

Lecture 10: Batty's Lecture 2-2

Fractals and Cities: Simulation Using Cellular Automata

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The course web site: www.spatialcomplexity.info/CUSP

Outline of the Lecture

- 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.

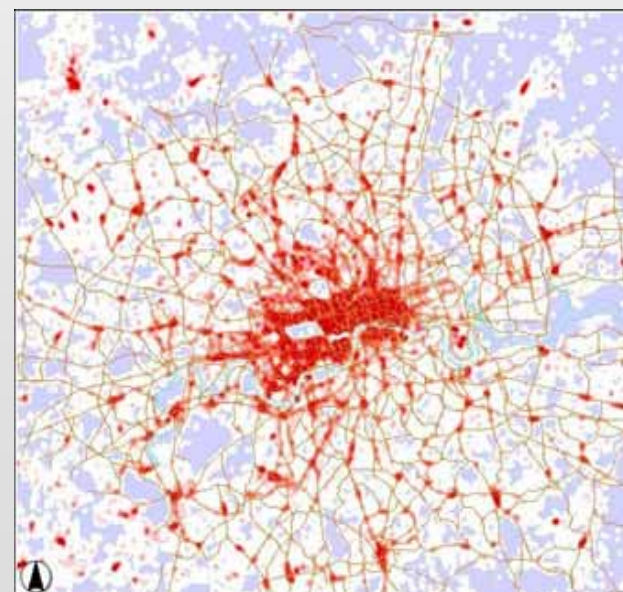
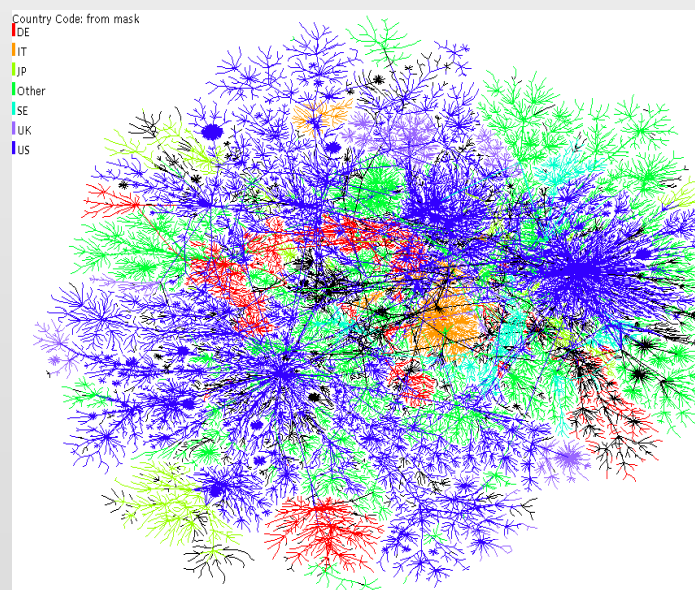
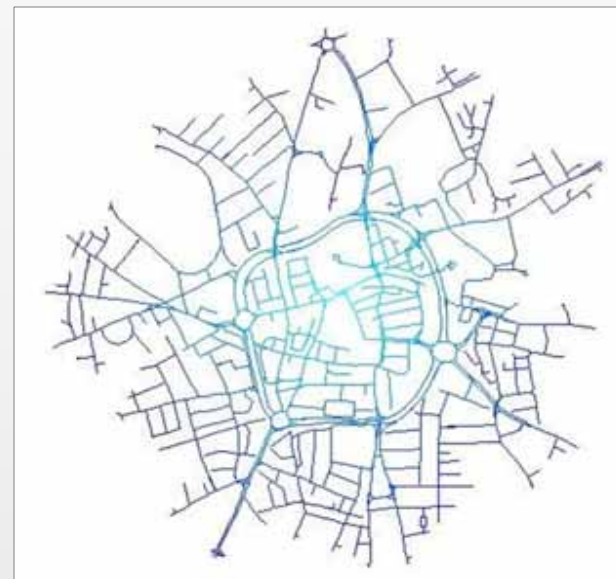
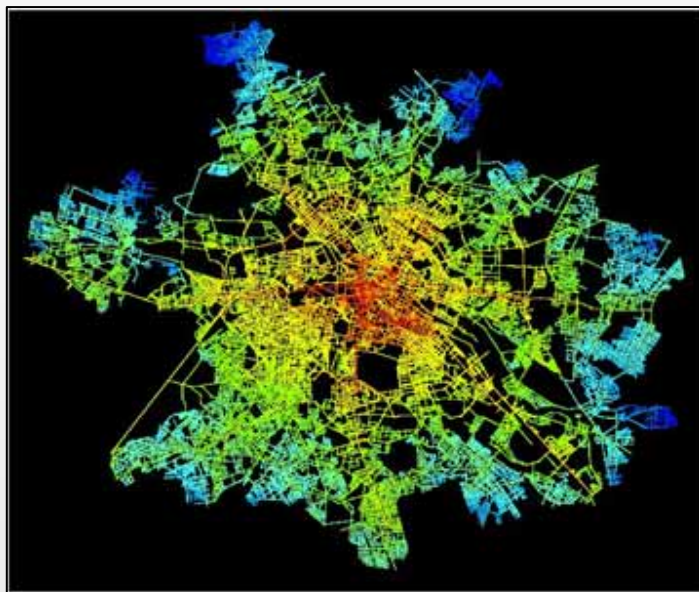
Modularity, Scale, Hierarchy, Rules, Geometry

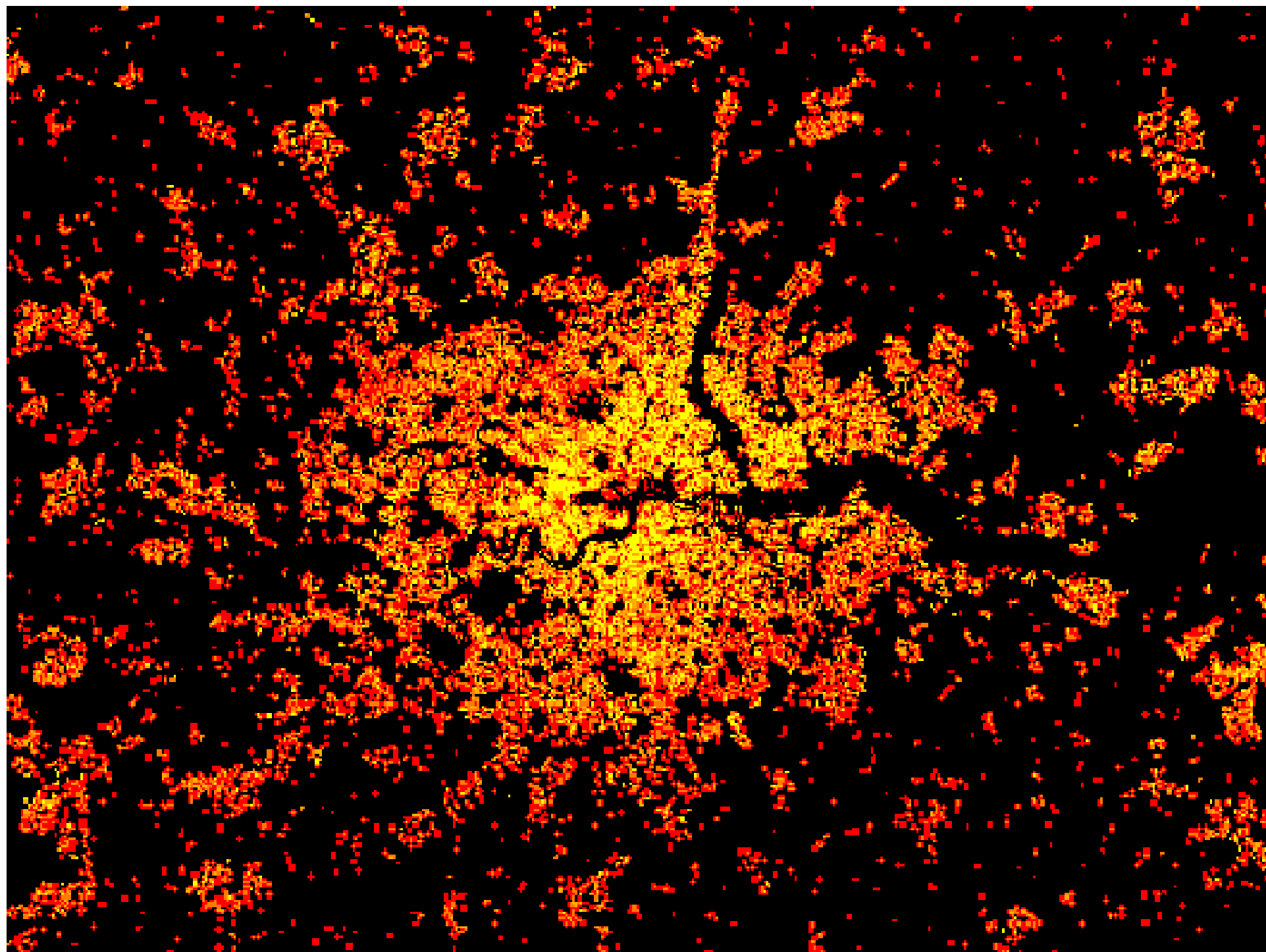
But before we introduce each of these views through geometric and physical models, we want to identify some key issues about complex systems like cities. I want to suggest that all complex systems only hold together through modularity and hierarchy where modules repeat themselves at different scales.

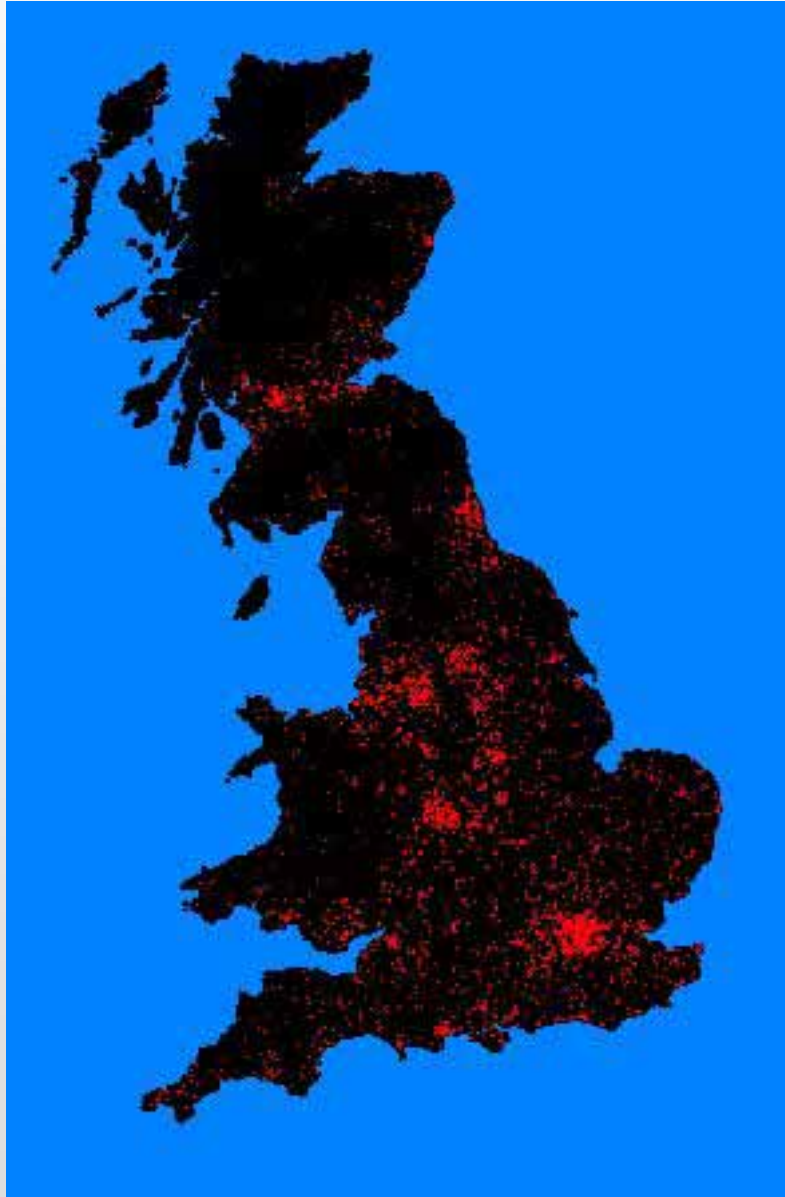
We can build models of cities in this modular fashion noting that geometry constrains what we can do.

