Algorithmic Sustainable Design: The Future of Architectural Theory.

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Lecture 9

A. Symmetry production.

B. Symmetry breaking.

C. Classical moldings.

D. Elementary particle symmetries.

E. Binding energy.

A. Symmetry production

- Humans throughout history have produced multiple symmetries in artifacts, buildings, and cities
- The cultural record demonstrates an essential need for symmetry in our environment
- Not simplistic, but complex symmetry

Why we need symmetries

- Random information is too much for human cognitive system to handle
- In a random design, every single point has to be coded for representation
- Symmetries significantly reduce the amount of information that needs to be processed by the brain

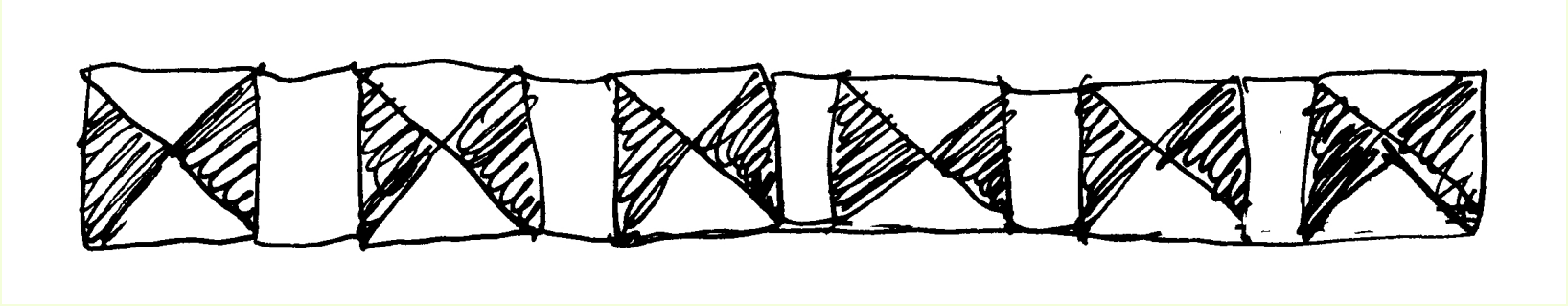
Cognitive alarm

- Our neural system evolved to interpret our environment
- Random information overwhelms our cognition, thus causing alarm
- The same occurs for visually empty environments — unnatural, hence physiologically threatening

Different types of symmetry

- *Translational symmetry* — shift something along one direction
- *Reflectional symmetry* about an axis
- *Rotational symmetry* about a point
- *Glide reflection* — combines translation with reflection

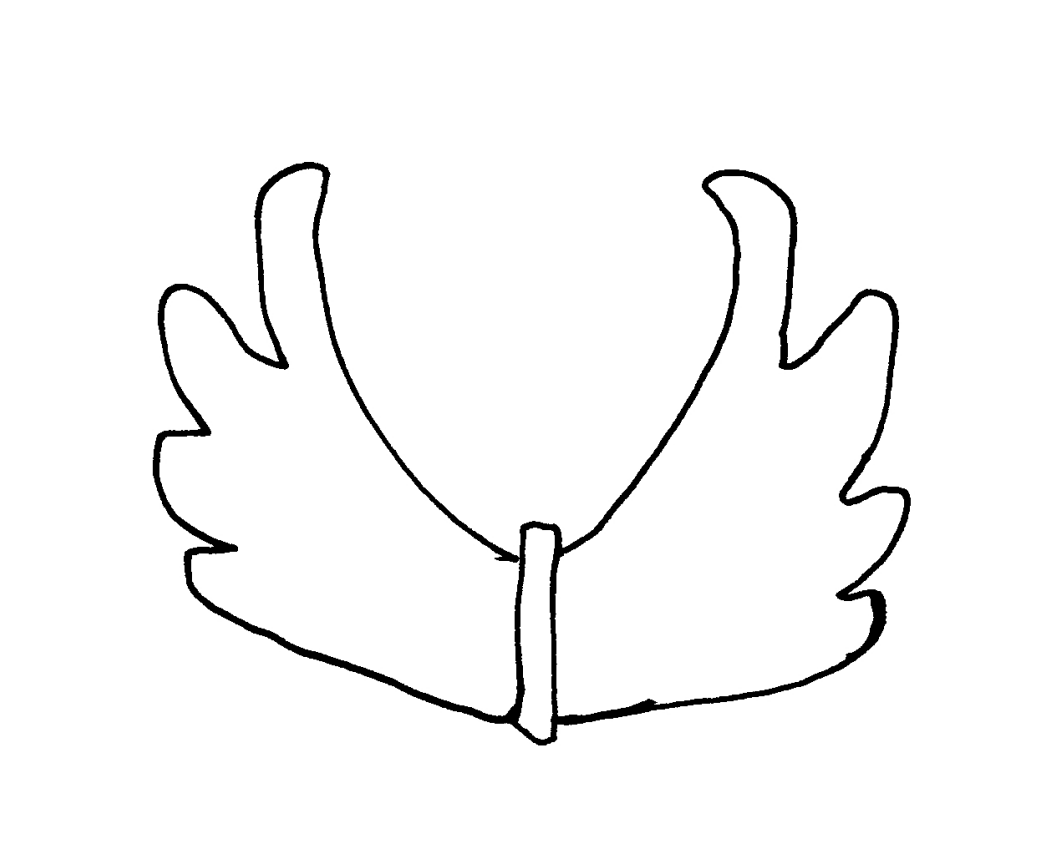
Translational symmetry



Translational symmetry

- Straight line defines symmetry axis
- Repetition of non-trivial units
- Alternation defines the repeating unit better, by using contrast, than simply empty repetition
- “Alternating repetition” (*lecture 6*)

Reflectional symmetry



Reflectional symmetry

- Mirror symmetry about some axis
- Any axis is fine on the floor
- But *vertical* axis is essential for our physiological feeling of stability
- Mirror symmetry must define an implicit vertical axis — otherwise design or structure feels unbalanced

