A new kind of science?

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- Analyze other people reviews and opinions.

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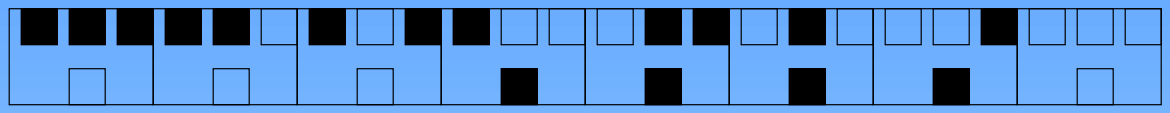
Chapter 10-12 The concept of computation.(Philosophical, but little scientific value.)

Simplest cellular automata



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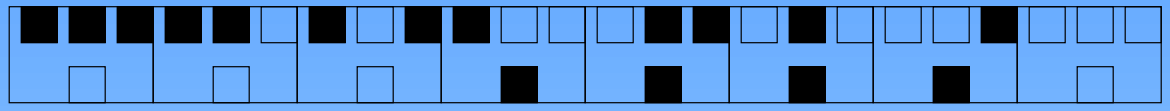
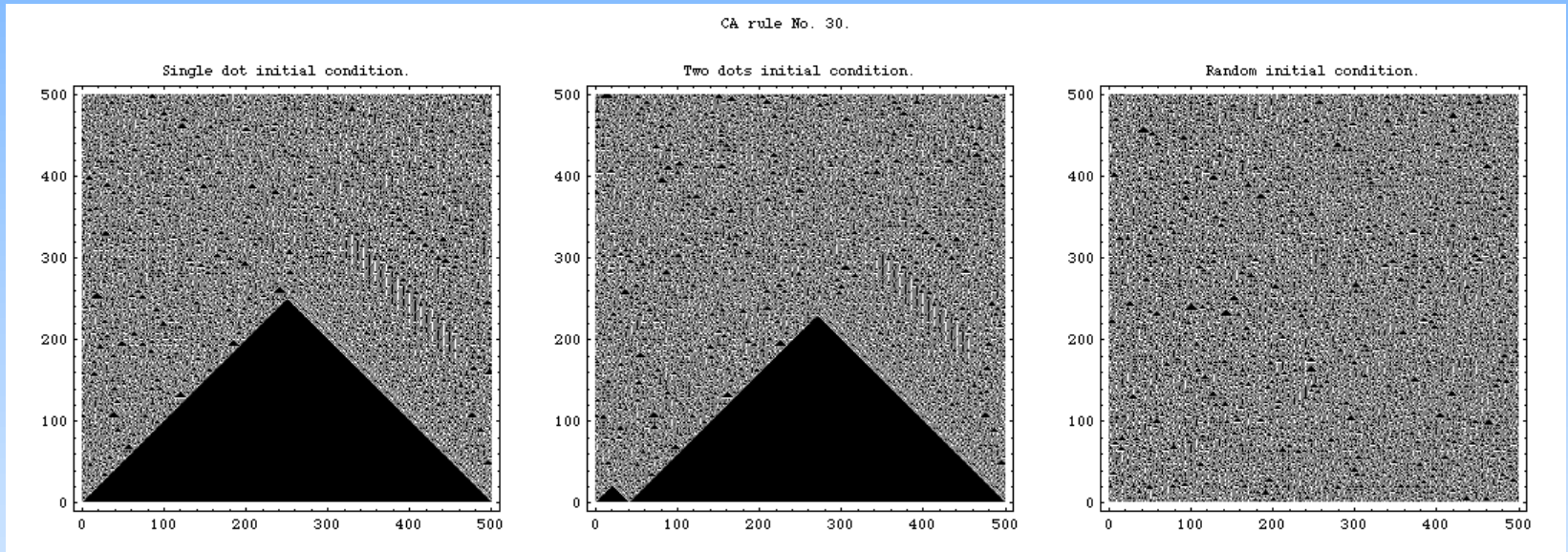
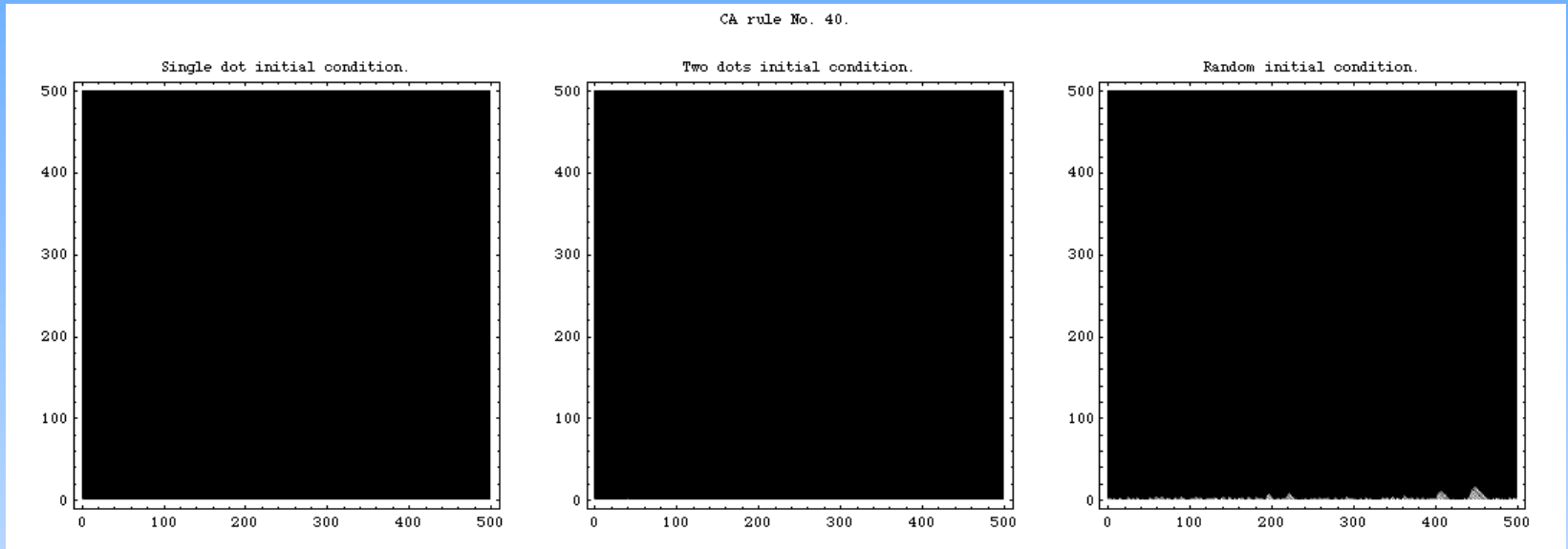


