Session 3: Lecture 3:

Fractals and Cities

Simulation Using Cellular Automata

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Outline of the Talk

- What are Models? Abstractions, Idealisations
- Design: Natural or Organic v Planned, Unself-Conscious v. Self Conscious
- Modularity, Scale, Hierarchy, Rules, Geometry
- Generating Organically Growing Cities
- Modelling Planned Cities
- Exploring the Design Space
- Questions

What are Models? Abstractions, Idealisations

Models are simplifications of the real thing.

Science explains existing phenomena through models in contrast to designers who articulate a future through models. The word model is thus ambiguous. Models are both realisations and idealisations (as are cities, towns).

All models are abstractions – and our quest for the best model is one that pertains to the real as well as the ideal. This may well be unattainable.

Design: Natural or Organic v Planned, Unself-Conscious v. Self-Conscious

At the outset, we need to make the distinction between the real and the ideal and this can be seen as a distinction between natural or organic ‘unplanned’ artifacts in contrast to the ‘planned’. Alexander in his classic Notes on the Synthesis of Form (1964) articulates this distinction as one between unself-conscious and self-conscious design, and he sides with the unself-conscious arguing that organic growth is bottom-up growth, a synthesis of many actions well adapted.

As a slight digression, over the last 50 years we have moved from a world that is based on creating ideals through planning as a top-down centralised activity to one that is much more comfortable with design from the bottom-up.

My argument here favours the latter but we are conscious that we cannot depend on one or the other – there is an inevitable tension between the top-down and bottom-up and we need both.

Here we will suggest in designing better towns we can learn from both.

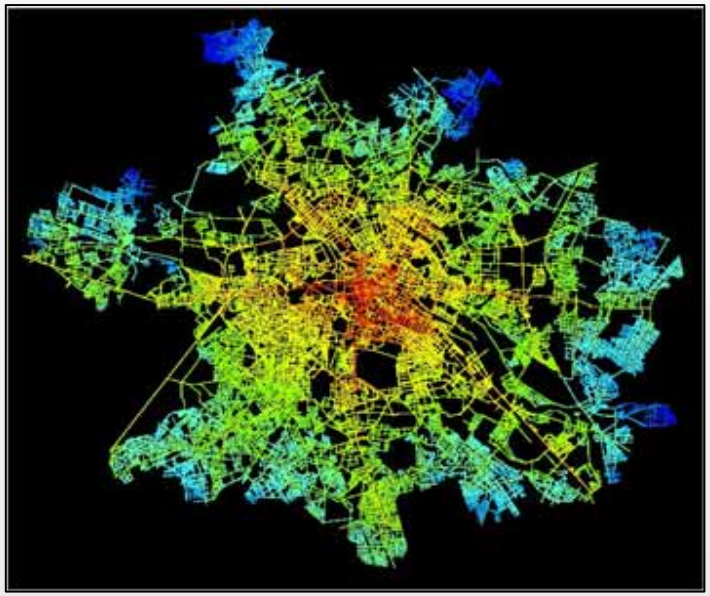
Modularity, Scale, Hierarchy, Rules, Geometry

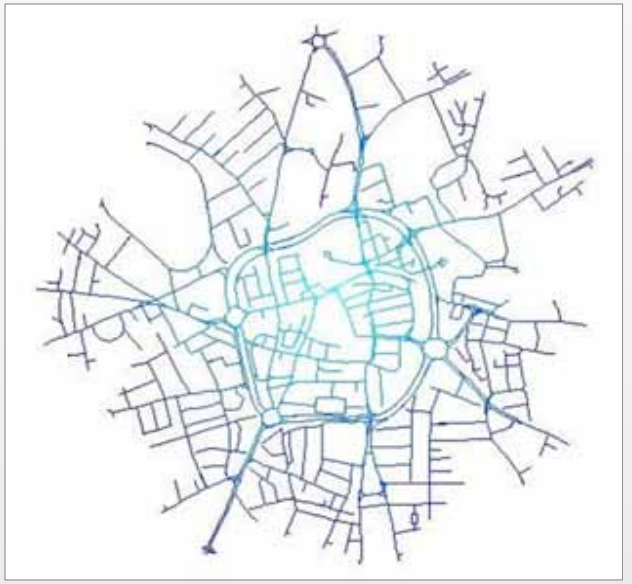
But before we introduce each of these views through geometric and physical models, we want to identify some key issues about complex systems like cities. I want to suggest that all complex systems only hold together through modularity and hierarchy where modules repeat themselves at different scales.

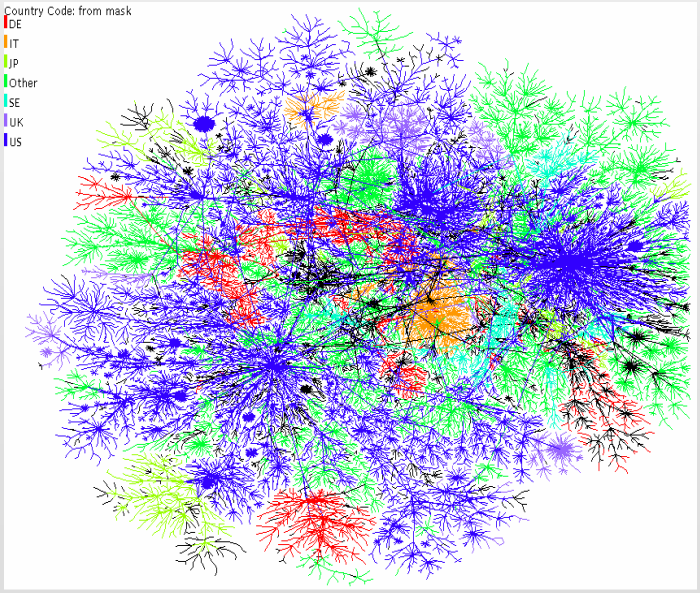
We can build models of cities in this modular fashion noting that geometry constrains what we can do.

There are many ways of simulating cities but here we will show that geometry is key in terms of constraining what we can do.

Our models depend on activities competing for space which is always in short supply. Cities grow through agglomeration – economies of scale – which are constrained in terms of transport between the parts and the density at which they can exist – there are many urban economic theories. But let us look at some examples of organic and planned towns to make the point.



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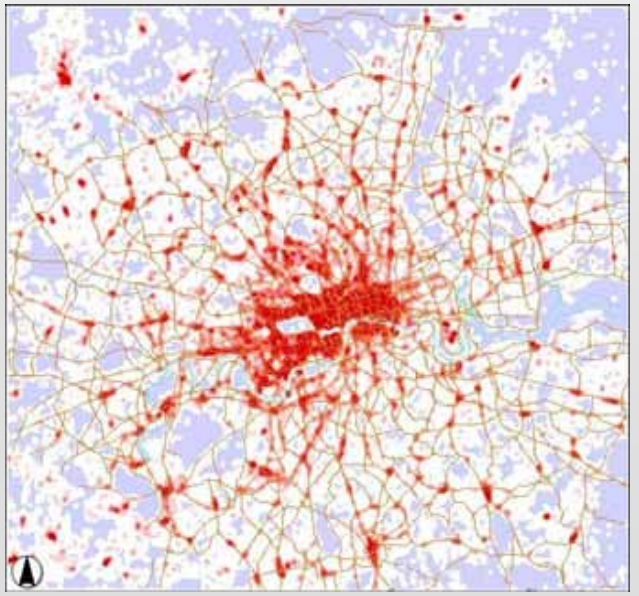
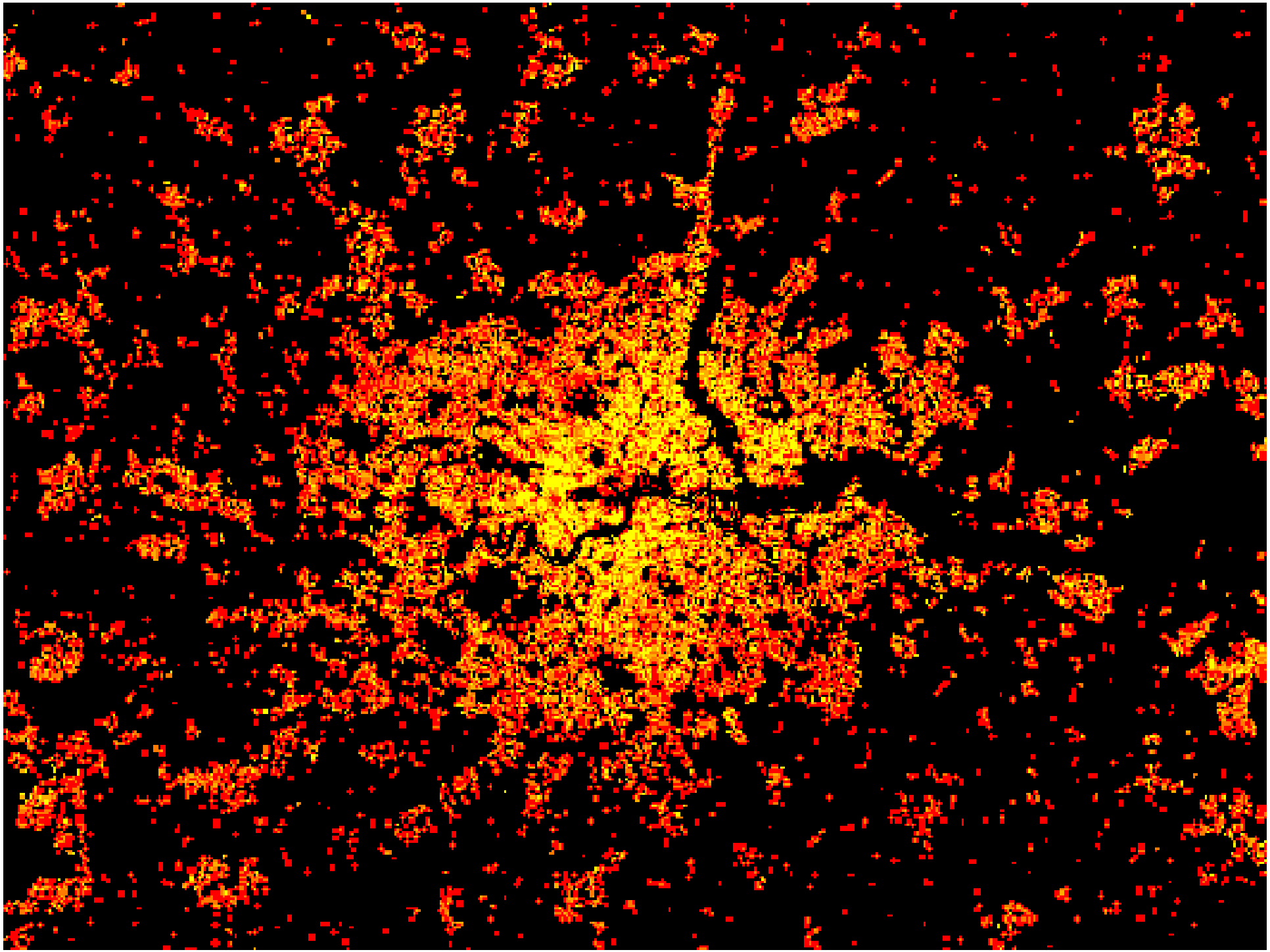
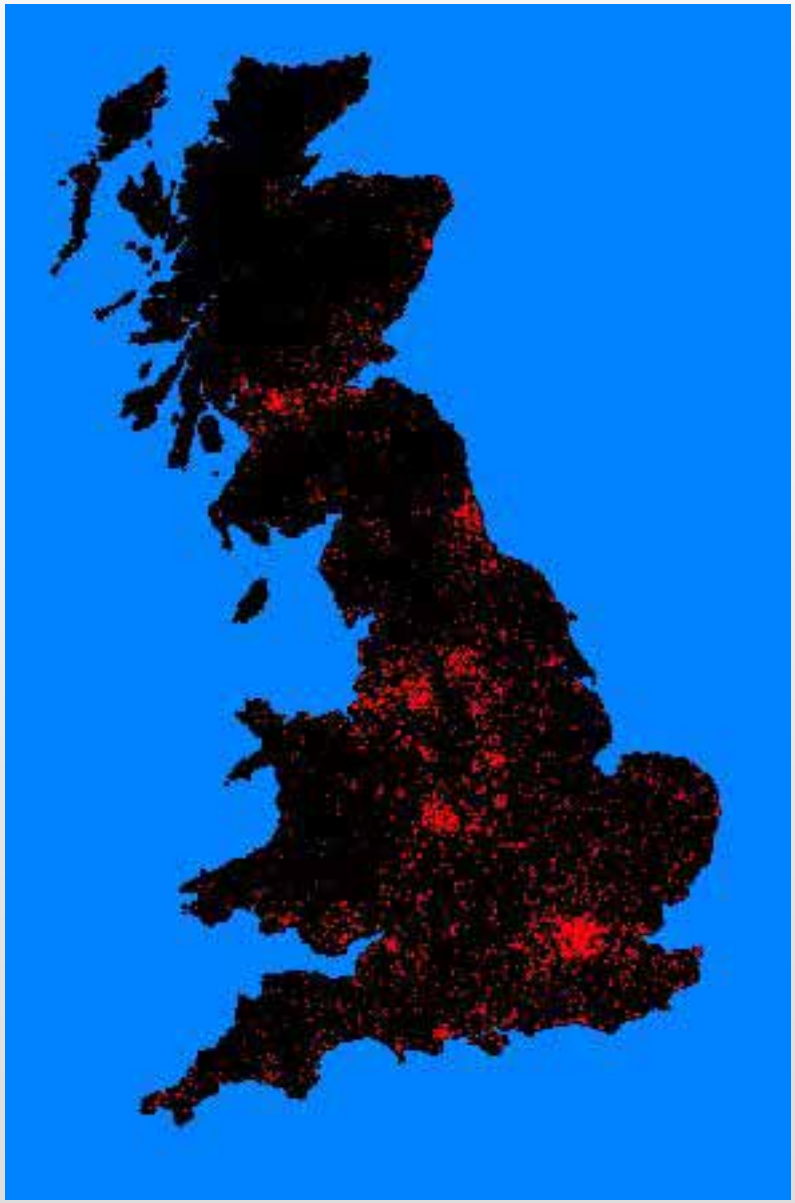
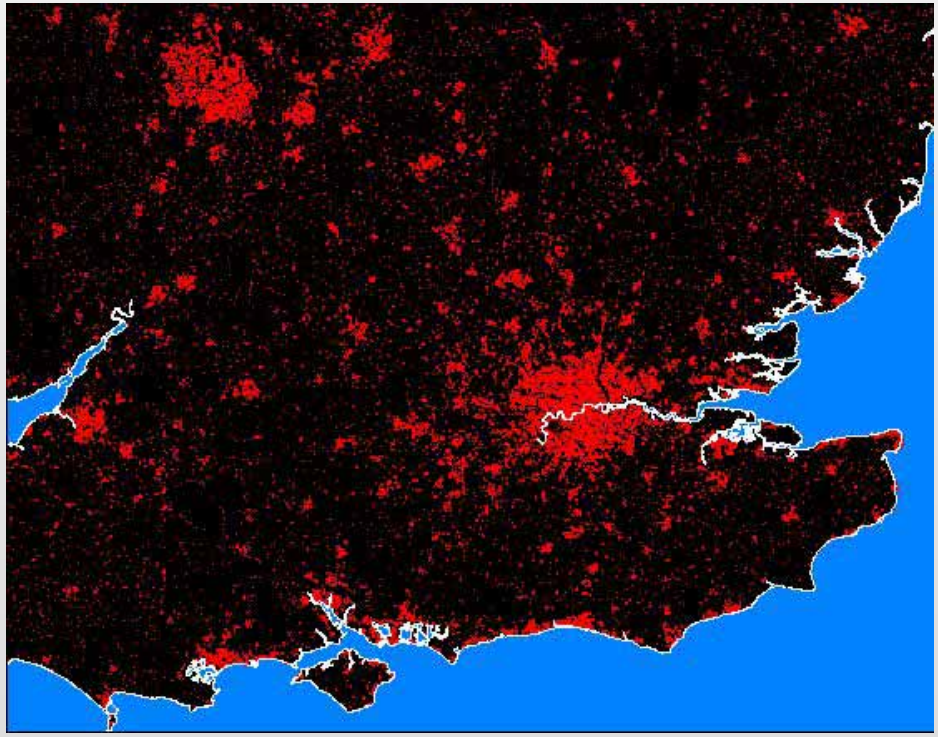
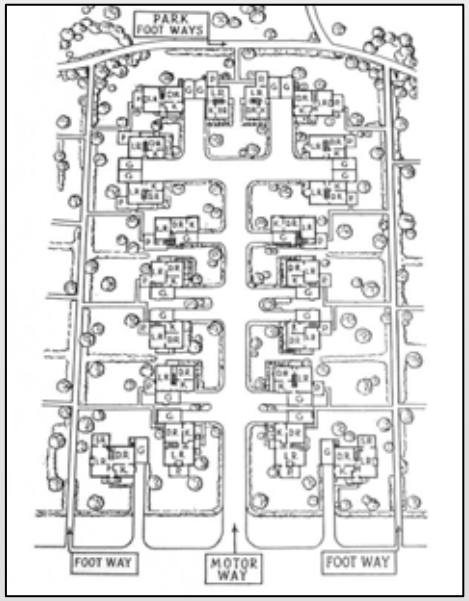


