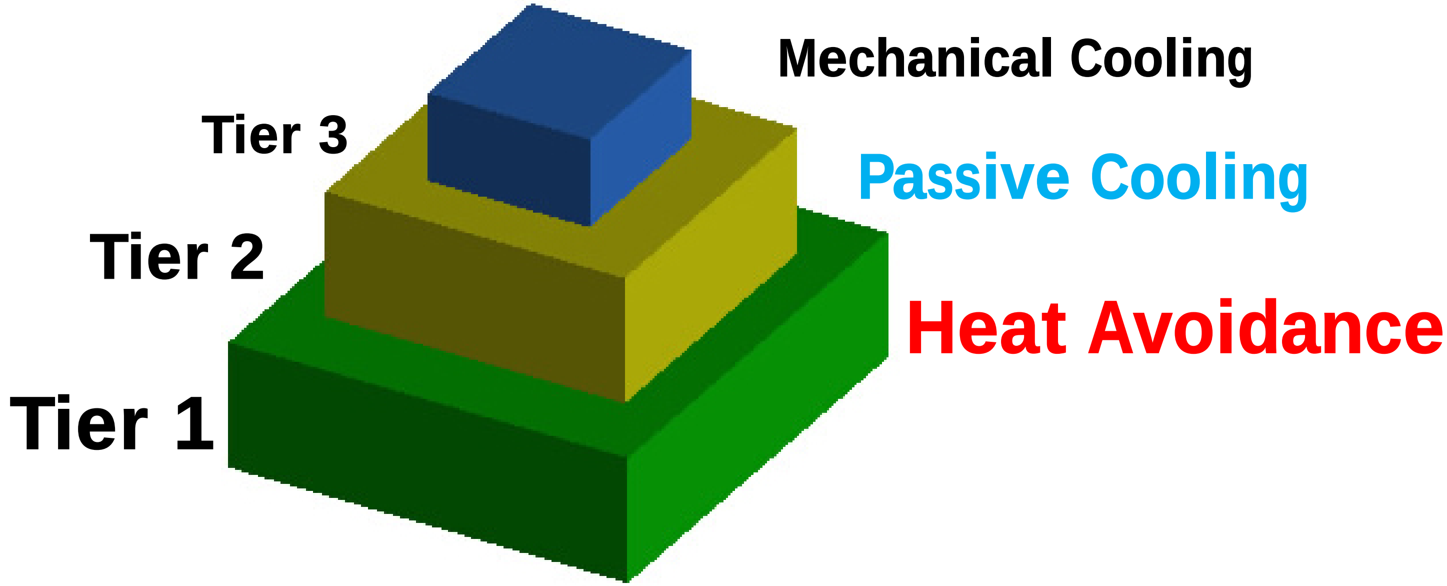

Chongqing,
China


Cairo,
Egypt

Simmons Hall, MIT – Stephen Holl


Panasonic
TOWER C
STAIR-5

The tiered approach to reducing carbon for COOLING:



Maximize the amount of energy required for mechanical cooling that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Cooling, General Principles:

Passive cooling is the counterpart of passive heating. While passive heating is driven only by the sun, passive cooling can use various heat sinks and climate influences to decrease heat.

1. **Ventilative Cooling**
2. Radiative Cooling
3. Evaporative Cooling
4. Dehumidification
5. Mass effect Cooling

Strategies for Summer Climate Control

CONTROL STRATEGIES		CONDUCTION	CONVECTION	RADIATION	EVAPORATION
WINTER	PROMOTE GAIN			Promote solar gain	
WINTER	RESIST LOSS	Minimize conductive heat flow	Minimize external air flow Minimize infiltration		
SUMMER	RESIST GAIN	Minimize conductive heat flow	Minimize infiltration	Minimize solar gain	
SUMMER	PROMOTE LOSS	Promote earth cooling	Promote ventilation	Promote radiant cooling	Promote evaporative cooling
	HEAT SOURCES		Atmosphere	Sun	
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere

Strategies of Climate Control

(chart modeled after Watson "Climatic Building Design")

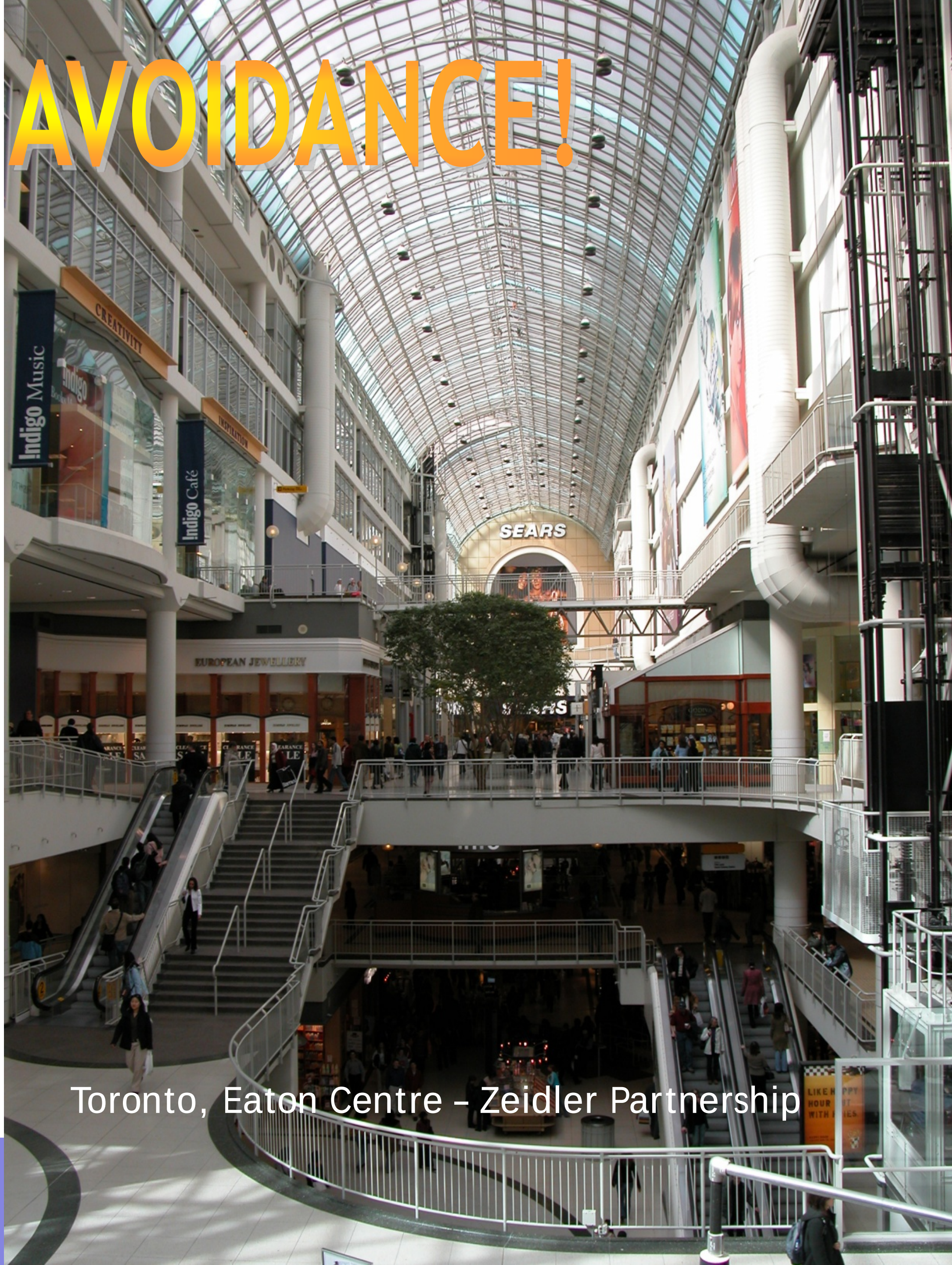
But first, think about

Think Heat AVOIDANCE!

If it does not get IN, you don't have to deal with it!

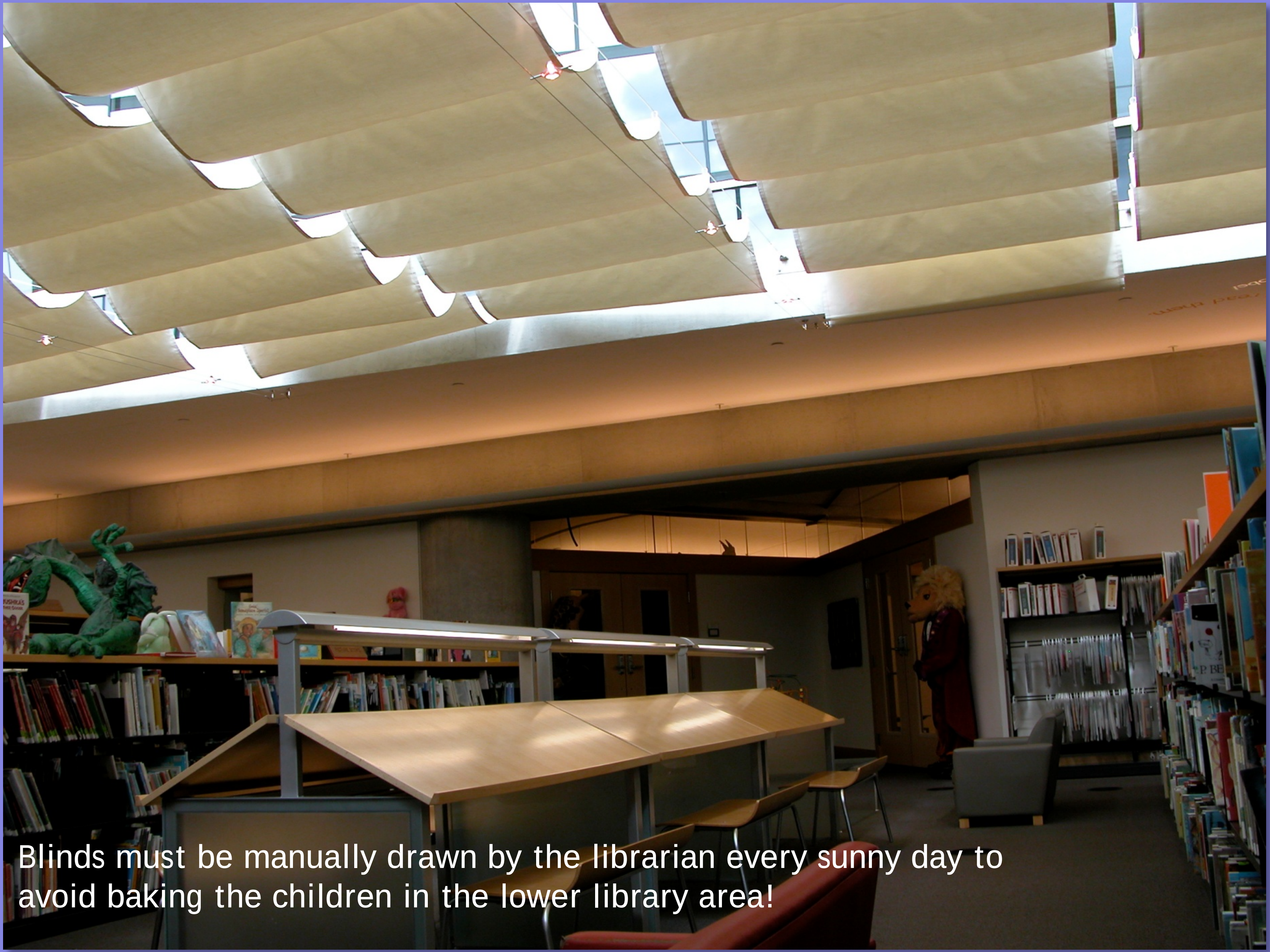
One way to avoid heat gain is by modifying the glazing.

Atrium buildings have long had issues with solar gain, so some of the glass is opaque to give the appearance of "sky" without the solar gain.



Toronto, Eaton Centre – Zeidler Partnership


Salt Lake City Library, Moshe Safdie

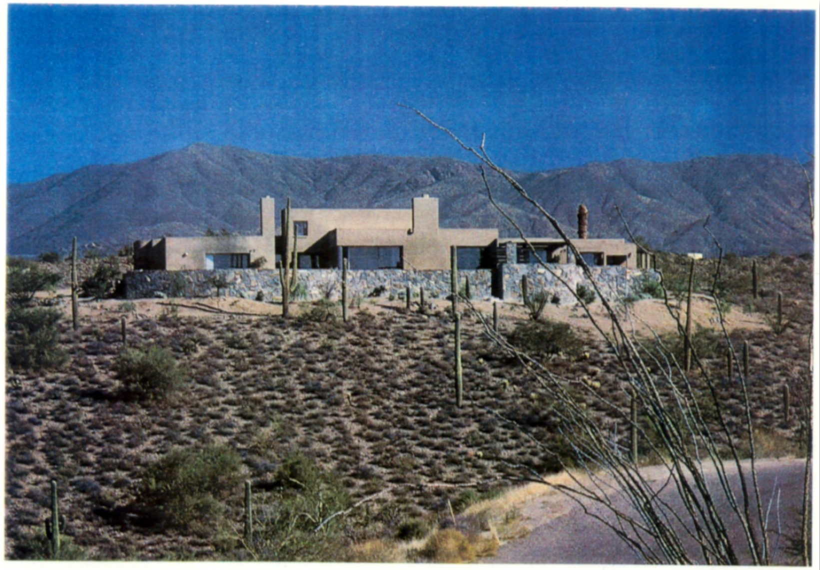


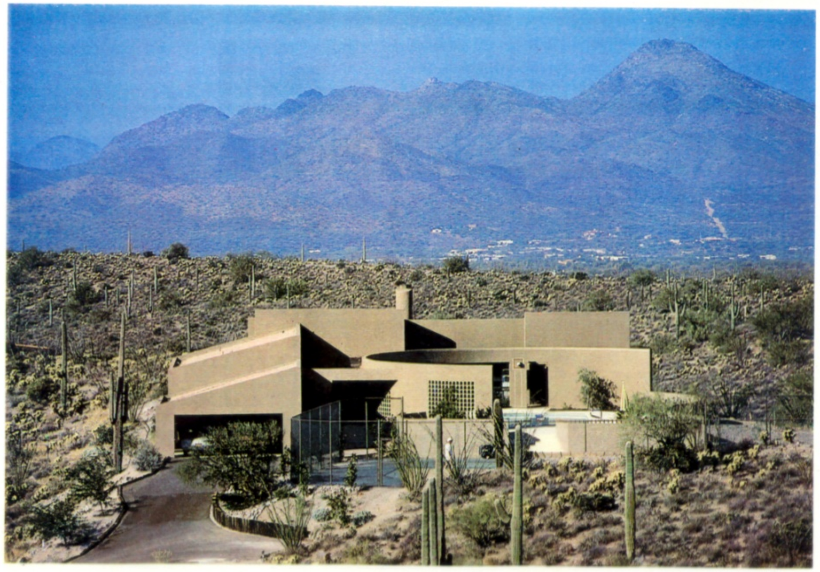
Blinds must be manually drawn by the librarian every sunny day to avoid baking the children in the lower library area!

Shading is Heat AVOIDANCE!

Before resorting to expensive glass, think shading systems!


Shading systems need not
be complex or highly
technical!





It is important to recognize that passive cooling is much more dependent on climate than passive heating. Thus the passive cooling strategies for hot and dry climates are very different from those for hot and humid climates.

Often the temperate climate is the hardest to design for to balance heating and cooling requirements as neither dominates for decision-making.

Hot arid climates use diurnal (day to night) temperature variation and avoid heat gain AND natural ventilation!

Hot humid climates count on natural ventilation and light weight materials as the day to night temperature variation is minimal.

Temperate and cold climate buildings must hit the middle ground as not to compromise their more dominant heating season passive gain strategies.


Phoenix Public
Library
OK, we have maxxed out on Heat
Avoidance…
Now what??

Passive Cooling: What is it?

As much as possible, passive cooling **uses natural forces, energies, and heat sinks.**

Since the goal is to create thermal comfort during the summer (the over-heated period), we can either :

1. cool the building by removing heat from the building by finding a heat sink
2. raise the comfort zone sufficiently to include the high indoor temperature by increasing the air velocity so that the comfort zone shifts to higher temperatures.

Passive Cooling: How do we do it?

Passive cooling relies on **two primary strategies**:

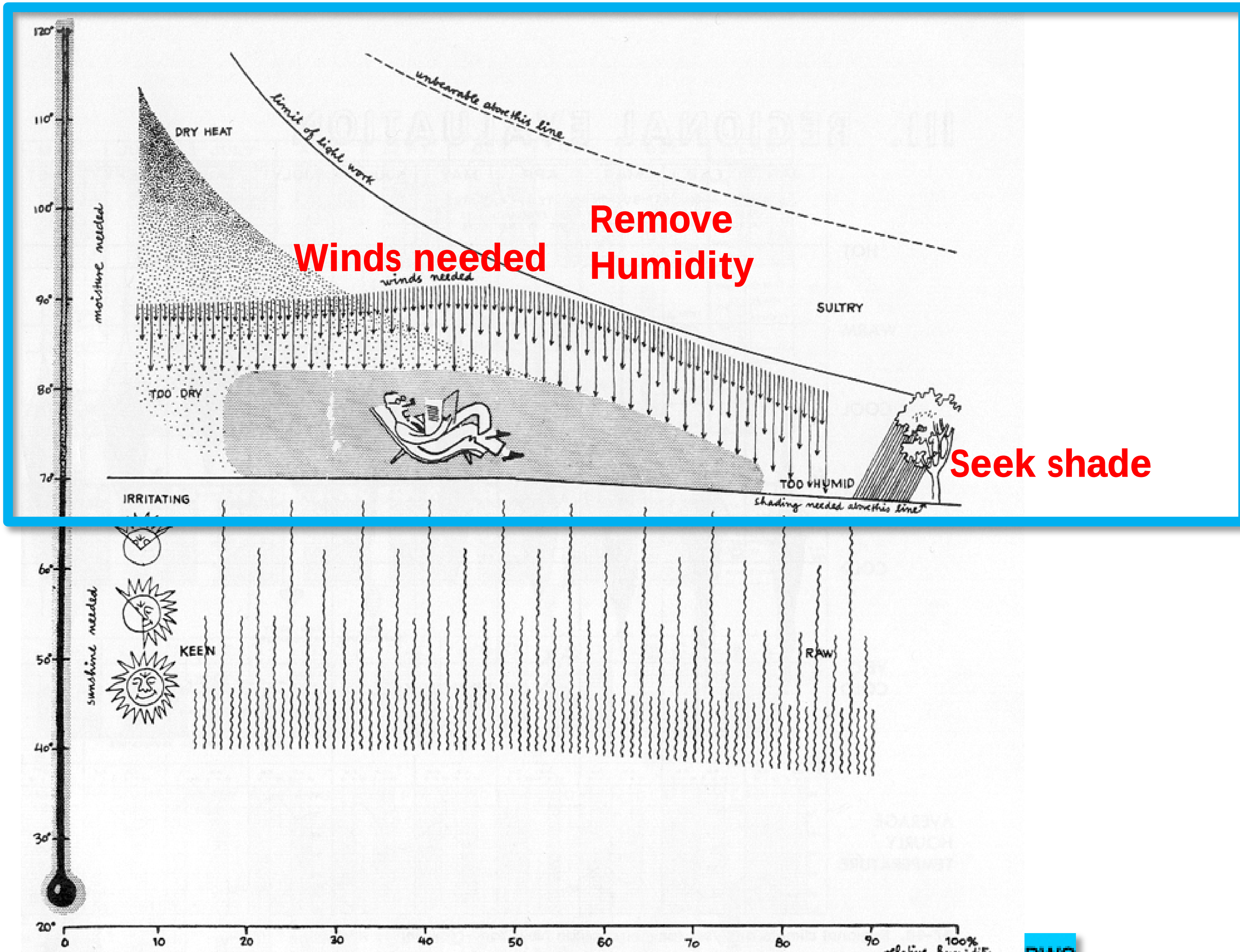
1. First and foremost, HEAT AVOIDANCE, **prevent heat from getting into the building!** If it does not come in, we don't need to get rid of it.

