Materiality of air: fishing nets hung in air - Brisbane 2023

Sound, Music Architecture

Marcus Beale

[Slides from CPD at Stanton Williams on 18 January 2024]

Marcus Beale RIBA

- Architect doing new things in old places
- Student and practitioner of music, violin, voice
- Composer
- Interested in the poetry of physics
- Worked with Stanton Williams at Rhodes House

marcus-beale.com

Chanot Guitare-violon by Nicholas Florentin 1820s

SOUND, MUSIC, ARCHITECTURE

We will cover:

- Introduction - **what architecture and music have in common**

- **Sound** propagation, effects of enclosure, harmonics

- **Soundscape:** sound landscapes: sound and place

- **Hearing**, voice, movement, balance, health

- **Architectural acoustics**:
  Passive: shape, material, geometry
  Active: introducing sound into space
  Symbolic: borrowing formal musical structures

- **Where next**,
  Noise, cities and civic communication.

Architecture and Music

Architecture: conscious design of spaces and interrelationships of spaces
Music: deliberate use of voice and other instruments, practice and performance

In common:

- **Space and time**: 3D sensory experience of space and place, location, ambience
- **Plan, pattern, logic, structure**, geometry, ‘arithmetic in motion’
- **Scale in relation to human body and movement**
- **Tactile**: hear: touch the air, and the walls ‘at a distance’

Not in-common:

- Architecture: **static** Music: **moving**
- Buildings: **material**, Sound: vibrational **energy** (immaterial) using gas, liquid, solid as a medium
- Architecture **visible**; Sound generally **invisible**

SOUND

- Sound is pure energy, lends temporary shape: vibration

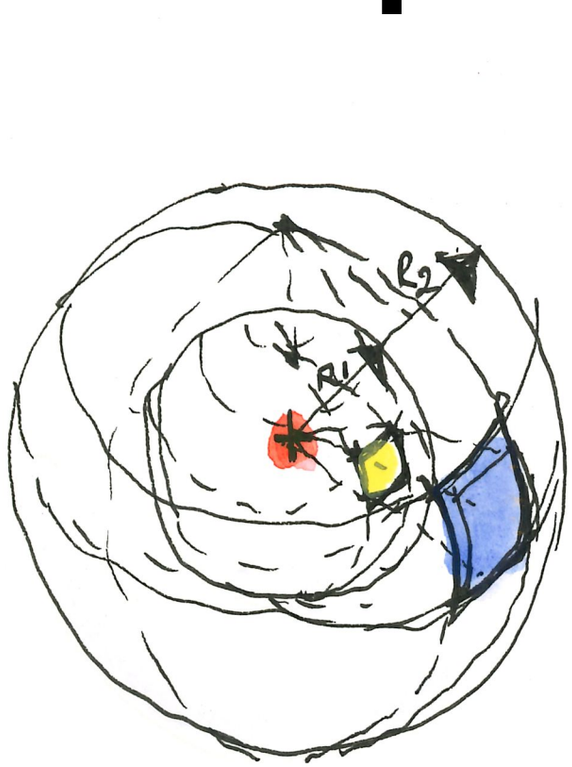
- Spatial, travels fast but not too fast 1/3 km/s in air
  Air-wavelengths of audible sounds body sized, room sized

- Has a source: point, line, plane.
  Propagation through space, diffraction, sound shadows

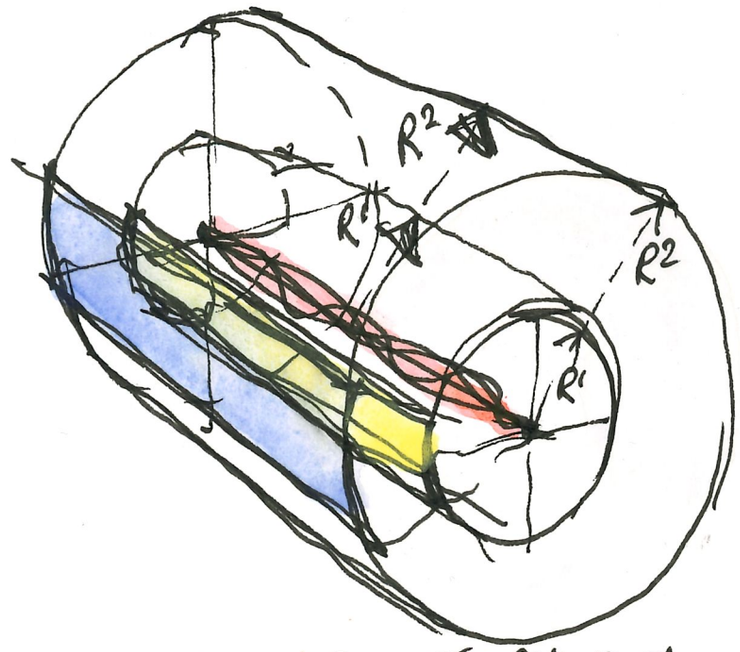
- Effects of enclosure:
  reflection, absorption, diffusion, focusing, openings, sequences

- Harmonics: ratios and decibels

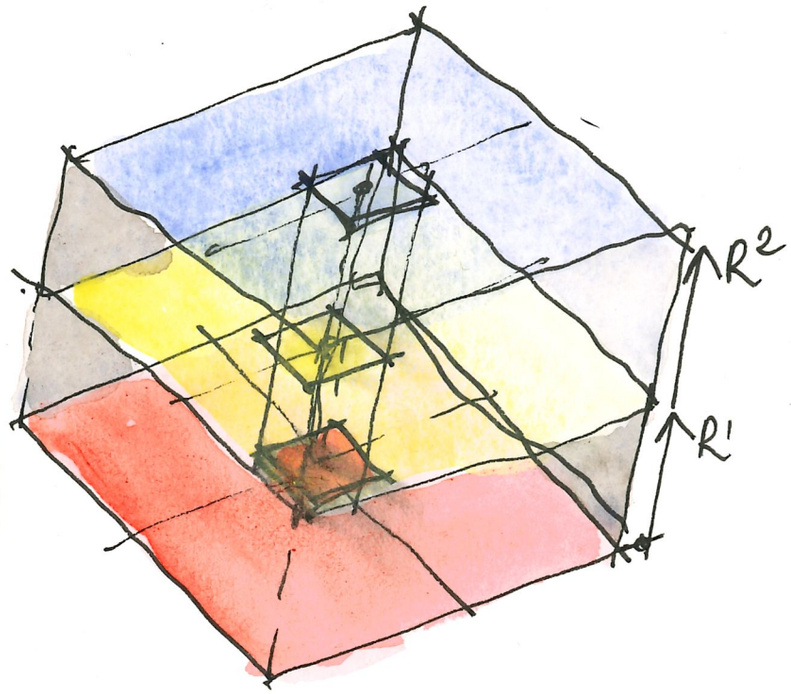
Sound propagation in air



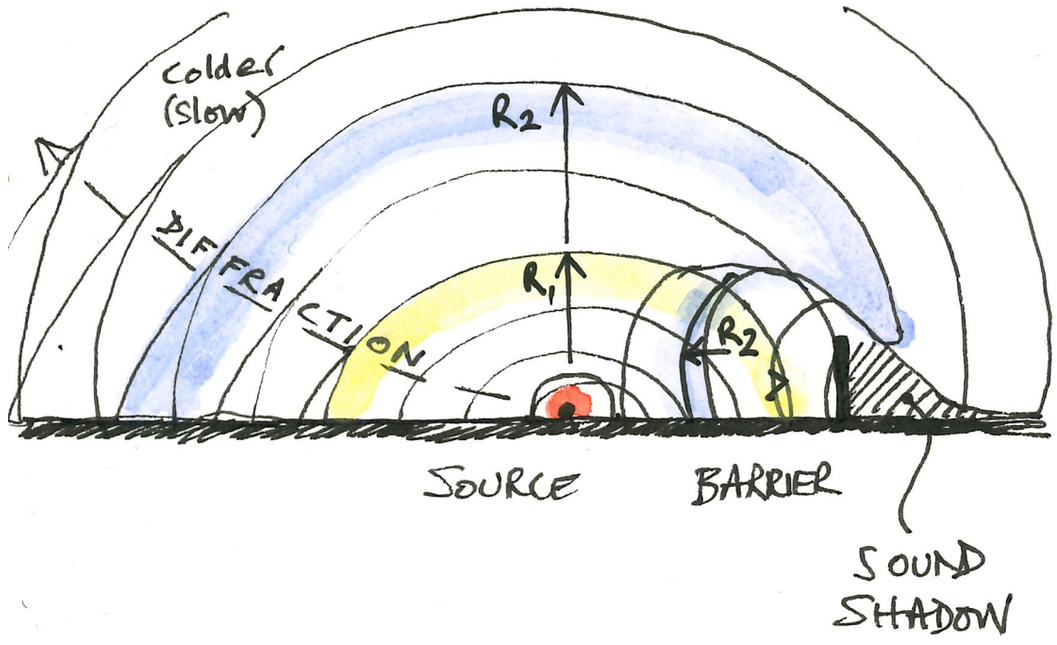
POINT SOURCE - SPHERE

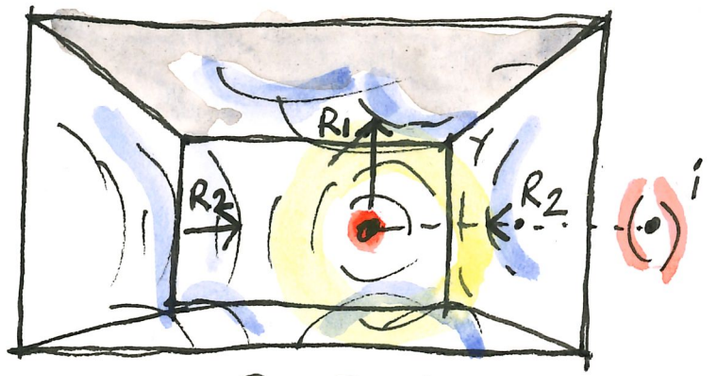


LINE SOURCE-CYLINDER



FIELD SOURCE





SOUND IN
AN ENCLOSED SPACE

SOUNDSCAPE

- Like landscape, soundscape is the sonic landscape of a place

- Sonic ingredients: cultural and musical sounds, sounds of people, natural sounds, sounds of movement, buildings, trades and industries, awareness (alarms) [R. Murray Schafer]

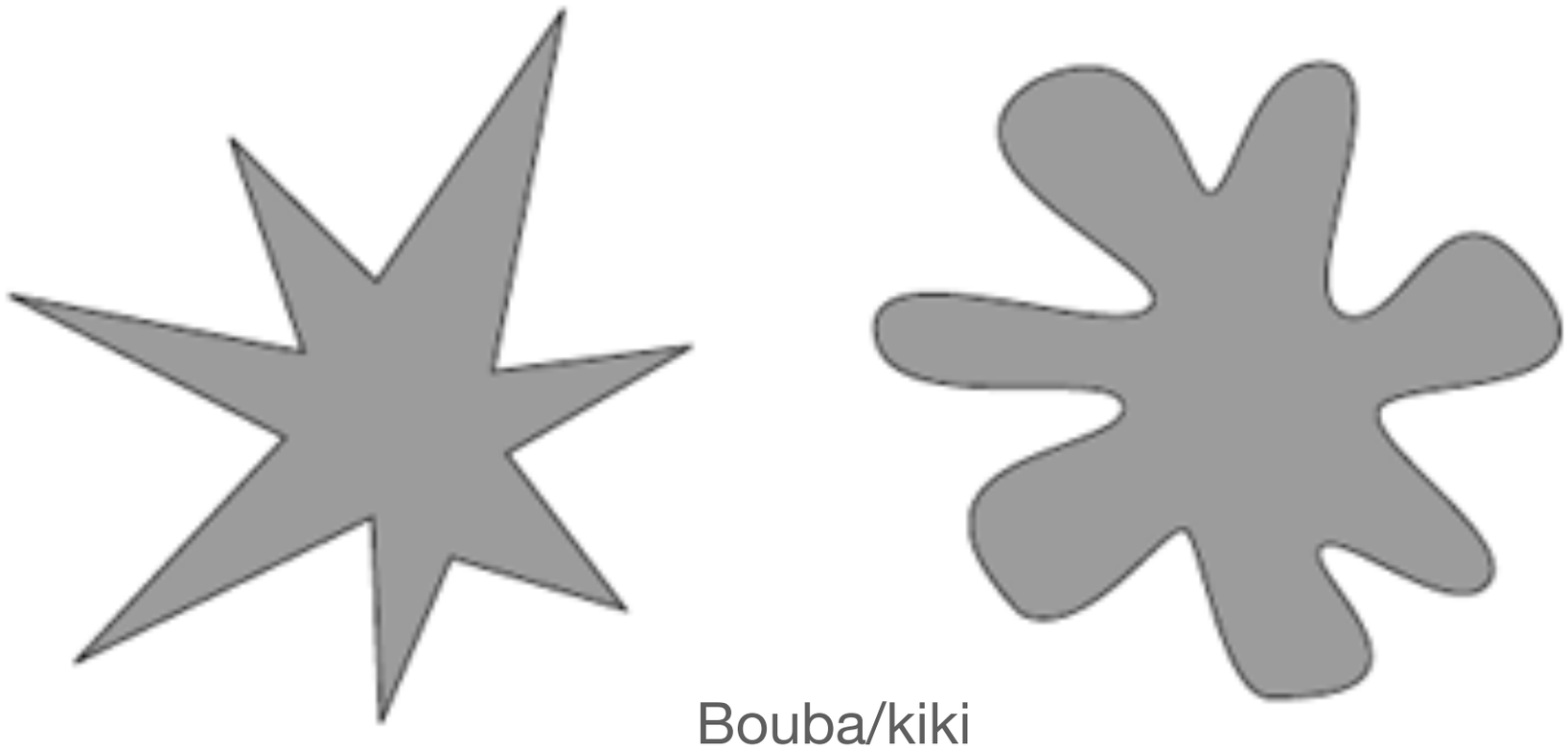
- Sonic materials: materials like brass have high potential [for] sound, materials like cloth or wool, low potential [Aristotle]