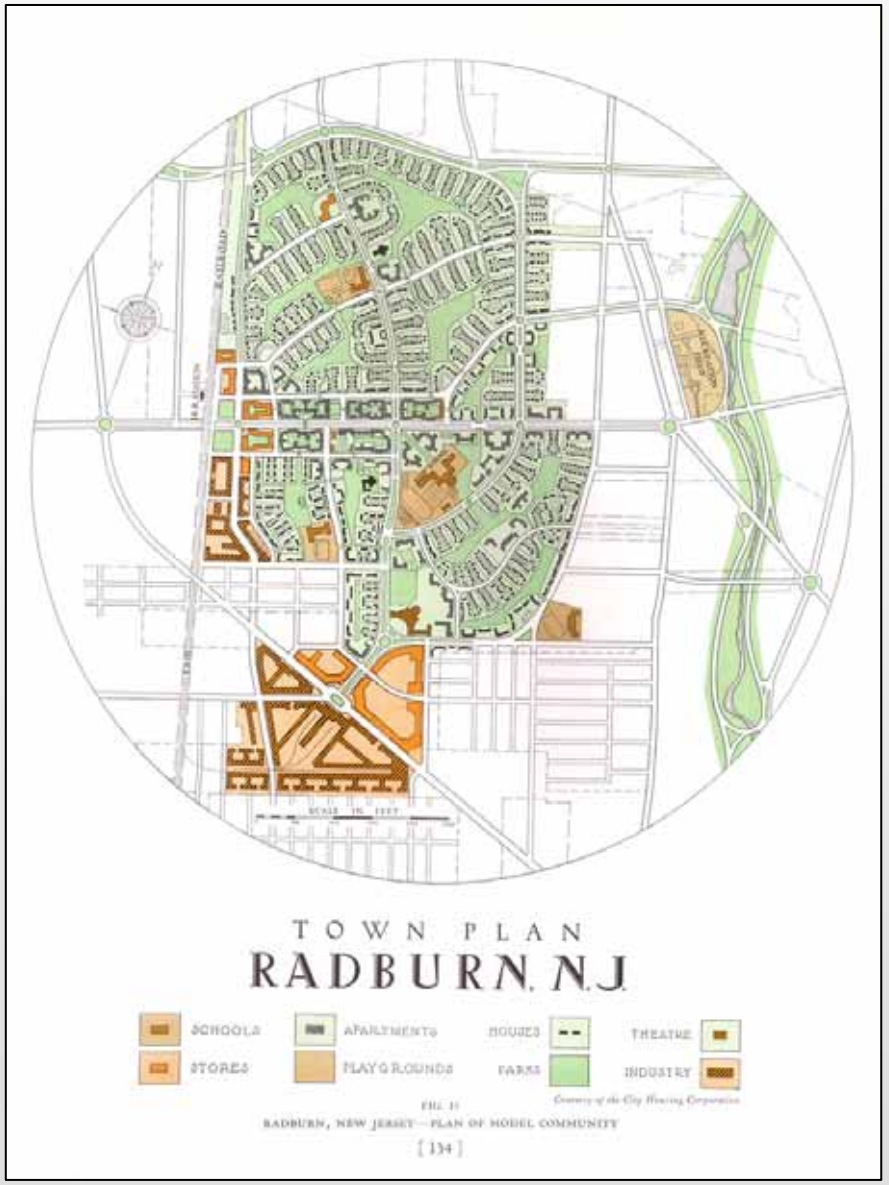




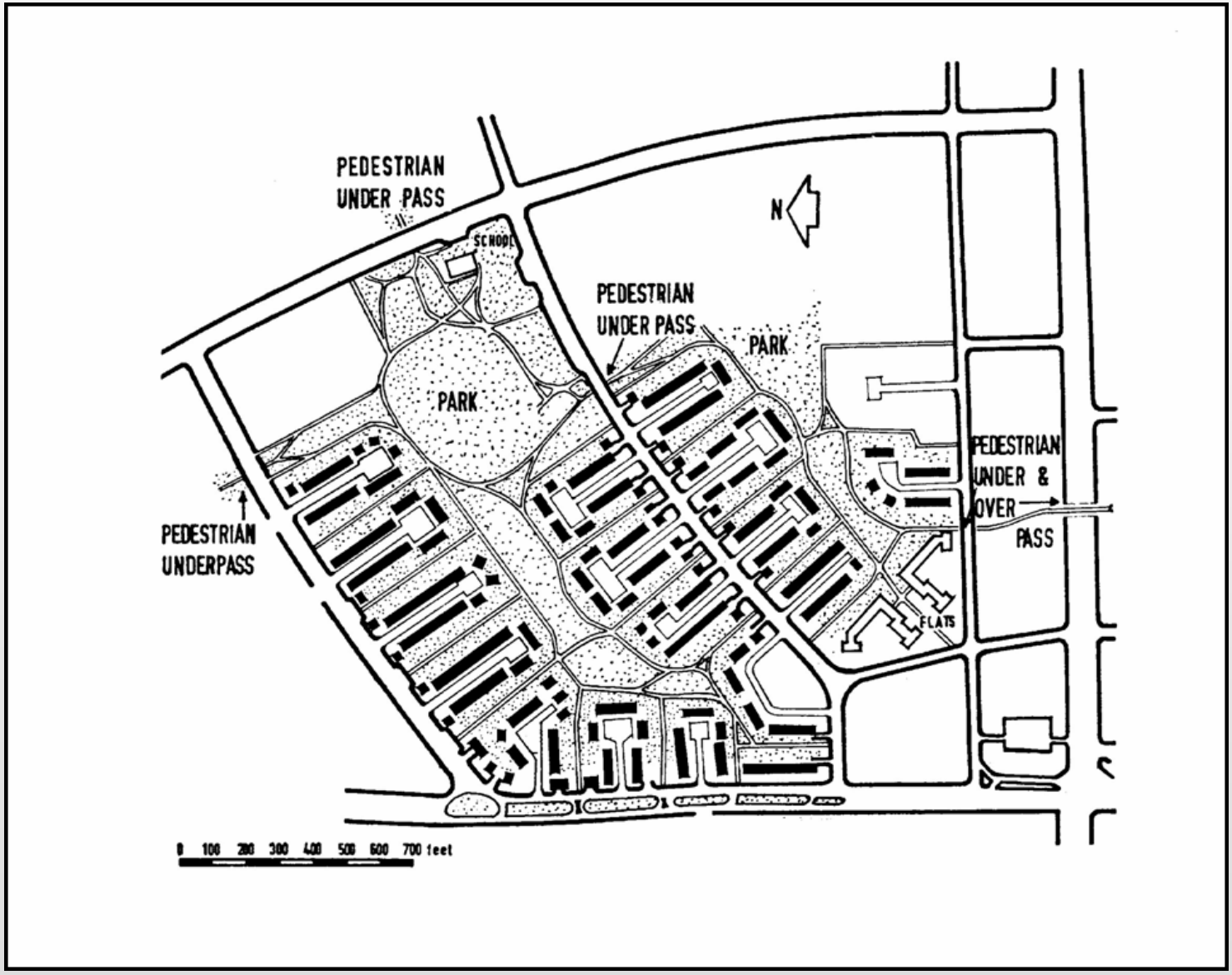
These clusters scale geometrically and their organization is ‘fractal’. This is fractal geometry where objects of the same shape exist at all scales







An early ‘new town’
RADBURN, NJ
1920s


PEDESTRIAN
UNDER PASS
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N
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OVER
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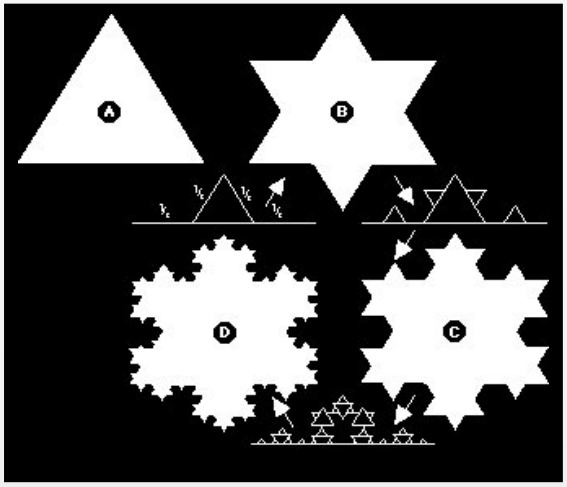
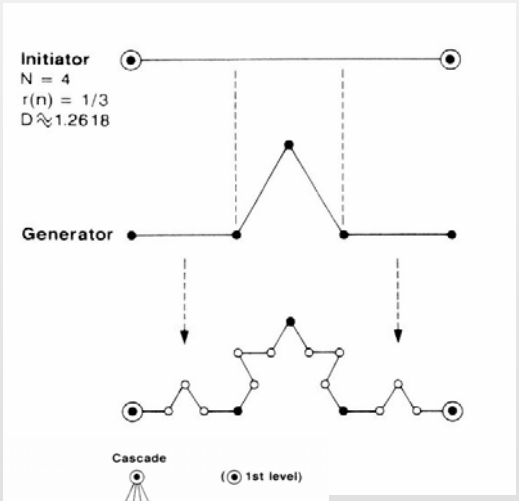
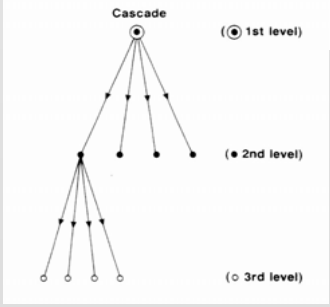
UNDERPASS
FLATS
0 100 200 300 400 500 600 700 feet



