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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 SYMMETRICAL
- 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
- \textit{ALTERNATION, CONTRAST, SCALE, REPETITION, COORDINATION, PROPORTION, REDUCTION, etc.}
- Compare with Alexander’s observed 15 fundamental properties (\textit{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, $\Sigma$ particle, $\Lambda$ particle, $\Xi$ particle, each with different mass
Breaking hypercharge symmetry

\[ N \text{ mass} = 1,000 \text{ MeV} \]

\[ \Lambda \text{ mass} = 1,115 \text{ MeV} \]

\[ \Sigma \text{ mass} = 1,190 \text{ MeV} \]

\[ \Xi \text{ mass} = 1,317 \text{ MeV} \]
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 $p$ ($+$)
- $\Sigma$ separates into $\Sigma^-$, $\Sigma^0$, and $\Sigma^+$
- $\Xi$ separates into $\Xi^-$ and $\Xi^0$
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 $5\text{eV}/0.5\text{MeV} = 10^{-5} = 0.001\%$
- **Nuclei made from nucleons:** ratio is $8\text{MeV}/940\text{MeV} = 10^{-2} = 1\%$
- **Nucleons made from quarks:** ratio is $1\text{GeV}/1\text{GeV} = 1 = 100\%$
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