Algorithmic Sustainable Design: The Future of Architectural Theory.

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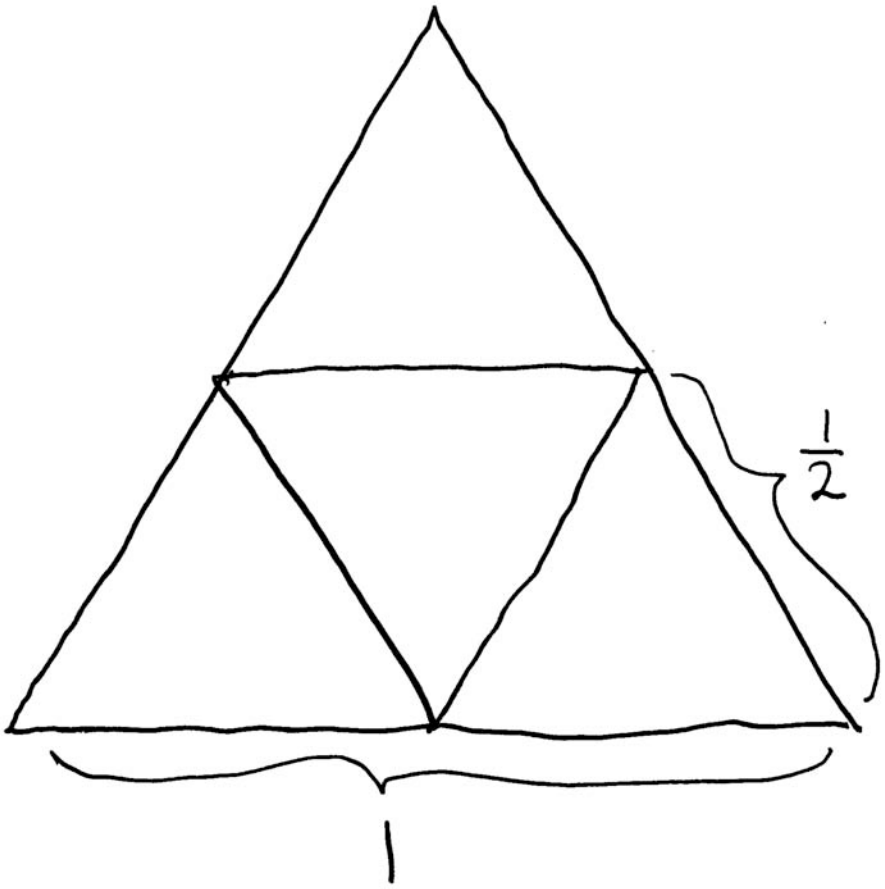
Lecture 2
2.1. Geometric recursion and fractals: the Sierpinski gasket.
2.2. Perforation, bending, and folding.
2.3. Anti-gravity anxiety.
2.4. Architecture of the horizontal.

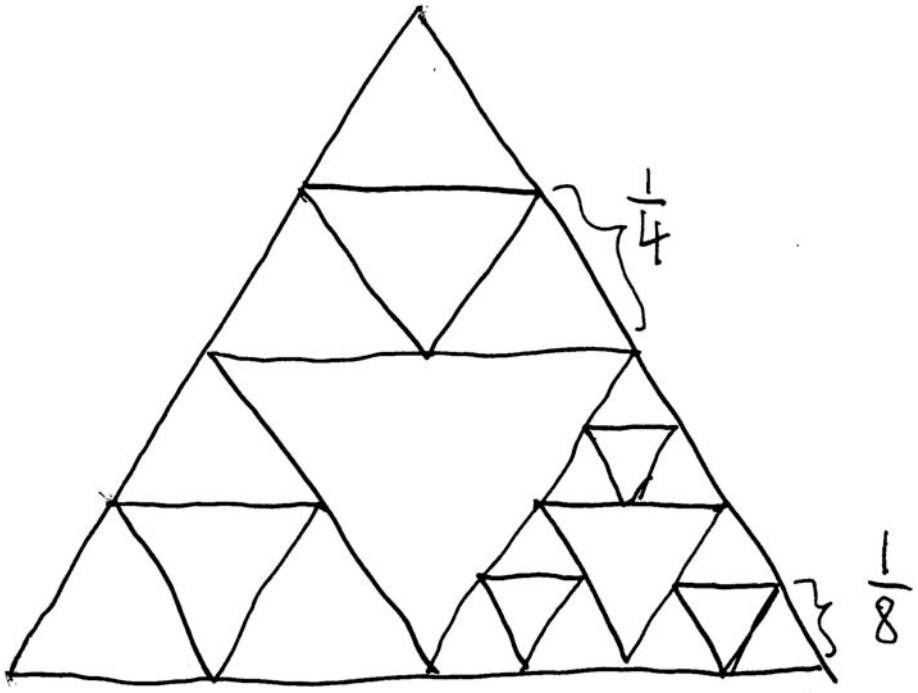
2.1. Geometric recursion and fractals: the Sierpinski gasket

Algorithm for generating the Sierpinski gasket

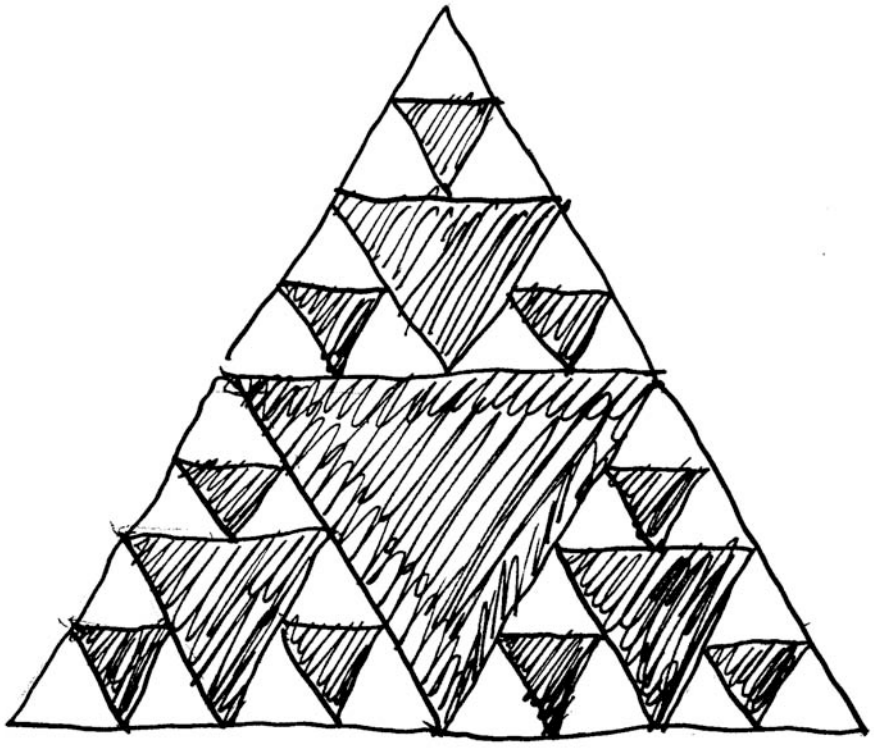
- Start with an equilateral triangle
- Subdivide its sides into 1/2, and draw 3 triangles inside the original triangle
- Now subdivide those smaller triangles into 1/2, and repeat the process
- Geometric Recursion



Sierpinski gasket (first iteration)



