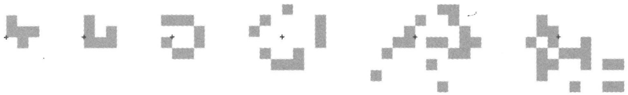
Cellular automaton



In 1970, John Horton Conway devised the Game of Life, a zero-player game. It is an evolutionary process that depends only on its initial state with no further input from humans. The universe of the game is an unlimited orthogonal grid of square cells, each of which can exhibit one of two possible states at any time: dead or alive. Each cell interacts with its eight vertically, horizontally and diagonally neighbouring cells. The rules are as follows:

- Any live cell with fewer than two live neighbours dies, as if caused by under-population.
- Any live cell with more than three live neighbours dies, as if by overcrowding.
- Any live cell with two or three live neighbours lives, unchanged, to the next generation.
- Any tile with exactly three live neighbours cells will be populated with a living cell.

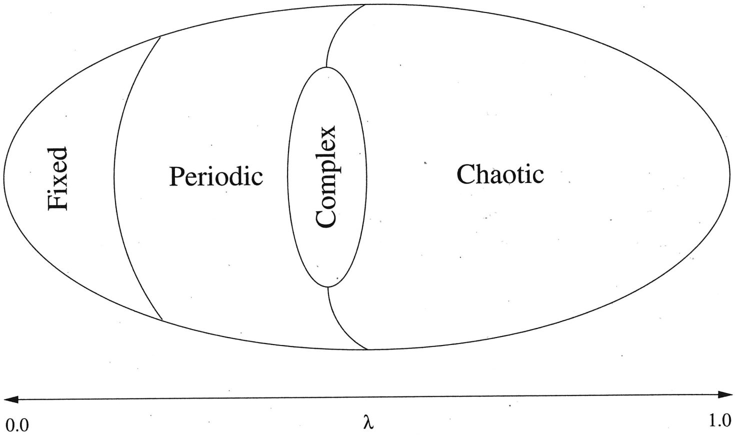


Figure 15.9 Langton's schematic representation of CA rule space characterized by the λ parameter

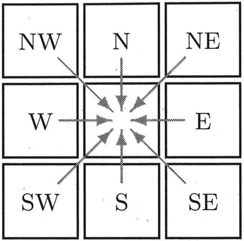


Figure 15.10 The neighborhood of Conway's Game of Life

- If a live cell has less than two neighbors, then it dies (loneliness).
- If a live cell has more than three neighbors, then it dies (overcrowding).
- If an empty cell has three live neighbors, then it comes to life (reproduction).
- Otherwise (exactly two live neighbors), a cell stays as is (stasis).

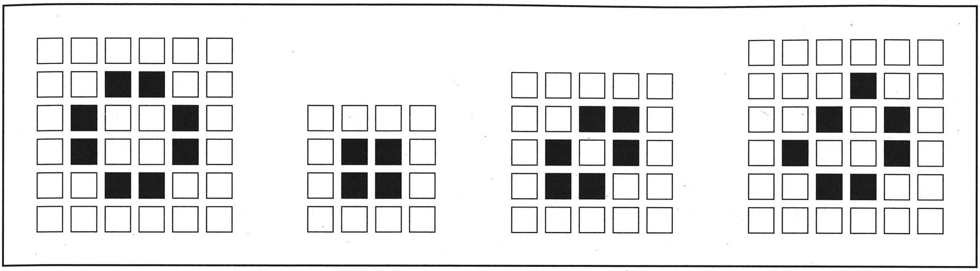


Figure 15.11 Examples of static objects in Conway's Game of Life

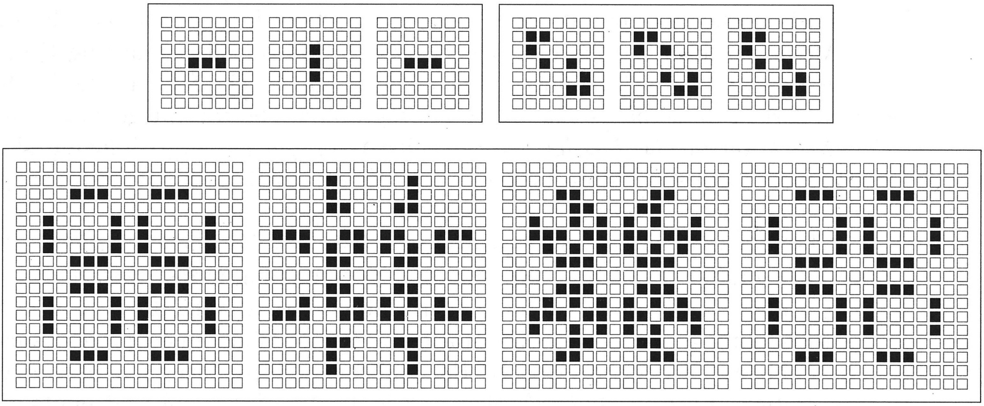


Figure 15.12 Examples of simple periodic objects in Conway's Game of Life

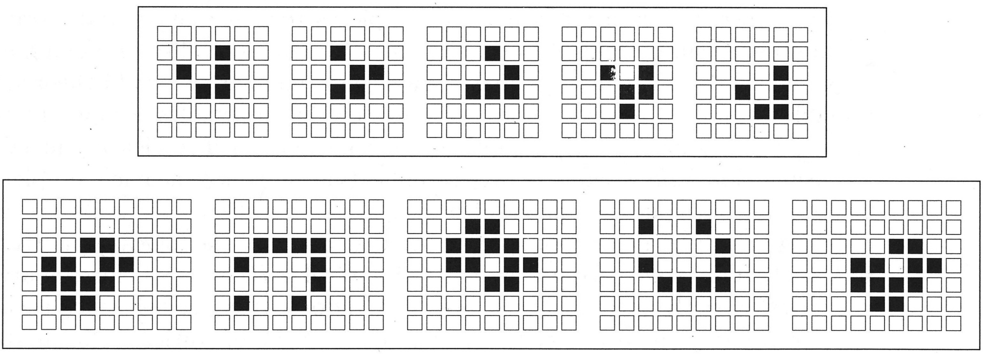
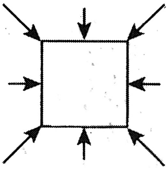


Figure 15.13 Examples of moving objects in Conway's Game of Life

Basic mechanism for Conway's automaton:



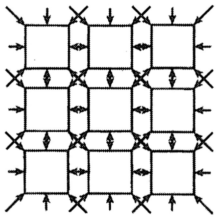
8 inputs, 2 states {1, 0}

Transition function:

If the state is 0 and exactly three neighbors are in state 1, then the state becomes 1; otherwise it remains 0.

If the state is 1, and either two or three neighbors are in state 1, then the state remains; otherwise it becomes 0.

Basic mechanism connected to its immediate neighbors:



One-step transitions for some simple state patterns:

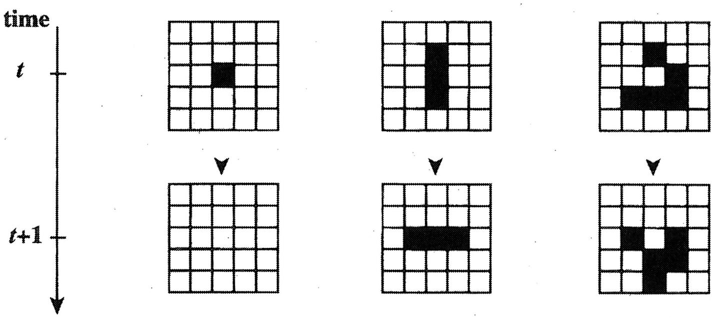


Figure 3. Conway's automaton. Reprinted by permissions of Basic Books, a member of the Perseus Books Group, and John Holland. © Brockman/Holland.