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

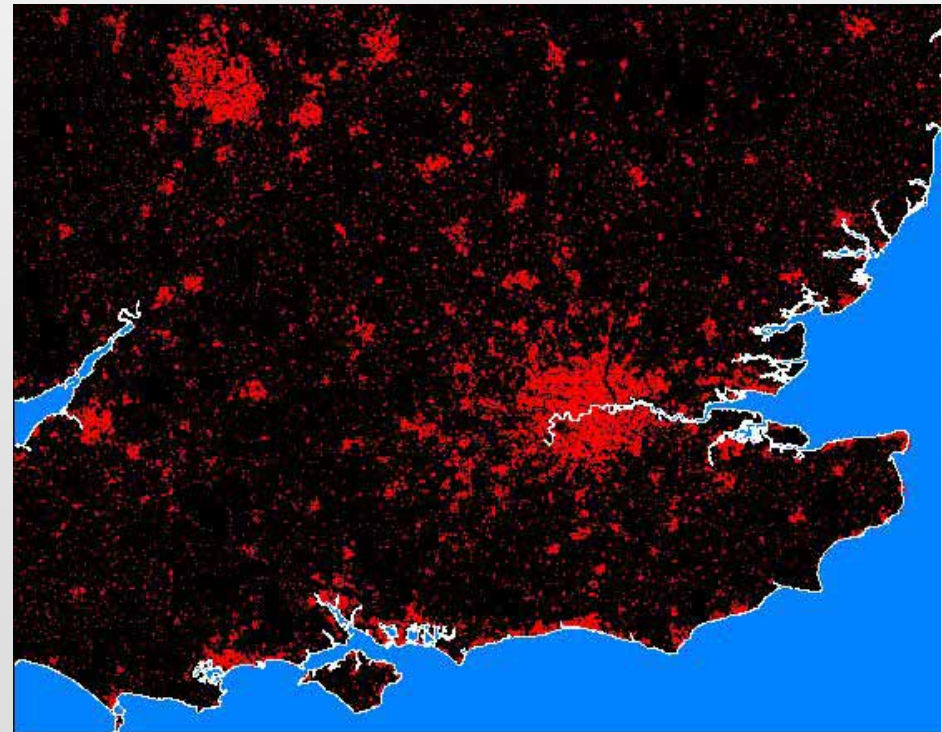
Our models depend on activities competing for space which is always in short supply. Cities grow through agglomeration – economies of scale – which are constrained in terms of transport between the parts and the density at which they can exist – there are many urban economic theories. But let us look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





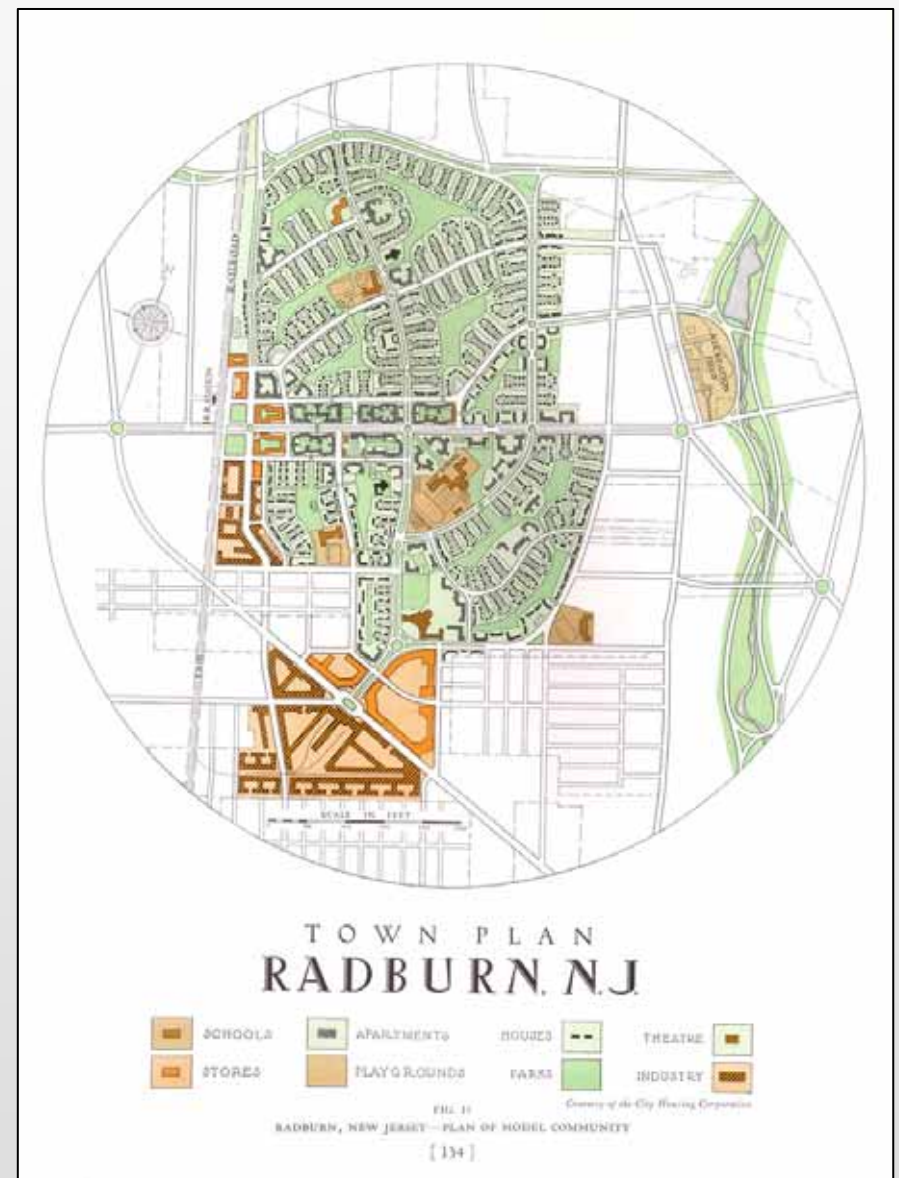
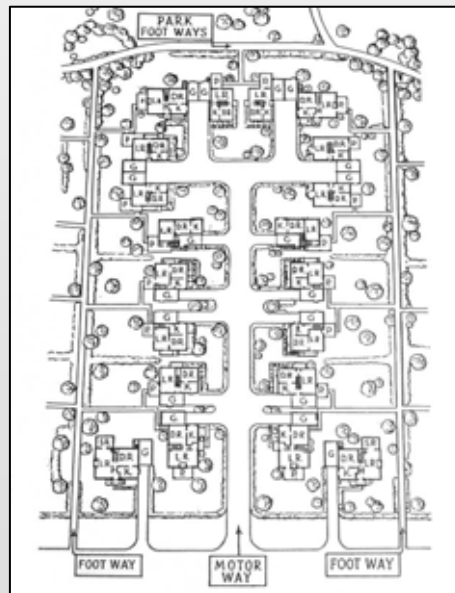


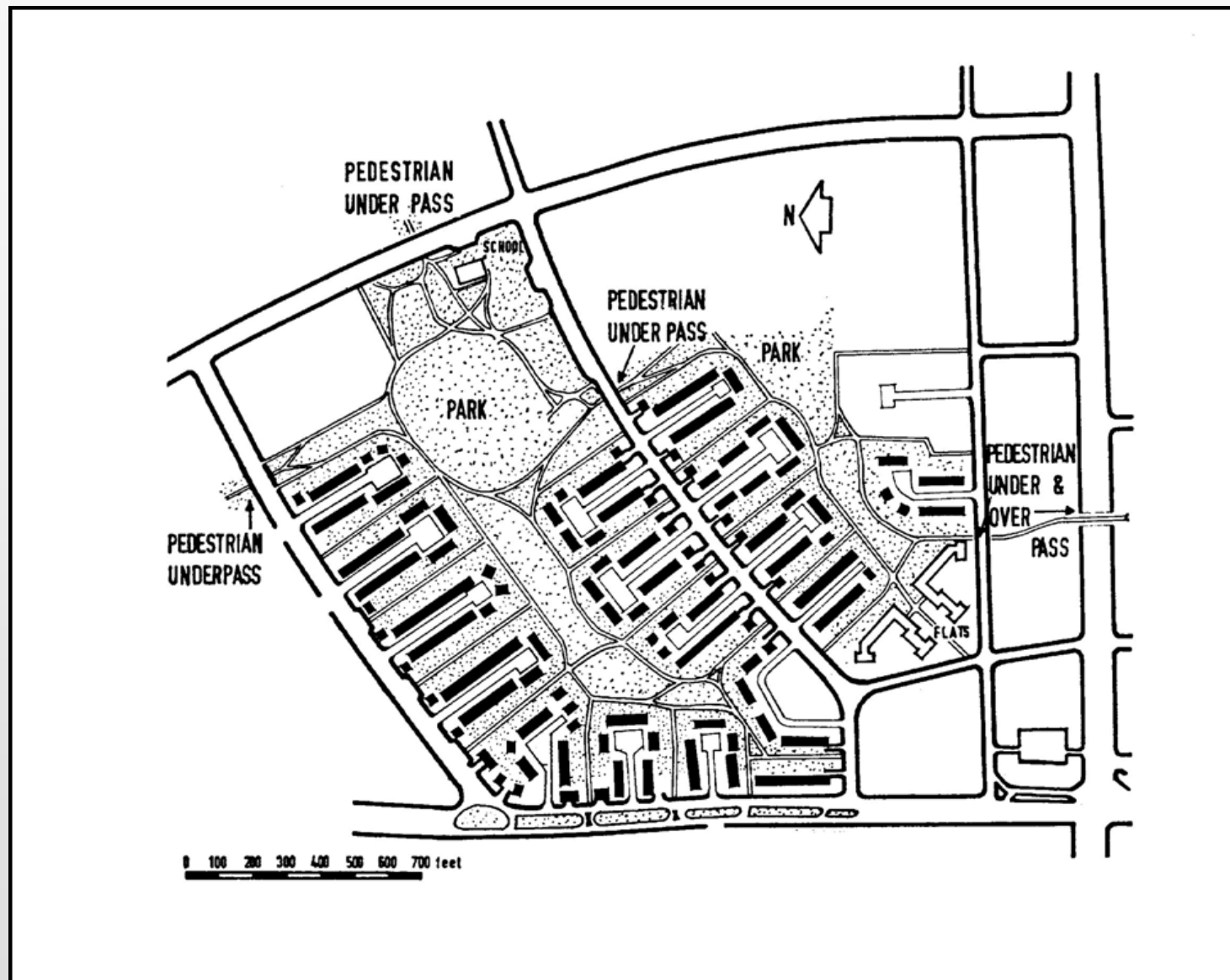
These clusters scale geometrically and their organization is 'fractal'. This is fractal geometry where objects of the same shape exist at all scales