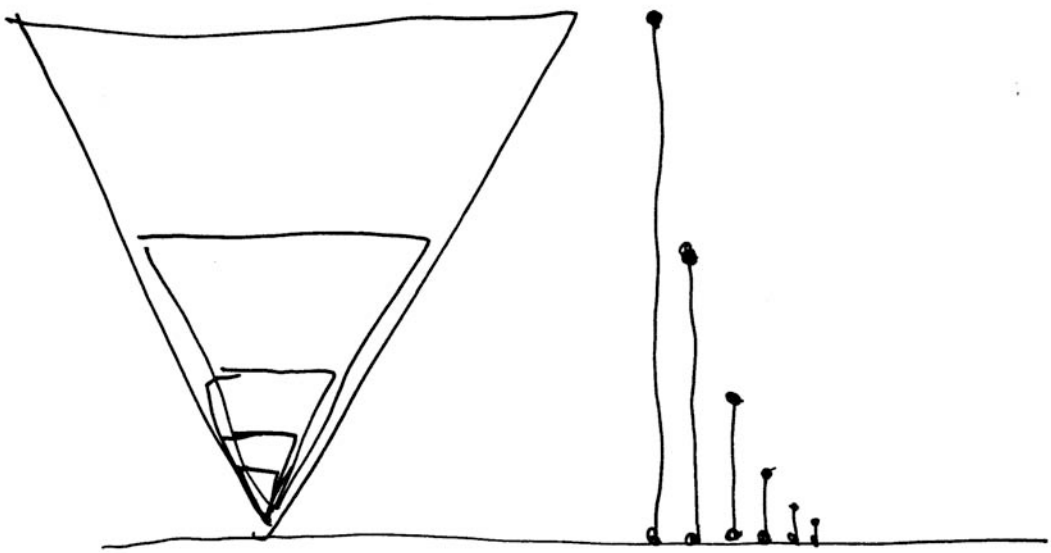
Sierpinski gasket (cont.)



Cut out down-pointing triangles

Mathematical, natural, and architectural fractals

- The Sierpinski gasket is an exact fractal with an infinite number of decreasing scales
- Its scaling factor is 2, not 2.72, so it does not precisely follow universal scaling
- Triangles are a very specific geometry — we are not proposing triangles for the shape of buildings or cities



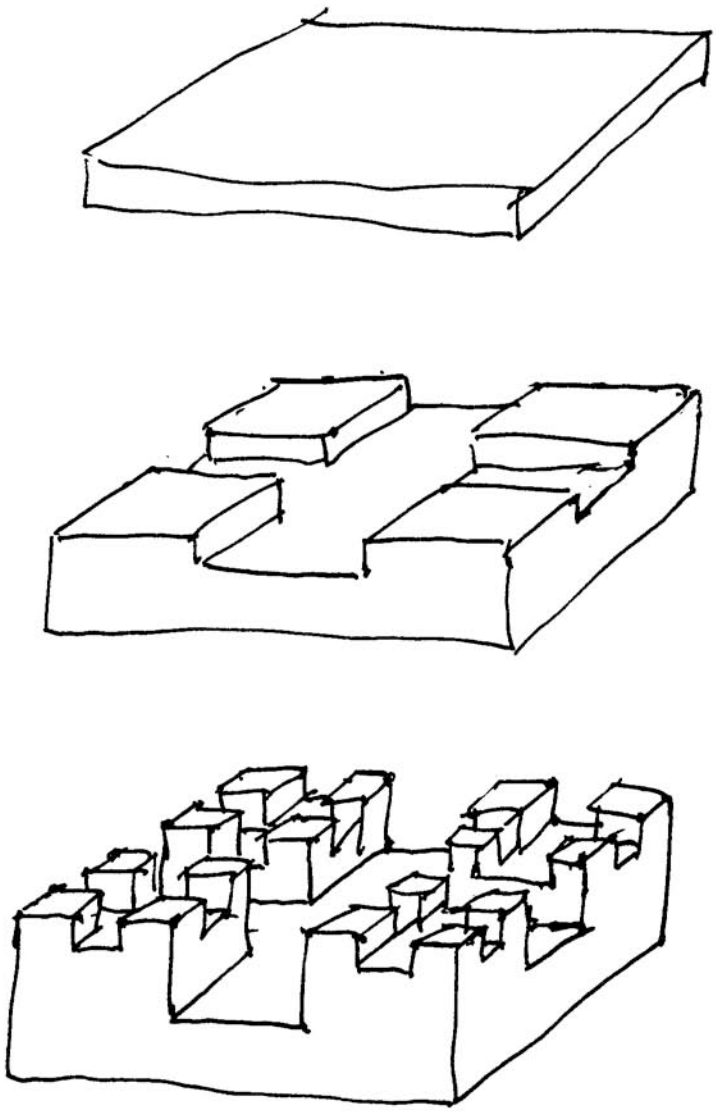
Scaling by factor of 2

Two types of fractals

- All fractals depart from uniformity
- PERFORATED fractals cut out smaller and smaller pieces (gaskets, sponges, sieves)
- ACCRETIVE fractals add smaller and smaller pieces to build up fine structure

3-D accretive fractal castle

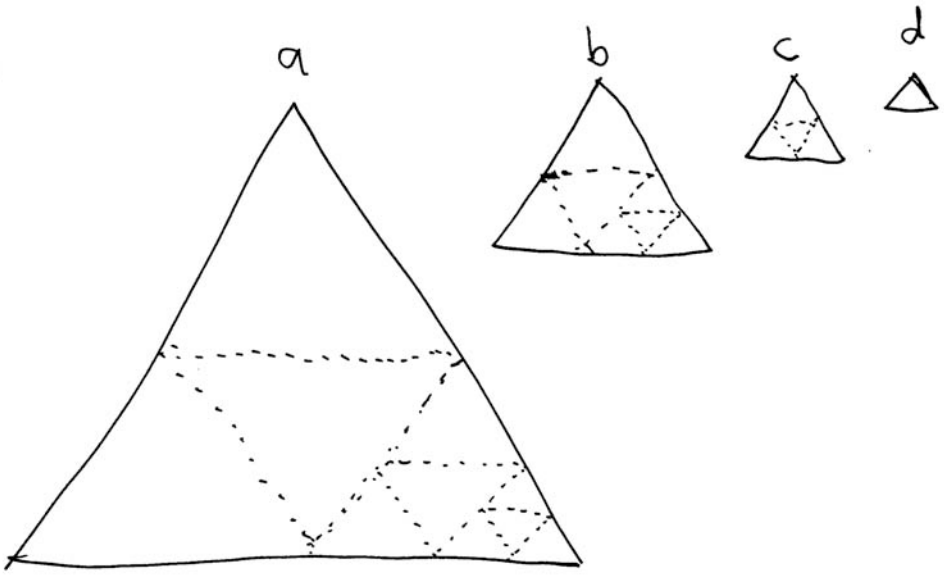
- Start with a thick square slab
- Add four smaller square slabs on top of the corners
- Repeat on smaller scales (scaling factor 3)



3-D accretive fractal castle

Scaling symmetry creates coherence

- Similar shape when a fractal's particular details are magnified
- The brain handles more information encoded in a fractal than if random
- Key to fractal information compression
- Fractals in nature have similar but not identical features under magnification