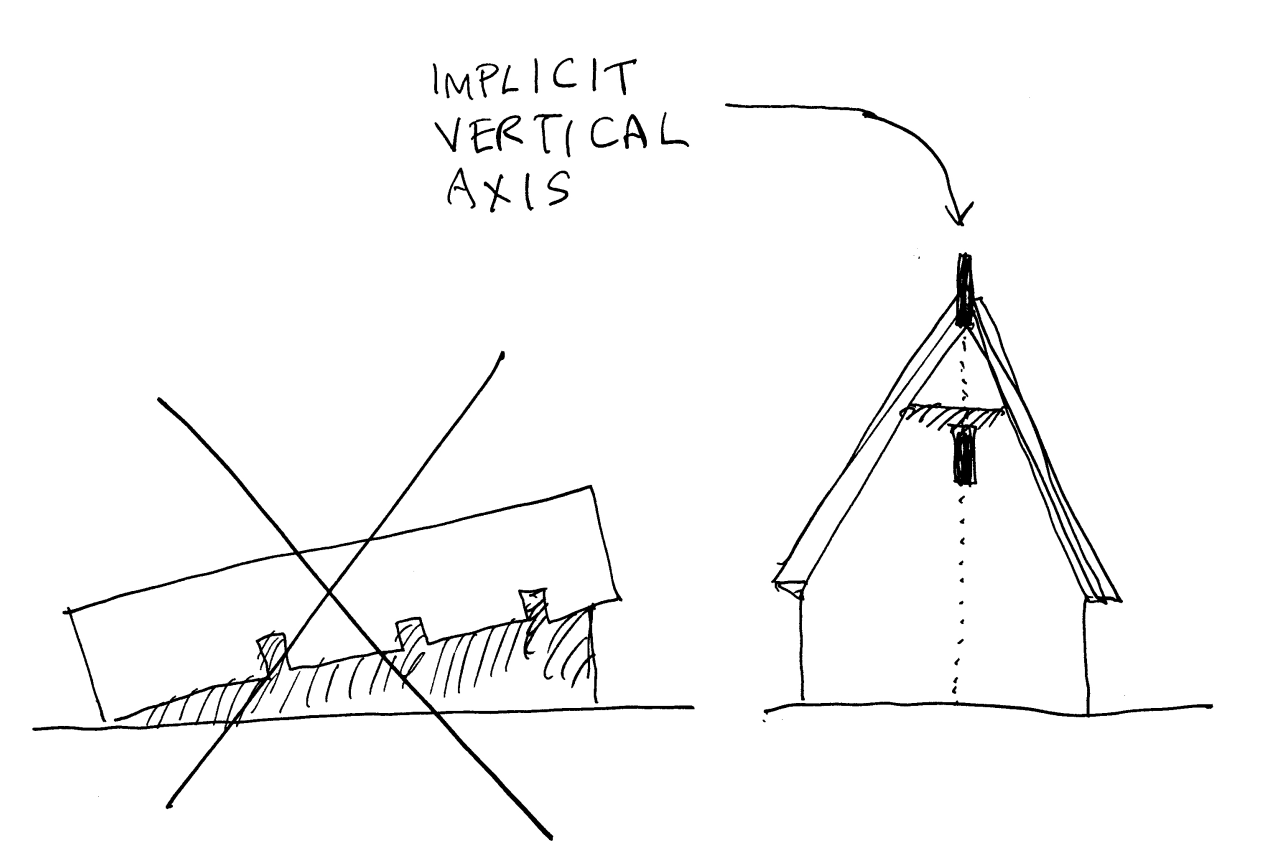
Implicit axis

- A symmetric form implicitly defines its axis of symmetry (not explicit)
- Human reaction to axis of symmetry is the same as the reaction to visible line
- Vertical or horizontal — ***positive***
- Diagonal — ***negative*** (causes anxiety)

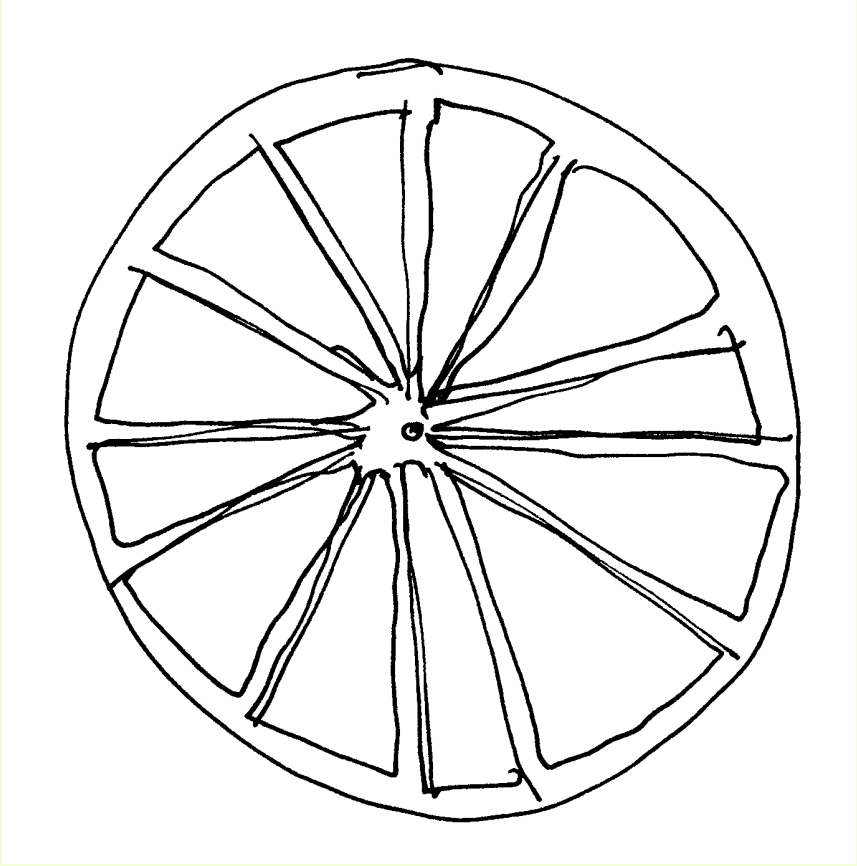
Physiological reaction

- Human sensory system evolved with gravity, to orient us to gravity
- Vertical axis built into our physiology
- We react with alarm or nausea to non-vertical axes (explicit or implicit)
- Reaction cannot be learned or changed