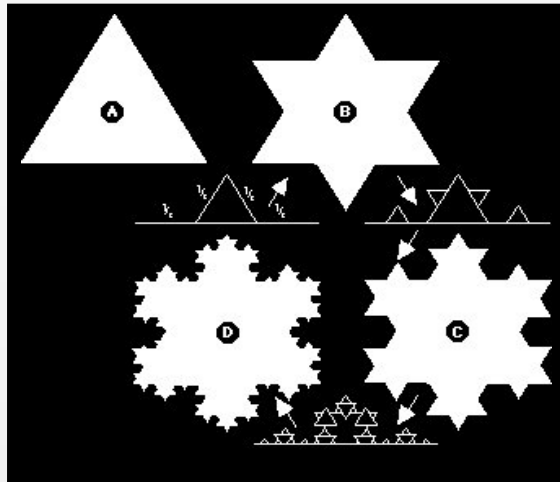




An early 'new town'
RADBURN, NJ
1920s

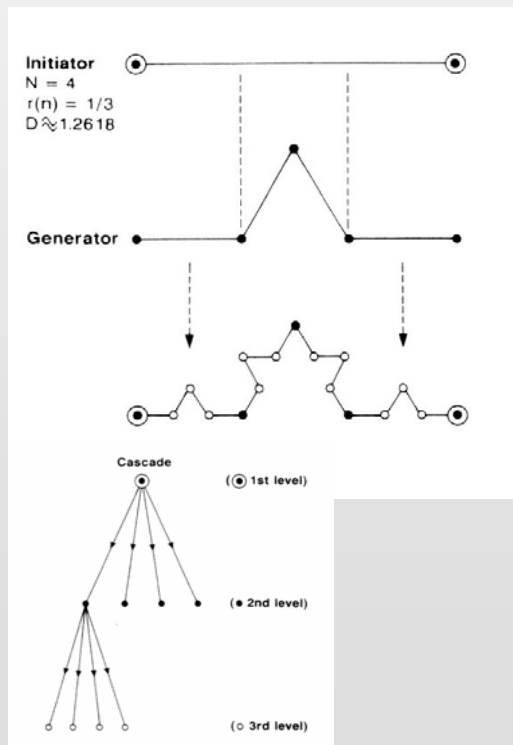




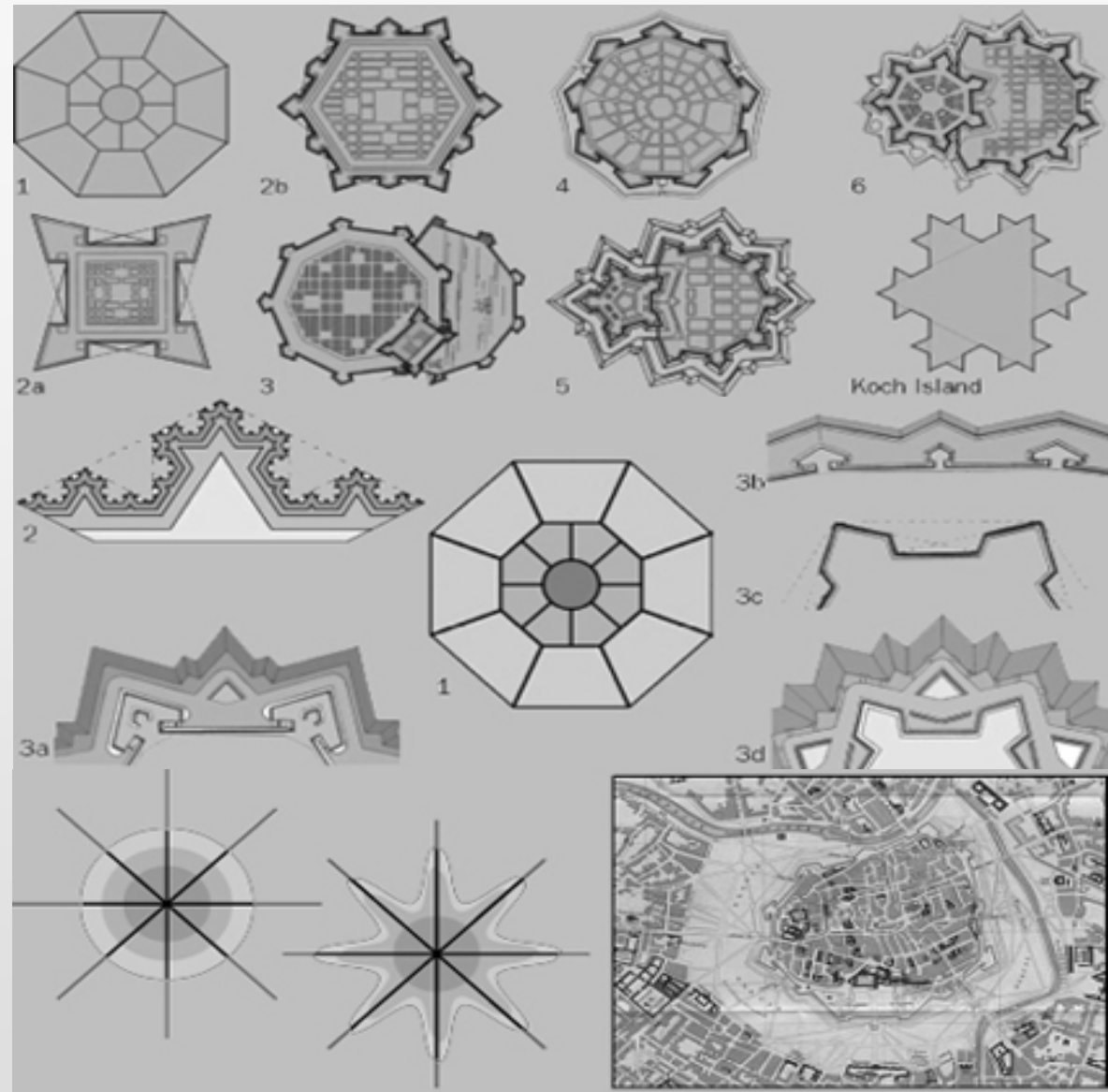
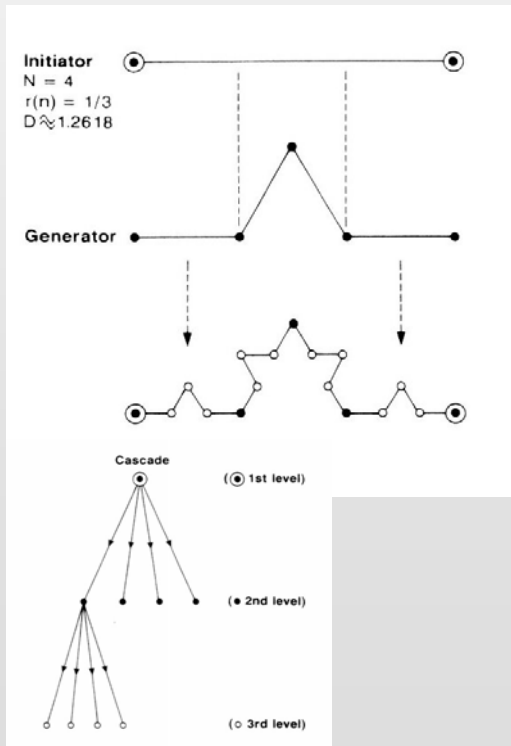
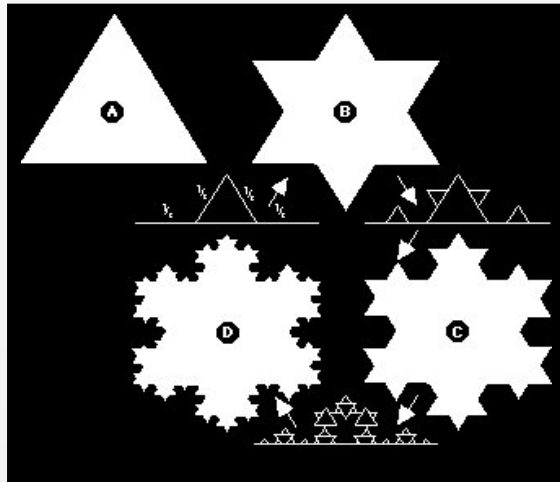


A Way of Generating Such Order

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.



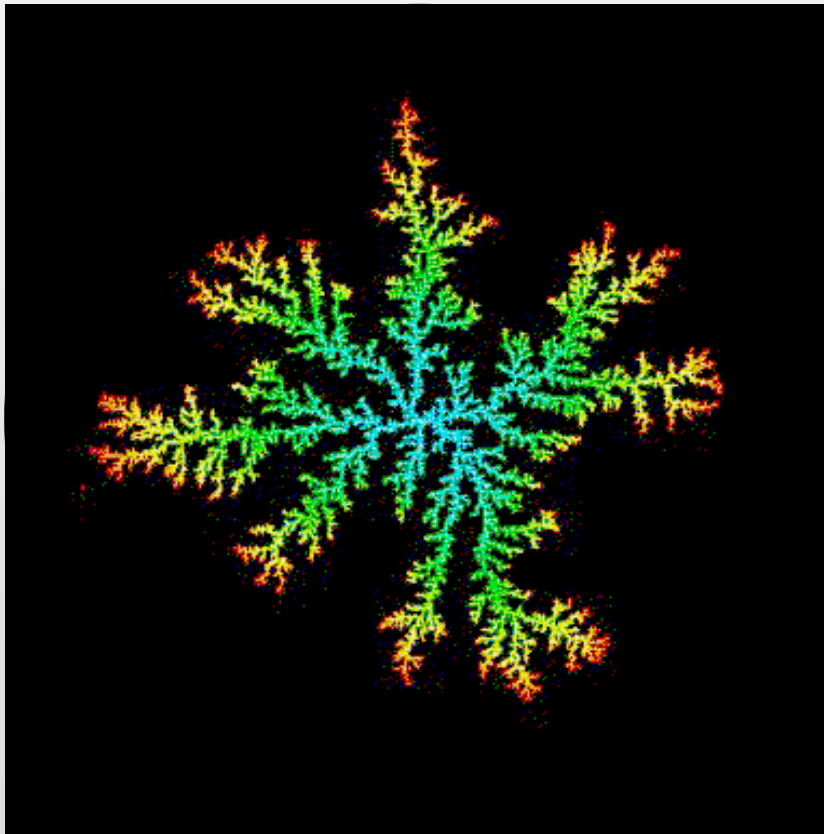
Generating Organically Growing Cities

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.

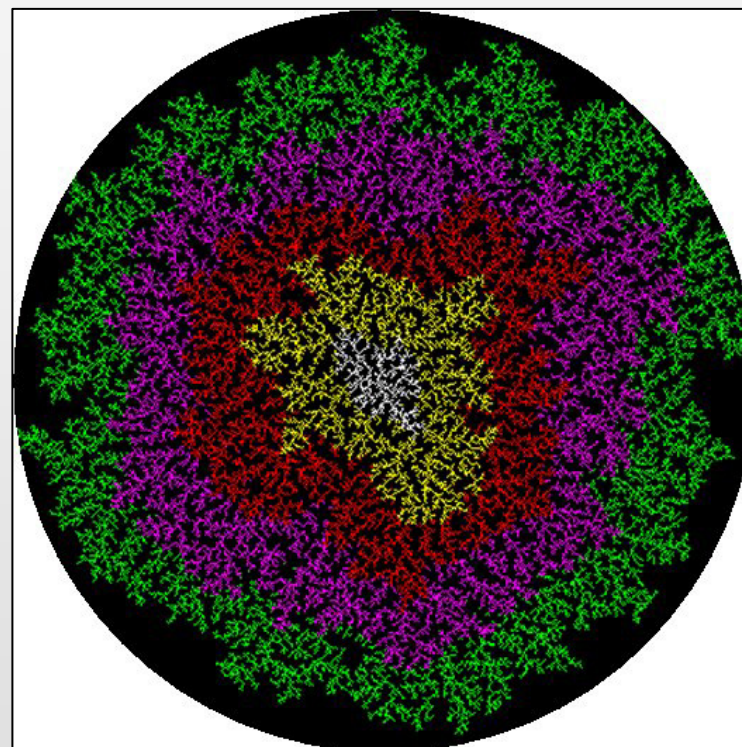
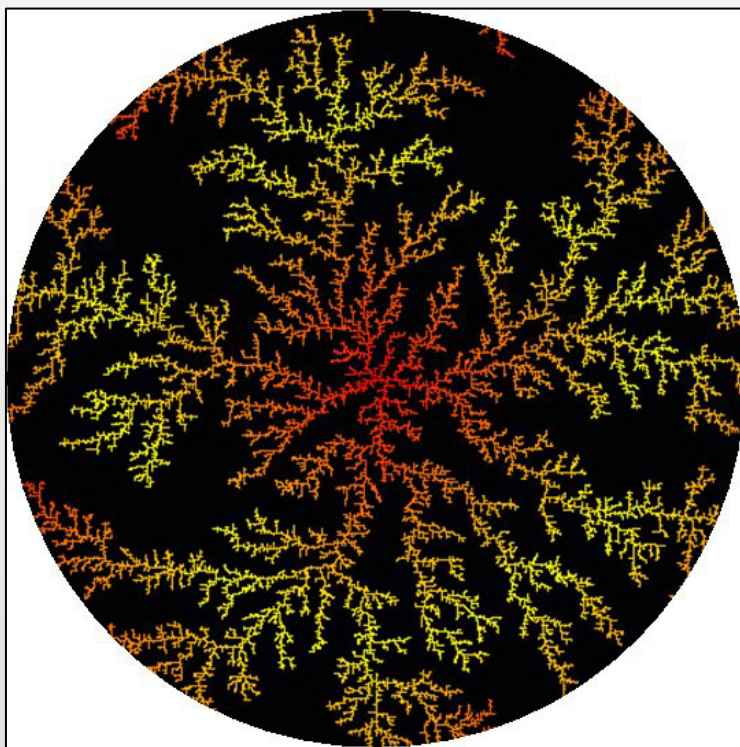
In essence, this is random walk in space which is can be likened to the diffusion of particles around a source but limited to remain within the influence of the source – the city