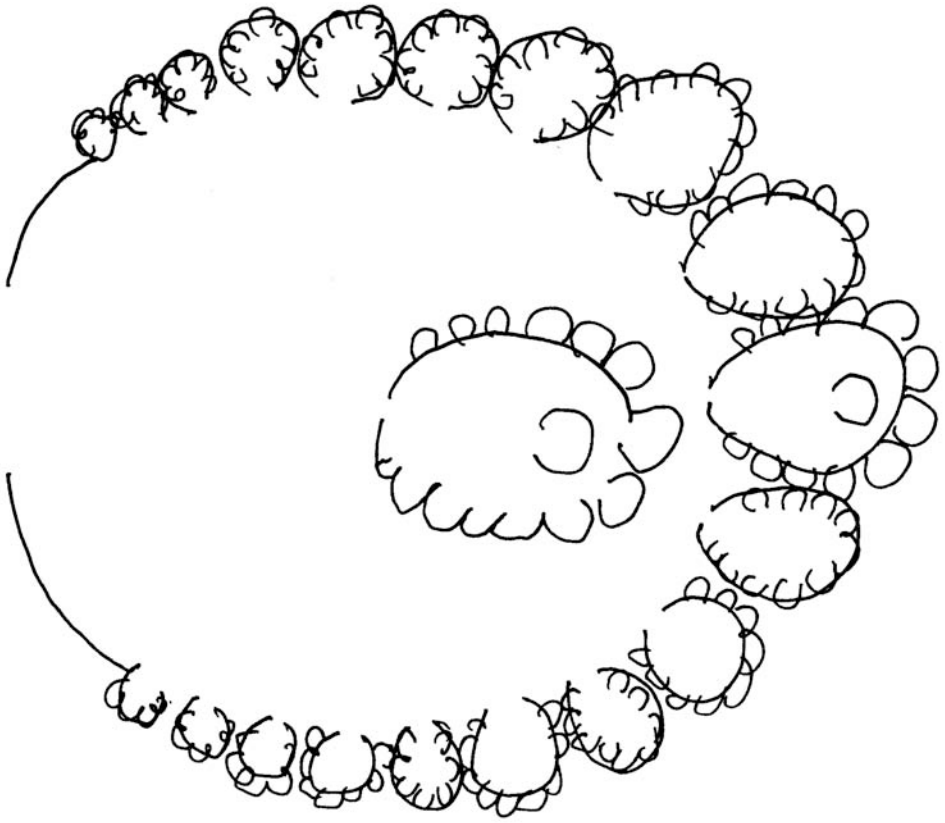
Self-similarity

Physiological wellbeing

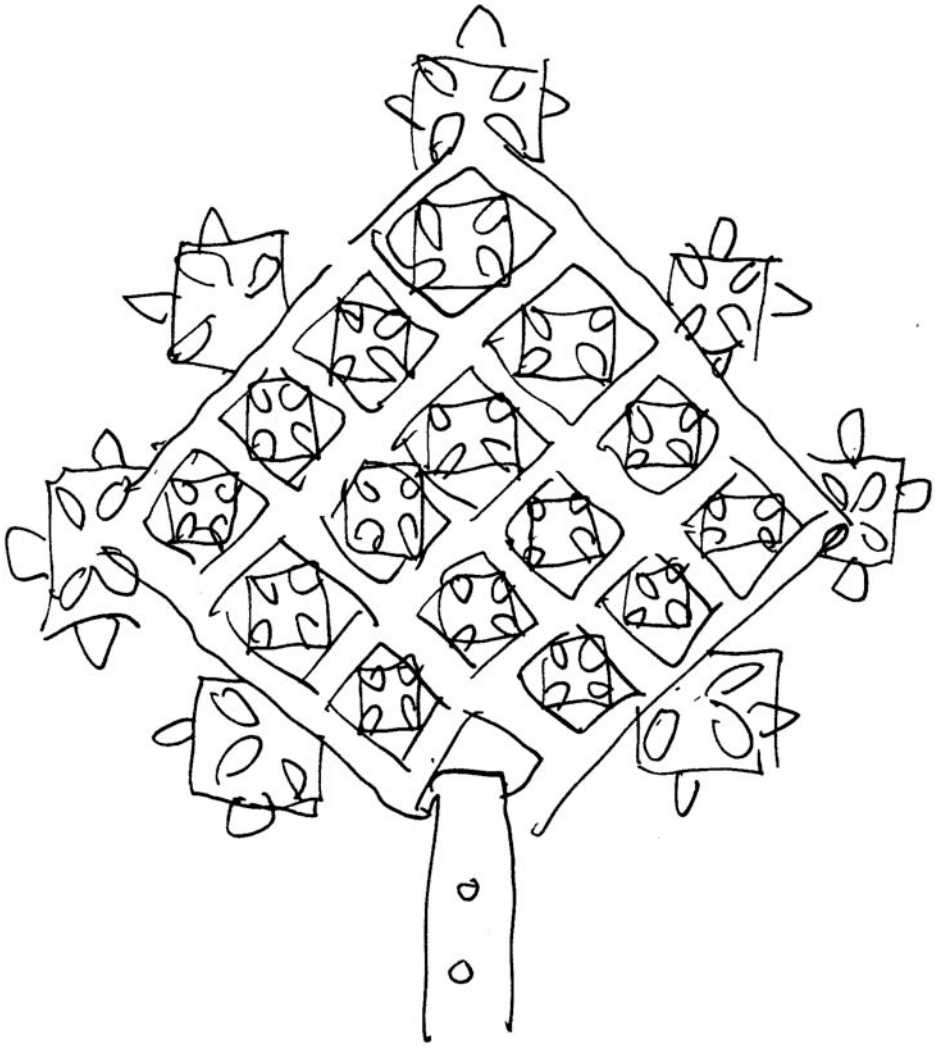
- Self-similarity endows visual coherence — important to human perception
- The brain evolved to handle self-similar natural structures
- We react with alarm at structures that exhibit no scaling coherence

Fractals in architecture 1

- The Cosmati family of mosaicists and floor builders created a series of Sierpinski pavements in 12-14C Italian churches
- African villages have naturally fractal plans, not triangular but circular
- Islamic tile patterns are intrinsically fractal, showing high degree of self-similarity



Plan of Ba-ila, Zambia (documented by Ron Eglash)



Ethiopian silver cross

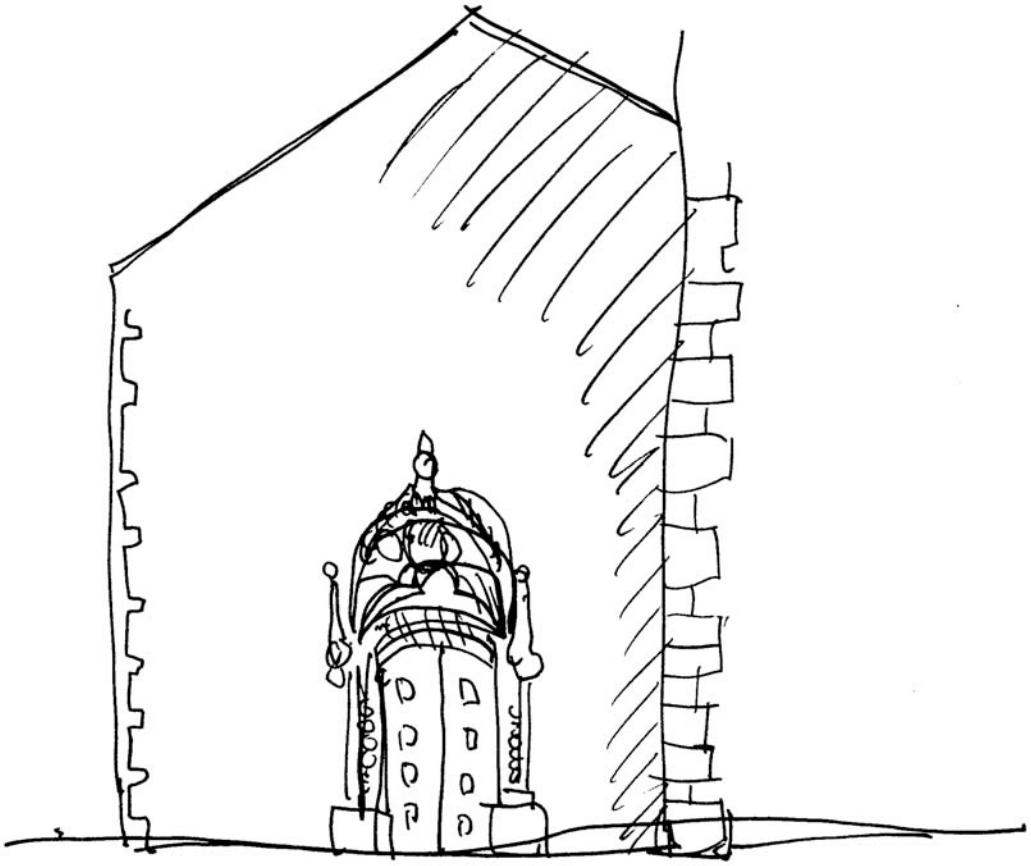
Western arrogance!