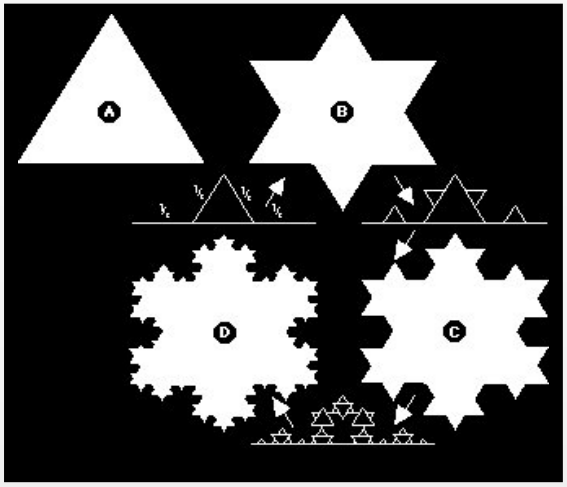
A Way of Generating Such Order

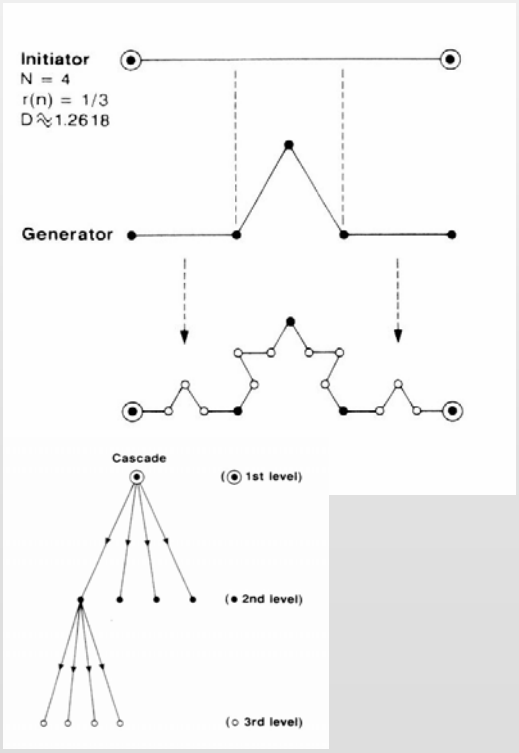
This is how we generate self-similar objects across many scales this developing fractals objects

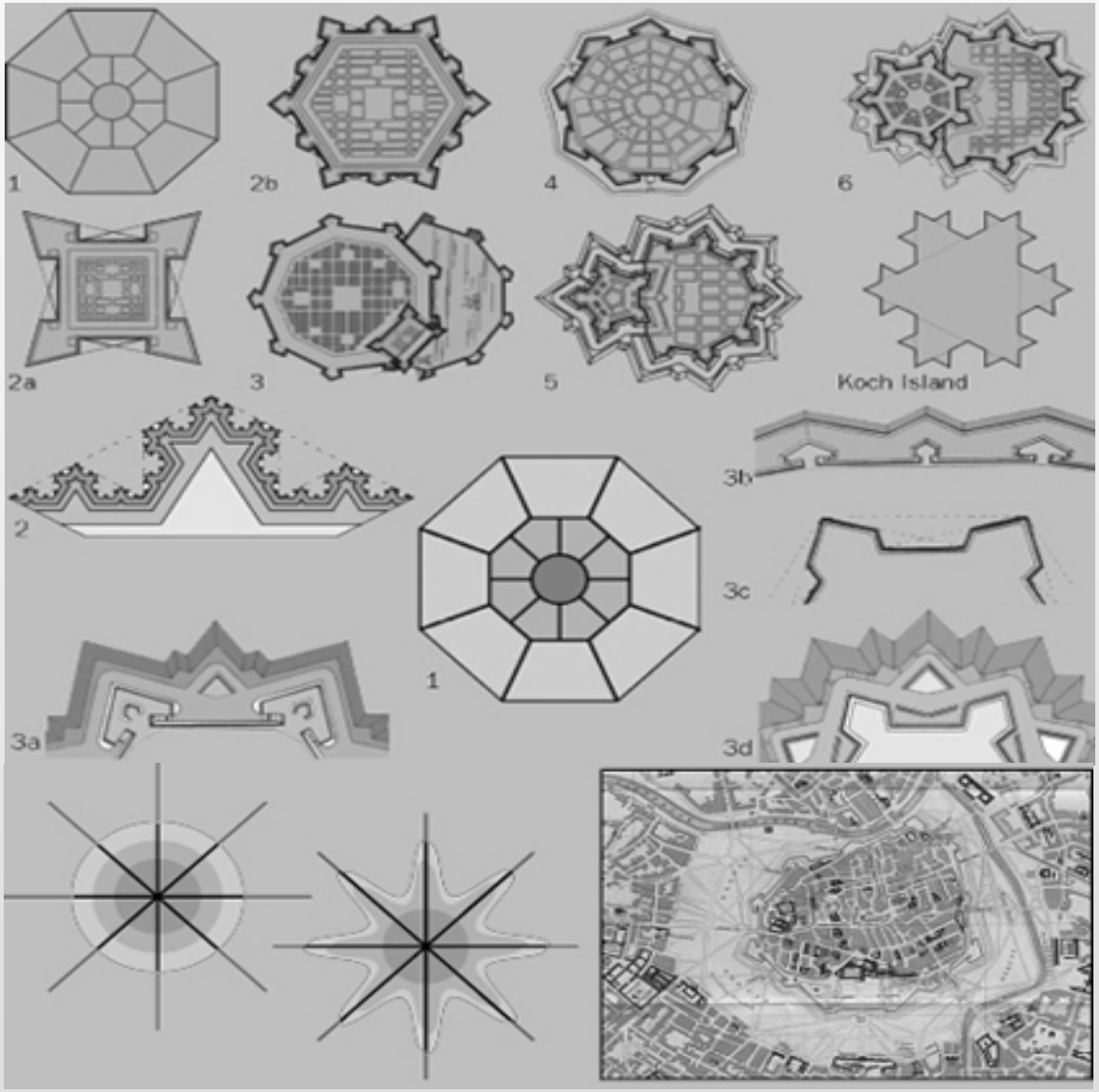




In the history of idealized town shapes, such fractal modularity in its pure deterministic form has been used over and over again.


A
B
C
D


Initiator
N = 4
r(n) = 1/3
D≈1.2618
Generator
Cascade
(◉ 1st level)
(● 2nd level)
(○ 3rd level)


1
2b
4
6
2a
3
5
Koch Island
2
3b
3c
1
3a
3d

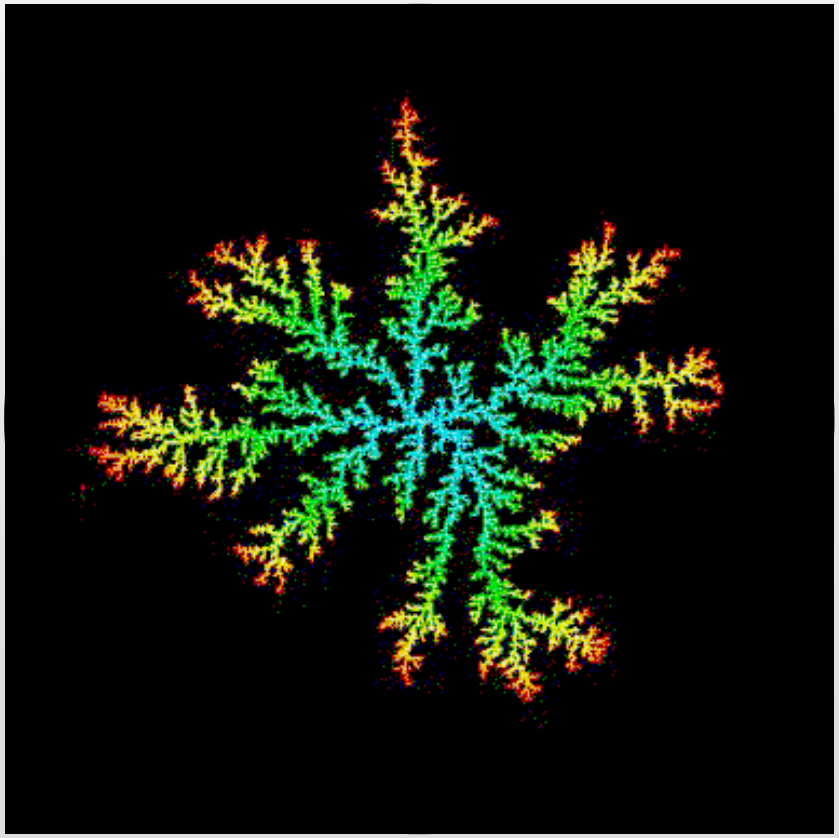
Generating Organically Growing Cities

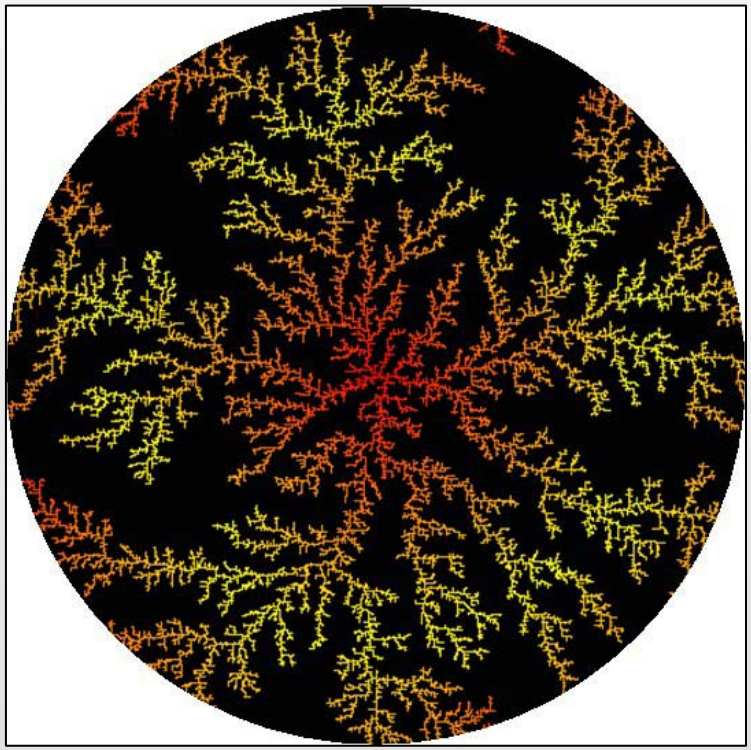
Ok, let us show you the simplest possible model of an organically growing city – based on two simple principles

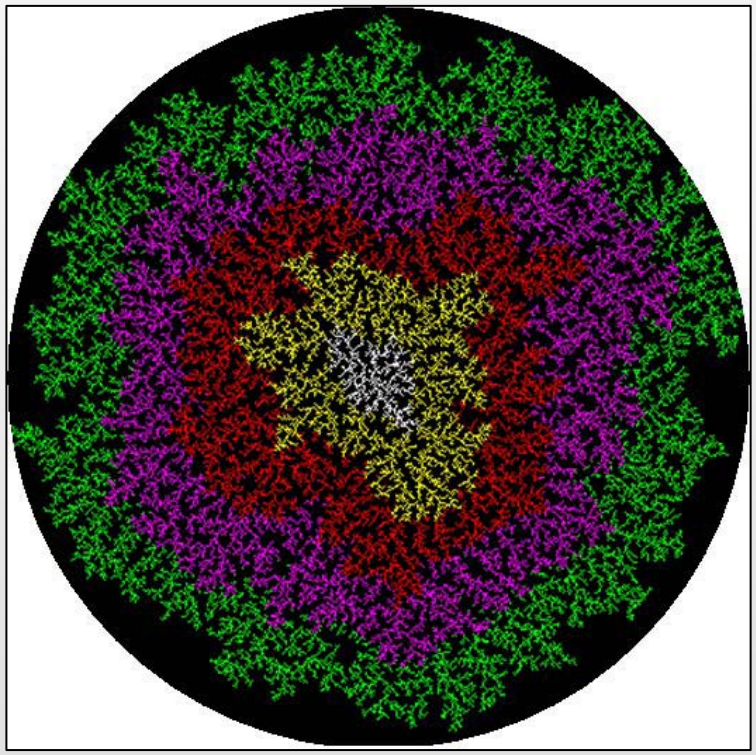
- *A city is connected in that its units of development are physically adjacent*
- *Each unit of development wants as much space around it as it needs for its function.*