Implicit vertical axis



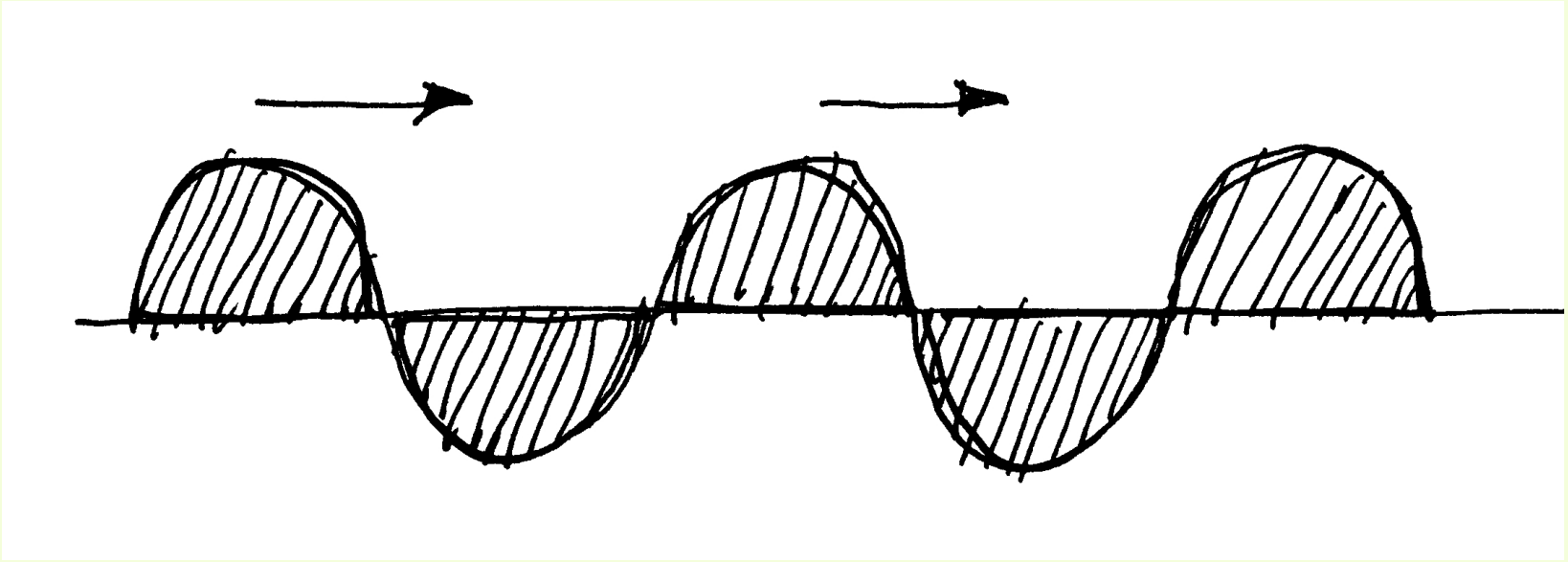
Rotational symmetry



Rotational symmetry

- Great stained-glass windows in medieval cathedrals
- Open ground plans of religious buildings and circular plazas
- Rotationally invariant architectural elements are usually embedded into a larger symmetric scale

Glide reflections



Glide reflections

- Combine translations with reflections into new symmetry
- There are a total of 14 ways we can combine the three fundamental symmetries nontrivially
- Glide reflections is only the first combination — there exist 13 more

The 17 plane symmetry groups

- Combinations of the basic symmetries: *translation, reflection,* and *rotation* — used on the small scales
- Regular tiling patterns — one complex tile repeats to fill in plane
- Known as the “wallpaper groups”

Symmetries of culture

- Great achievement of the human brain
- Found in all human art and artifacts
- Very sophisticated examples of the 17 plane symmetries throughout history
- *But they were **ERASED BY 20TH CENTURY MINIMALISM!***

The arch-racist Le Corbusier

- “*Decoration is of a sensorial and elementary order, as is color, and is suited to simple races, peasants and savages ... The peasant loves ornament and decorates his walls.*”
- — Le Corbusier, “*Towards a New Architecture*”, 1927; page 143

Authority condemns symmetries

- Ideology behind dominant design system erases multiple symmetries on all the smaller scales
- Instead, it insists upon simplistic overall symmetry on the largest scale
- Our artifacts and built environment are lifeless without complex symmetries

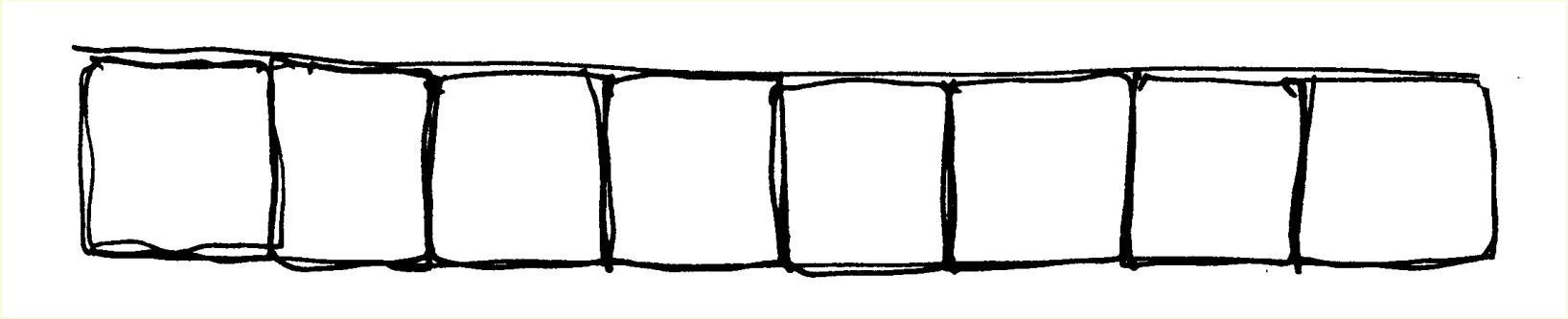
B. Symmetry breaking.

- It all has to do with information compression
- The human brain gains most sensory pleasure from designs that can be compressed, but not too easily
- Representation code should be neither too long (random design), nor too short

Identical repeated units

- Contain very little information
- Just one unit repeated indefinitely
- Representation code is very short: “*describe one unit, then repeat it indefinitely*”

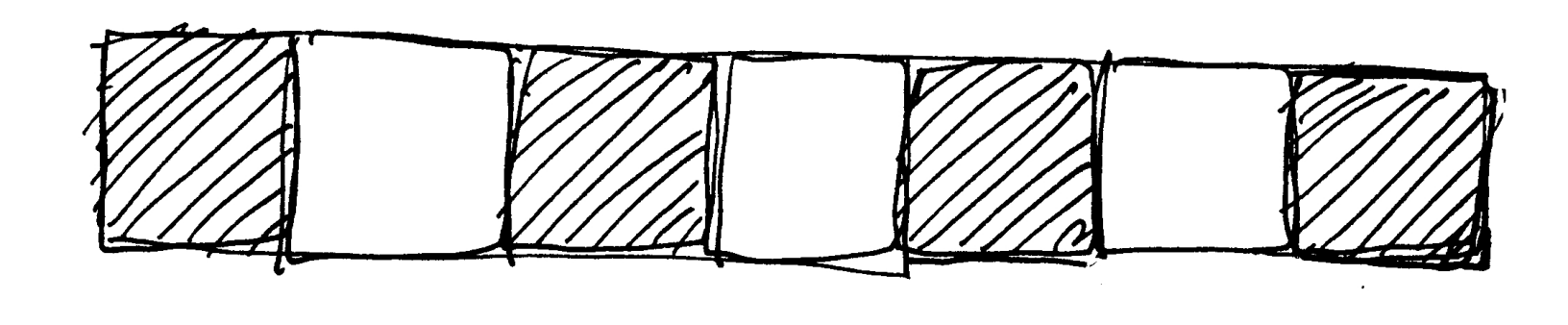
Empty repetition



Just a little more information

- Establishes larger scale by taking advantage of symmetry breaking
- Change units enough so they are no longer informationally collapsible into one identical unit
- But do not change them so much that translation or reflection symmetry is lost — then they become random