- We can learn from vernacular architecture
- Unfortunately, the West exports non-adaptive, absurd design styles and typologies tied to industrialization
- These erase sustainable local traditions
- Massive media coverage in league with globalization convinces the rest of the world to abandon their culture of building

Fractals in architecture 2

- Manueline Portuguese architecture consists of accretive fractals

- Smallest details are most effectively used on regions closest to users
- Structural information is never lost by zooming into the area of detail
- Sometimes detail is distributed all over — Hindu temples with sculptures



Detail focused in small region

Minimalist modernism is not fractal

- Only the largest scales are defined
- Maybe one or two scales are present — enormous gap between scales
- No intermediate scales to tie the form together according to universal scaling
- **No scaling coherence**

Postmodernist & Deconstructivist buildings are not fractal

- Opposite problem of minimalist style
- Too many things going on in too many different scales — no scaling hierarchy

- Scale of free-flowing forms is ambiguous
- Nothing is self-similar, because designs deliberately avoid symmetries
- **No scaling coherence**

Adaptive buildings

- The human body has a hierarchy of scales, from 2 meters down to 1 mm
- Adaptation to human use and senses generates substructures and details
- Adaptive buildings connect through a scaling hierarchy to the microscopic structure of the natural materials

2.2. Perforation, bending, and folding

Process necessary for scaling hierarchy

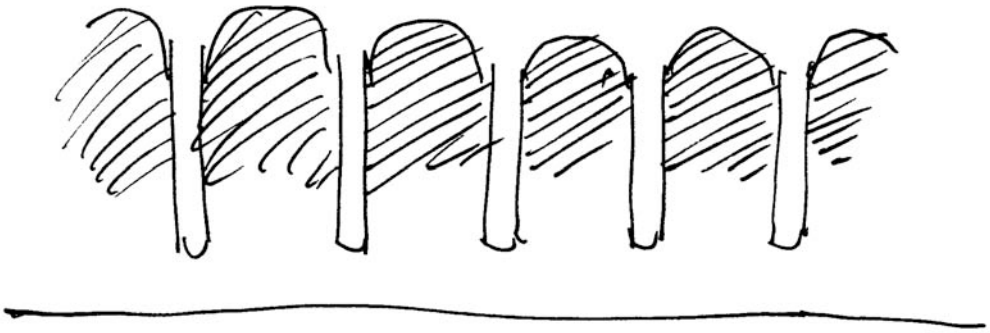
- Morphogenetic development in architecture
- Architectonic elements necessary to define a scaling hierarchy
- Physical model helps to visualize how fractals are generated by stresses

Three processes

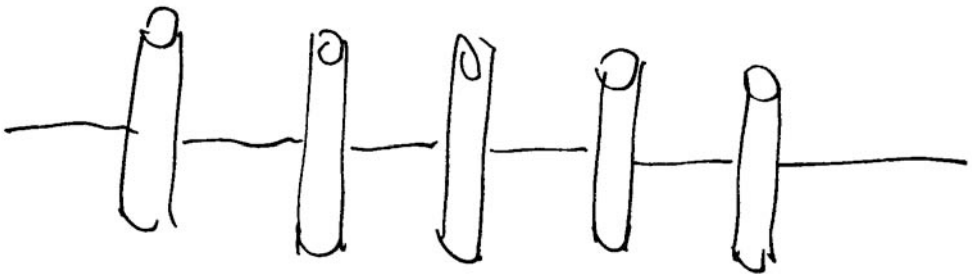
- PERFORATION: windows, doors, arcades
- BENDING: departing from straight lines creates structure on smaller scales
- FOLDING: crenellation, pilasters, fluting on columns

Perforation: semi-permeability

- In adaptive architecture, biology, and urbanism, boundaries are not absolute
- Semi-permeable membranes let something through while keeping other things out
- Arcades & bollards: let people through while keeping cars out
- Window grille or **Mashrabiya**: lets air and light through while keeping people hidden



