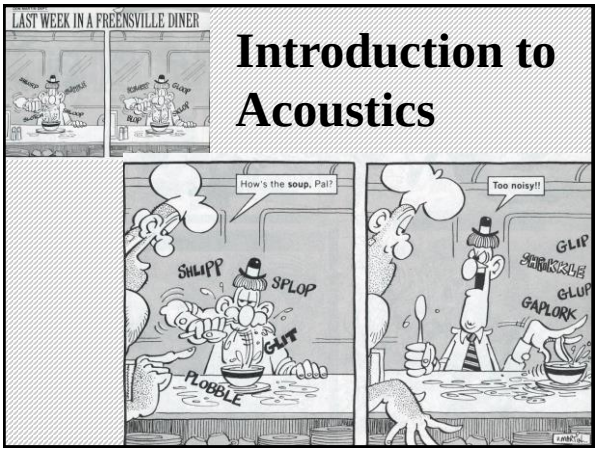
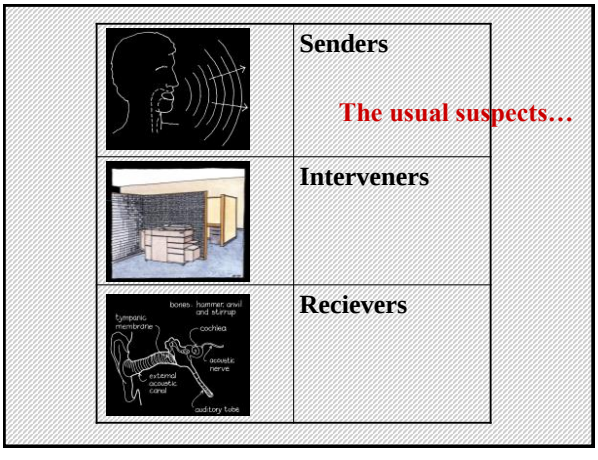
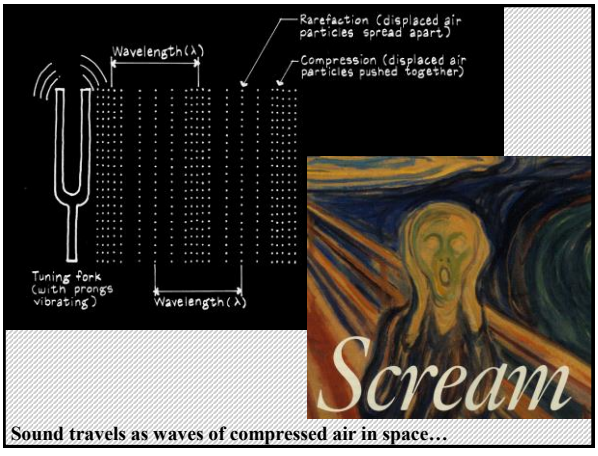

LAST WEEK IN A FREENSVILLE DINER
Introduction to Acoustics
How's the soup, Pal?
SHLIPP
SPLOP
GLUT
PLOBBLE
Too noisy!!
GLIP
SPRAKKLE
GLUP
GAPLORK

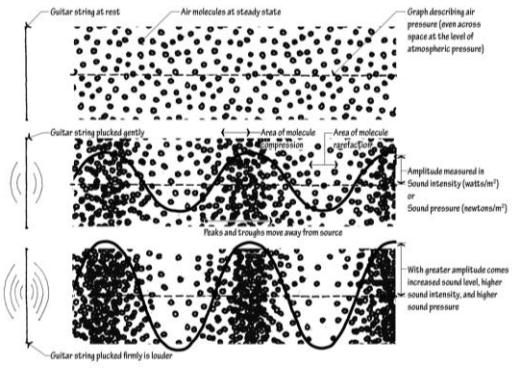
1


Senders
The usual suspects…
Interveners
Recievers
tympanic membrane
bones: hammer, anvil and stirrup
cochlea
acoustic nerve
external acoustic canal
auditory tube

2


Wavelength (λ)
Rarefaction (displaced air particles spread apart)
Compression (displaced air particles pushed together)
Tuning fork (with prongs vibrating)
Wavelength (λ)
Scream
Sound travels as waves of compressed air in space…

3



More realistically—the effect of a guitar string

4

Frequency - measured in the number of compressions per unit time

usually cycles per seconds or also called hertz

lower frequency means lower pitch

human voice has a range of about
100 – 600 hz fundamental
up to 7500 hz w/ harmonics

human ear perceives 20 - 20,000 hz
(upper limit drops as you age)
most sensitive to 4000 hz
(baby's cry is at this freq.)
perhaps natural selection

5

Wavelength - measured as distance between compressions (λ)

usually in cm or inches

related to frequency inversely

$\lambda = \frac{c}{f}$ λ = wavelength, c = velocity, f = frequency

So large λ means low freq.