- use shading devices

- create a cool microclimate to discourage heat buildup

2. **Get rid of unwanted heat** that comes into the building

- in cold and temperate climate, mainly via ventilation



46. Schematic bioclimatic index.

DWC

Cooling thru microclimate and shading:

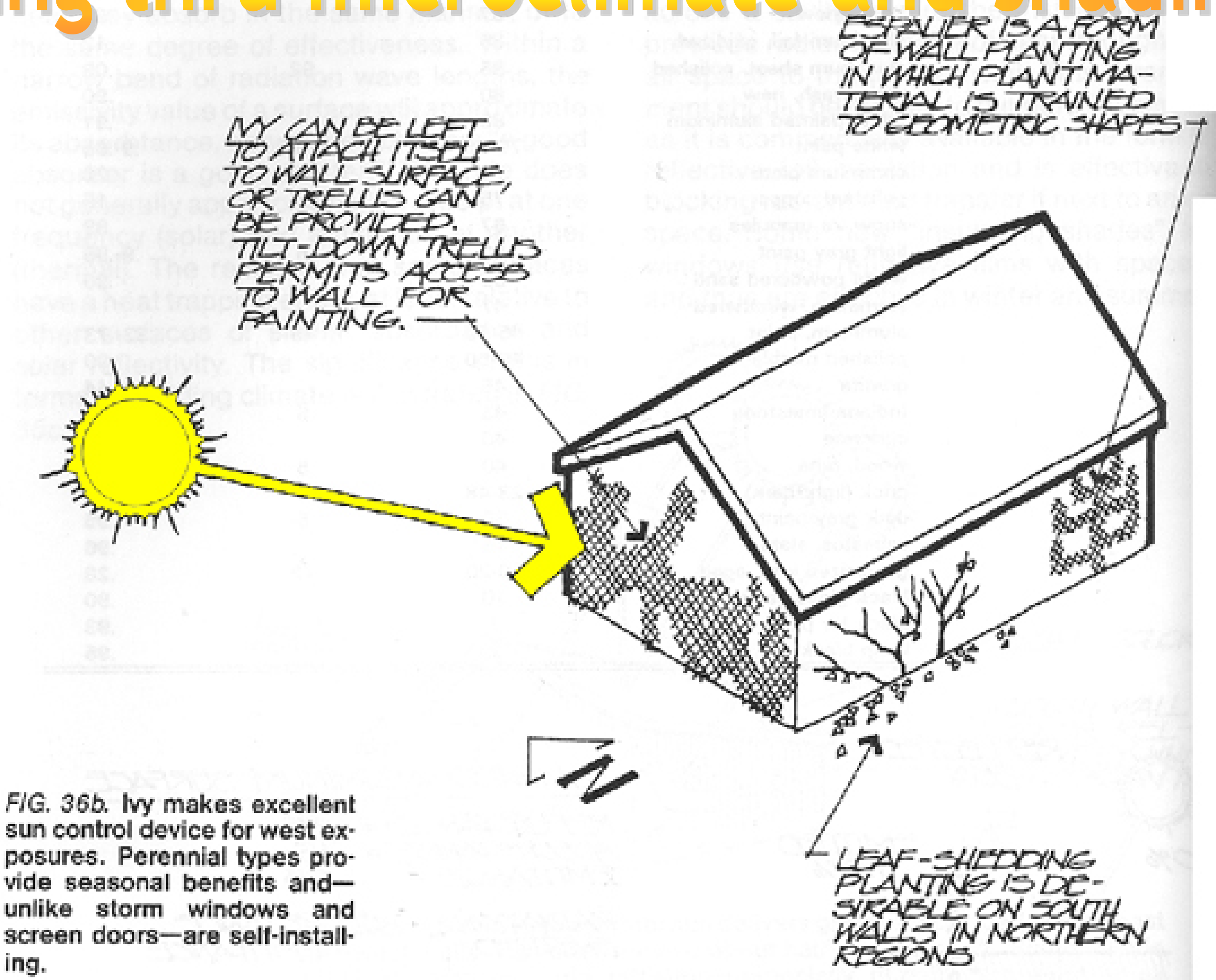
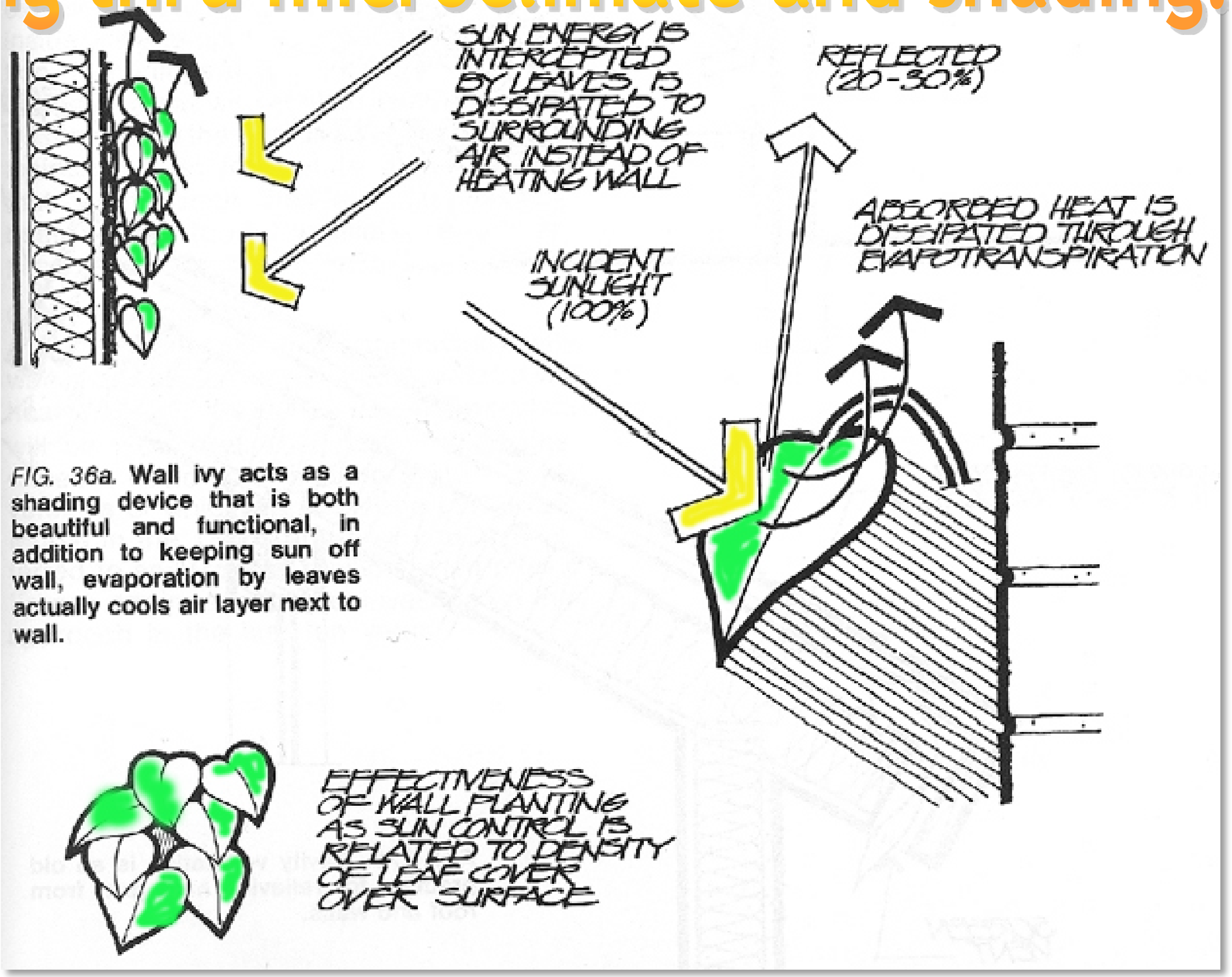


FIG. 36b. Ivy makes excellent sun control device for west exposures. Perennial types provide seasonal benefits and—unlike storm windows and screen doors—are self-installing.

CBD

Cooling thru microclimate and shading:



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Cooling thru microclimate and shading:

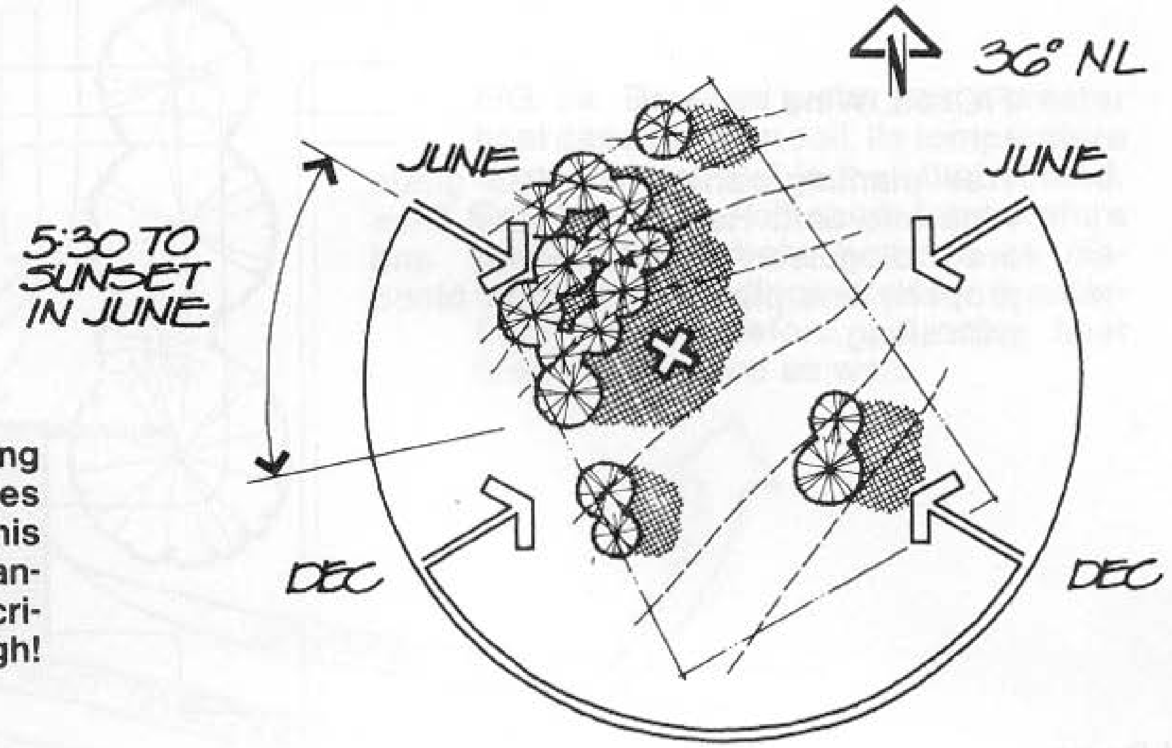

FIG. 4a "X" marks the spot for existing on-site sun protection. Look for sites shrouded by trees on west side. In this example, trees are on upslope, enhancing their shading ability. Don't sacrifice winter southern exposure, though!

CBD


Massey College, Ron Thom Architect,
University of Toronto

Cooling thru microclimate and shading:

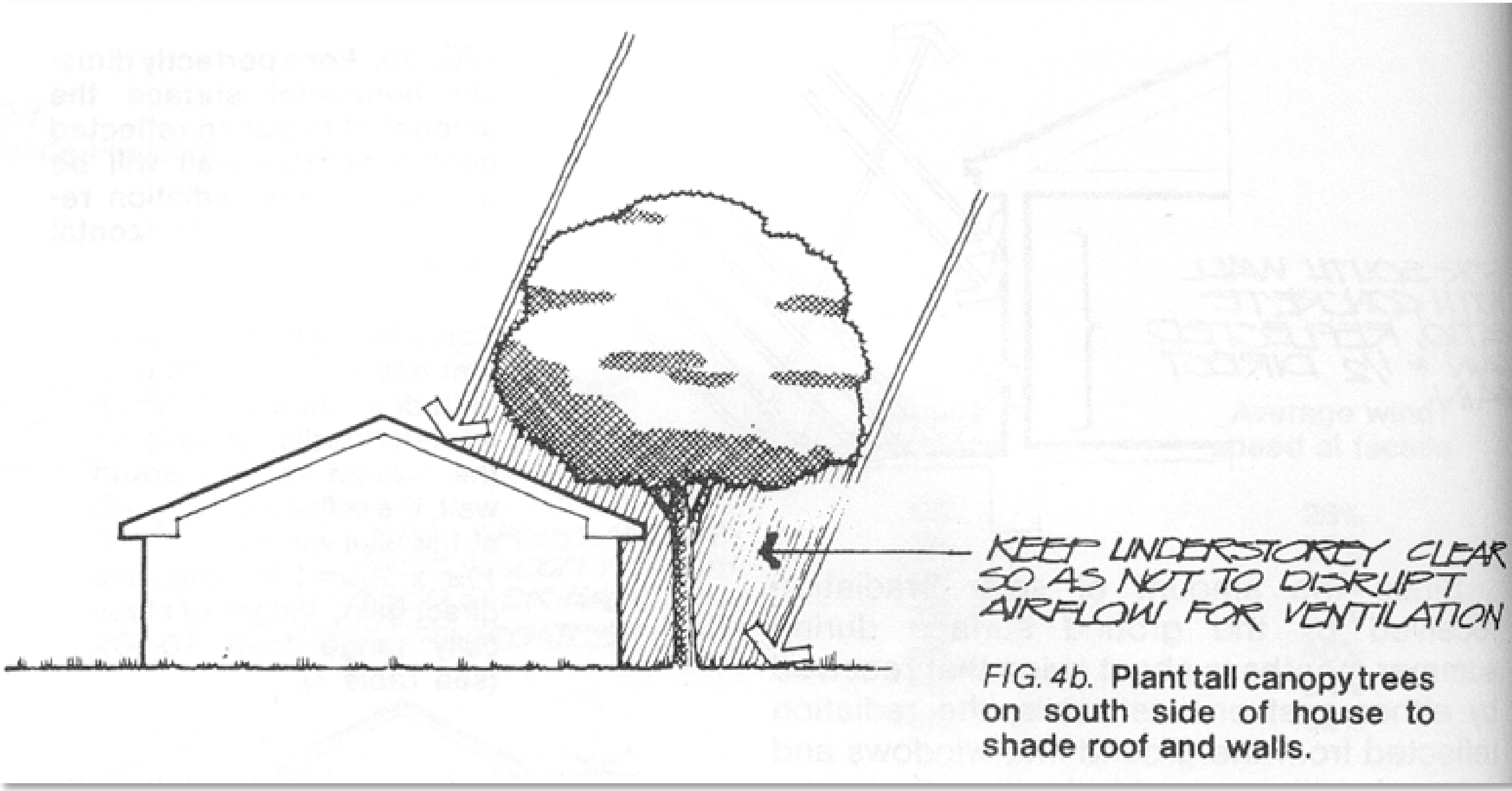

FIG. 4b. Plant tall canopy trees on south side of house to shade roof and walls.

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Trees planted close to the building on the south side can shade the walls and roof.

Cooling thru microclimate and shading:

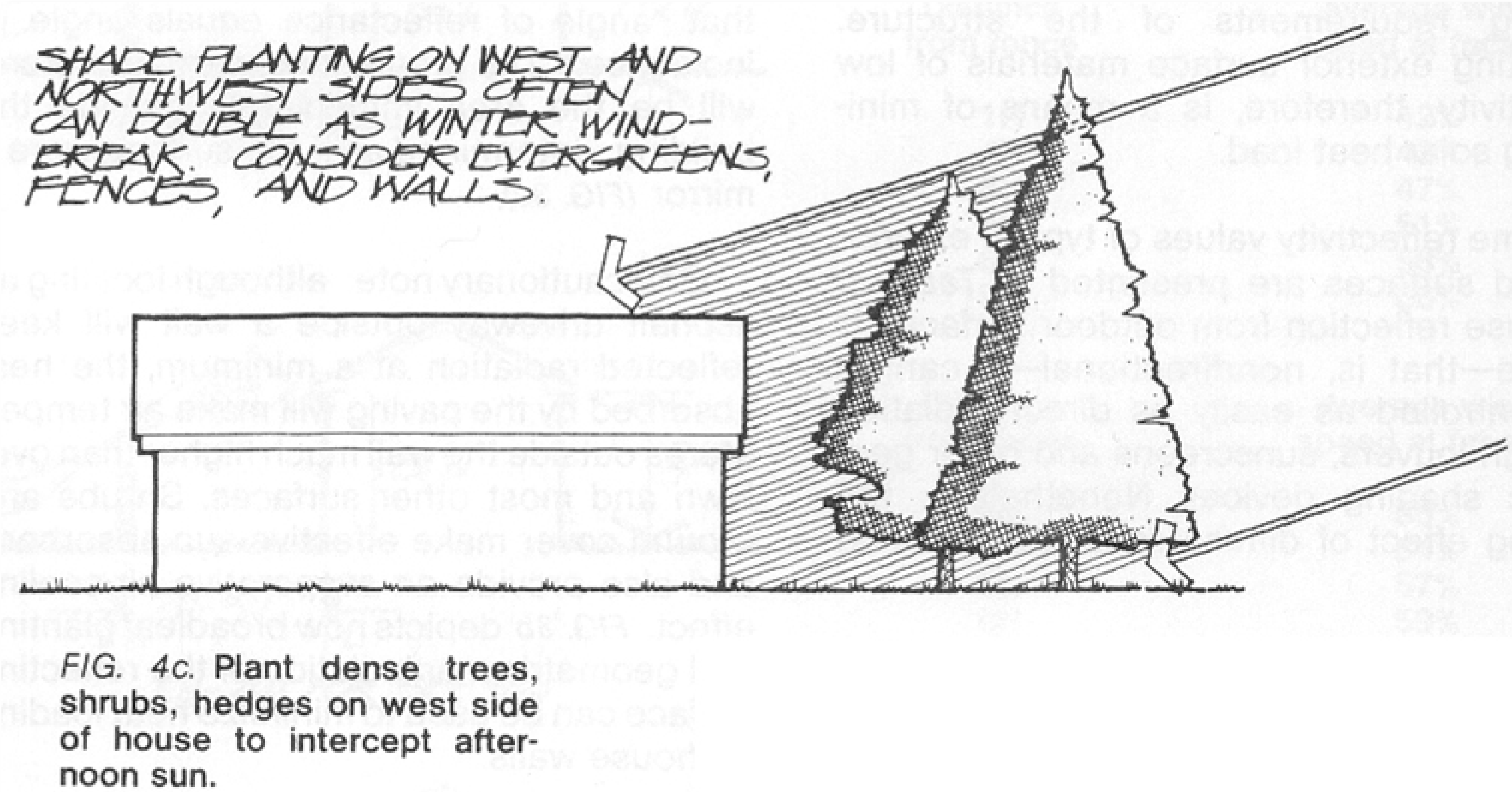

FIG. 4c. Plant dense trees, shrubs, hedges on west side of house to intercept afternoon sun.

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Trees on the west and east sides can block low sunlight in the morning and afternoon.


Exterior shading like this
cools the microclimate.
More on this later!

Cooling thru microclimate and shading:

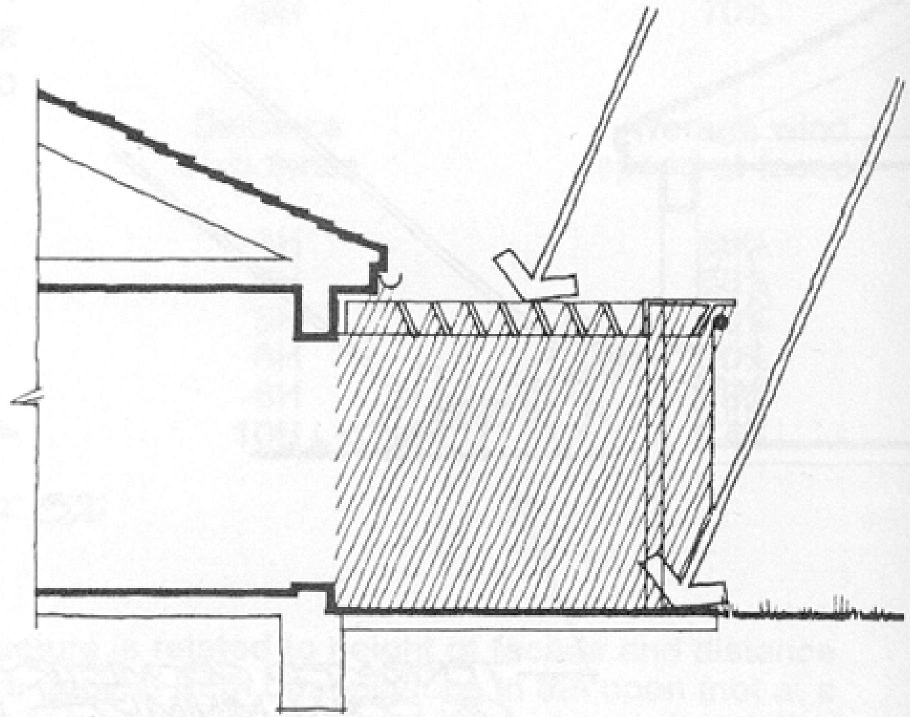

FIG. 4d. Attached overhead shading structures can provide multiple benefits. Not only does this patio cover shade the wall, it also reduces reflected gain from loading on the wall.

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Trellises can provide shade to the building and outdoor rooms.



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ArchitectureWeek.com

St. John Ambulance Headquarters, Edmonton, Manasc Isaac Architects


Watch for
falling ice if
you dare sit
on those
benches!


Office building in Des
Moines, Murphy and
Associates

Stratus Vineyards, Niagara-on-the-Lake

What is Ventilative Cooling??

1. Exhausting warm building air and replacing it with cooler outside air

2. Directing moving air across occupants' skin to create convection and evaporation

3. Achieved by the wind, stack effect or fans.

You have to not only provide openings but also, locate them correctly, make sure they are large enough, for this to work properly!!

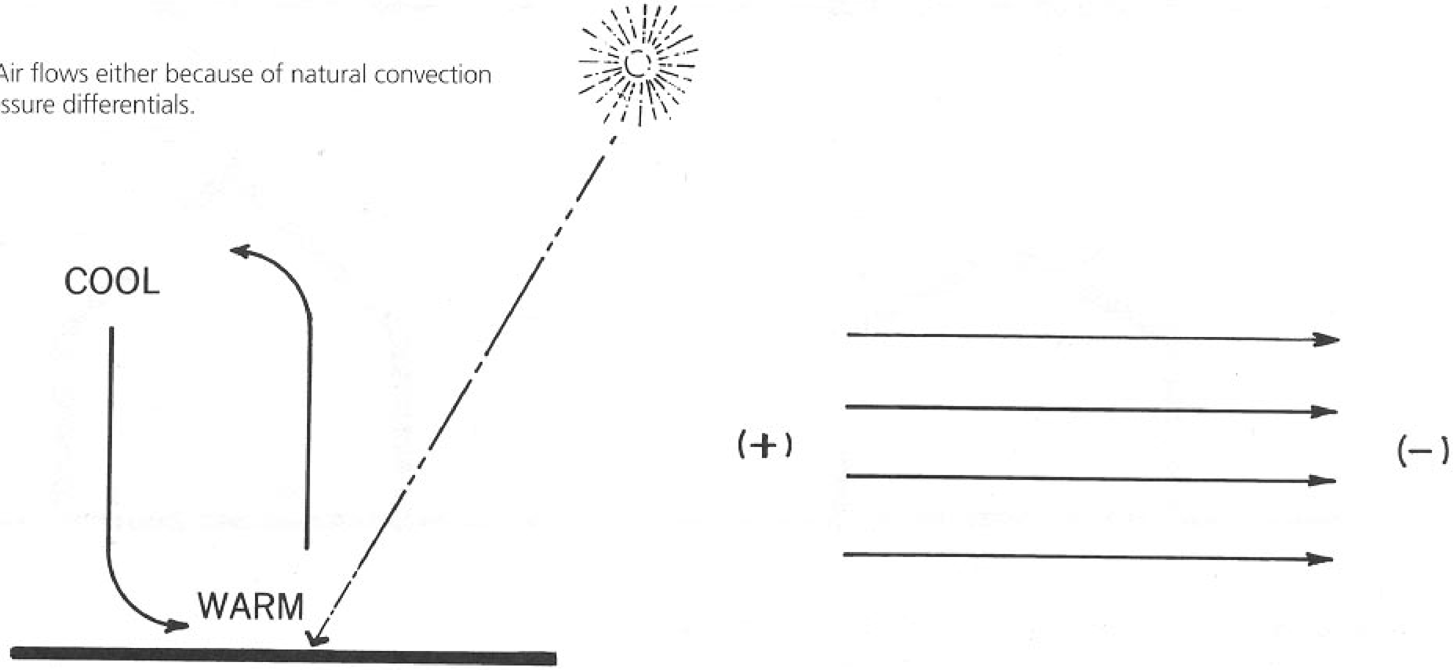

Figure 10.5a Air flows either because of natural convection or because of pressure differentials.

Reason for the air to flow:

1. Natural convection currents caused by differences in temperature
2. Differences in pressure

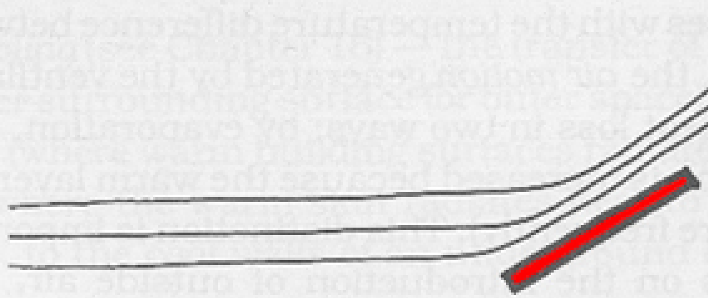

Figure 15.4: Ventilation principle #2 — Air has mass (and thus momentum) and it will tend to continue in its direction until altered by an obstruction or adjacent airflow.

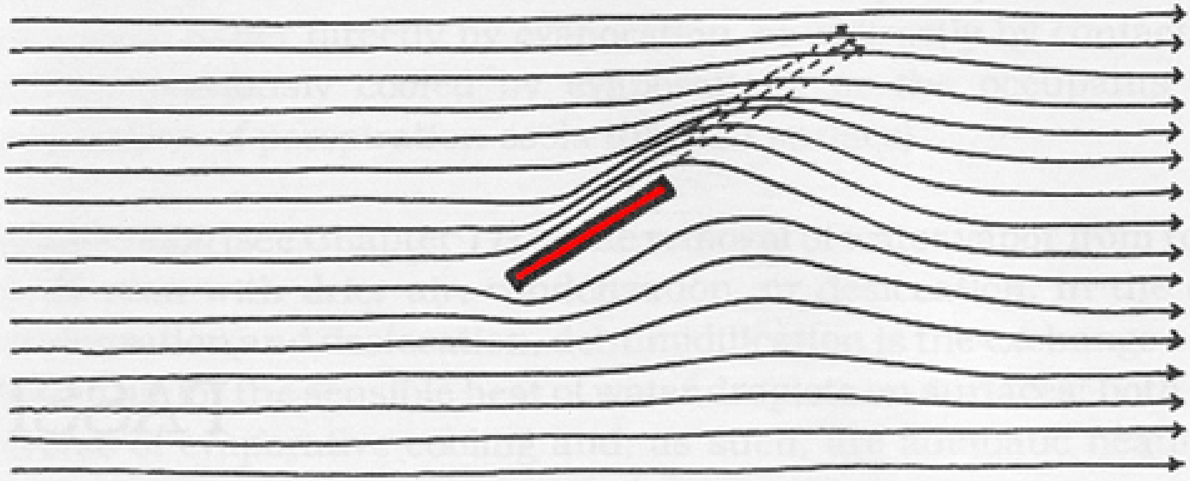

Figure 15.5: Ventilation principle #3 — The overall effect of wind at a site is so large that locally deflected airflow (by trees or buildings, for example) will tend to return to the direction and speed of the site wind.

