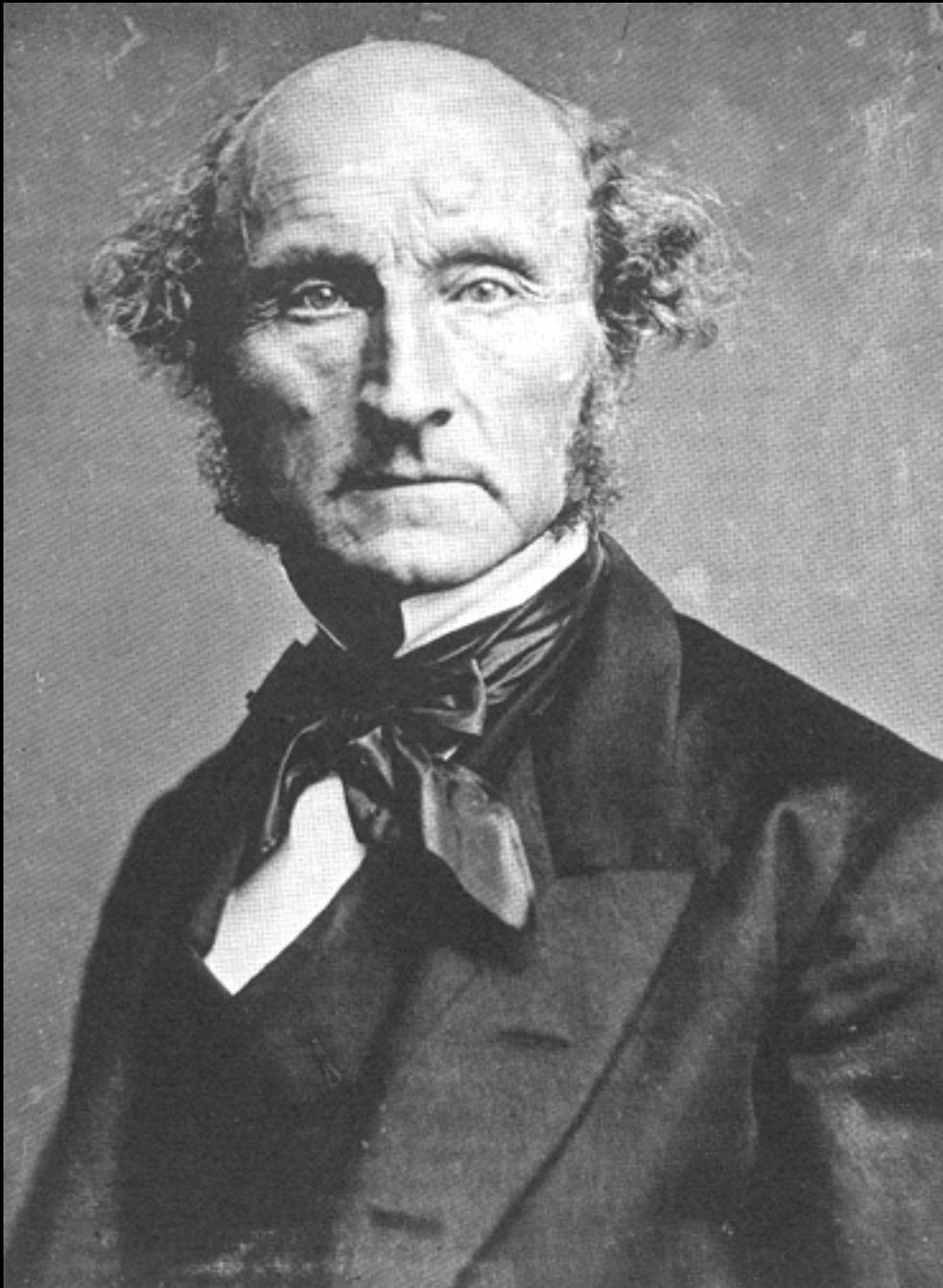# emergence and predictability

John Stuart Mill

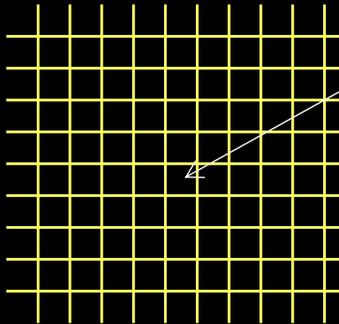**emergence**

nonadditive

novelty

hierarchical

complexity

unpredictable (sometimes)

cellular automaton

space

cell
is in some *state*
depending on its
neighborhood

time

time 0 → time 1 → time 2 → time 3 → . . . .