6

Sound propagation in building materials….

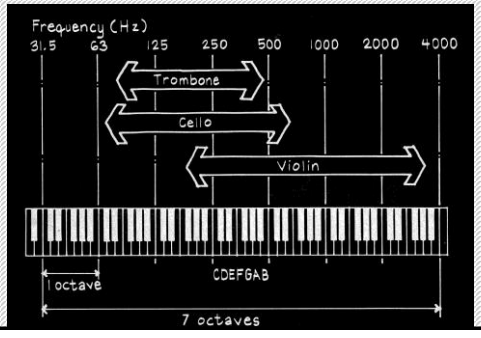
TABLE 26.1 **Sound Propagation Velocity in Various Media**

Medium	Velocity: Meters per Second	Velocity: Feet per Second
Air	344	1130
Water	1410	4625
Wood	3300	10,825
Brick	3600	11,800
Concrete	3700	12,100
Steel	4900	16,000
Glass	5000	16,400
Aluminum	5800	19,000

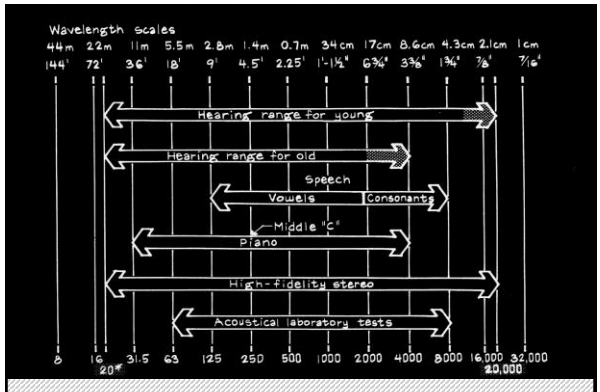
NOTE: These figures are approximate, since the listed materials vary in density. Average frequency is used.

7

Wavelength
36 feet *(1130fps/31.5=36)*
3.6 inches *(1130fps/4000=0.3)*



8



Range, wavelength, & frequency in air…

9

Intensity - measure of loudness

$I = \frac{P}{A}$ where I is in w/cm², P is power watts, A is in cm²

since sound from a point source spreads freely in all directions A is area of sphere or $4\pi r^2$

$I = \frac{P}{4\pi r^2}$ (r is in cm)

the intensity of sound like light thus follows inverse square law

for line source - surface area of cylinder

$I = \frac{P}{2\pi r \ell}$

Analogous to point and line sources of light…

10

About the only place you see the intensity of sound measured in w/cm² is on the tech. registration exam —

the more common scale is in decibels

The reason for this is that the range of human hearing is from

10^{-16} watts/cm² (barely audible)

10^{-4} watts/cm² (causes pain)

this is a ratio of one to one trillion from the lowest to highest ($1:10^{12}$) numbers that large tend to be meaningless

11

So a logarithmic scale based on the threashhold of human hearing (10^{-16} w/cm²) has been developed