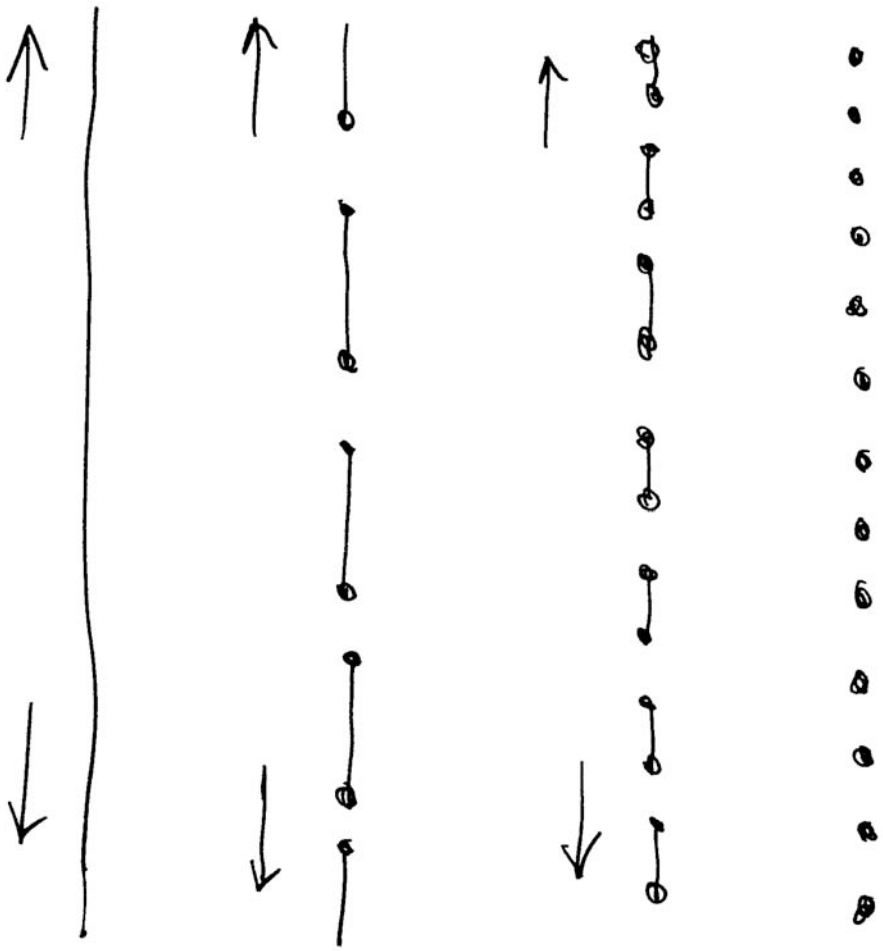
Perforation: arcade



Perforation: bollards

The “push-pull” model — PULL

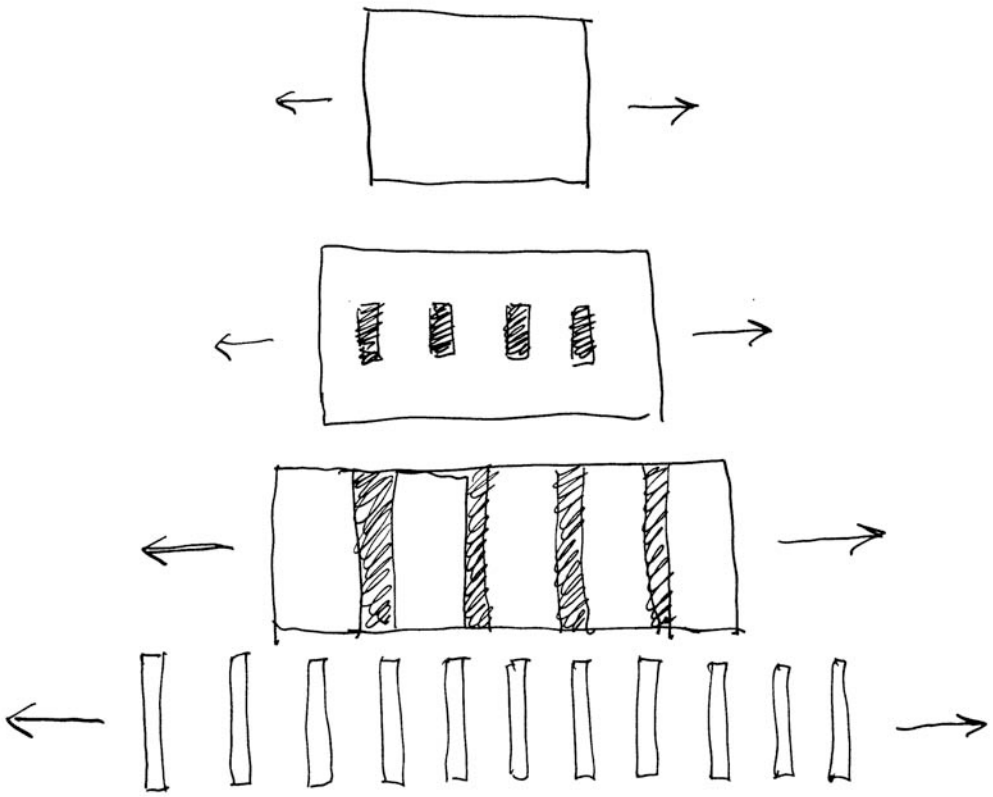
- Pulling uniformly along a line breaks it at regular intervals (sealing wax on rubber)
- Tension generates perforations — gaps on smaller scale
- Eventually leaves only points
- Examples: colonnades, arcades, monumental axis outside Egyptian temples



Tension perforates; eventually separates line into points

Horizontal tension

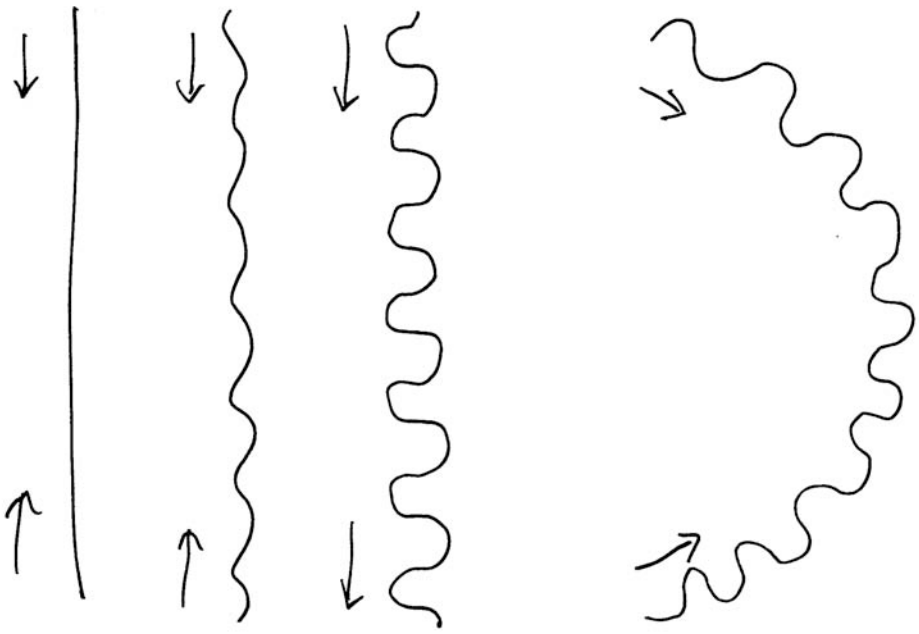
- Pulling first separates smooth wall into mostly vertical window and door openings
- Uniform lateral tension separates wall into sections with vertical cuts — arcades
- Further tension separates all wall pieces into columns — creating a straight colonnade
- (This model questions curved colonnades)



Horizontal tension subdivides

The “push-pull” model — PUSH

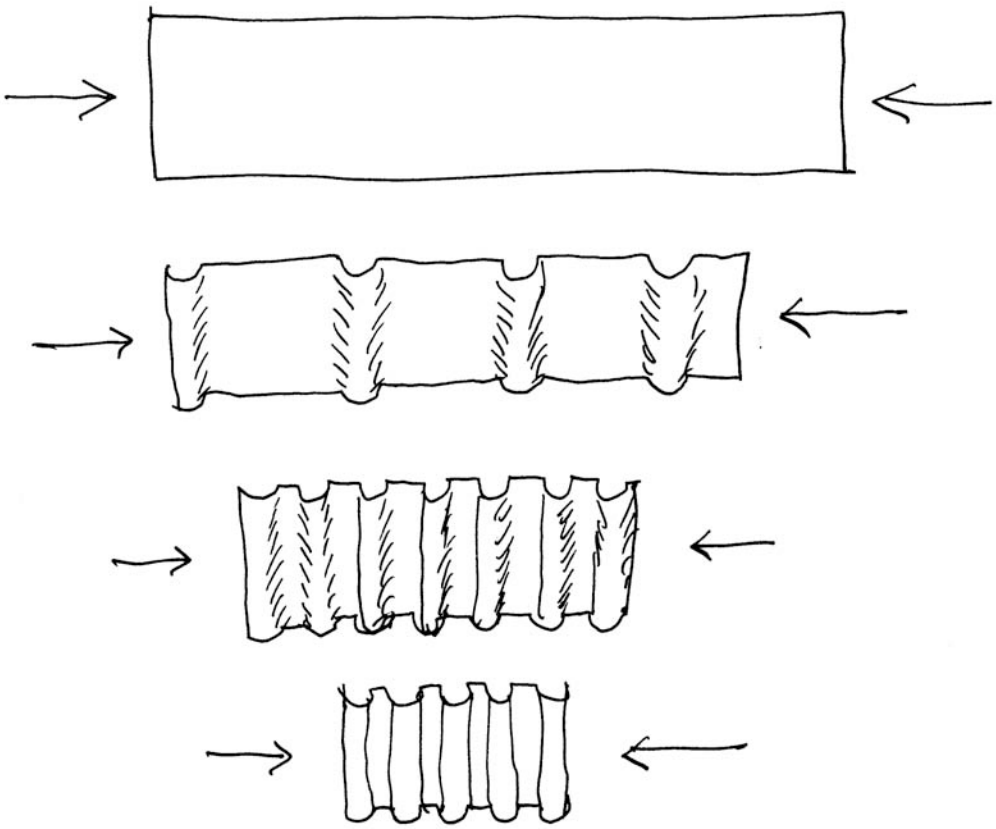
- Push a line along its axis so that it folds uniformly
- Generates meanders — new fractal scale
- Compression will eventually bend the whole line to create a curve
- Examples: Circus at Bath; circular plazas surrounded by coffee tables and café alcoves; temple interiors