HCL

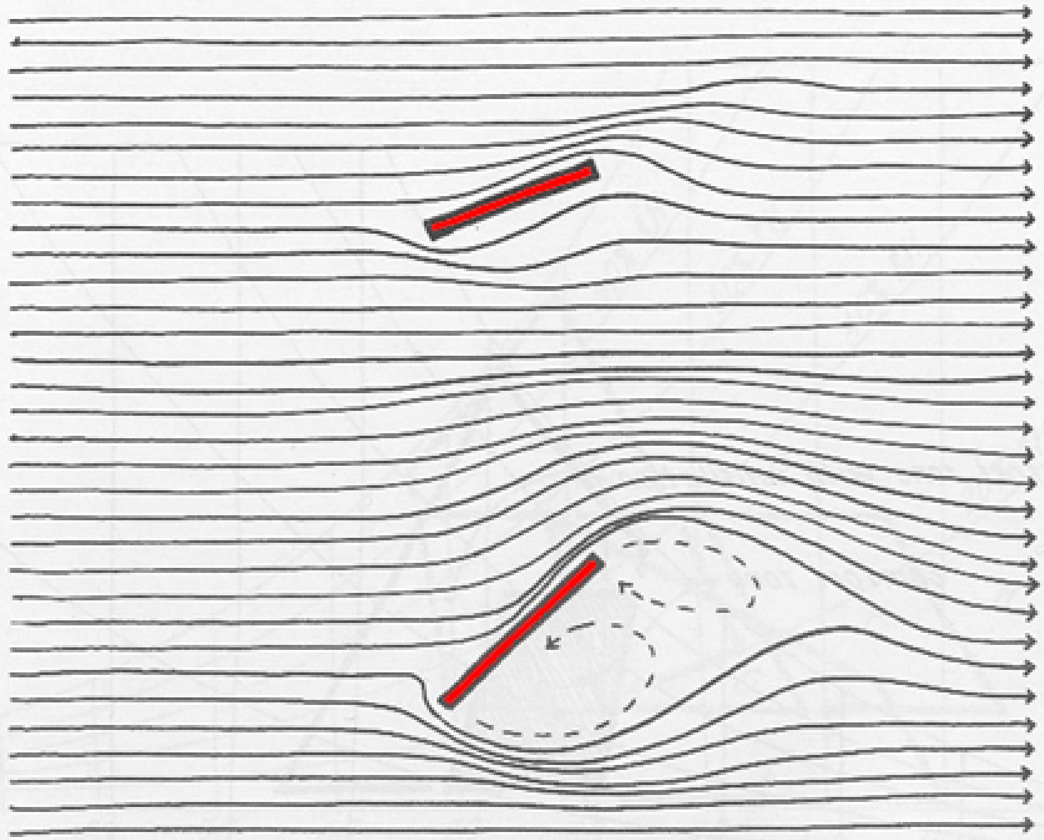

Figure 15.6: Ventilation principle #4 — “Laminar” airflow is smooth with adjacent air moving in similar direction and speed. Slow, gentle alterations of flow direction will preserve laminar flow, while abrupt alterations results in “turbulent flow” whereby adjacent air currents separate abruptly into swirling, unpredictable directions. When two currents of air are traveling in opposite directions, they will always be separated by eddies because adjacent particles of air always move in the same direction.

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How does ventilation work?

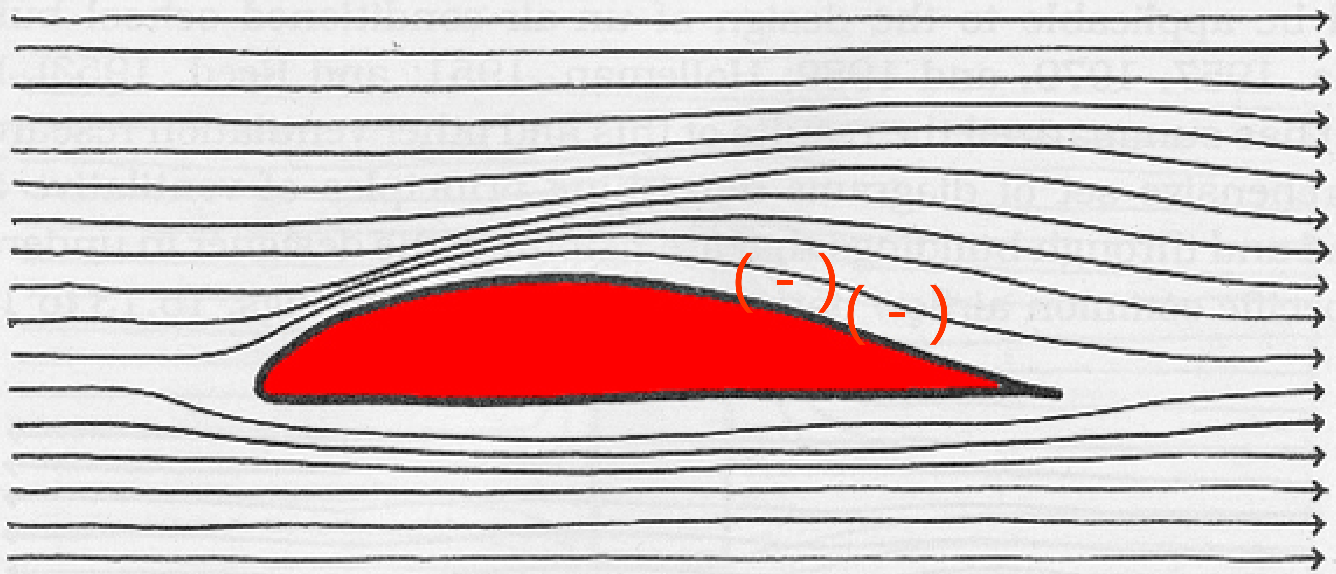

Figure 15.7: Ventilation principle #5 — The "Bernoulli effect" causes a decrease in pressure when air is accelerated in order to cover a greater distance than adjacent airflow. The classic example is the airplane wing which is shaped so that air passing over the top must travel further than that passing below; the Bernoulli effect reduces pressure on the top of the wing as the air is accelerated, creating "lift."

HCL

Ventilation:

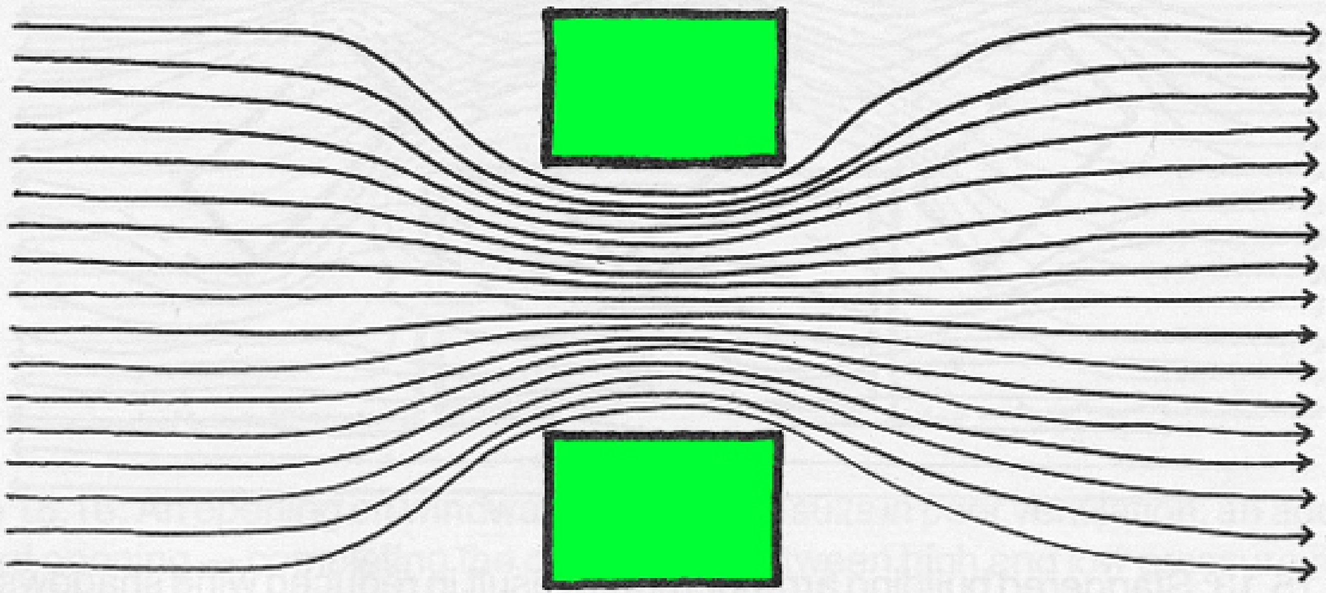

Figure 15.8: Ventilation principle #6 — The "Venturi effect" causes an acceleration when laminar airflow is constricted in order to pass through an opening (because the same volume of air must now pass through a smaller area). If the constriction is so abrupt as to create turbulence, Venturi acceleration is minimized.

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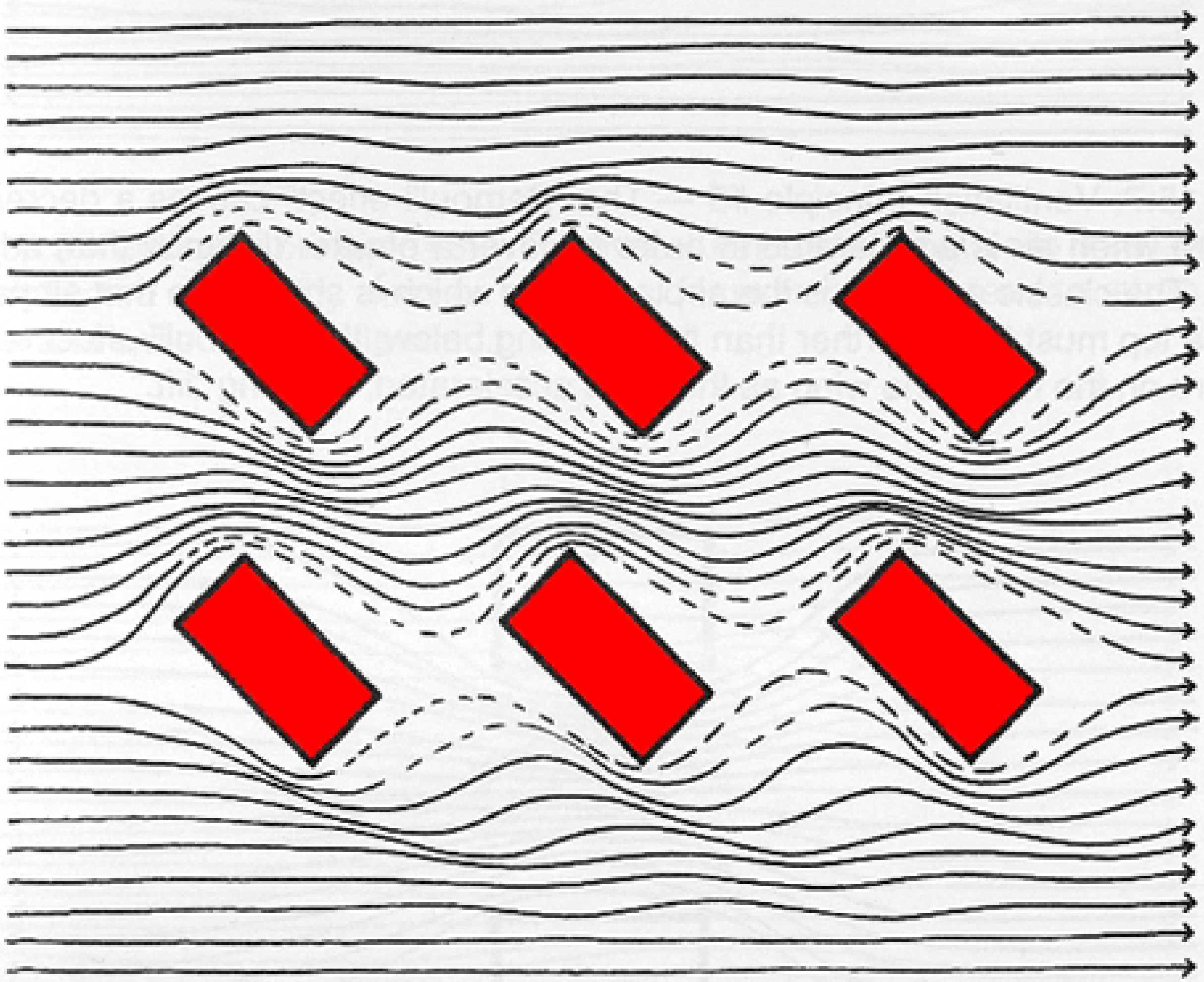
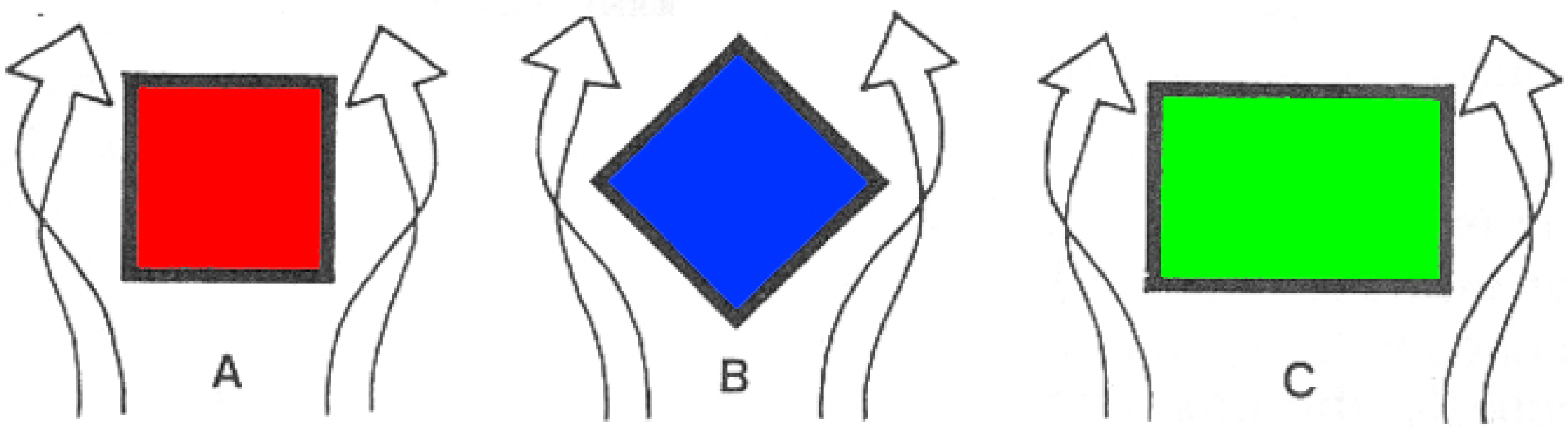


Figure 15.13: Staggered building arrangements result in reduced wind shadows. *(After Bowen, 1981.)*

HCL

FIG. 10d. A compact form–in plan as well as section–is the first rule in minimizing wind exposure. Orientation is equally important: plan B has the same configuration and area as plan A, yet orientation increases its apparent width to the same as C when rotated 45°.



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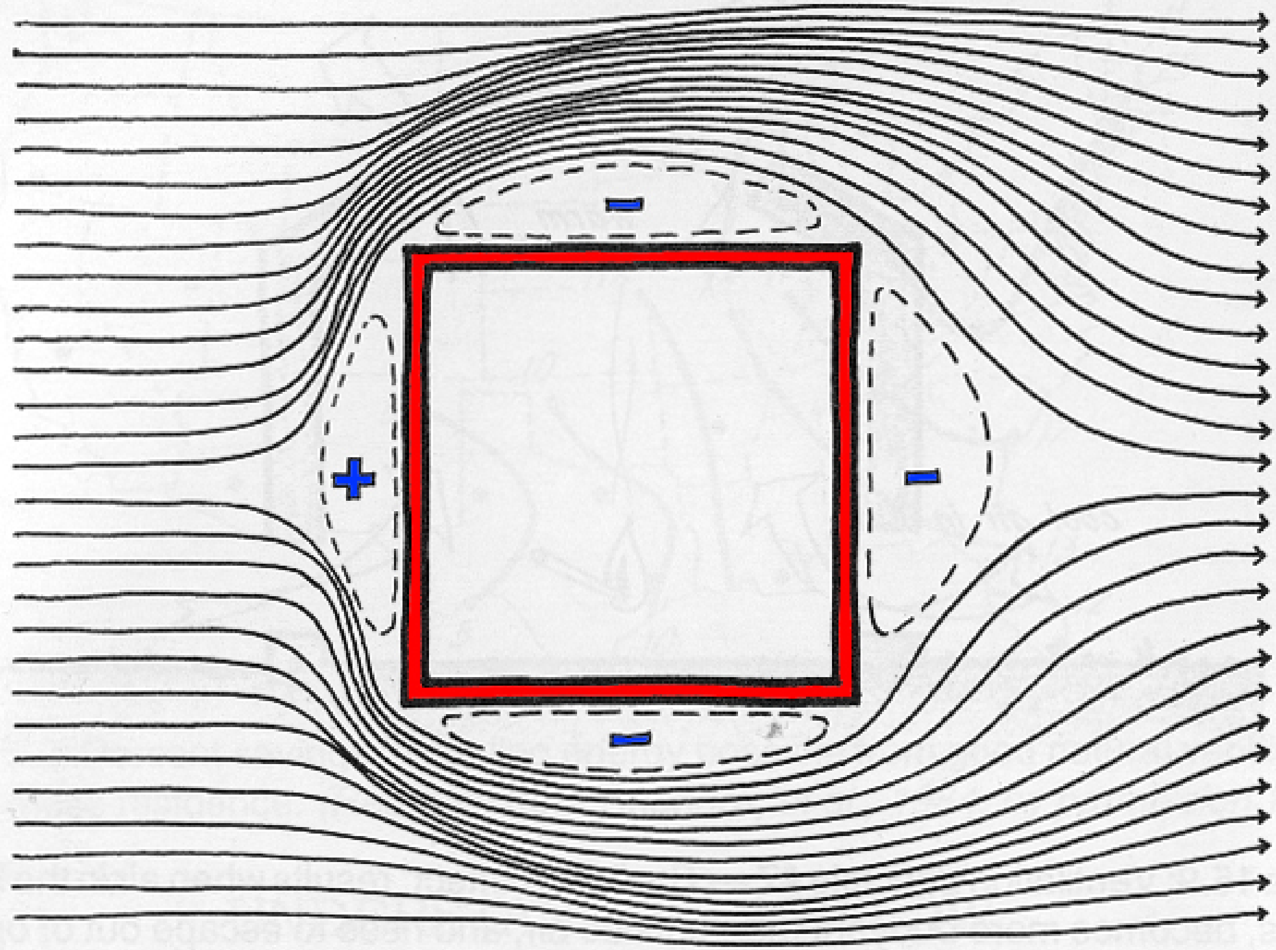

Figure 15.11: Low-pressure zones occur along the sides parallel to the wind and on the leeward side of the building. *(After Bowen, 1981.)*

HCL

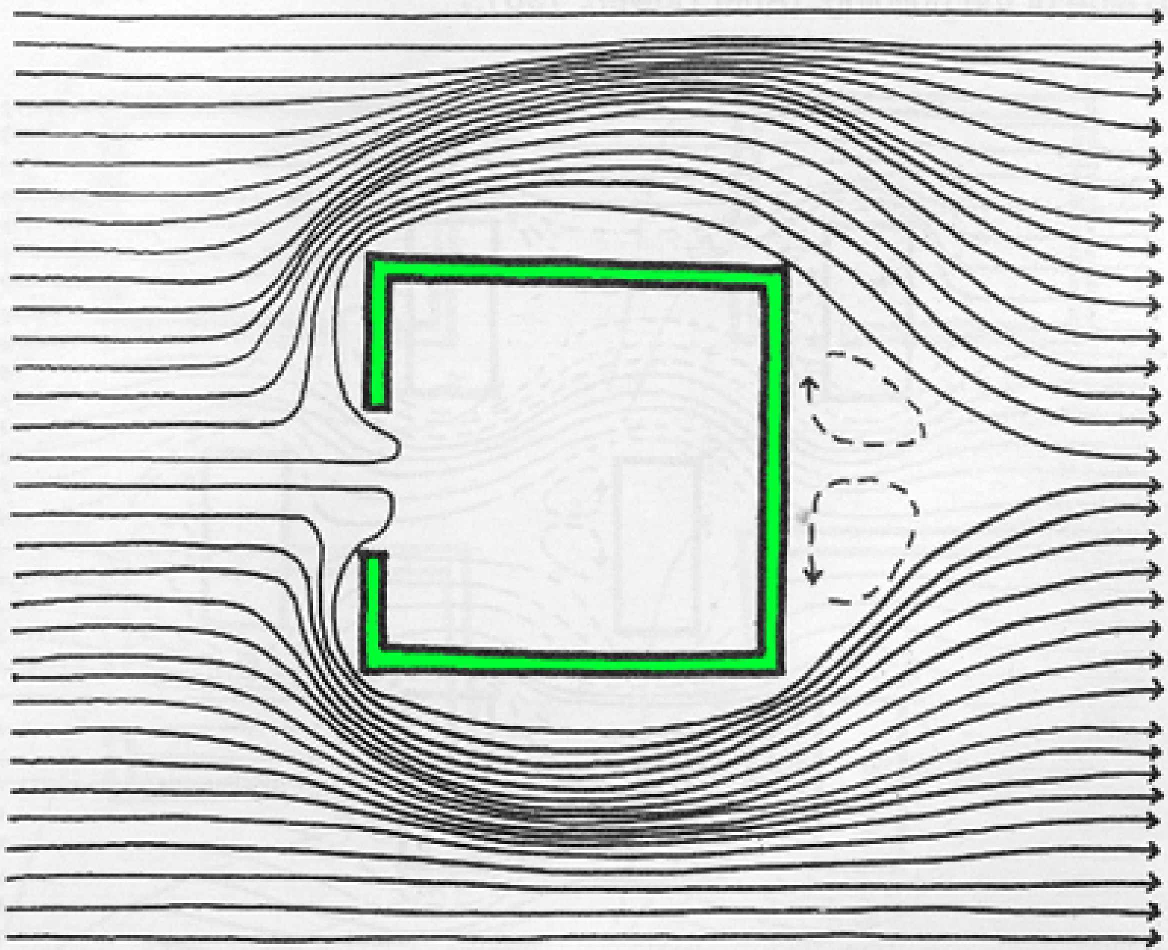

Figure 15.10: Ventilation principle #8 — Cross-ventilation requires an outlet as well as an inlet. (Analogy: water cannot be put into a bottle that is already full unless some old water is removed first — through a hole in the opposite end of the bottle, for example.)