laws

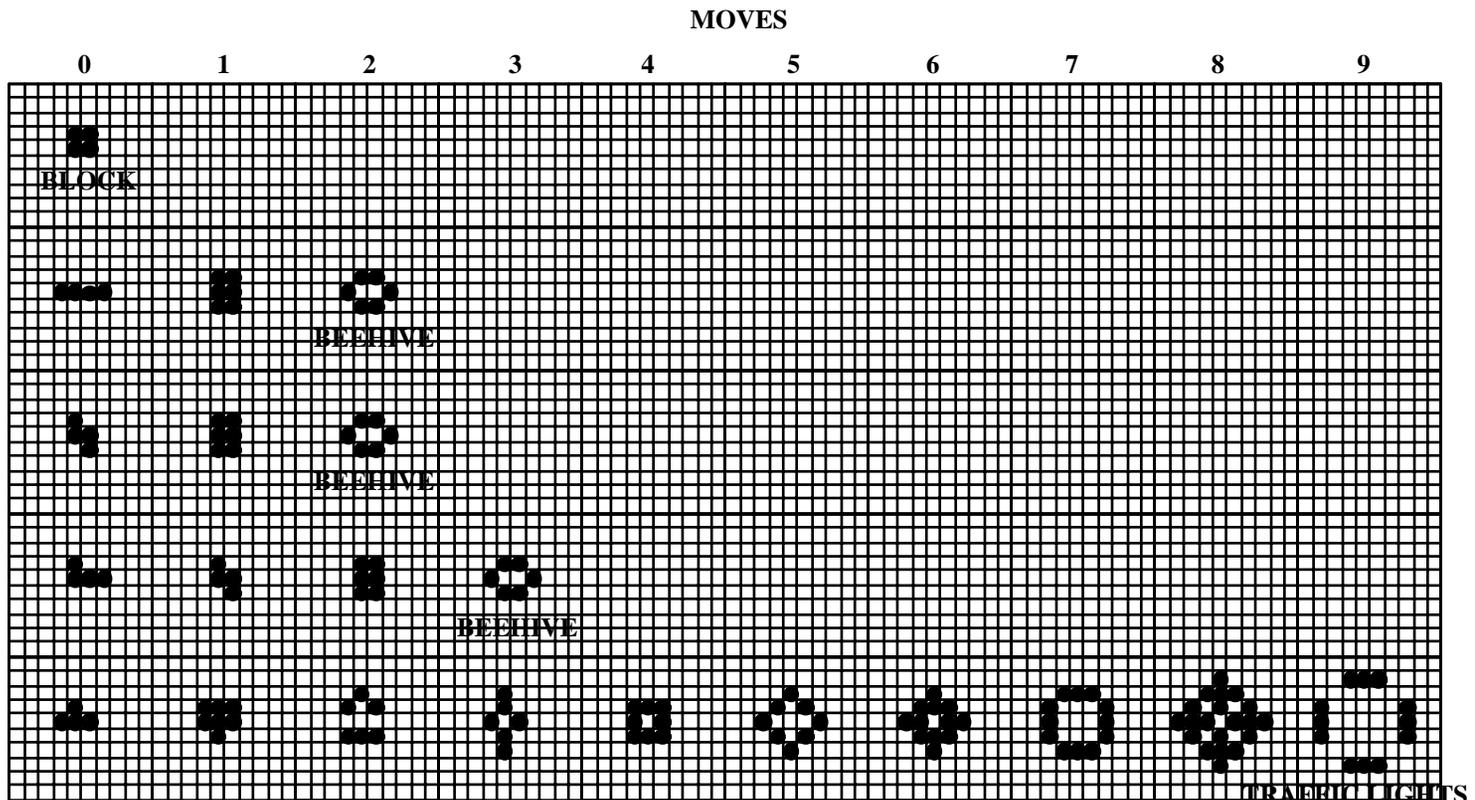apply simultaneously (in parallel) to all cells in the space

Game of Life

Survival: If a live cell has two or three neighbors, it survives.