- Changes in material or density create potential for sound to be reflected

- Designed soundscapes: deploying sounds in space

Hearing & perception

- External senses: 5? heat, balance
- Proprioception: sense of oneself
- Multi-sensory, synaesthetic
- Memory, training, culture



Bouba/kiki

- Hearing a space and the activities, surfaces, geometry, ambience, micro-sounds
- Cognitive dissonance : a mouse that roars

HEARING AND SPEAKING

- A feedback loop: we adjust our voice and behaviour to the sounds we hear

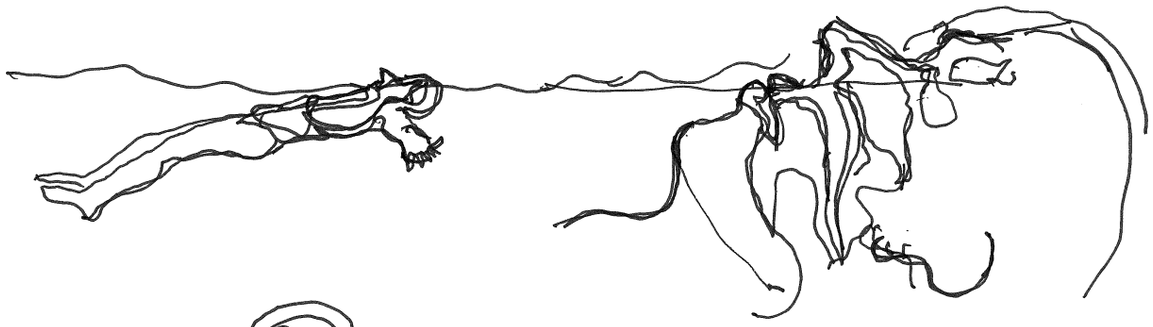
- Hearing: Range of ear hearing
  range of extreme sensitivity coincides with voice, air wavelengths that are body sized, related to the sound source.

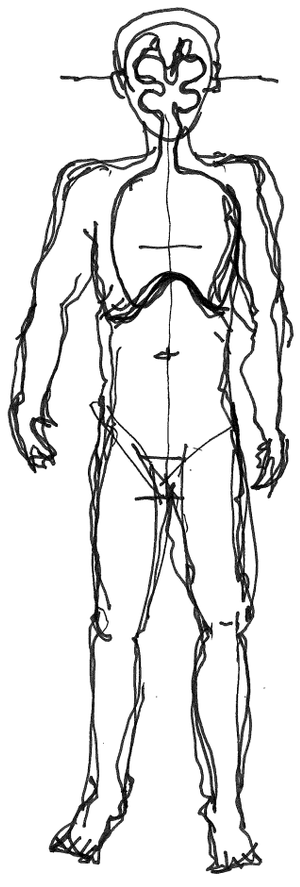
- Acoustics: voice = intelligible sound [Zarlino]
  modes of speech: sliding or intervallic. [Nicomachus]

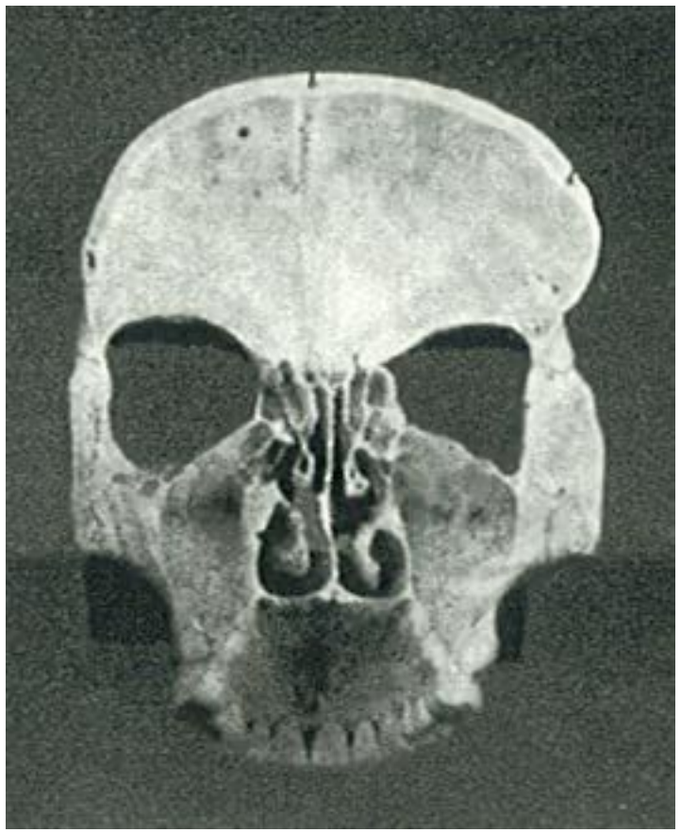
- Voice is a wind instrument, vibrates like a tube of air.

Breathing & speaking

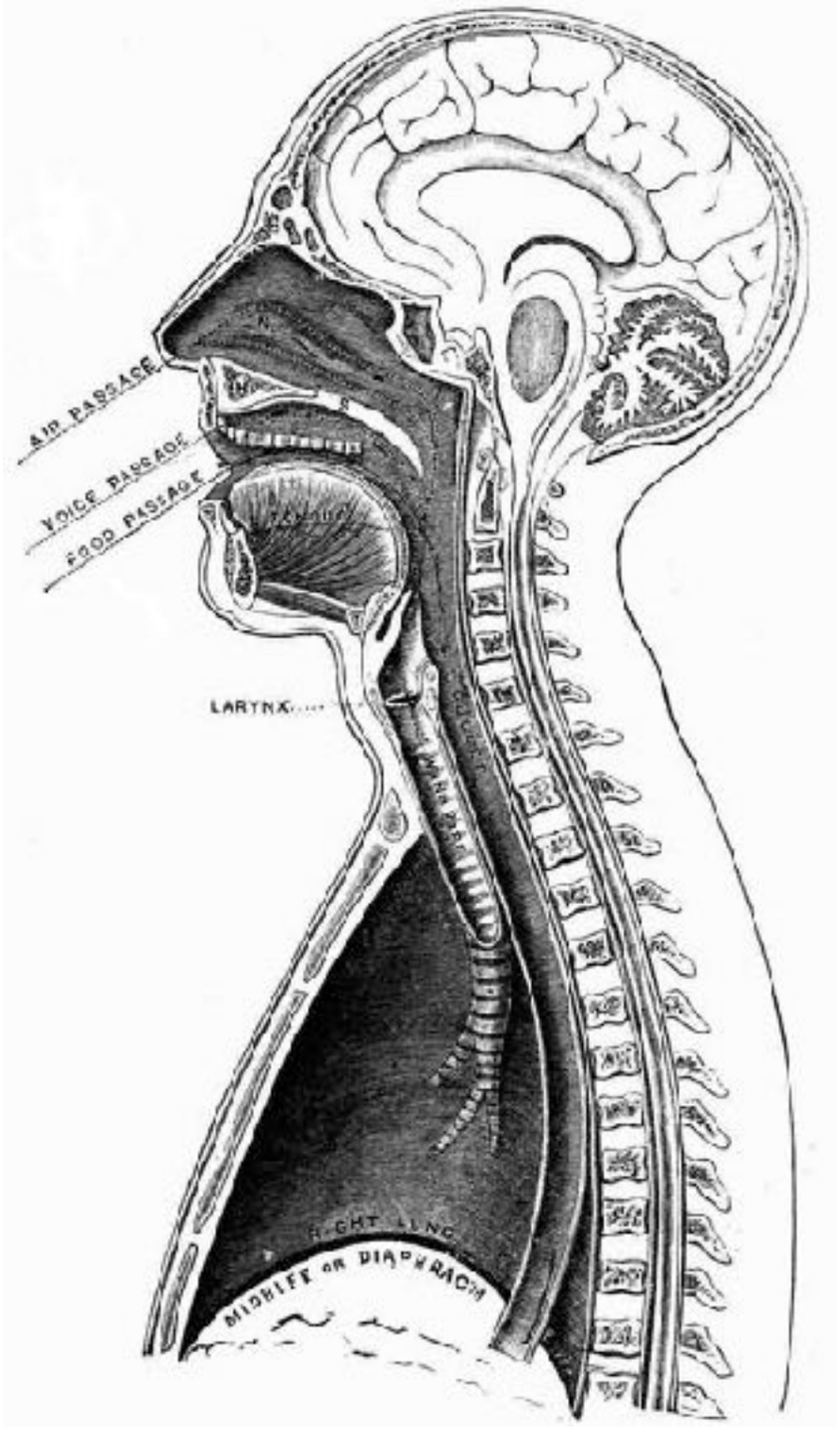
Body has same density and salinity as the sea