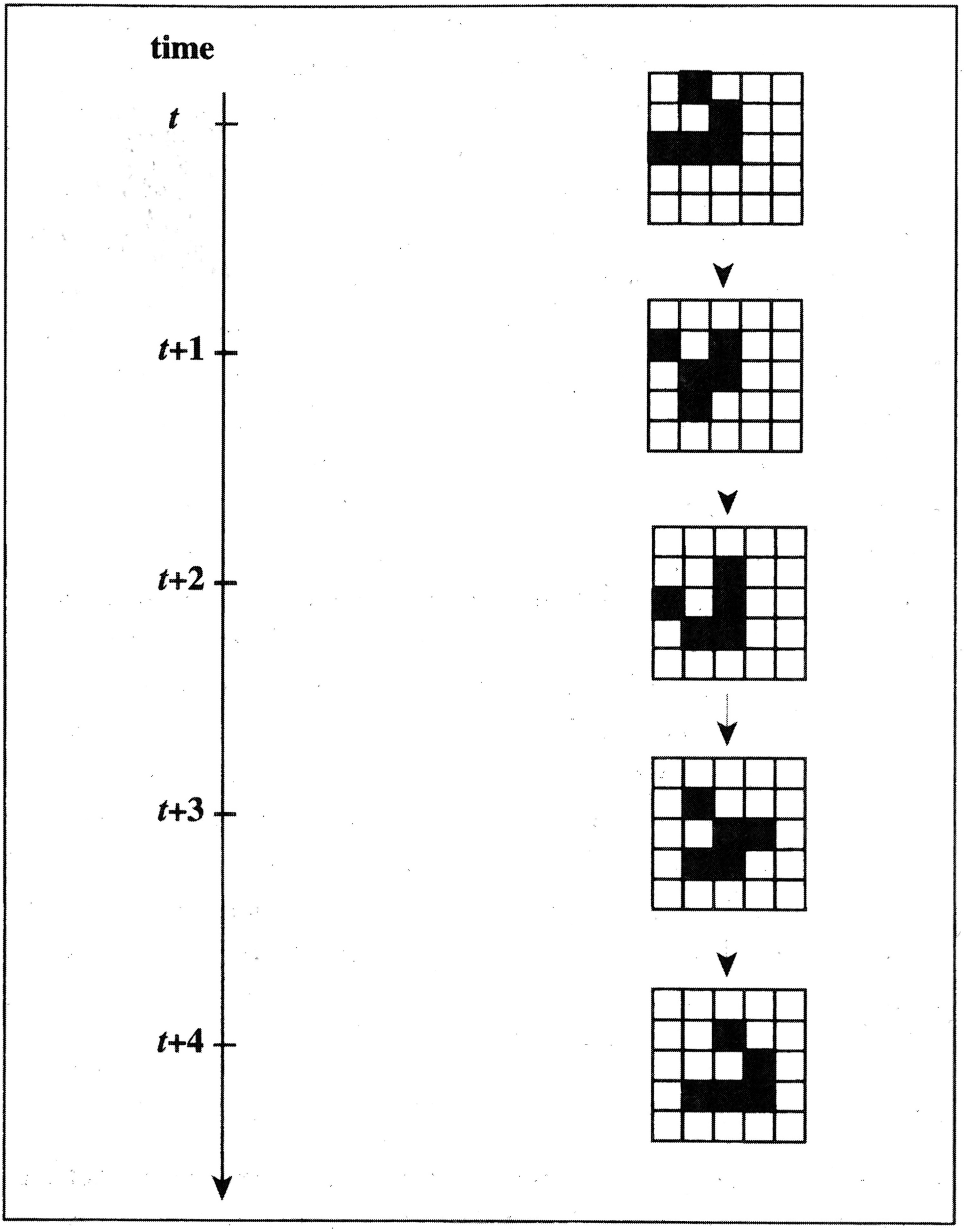
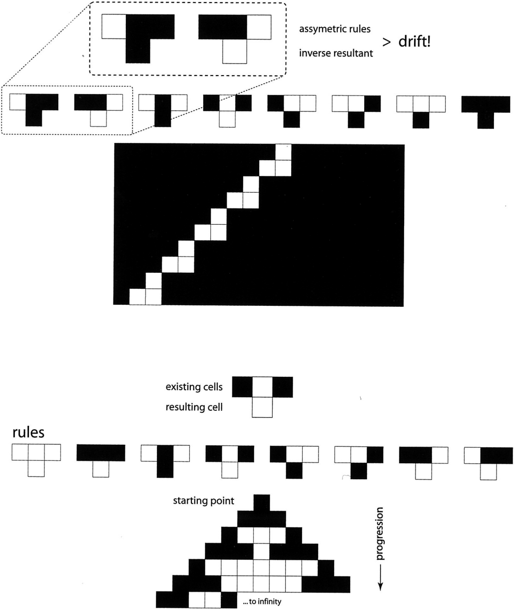
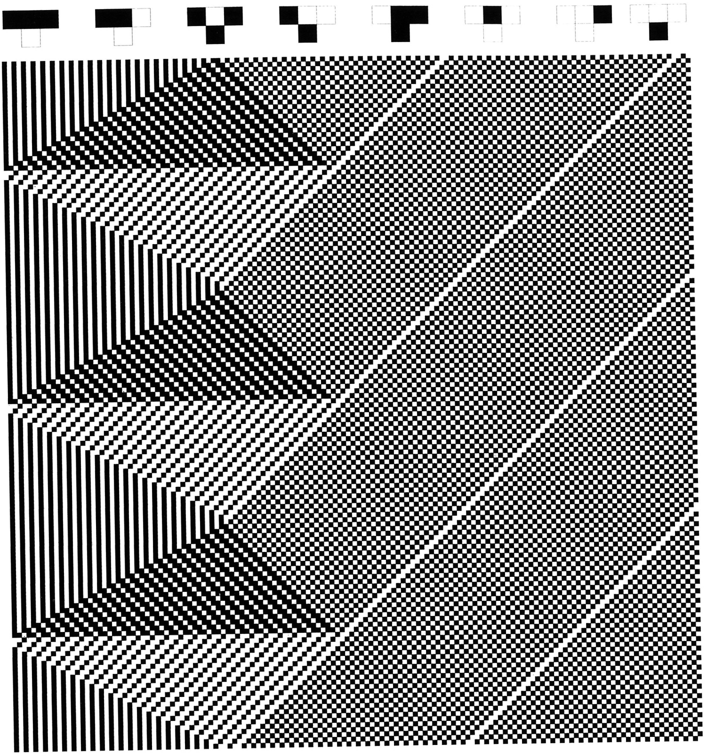
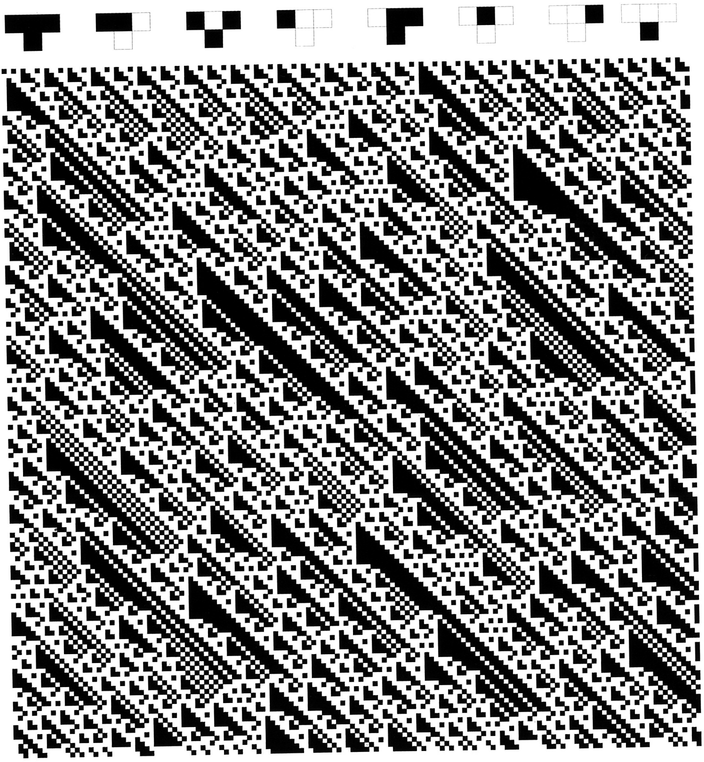


Figure 4. Successive transitions of the glider state pattern in Conway's automaton. Reprinted by permissions of Basic Books, a member of the Perseus Books Group, and John Holland. © Brockman/Holland.

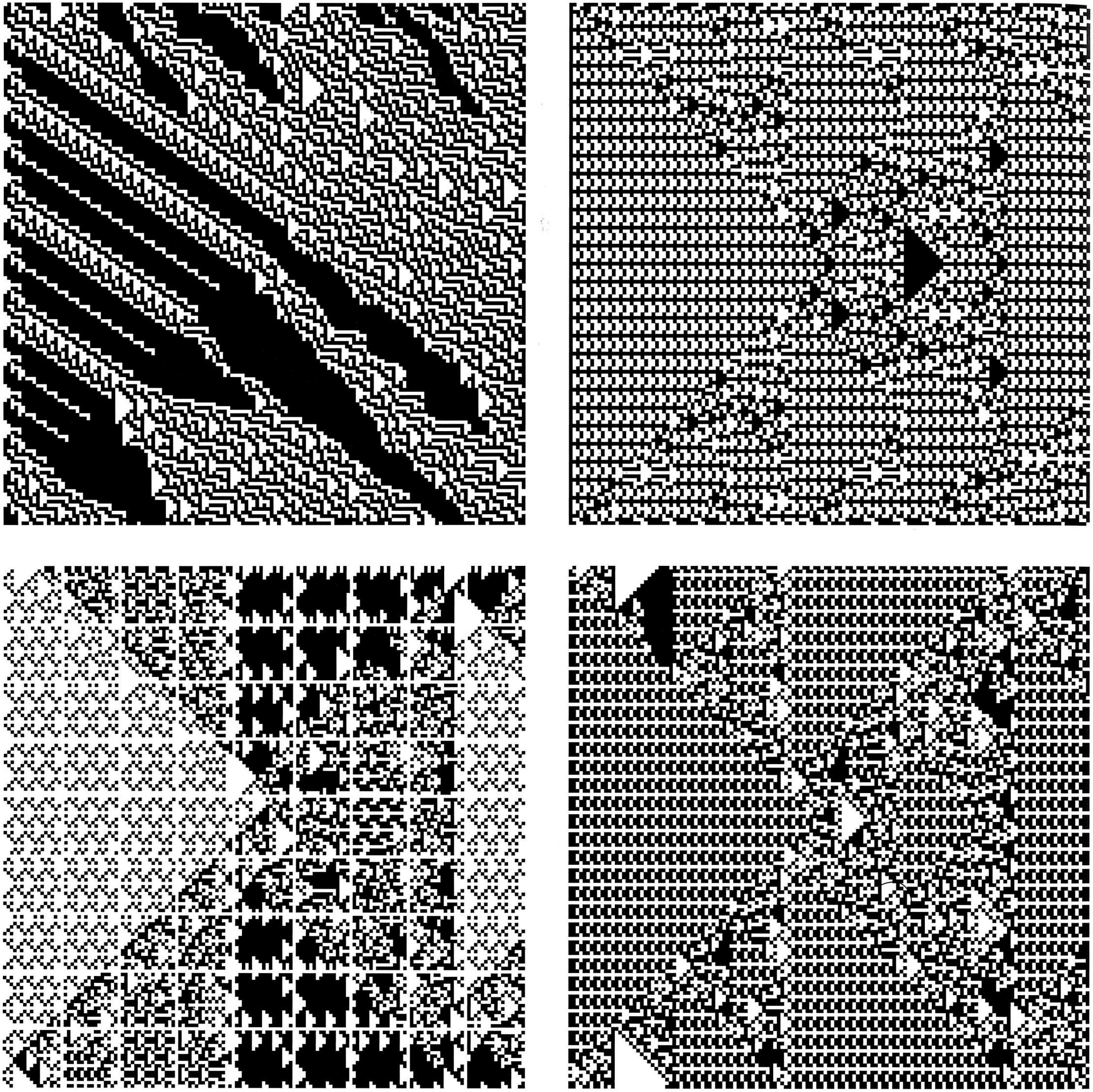


1.43. Locating drift *in a CA rule-set. Characteristics such as drift, asymmetry and striping are mined alongside a simple manipulation of the starting and resultant arrangements of cells and corresponding rules.*