Death: If a live cell has four or more neighbors, it dies from overcrowding.

           If a live cell has one or no neighbors, it dies from isolation.

Birth: If an unoccupied cell has exactly three neighbors, it becomes alive.

MOVES

THE LIFE HISTORIES OF THE FIVE TETROMINOES

emergence in shape grammars
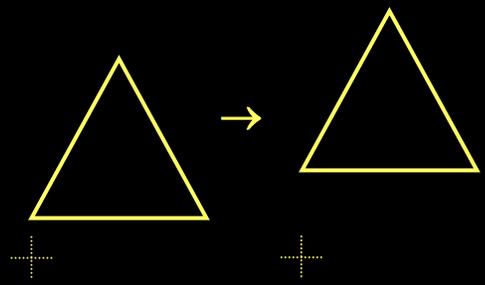
emergent shapes

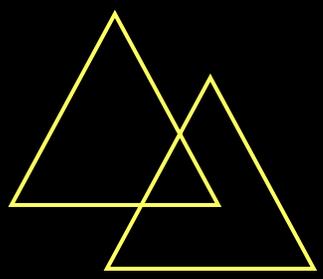**emergence in shape grammars**

nonadditive
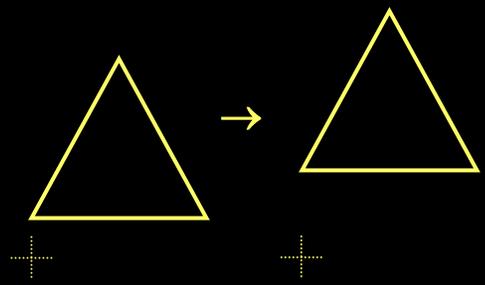
novelty

~~hierarchical~~
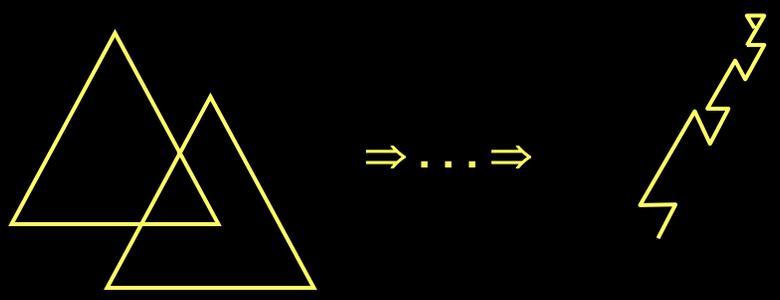
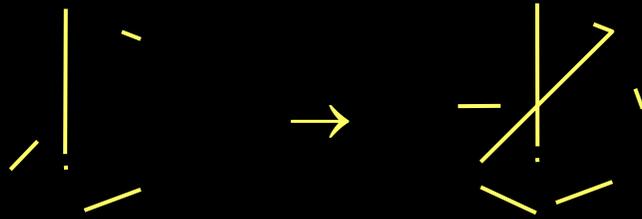~~complexity~~