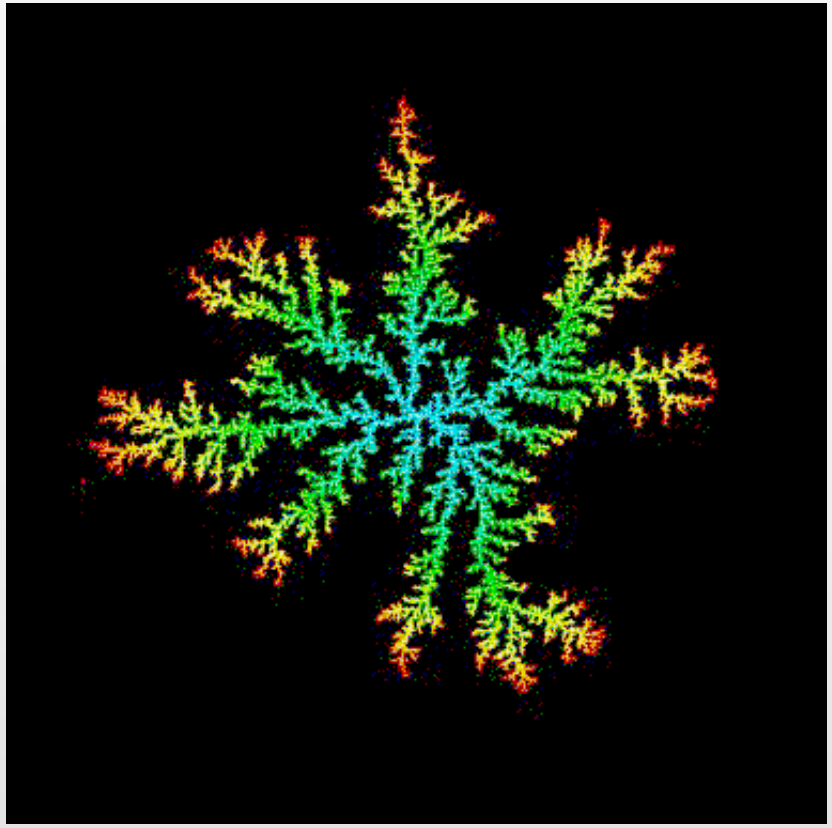
We start with a seed at the centre of a space and then simply let actors or agents randomly walk in search of others who have settled. When they find someone, they stick. That is all.

In essence, this is random walk in space which is can be likened to the diffusion of particles ○ around a source ● but limited to remain within the influence of the source – the city

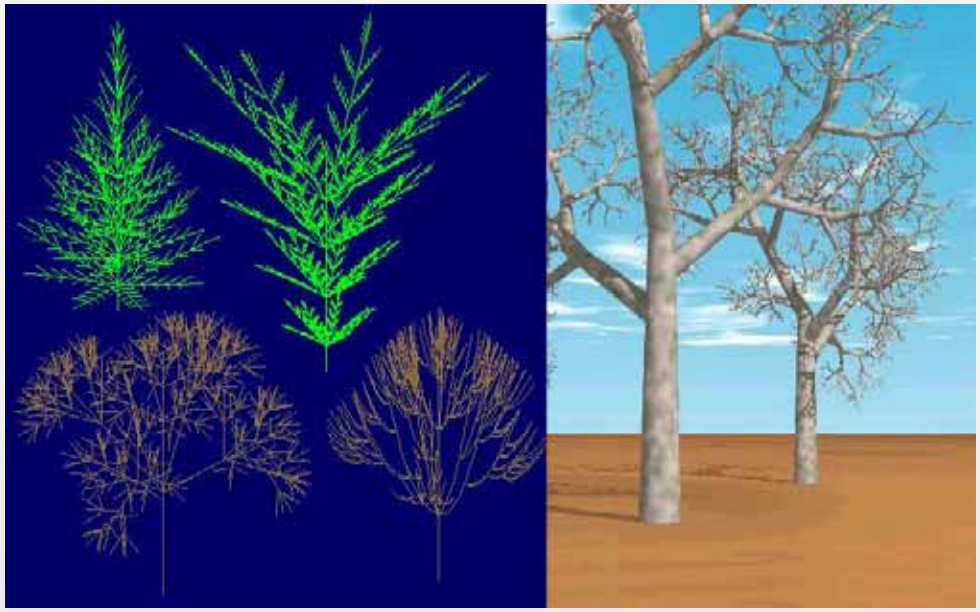








DLA – Diffusion Limited Aggregation



Fractal Trees

Barnsley's Fern

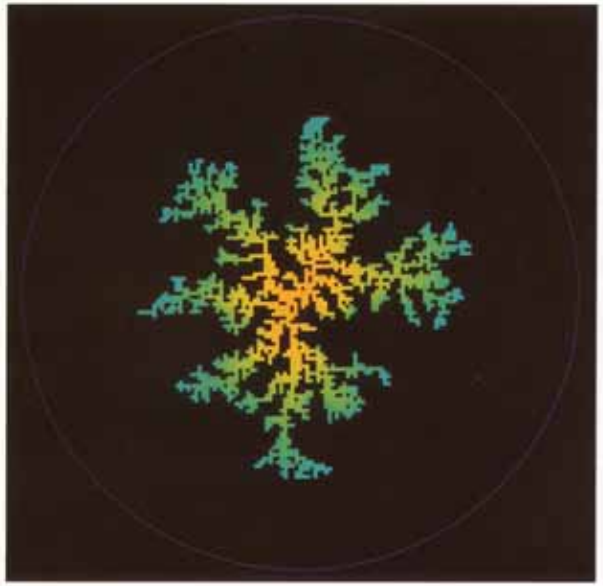


Plate 8.3 *(left)* The Baseline Simulation η =

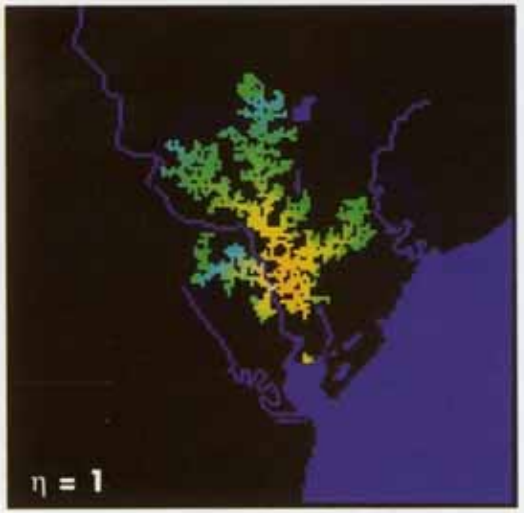
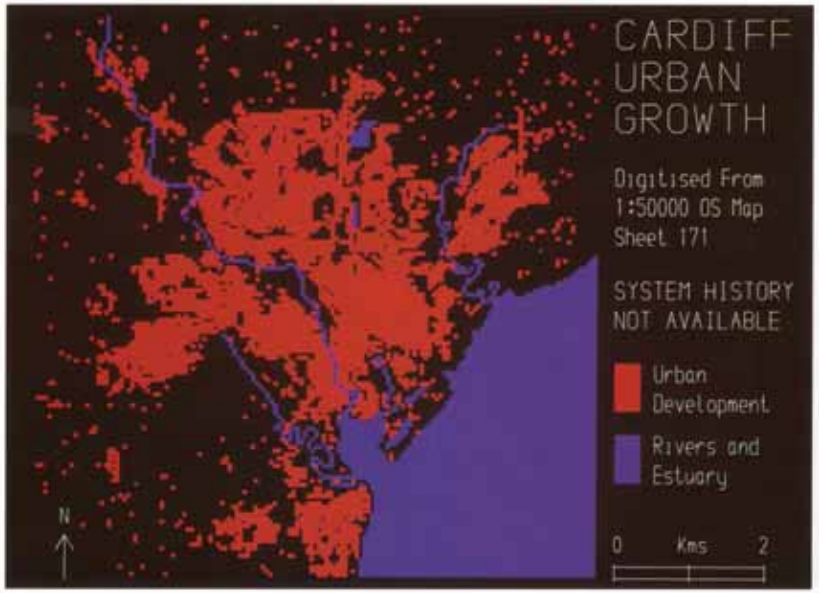


Plate 8.5 *(below)* The Urban Area of Cardiff.



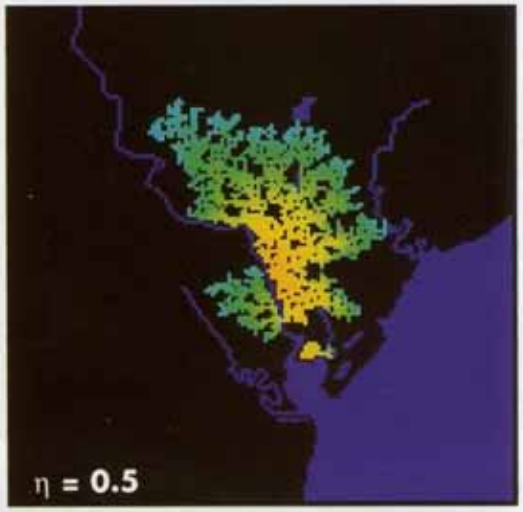
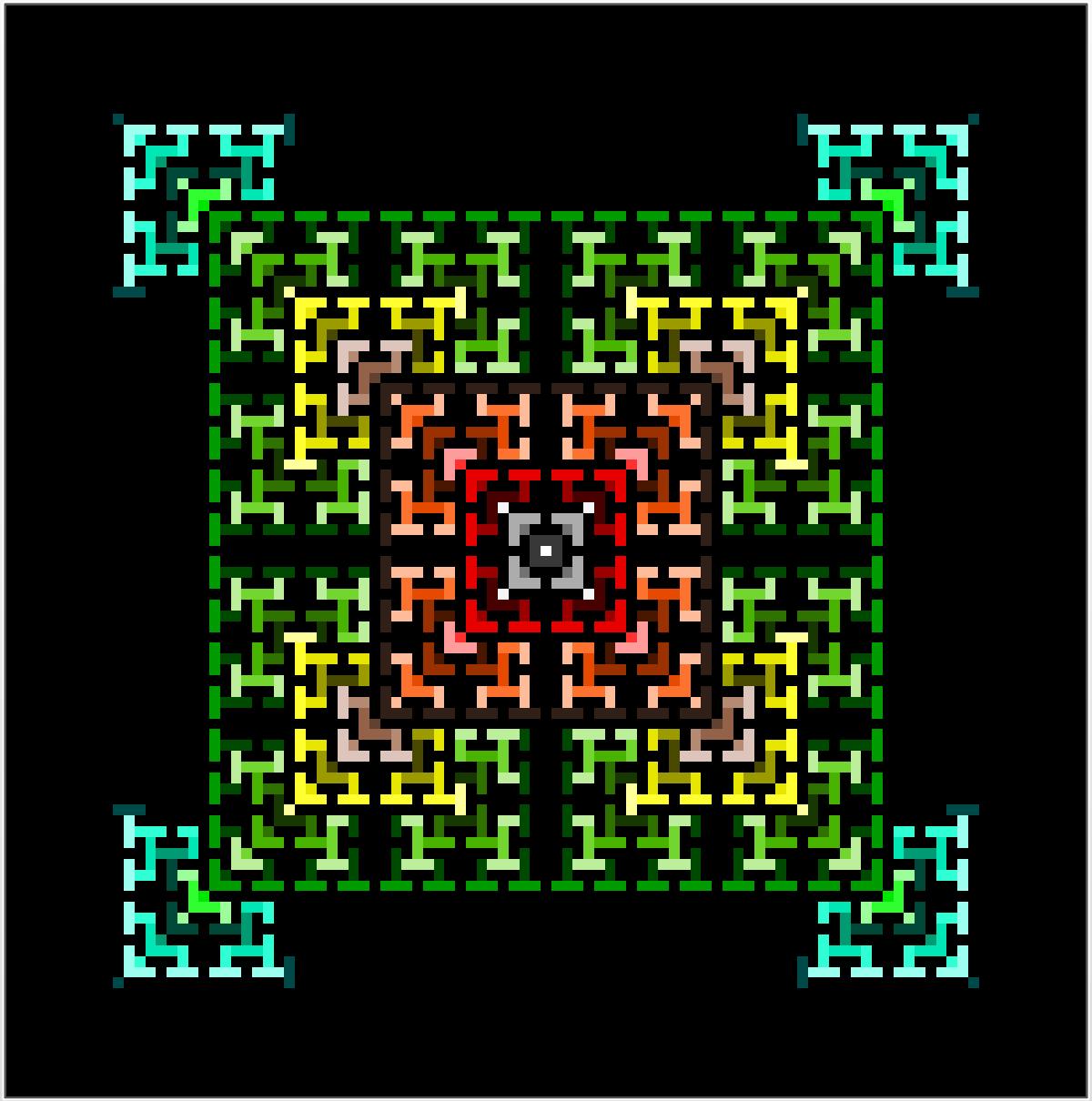


Plate 8.6 Simulating the Urban Growth

Modelling Planned Cities

In some senses, planned cities are simply what we would like in a perfectly ordered world. Planned cities assume a perfect order of some sort which is an ideal to be aspired for. But can such order ever be created? Do people behave in a manner or will they behave in a manner that is consistent with a top down order?