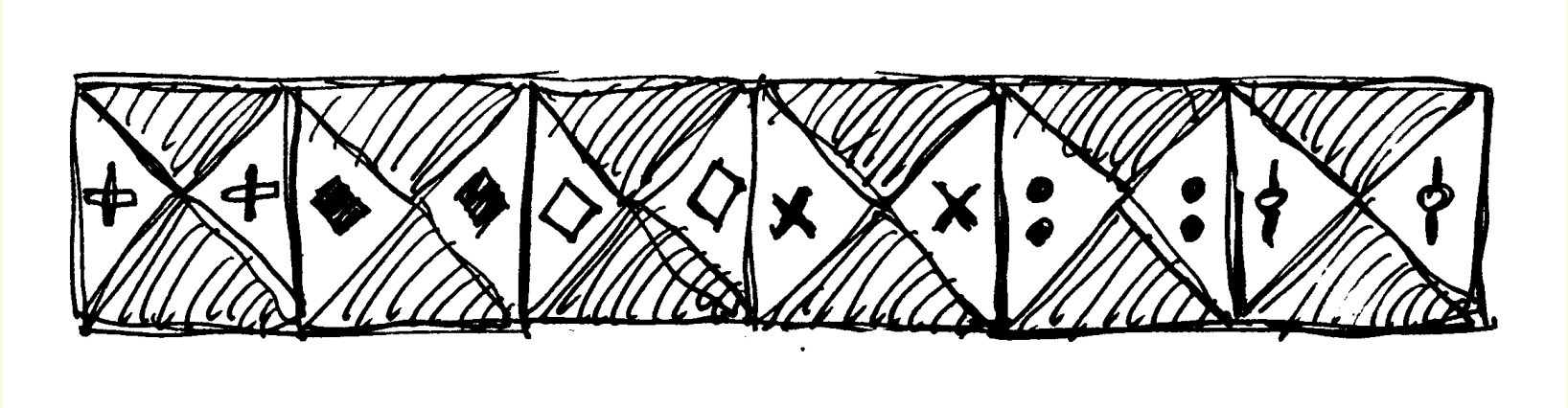
Alternating repetition (*lecture 6*)



Informational richness

- Monotonous repetition is unsatisfying precisely because it is compressible
- The mind craves richer information
- Symmetry breaking provides variety by carefully introducing randomness on particular scales

Symmetry breaking



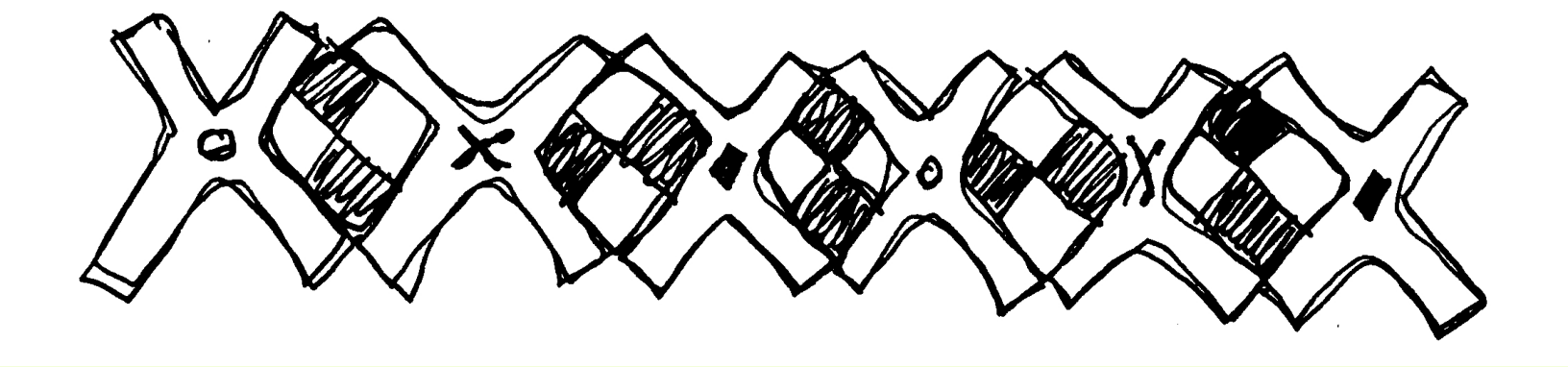
Traditional artifacts

- Look carefully at traditional artifacts
- Repetition is most often NOT simple
- Repeating units always have subtle changes, on a certain scale
- Symmetry and symmetry breaking are found co-existing on distinct scales

Roughness

- Symmetries found in both nature and in human artifacts are approximate
- This is a much more sophisticated mathematical notion than regularity
- "Roughness" property (*lecture 6*) breaks perfect symmetry

Alternating repetition with symmetry breaking



Symmetry breaking creates irreducible hierarchy

- Symmetry breaking establishes hierarchy in a sophisticated manner
- Larger scale in a scaling hierarchy is fixed when the smaller scale can no longer be collapsed into one unit
- Symmetry breaking stabilizes the hierarchy against collapse

Artisan work

- We value artisanal production of the same artifact, because of the inevitable minor variations
- A wall of identical machine-made tiles is not as attractive as a wall made of imperfect hand-painted tiles
- The brain perceives the effect of minor variations in the individual tiles!