0 0 0 1 1 1 1 0 = 30



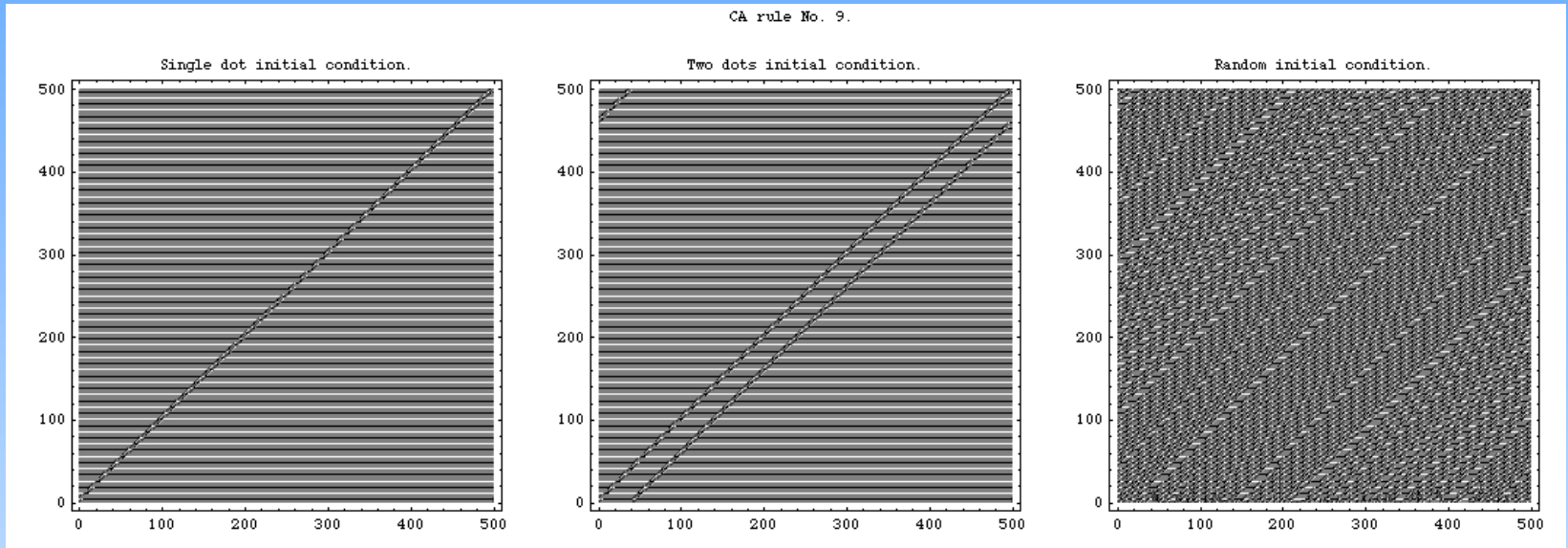
Looks random, at least partially

Other examples



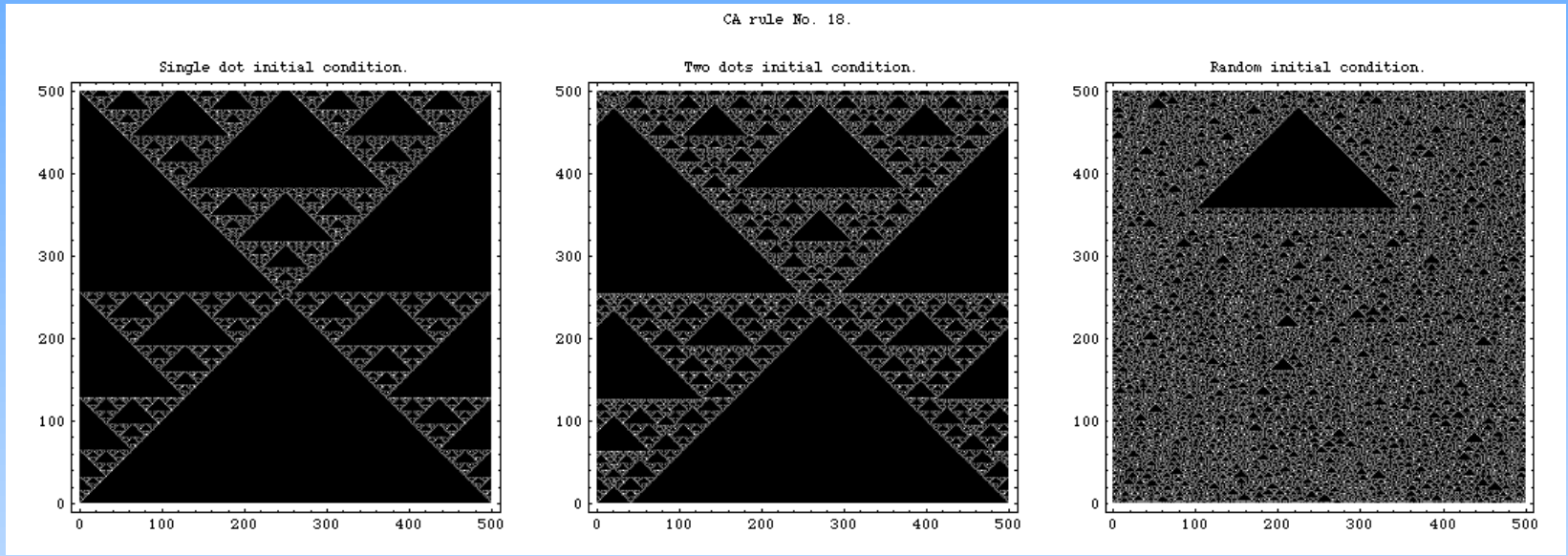
Evolves to a simple fixed point.