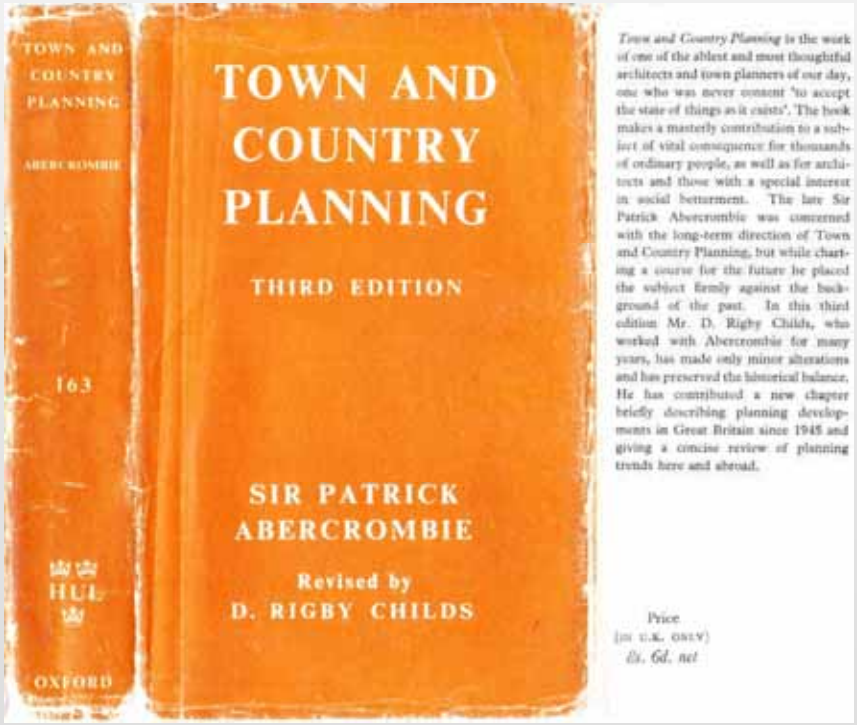
But first, imagine we throw out the randomness, what do we get. Here is an illustration using our simplest organically growing fractal city ….



Many architects and planners have idealised towns in this way – suggesting that the ideal form is inherent in the real form

Sir Patrick Abercrombie in his little book published in the 1930s did so

And here are some of his ideals in terms of town forms



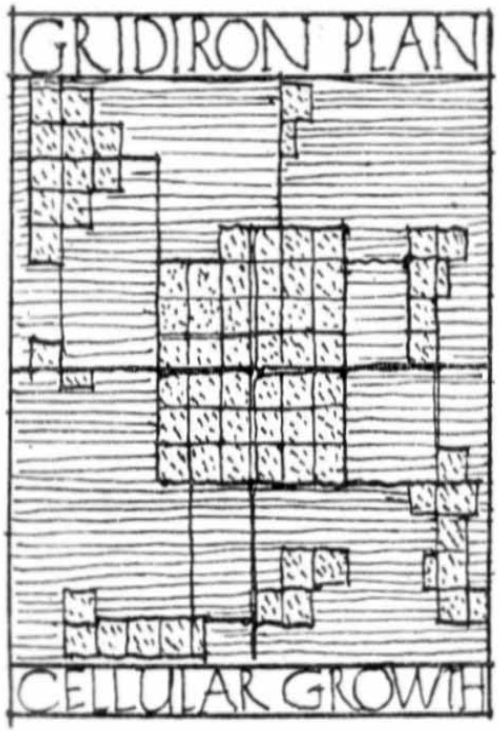


FIG. 1.

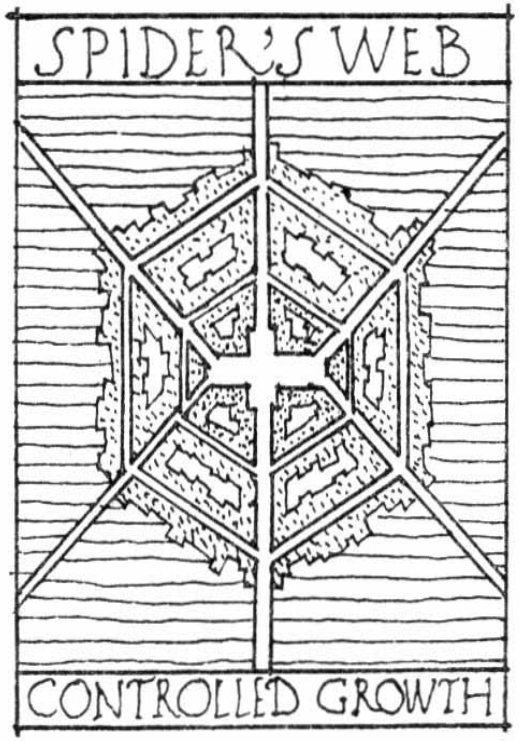


FIG. 3.

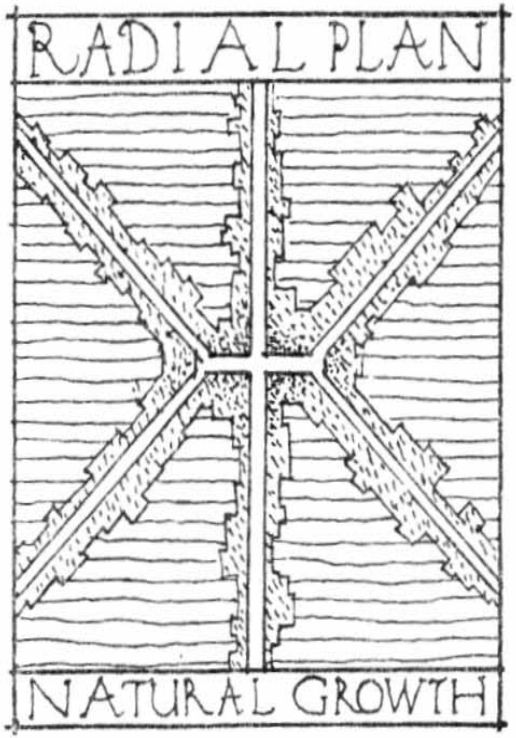


FIG. 2.

How do we grow such forms? – well, not so very different really from those we have seen – we use a modular algorithm which is a cellular automata (CA).

We define

- a *grid of cells*,
- a *neighbourhood* around each cell which is composed of the nearest cells,
- and some *rules* for how what happens in the neighbourhood affects the development of the cell in question.

This is Cellular Automata (CA). We can build machines that generate cities this way with the rules based on the functions and processes that lead to growth and change. It works like this.

(a)

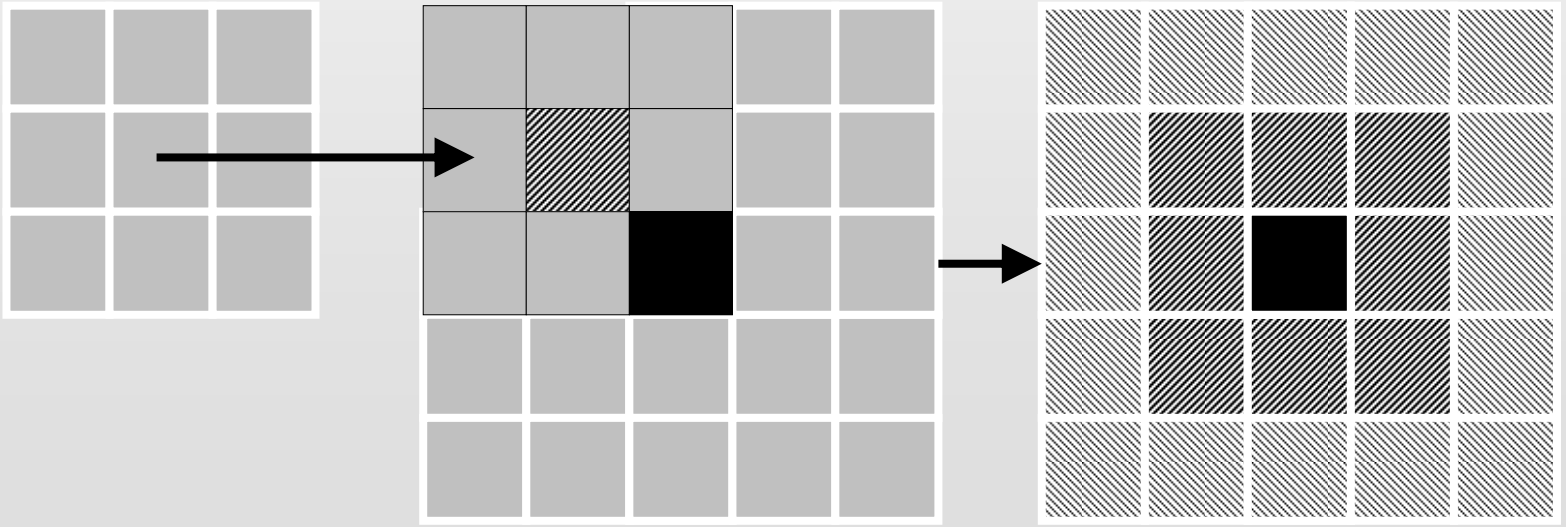
The neighbourhood is composed of 8 cells around the central cell

(b)

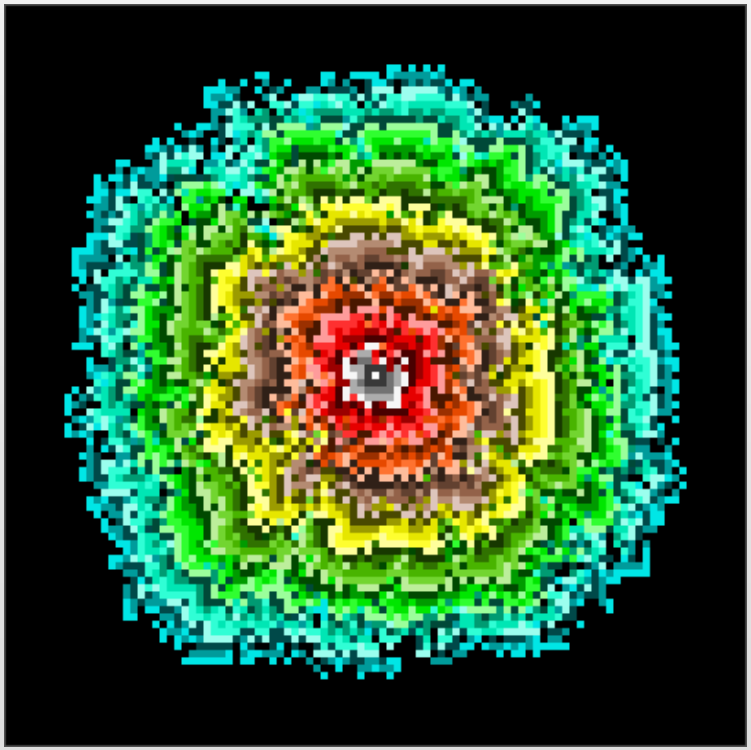
Place the neighbourhood over each cell on the grid. The ***rule*** says that if there is one or more cells developed (black) in the neighbourhood, then the cell is developed.