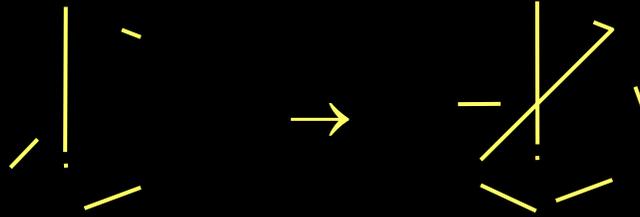unpredictable (sometimes)
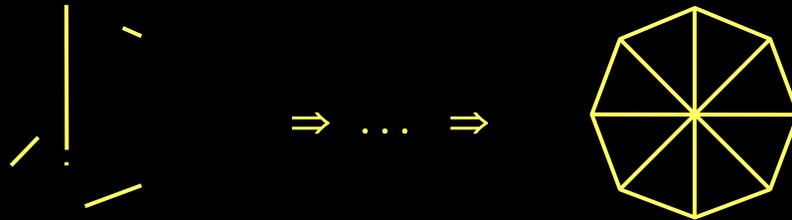
shape rule

initial shape

shape rule

result of applying the rule

shape rule

initial shape

shape rule

result of applying the rule

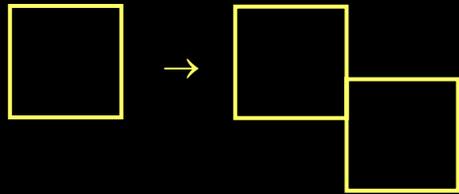**emergence in shape grammars**

nonadditive

novelty
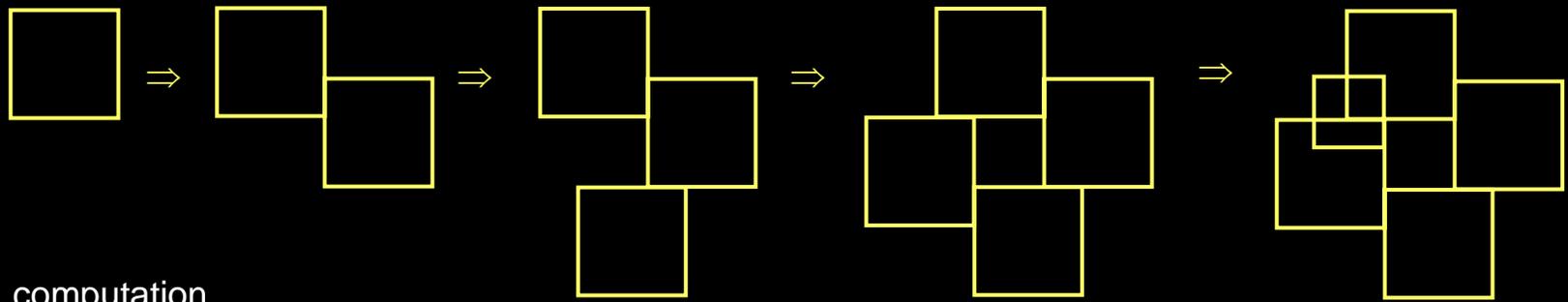
~~hierarchical~~

~~complexity~~
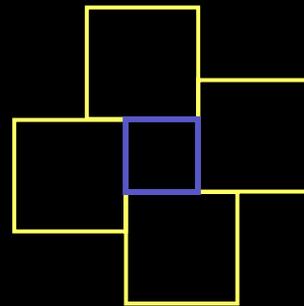
unpredictable (sometimes)

active
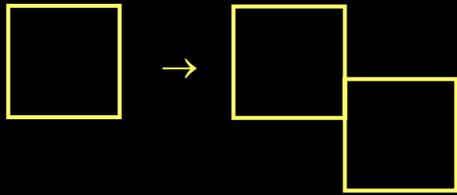
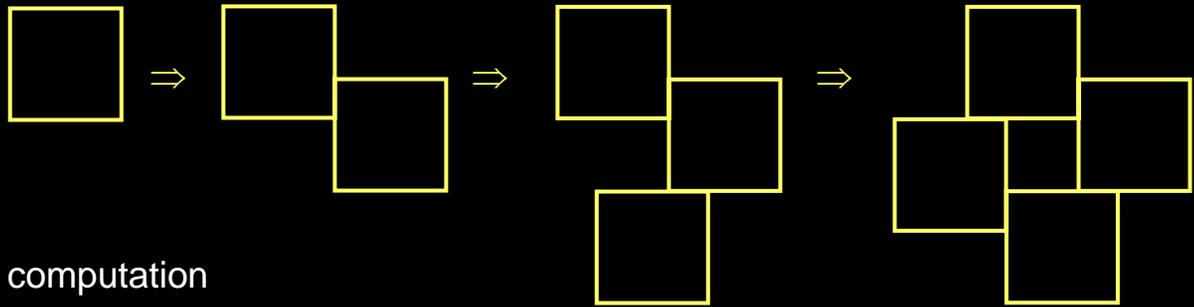# active emergence