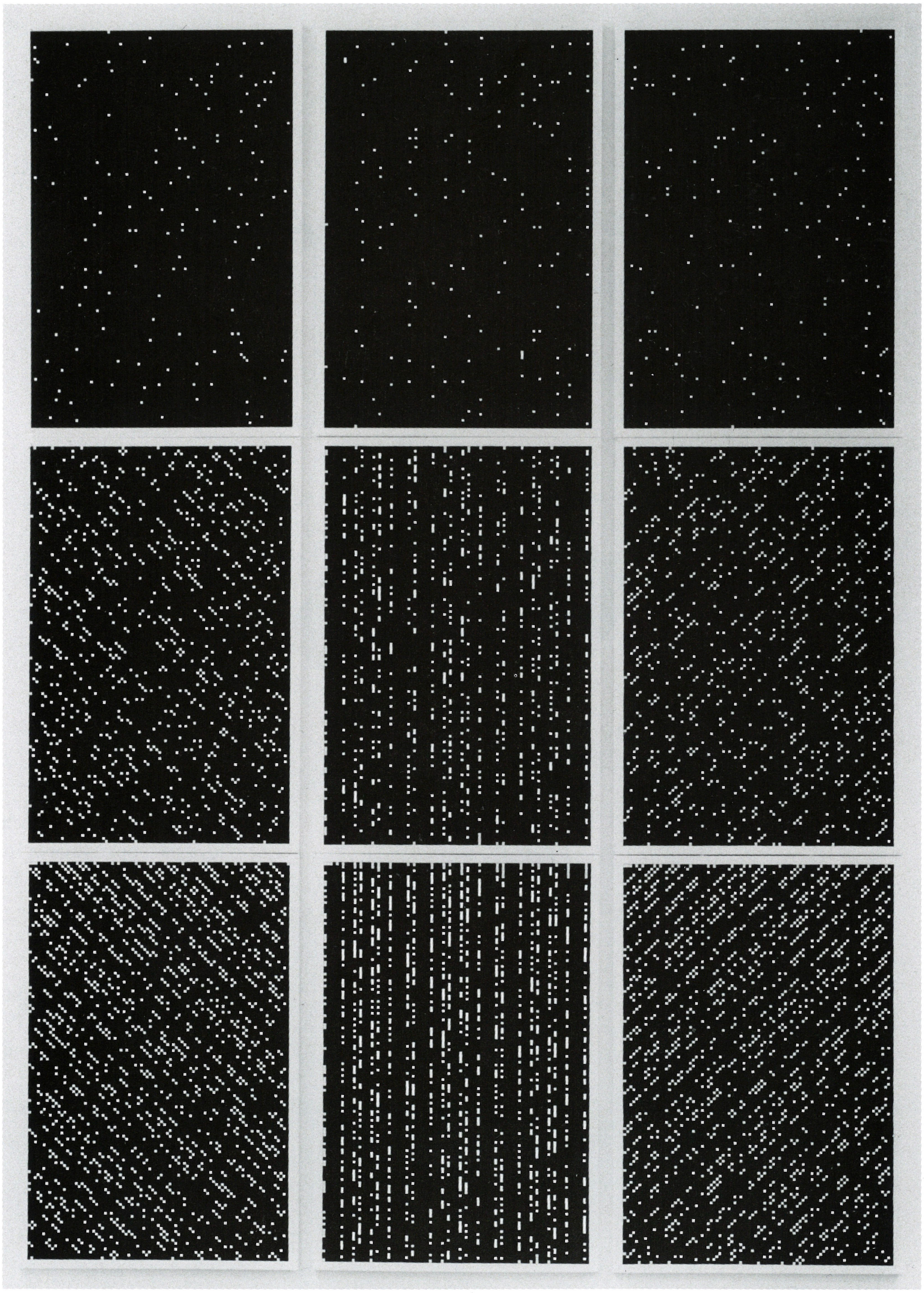




1.44



1.45. Production of draft notations. This set of weaving designs, generated by cellular automata simulations, were eventually woven on a digitized Jacquard Loom.



1-24. Rune Mields (German, b. 1935), *The Sieve of Eratosthenes*, 1971. Ink on linen. Courtesy of the artist and the Galerie Angelika Harthan, Stuttgart. © 2014 VG Bild-Kunst, Bonn/Artists Rights Society, New York.

In the Greek city of Alexandria in the third century BC, Eratosthenes of Cyrene, who was director of the city's great classical library, taught a method for finding prime numbers. Beginning with the first whole number greater than 1, circle 2 and cross out every second number after 2. Circle 3 and cross out every third number after 3. Skip 4 because it is already crossed out (which means it is composite), circle 5, and cross out every fifth number after 5. Continue in this way; the procedure is a tool—a sieve—for separating circled prime numbers from crossed-out composites. For another of Eratosthenes's discoveries, see the sidebar on page 29.

Since antiquity, mathematicians have observed patterns in the prime numbers. If we arrange the whole numbers in rows of ten (as in the diagram), then the primes form columns of circles between columns of crossed-out even numbers and multiples of 5. In the lower central panel of Mields's work, she began with 1,2,3, . . . and arranged the whole numbers in rows of 90, using white squares to symbolize prime numbers and black for composites. Since 90 is even, the prime numbers form vertical white bands. The lower-left panel has 89 to a row and the lower-right panel has 91, yielding slanted bands. The central panel in the middle row begins on a higher number, and the central top panel begins on an even higher number; both panels are similarly arranged in rows of multiples of 10. Together the array of nine panels visualizes the pattern of prime numbers (white squares), which occur less frequently as the whole numbers increase. Despite the observation of many patterns in the primes, an understanding of an *overall* pattern—the ability to predict the *next* prime number—had so far eluded mathematicians.

1	(2)	(3)	~~4~~	(5)	~~6~~	(7)	~~8~~	~~9~~	~~10~~
(11)	~~12~~	(13)	~~14~~	~~15~~	~~16~~	(17)	~~18~~	(19)	~~20~~
~~21~~	~~22~~	(23)	~~24~~	~~25~~	~~26~~	~~27~~	~~28~~	(29)	~~30~~
(31)	~~32~~	~~33~~	~~34~~	~~35~~	~~36~~	(37)	~~38~~	~~39~~	~~40~~
(41)	~~42~~	(43)	~~44~~	~~45~~	~~46~~	(47)	~~48~~	~~49~~	~~50~~
~~51~~	~~52~~	(53)	~~54~~	~~55~~	~~56~~	~~57~~	~~58~~	(59)	~~60~~
(61)	~~62~~	~~63~~	~~64~~	~~65~~	~~66~~	(67)	~~68~~	~~69~~	~~70~~
(71)	~~72~~	(73)	~~74~~	~~75~~	~~76~~	~~77~~	~~78~~	(79)	~~80~~
~~81~~	~~82~~	(83)	~~84~~	~~85~~	~~86~~	~~87~~	~~88~~	(89)	~~90~~
~~91~~	~~92~~	~~93~~	~~94~~	~~95~~	~~96~~	(97)	~~98~~	~~99~~	~~100~~

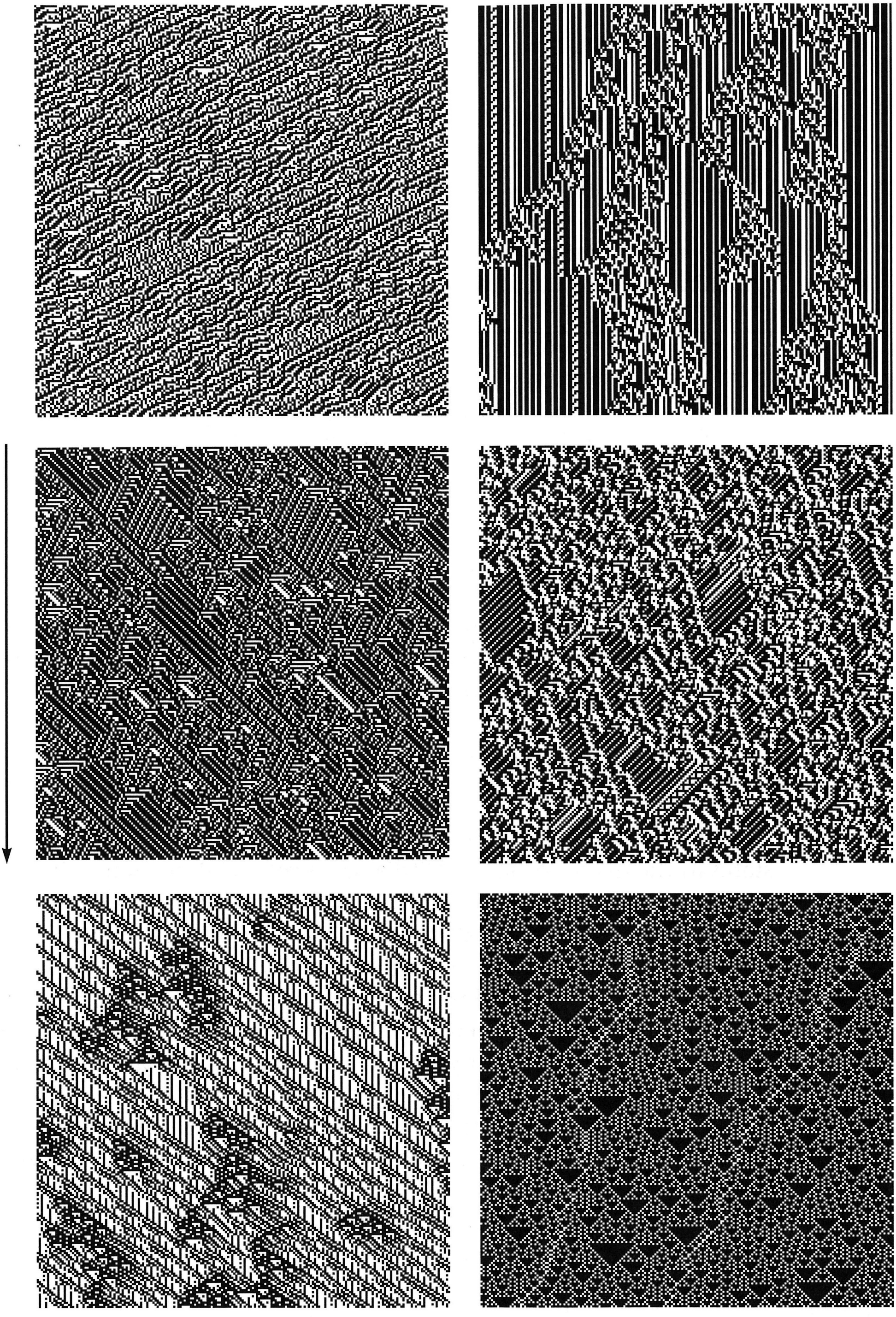


Figure 1.2 Some examples of one-dimensional binary cellular automata. Each row of pixels is determined by the states of the pixels in the row above it, as operated on by the particular set of rules.