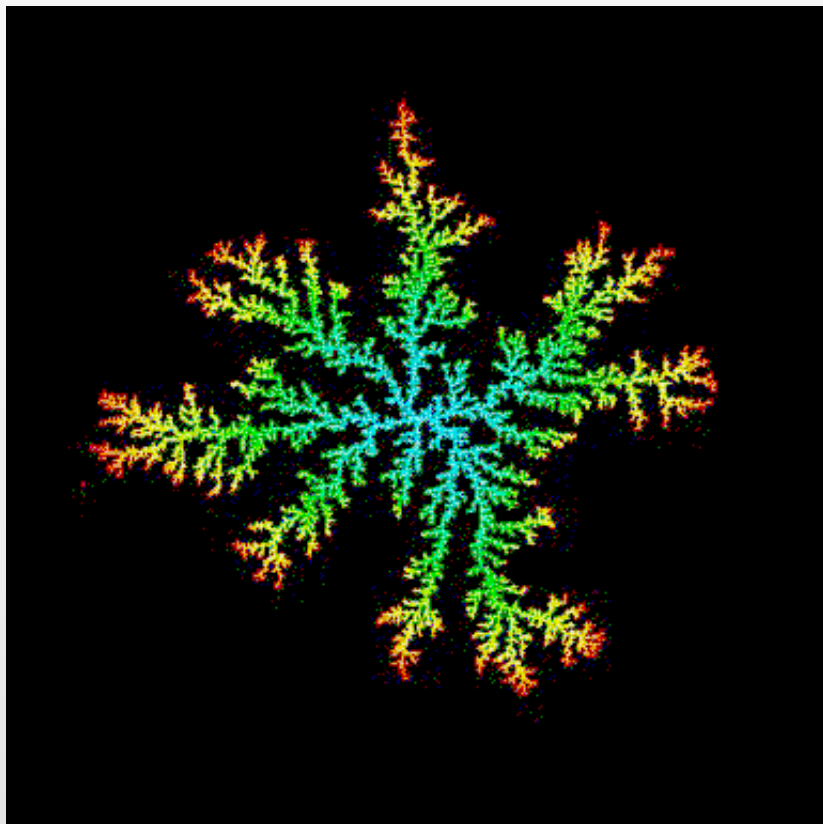


In fact let me show you a better model of this than last time: in fact the basic ABM-CA package is NetLogo and there are many models there you can explore and adapt

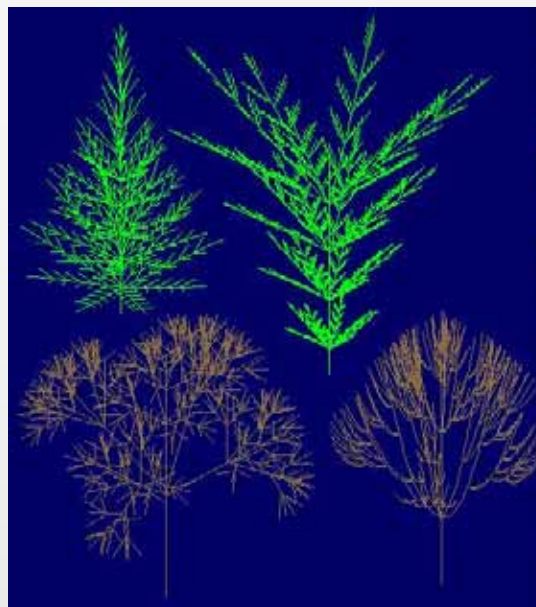
<http://ccl.northwestern.edu/netlogo/>

If you look at the Urban Suite some of these models pertain to my own work in ***Cities and Complexity*** book





DLA – Diffusion Limited Aggregation



Fractal Trees



Barnsley's Fern

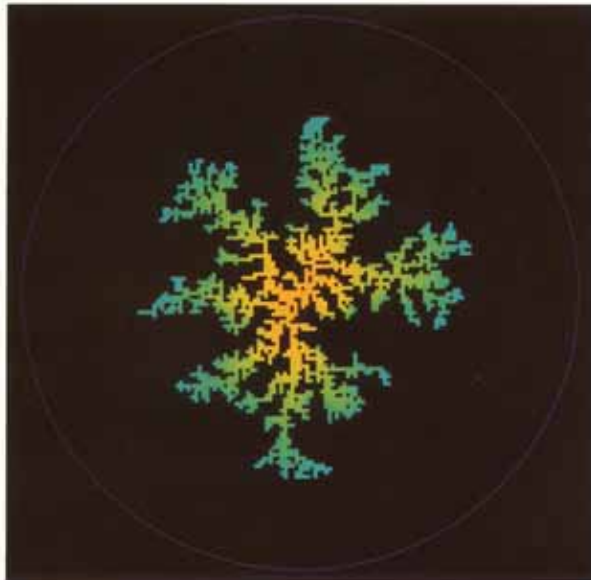


Plate 8.3 (left) The Baseline Simulation $\eta = 0$

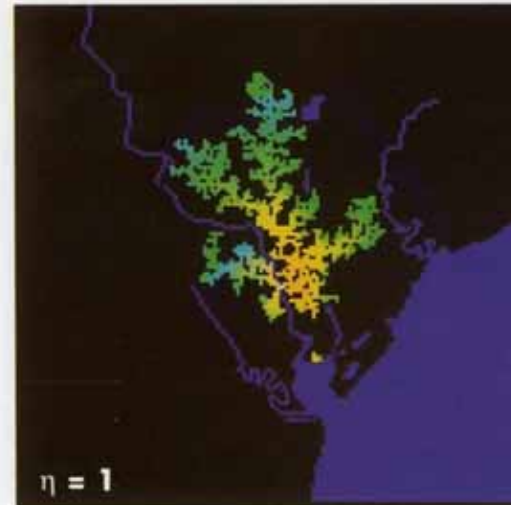


Plate 8.5 (below) The Urban Area of Cardiff.

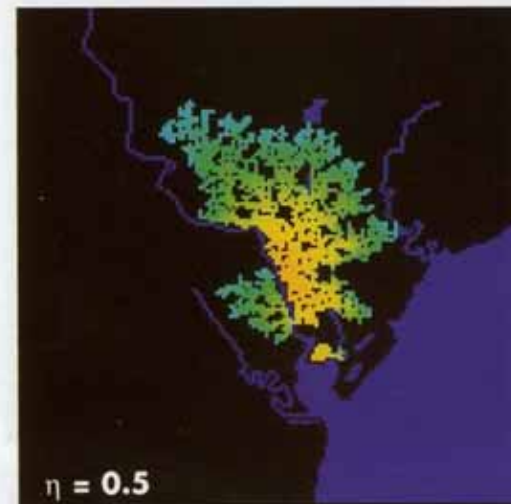
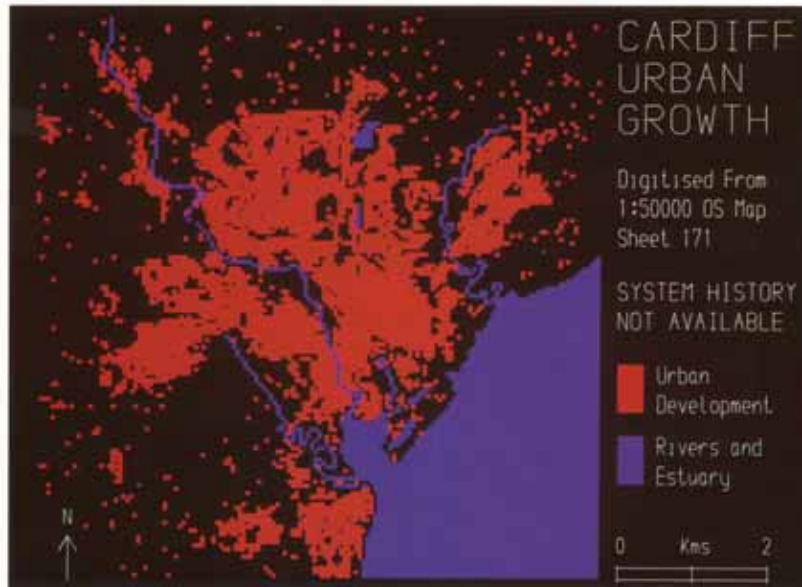
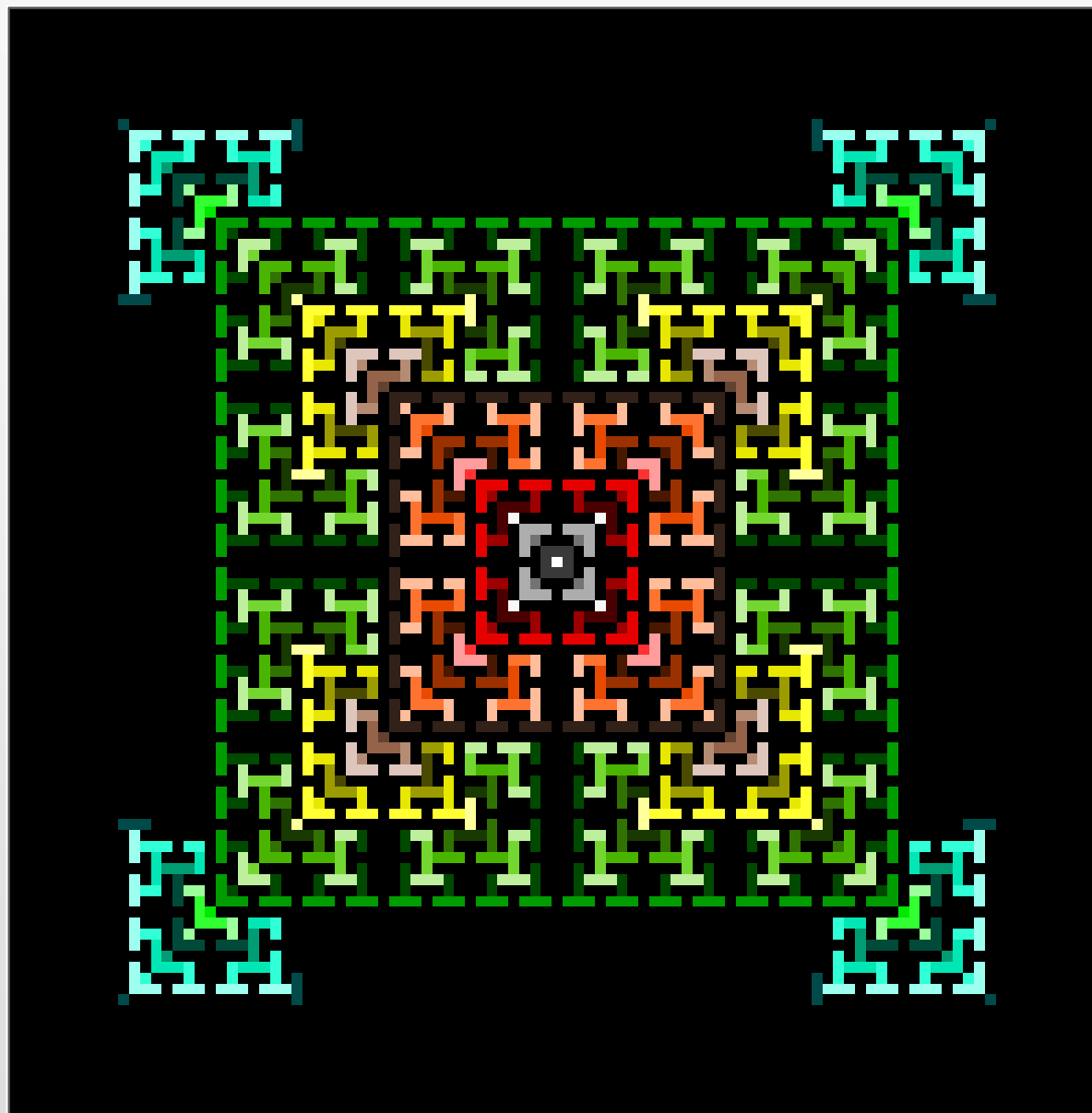