shape rule

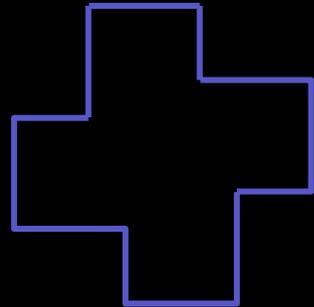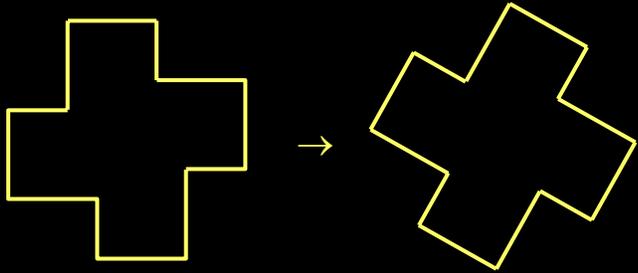computation

emergent courtyard

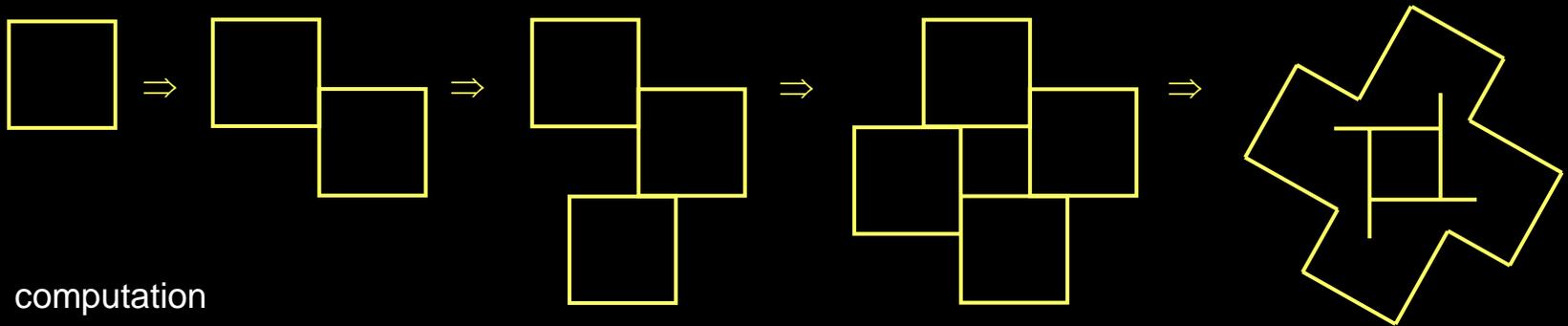# active emergence

shape rule

computation

emergent boundary

active emergence

new rule

computation

emergence in shape grammars

nonadditive

novelty

~~hierarchical~~

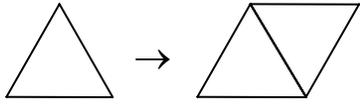~~complexity~~

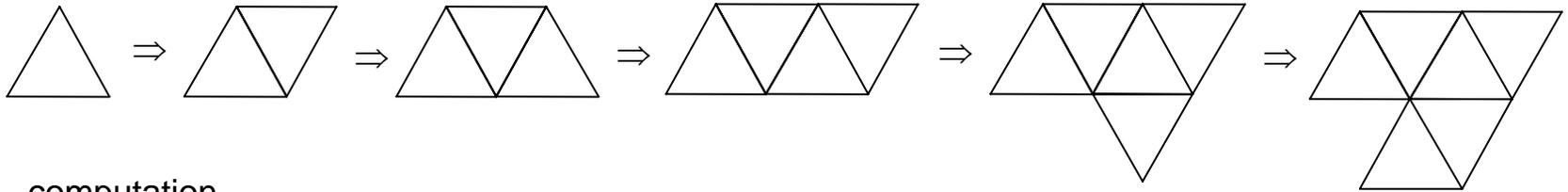unpredictable (sometimes)