HCL

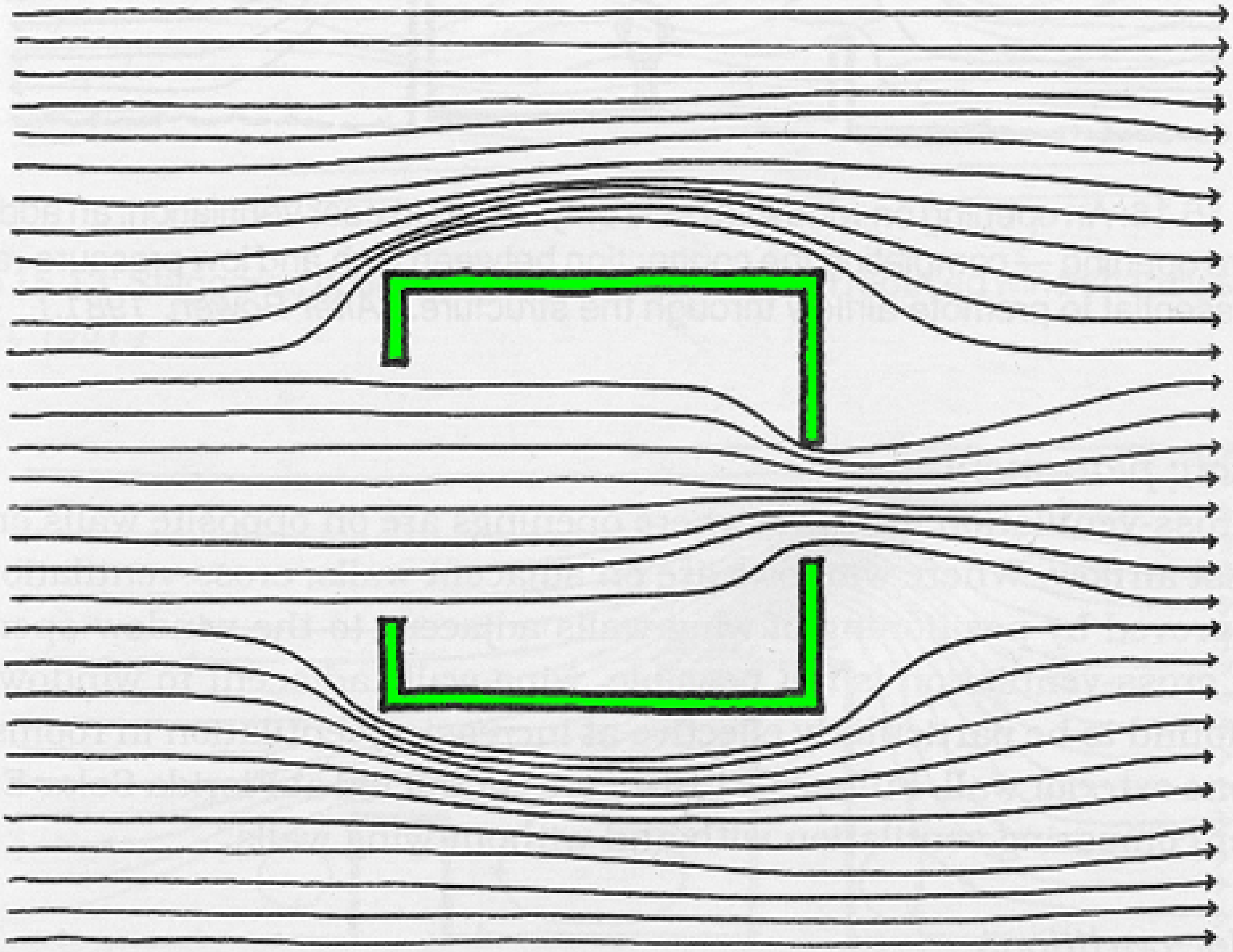

Figure 15.21: If the inlet is larger than the outlet, velocity in the room is reduced (although velocity outside just to leeward of the outlet is increased). This has potential for cooling a localized exterior area such as a patio. *(After Bowen, 1981.)*

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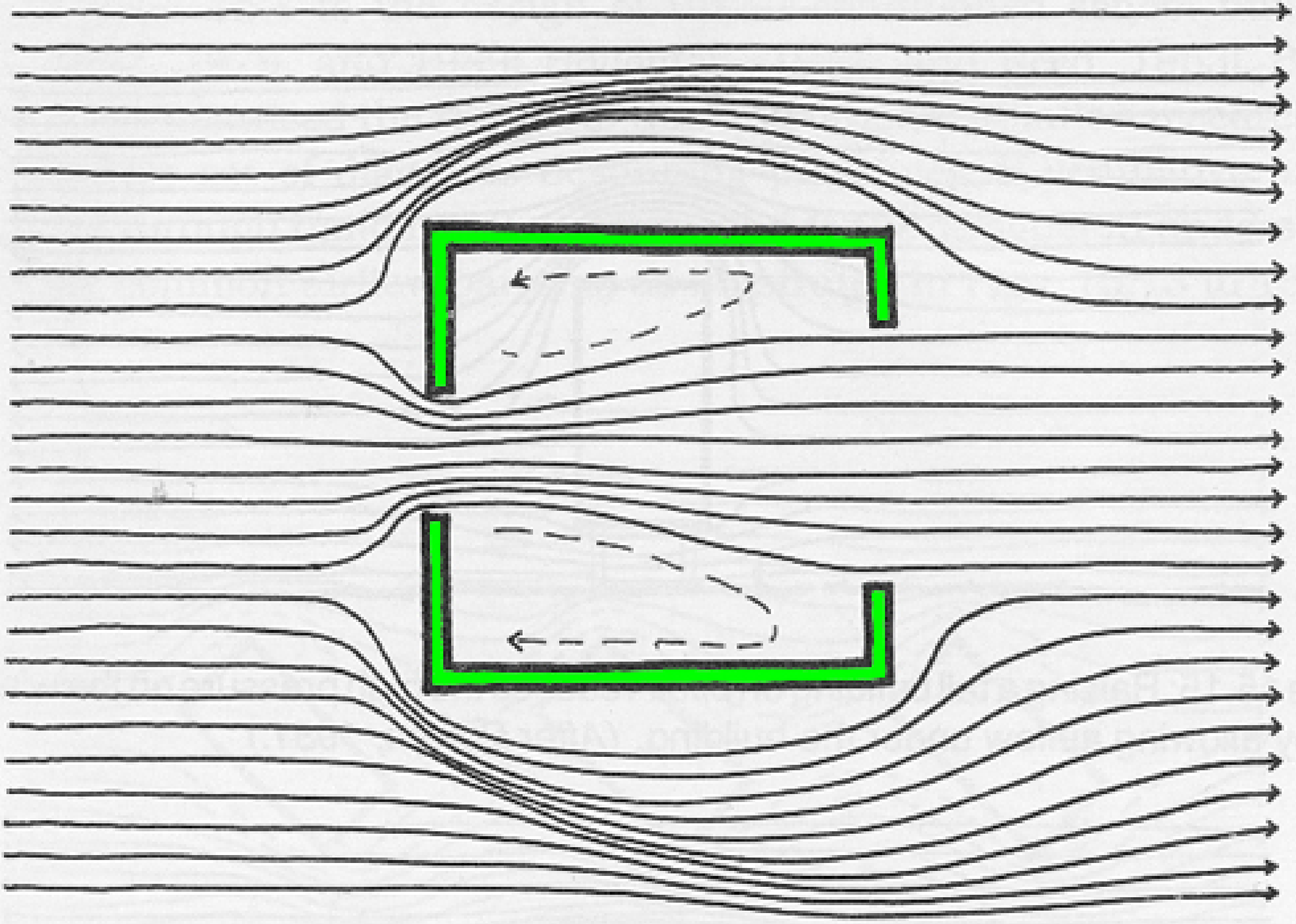

Figure 15.20: Maximum *interior airspeed* is created when the inlet is smaller than the outlet, making this the optimum configuration when *people* cooling is the goal. *(After Bowen, 1981.)*

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- Fin walls can significantly increase ventilation through windows on the same wall.
- Poor ventilation results from fin walls placed on the same side of each window or when two fins are used on each window.

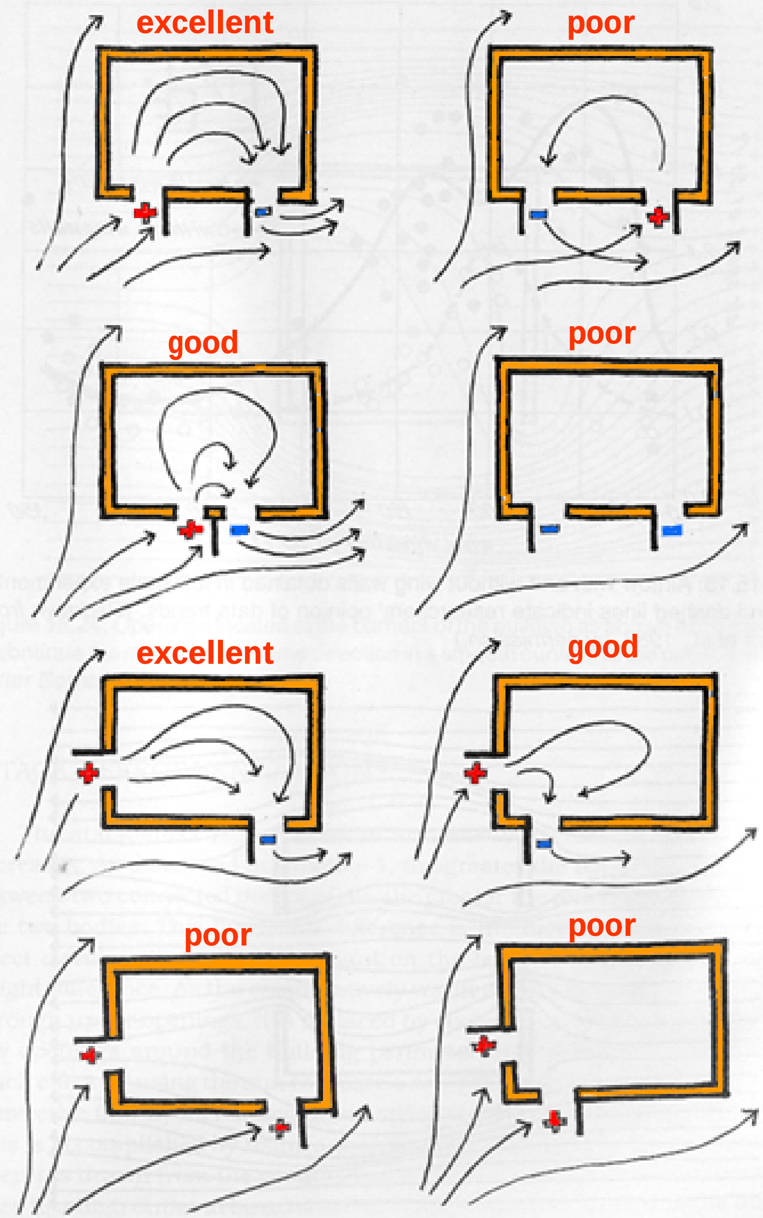

Figure 15.17: Wing wall design patterns for two windows on the same or adjacent walls showing probable airflow patterns and wind directions for improved ventilation performance due to wing walls: (a) excellent, (b) poor, (c) good, (d) poor, (e) excellent, (f) good, (g) poor, and (h) poor. *(After Chandra et al., 1983.)*

HCL

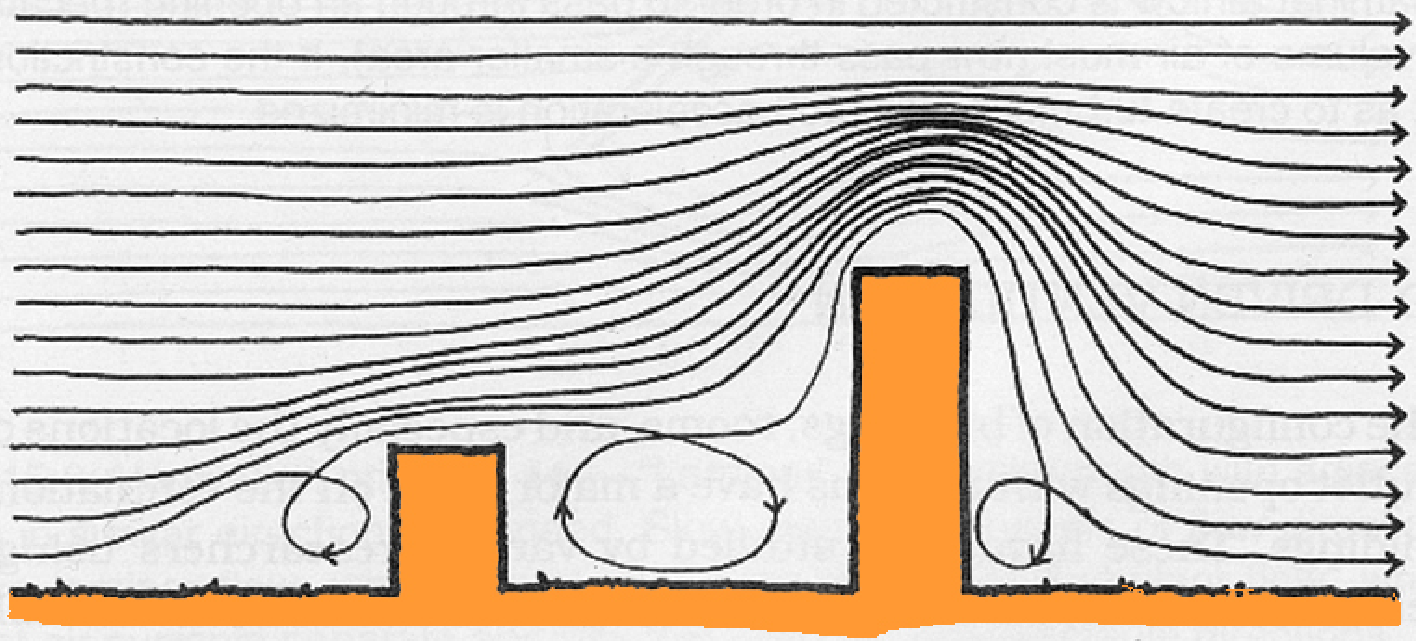

Figure 15.14: A low building placed in the windward path of a tall building produces a large amount of turbulence between the two. *(After Bowen, 1981.)*

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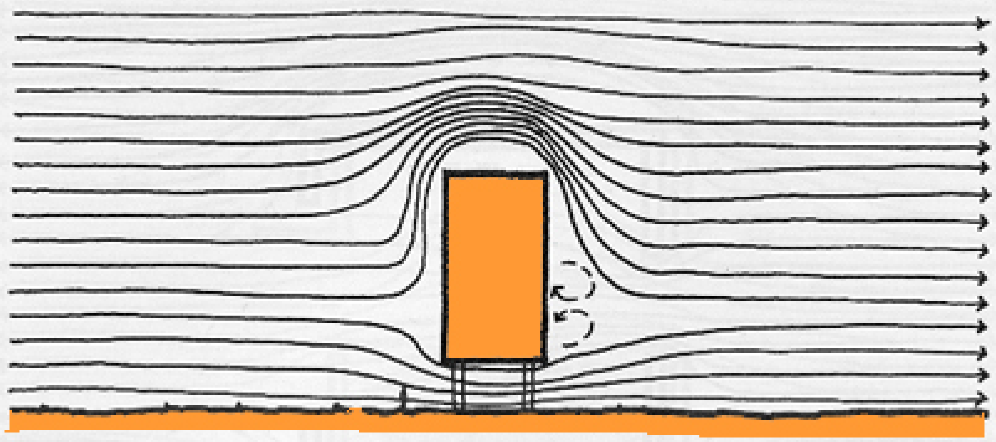

Figure 15.15: Raising a tall building on *piloti* reduces the high pressure on the windward side by allowing airflow under the building. *(After Bowen, 1981.)*

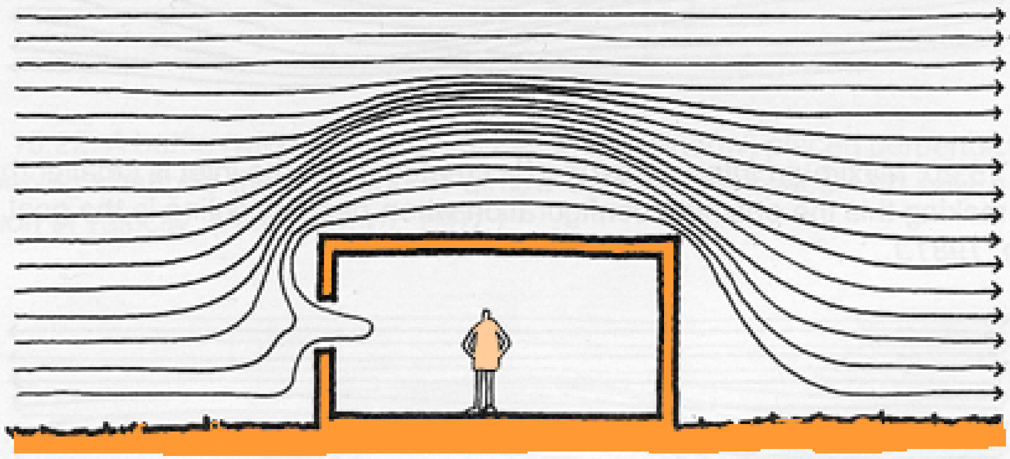

Figure 15.16: An opening on windward side only results in poor ventilation; an additional leeward opening — completing the connection between high and low pressure regions — is essential to promote airflow through the structure. *(After Bowen, 1981.)*

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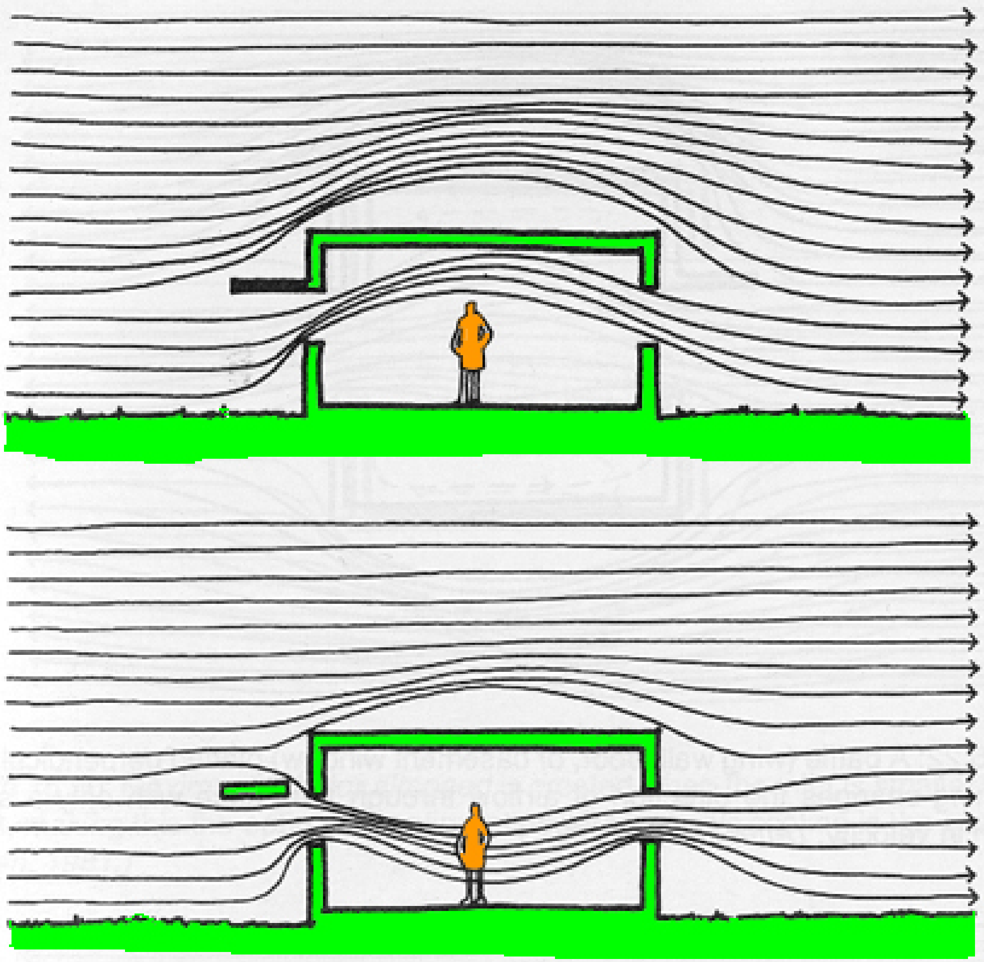

Figure 15.26: An overhang above the inlet window directs the interior airflow along the ceiling out of the occupied zone; the addition of a slot separating the overhang from the building redirects the flow down into the room, increasing the useful cooling effect. *(After Bowen, 1981.)*

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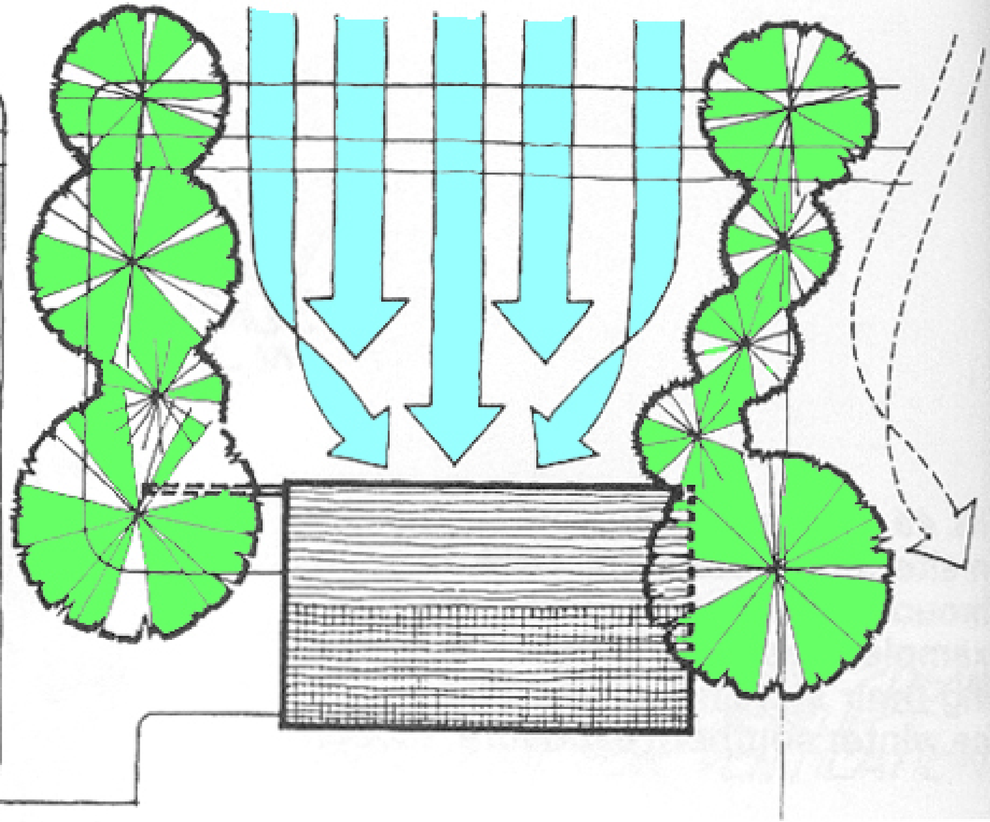
FIG. 5b. Wind Funnels

Tree planting can be used to guide wind into unit. Here tree funnel lines are "disguised" as driveway and property line planting to better blend with siting.