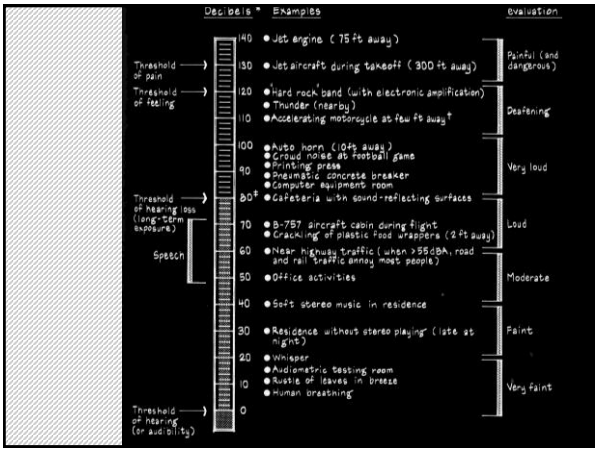
so 10^{-16} w/cm² = 0 dB

and 10^{-4} w/cm² = 120 dB pain

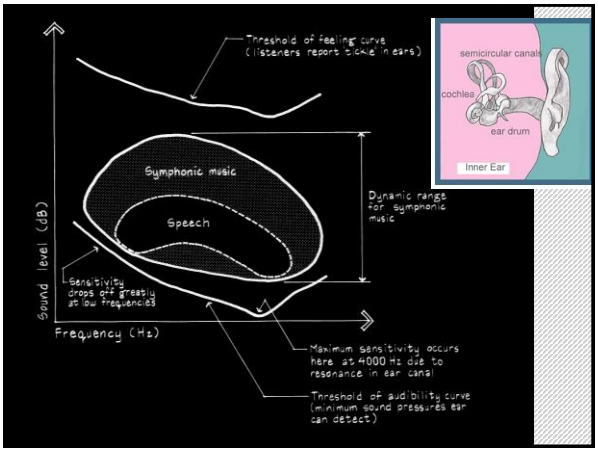
the formula for conversion from w/cm² to dB's is

$$dB = 10 \log_{10} \left(\frac{I \text{ in w/cm}^2}{10^{-16} \text{ w/cm}^2} \right)$$

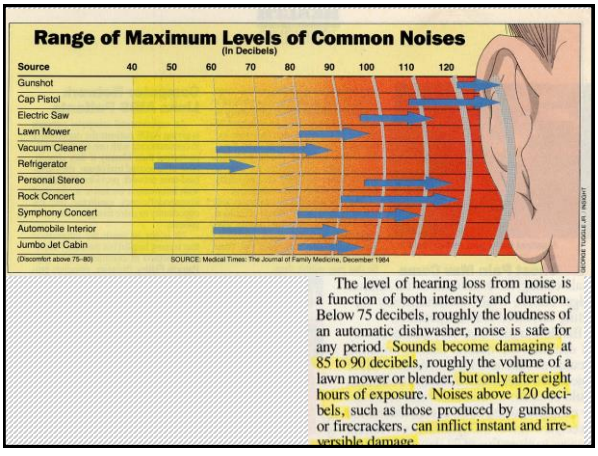
12


Decibels*
Examples
Evaluation
140
Jet engine (75 ft away)
130
Jet aircraft during takeoff (300 ft away)
120
"Hard rock" band (with electronic amplification)
Thunder (nearby)
110
Accelerating motorcycle at few ft away†
100
Auto horn (10 ft away)
Ground noise at football game
90
Printing press
Pneumatic concrete breaker
Computer equipment room
80†
Cafeteria with sound-reflecting surfaces
70
B-757 aircraft cabin during flight
Cracking of plastic food wrappers (2 ft away)
60
Near highway traffic (when >55 dBA, road and rail traffic annoy most people)
50
Office activities
40
Soft stereo music in residence
30
Residence without stereo playing (late at night)
20
Whisper
Audiometric testing room
10
Rustle of leaves in breeze
Human breathing
0
Threshold of pain
Threshold of feeling
Threshold of hearing loss (long-term exposure)
Speech
Threshold of hearing (or audibility)
Painful (and dangerous)
Deafening
Very loud
Loud
Moderate
Faint
Very faint

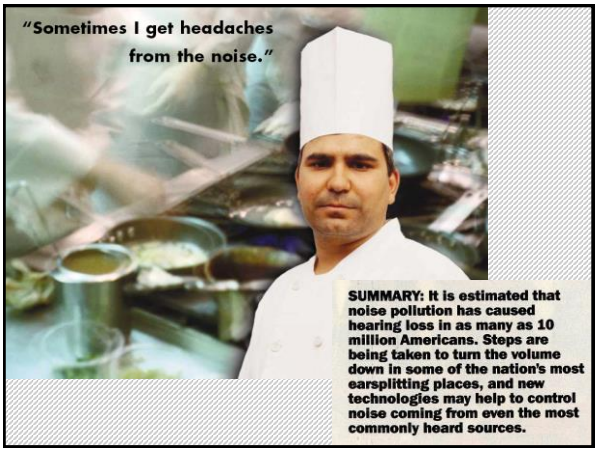
13


Threshold of feeling curve (listeners report tickle in ears)
semicircular canals
cochlea
ear drum
Inner Ear
Symphonic music
Speech
Dynamic range for symphonic music
Sound level (dB)
Sensitivity drops off greatly at low frequencies
Frequency (Hz)
Maximum sensitivity occurs here at 4000 Hz due to resonance in ear canal
Threshold of audibility curve (minimum sound pressures ear can detect)