active

levels of emergence

anticipated

$\downarrow$

unanticipated

anticipated emergence

rule

computation

villa zeno

villa santa monica

villa sarraceno

villa sepulveda

villa badoer

villa vine
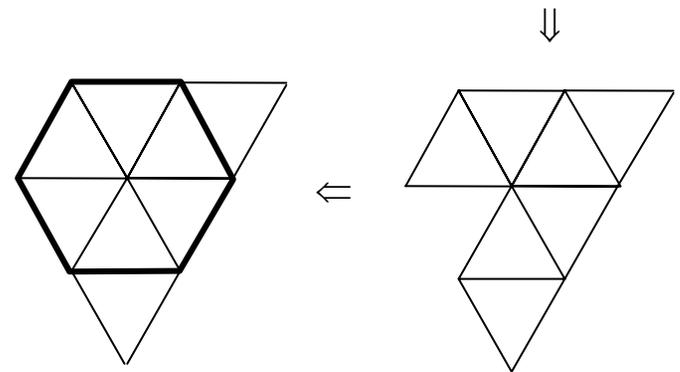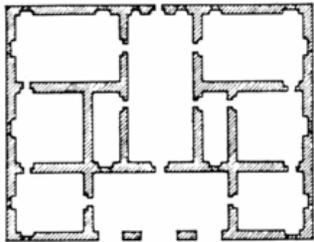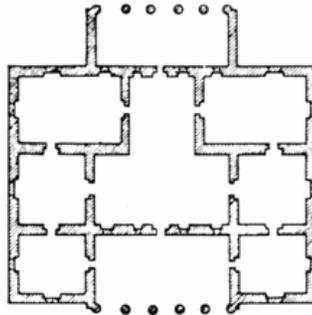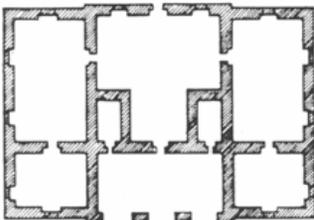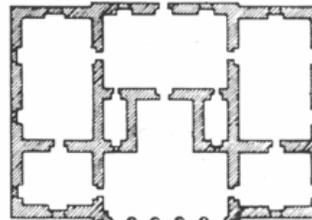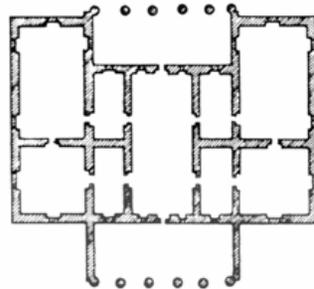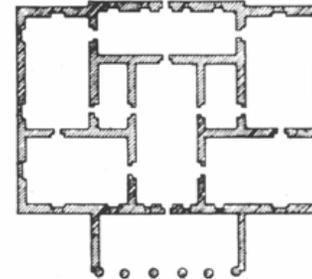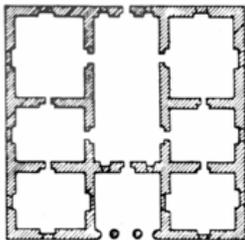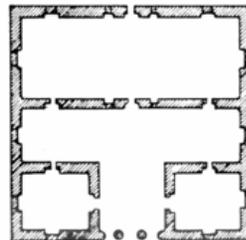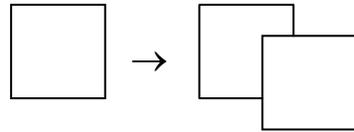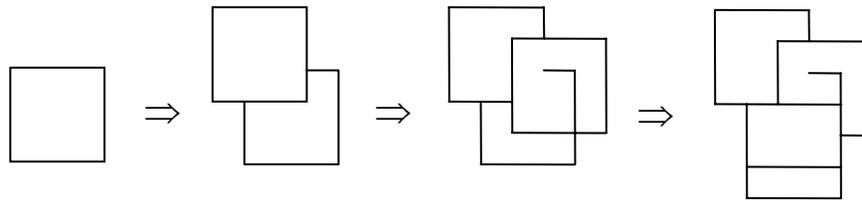
villa angarano