Compression creates meanders, then overall curve

Horizontal compression

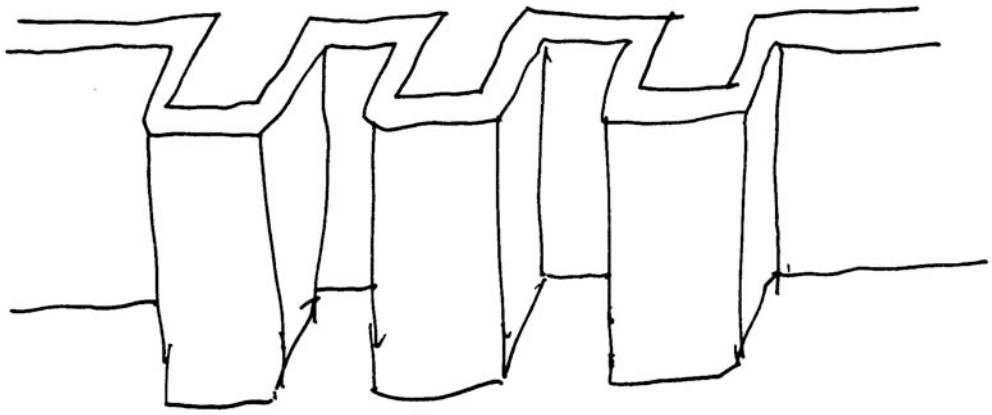
- Generates smaller structures
- Folding occurs along lines orthogonal to the direction of compression
- Pilasters, thick door and window frames, ceiling beams
- Departure from smooth, straight wall or ceiling



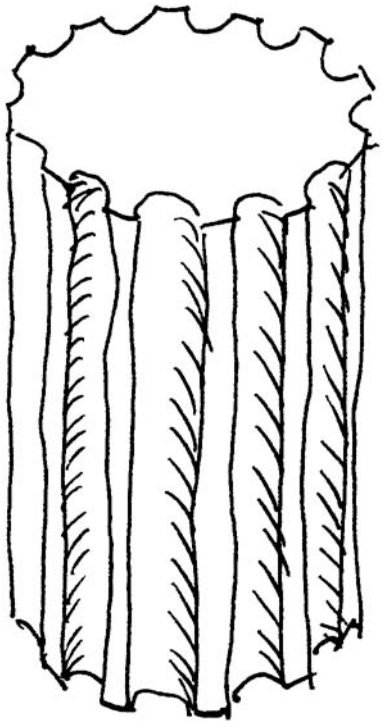
Horizontal compression folds

Folding: space-filling

- Folding a line is the first step to filling the space slightly
- Meanders create articulations on new, smaller scales
- The boundary of successful urban space needs those smaller scales — which accommodate human activity nodes



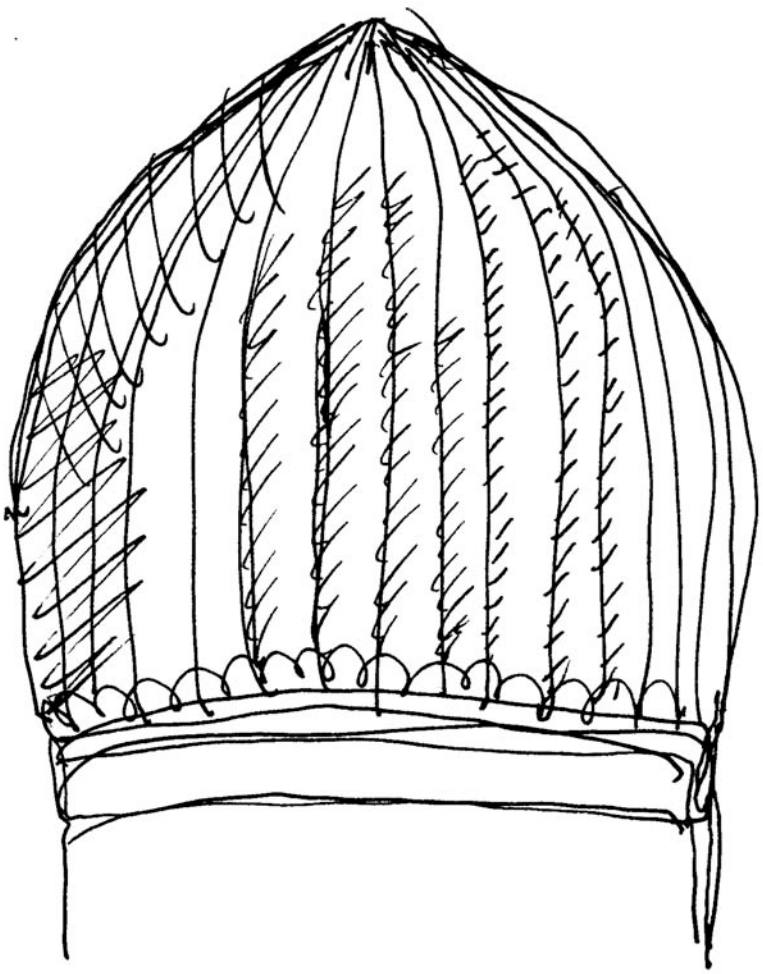
Folding: walls



Fluting on column drum

Bending adapts to volume

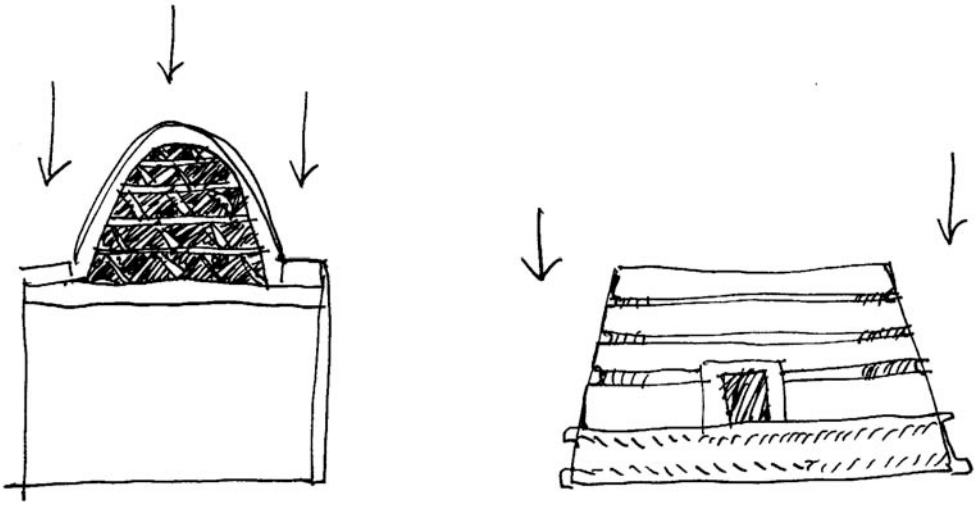
- Bending creates a boundary for space
- Domes are best for ceilings, giving the most positive sense of psychological enclosure
- Domes are also more structurally stable
- Urban space needs semi-enclosure on its perimeter, achieved by the surrounding building façades