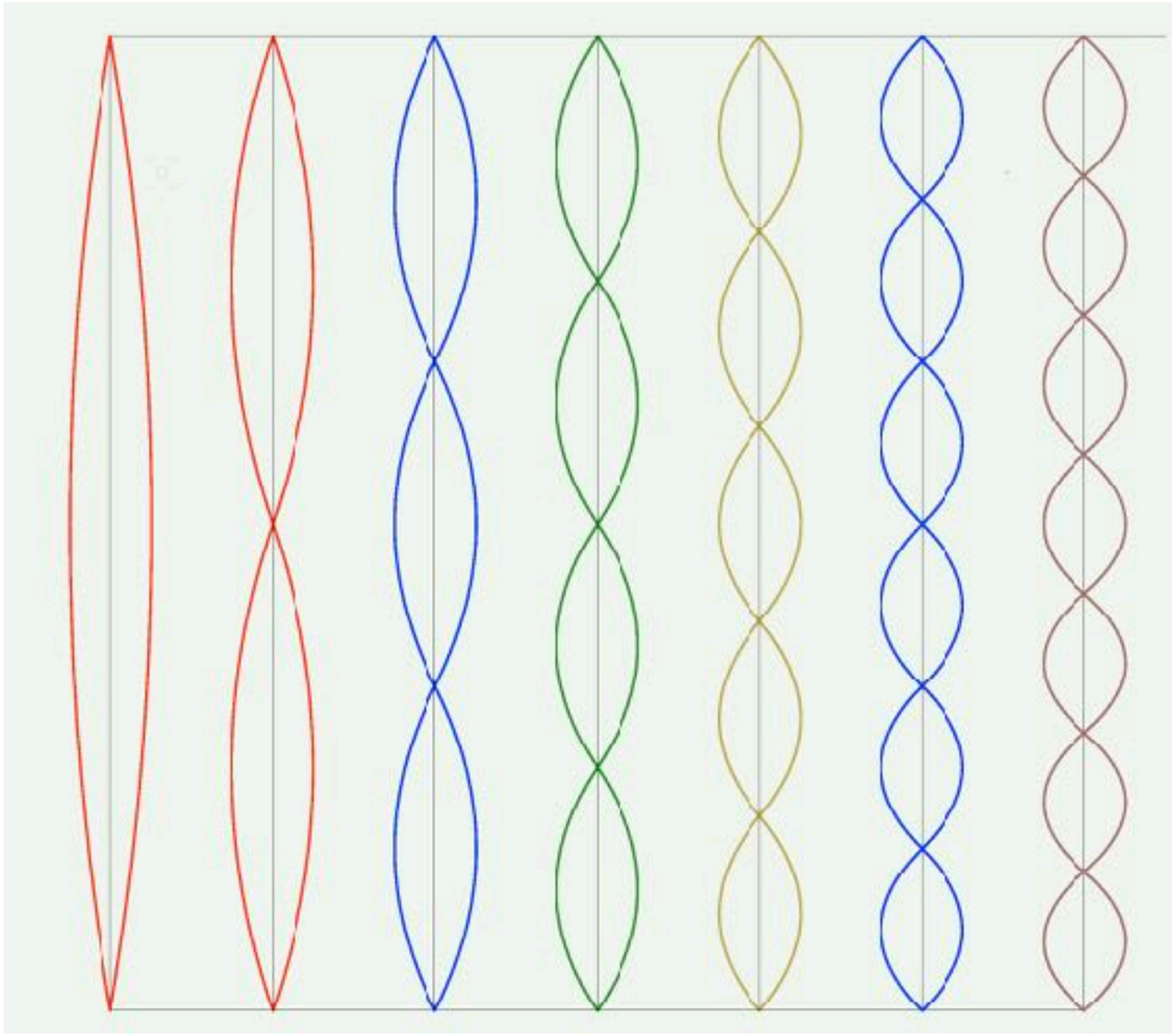




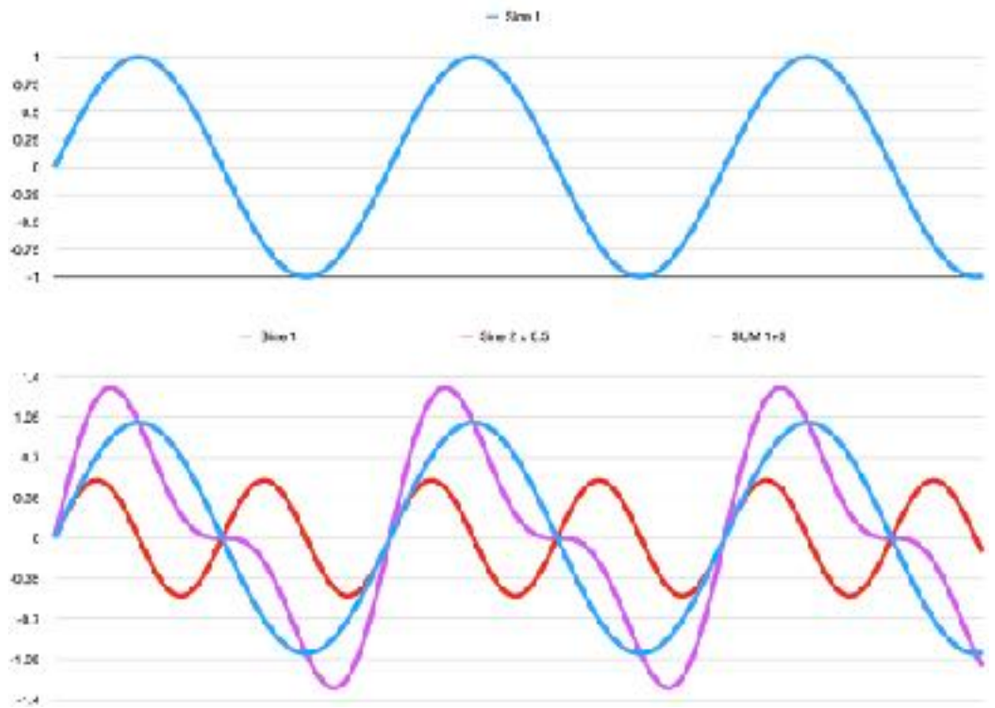
Air cavities concentrated in the top front



Harmonic sound

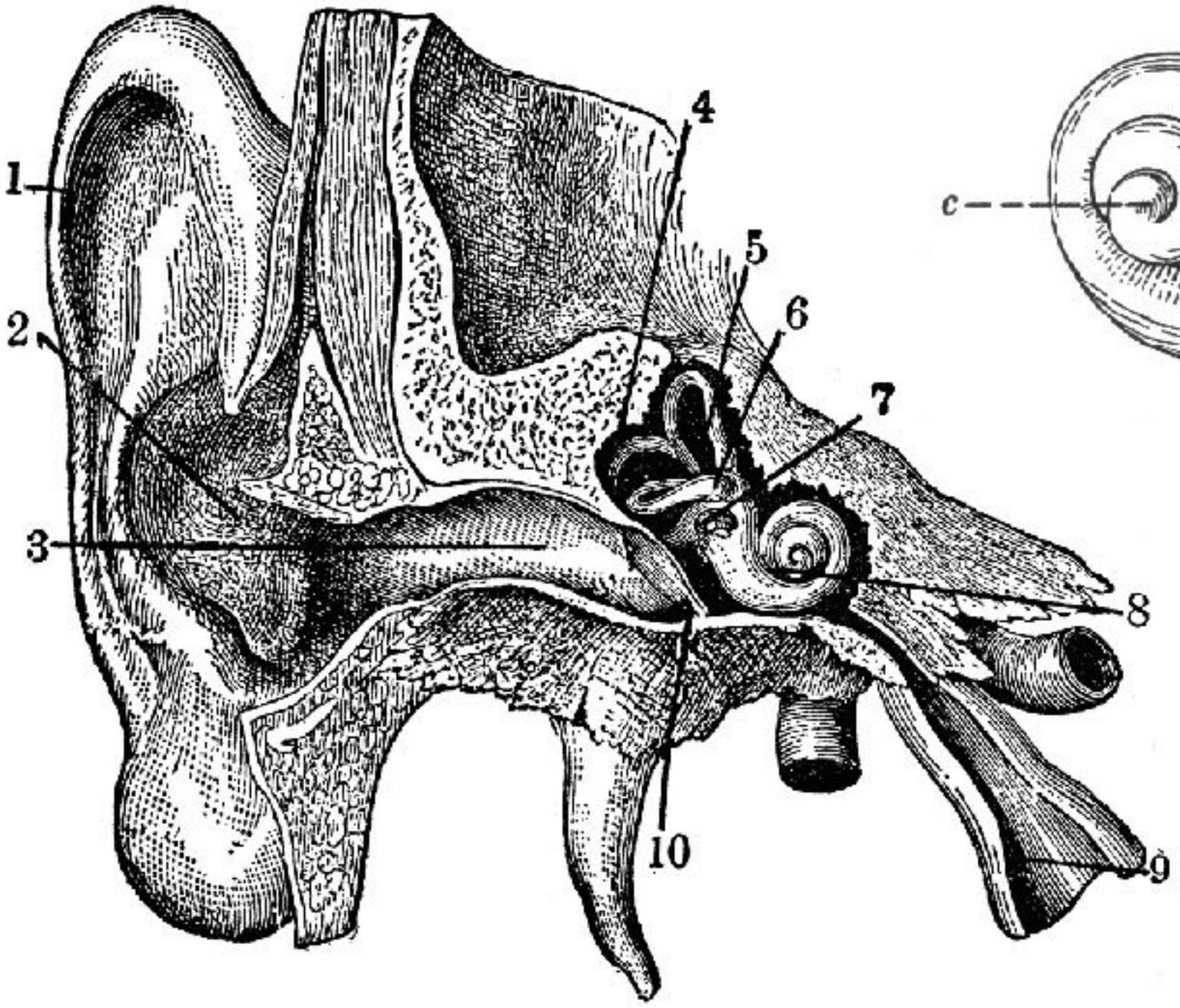


Vibration modes of a pipe or string

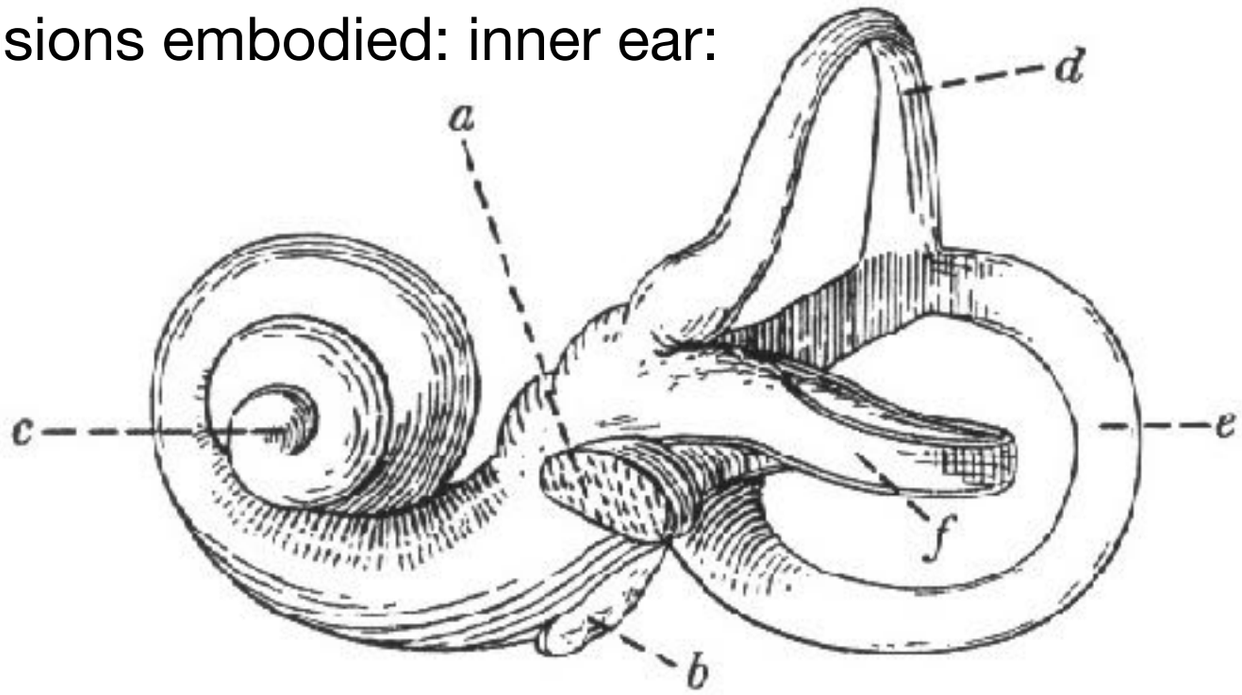


Oscillations combine into vibrations

Organs of hearing and balance

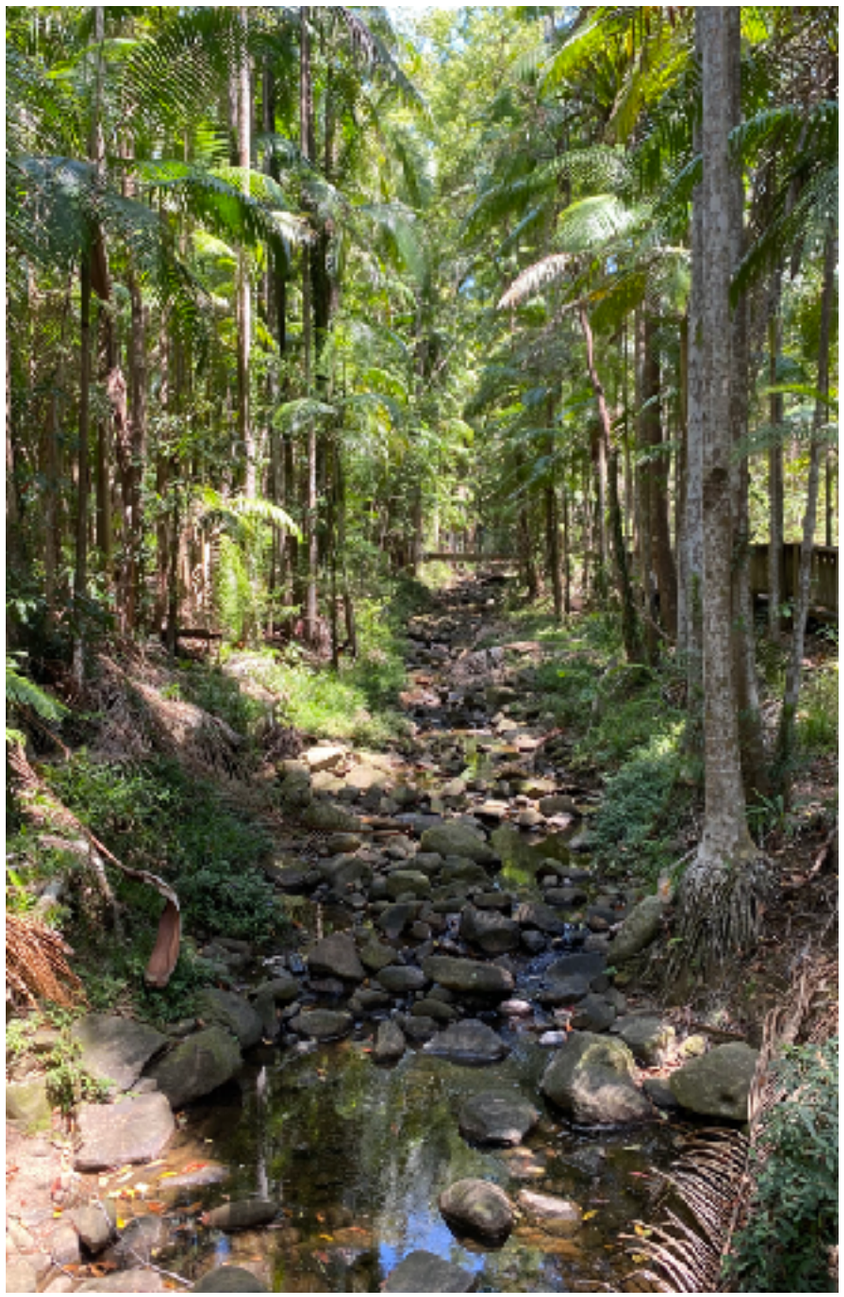


3 dimensions embodied: inner ear:

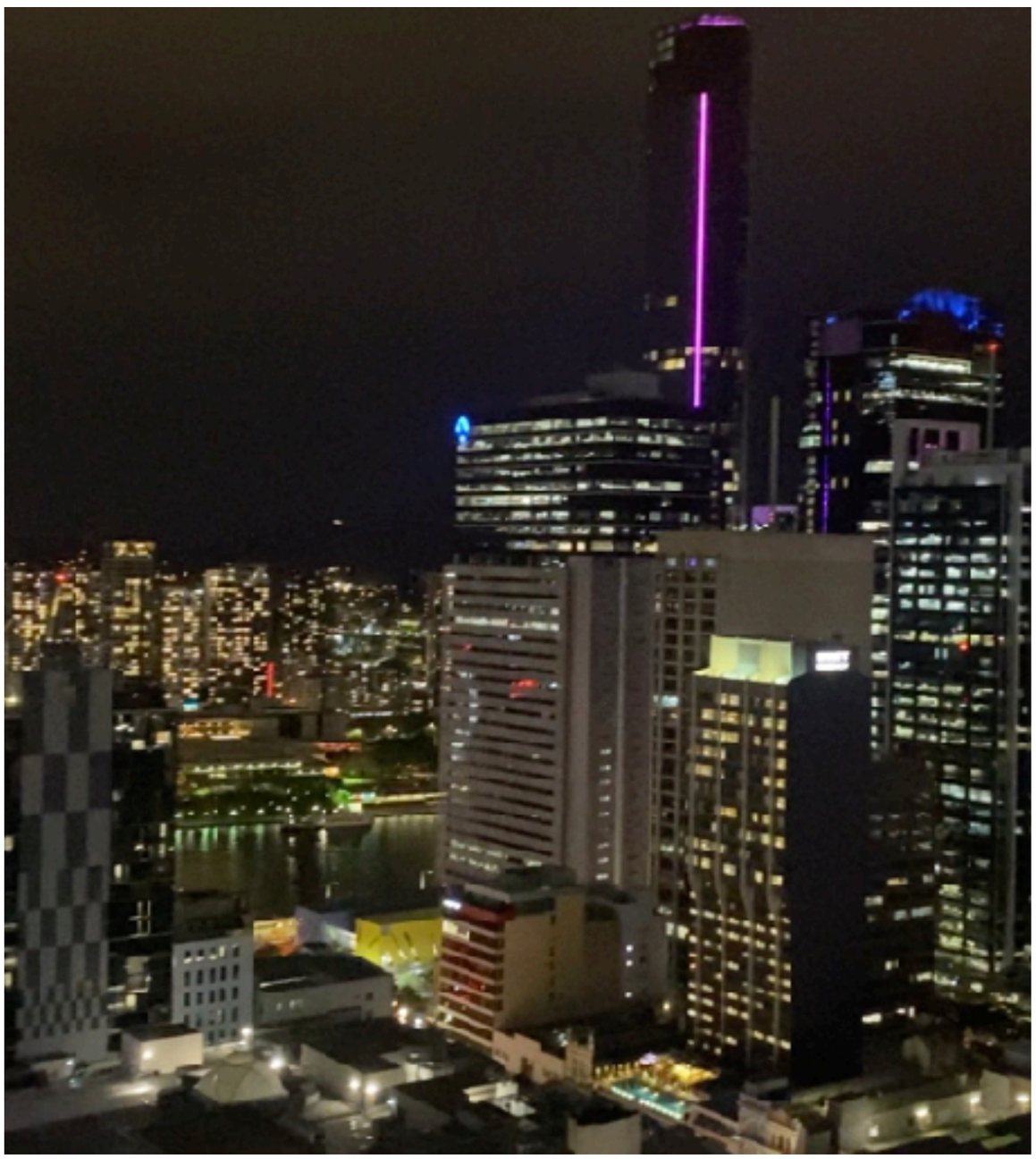


Cochlea [frequency analysis] and **Labyrinth** [space]: *d,e,f* are spirit levels at right angles to each other

Hearing & speaking



HI-fi, low noise



Lo-fi, high noise

Hearing & speaking

We are rhythmic, vibrating:

- Annual
- Monthly
- Daily
- Eating, Sleeping and attention patterns
- Movement, breathing, heartbeat
- Voice and hearing
- Hearing is a whole body experience.

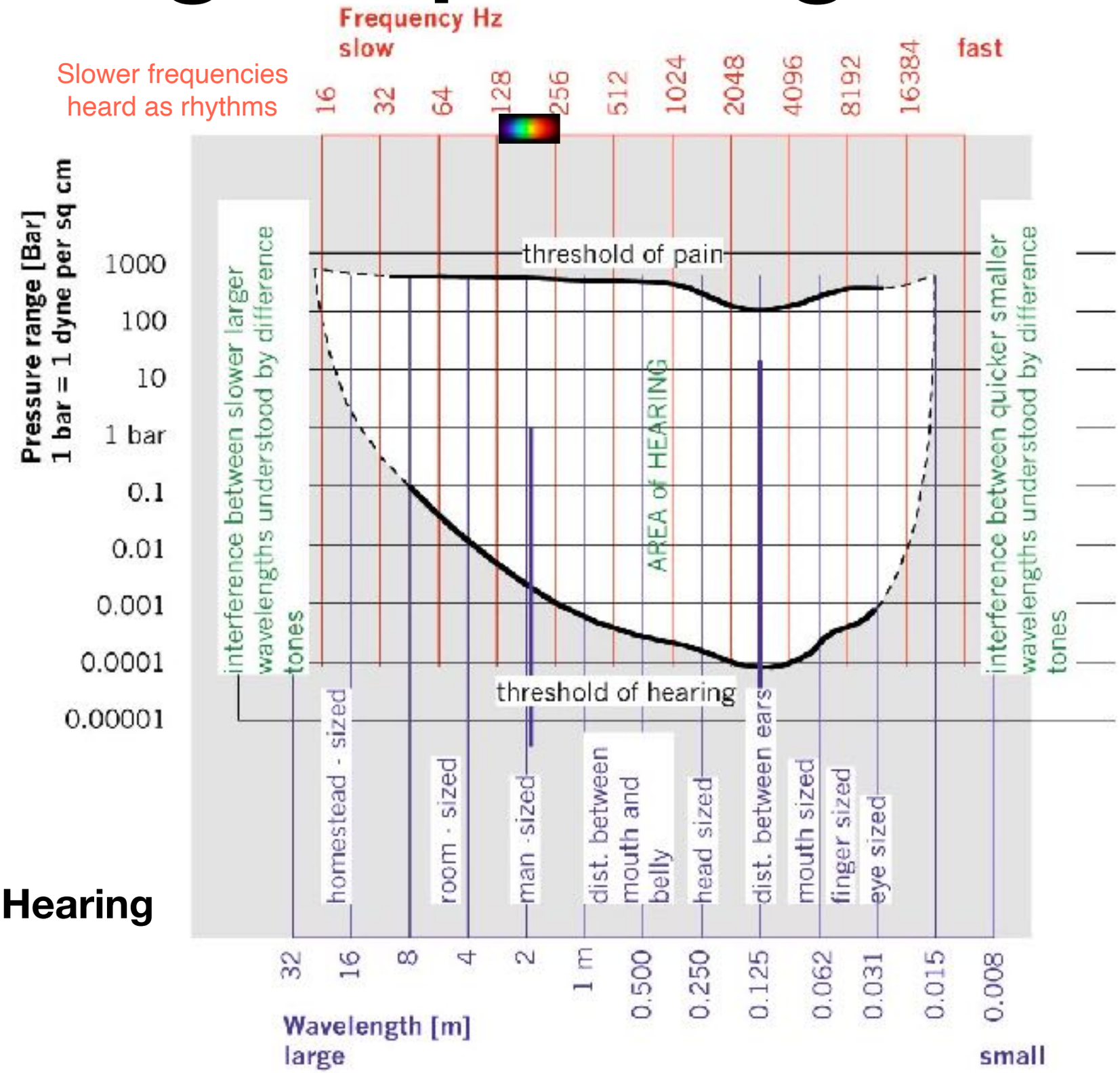
RHYTHM AND BODY

Resonant frequency of:

finger	**rotating about**	**knuckle**	**12.0 Hz**
fingers		**knuckles**	**6.4**
hand		**wrist**	**3.2**
forearm		**elbow**	**1.9**
arm		**shoulder**	**1.4**
torso		**pelvis**	**0.7**
foot		**ankle**	**2.0**
lower leg		**knee**	**1.3**
whole leg		**hip**	**0.9**
head		**neck**	**1.0**
whole body		**hands**	**0.48**

Hearing & speaking

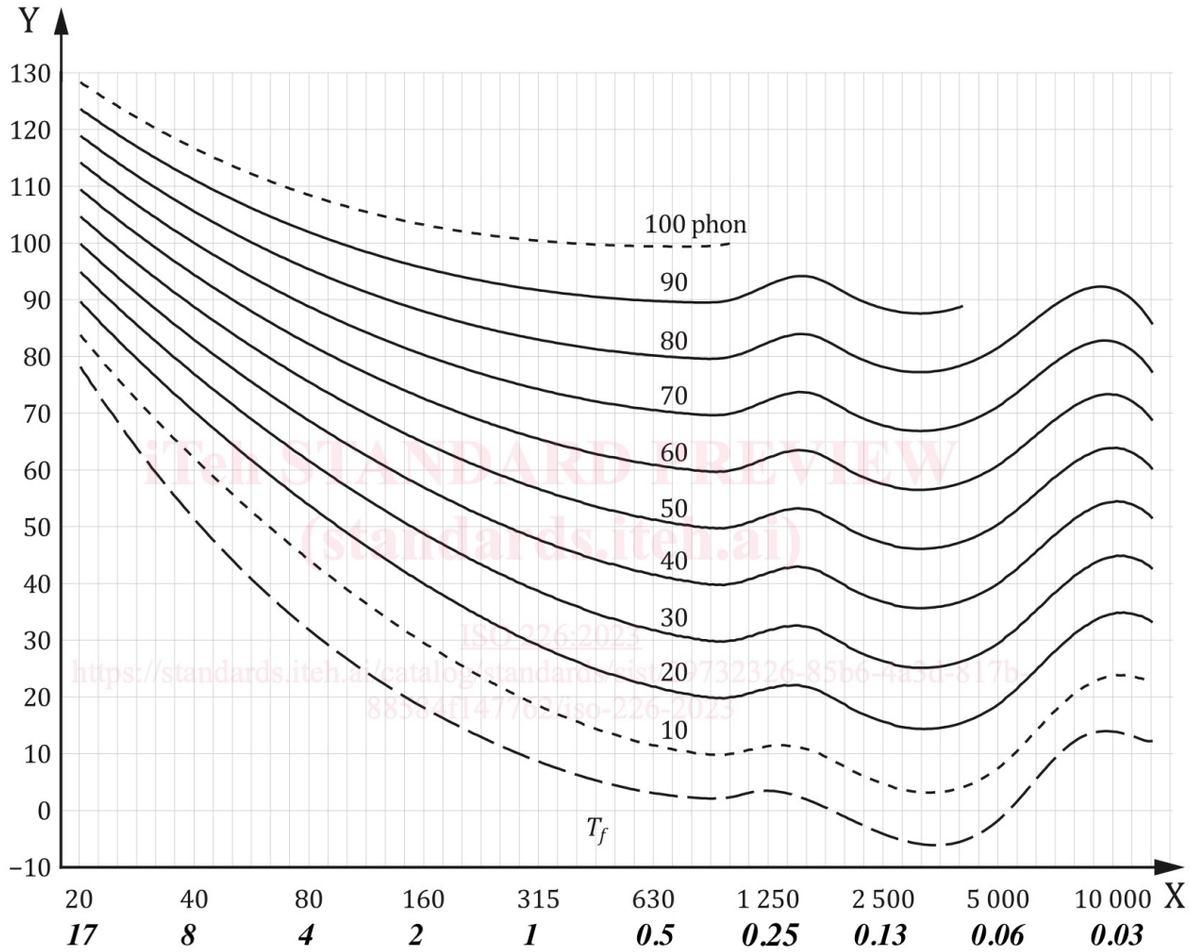
Slower frequencies heard as rhythms



Ear Hearing

Ear hearing

Normal equal-loudness-level contours for pure tones under free-field listening conditions