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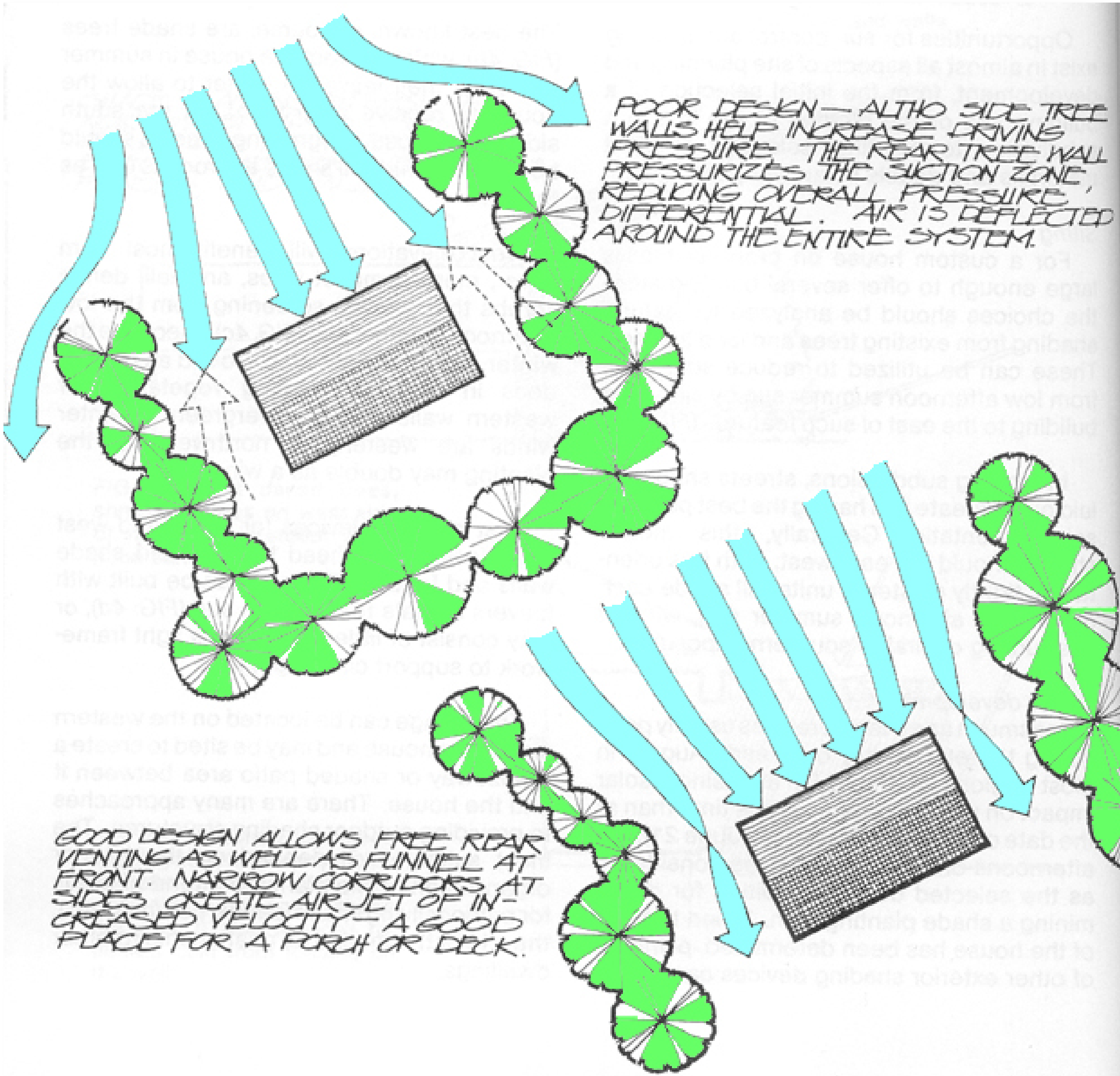
POOR DESIGN — ALTHO SIDE TREE
WALLS HELP INCREASE DRIVING
PRESSURE, THE REAR TREE WALL
PRESSURIZES THE SUCTION ZONE,
REDUCING OVERALL PRESSURE
DIFFERENTIAL. AIR IS DEFLECTED
AROUND THE ENTIRE SYSTEM.
GOOD DESIGN ALLOWS FREE REAR
VENTING AS WELL AS FUNNEL AT
FRONT. NARROW CORRIDORS AT
SIDES CREATE AIR JET OF IN-
CREASED VELOCITY — A GOOD
PLACE FOR A PORCH OR DECK.

CBD

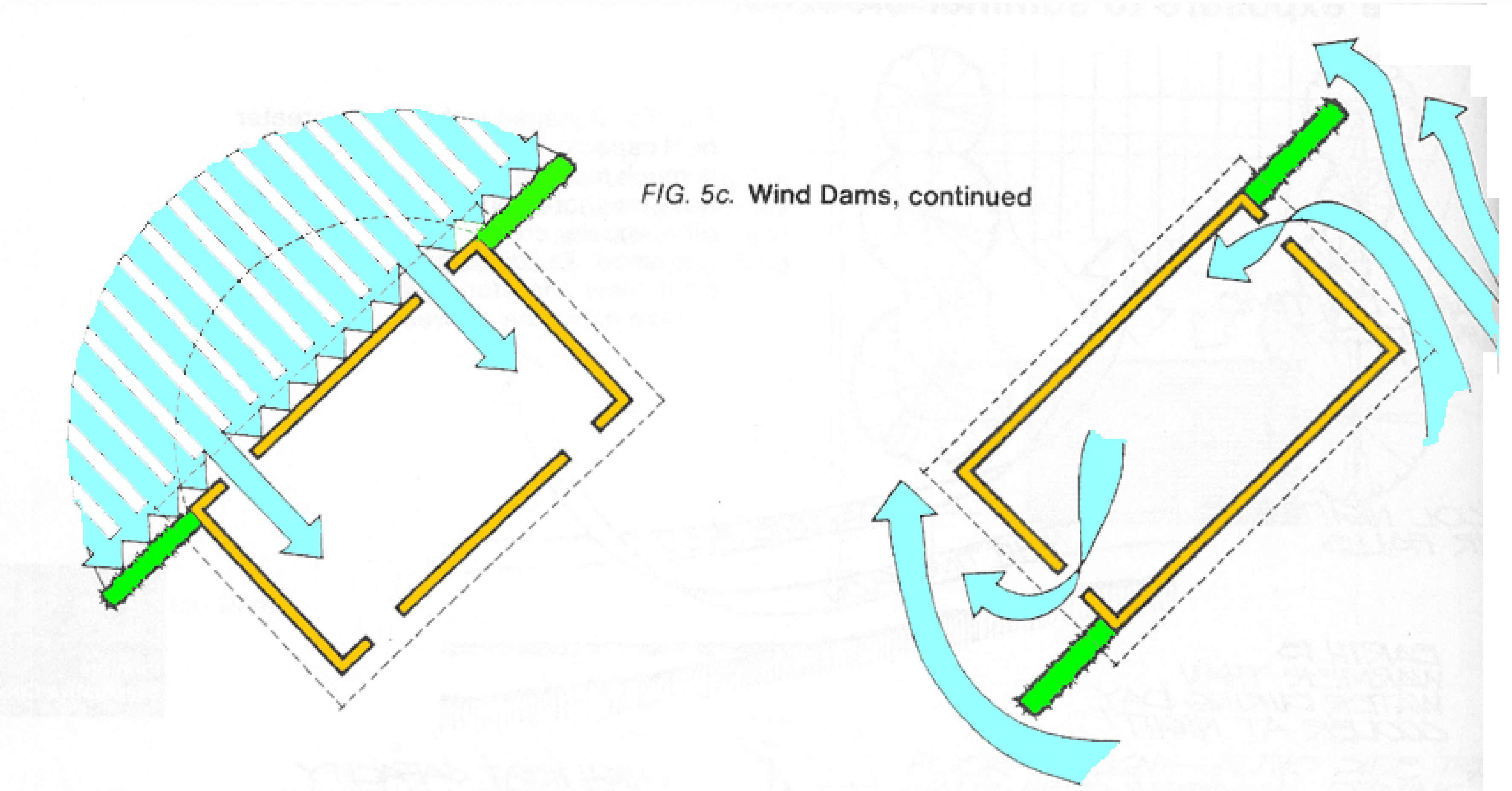

FIG. 5c. **Wind Dams, continued**

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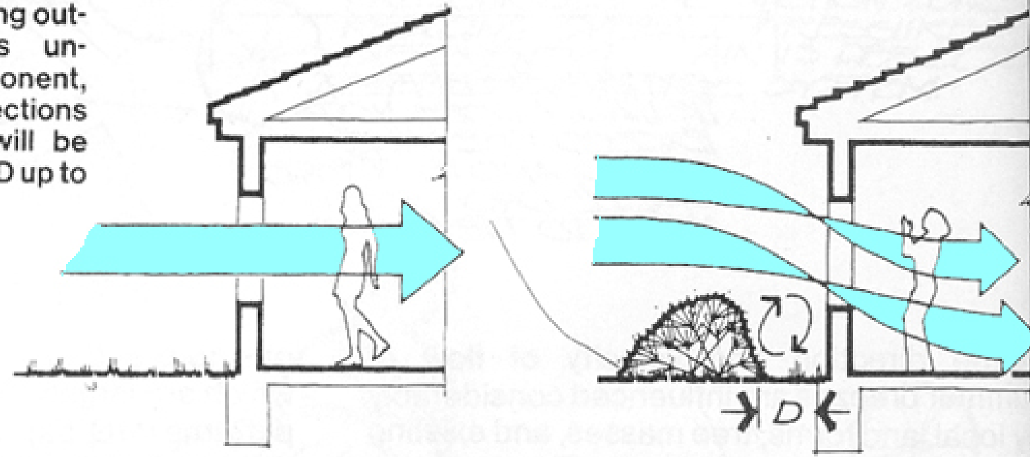
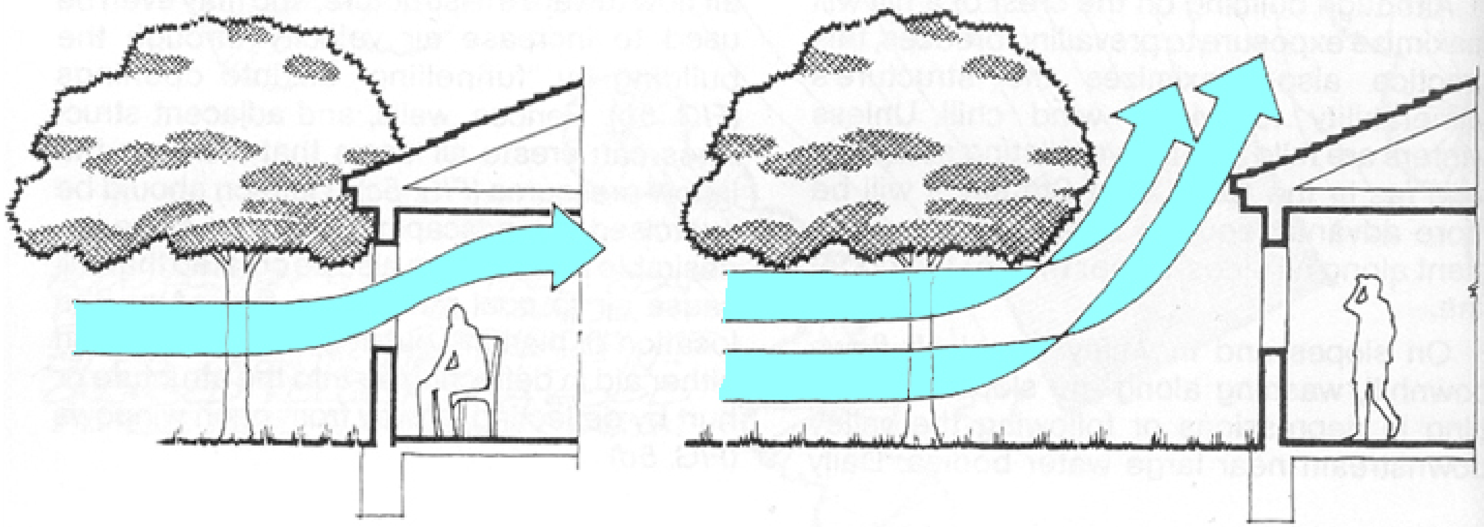
FIG. 5d. **Wind Deflectors**

Hedge and shrub planting outside window relieves unwanted pressure component, fosters downward deflections of air stream. Effect will be produced for distances D up to 15 to 20 ft.



Influence of tree canopy outside the window is to "lift" or warp the airstream upward by relieving downward pressure (opposite of shade-effect). If tree is immediately outside window it will produce a ceiling wash flow. At a distance from the house, canopy may warp the airstream sufficiently to miss the house altogether.



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Green on the Grand, Kitchener:

For operable windows to be able to work, you have to have enough of them as well as provide for through ventilation.

IMPORTANT!

For natural ventilation to work you need:

OPERABLE WINDOWS – the more the better in our climate

FLOW THROUGH ABILITY – air must be able to *move*

Stack Effect (ie. warm air rises):

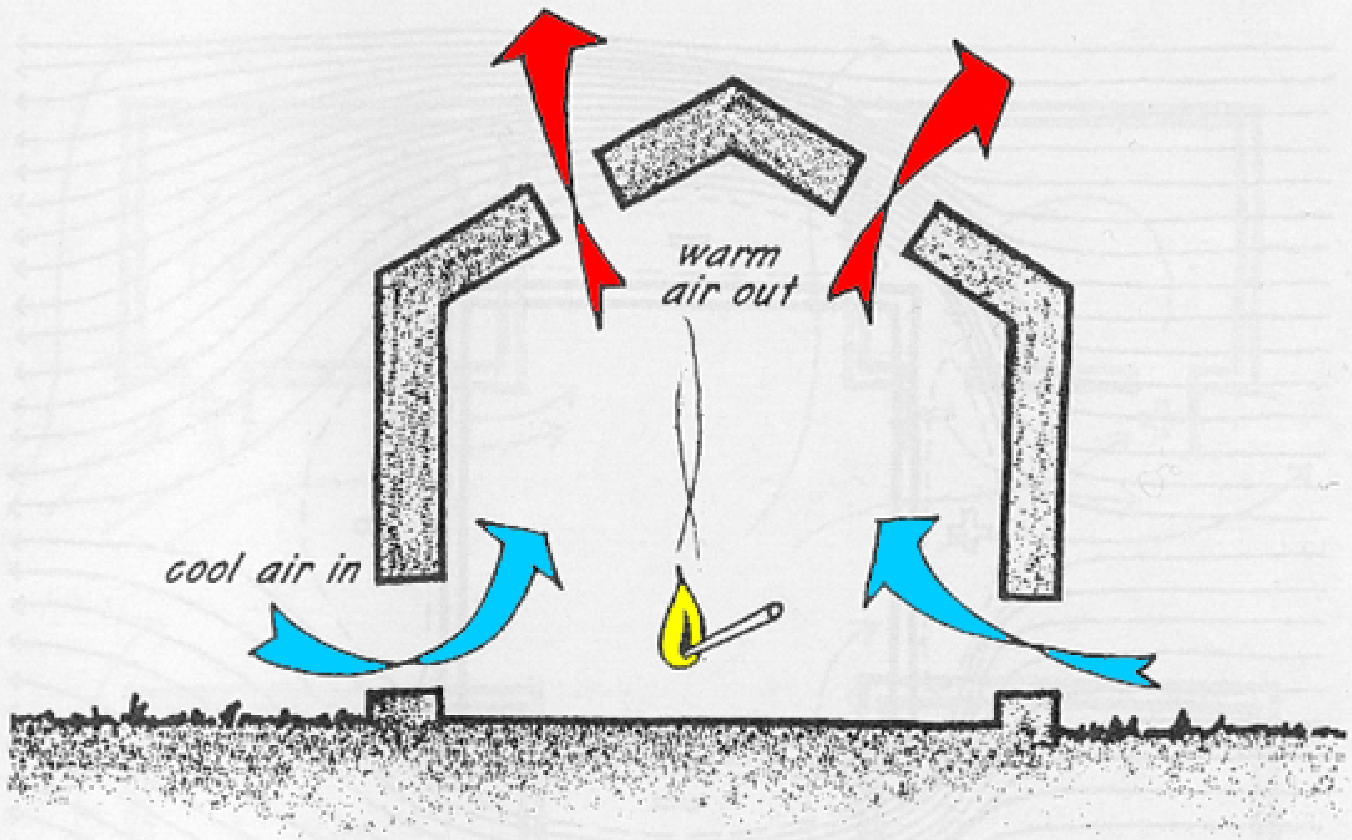

Figure 15.9: Ventilation principle #7 — The "stack effect" results when air in the building warms, becomes more buoyant than outside air, and rises to escape out of openings high in the building.

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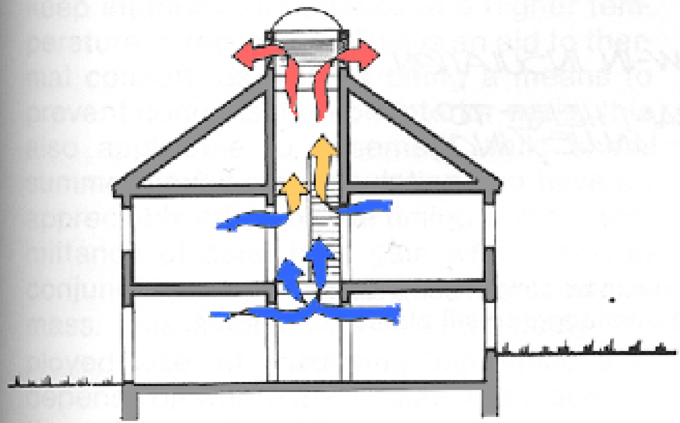
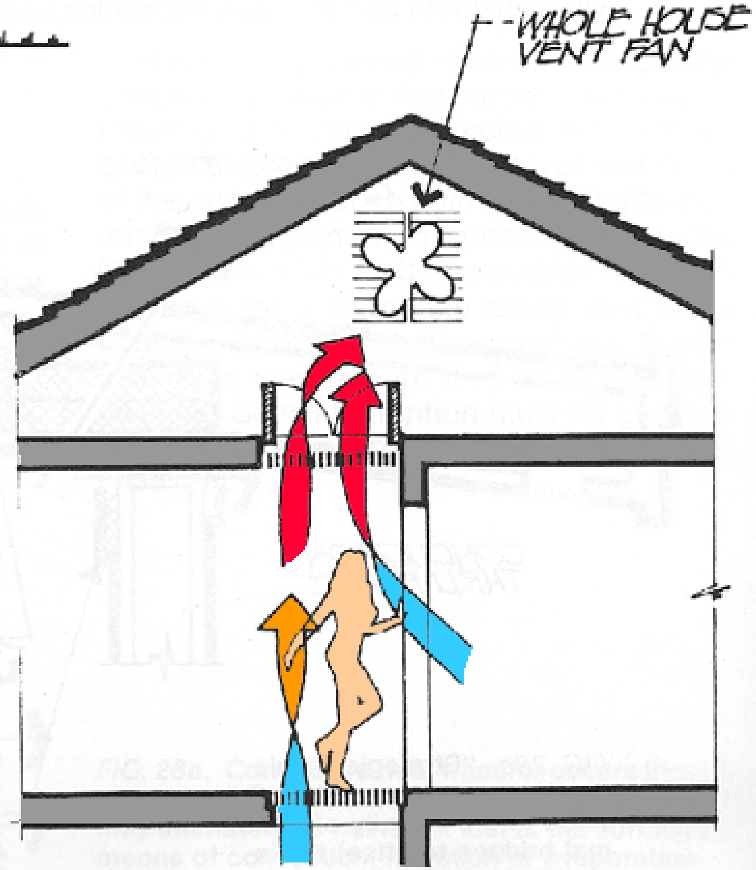


FIG. 27a. Central stair to vent capped with skylight & monitor makes an excellent "central ventilating" system as well as a potential sales appeal item.

FIG. 27b. (Right) Stack action can be coaxed through conventional house without unorthodox architectural style if adequate passage is provided. Floor grates, louvered ceilings, gable ends or ridge vents can provide the route.



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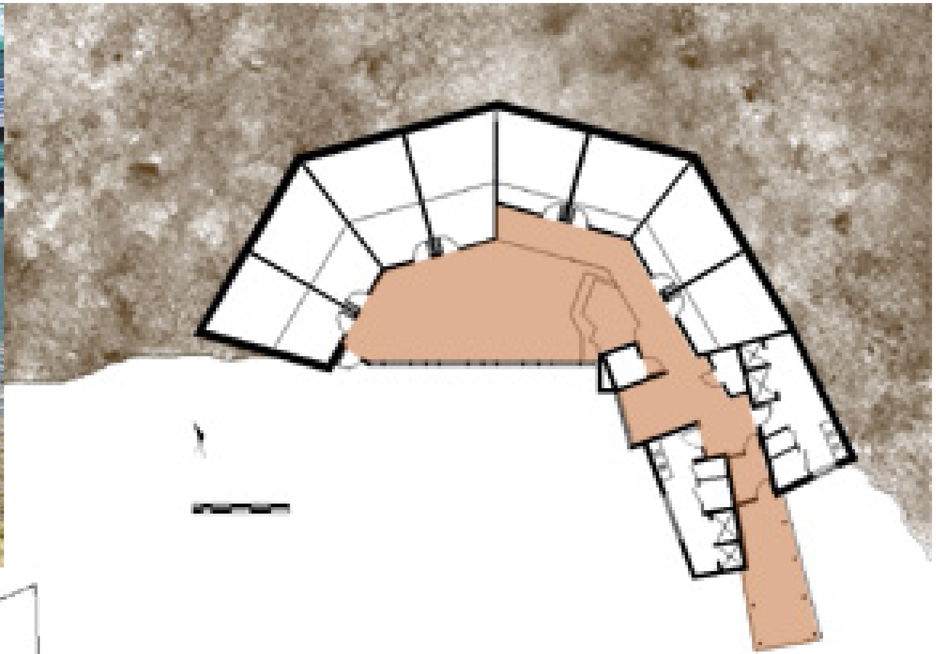
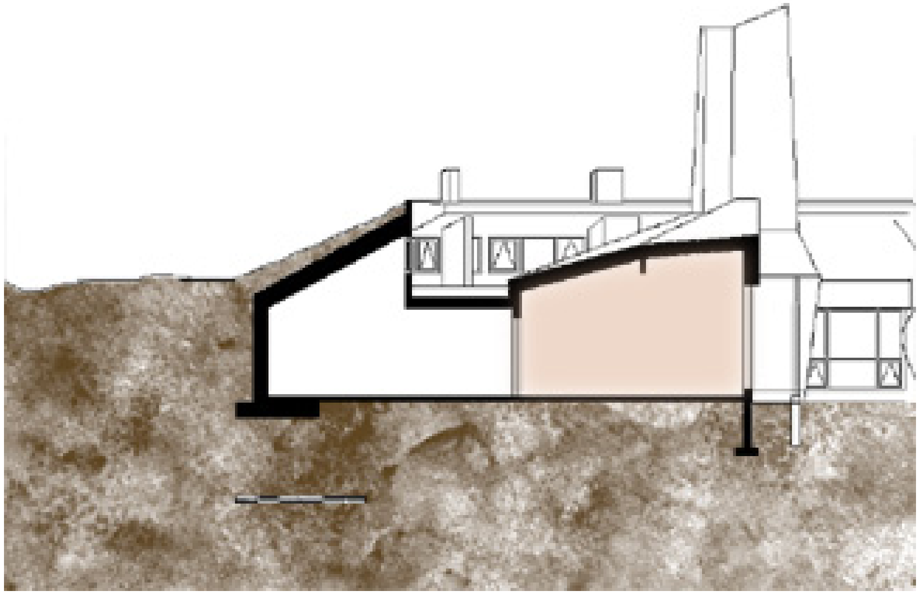
YMCA Environmental Learning Centre





YMCA Burrows:

What is Evaporative Cooling??