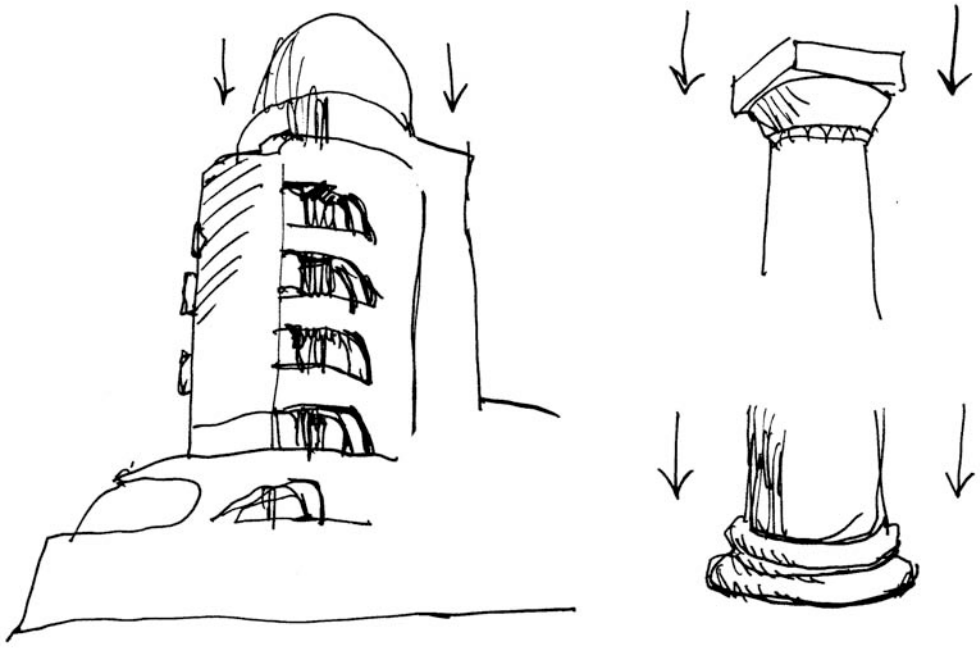
Folding on dome

Implications of vertical push

- Vertical compression creates folding
- Folding creates horizontal bulges
- There are no horizontal gaps, since those would be generated by vertical tension
- No natural mechanism for vertical tension!
- Buildings that show horizontal gaps are perceived as unnatural, and create anxiety



Vertical push generates morphological features



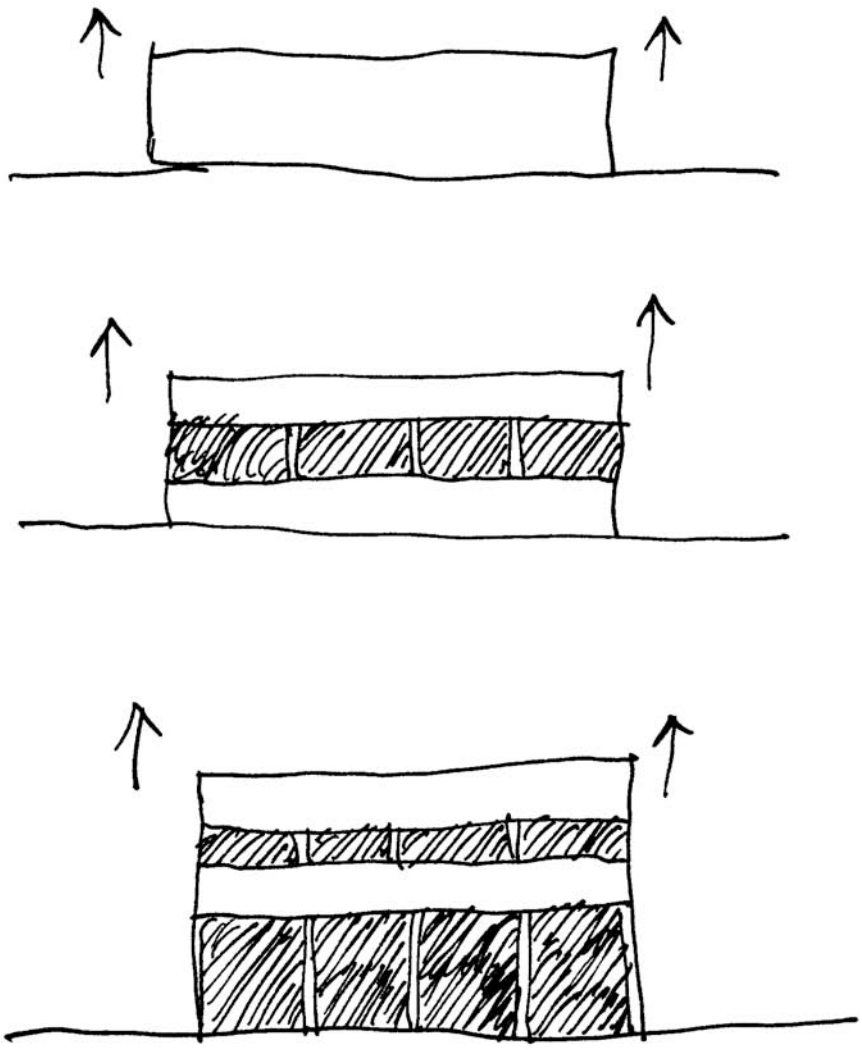
Gravity influences curvature, thickens capitals and bases

Biophilic constraints on the "push-pull" model

- Human physiological sensors orient us with the vertical and horizontal axes
- Diagonals generate distress, except when symmetry creates an implicit vertical axis
- BOTH PUSH OR PULL CAN ACT HORIZONTALLY
- Because we evolved with gravity, ONLY PUSH CAN ACT VERTICALLY!

2.3. Anti-gravity anxiety

- Anti-gravity pulls building upwards
- Vertical tension breaks façade, cutting it and separating it into horizontal windows
- Pull creates horizontal gaps and slits between horizontal slabs
- Vertical tension can pull entire building off the ground — maintained by minimal supports (not columns, but stretched pilotis)



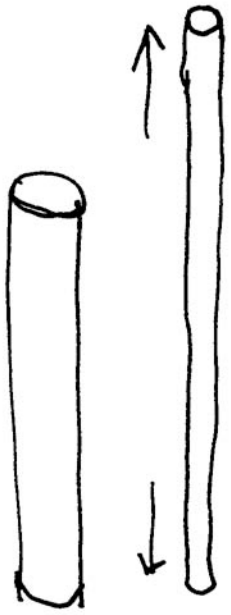
Anti-gravity design pulls building upwards

Not rooted to the earth

- Vertical pull lifts building up, like a space ship
- Building pulls away from humanity
- Something alien — appears to want to detach from life on earth
- Columns are the opposite of pilotis

Pilotis are stretched cylinders

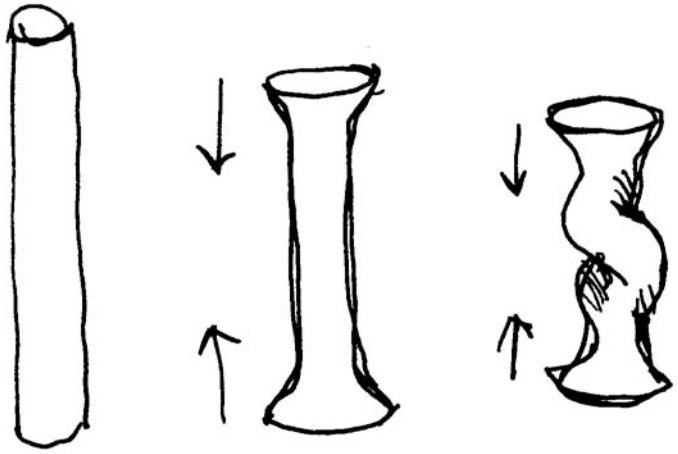
- Pull cylinder uniformly
- If it is elastic, it will stretch
- Cylinder will also narrow in diameter