Key

X frequency, expressed in Hz ***air wavelength, expressed in m***

Y sound pressure level, expressed in dB

T_f hearing threshold

ARCHITECTURAL ACOUSTICS

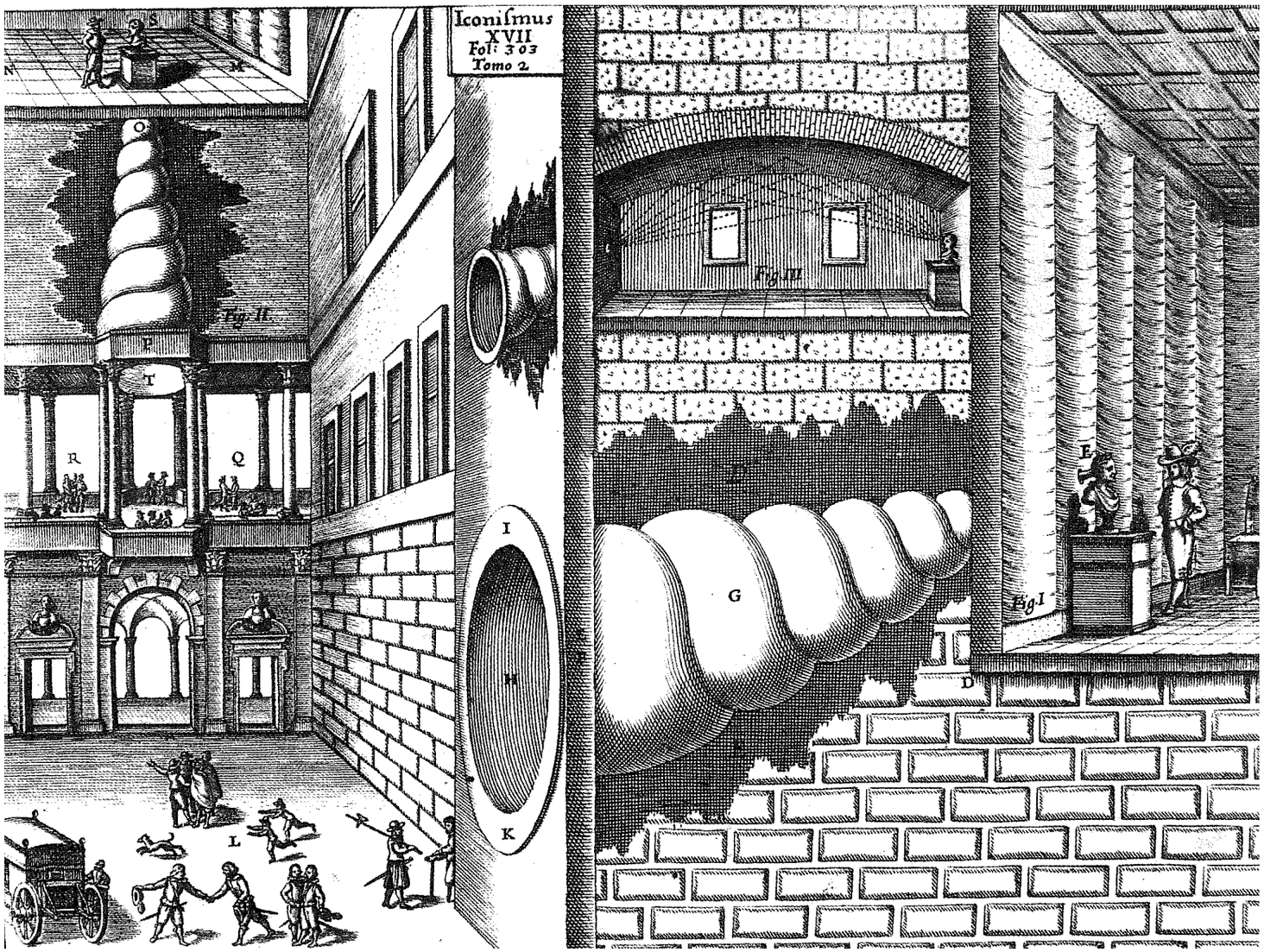
- **Passive**: shape, material, geometry reflect/absorb
  Reverberation time
  Absorbency tables

- **Active**: fountains water, trees, birds
  speakers, Musak

- **Symbolic**: musical structures incorporated into architecture:
  structures of the cosmos

Passive acoustics

- **Absorbency and reflection**
- **Reverberation**
- **Geometry**
- **Sequences of spaces**



Athanasius Kircher 1602-1680

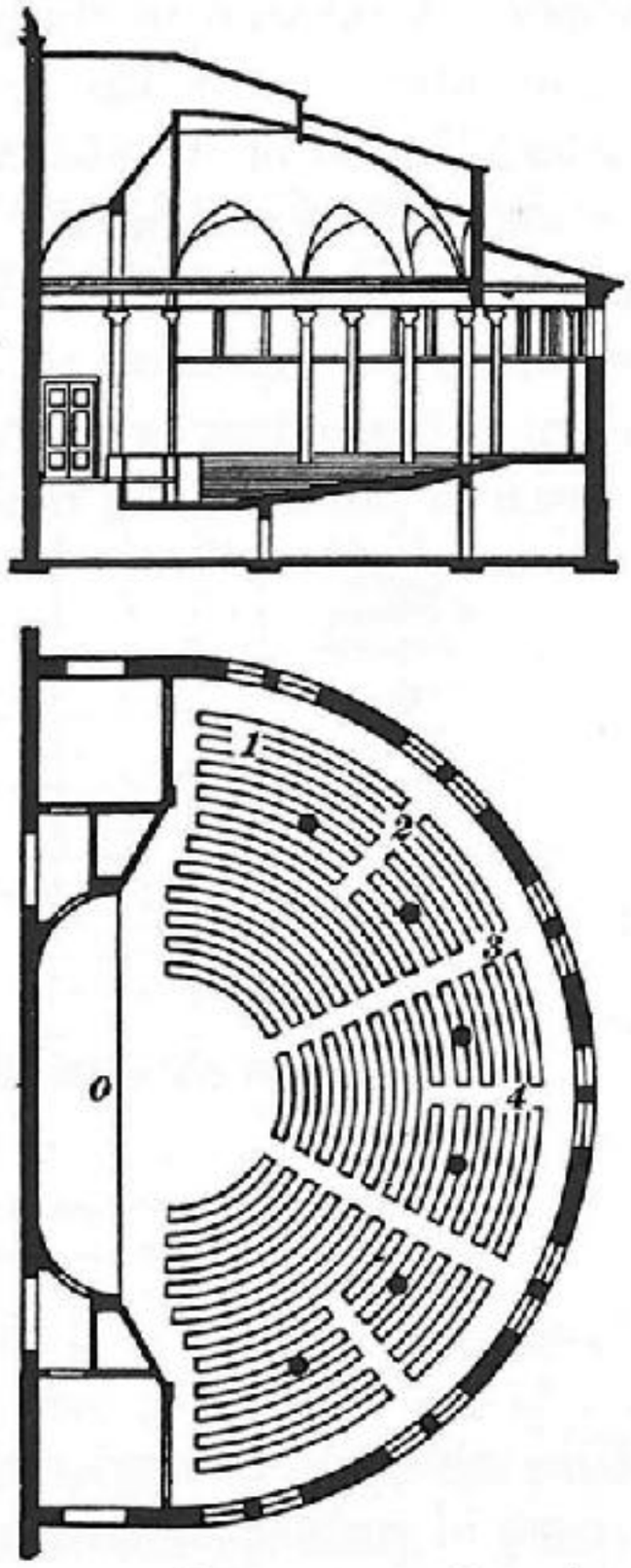
SOUND, MUSIC, ARCHITECTURE

Reverberation

- **Reverberation -** how long a sound lingers in a room measured in seconds [loss of 60 dB]

- Increases with volume of the room,
  decreases with sum of absorbencies. Sabine:
  R = 0.161 x V/sum of Absorbencies

- Outside in deep snow 0s
  Small room/speech 1s
  Concert hall 1.8-2.5s
  Large church 3s plus…
  St Paul's Cathedral 11s
  [empty] reducing to 7-8s [full]



Lecture-room, Fogg Art Museum: position of observer at *O*; positions of absorbent at 1-4, and in the dome.

Absorption and reflection

- **Absorbent materials** allow the sound wave to penetrate and dissipate. Perforated/ fibrous/ resonators. Absorption coefficient 1= total absorption 0 = total reflection.

Material / Frequency Hz / Wavelength m	125 (2.66)	250 (1.33)	500 (0.67)	1000 (0.33)	2000 (0.17)	4000 (0.08)
Concrete or terrazzo floor	1%	1%	2%	2%	2%	2%
Concrete poured, unpainted	1%	1%	2%	2%	2%	3%
Brick, unglazed, painted	1%	1%	2%	2%	2%	3%
Vinyl on concrete floor	2%	3%	3%	3%	3%	2%
Plaster 20mm on brick	1%	2%	2%	3%	4%	5%
Brick unglazed, unpainted	3%	3%	3%	4%	5%	7%
Plasterboard 12mm on 100 x 50 studs	29%	10%	5%	4%	7%	9%
Plaster on concrete block	12%	9%	7%	5%	5%	4%
Glass 6 mm large plate	18%	6%	4%	5%	2%	2%
Wood parquet on concrete	4%	4%	7%	6%	6%	7%
Wood panelling 25mm with airspace behind	19%	14%	9%	6%	6%	5%
Wooden floor	15%	11%	10%	7%	6%	5%
Concrete block painted	10%	5%	6%	7%	9%	8%
Wood panelling 6mm with airspace behind	42%	21%	10%	8%	6%	6%
Plywood 6mm, 75mm air space 25mm batt	60%	30%	10%	9%	9%	9%
Glass 2.5 mm	55%	25%	18%	12%	7%	4%
Wooden platform floor with airspace	40%	30%	20%	17%	15%	19%
Fabric: light velour 10oz/yd2 in contact with wall	3%	4%	11%	17%	24%	35%
Concrete block unpainted	36%	44%	51%	29%	39%	25%
Carpet heavy on concrete	2%	6%	14%	57%	60%	65%
Unoccupied upholstered seats	19%	37%	56%	67%	61%	59%
Fabric: heavy velour 18oz/yd2 draped	14%	35%	55%	72%	70%	65%
Fabric medium velour 14 oz/yd2 draped to half area	7%	31%	49%	75%	70%	60%
Ceiling tile 18mm mineral fibre	72%	84%	70%	79%	76%	81%
Informal seating tablet armchairs	30%	41%	49%	84%	87%	84%
Audience in upholstered seats	39%	57%	80%	94%	92%	87%