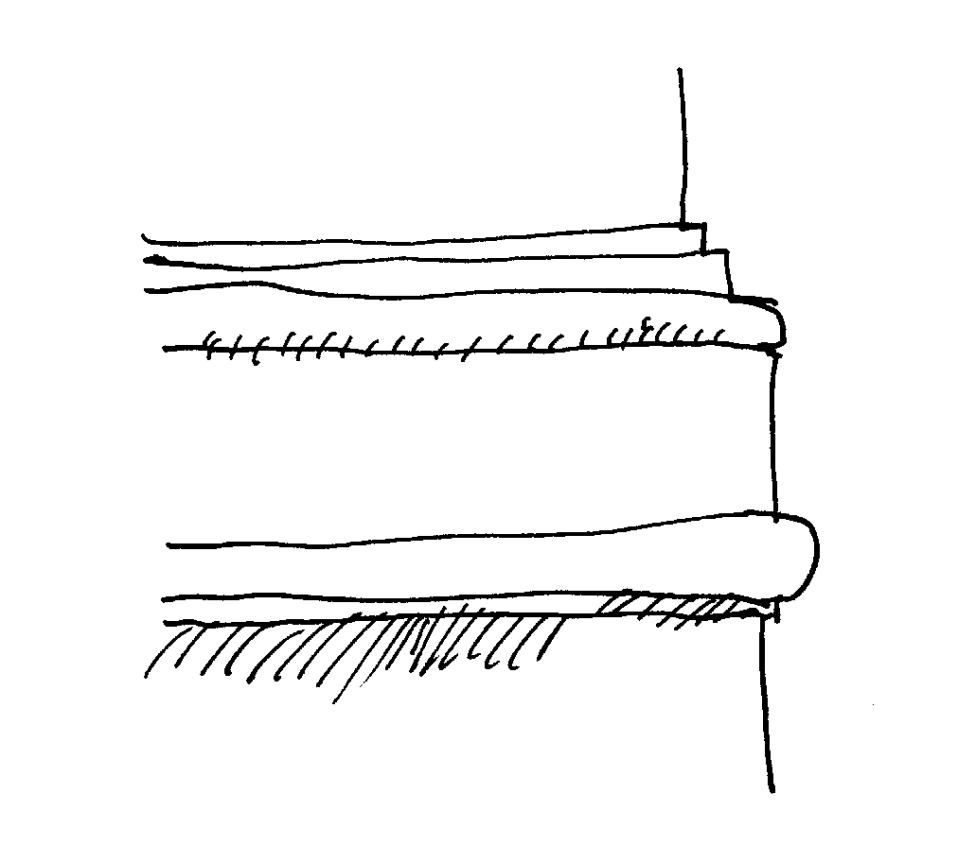
C. Classical moldings

- Unexpected support from (and for) the Classical form language
- Moldings presented as the atomic units of Classical architecture
- Educational system of Donald M. Rattner (architect, New York City)

Combinatorial elements

- Moldings are the smallest elements in the Classical form language
- THEY ARE ALL SYMMETRIC
- Classical moldings are used in combination to create large-scale units
- Never taught in architecture schools!