14


Range of Maximum Levels of Common Noises
(In Decibels)
Source
40
50
60
70
80
90
100
110
120
Gunshot
Cap Pistol
Electric Saw
Lawn Mower
Vacuum Cleaner
Refrigerator
Personal Stereo
Rock Concert
Symphony Concert
Automobile Interior
Jumbo Jet Cabin
(Discomfort above 75–80)
SOURCE: Medical Times: The Journal of Family Medicine, December 1984
The level of hearing loss from noise is a function of both intensity and duration. Below 75 decibels, roughly the loudness of an automatic dishwasher, noise is safe for any period. Sounds become damaging at 85 to 90 decibels, roughly the volume of a lawn mower or blender, but only after eight hours of exposure. Noises above 120 decibels, such as those produced by gunshots or firecrackers, can inflict instant and irreversible damage.

15



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Acoustics in Green Buildings…could be a problem?

—UC Berkeley POE analysis.

Figure 1: Environmental satisfaction results from CBE's POE survey. More positive numbers indicate greater satisfaction and more negative numbers indicate greater dissatisfaction. Results show that occupants are dissatisfied with the acoustics of green buildings.

17

Since sound levels are logarithmic,

60 dB + 60 dB ≠ 120 dB

= 63 dB

60 dB + 63 dB = ?

Difference in dB Level	Add to Larger dB Level
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4

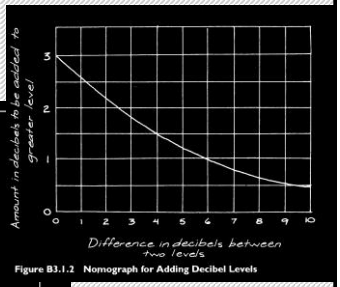


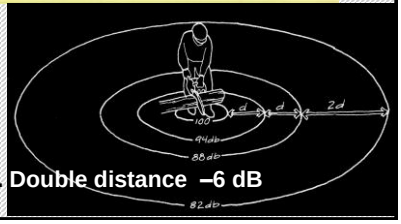
Figure B3.1.2 Nomograph for Adding Decibel Levels

18

this is a dB scale convenient because your ear perceives sound on a logarithmic scale.

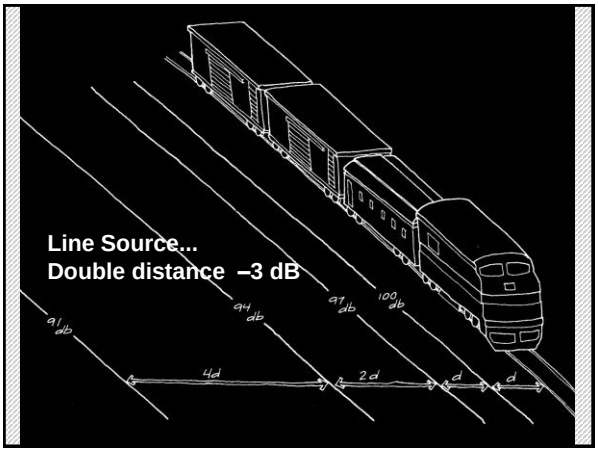
Weber's Law!

for example
you can barely perceive a Δ dB = 3 dB
no matter what the initial level was
or clearly perceive a Δ dB of 6 or 7 dB
you perceive a Δ 10 dB as twice / half as loud
Δ 20 dB as four x / ¼ as loud



Point Source... Double distance –6 dB

19



20

Acoustic Intimacy

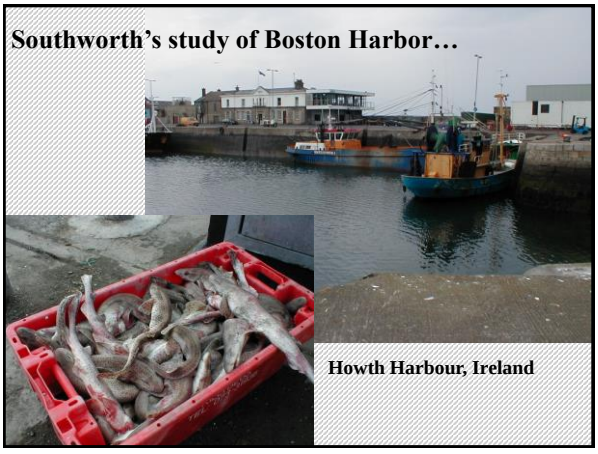
Sight isolates, whereas sound incorporates; vision is directional, whereas sound is omni-directional. The sense of sight implies exteriority; but sound creates an experience of interiority.