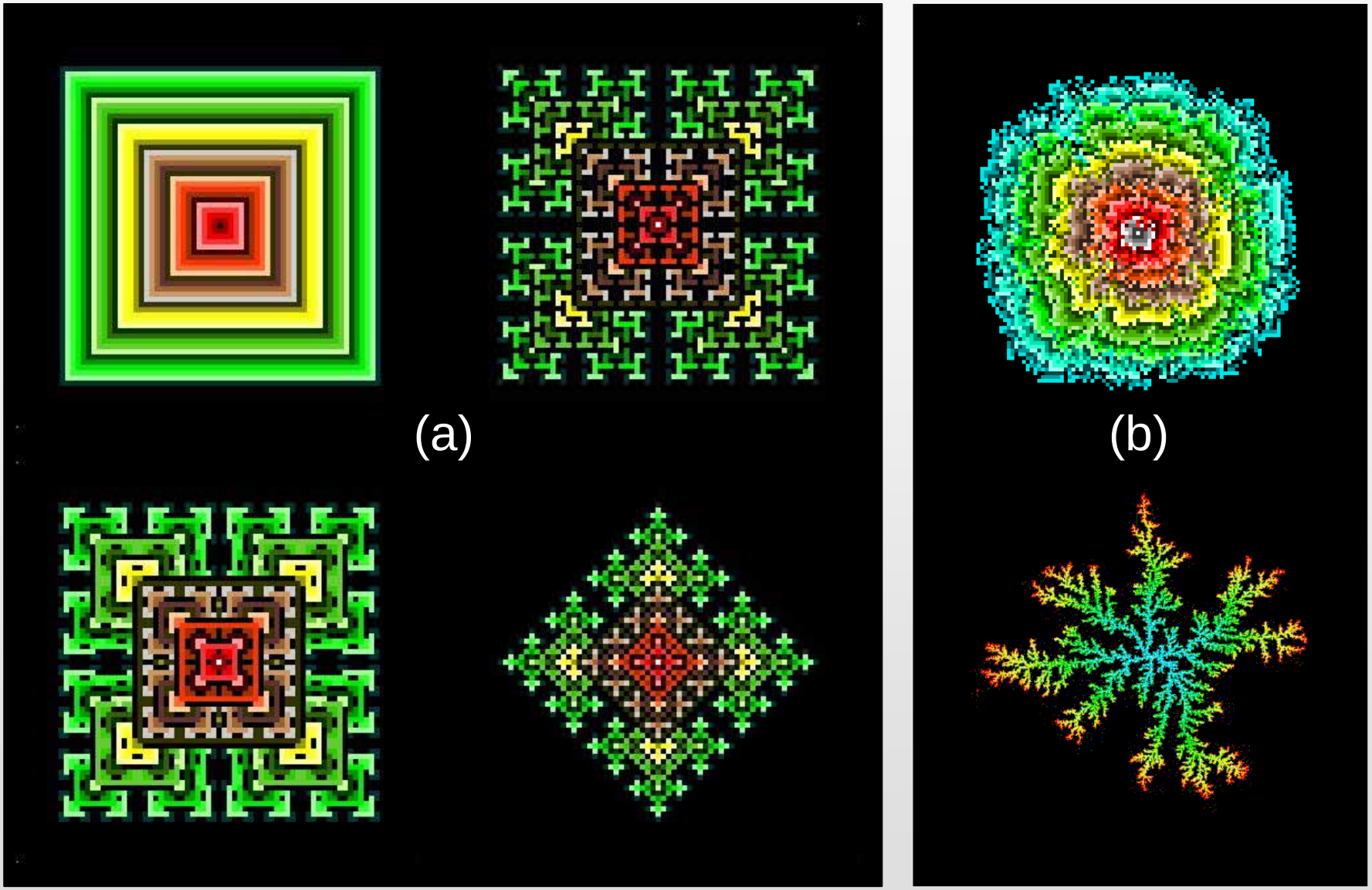
(c)

If you keep on doing this for every cell, you get the diffusion from the central cell shown below.

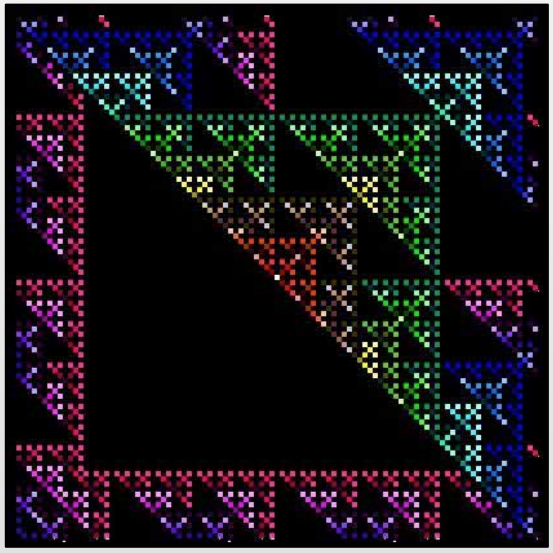


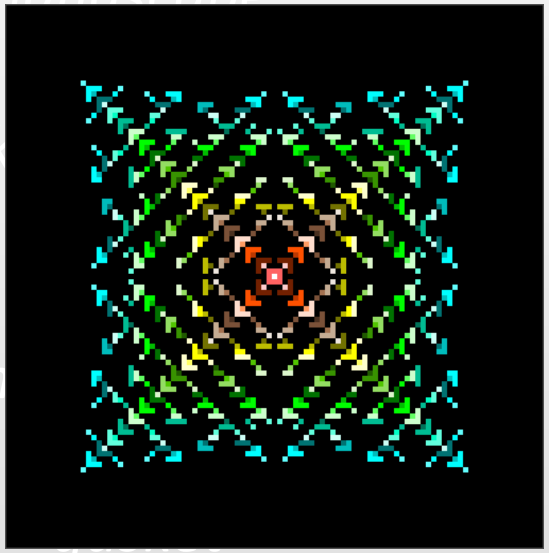
And here are various cellular constructions which reflect growing cities under different kinds of rules – they grow from their centres according to the density of development in their neighbourhoods



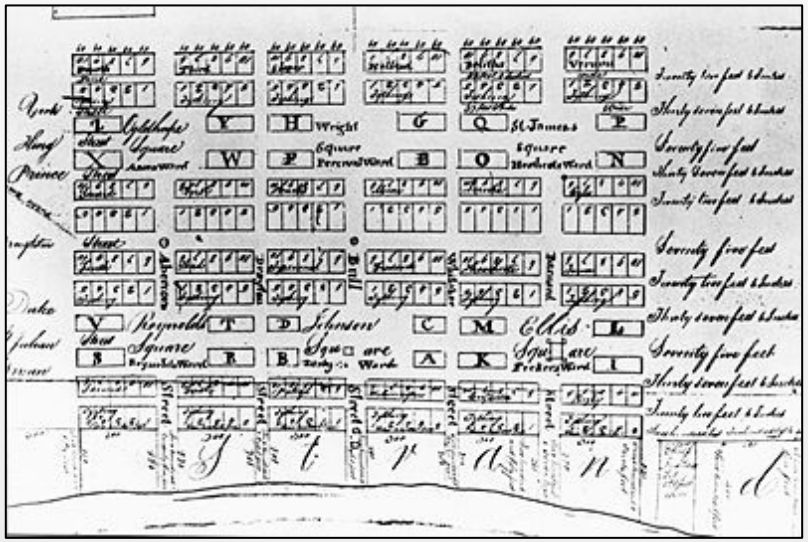

(a)
(b)

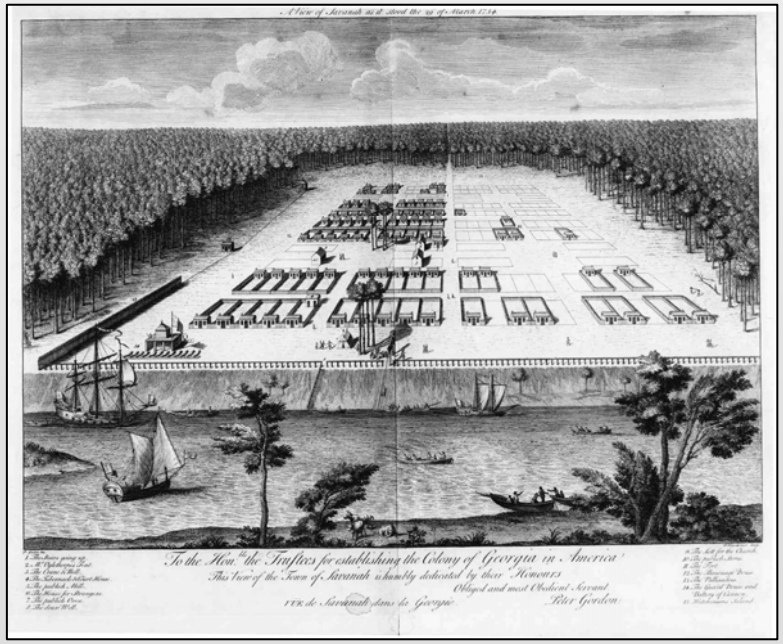
There are literally millions of feasible or reasonable shapes we can generate with different rule sets….. A countable infinity? Maybe?

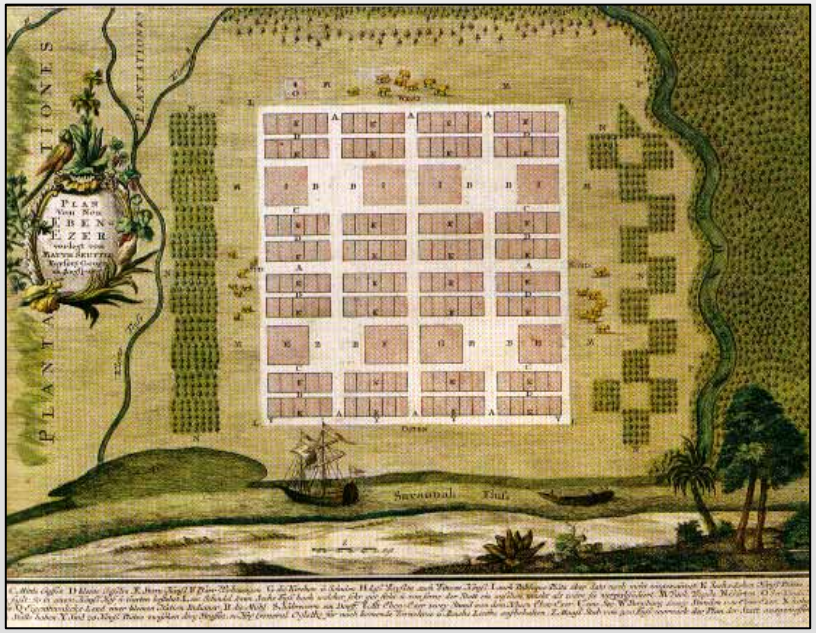




Here is one from history – Savannah, Georgia




To the Hon.ble the Trustees for establishing the Colony of Georgia in America
This View of the Town of Savanah is humbly dedicated by their Honours
Obliged and most Obedient Servant
Peter Gordon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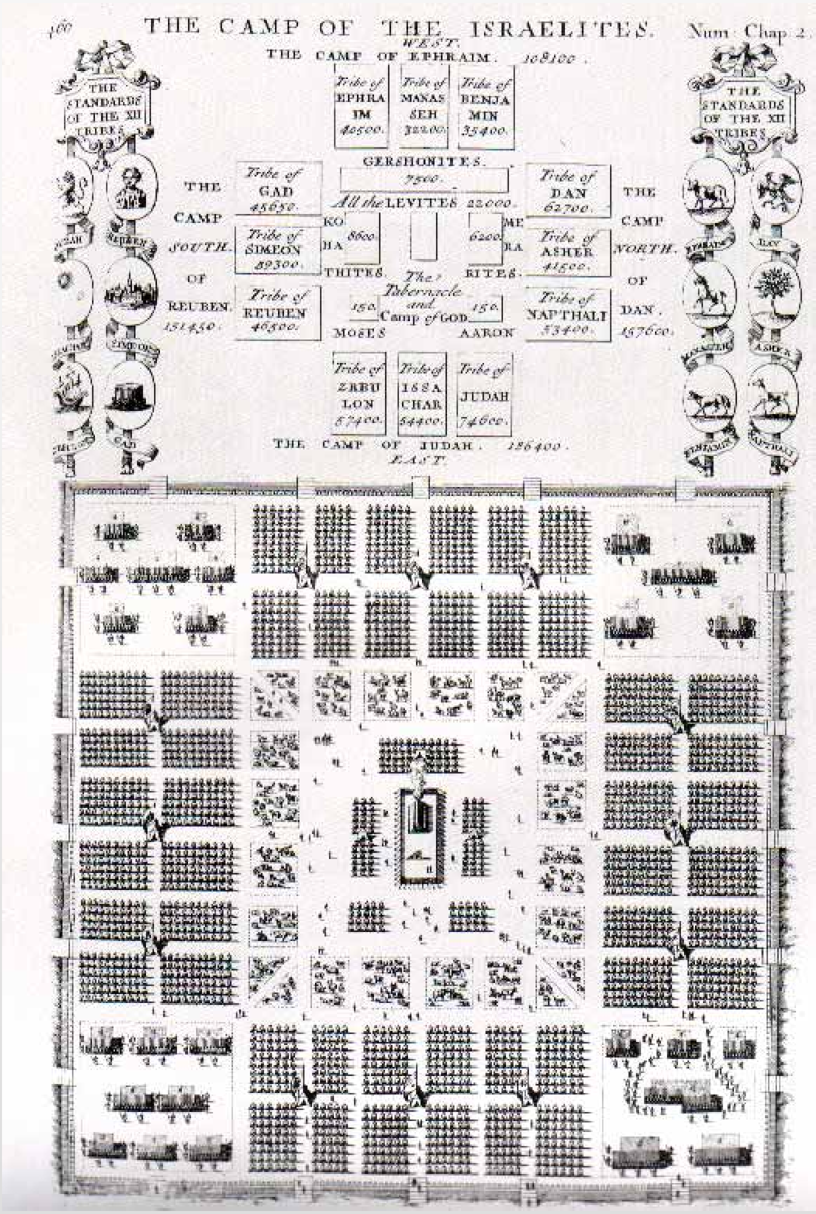
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Tribe of MANASSEH 32200.
Tribe of BENJAMIN 35400.
GERSHONITES. 7500.
All the LEVITES 22000.
Tribe of GAD 45650.
Tribe of SIMEON 59300.
Tribe of REUBEN 46500.
THE CAMP SOUTH. OF REUBEN. 151450.
Tribe of DAN 62700.
Tribe of ASHER 41500.
Tribe of NAPTHALI 53400.
THE CAMP NORTH. OF DAN. 157600.
The Tabernacle and Camp of GOD.
MOSES
AARON
Tribe of ZEBULON 57400.
Tribe of ISSACHAR 54400.
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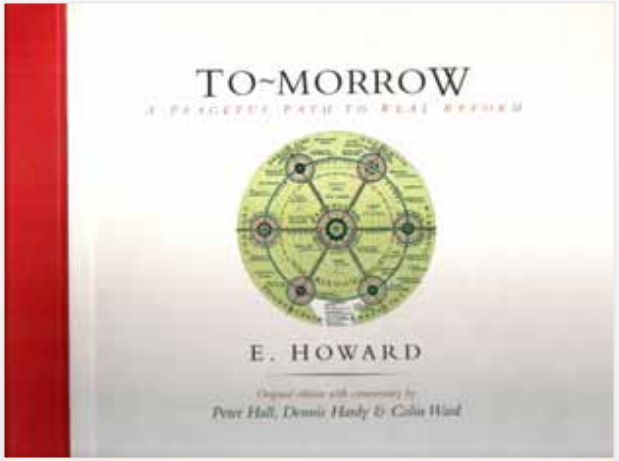
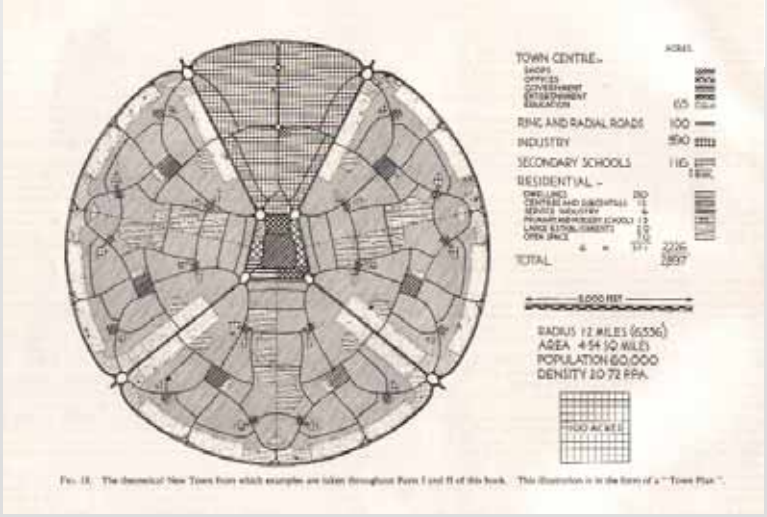