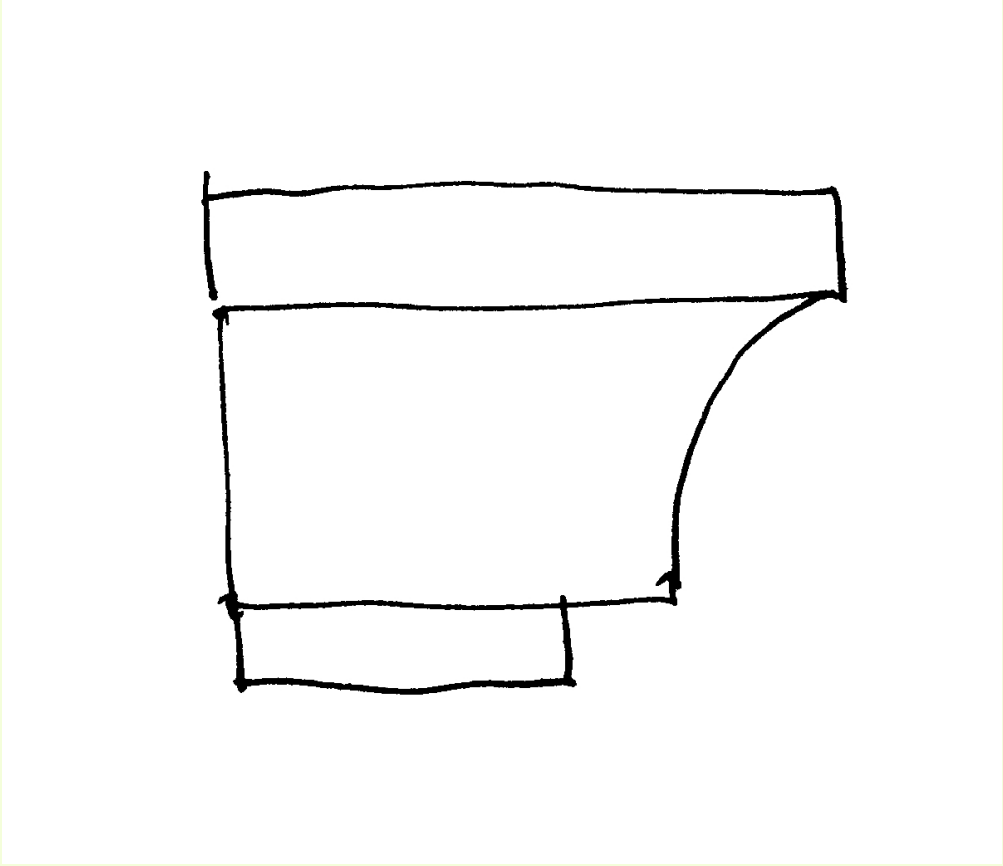
Moldings add translational symmetry



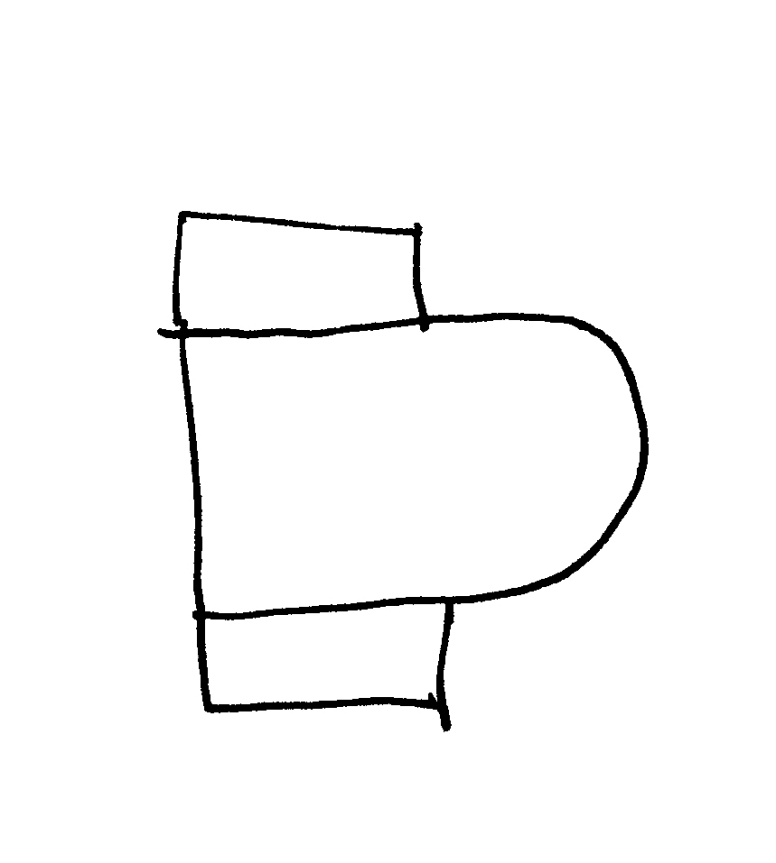
Express gravitational force

- Moldings express the effects of gravity by appropriate horizontal articulations
- Mimic the effects of squeezing materials through weight
- Moldings are NOT decorative, but directly enhance human wellbeing
- Opposite aim from Le Corbusier's deliberate "anti-gravity" typologies

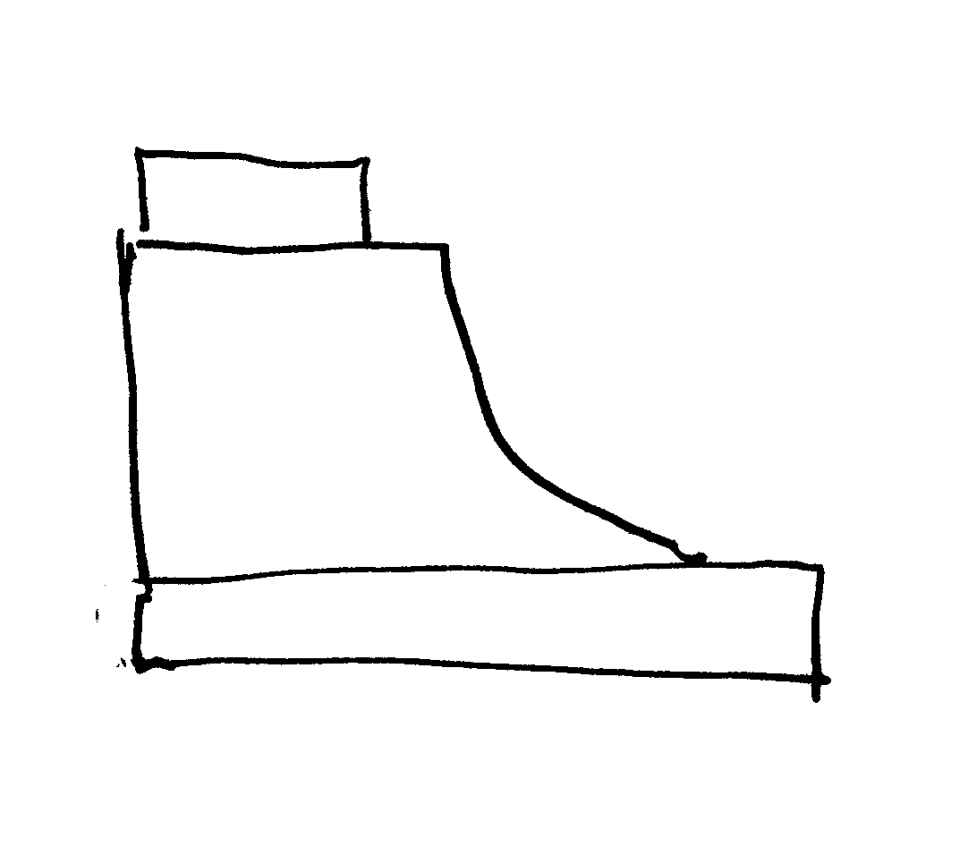
Molding for top



Molding for middle



Molding for bottom



Variety of moldings

- Actually, within the three categories of moldings for top, middle, and bottom, there are further internal variations
- Classical architecture uses all of these to achieve solidity and balance
- Classical architecture also satisfies universal scaling through moldings

Combinatorics for moldings

- Language of moldings is already part of the Classical design vocabulary
- *ALTERNATION, CONTRAST, SCALE, REPETITION, COORDINATION, PROPORTION, REDUCTION, etc.*
- Compare with Alexander's observed 15 fundamental properties (*lecture* 6)

Universality and adaptation

- The Classical form language is one of the most successful ever discovered
- It has evolved its own version of mathematical coherence
- This is why the Classical language has been so useful, and for so long
- It is also extremely adaptive!

World architecture

- Every place has evolved its traditional form language (not Classical)
- During many centuries, the Classical language was applied around the world
- Buildings adapted to include elements from the local form language
- Dismissed as “hybrid” by modernists!

Classical adaptations

- From the Greeks and Romans, to the European colonial powers, buildings have adapted to the local vernacular
- Extremely successful “colonial” buildings, now totally ignored by architectural historians
- Among the most loved older examples!

Emphasis on the smallest scale

- Classical moldings are an essential component of this form language
- They help to establish the smallest scale, by focusing on it directly
- According to our theory of design coherence, the smallest scale supports all the higher-order forms

New approach to design

- We take Donald Rattner at his word: *use moldings as atomic units of design*
- Design a project by starting with the most appropriate moldings
- Then connect the moldings with plane surfaces (wall, ceiling, floor)
- Bottom-up process of design

Duality between units and connections

- Which are the tectonic units, and which are the connections?
- Theory of centers tells us there is no distinction — we have a duality:
- 1. MOLDINGS CONNECT PLANES
- 2. PLANES CONNECT MOLDINGS

Support from the fundamental structure of matter

- The duality between units and their connecting “glue” has a precedent
- The same phenomenon occurs in elementary particle physics
- Basic units of the physical universe
- Physics supports our theory of design!