Hearing structures and articulates the experience and understanding of space.

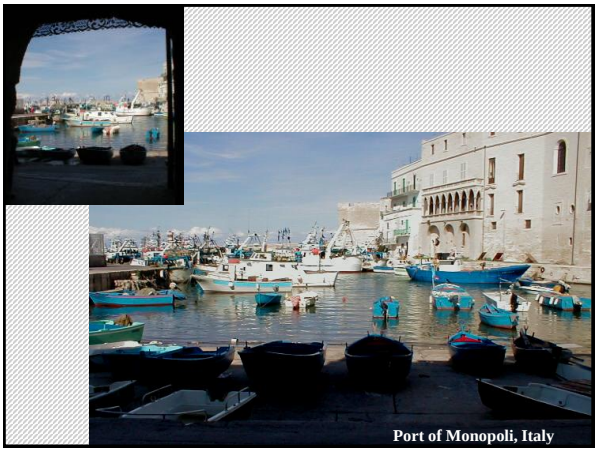
—Juhani Pallasmaa
The Eyes of the Skin:
Architecture and the Senses

←1812 Overture, Fourth of July, Boston Pops

21


Southworth's study of Boston Harbor…
Howth Harbour, Ireland

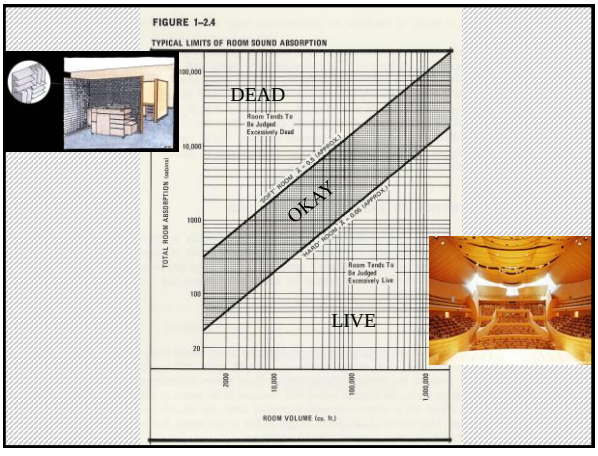
22


Port of Monopoli, Italy

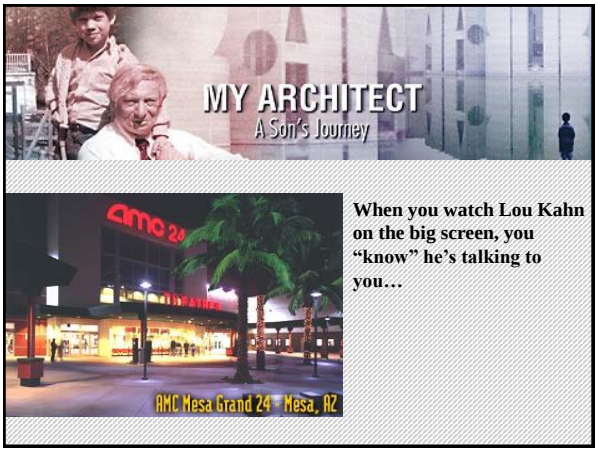
23


Quiet at 70 dB…
Paley Park, NYC

24



25

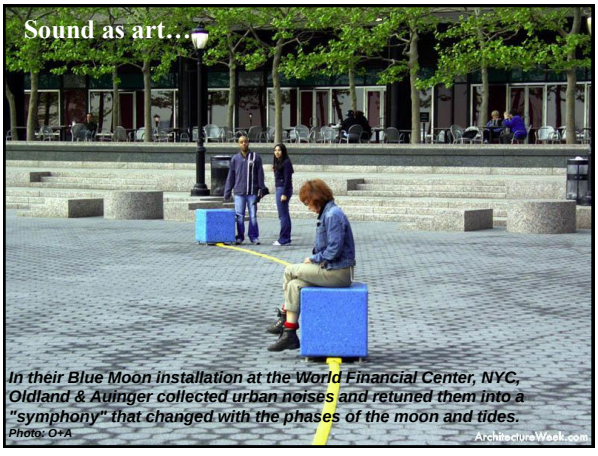


When you watch Lou Kahn on the big screen, you "know" he's talking to you…

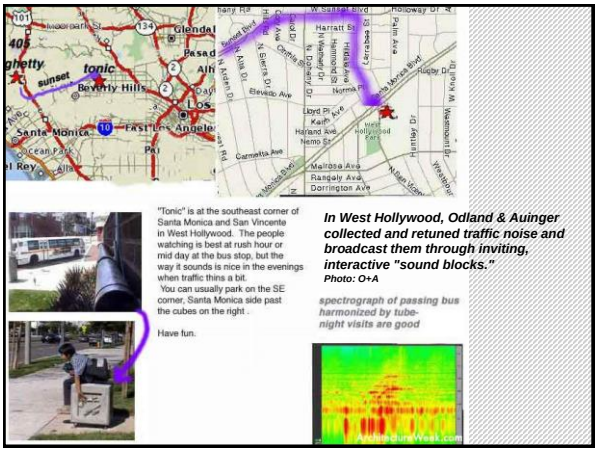
26

Finding a chirping cricket in the lawn…

27


Sound as art…
In their Blue Moon installation at the World Financial Center, NYC, Oldland & Auinger collected urban noises and retuned them into a "symphony" that changed with the phases of the moon and tides.
Photo: O+A
ArchitectureWeek.com

28


"Tonic" is at the southeast corner of Santa Monica and San Vincente in West Hollywood. The people watching is best at rush hour or mid day at the bus stop, but the way it sounds is nice in the evenings when traffic thins a bit.
You can usually park on the SE corner, Santa Monica side past the cubes on the right .
Have fun.
In West Hollywood, Odland & Auinger collected and retuned traffic noise and broadcast them through inviting, interactive "sound blocks."
Photo: O+A
spectrograph of passing bus harmonized by tube-
night visits are good

29