Pilotis are stretched cylinders

Columns are compressed cylinders

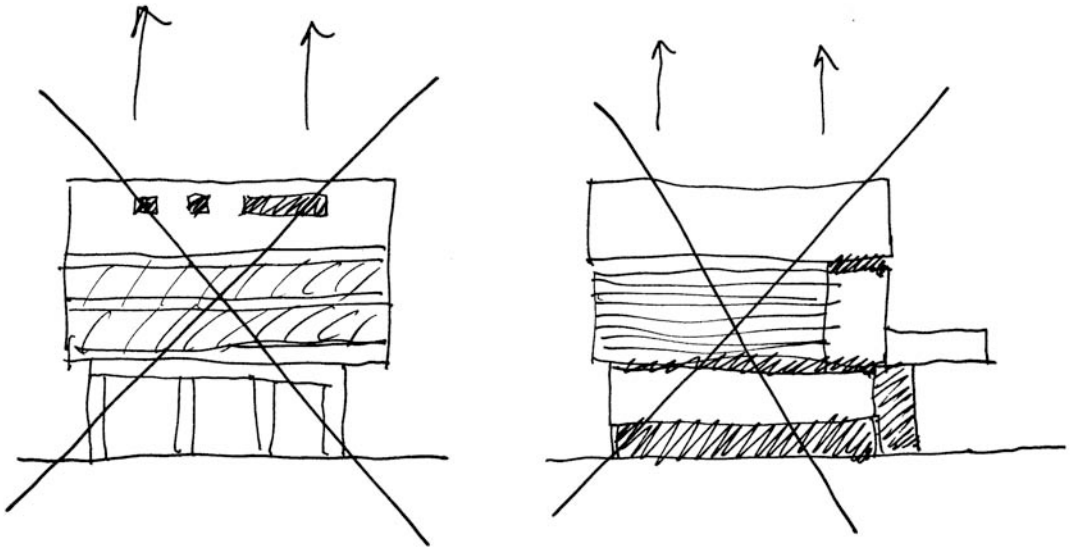
- Push cylinder to create column
- Pressure widens capital and base
- Further pressure can buckle column
- Serpentine column



Columns are compressed cylinders

Perverse application of "pull"

- Universally applied to world architecture
- Consistent application of our "pull" rule
- Stretching creates horizontal gaps on many different scales — sometimes fractal?
- BUT IN THE ONLY DIRECTION THAT CAUSES ANXIETY — VERTICAL



Anti-gravity generates anxiety

Poverty of conception

- Some vertical "pull" designs show subdivisions on smaller scales
- But vertical "pull" buildings are mathematically one-dimensional
- Any fractal structure is 1-D, because subdivisions are only in one dimension

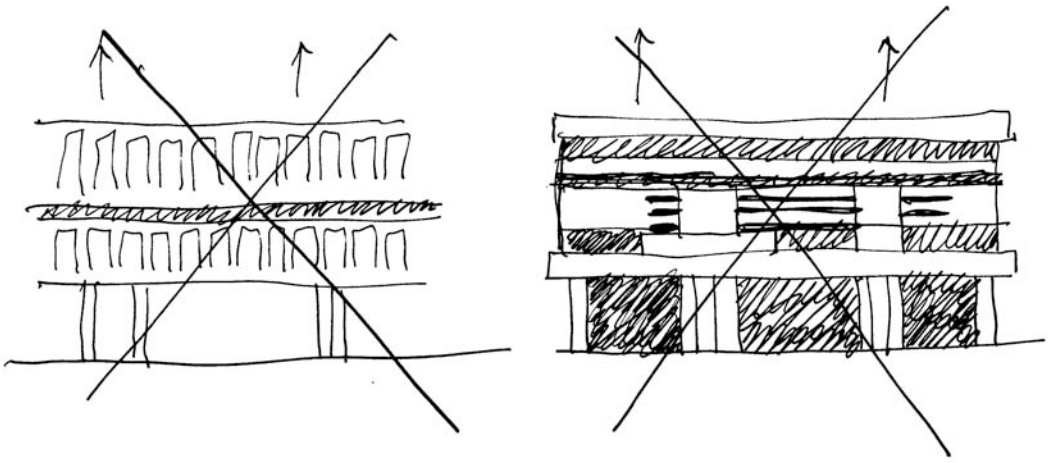
2.4. Architecture of the horizontal

Suppress vertical dimension

- The British philosopher Roger Scruton first described this idea in a 1980 BBC talk (reprinted in "The Classical Vernacular")
- This method kills design on the vertical dimension, by simply moving the plan up
- Buildings become stacks of horizontal slabs
- The "Domino" house by Le Corbusier

Absurd design idea

- "The plan is the generator" — Le Corbusier writing in his propaganda pamphlet "Towards a New Architecture"
- Draw a ground plan, then translate it upwards to define the building's volume
- Design method taught in all architecture schools today



Vertical "pull" design has become the world standard

End of 3-D design

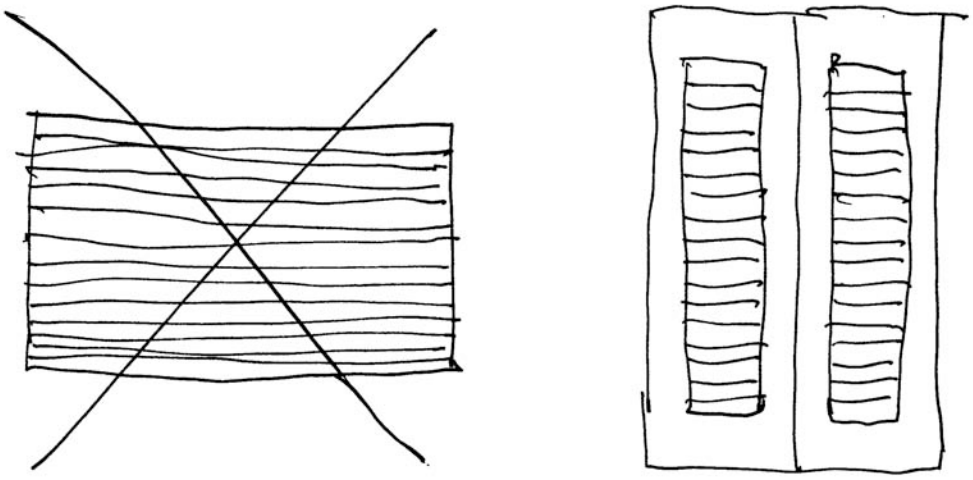
- Lifting ground plan to define building eliminates 3-D design altogether
- No façade for human beings to be able to relate to — no adaptivity to senses
- Reduces architecture to 2-D, and just the ground dimensions that are not perceivable!
- Spaces in actual building not designed!

Multi-storey parking garages

- Lend themselves to horizontal slab typology
- Anti-gravity anxiety is one reason why they destroy the urban fabric
- Solution: surround them with real façades
- Older parking garages had stores on ground floor, and fronting the street on all sides

Venetian blinds

- All details contribute either towards anxiety or wellbeing in the built environment
- Illustration of anti-gravity anxiety from minor elements such as window shades!
- Venetian blinds fit into windows that are wider horizontally — anxiety
- Older louvres were embedded into vertical frames — pleasing



Anxiety-inducing horizontals enclosed by vertical frame

Garages in suburbia

- The garage opening is a horizontal gap
- Widespread architectural typology, most prominent feature of today's house façades
- Contributes to dead feeling of suburbia
- No attempt made to frame a garage opening or to provide a canopy or roof, which would improve the design

Typologies that induce anxiety

- Many building and urban typologies that induce anxiety in the viewer were introduced in the early 20th century
- Those typologies have become standardized
- Standardized typologies are copied without even thinking about their consequences
- Our built environment has become deadening and we don't realize why