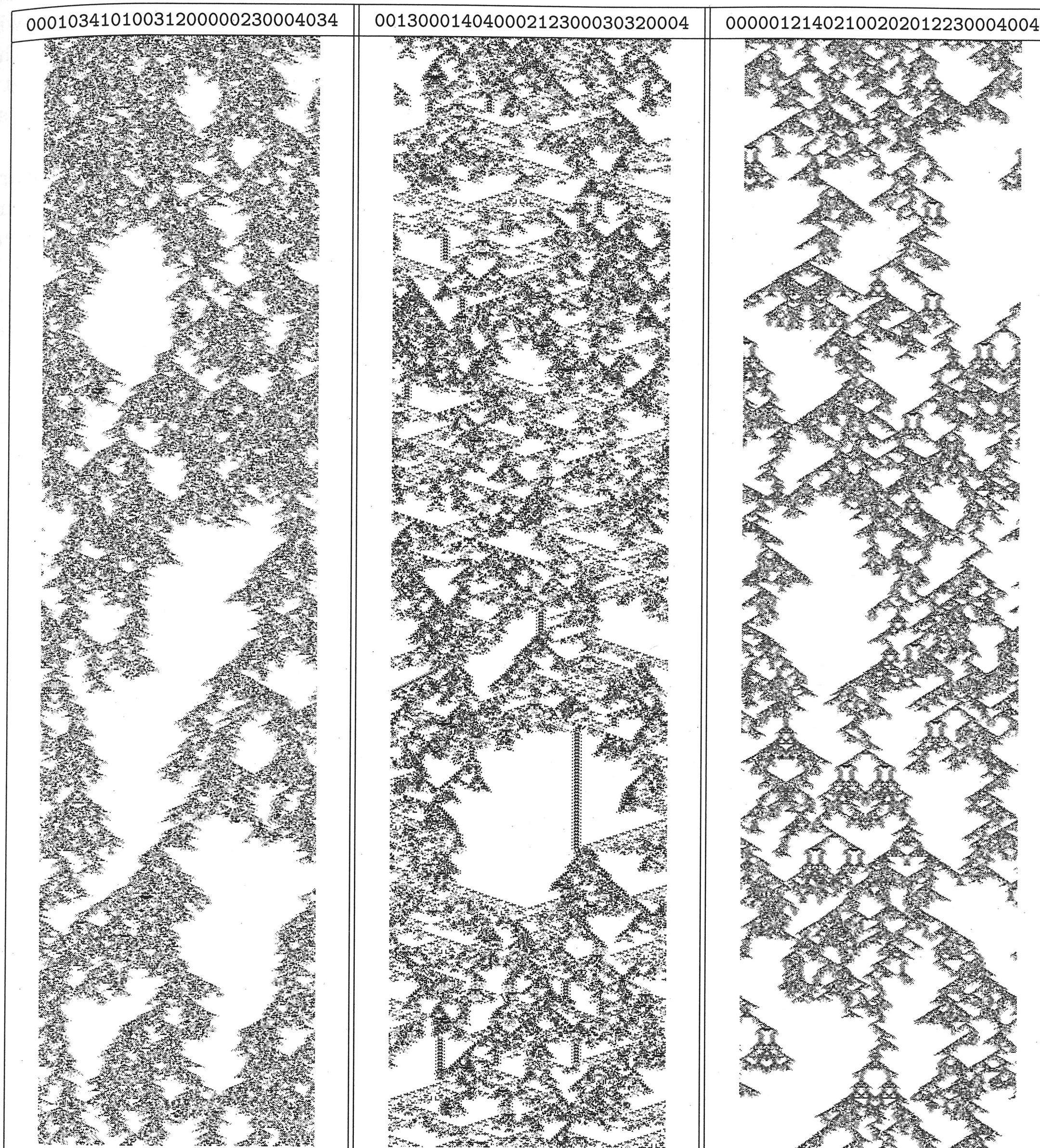
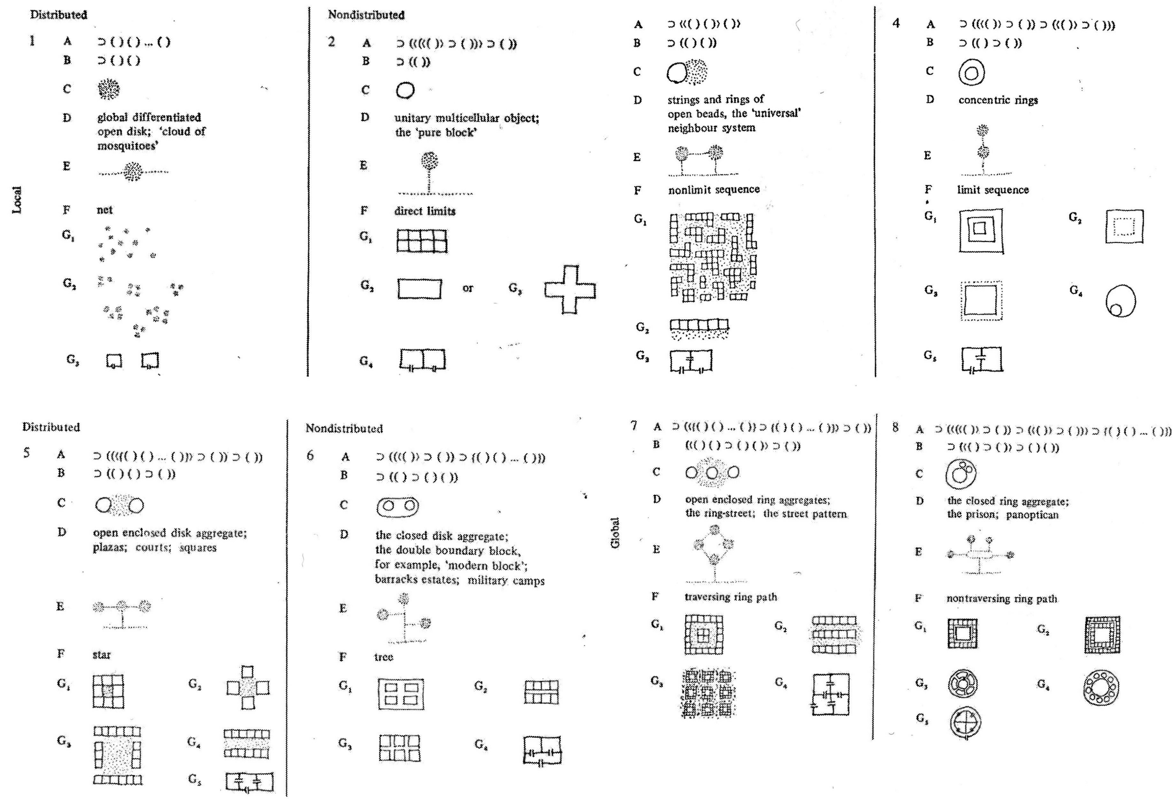


Figure 15.8 Examples of Wolfram's Class IV



The original set of eight syntaxes. The one chosen to experiment with was no. 3, the universal neighbour system

The Alpha Syntax village generator

1. Procedural/recursive

```
To grow (x, y)
  try one of
    neighbours of this patch at x, y
    to see if they can be a new openpatch
  if ok then
  try one of
    neighbours of this new openpatch
    to see if they can be a closed patch

    if ok then
  grow (newOpenpatch)
end
```

2. Parallel

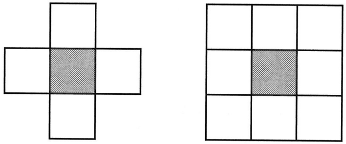
```
to grow

if this patch = carrierspace then
  if it has openspace in its neighbourhood
      then
    on the toss of a coin
    turn openspace or closedspace
end
```

The San'a algorithm uses both neighbourhoods. These values are used in the state change rules which are as follows:

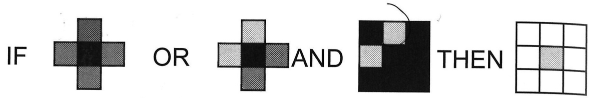
1. The general case of putting a garden 'behind' a house – if a cell is empty and has exactly one house in the nsum4 count, or there is more than one garden in the nsum4 count and there are no roads in the nsum count, then turn the patch into a garden.
2. Extend garden area beyond houses – if a cell is empty and there are more than two gardens in the nsum count, then turn the patch into a garden.
3. Make roads and houses – if a cell is empty and there are some roads near and less than two gardens, then on the flip of a coin set it to either road or house.

And two tidying up rules:

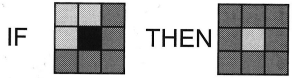
4. Houses demoted to roads – if a cell is a house and there is a road and no other houses in the big neighbourhood and less than four garden cells, then the house become a road.
5. Gardens become houses – if the cell is a garden with some neighbouring roads, then it becomes a house.



Nsum4 and Nsum neighbourhood

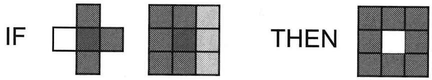


If pc = 0 and courthouse = 1 or courtgarden > 1 and countroadbig = 0 [setgarden 1 setroad 0 sethouse 0]



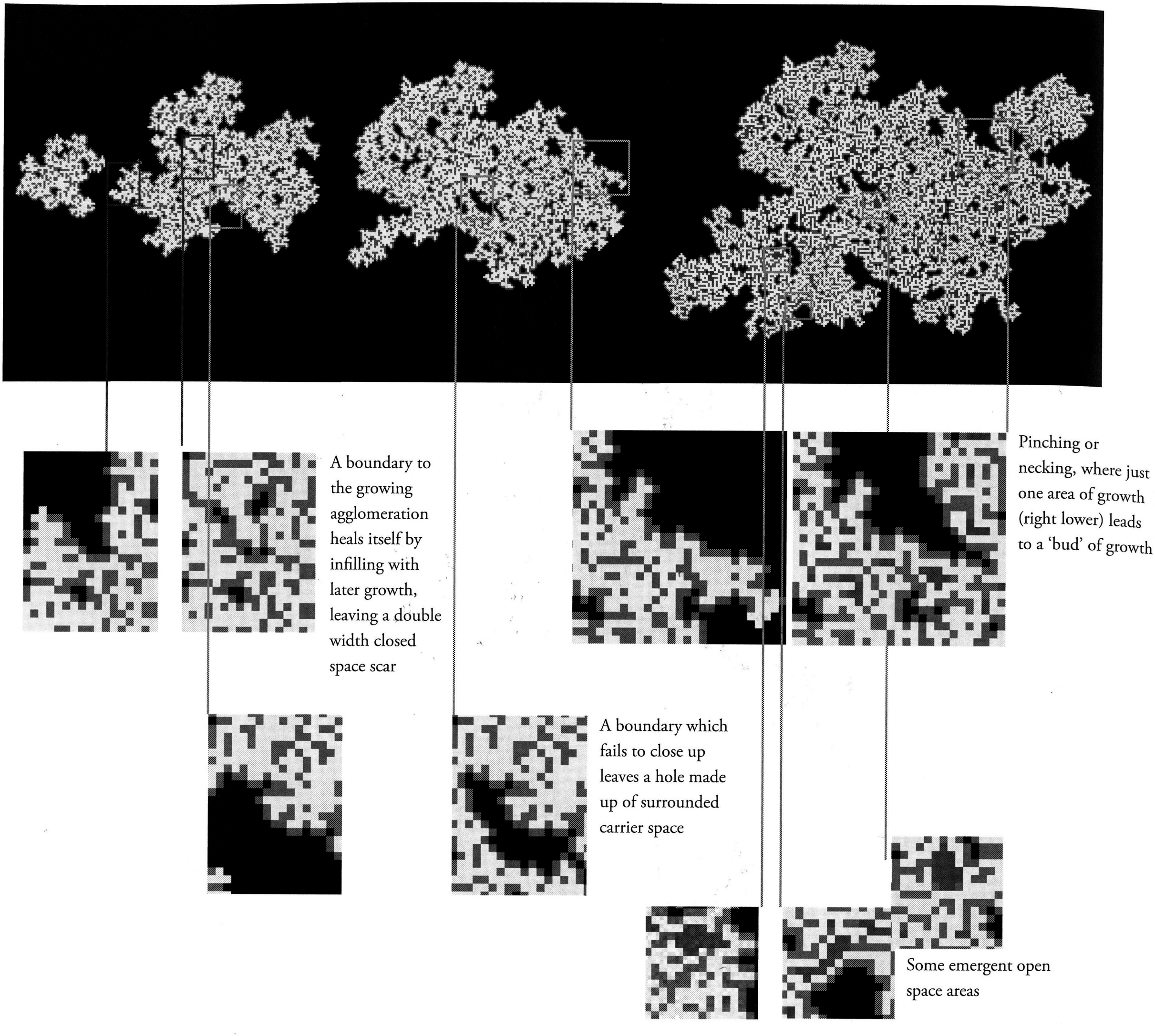
If pc = 0 and countgardenbig > 2 [setgarden 1 setroad 0 sethouse 0]