villa hollywood

Palladian villas
(Stiny and Mitchell, 1978)

unanticipated emergence

rule

computation
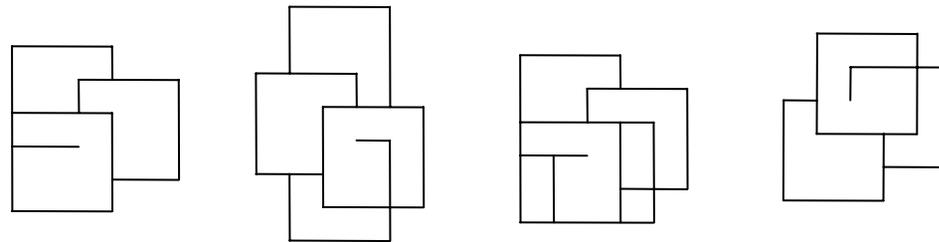
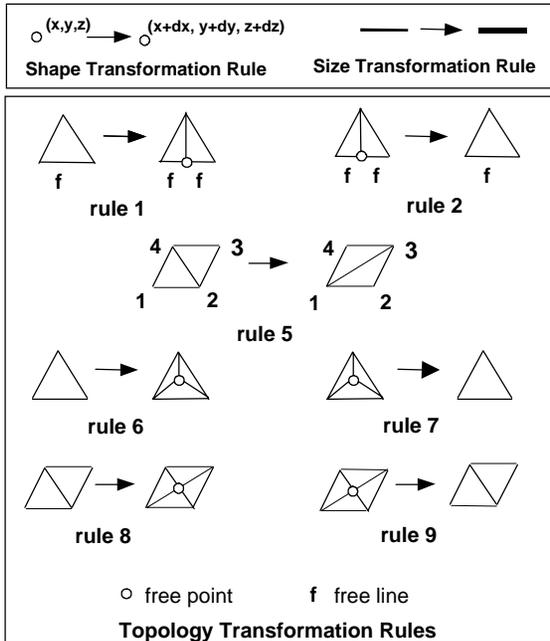other design possibilities

unpredictability

unpredictability $\longleftrightarrow$ **emergence**

indirect

generate and test

direct

define smart rules

(x,y,z) → **(x+dx, y+dy, z+dz)**

Shape Transformation Rule   **Size Transformation Rule**

f   f f   **rule 1**

f f   f   **rule 2**

4 3 → 4 3
1 2   1 2
rule 5

rule 6   **rule 7**

rule 8   **rule 9**

○ free point   **f** free line

Topology Transformation Rules

Specifications (Syntax)	Constraints (Semantics)
• material properties	• stress
• number of supports and locations	• Euler buckling
• symmetry	• displacement
• joint angles	• geometric obstacles

Objectives (Semantics)

• efficiency
  minimum mass
• economy
  minimum number of distinct cross-sections
  minimum number of distinct lengths
• utility
  maximum enclosure space
  minimum surface area

• aesthetics
  uniformity metric = $\sigma(\text{member lengths})^1$
  golden ratio metric =

$$\sum_{numshapes} \left| -\frac{b}{a} \right| + \left| -\frac{b}{c} \right| + \left| -\frac{a}{b} \right| 2$$

rules

objectives

EifForm
grammar + optimization
(Shea, 1997)

indirect

generate and test

direct

define smart rules

hierarchy of shape grammars
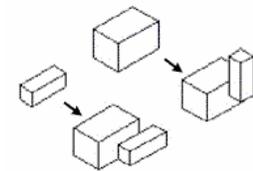
basic grammars

nondeterministic basic grammars

additive grammars

unrestricted grammars

apartment house complex (Murat Sanal)

underlying shape rules