Geometry

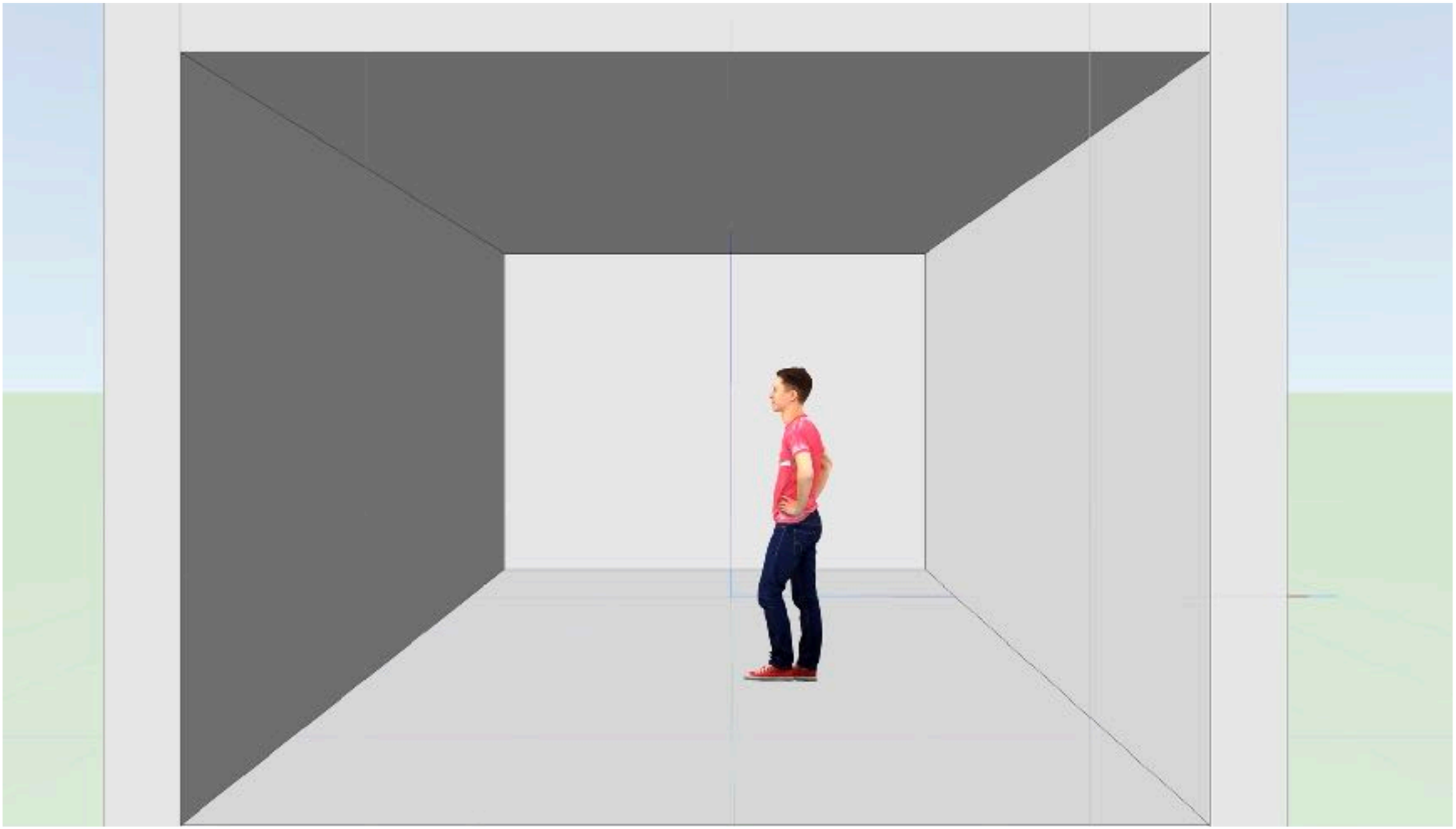
- **Rhomboid**
- **Vaulted**
- **Open loggia**
- **Open courtyard**
- **Cloister**
- **Street**

What is a wall?

- A concrete or plastered brick reflects sound [98%] like a mirror reflects light.