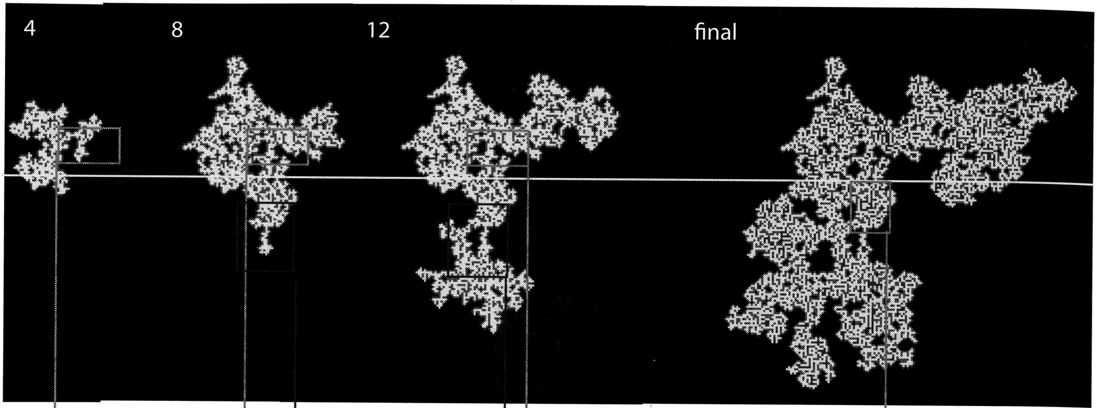
If pc = 0 and countroad > 0 and countgarden < 2 chose randomly 50:50 between

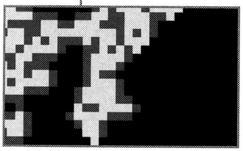


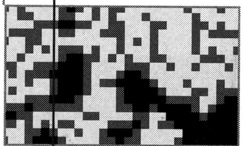
if house = 1 and count road = 1 and courthouse = 0 and courthousebig >0 and countgardenbig < 4

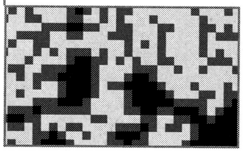
if garden = 1 and countroad >0


A boundary to the growing agglomeration heals itself by infilling with later growth, leaving a double width closed space scar
Pinching or necking, where just one area of growth (right lower) leads to a 'bud' of growth
A boundary which fails to close up leaves a hole made up of surrounded carrier space
Some emergent open space areas

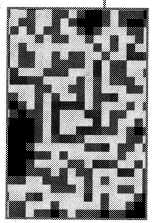




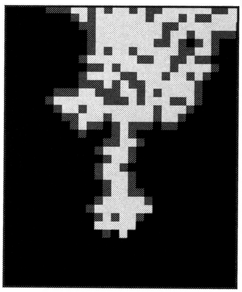




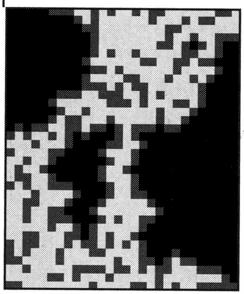
Gradual surrounding and filling up of space, but with persistent inlet of carrier space that becomes a historical feature determining the gross morphology of the developing pattern

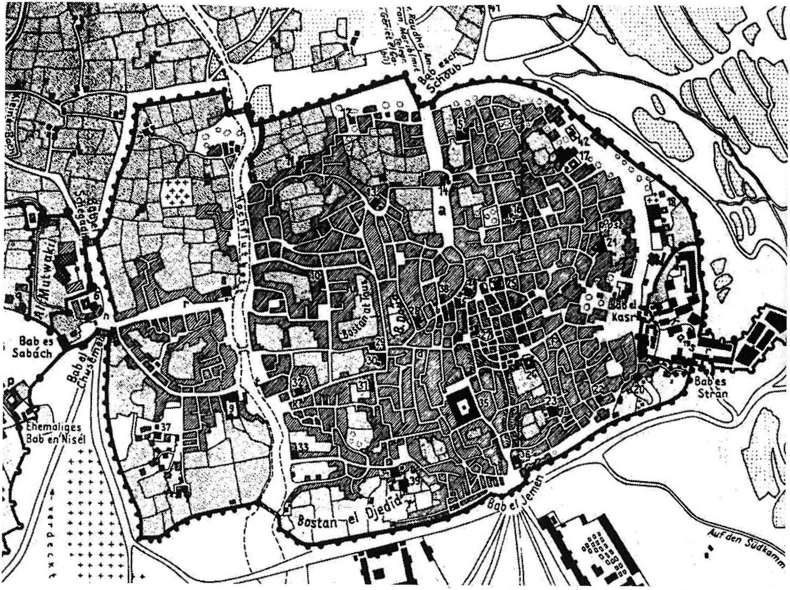


An example of the Y-Y-Y-Y space emerging after 18 generations of growth



The pinching off and bulb growing behaviour is easily observable here, where a promontory of y space is the only growing feature at Generation 8 (left) but by Generation 12 (right) this has extended and wrapped back to create two legs (one connected the other not)





San'a's morphology

1. Jami' al Kabir (Great Mosque)
2. Mosque of Salah ad Dīn (Saladin)
3. Mosque of Al Bakiliya
4. Mosque of Al Madrasa
5. Mosque of Mahdi 'Abbās
6. Mosque of Al Abhar
7. Mosque of Al Mutawakkil
8. Principal sūqs
9. Harat an Nahrein
10. The Imam's palace
11. Burjet Sherāra (open space)
12. Gateway to palace precincts
13. Solbi (open space in Jewish Quarter)
14. Ground formerly excavated for brick-making material.
15. Gate to Jewish Quarter