Plate 8.6 Simulating the Urban Growth

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?

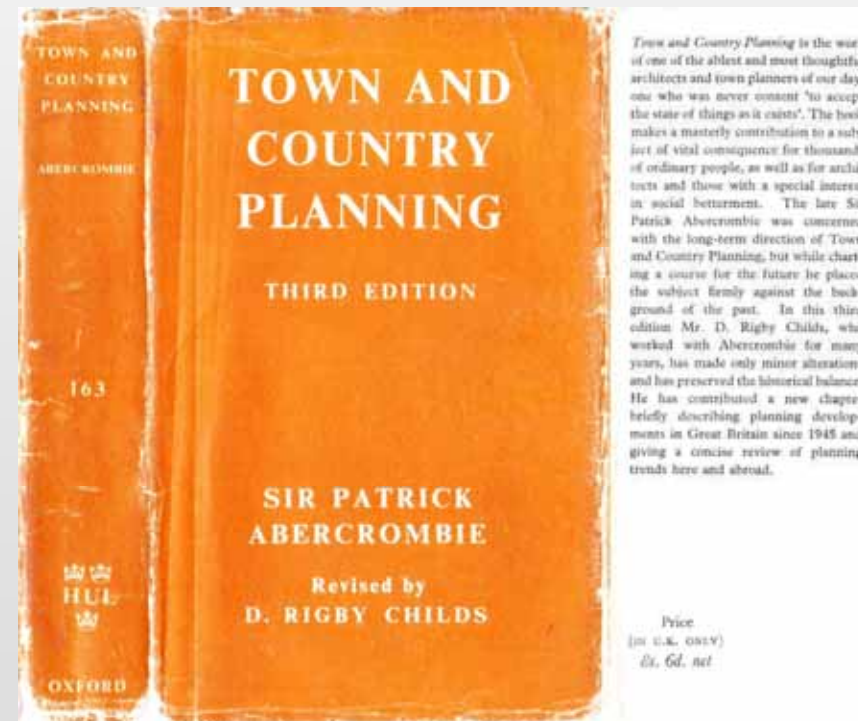
But first, imagine we throw out the randomness, what do we get. Here is an illustration using our simplest organically growing fractal city



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



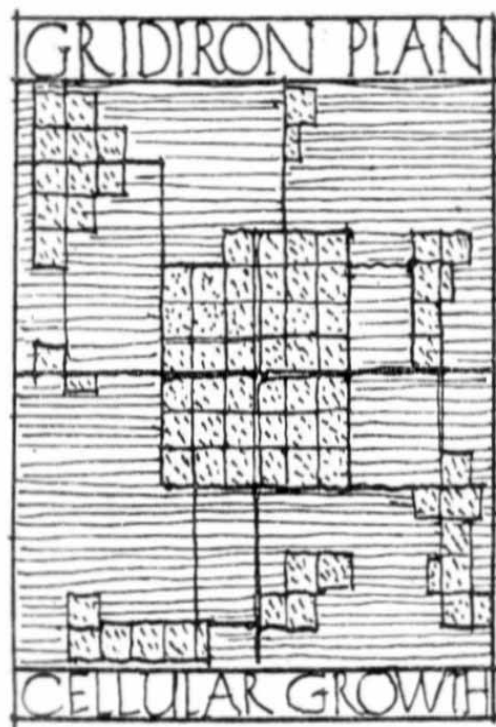


FIG. 1.

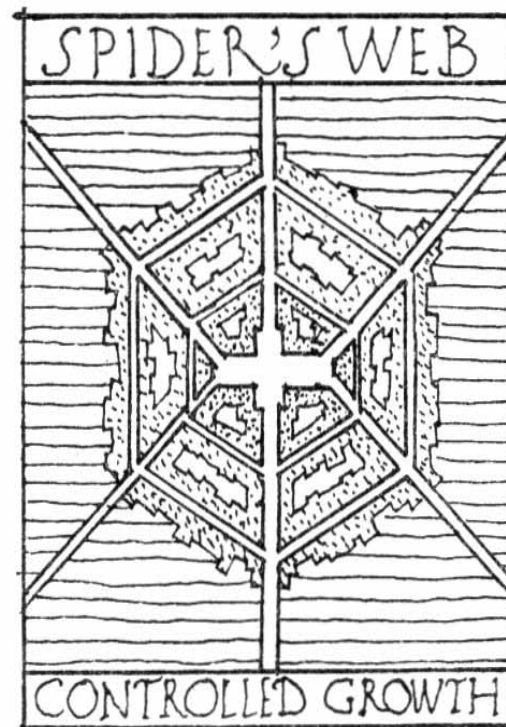


FIG. 3.

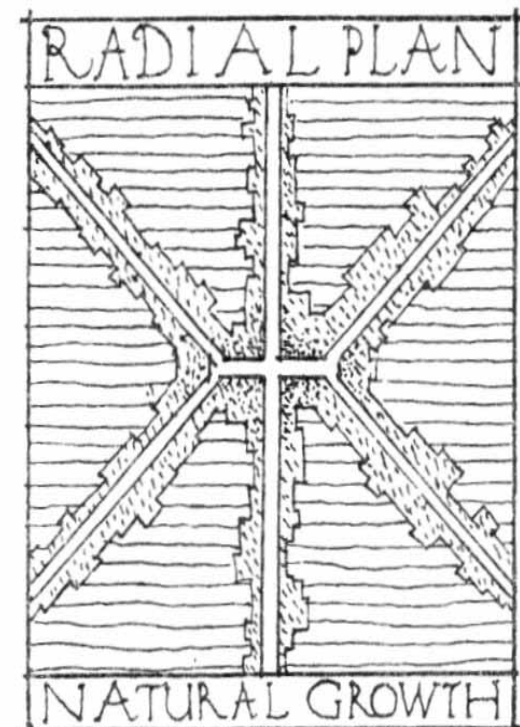


FIG. 2.

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).

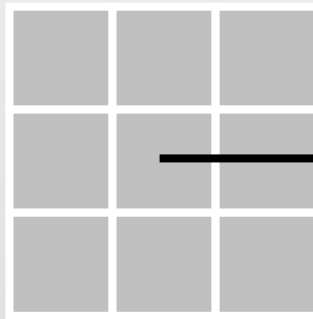
We define

- 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.

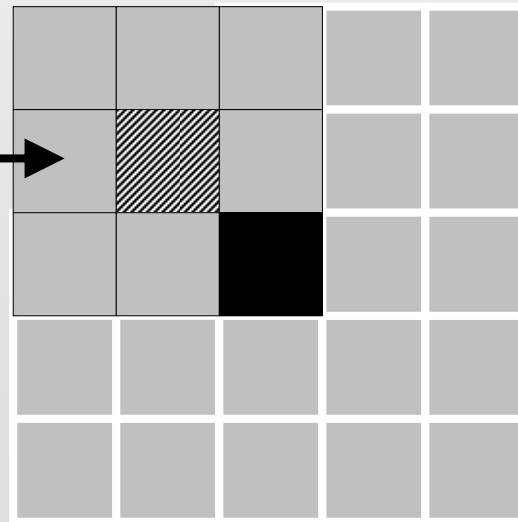
(a)

The neighbourhood is composed of 8 cells around the central cell



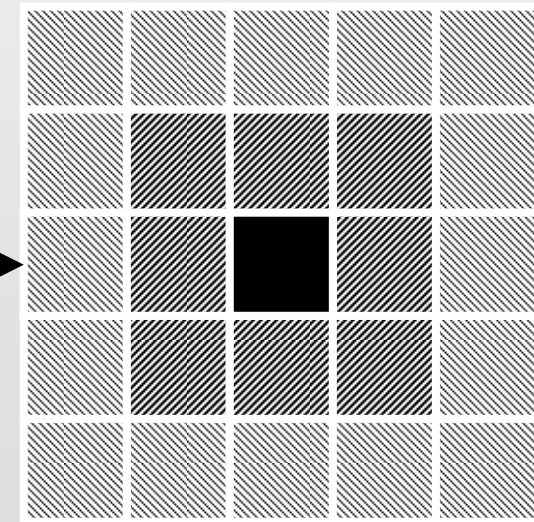
(b)

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.

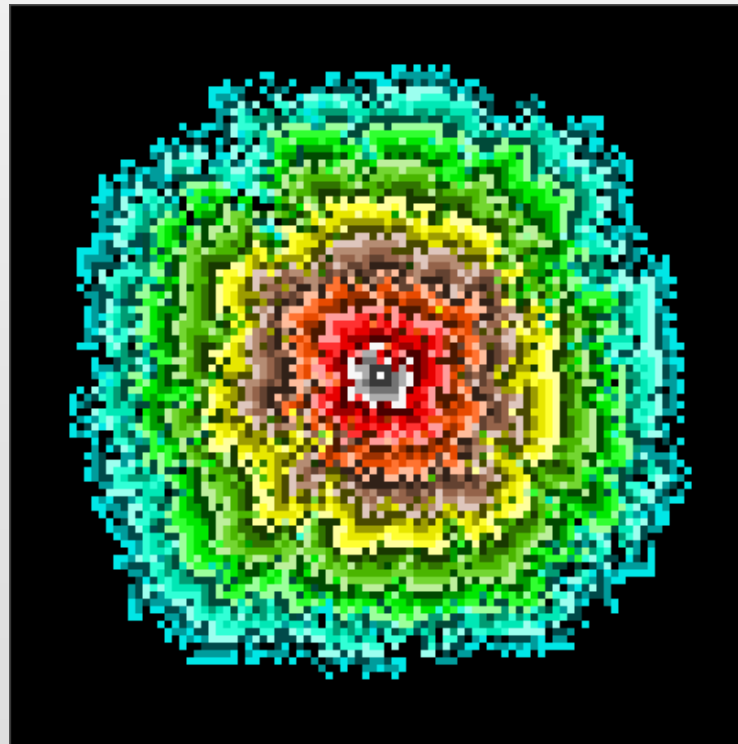


(c)