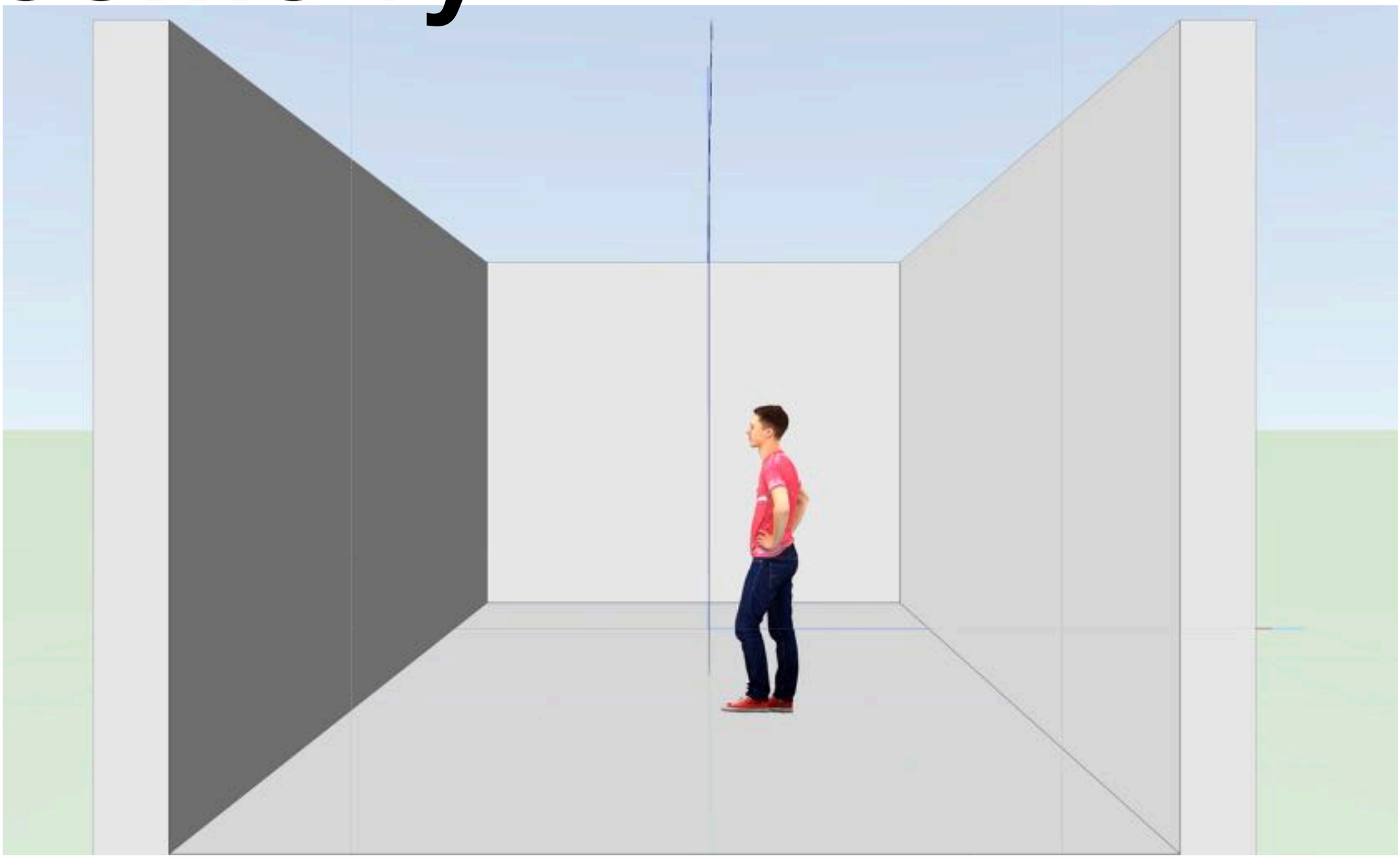
Fictional space beyond the wall

Geometry



- **Rhomboid, 3x4x5m**

Geometry



- **Rhomboid open top**

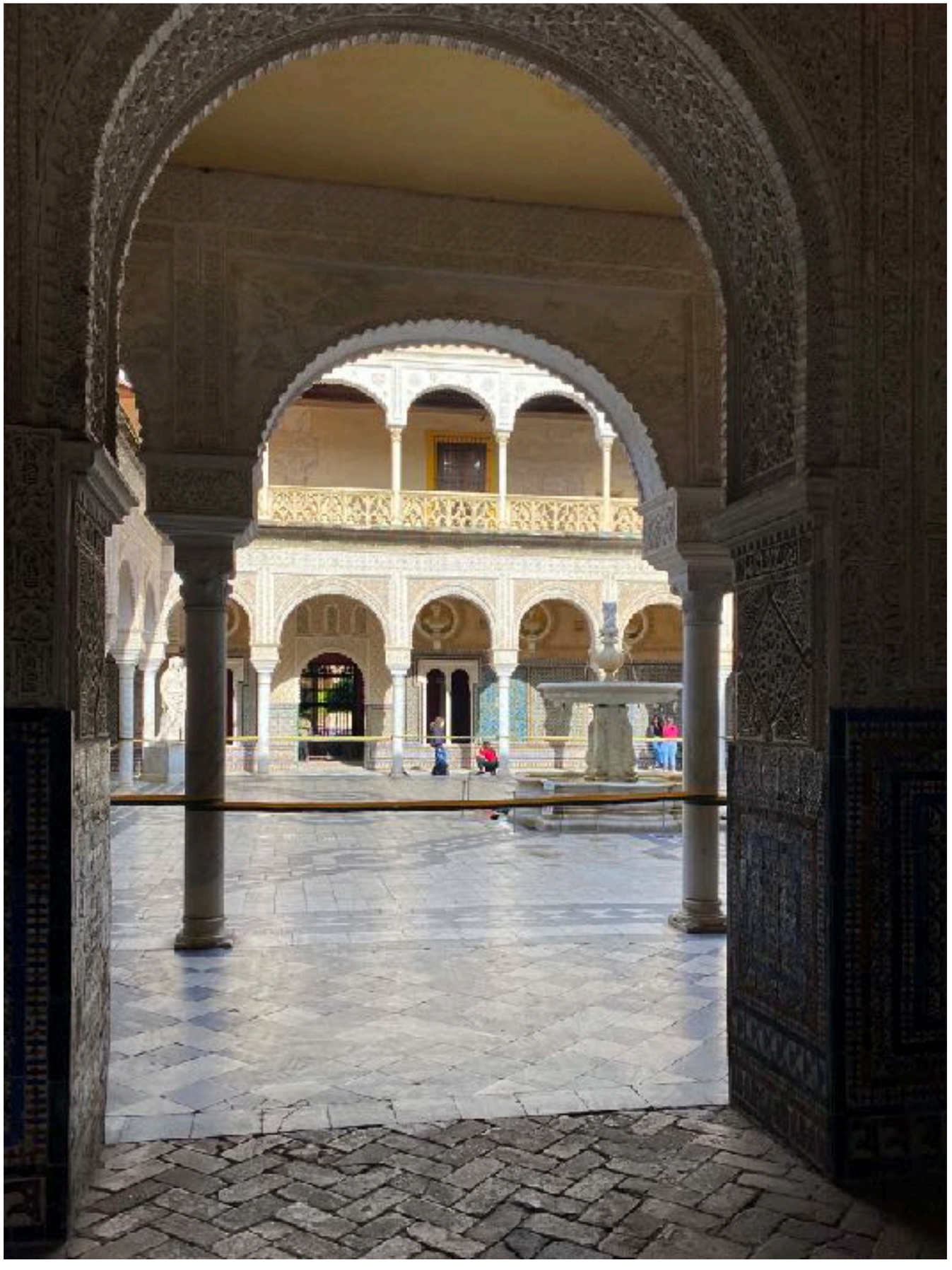
Geometry

- **Vaulted loggia**

SOUND, MUSIC, ARCHITECTURE

Geometry

- **Open courtyard**



SOUND, MUSIC, ARCHITECTURE

Geometry

- **Cloister**

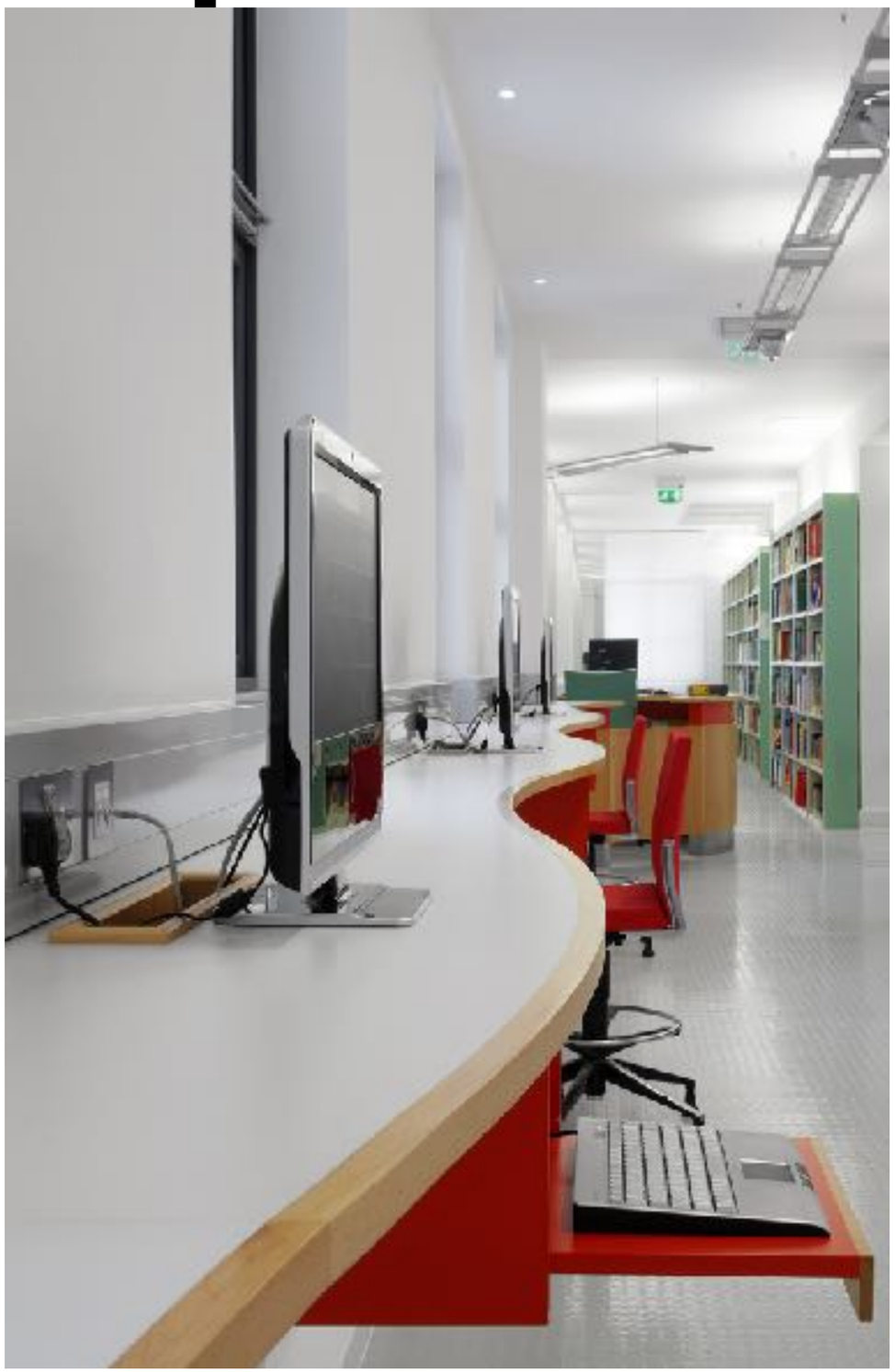
Geometry

- **Street**

Sequences of spaces

- **Road**
- **Forecourt**
- **Loggia**
- **Entrance hall**
- **Spaces for eating, working, living**
- **Courtyards, gardens, aspects, connections, opening**
- **Bedrooms**
- **Bathrooms**

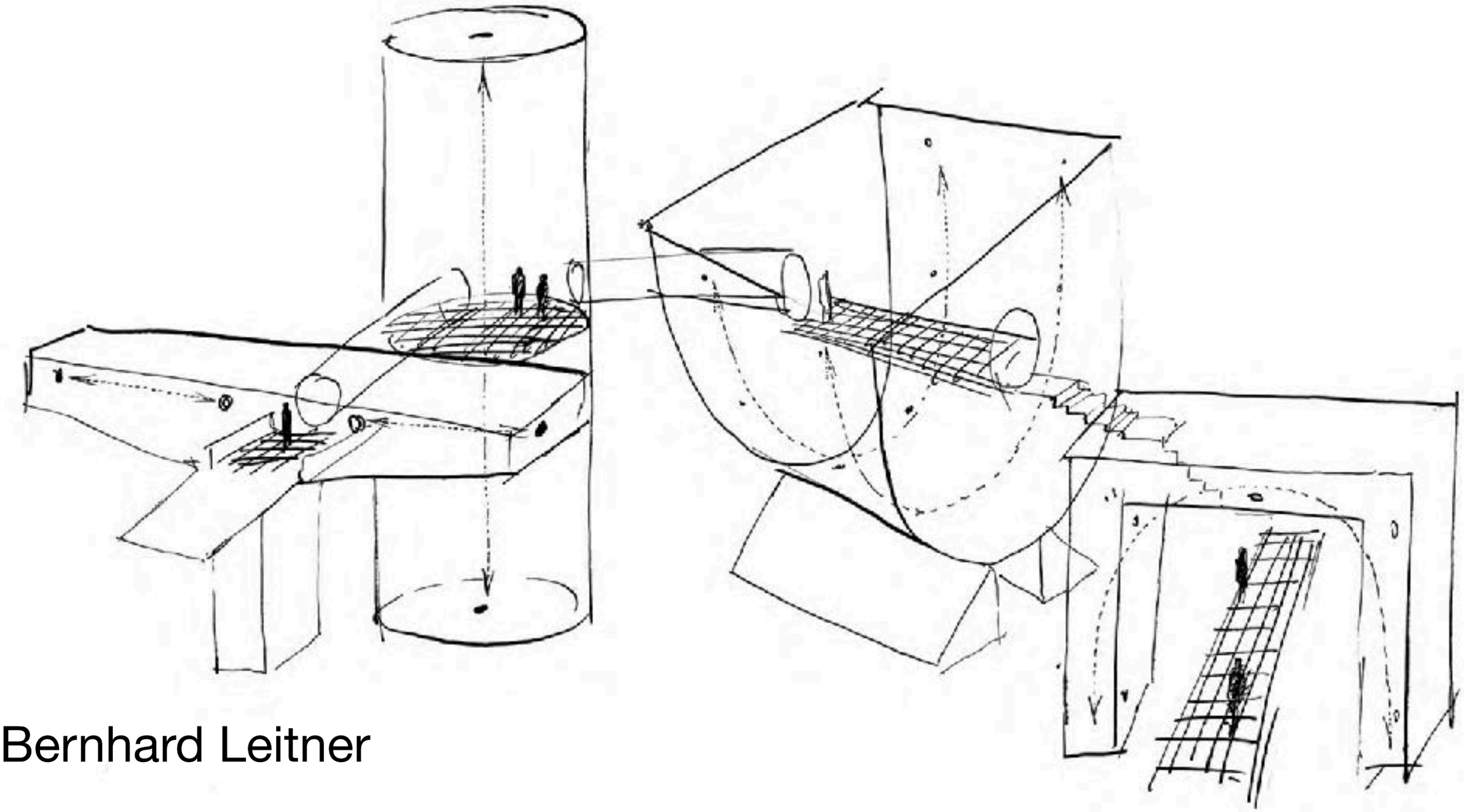
Sequences of spaces



Active acoustics

- **Masking**: Water, white noise
- **Trees**: wind, birdsong
- **Bells**, timekeeping, notification
- **Electronic**: speakers, public address, amplified sounds
- **Alarms**

Active acoustics



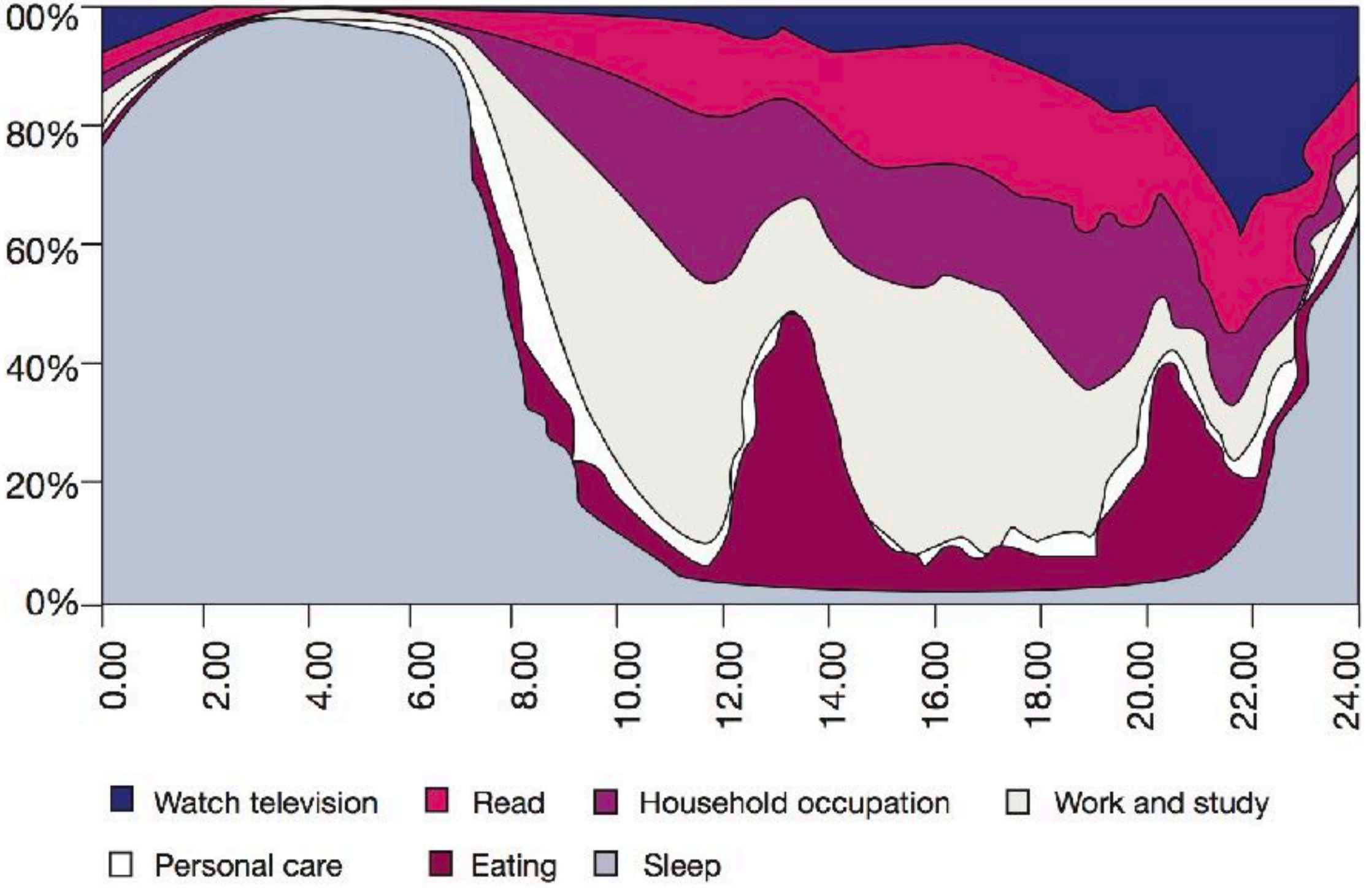
Bernhard Leitner

‘sound as a building material… use sound to build spaces’

Designing around activity

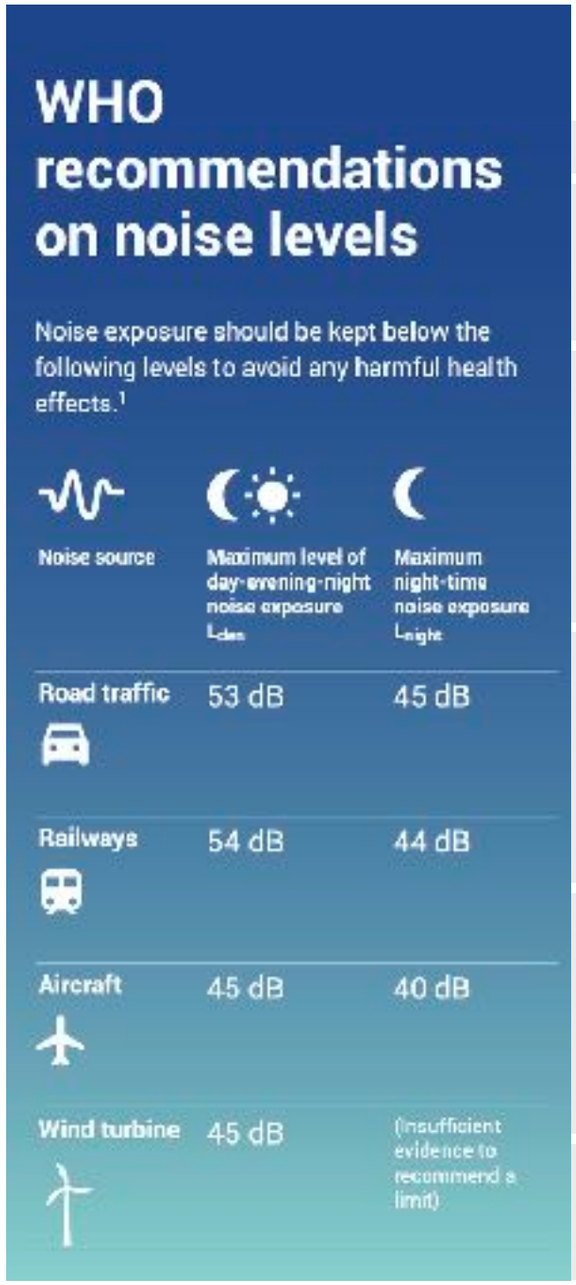
- **Sleep**
- **Washing**
- **Cooking**
- **Eating**
- **Relaxing, conversing**
- **Working - workplace acoustics - factory, library**
- **Transport and transit**

Designing around activity



Noise

- Noise and landscape/soundscape
- Urban noise: health effects. Rumbles. No ear-lids
- Political economy of noise, cultural and formal elements.
- Dealing with noise: enclosure, sheltering forms, pockets of quietness, festivals and timings, acoustic awareness.
- Common errors: noisy restaurant effect, standing waves, visual and acoustic sensory dissonance, flanking sounds.
- Living city, variety, humane, biophilic.
- Noise-music: making noise into music.