Other examples



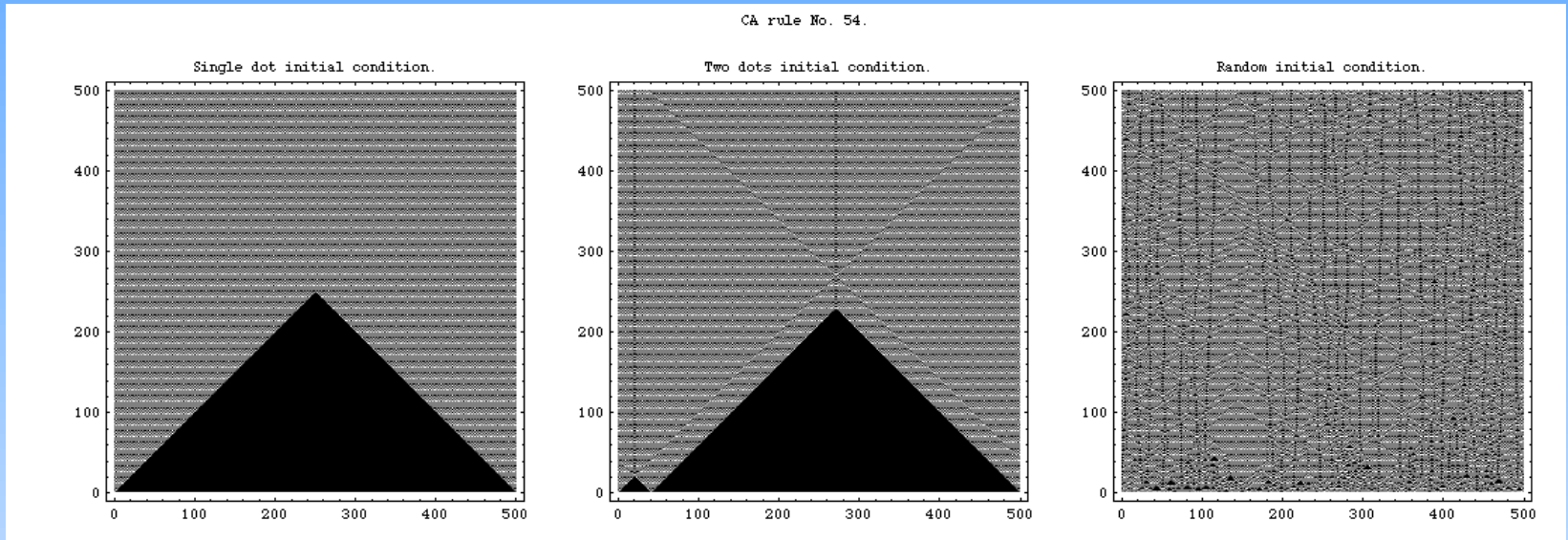
Moves points to the right.

Other examples



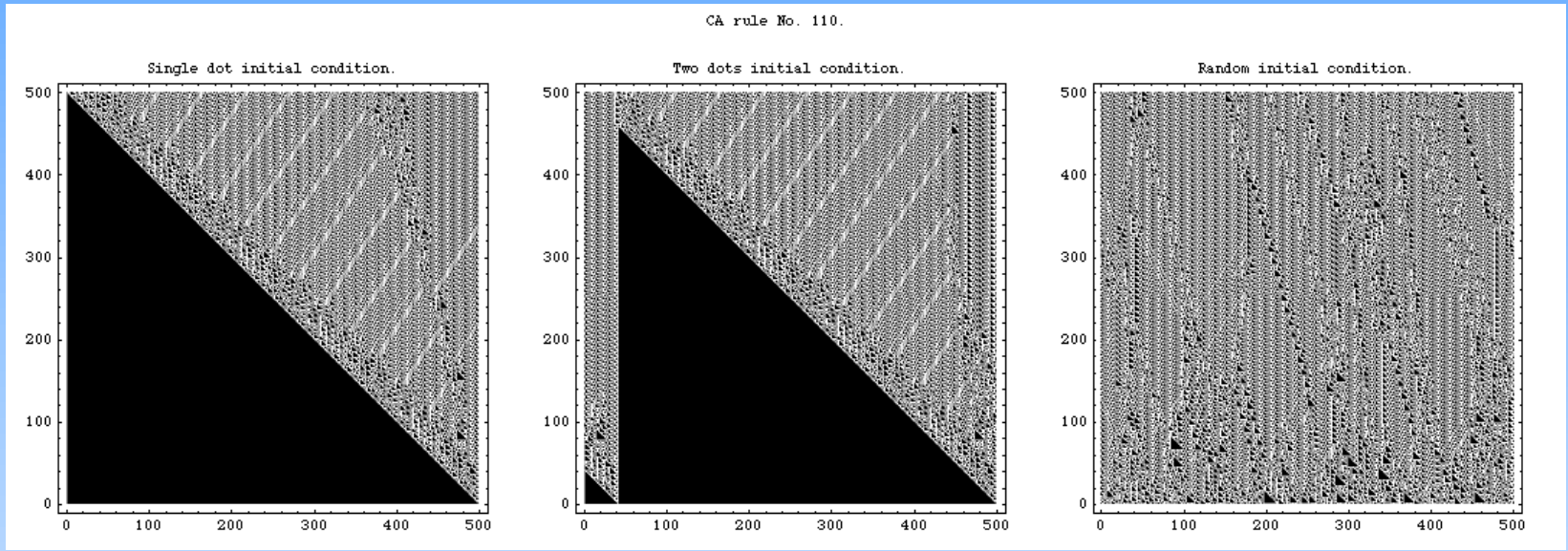
Superposition of nested structures. Randomness with structure.