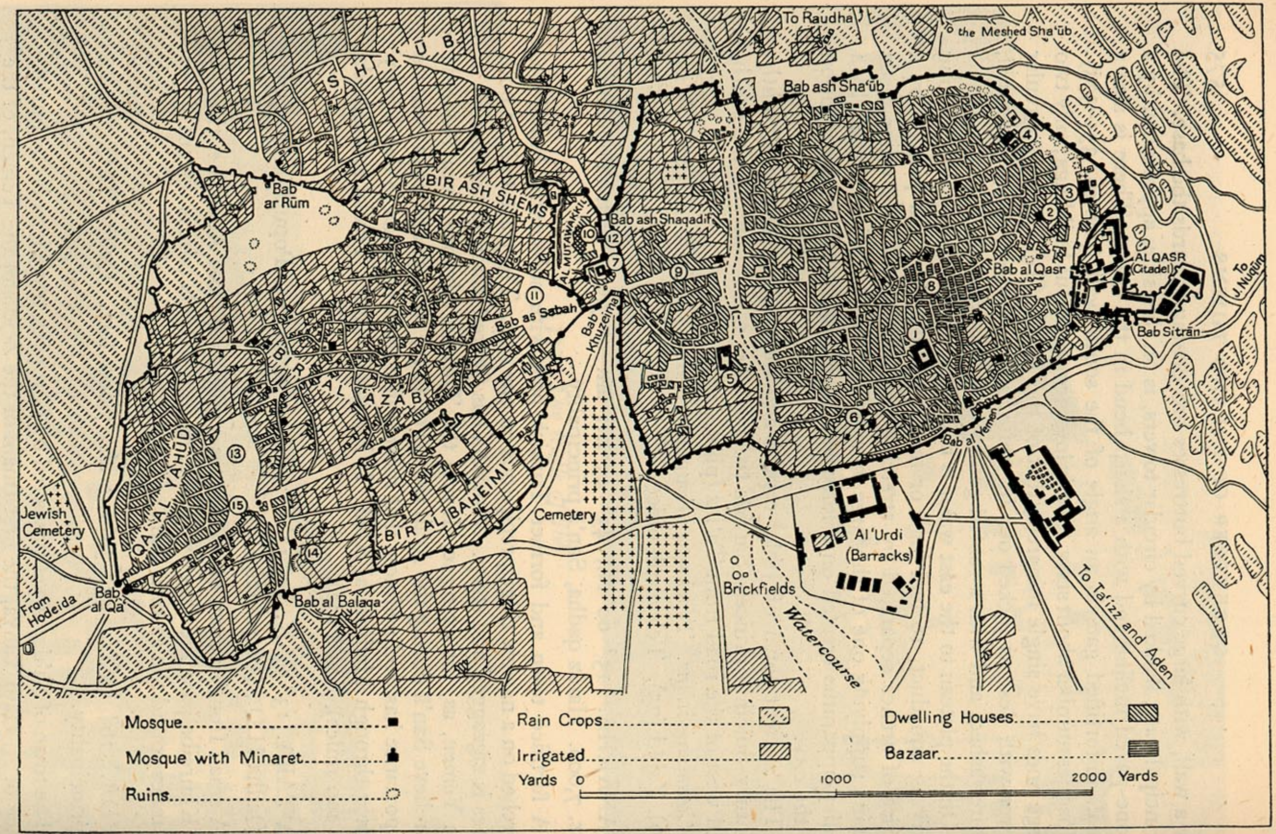
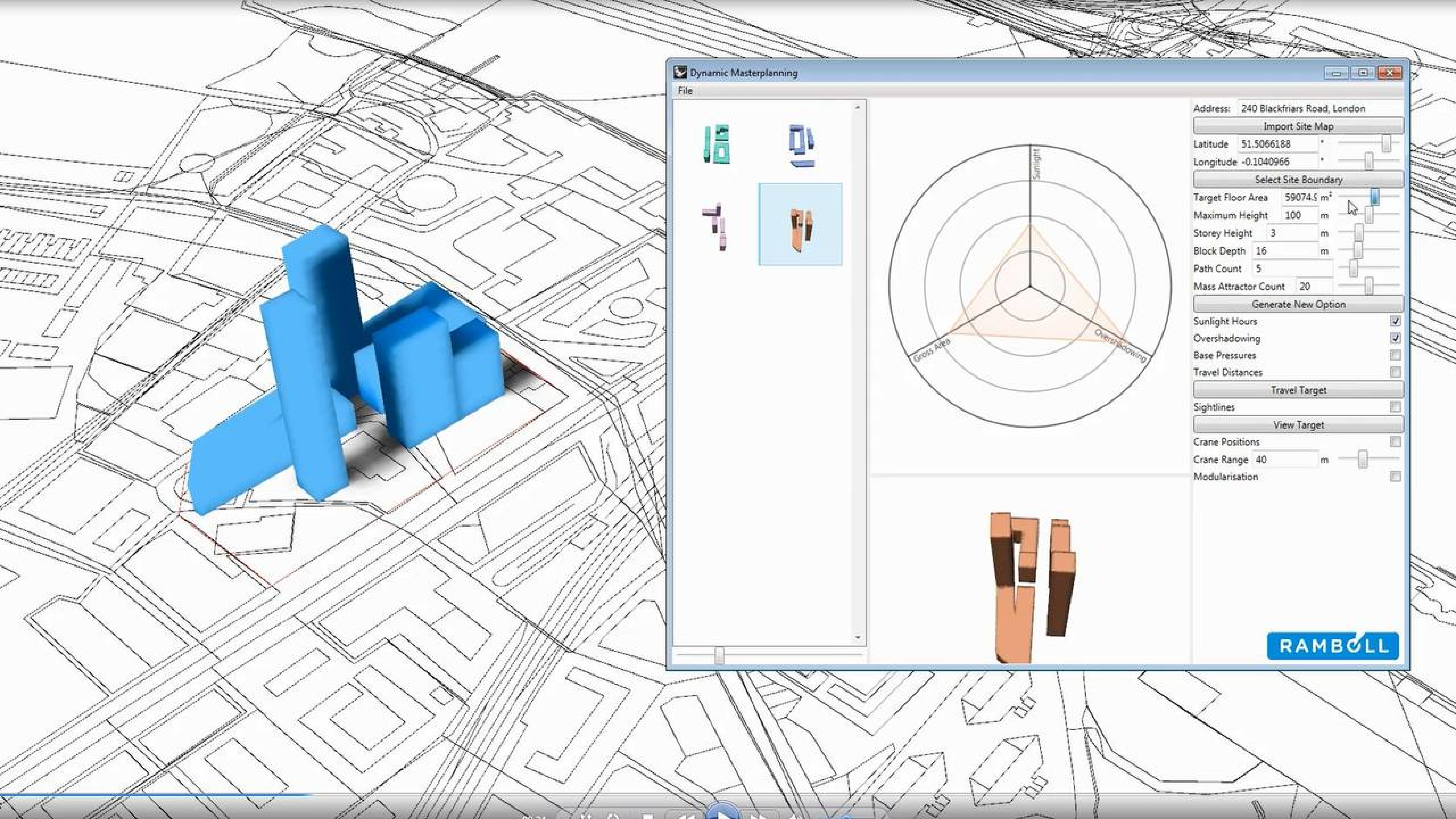
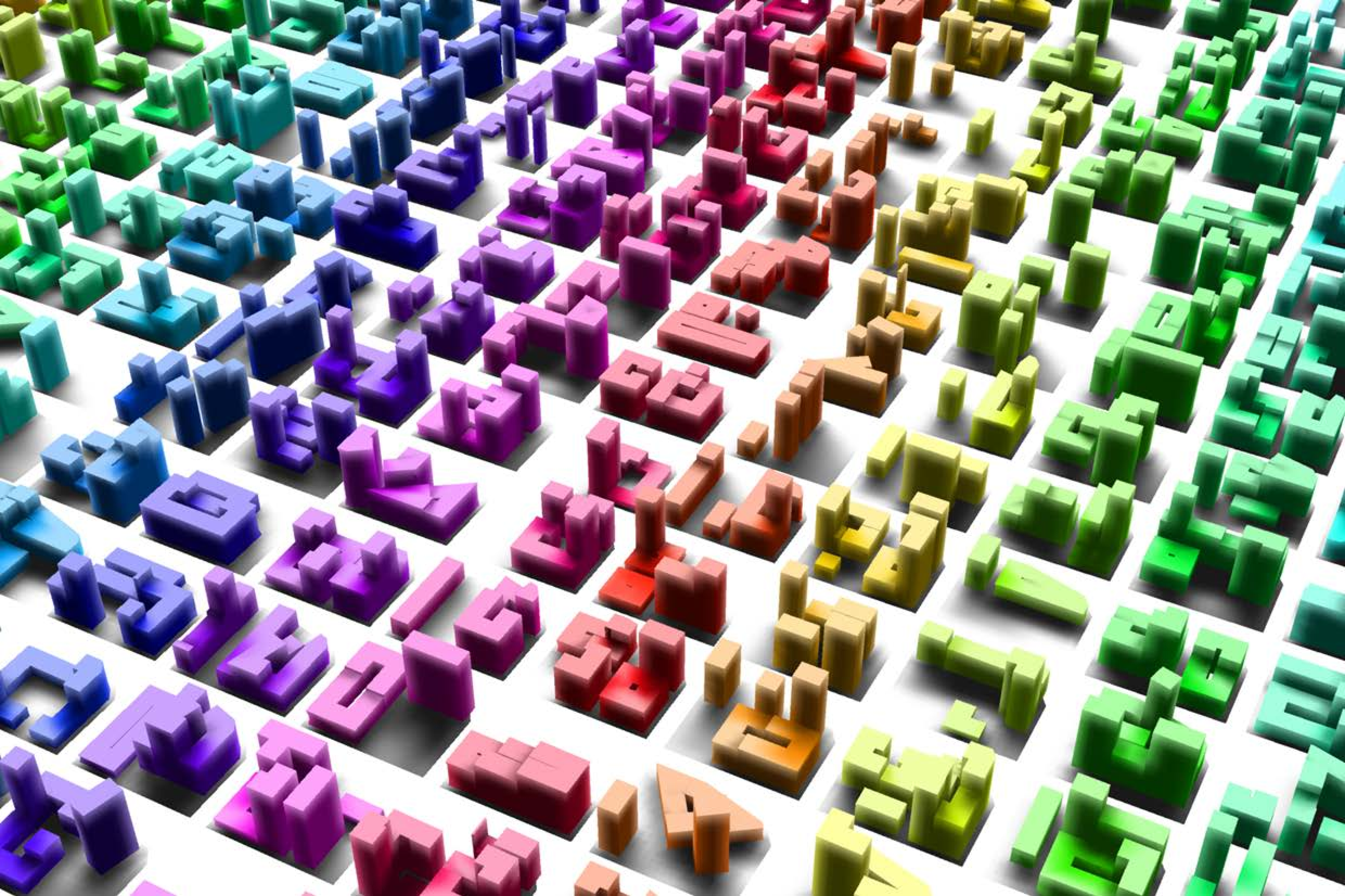
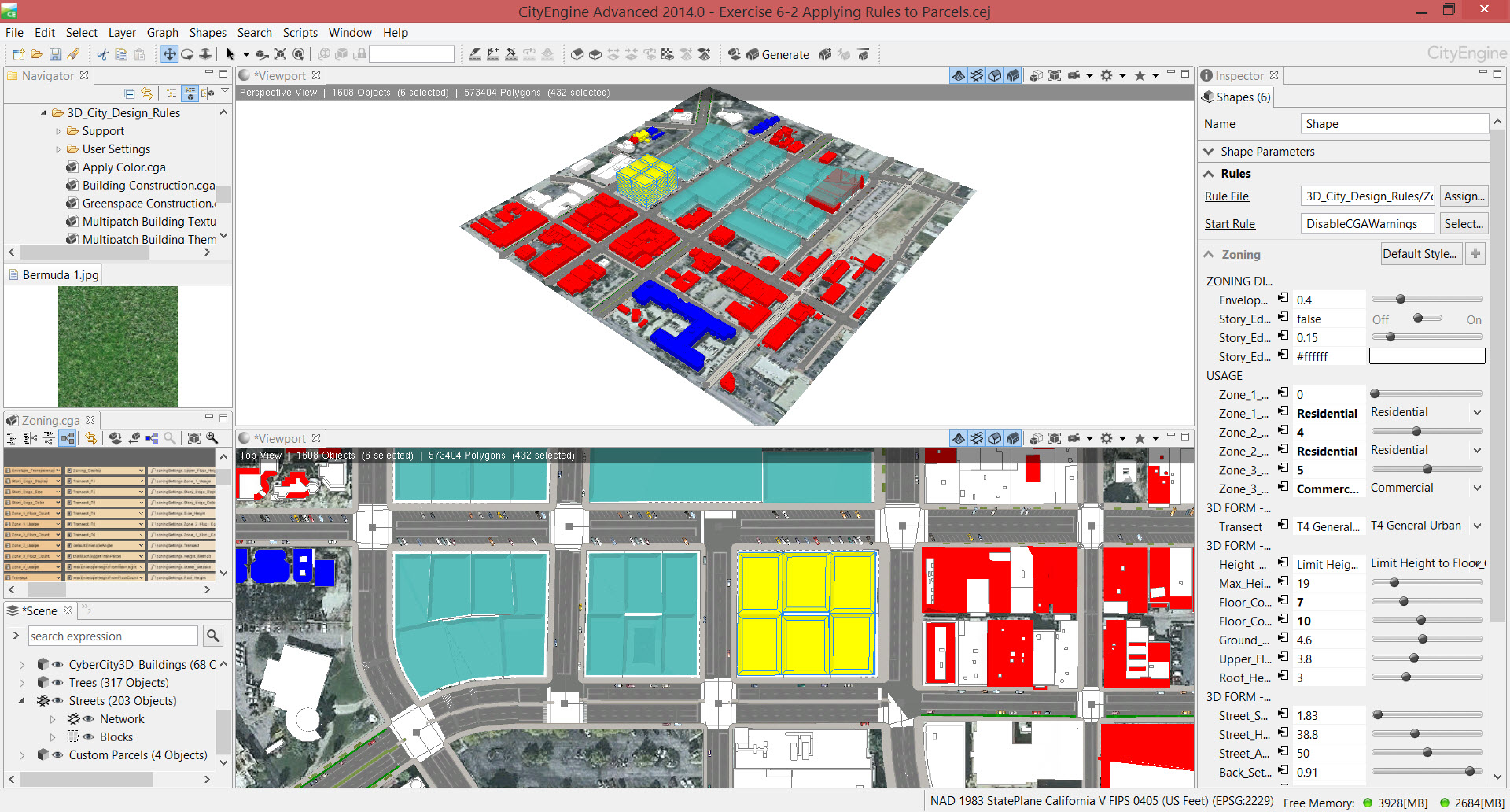
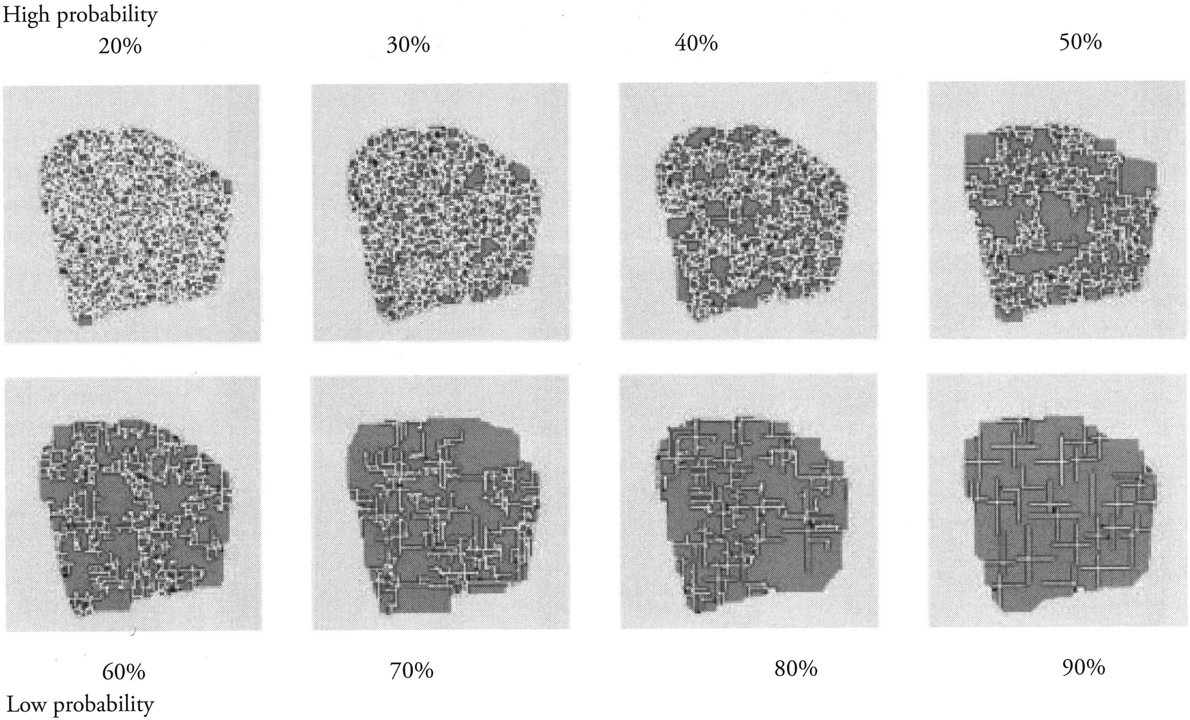