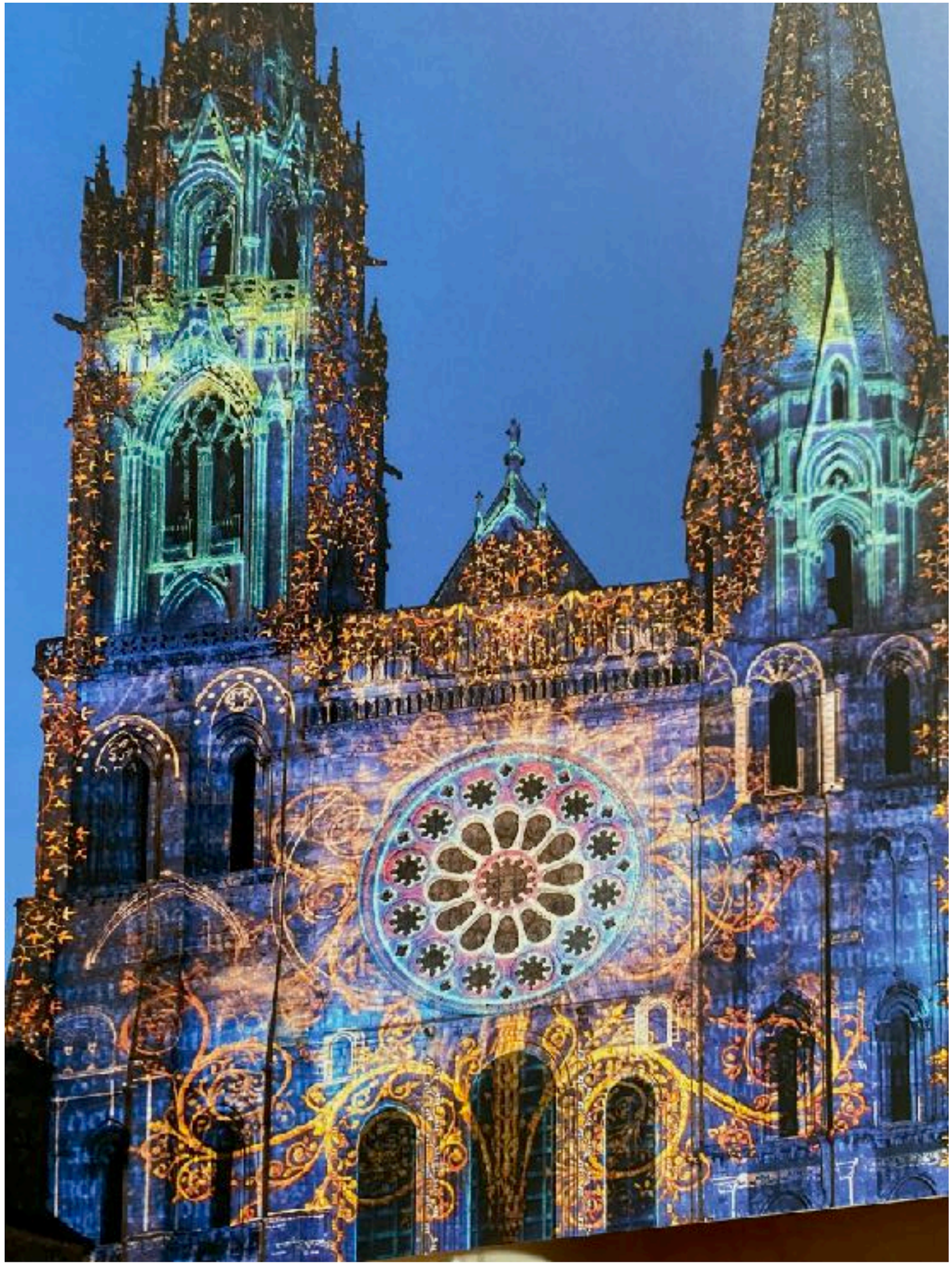


Consequences of sleep deprivation

Type	Short-term	Long-term
Behavioural	Sleepiness Mood changes Irritability and nervousness	Depression/mania Violence
Cognitive	Impairment of function	Difficulty in learning new skills Short-term memory problems Difficulty with complex tasks Slow reaction time
Neurological	Mild and quickly reversible effects	Cerebellar ataxia, nystagmus, tremor, ptosis, slurred speech, increased reflexes, increased sensitivity to pain
Biochemical	Increased metabolic rate Increased thyroid activity Insulin resistance	Decreased weight despite increased caloric intake (in animals) Diabetes, obesity (in humans)
Others	Hypothermia Immune function impairment	Susceptibility to viral illness

SOUND, MUSIC, ARCHITECTURE

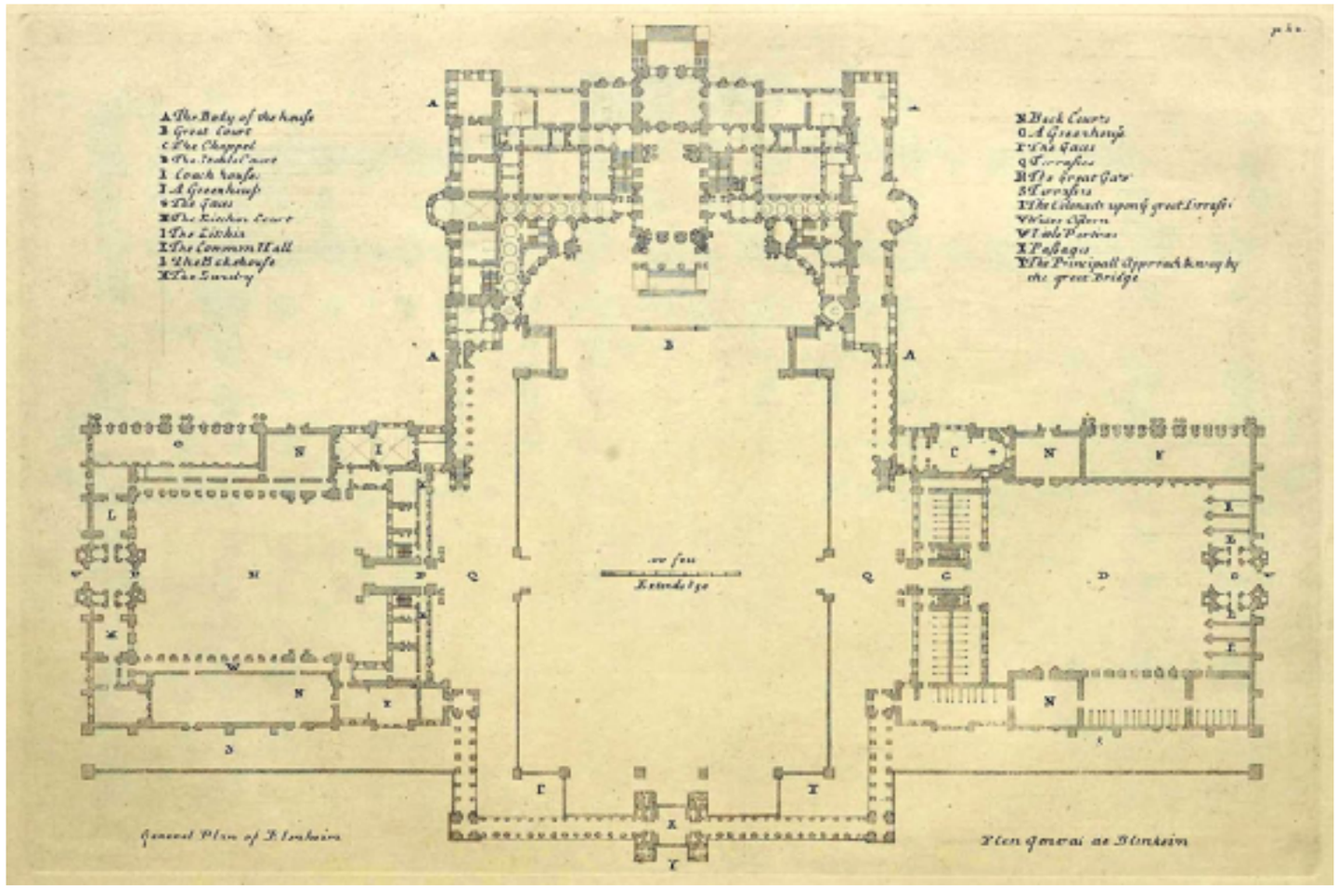
Symbolic acoustics



Chartres

Symbolic acoustics

- **Architectural structure,** repetition, pattern making, variation
- **Ornamentation,** vibrato, rubato,
- **Musical forms:** arch, rondo, theme and variations, fugue
- **Musical intervals** numbers 1 to 4, 5 and upwards and the golden ratio
- **Imperfection**: score and performance



Musical forms

- **Timbre: texture** Upper harmonics 0.5m - 2cm
- **Tones:** sized 17m - 17mm windows doors rooms, textures
- **Rhythms:** courtyards, urban layout, building heights etc
- **Tunes and counterpoint** - sequences
- **Musical formal structures for a piece**: Such as
  A B A, Arch form
  A B A C A D A Rondeau
  A B C B A Sonata
- **Musical forms collections of movements, suites** , operas, e.g.
  Overture R A R A R C A R A C Finale
- **Rhythmic/growth relationships**
  numbers 1 to 4,
  5 and upwards
  and the golden ratio
- **Imperfection**: score and performance

Building dances: FOGA at Arles

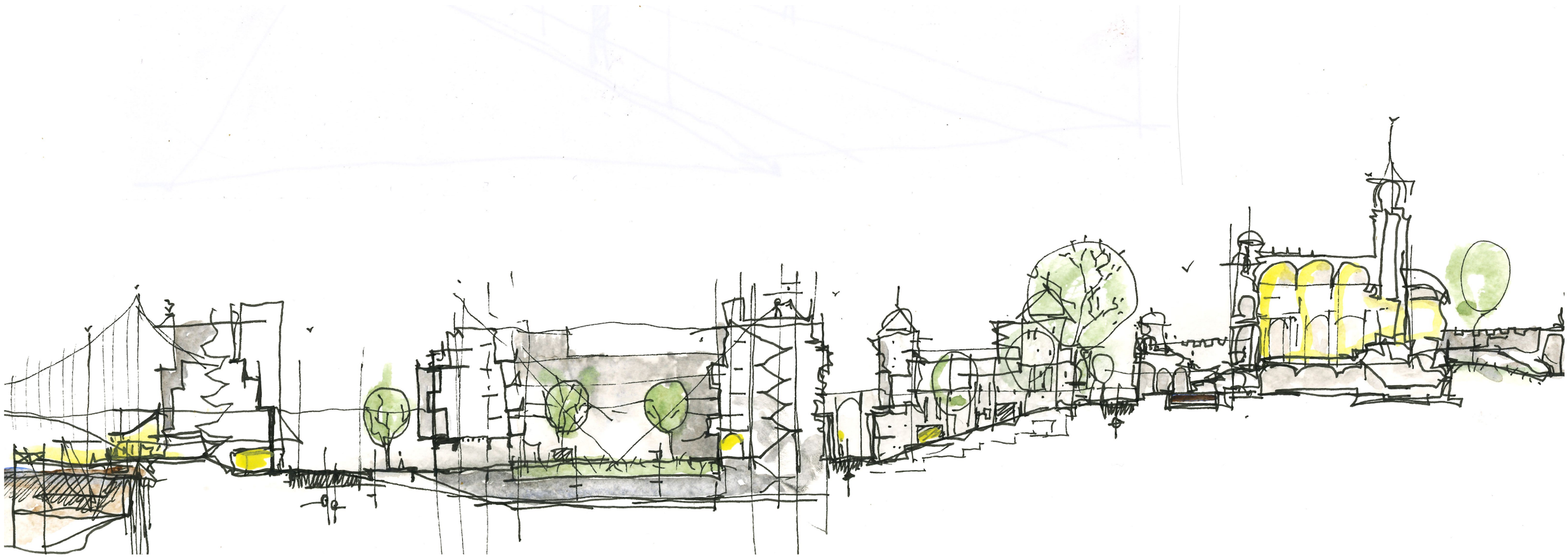
Vers une architecture sonique

- Deal with noise at source, treat ‘noise’ creatively.
- Deploy absorption: in overhangs, building facades as well as internally
- Pockets of quietness, emphasised by masking and natural sounds [planting, water, parks etc.]
- Sequences of spaces
- Relationships between spaces and between buildings
- Achieve WHO noise standards

Vers une architecture sonique

Vers une architecture sonique

Vers une architecture sonique



Imaginary section through Stockholm