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

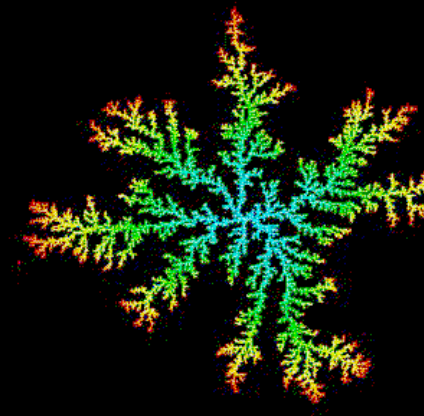
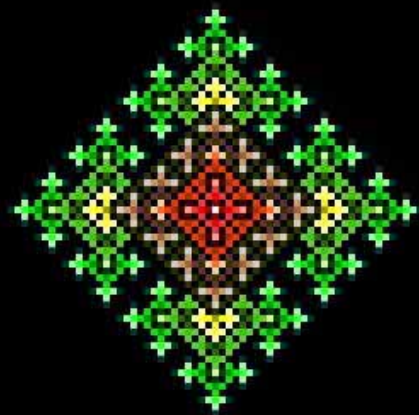




(a)

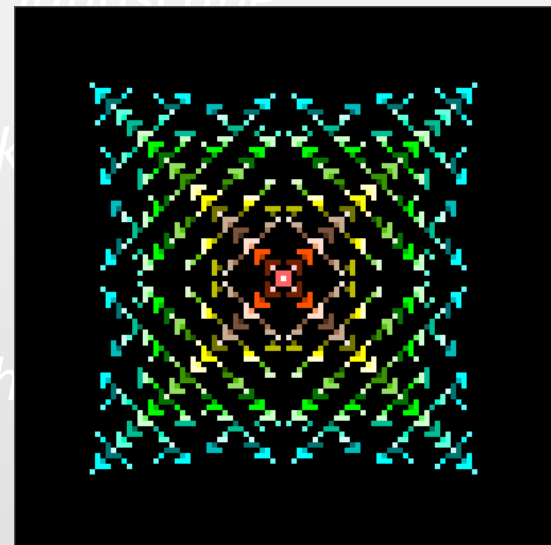
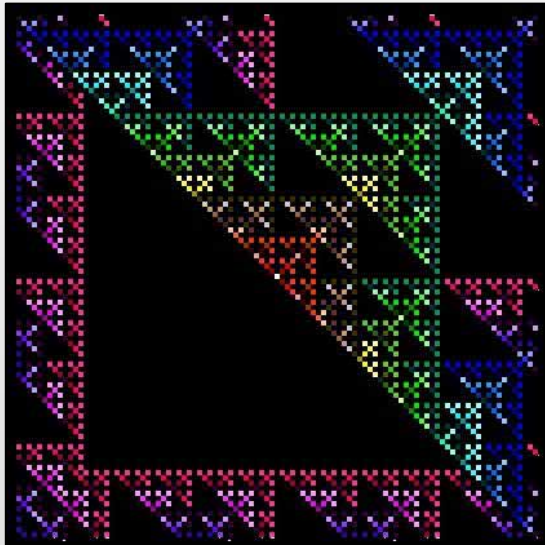


(b)

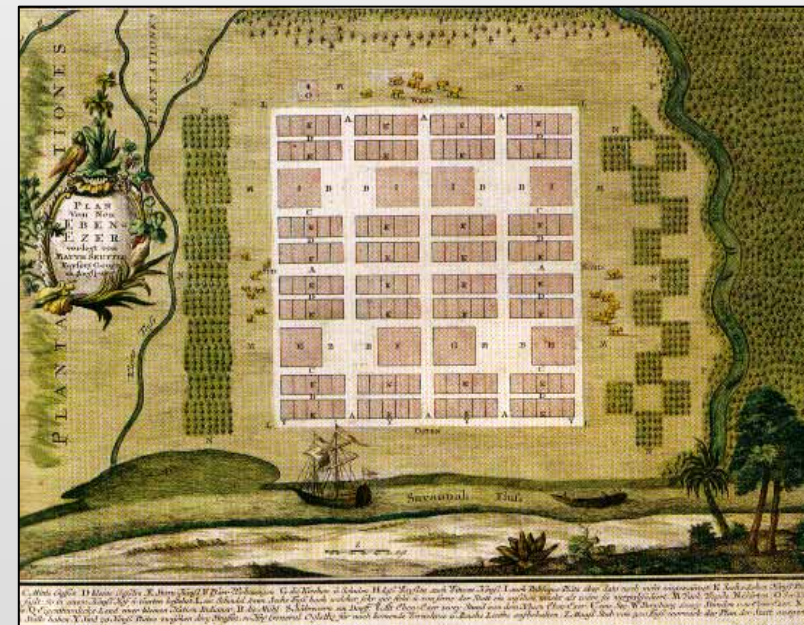
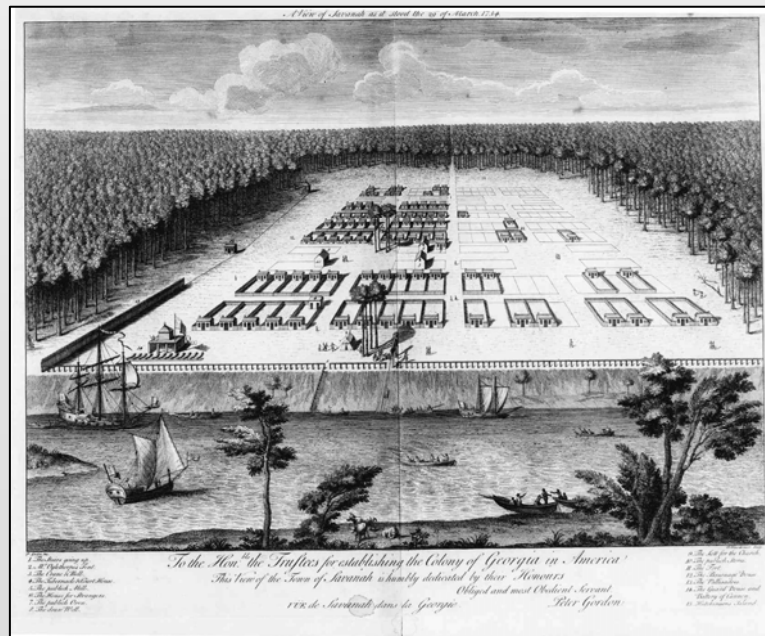
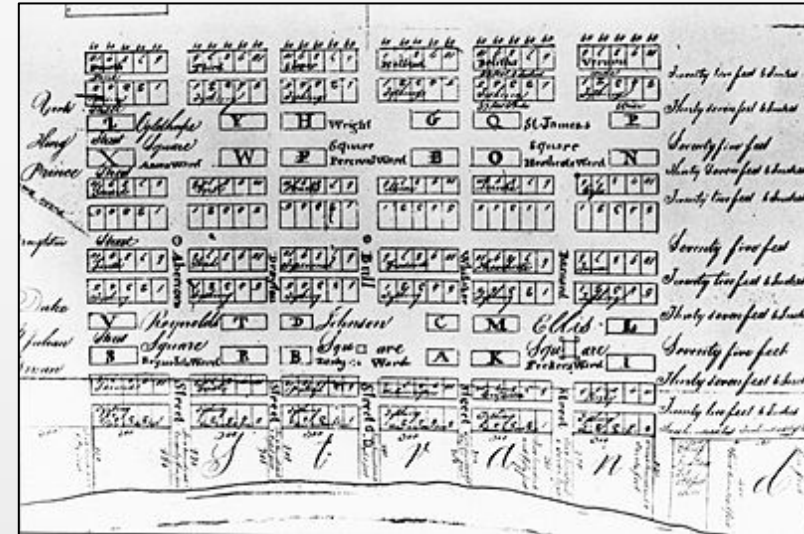


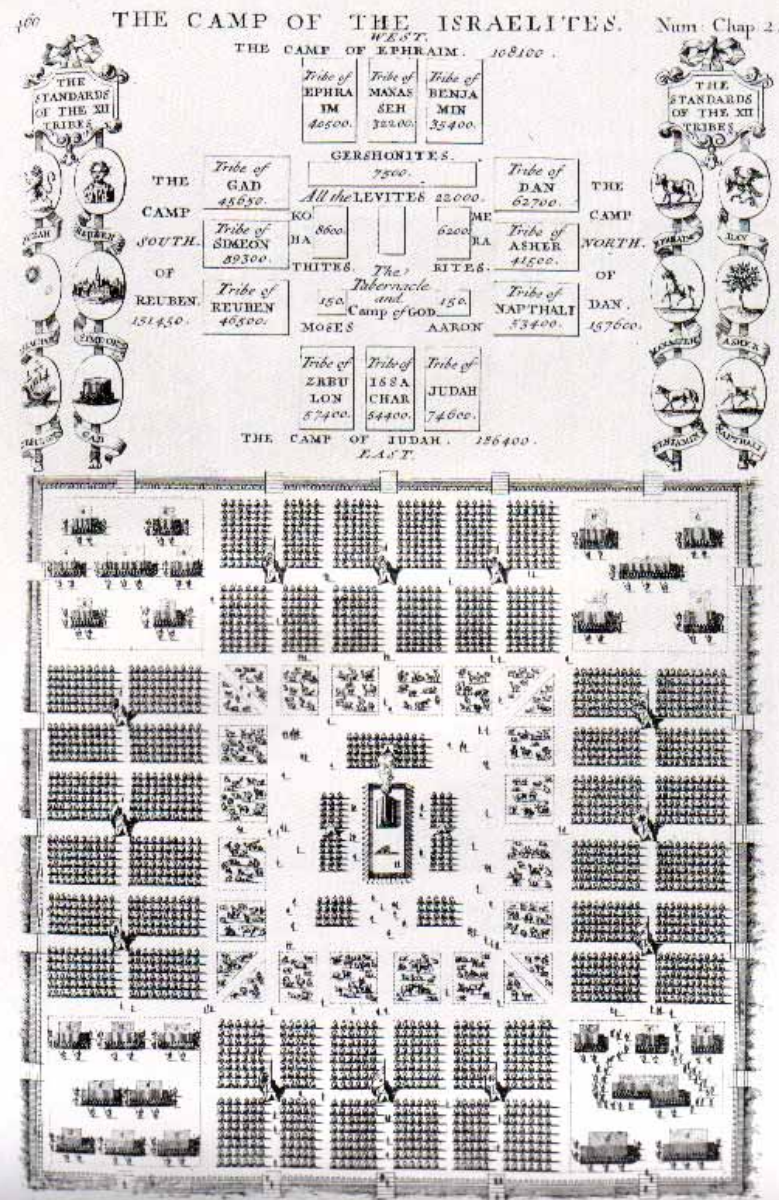
There are literally millions of feasible or reasonable shapes we can generate with different rule sets..... A countable infinity? Maybe?