TO-MORROW
E. HOWARD
Peter Hall, Dennis Hardy & Colin Ward


TOWN CENTRE
RING AND RADIAL ROADS
INDUSTRY
SECONDARY SCHOOLS
RESIDENTIAL
TOTAL
RADIUS 12 MILES (6336)
AREA 454 SQ MILES
POPULATION 60,000
DENSITY 20·72 PPA


— No 7 —
GROUP OF SLUMLESS SMOKELESS CITIES
CENTRAL CITY
MUNICIPAL
CANAL
GRAND CANAL
INTER MUNICIPAL RAILWAY
POPULATION 12,000

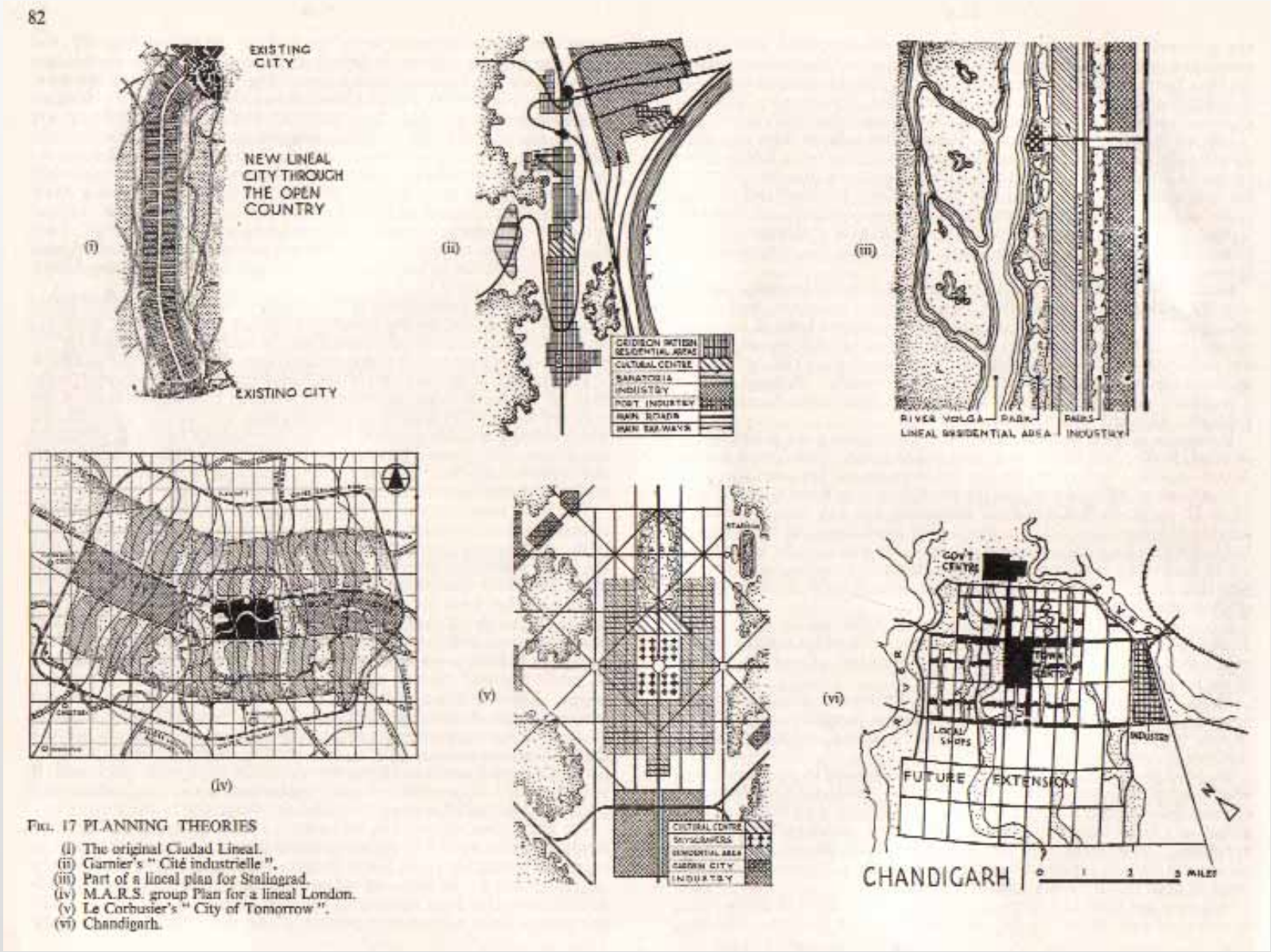


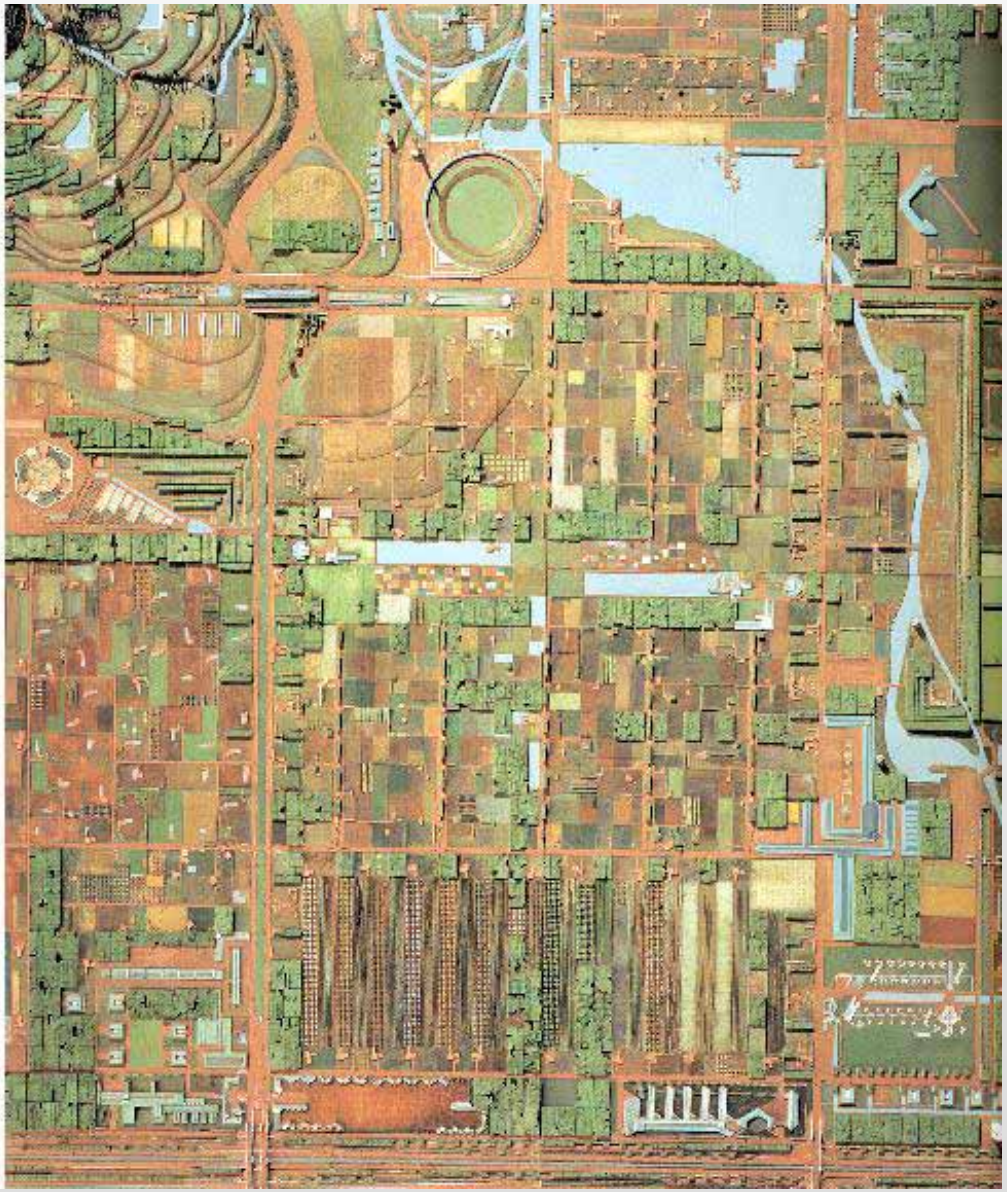
FIG. 17 PLANNING THEORIES

(i) The original Ciudad Lineal.
(ii) Garnier's " Cité industrielle ".
(iii) Part of a lineal plan for Stalingrad.
(iv) M.A.R.S. group Plan for a lineal London.
(v) Le Corbusier's " City of Tomorrow ".
(vi) Chandigarh.