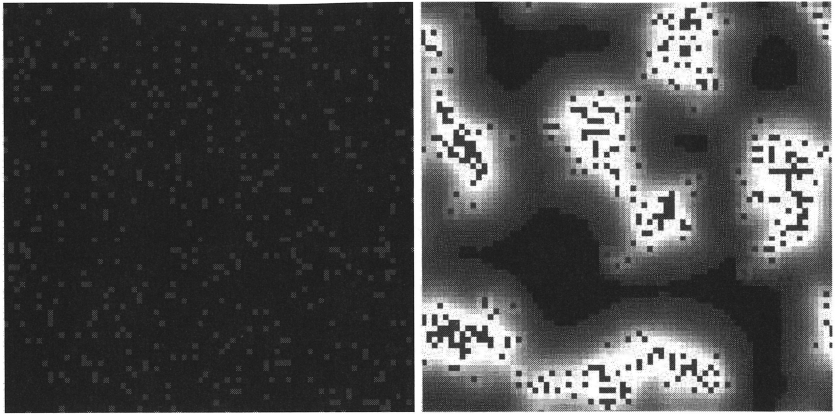
FIG. 46. *Plan of San'ā*


Dynamic Masterplanning
File
Sunlight
Gross Area
Overshadowing
Address: 240 Blackfriars Road, London
Import Site Map
Latitude 51.5066188 °
Longitude -0.1040966 °
Select Site Boundary
Target Floor Area 59074. m²
Maximum Height 100 m
Storey Height 3 m
Block Depth 16 m
Path Count 5
Mass Attractor Count 20
Generate New Option
Sunlight Hours
Overshadowing
Base Pressures
Travel Distances
Travel Target
Sightlines
View Target
Crane Positions
Crane Range 40 m
Modularisation
RAMBØLL



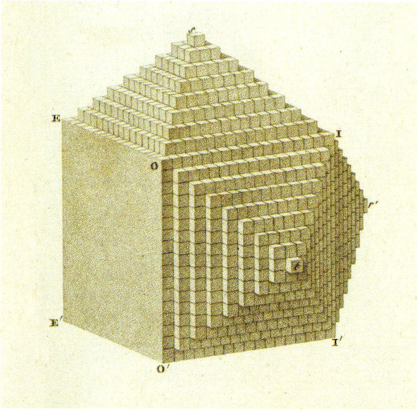

CityEngine Advanced 2014.0 - Exercise 6-2 Applying Rules to Parcels.cej
File Edit Select Layer Graph Shapes Search Scripts Window Help
Generate
Navigator
3D_City_Design_Rules
Support
User Settings
Apply Color.cga
Building Construction.cga
Greenspace Construction.
Multipatch Building Textu
Multipatch Building Them
Bermuda 1.jpg
*Viewport
Perspective View | 1608 Objects (6 selected) | 573404 Polygons (432 selected)
Top View | 1608 Objects (6 selected) | 573404 Polygons (432 selected)
Zoning.cga
*Scene
search expression
CyberCity3D_Buildings (68 C
Trees (317 Objects)
Streets (203 Objects)
Network
Blocks
Custom Parcels (4 Objects)
Inspector
Shapes (6)
Name
Shape
Shape Parameters
Rules
Rule File
3D_City_Design_Rules/Z
Assign...
Start Rule
DisableCGAWarnings
Select...
Zoning
Default Style...
ZONING DI...
Envelop... 0.4
Story_Ed... false Off On
Story_Ed... 0.15
Story_Ed... #ffffff
USAGE
Zone_1_... 0
Zone_1_... Residential Residential
Zone_2_... 4
Zone_2_... Residential Residential
Zone_3_... 5
Zone_3_... Commerc... Commercial
3D FORM -...
Transect T4 General... T4 General Urban
3D FORM -...
Height_... Limit Heig... Limit Height to Floor
Max_Hei... 19
Floor_Co... 7
Floor_Co... 10
Ground_... 4.6
Upper_Fl... 3.8
Roof_He... 3
3D FORM -...
Street_S... 1.83
Street_H... 38.8
Street_A... 50
Back_Set... 0.91
NAD 1983 StatePlane California V FIPS 0405 (US Feet) (EPSG:2229)
Free Memory: 3928[MB] 2684[MB]


High probability
20%
30%
40%
50%
60%
70%
80%
90%
Low probability



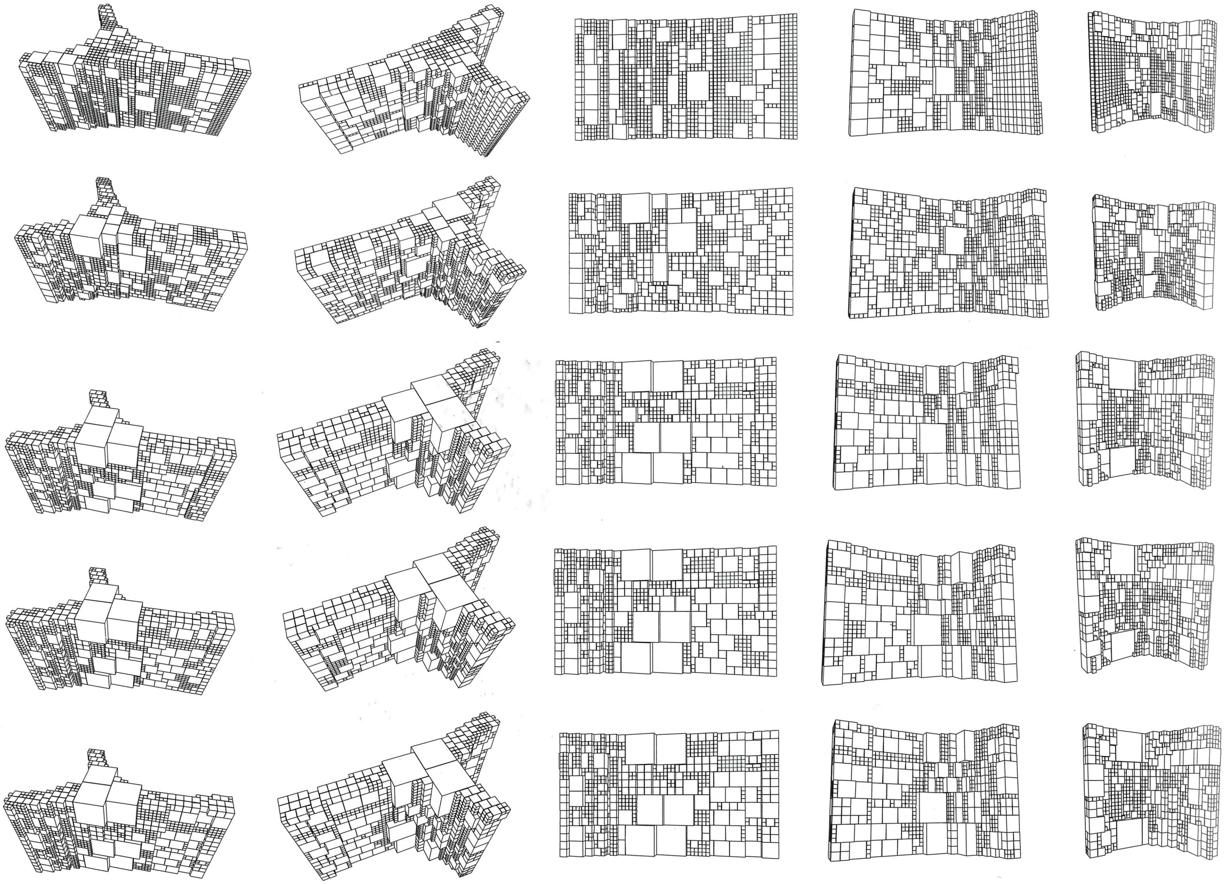
(a) (b)

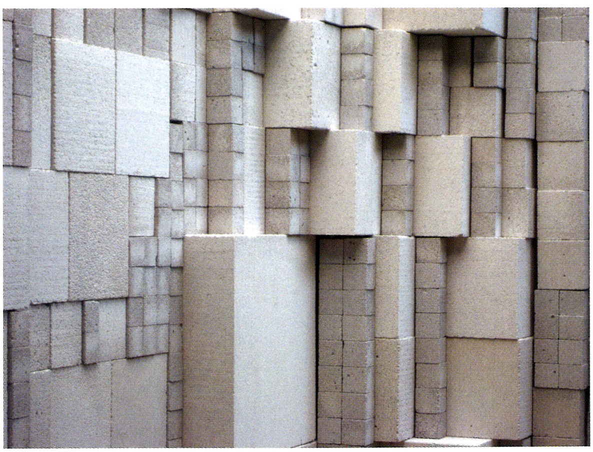
Figure 8.18: Slime-mold aggregation. (a) Initial distribution of slime molds. (b) Clusters of slime molds after some time has elapsed.