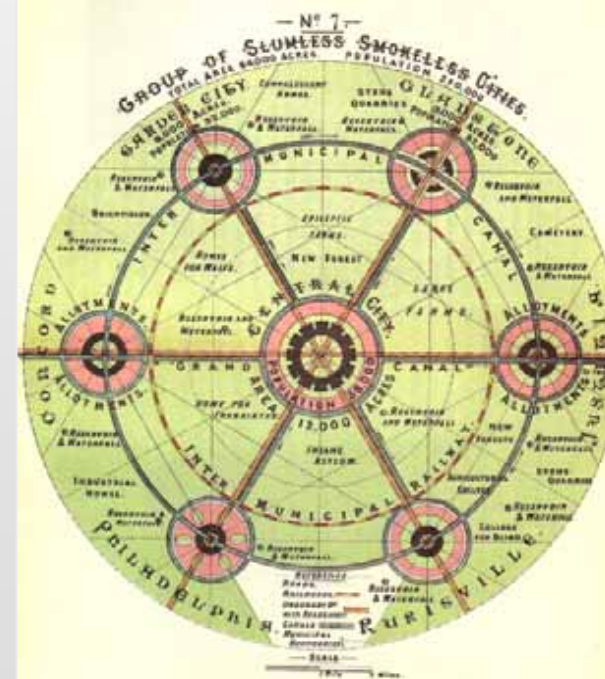
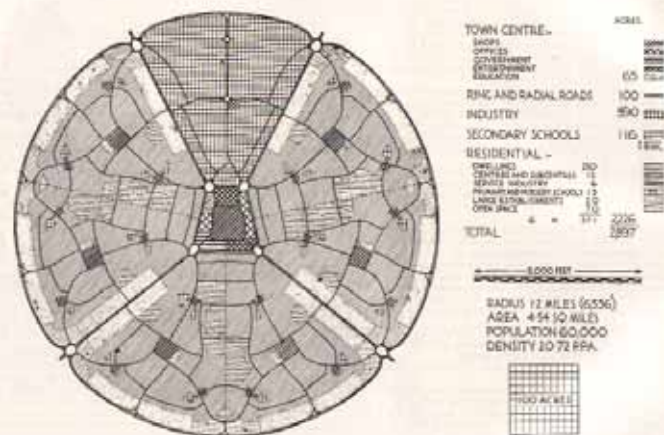
*A classic
landscape*

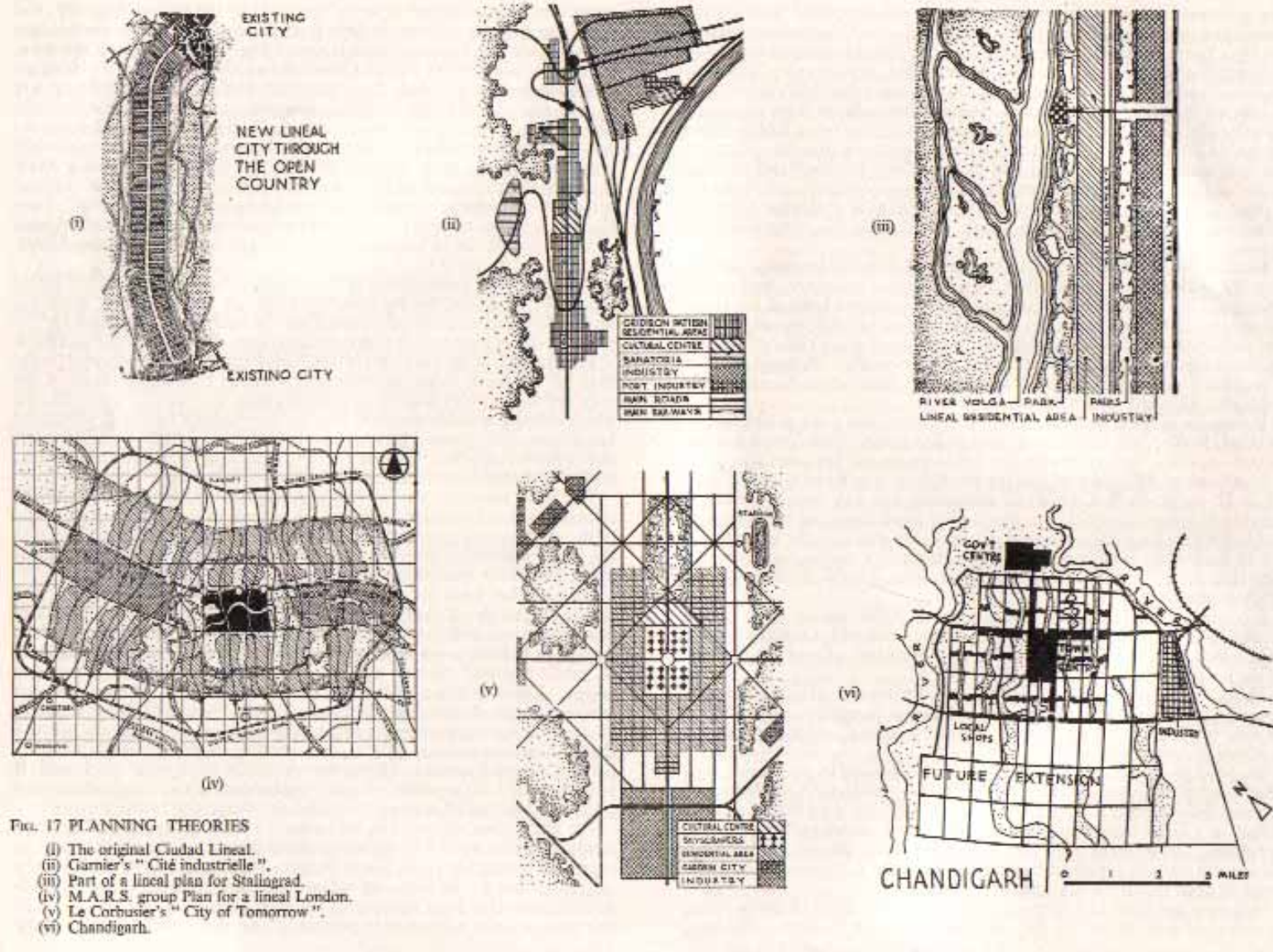


Here is one from history – Savannah, Georgia









Broadacre City

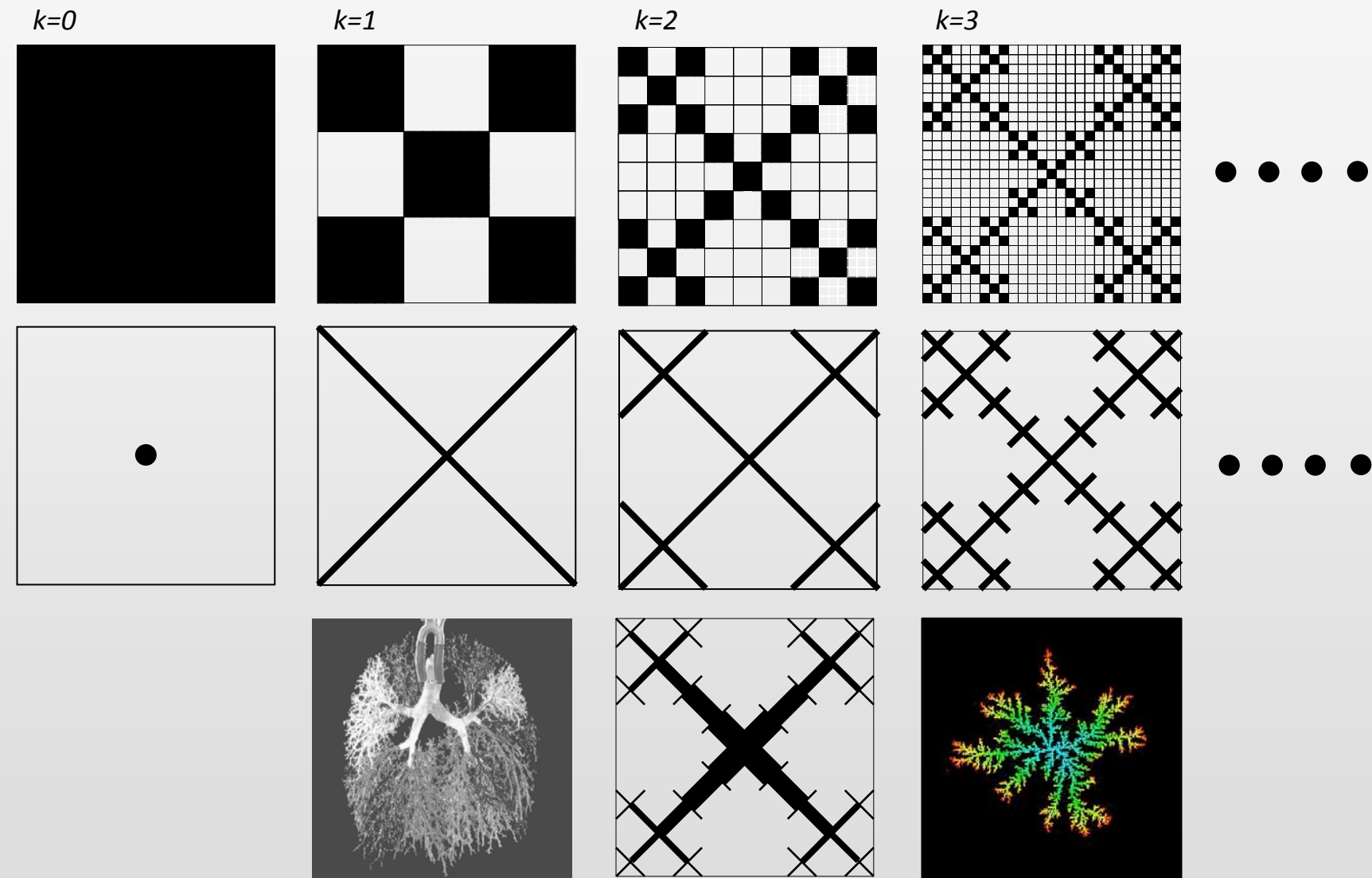


Frank Lloyd Wright, 1934

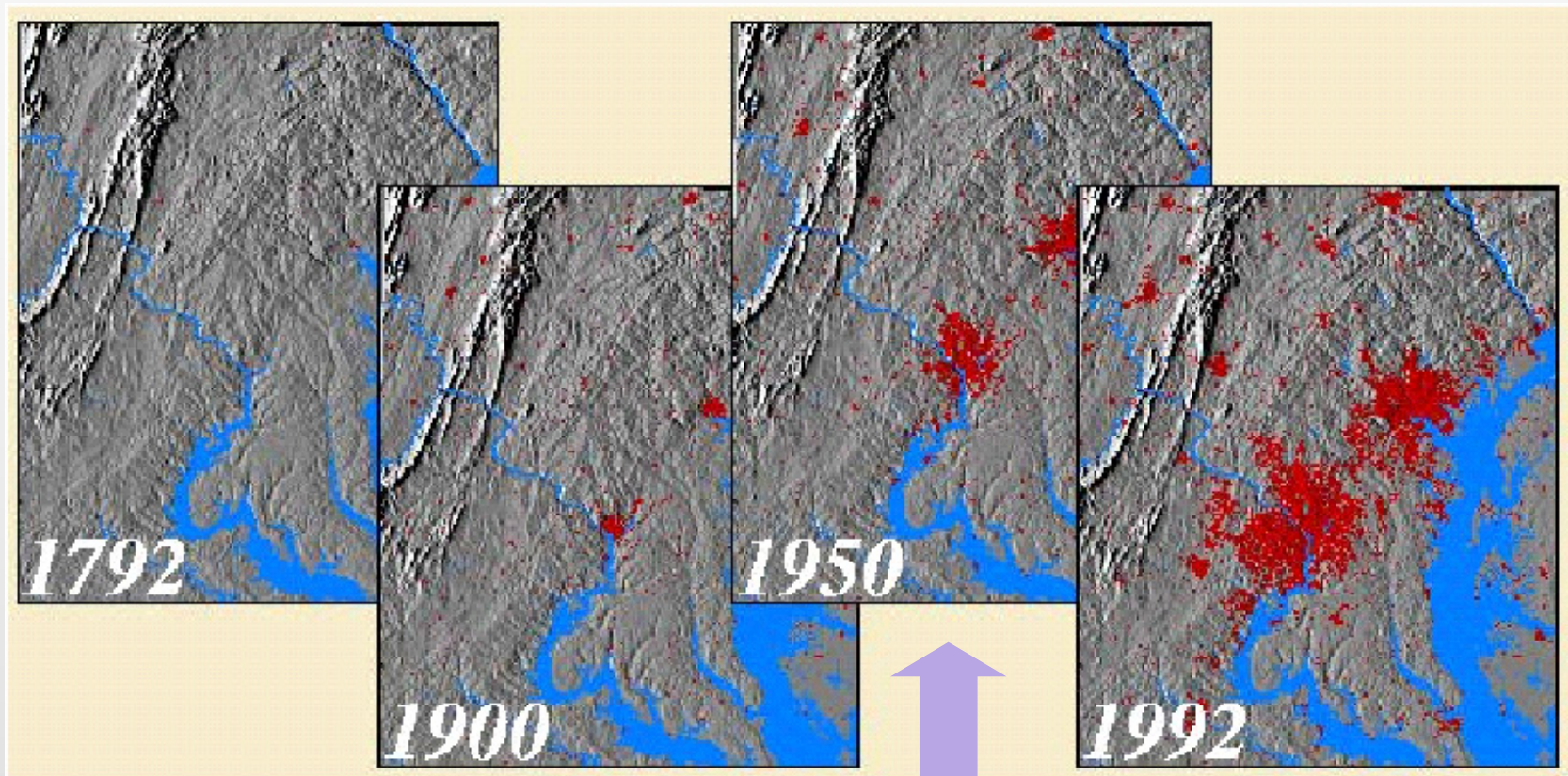
*A square mile section of what
was proposed to be a continuous
fabric of inhabited landscape
across the American continent*