The exchange of sensible heat in the air for the latent heat of water droplets of wetted surfaces. It may be used to:

- Cool the building (where wetted surfaces are cooled by evaporation),
- Cool building air (directly by evaporation or indirectly by contact with a surface previously cooled by evaporation),
- Or cool the occupants (where evaporation of perspiration cools the skin surface.)

Sensible heat is the dry heat in the air.

Latent heat is the wet heat released into the air as water changes from liquid to vapour by evaporation or boiling.

Direct Evaporative Cooling

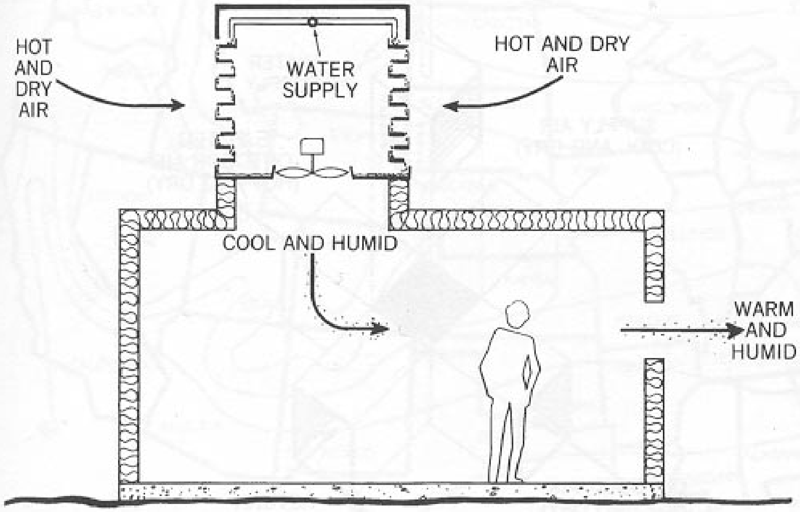
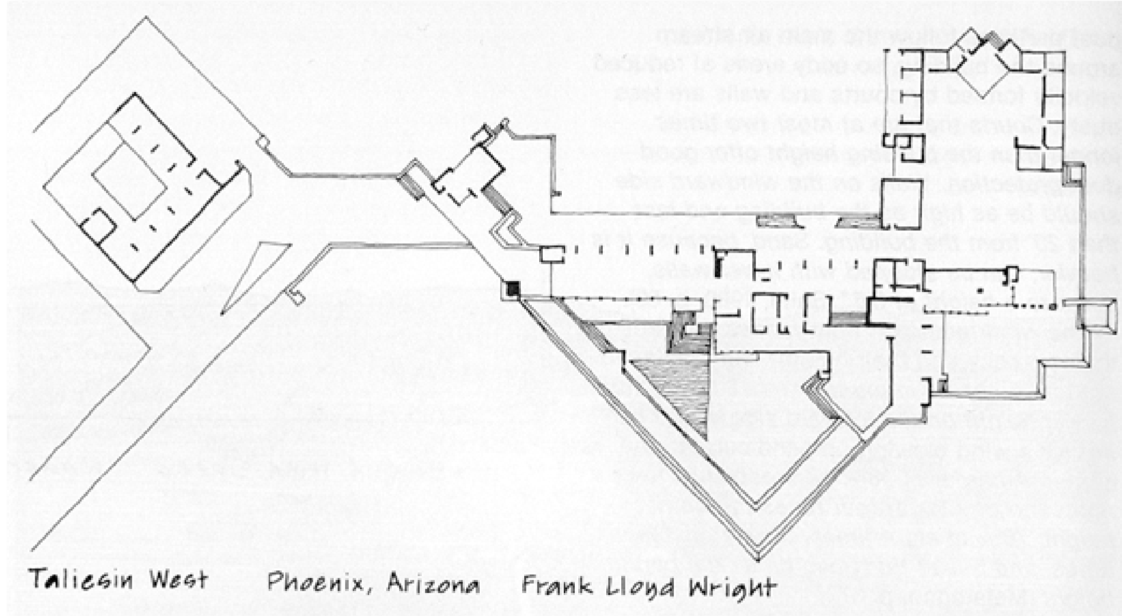
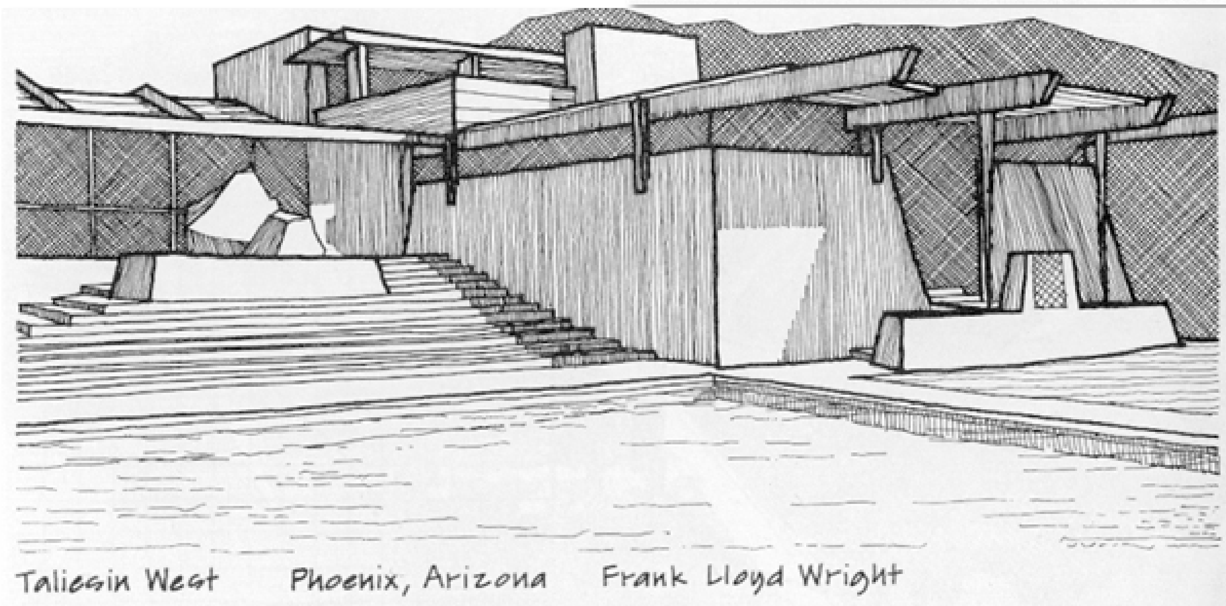


Figure 10.11a Evaporative coolers (swamp coolers) look a great deal like central Air Conditioning units, but their cooling mechanism is very simple and inexpensive. They are appropriate only in dry climates.

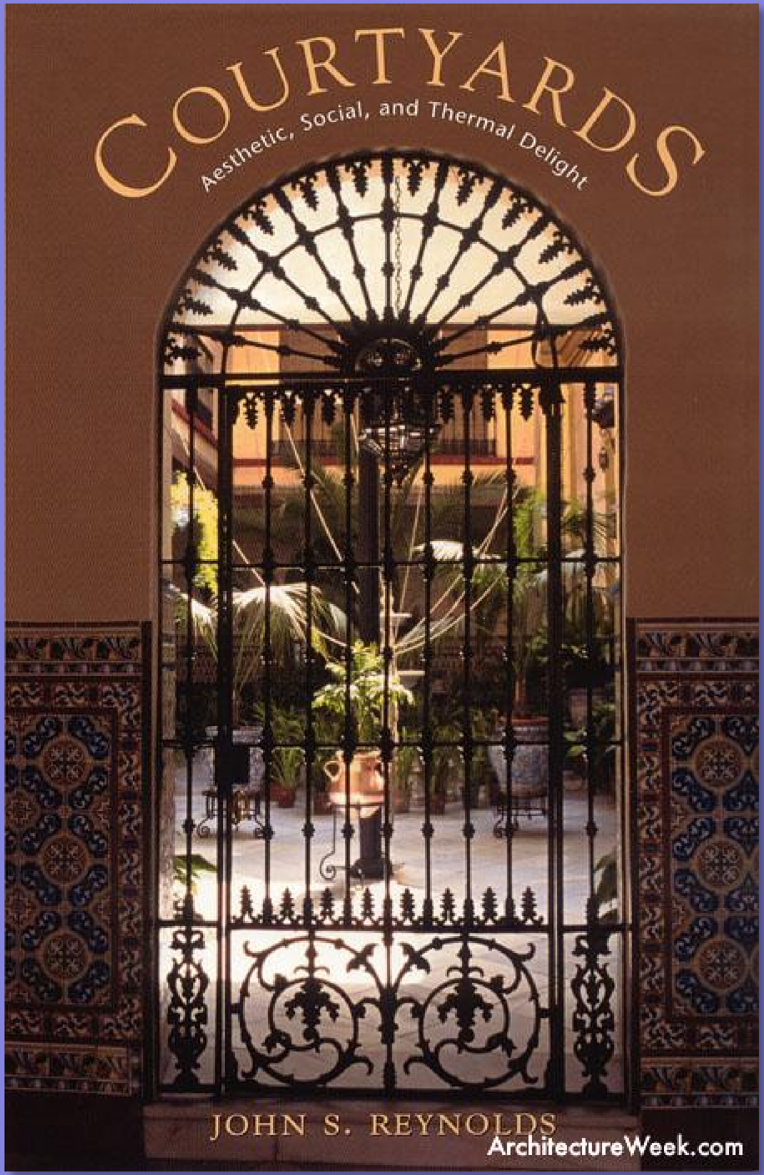
Figure 10.11b Evaporative coolers are widely used in hot and dry regions. This is an example of a direct evaporative cooler on the roof of a house.

Direct Evaporative Cooling





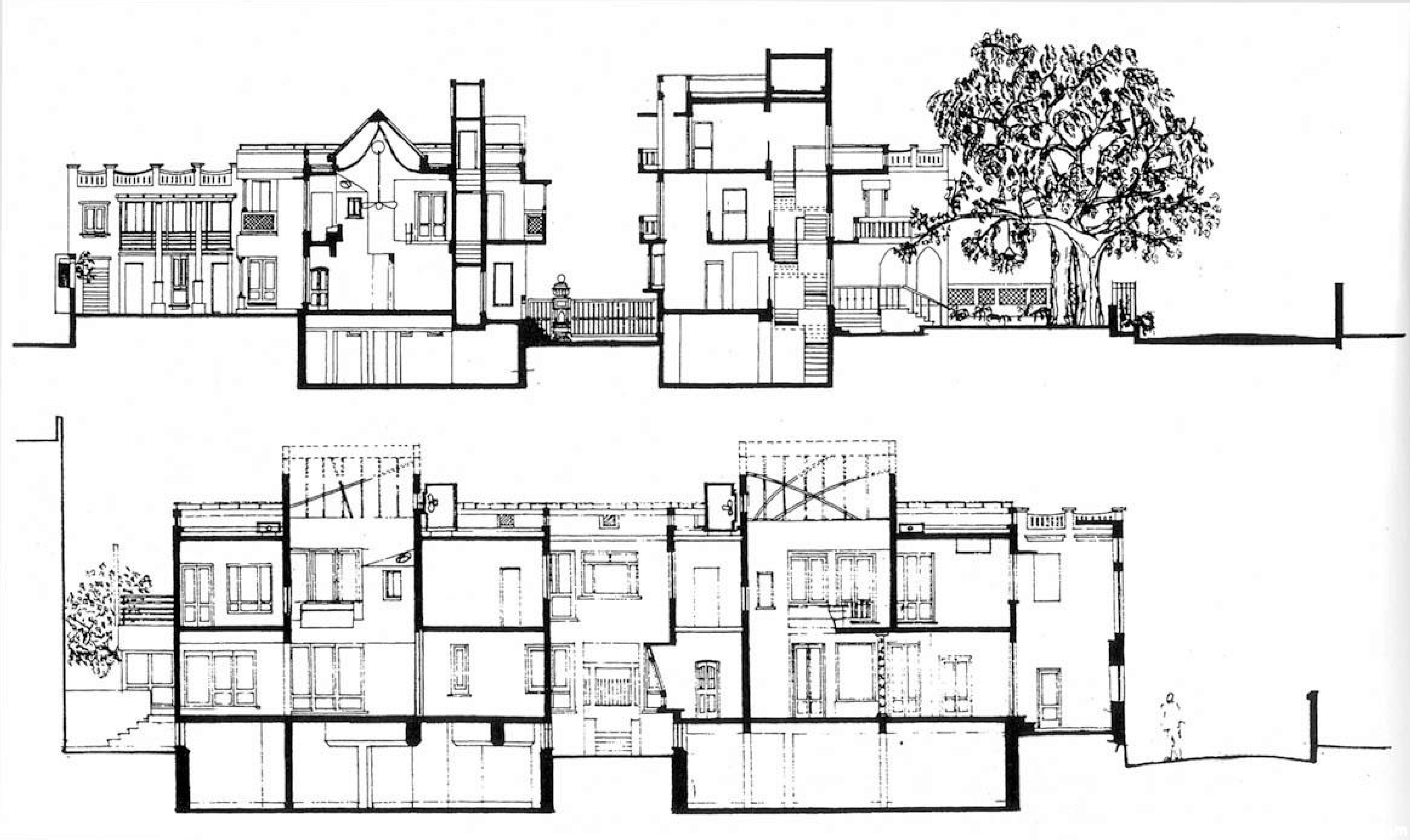
Wind passing over the water can pick up humidity in dry climates and carry it into the building.


COURTYARDS
Aesthetic, Social, and Thermal Delight
JOHN S. REYNOLDS
ArchitectureWeek.com


ArchitectureWeek.com

Massey College, Toronto

Eco Houses: Wind Towers



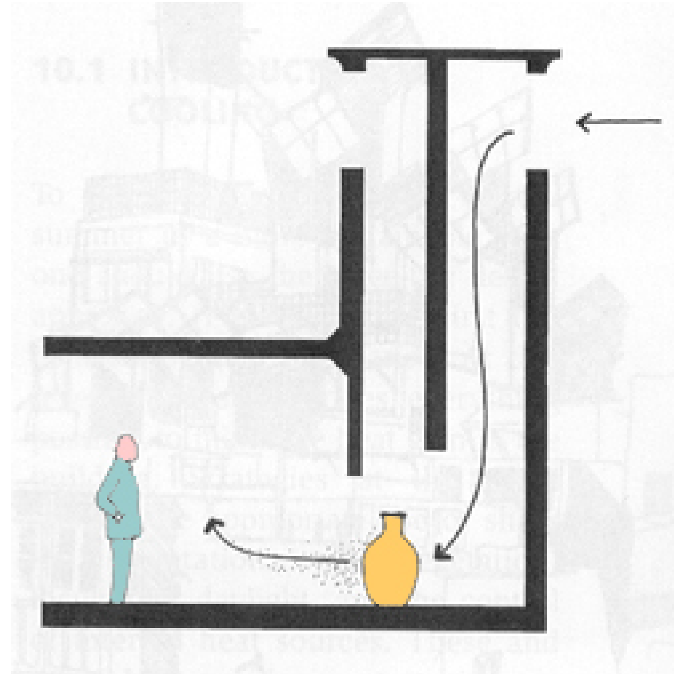
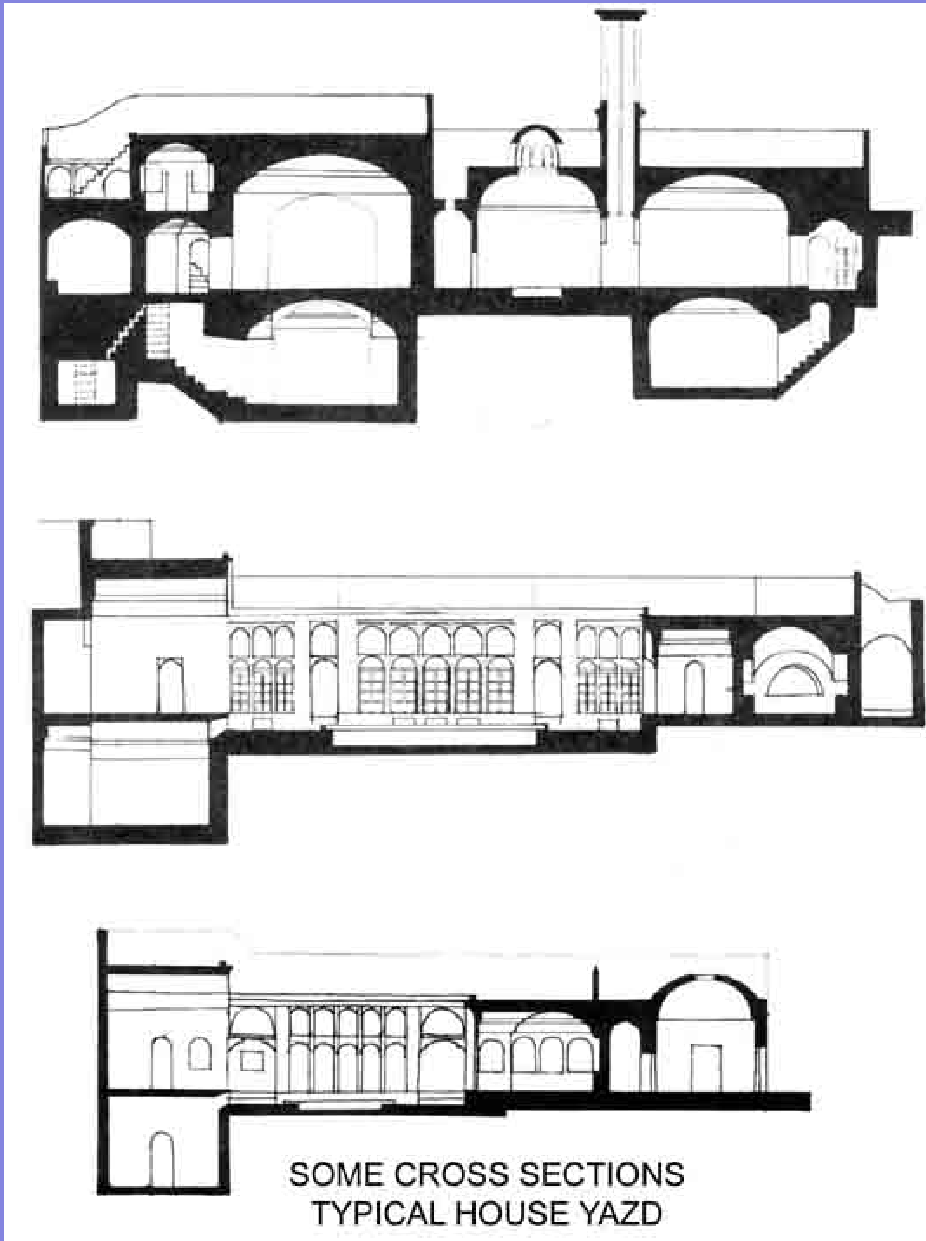
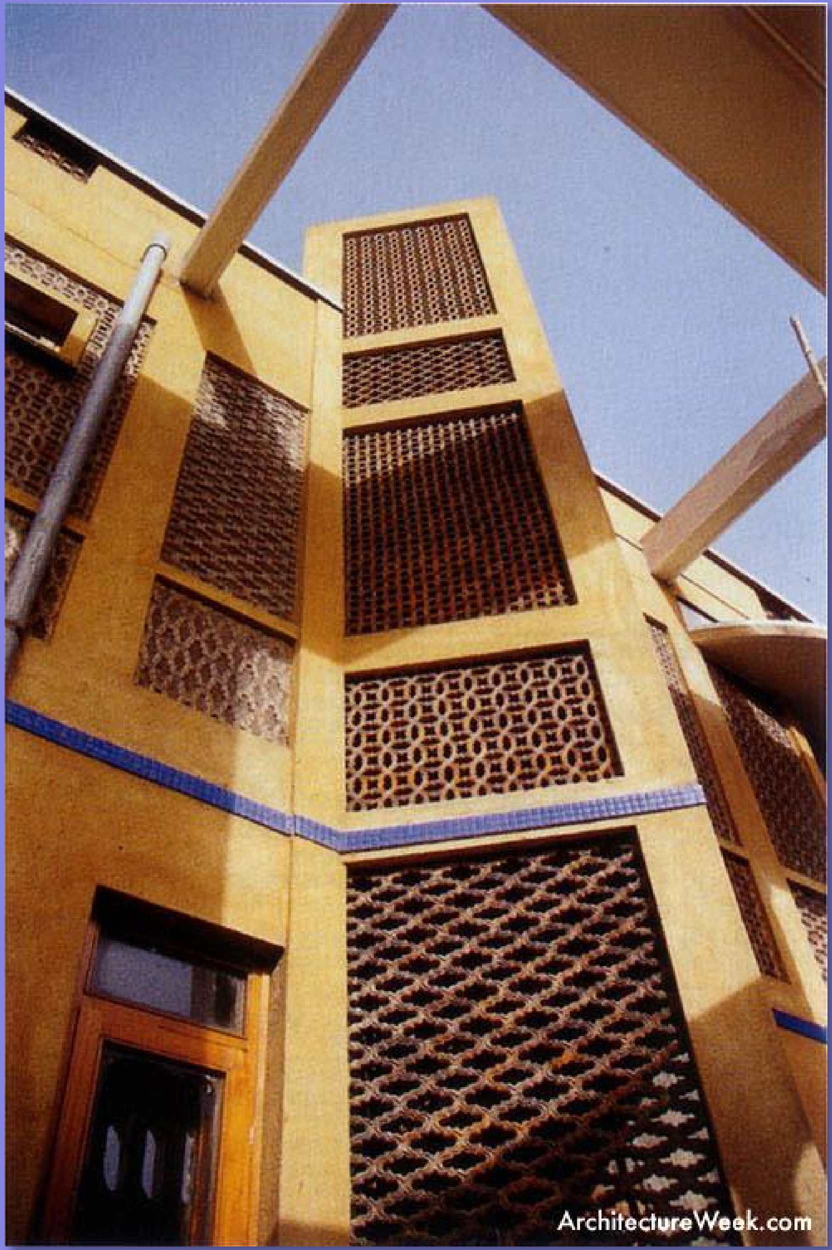
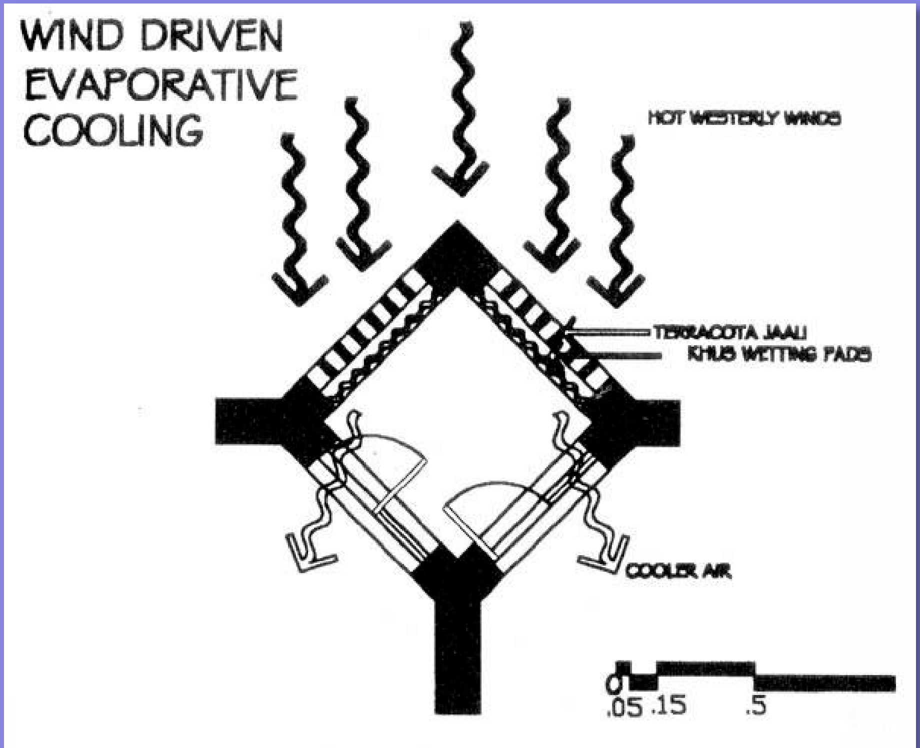


Figure 10.2e Some wind towers in hot and dry areas cool the incoming air by evaporation.