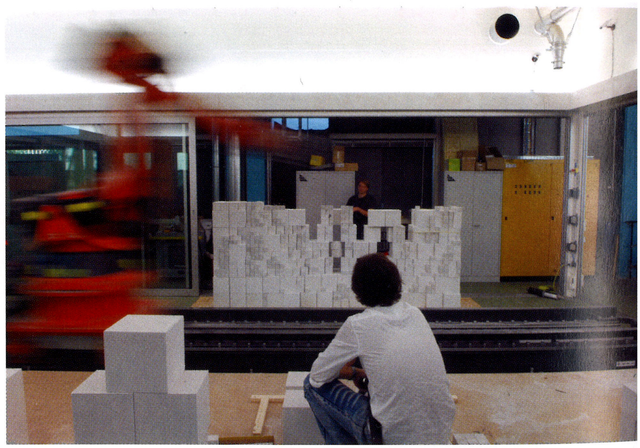


7-3. A rhombic dodecahedron built from molecular polyhedra, in René Just Haüy, *Traité de minéralogie* (Treatise on mineralogy; Paris: Louis Libraire, 1801), vol. 5, plate 2, fig. 13.

Haüy proposed that the building-blocks of crystals come in six basic forms: parallelepiped, rhombic dodecahedron, triangle-faced dodecahedron, hexagonal prism, octahedron, and tetrahedron.



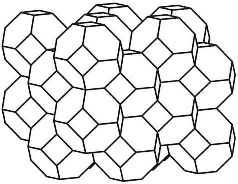


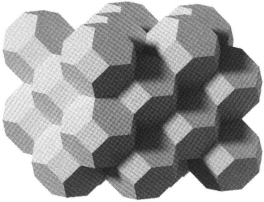


The Resolution Wall, by Gramazio & Kohler with the Architecture and Digital Fabrication department at ETH Zürich, 2007

Constructed by a robot, this wall is composed of aerated concrete blocks with a dimension ranging from 5 to 40 centimeters (1.9 to 15.7 inches). Smaller blocks allow for finer detail, but building with larger blocks is faster and therefore more cost effective. In a student course, a genetic algorithm was developed to evolve a design with a good balance between aesthetic detail, construction time, and structural stability.

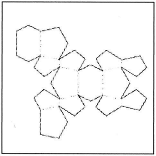
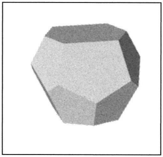
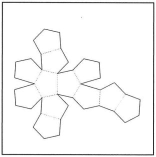
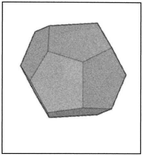
Kelvin conjecture



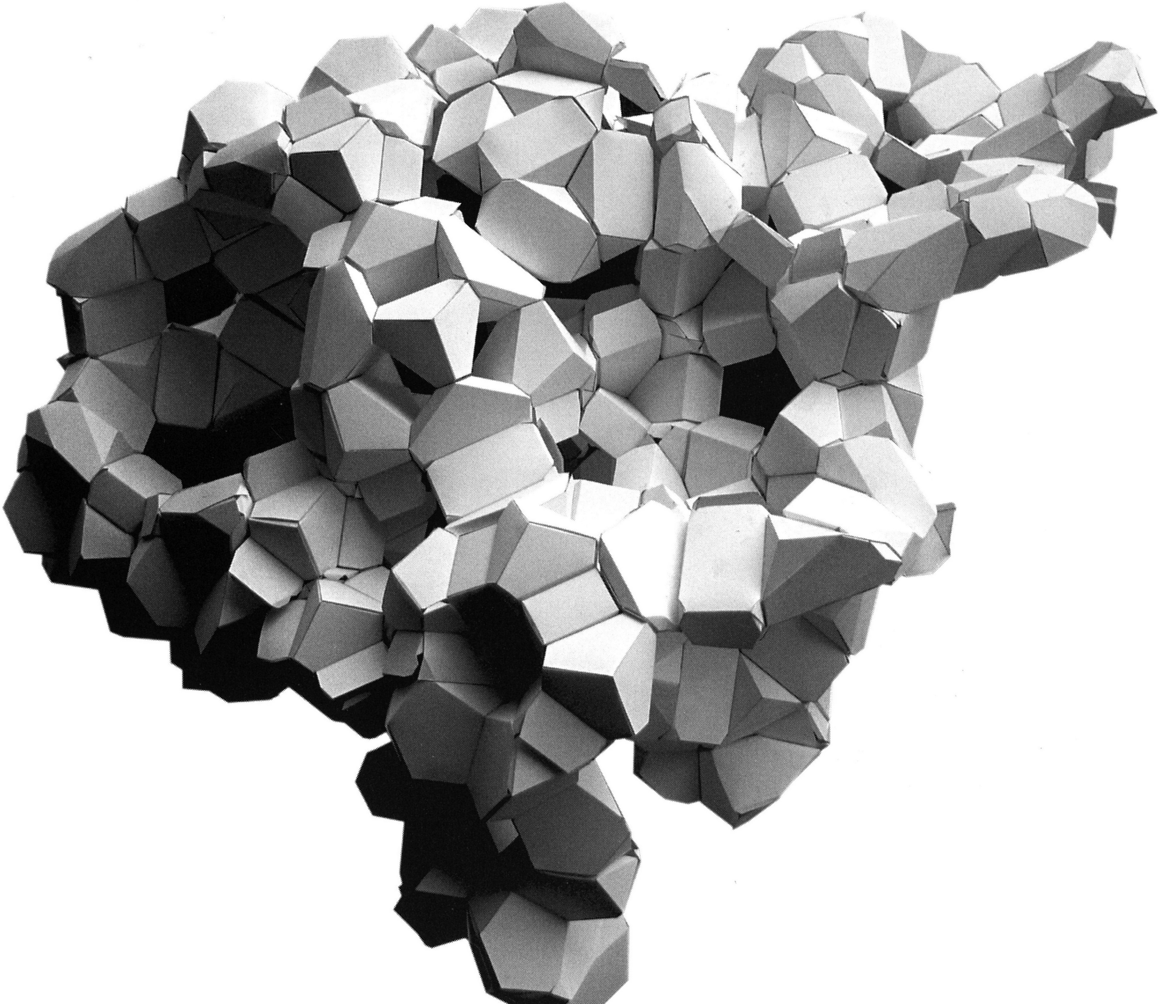


Sir William Thomson (later Lord Kelvin) (1824–1907) tackled the problem of the ideal ordered foam structure in 1887, when he was already in his sixties. His career publications then numbered over 600, and covered subjects as diverse as telegraphy and electrical technology to the second law of thermodynamics, giving his name to a unit of temperature. His reasons for investigations into the ordering of foam were driven by wider speculations, but arrived at a useful answer to the question: 'What partitioning of space into equal volumes minimizes their surface area?' His answer was accepted for over a century. The unit cell described by Kelvin for this foam of uniform bubbles was a form of truncated octahedron, to which Kelvin gave the longer name of tetradecahedron. It was one of the thirteen Archimedean solids. This solution, informed by Kelvin's knowledge of crystallography, survived as the packing model that gives the best solution until 1993, when Robert Phelan and Denis Weaire reopened the search.

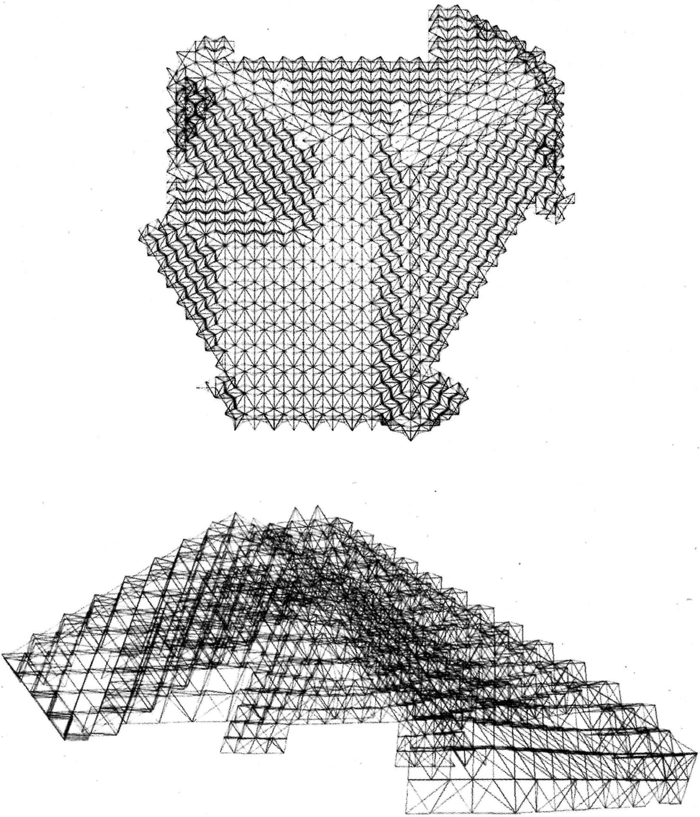
Weaire-Phelan model

Robert Phelan began his research at Trinity College Dublin in 1993 to explore the Kelvin problem and variations on the theme, using Ken Brakke's surface evolver programme. Phelan joined a group with a background in solid state and materials science, who already had some hunches about what types of structures might compete with Kelvin's conjecture that were already manifest in nature. Phelan started with the covalent bonding structure of clathrates compounds, in which the bonds can be envisaged as foam cells. Most of the rings of bonds on the sides of the cages are five-fold, creating pentagonal faces. It is a regular assembly of two types of irregular polyhedral cells with twelve and fourteen faces, respectively, combined in the ratio or 2:6 in a repeating unit of eight polyhedra. It turned out to have a cell surface area for volume that was 0.3 per cent less than the venerable conjecture of Kelvin.



Folded paper model of excavated grotto



John Frazer, plotted output of a structure entirely generated from just a seed, 1971.