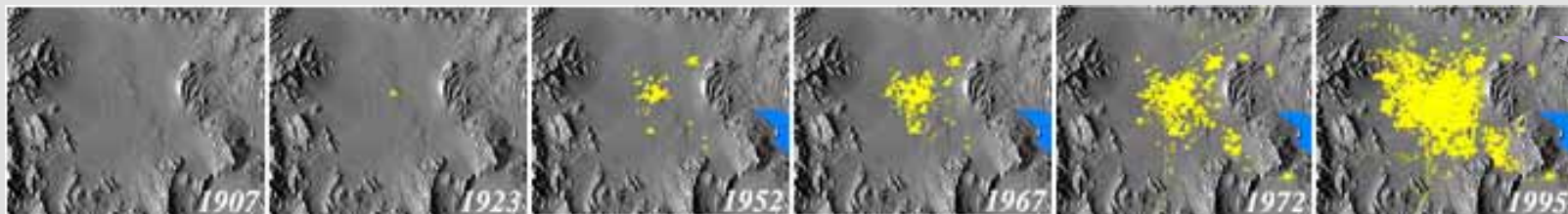
And these ideal cellular forms merge into the real.....



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

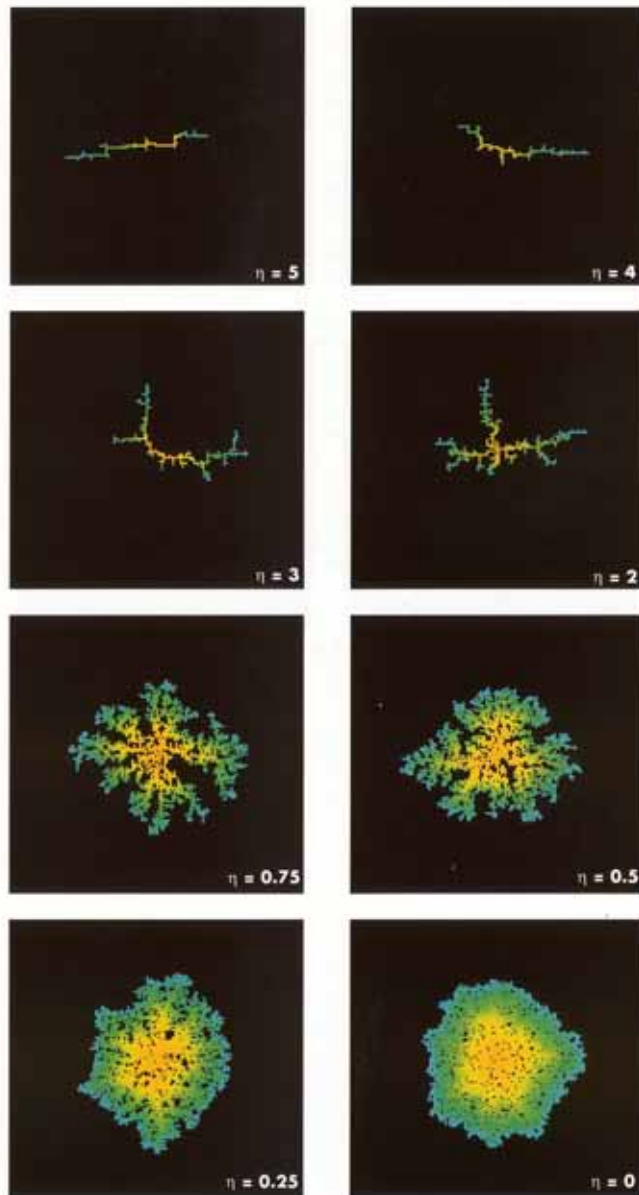


Plate 8.4 Urban Forms Generated by Systematic Distortions to the DBM Field

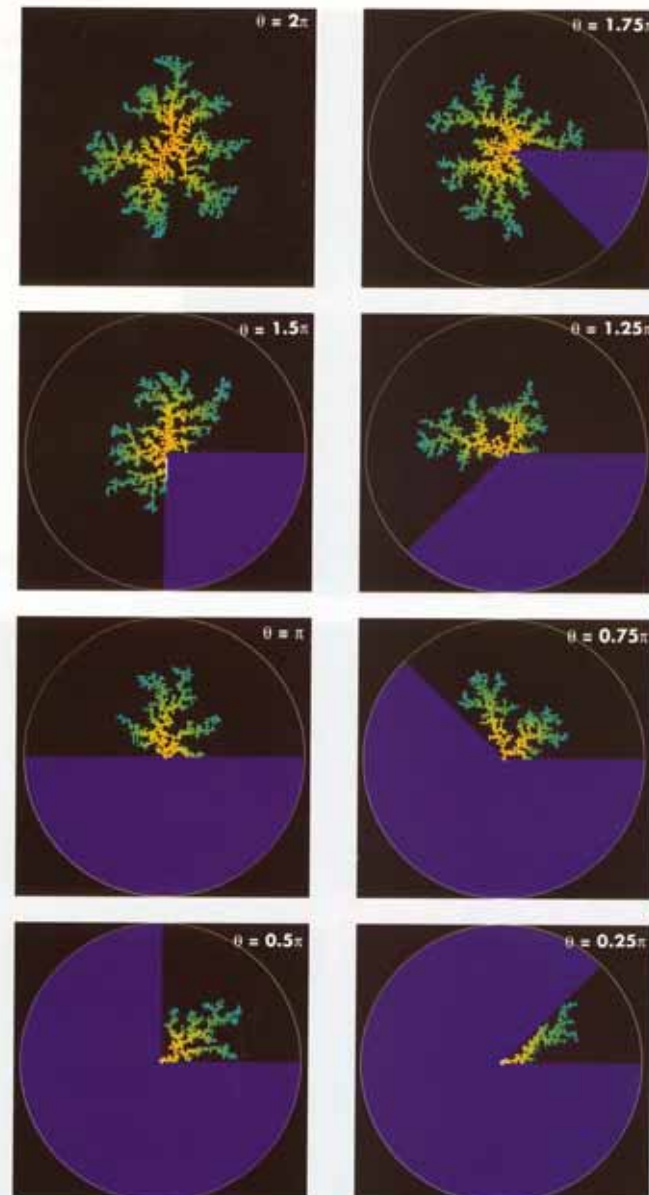
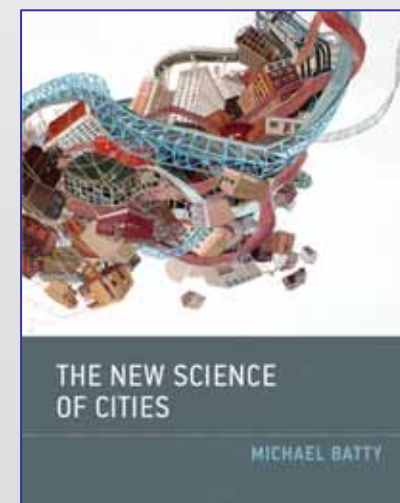
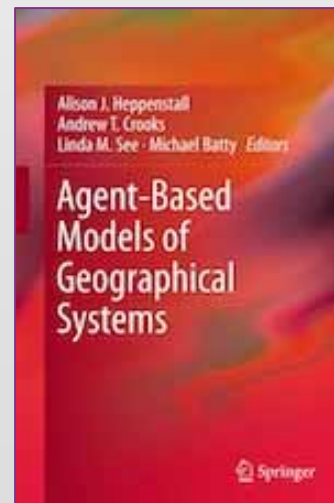
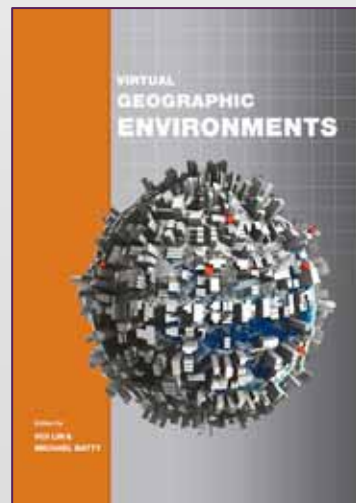
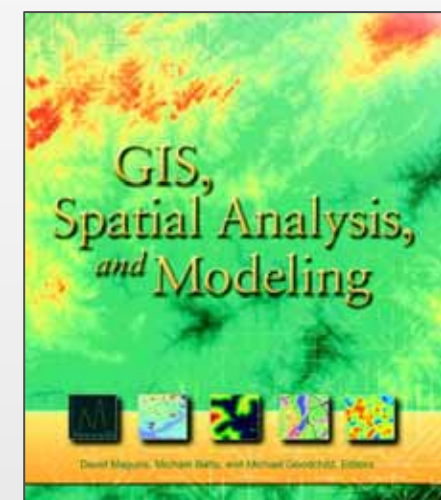
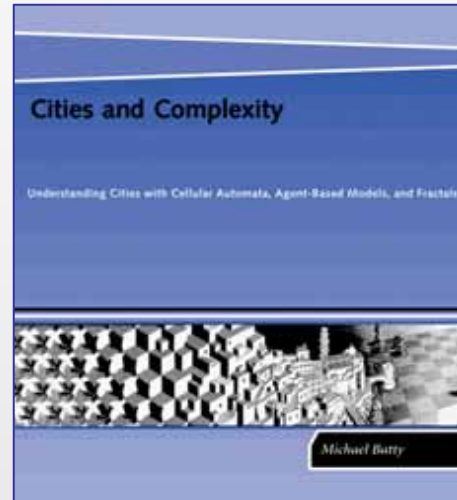
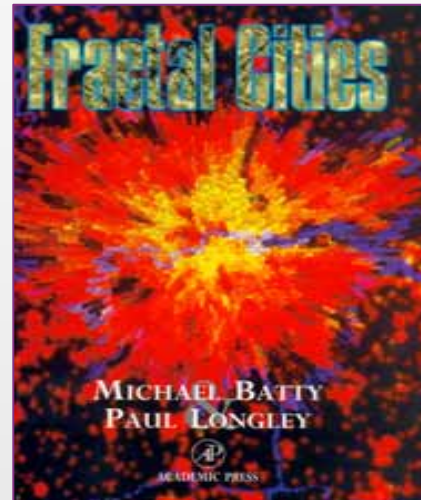
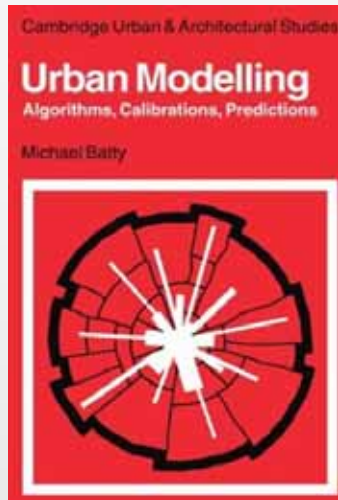


Plate 8.2 Physically Constrained DBM Simulations

Here are some books: you can access them from the blogs
www.spatialcomplexity.info & www.complexcity.info



Look at the blog –
It will be updated with this lecture.

Questions

www.complexity.info

www.spatialcomplexity.info