SOME CROSS SECTIONS
TYPICAL HOUSE YAZD


ArchitectureWeek.com


WIND DRIVEN
EVAPORATIVE
COOLING
HOT WESTERLY WINDS
TERRACOTA JAALI
KHUS WETTING PADS
COOLER AIR
0
.05 .15
.5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GOING GREEN
Behnisch in Ettlingen Mansilla + Tuñon in Madrid BedZED in use Timber extra

BedZED


One bedroom flat with 4 bed maisonette over.
Pedestrian access to workspaces.
Organic café / shop
3 bed maisonette with one bed flat over.
Vehicular mews - access to workspaces and dwellings
Workspaces with timber mezzanine and integral shower room
3 bed maisonette with one bed flat over.
Southern aspect maisonettes have ground floor gardens and access road.

Solar Chimneys:

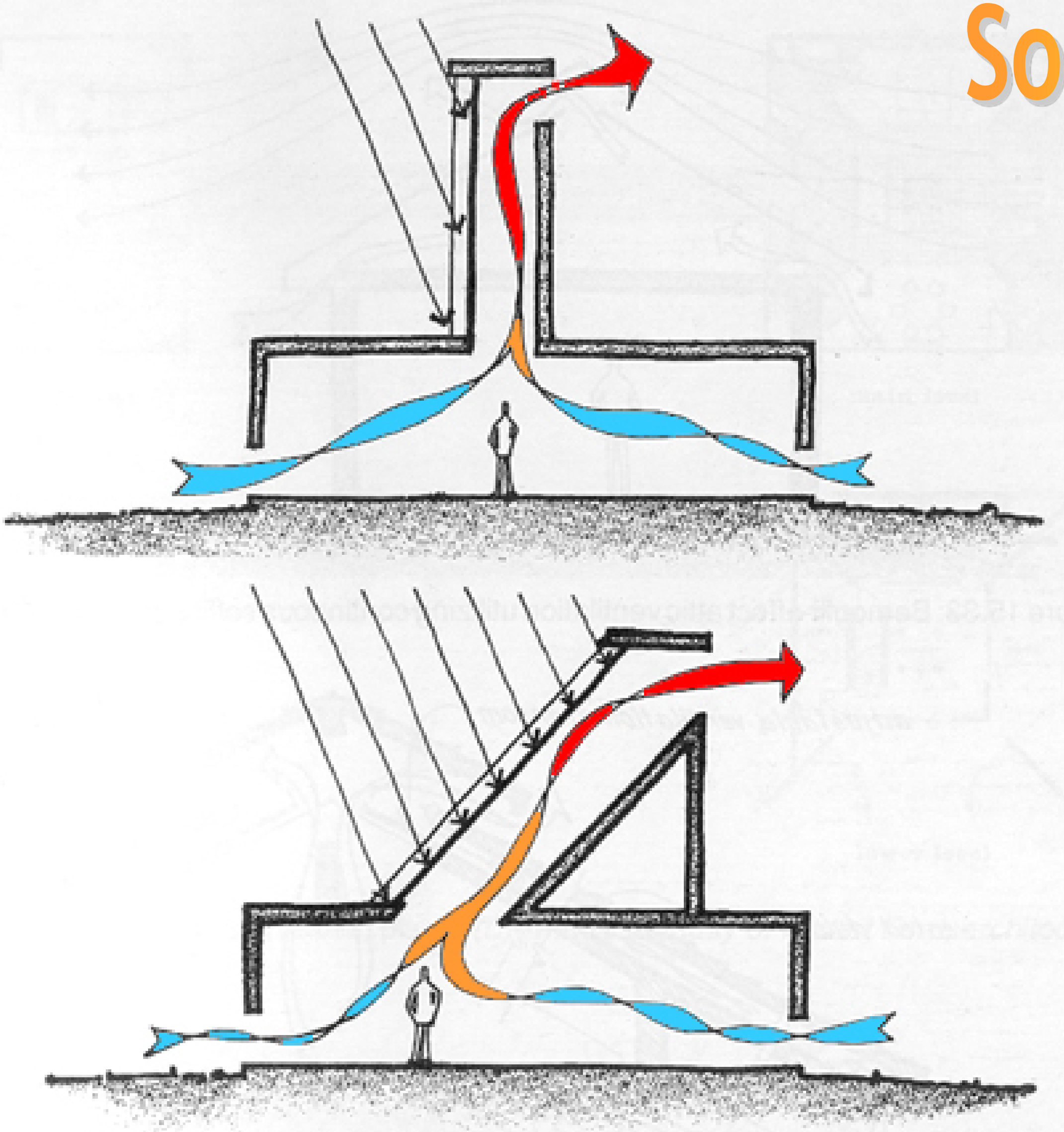


Figure 15.32: Vertical solar chimneys provide the greatest stack height for a given collector size but this tilt is not effective for summer collection. Sloped chimneys provide a better summer collection angle but must be taller to provide sufficient vertical "stack" height.

HCL

Solar chimney at the computer building, York University

What is Radiative Cooling??

Transfer of heat from warmer surface to cooler surrounding surface (or outer space). It may be used to cool the building (where warm building surfaces radiate heat to the sky) or to cool the people (where the warm skin radiates heat to the cooler building surfaces -- to the cool walls of an underground building, for example.

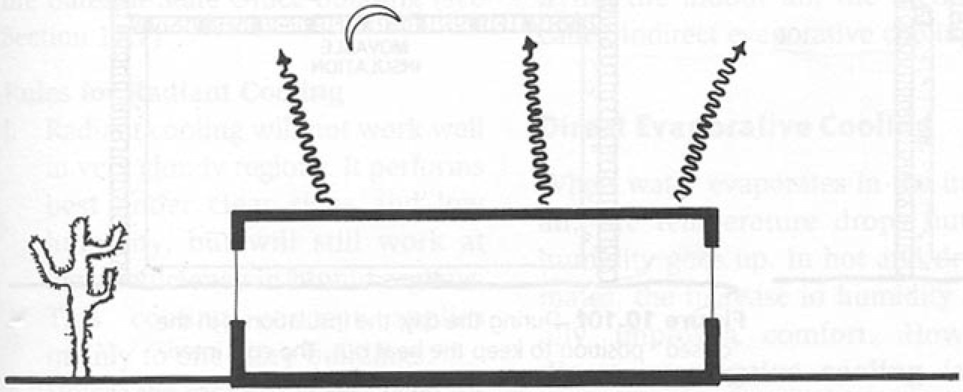


Figure 10.10a On clear nights with little humidity, there is strong radiant cooling.

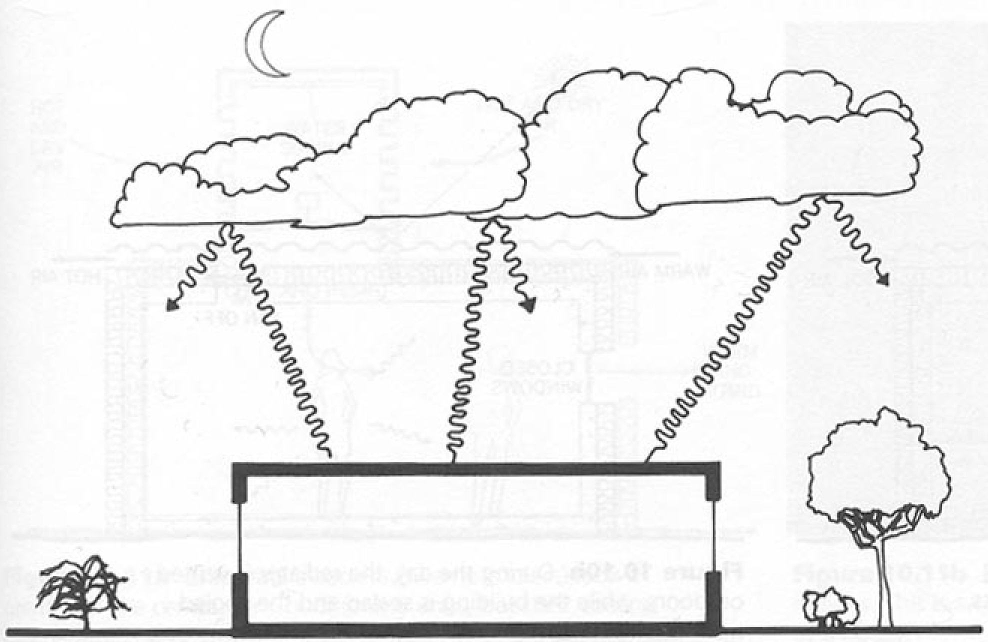
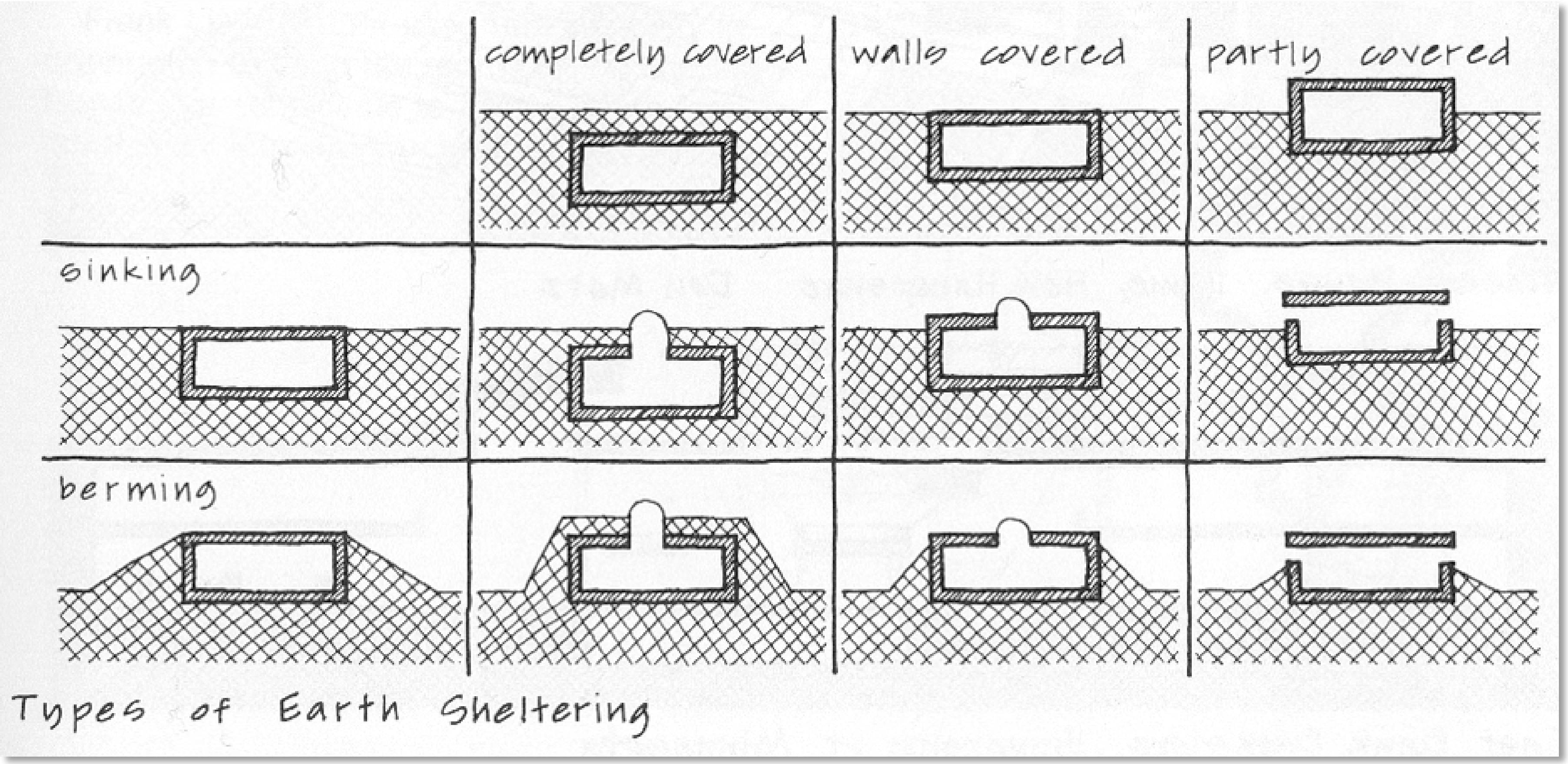


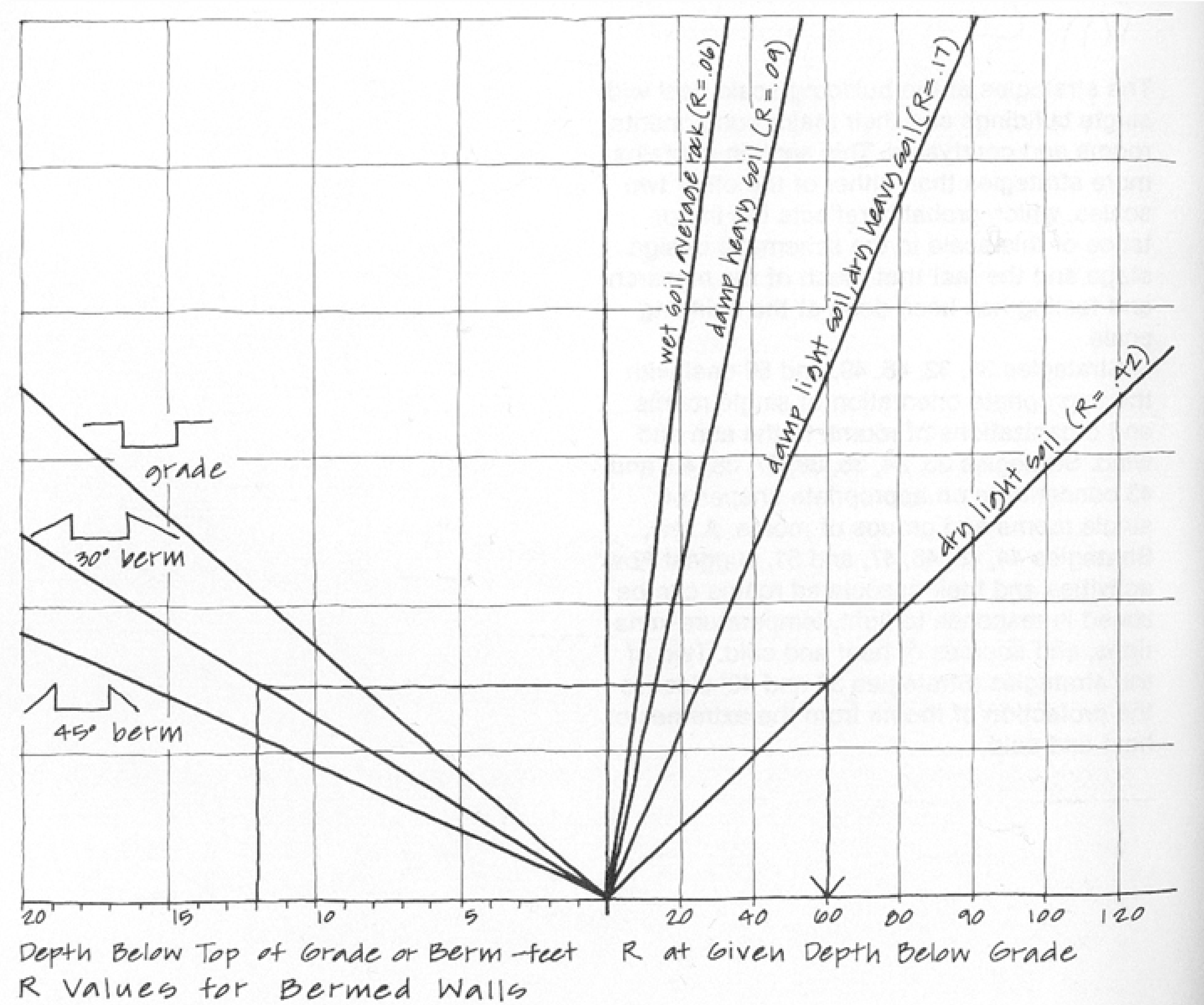
Figure 10.10b Humidity reduces radiant cooling, and clouds practically stop it.

Earth Berming used to cool buildings:



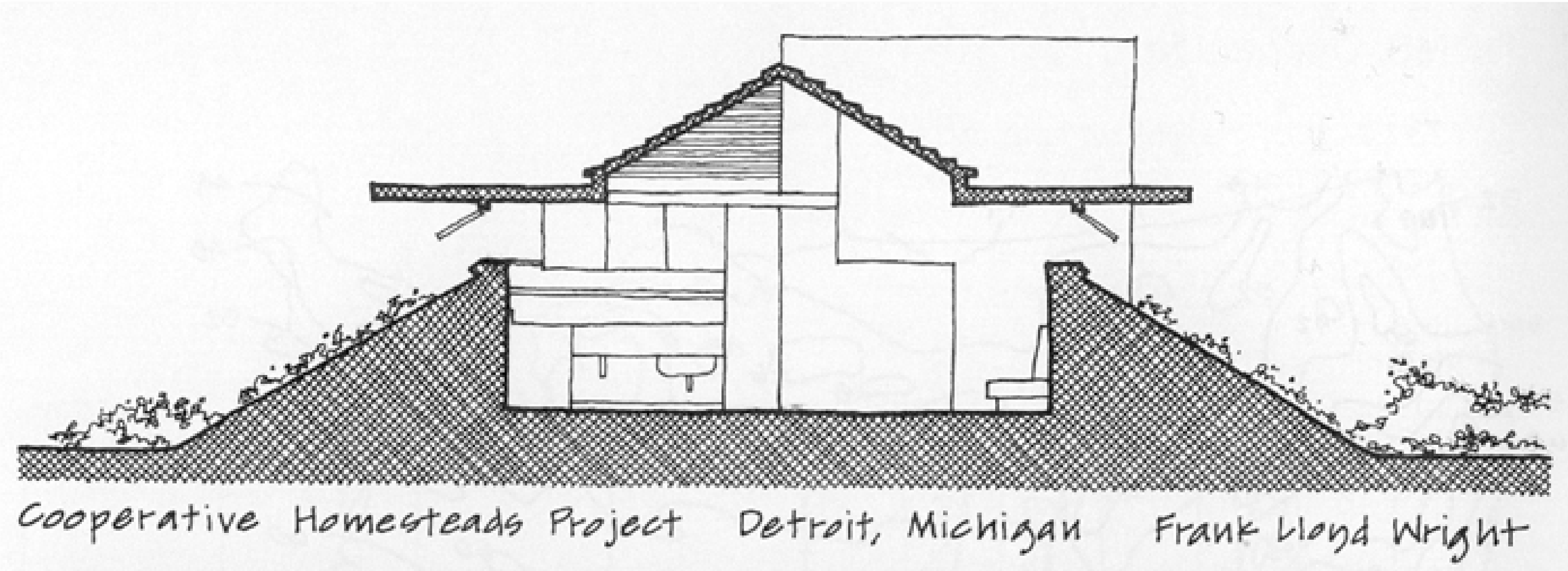
SWL



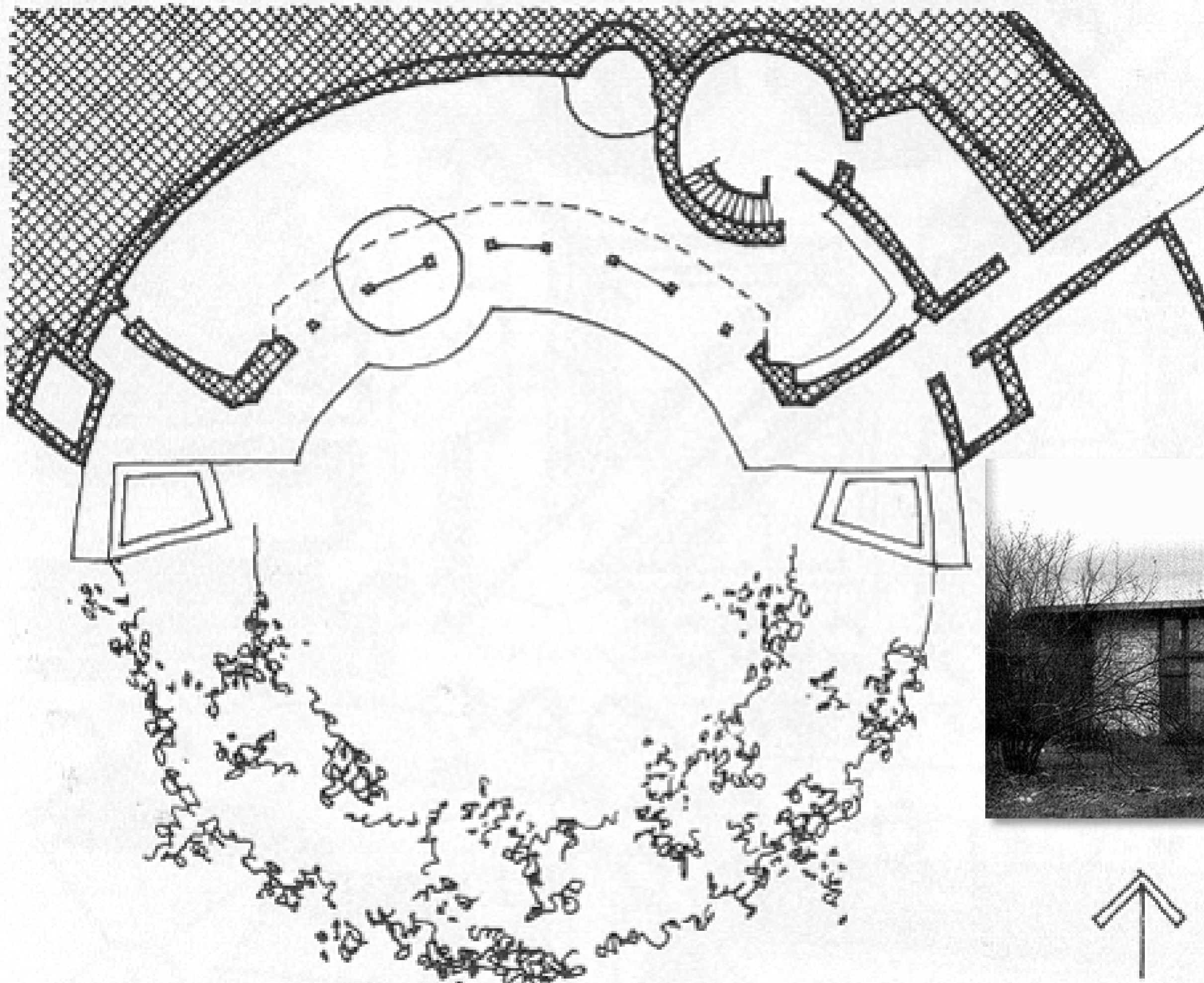



wet soil, average rock (R=.06)
damp heavy soil (R=.09)
damp light soil, dry heavy soil (R=.17)
dry light soil (R=.42)
grade
30° berm
45° berm
20
15
10
5
20
40
60
80
90
100
120
Depth Below Top of Grade or Berm -feet
R at Given Depth Below Grade
R Values for Bermed Walls

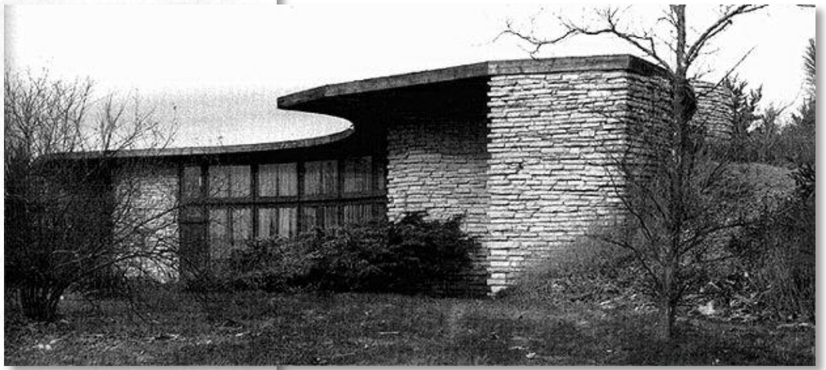
SWL


Cooperative Homesteads Project Detroit, Michigan Frank Lloyd Wright

SWL



Jacobs II House Middleton, Wisconsin
F.L. Wright



SWL

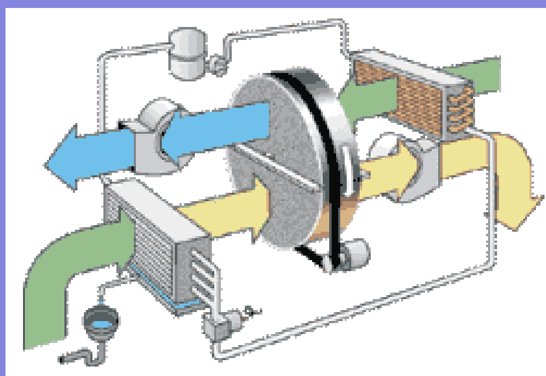
What is Dehumidification Cooling??