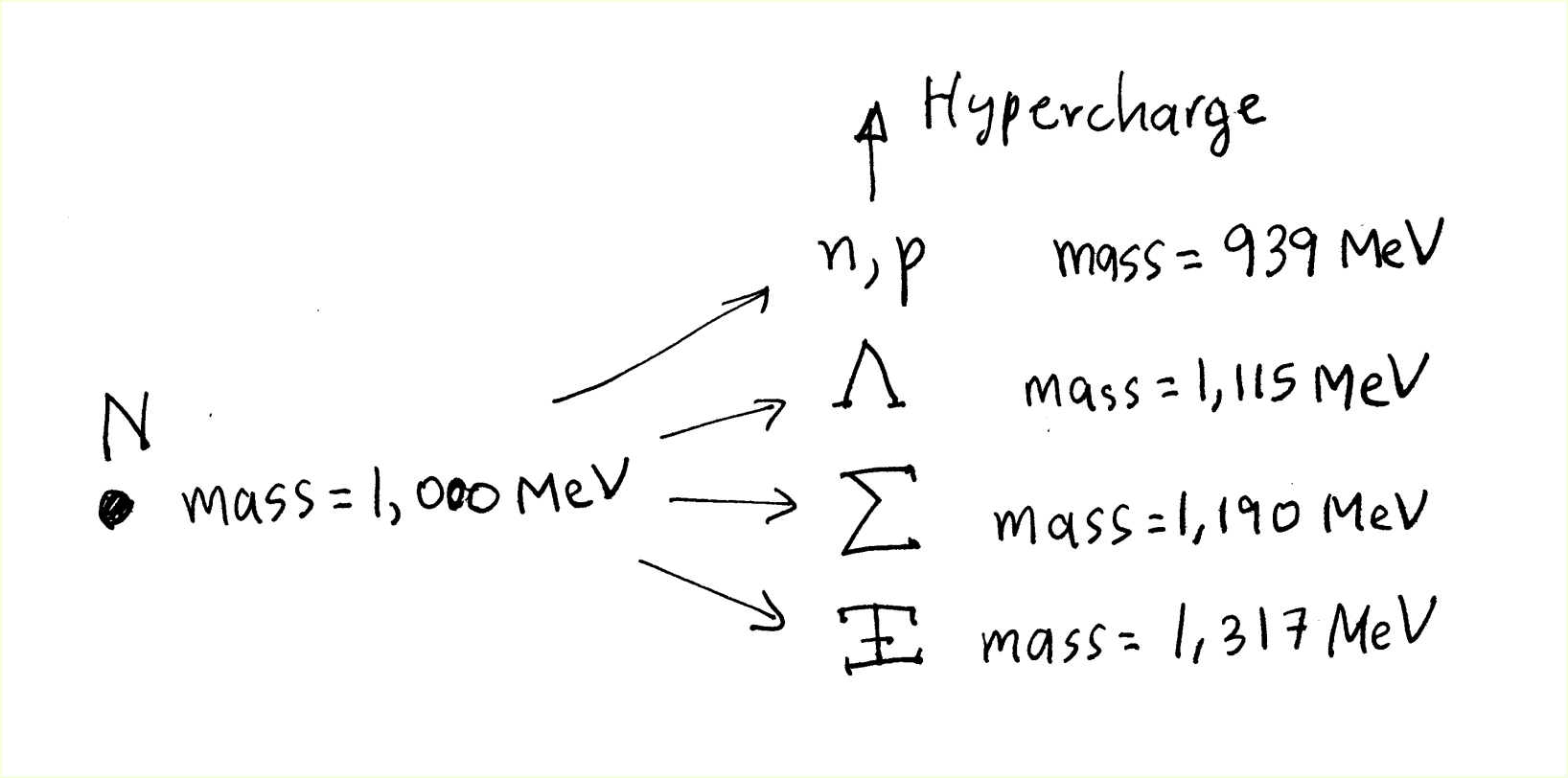
D. Elementary particle symmetries

- Analogy from fundamental physics
- Elementary particle interactions are symmetric under the group SU(3) (analogous to rotational invariance in a space of internal dimensions)
- But symmetry breaking also occurs in elementary particle symmetries

Degenerate nucleon

- With perfect hypercharge symmetry, there is only one nucleon (*neutron* and *proton* comprise the atomic nucleus)
- But that would mean no atoms!
- Spontaneously broken hypercharge symmetry creates different particles:
- N nucleon, Σ particle, Λ particle, Ξ particle, each with different mass

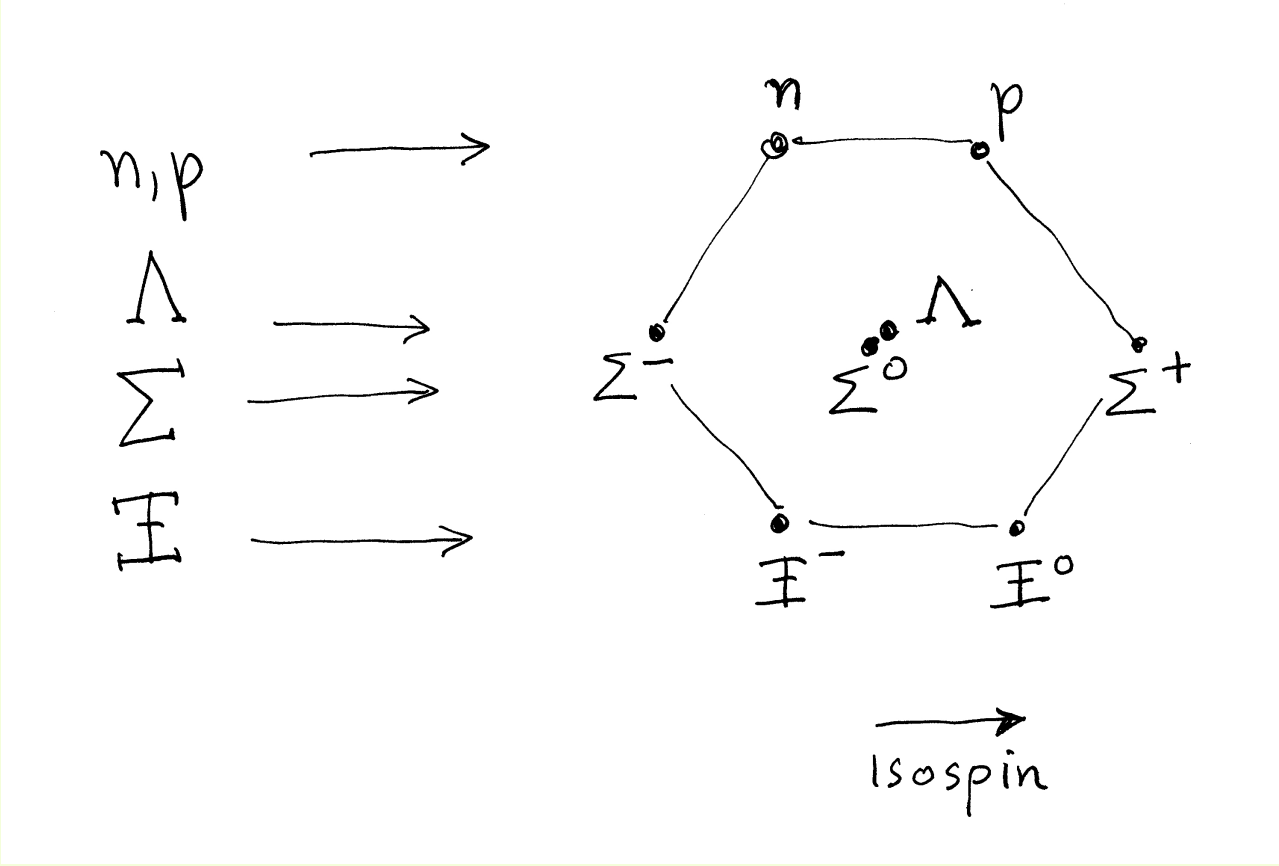
Breaking hypercharge symmetry



Electromagnetic symmetry breaking

- There is a further breaking of the symmetry along the isospin axis
- Creates particles with different charge
- N separates into ***n*** (neutral) and ***p*** (+)
- Σ separates into Σ^-, Σ^0 and Σ^+
- Ξ separates into Ξ^- and Ξ^0