At Trajan's Forum in Rome, sound artists Bruce Odland and Sam Auinger collected ambient traffic noise and, with "tuning tubes," created dynamic urban harmonies.
Photo: O+A
ArchitectureWeek.com

30

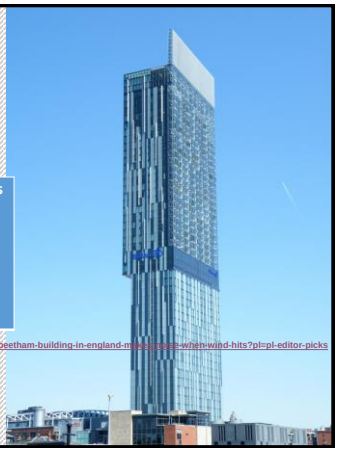
The Weather Channel

Beetham Building in England Makes Noise When Wind Hits

Meterologists Ari Sarsalari shares what happens when wind hits the Beetham Building in England at a special angle.

December 01, 2015

http://www.weather.com/series/great-outdoors/video/beetham-building-in-england-makes-noise-when-wind-hits?pl=pl-editor-picks



31

The Sea Organ, or the Morske Orgulje, is an incredible feat of architecture designed to bring life back to one of the world's oldest cities Zadar, Croatia.

https://soundcloud.com/srb445

architect Nikola Bašić

Carved into the steps are narrow channels that connect to 35 organ pipes, each tuned to different meticulously arranged musical chords.
As the waves lap against the steps, they push air through the pipes and out whistle-holes in the surface above, making a harmonious and completely random musical arrangement.

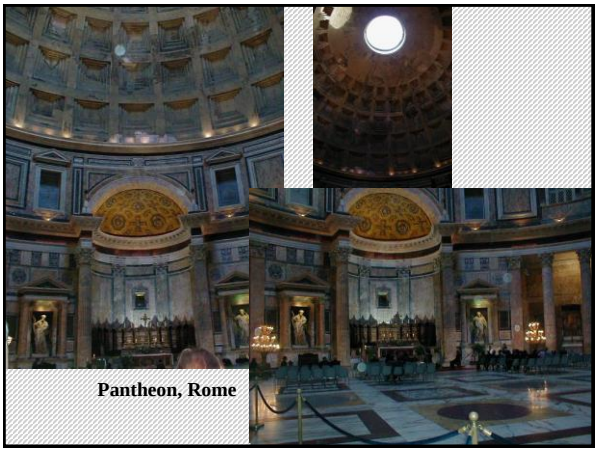
32

Aeolus by Luke Jerram,
Arup

33

Aeolian Harp Pavilion, RBGE, Mark Norris

34



Pantheon, Rome

35

Word of the day!

plangent

\'plan-jənt\ *adj* **1:** having a loud reverberating sound ***2:** having an expressive and especially plaintive quality

****The plangent** strains of a fiddle emanated from somewhere deep within the faceless gray stone building.*

36