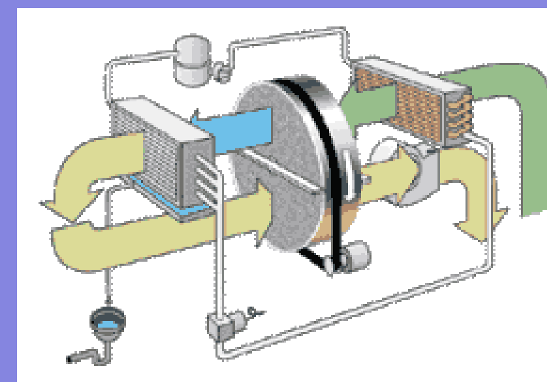
The removal of water vapour from room air by dilution with drier air, through condensation, or dessication.

This process can be very difficult to achieve in a *passive way* in hot humid climates where there is no dry air available to use to dehumidify and the relative humidity is above 80%.

SGAmerica

Integrated desiccant dehumidification and vapor compression cooling technologies, utilizing SSCR rotors.





EconoSorb:
Energy consumption is 25% of a standard desiccant dehumidifier and 50% of a mechanical unit rated at 68 F and 60% RH.
Available in standard and tropical designs.
Capacity range: 500 to 20,000 scfm. 20 to over 400 lbs/hr of water removal

CoolSorb:
Energy consumption is 33% of a standard desiccant dehumidifier and 60% of a mechanical unit rated at 68 F and 60% RH, requiring only one air stream.
Capacity range: 800 to 12,000 scfm. 8 to over 130 lbs/hr of water removal

What is Mass Effect Cooling??

The use of thermal storage to absorb heat during the warmest part of the day and release it during a cooler part. "Night flushing", where cooler air is drawn through a building to exhaust heat stored during the day in massive floors and walls is an example of daily-cycle-mass-effect-cooling.

A good strategy to couple with direct gain passive solar systems that will tend to absorb heat from its thermal mass component during the day of hot cycles.

Night Flush Cooling

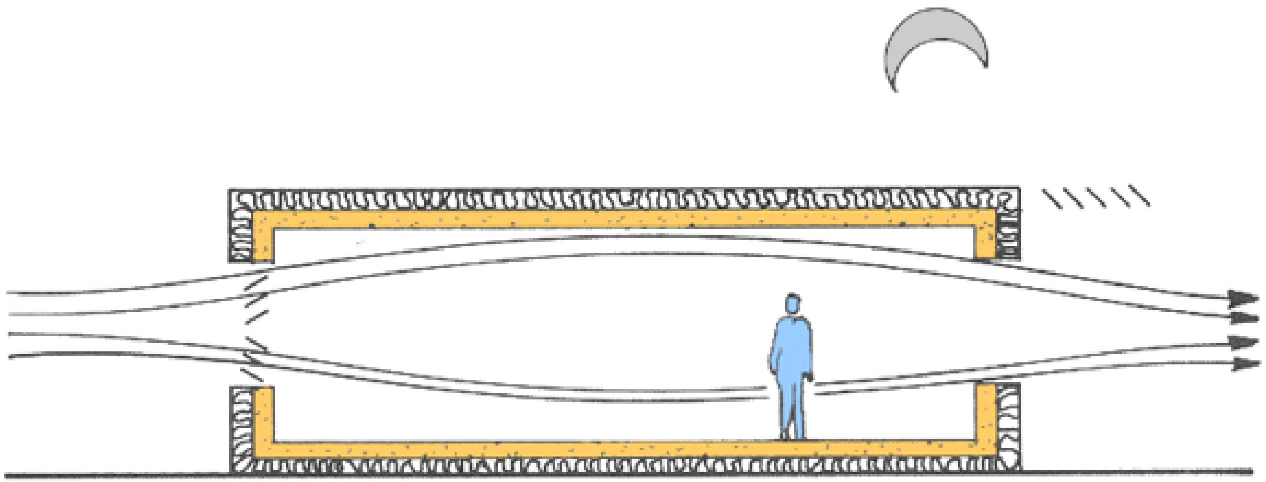


Figure 10.9a With "night-flush cooling," night ventilation cools the mass of the building.

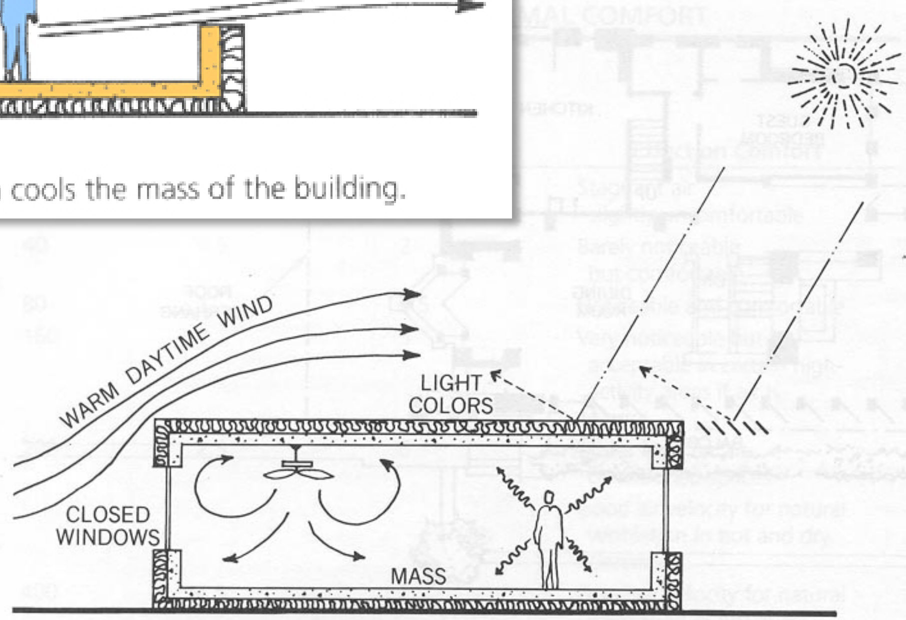


Figure 10.9b During the day, the night-flush cooled mass acts as a heat sink. Light colors, insulation, shading, and closed windows keep the heat gain to a minimum. Interior circulating fans can be used for additional comfort.

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Night Flush Cooling

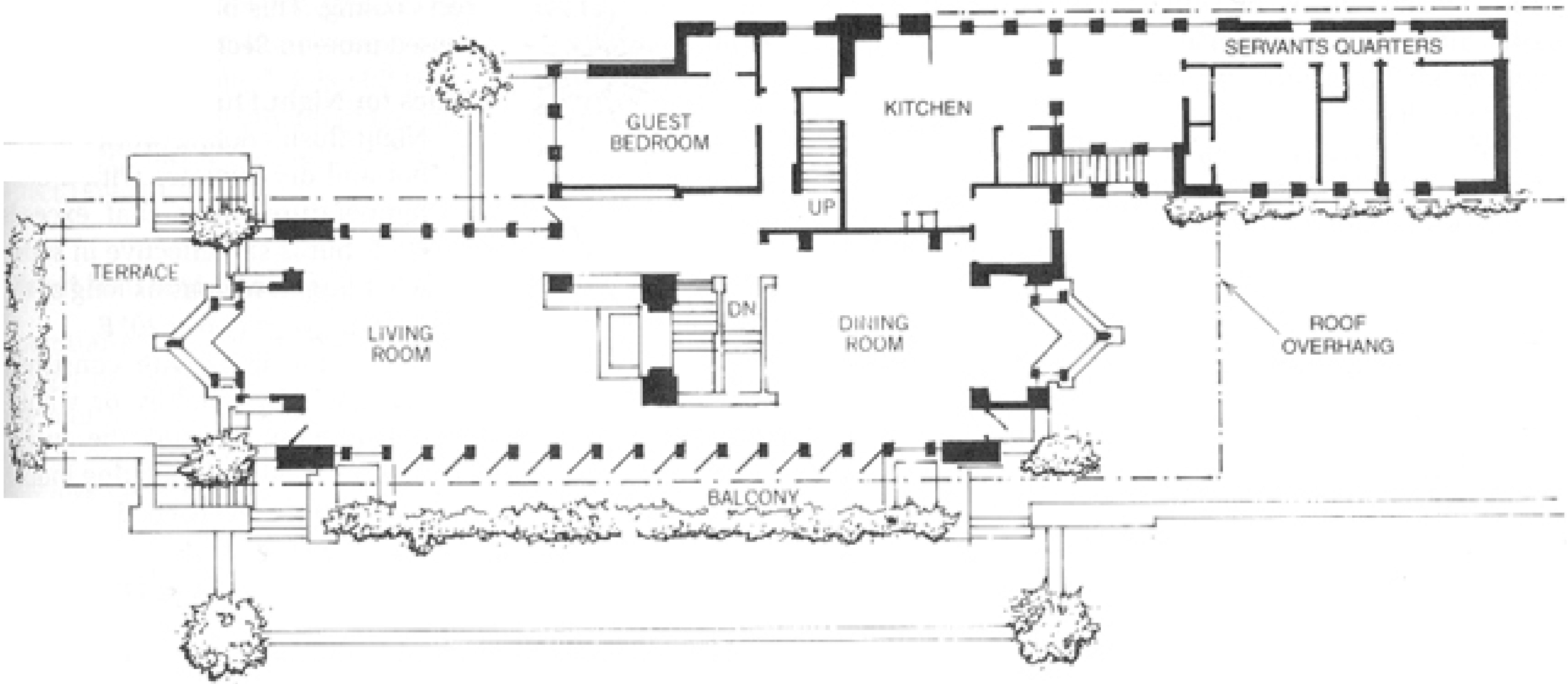
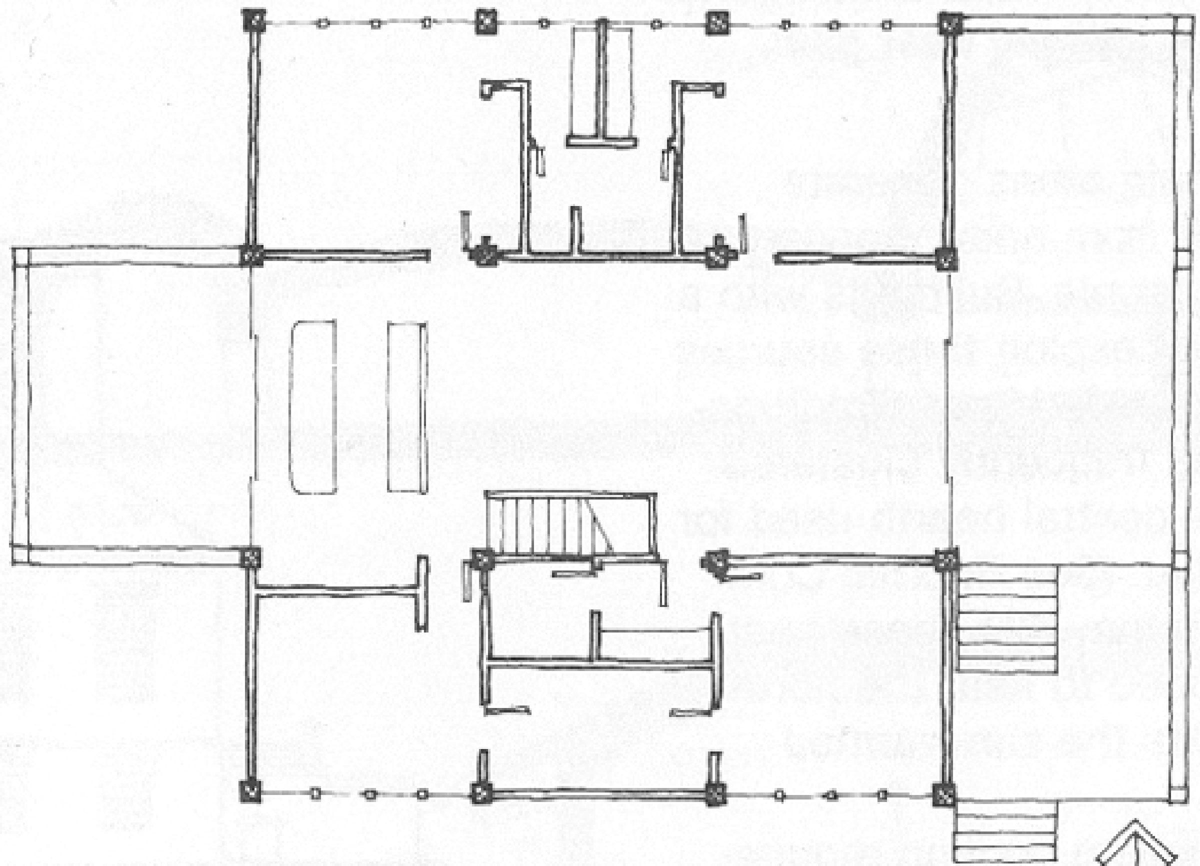


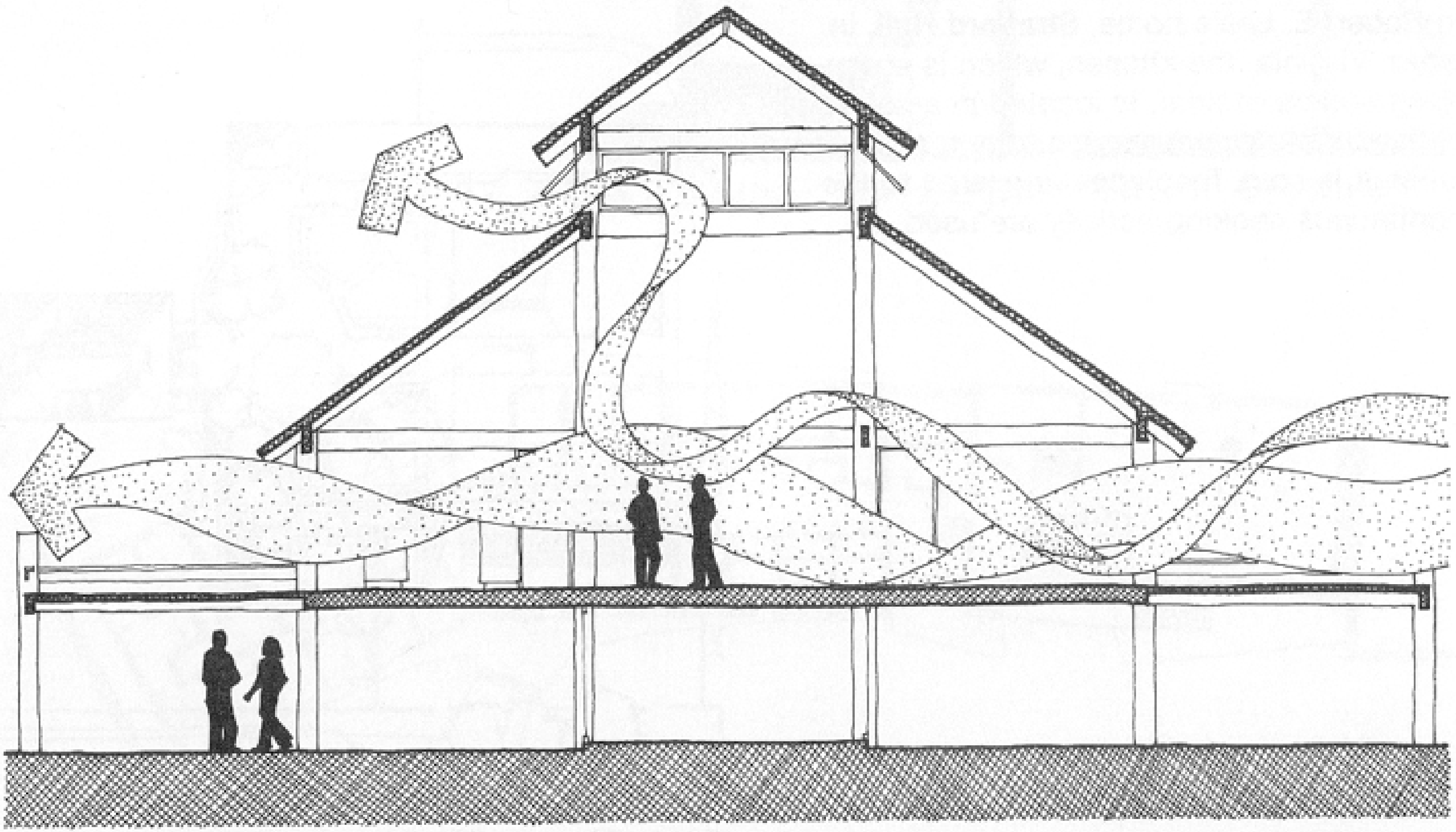
Figure 10.8b Frank Lloyd Wright's Robie House (1909) in Chicago had whole walls of doors and windows that opened for natural ventilation.

HCL



Logan House Tampa, Florida Rowe Holmes Assoc.

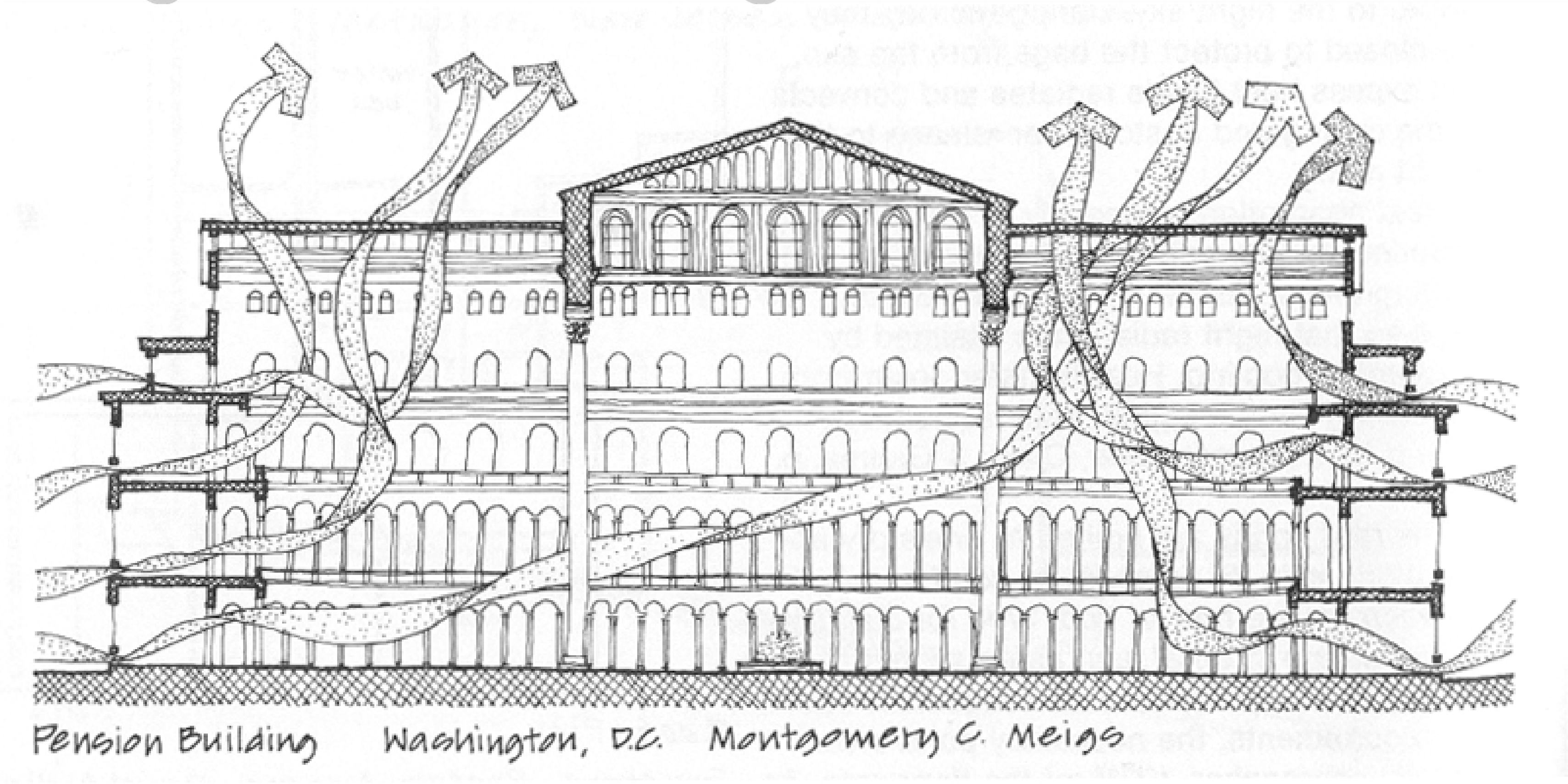
SWL



Logan House Tampa, Florida Rowe Holmes Assoc.

SWL

Magic Arrow Diagrams:



SWL

You have to make them to explain this, and they sure had better be based on sound thought…

Remaining “Wicked Problems”

Natural Ventilation

- A key way to reduce the energy required to power a building is via the elimination of A/C
- Not all buildings can tolerate the resulting humidity or fluctuations in interior environment that can result from no A/C
- Urban environments can be too “dirty” for natural ventilation
- Urban environments can be too noisy for natural ventilation