Breaking isospin symmetry



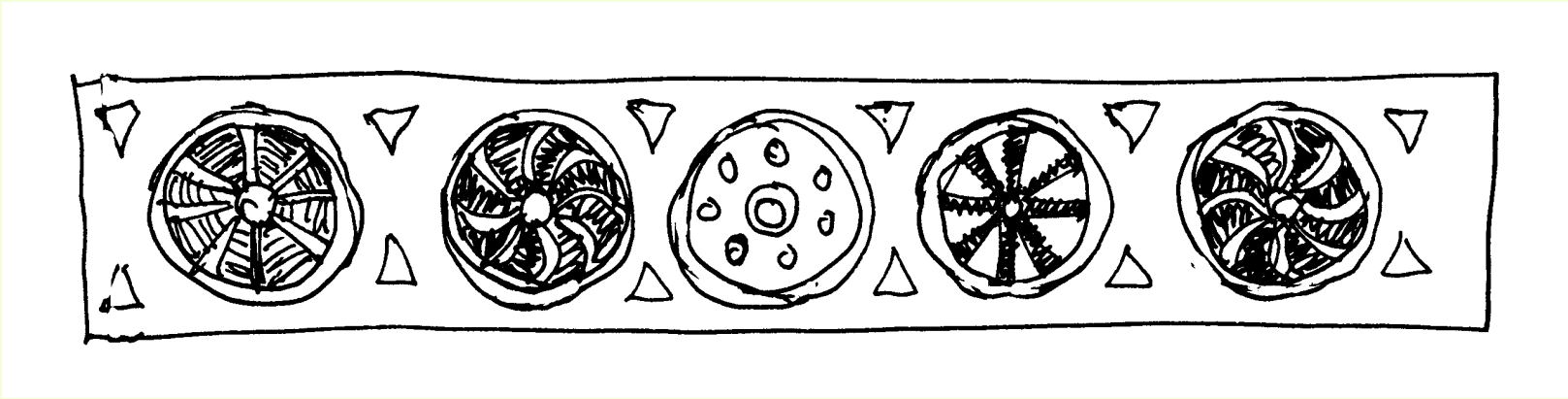
Summary of these results

- Fundamental constituents of matter have strong but approximate symmetry
- Small symmetry breaking is necessary to generate mass and charge
- ***Mass is responsible for matter!***
- ***Charge is responsible for atoms!***

Analogy and implications for design

- Strong but imperfect symmetries give rise to living structure
- Observed symmetry breaking has a remarkable parallel in broken elementary particle symmetries
- Local rotational symmetry on the small scales, imperfect on the large scale

Broken large-scale translational symmetry containing perfect small-scale rotational symmetries



Large-scale versus small-scale symmetries

- Analogy with fundamental physics
- Imperfect large-scale symmetries, but essential symmetries on the smallest scales — in internal dimensions
- *Something fundamental is happening on the small scale, also in architecture and urbanism*

E. Binding energy

- Well-known conversion relation between mass and energy
- $E = mc^2$ (where c is the speed of light)
- Derived by Albert Einstein
- Energy is needed to bind components of mass together into larger wholes

Combine subatomic constituents

- Constituents will not bind together without extra binding energy, but will forever remain as separate units
- Binding energy is the “glue” of matter
- Mass of the whole equals mass of constituents plus the binding energy

Some basic physical bound states (in decreasing size)

- Atoms bind together to form molecules
- Nuclei and electrons bind together to form atoms
- Nucleons (***n*** and ***p***) bind together to form the atomic nucleus
- Quarks bind together to form nucleons (*neutron, proton*, other octet members)

Amount of binding energy

- How much binding energy is required to bind masses together into a larger coherent whole?
- It depends on the size of the whole!
- As we go down in scale, the binding energy *becomes as large as the mass*

Binding energy as percentage of total mass of composite unit

- *Atoms made from nuclei and electrons: ratio is* 5eV/0.5MeV = 10^{-5} = 0.001%
- *Nuclei made from nucleons: ratio is* 8MeV/940MeV = 10^{-2} = 1%
- *Nucleons made from quarks: ratio is* 1GeV/1GeV = 1 = 100%

Binding energy in architecture

- In physics, binding energy becomes matter on the lowest scale
- In architecture, the smallest perceivable scale is ornamental
- Here, the binding energy becomes the design itself
- *Ornament becomes substance*

Analogy with architecture

- Perceivable quality of ***substance*** in architecture is analogous to the mass in physical matter
- Positive ***substance*** anchors a building in our cognition, making it possible for us to connect to that structure
- Achieved by combining different tectonic components into a whole

“Glue” becomes substance

- In architecture and urbanism, the strongest binding energy acts on the smallest perceivable scale to humans
- Tectonic components are held together in our mind by connections, symmetries, and symmetry breaking
- At the smallest scale, the binding glue itself becomes the substance!

The necessity for ornament

- Binding on the smallest scale is essential for coherence and sense of substance in any building, of any shape or size
- At the level of ornamentation, the connections become the object itself
- *All larger scales are dependent upon the smallest scale — ornamentation*

Precision is not ornament!

- Modernist buildings sometimes have a precision on the smallest scale
- Precise alignment of straight edges
- But precise edges do not generate any coupling or binding energy!
- No small units; no coupling; no binding energy — form is dead

Ornament is often imprecise

- Ornament often requires imprecision
- “Roughness” property of Alexander
- This is not a celebration of sloppiness, but an intrinsic phenomenon
- Paying attention to the binding energy does not permit us the luxury of being concerned with useless precision

Conclusion: architectural life depends upon ornament

- Living quality of structure and form comes from binding energy
- Ultimately depends strongly upon lowest scale — that of ornament
- Architecture = form + ornament
- ***Ornament becomes substance***