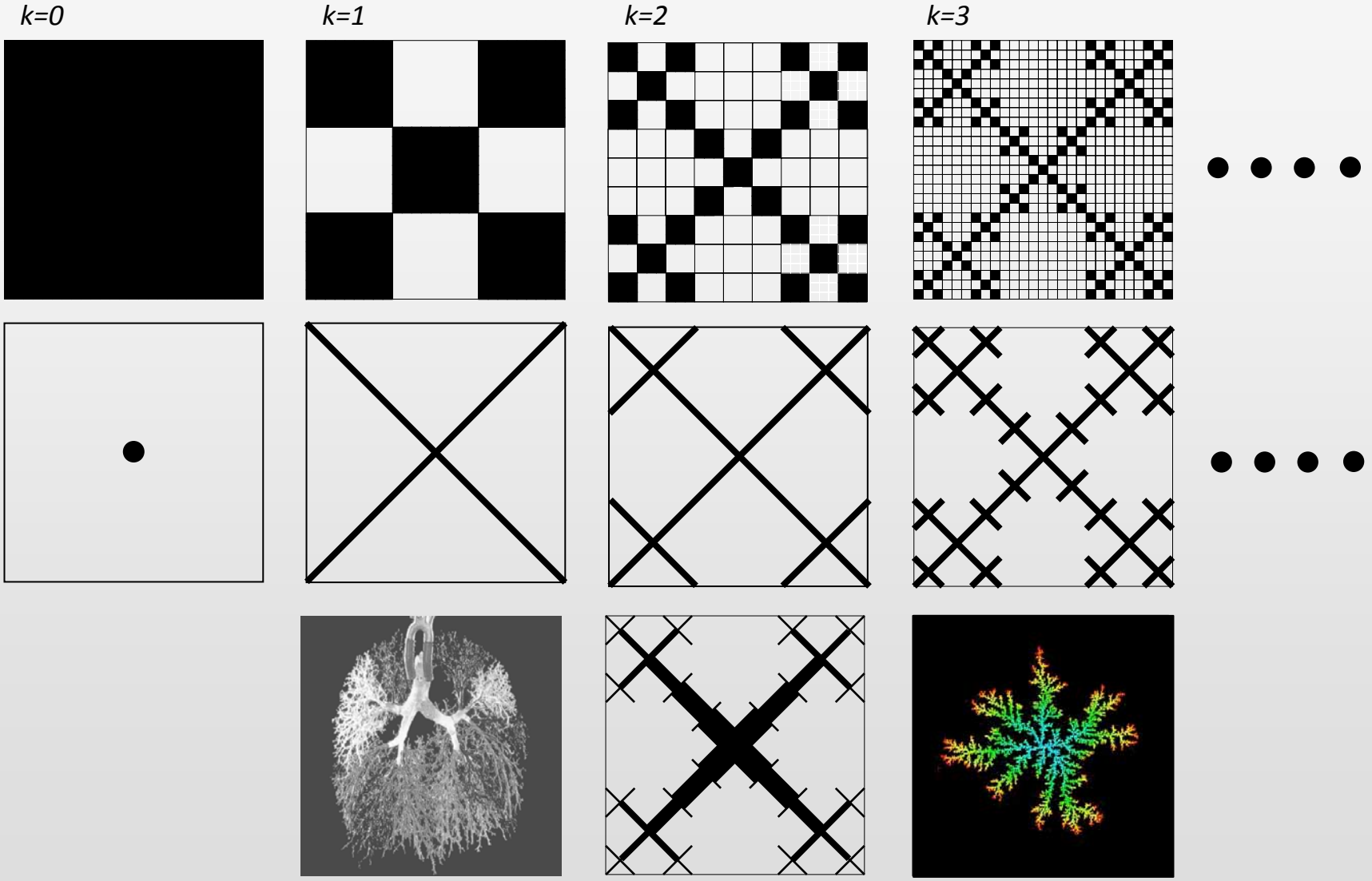
Broadacre City

Frank Lloyd Wright, 1934

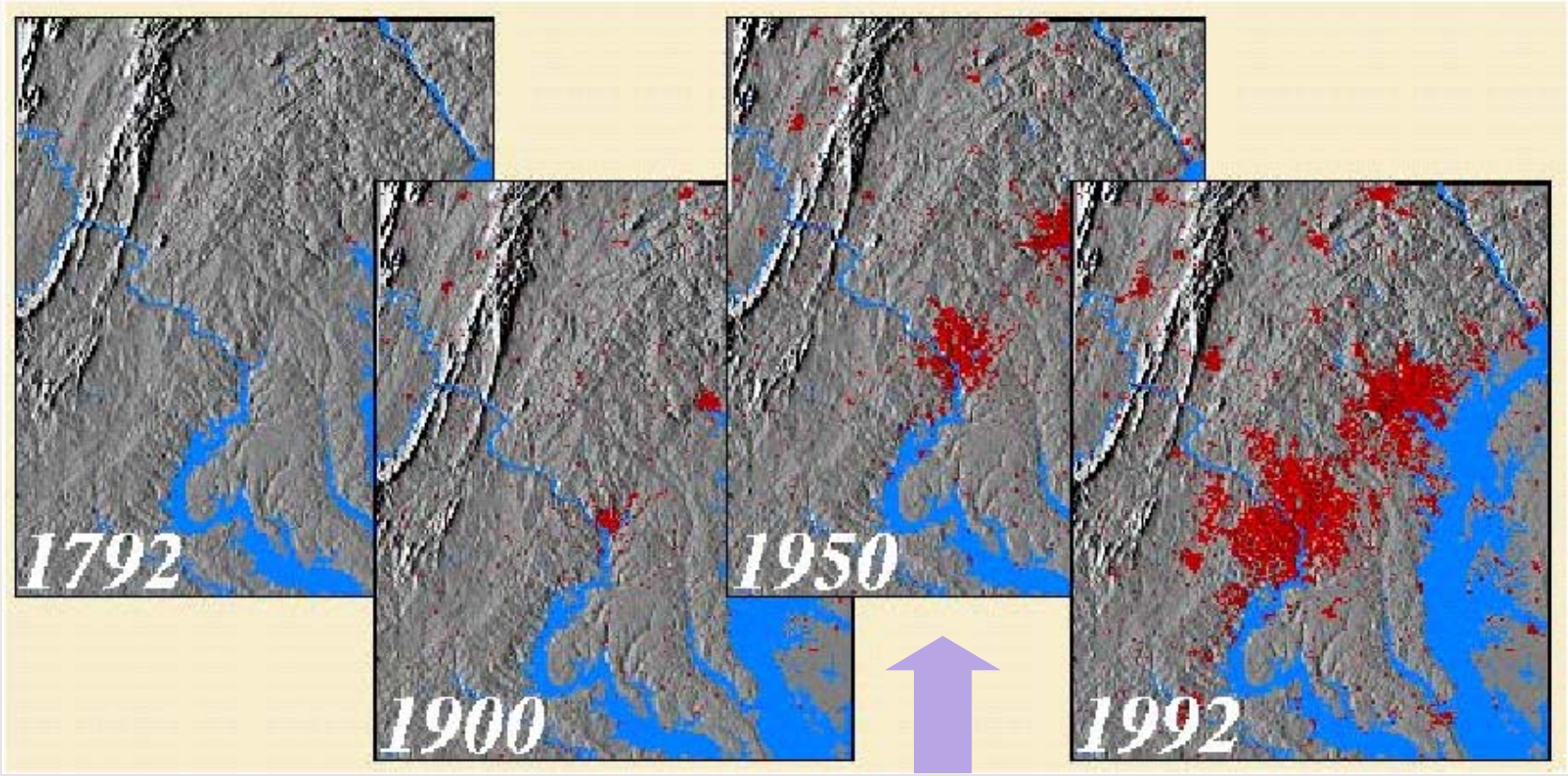
A square mile section of what was proposed to be a continuous fabric of inhabited landscape across the American continent



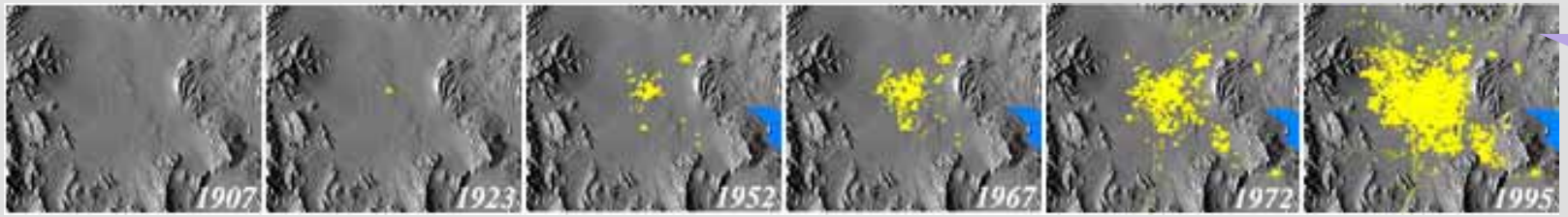
And these ideal cellular forms merge into the real…..



Real City Growth



Growth through time: Washington DC-Baltimore Las Vegas



Exploring the Design Space

Once we have a model like CA which generates deterministic regular or probabilistic irregular fractal shapes, then we have a mechanism for exploring many possible town shapes.

We do this by varying the rules. A simple way to do this is to vary the sticking probability in the DLA model. Here we can generate all possible forms between one and two dimensional – between the linear and the concentric as ……

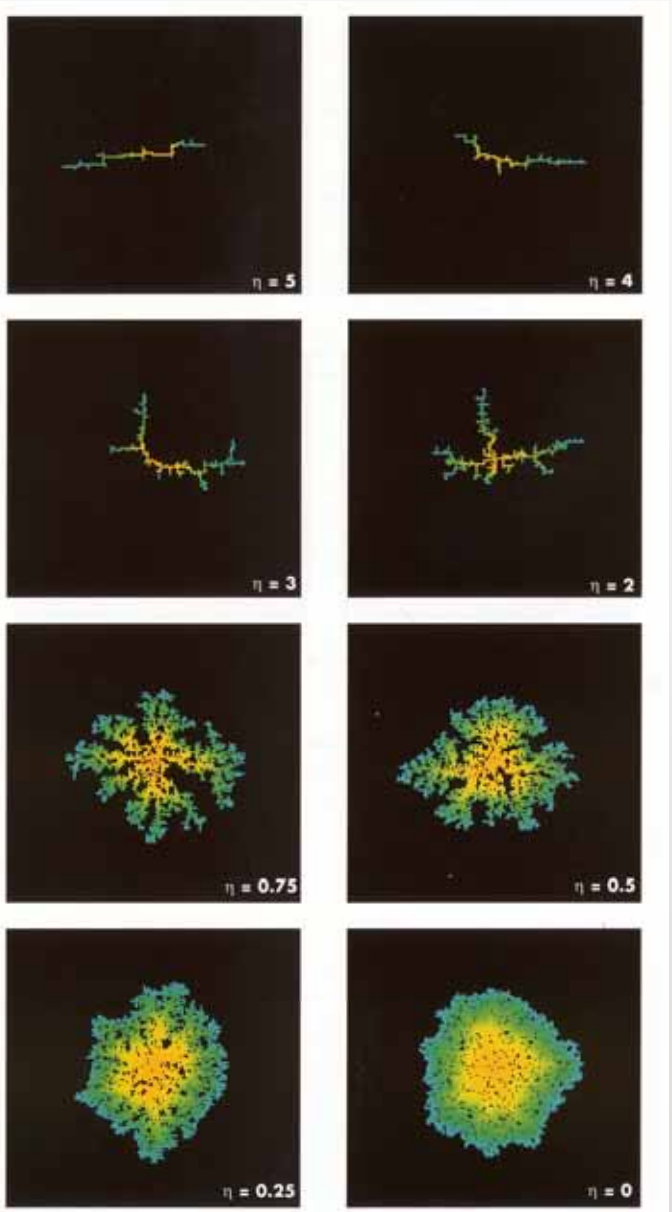


Plate 8.4 Urban Forms Generated by Systematic Distortions to the DBM Field

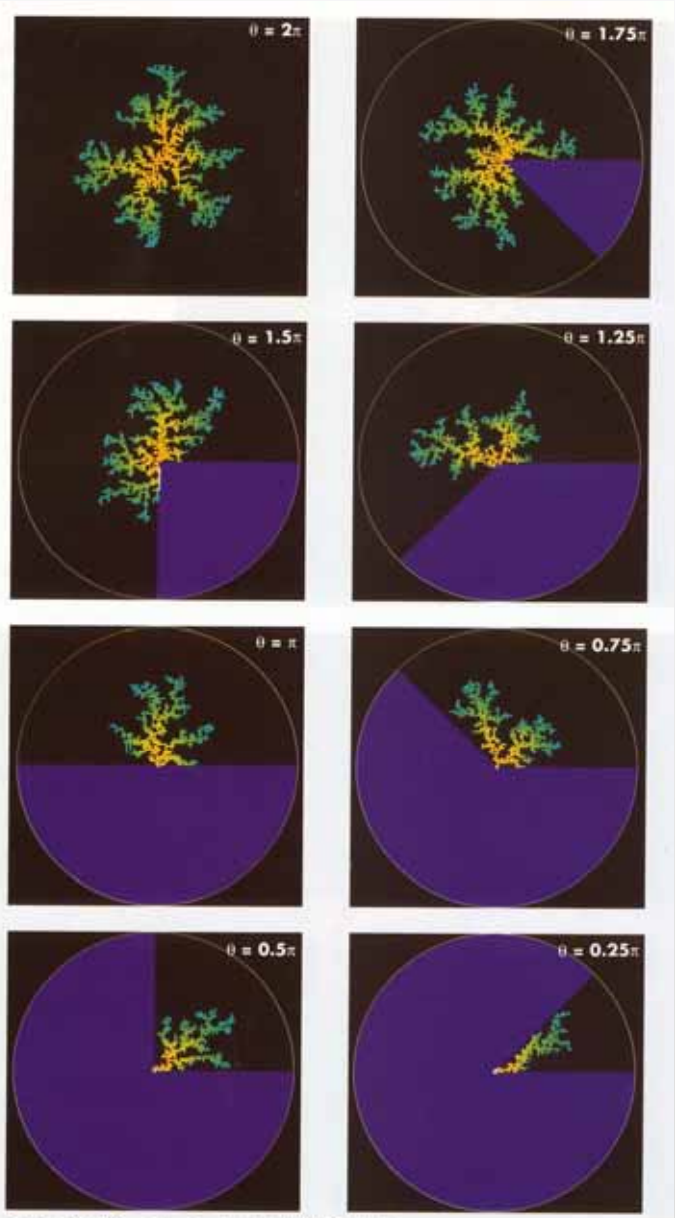


Plate 8.2 Physically Constrained DBM Simulations

Look at the blog – it will be updated with this lecture. And with these lectures in place on Moodle

Questions

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