Other examples



Semi-random behavior.

Other examples



Intricate behavior – interacting structures.

Other simple programs

- 2-d, 3-d cellular automata (cf. *Game Of Life*)
- Multicolor, long range or memory cellular automata
- Mobile automata and Turing machines
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- Numbers for generating structure, randomness, or complexity
  - ⋆ arithmetic operations in different bases (remember linear congruential random number generators)
  - ⋆ recursive sequences, continued fractions (roots, etc.), networks
  - ⋆ primes and important constants (e is nested, π is not)
  - ⋆ iterated maps and chaos

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- Not a single example of continuous system shown (continuous CA are not good)

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- Should focus on discrete simple systems and on evolution, rather than constraints.

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- Nothing is simpler than a harmonic oscillator, but a lot of them make QFT (and us). (The analogy with QFT can possibly be made more precise – ordered, random, critical phases. Governed by strength of couplings, and thus by predictability and information transmission.)

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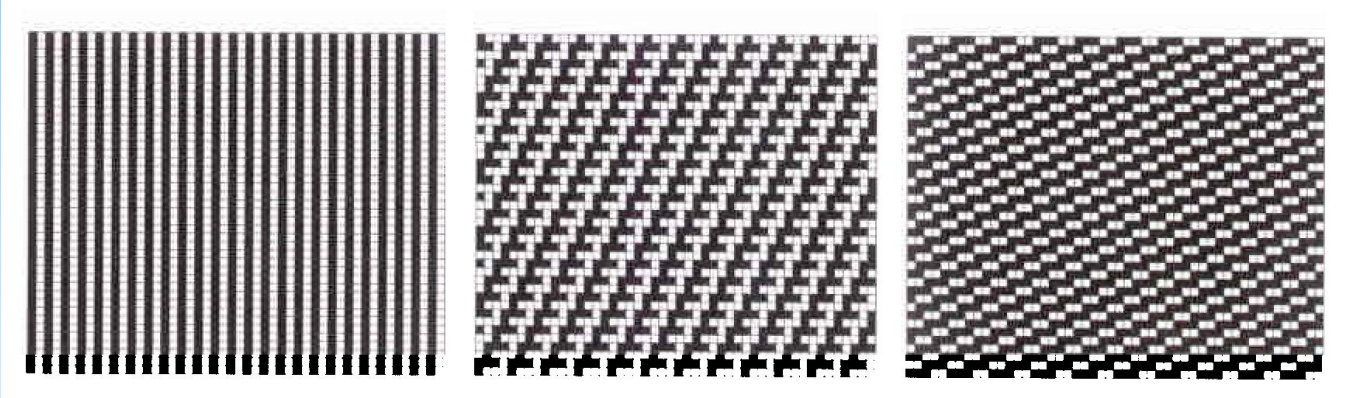
- One must talk about ensembles of possible initial conditions – complexity is a function of the rule and a typical set of initial conditions. Example: usually random CA30 may behave like:



Possible solution

There exists complexity classification scheme (Bialek, Nemenman, Tishby, 2001) based on predictability – mutual information between past and future.

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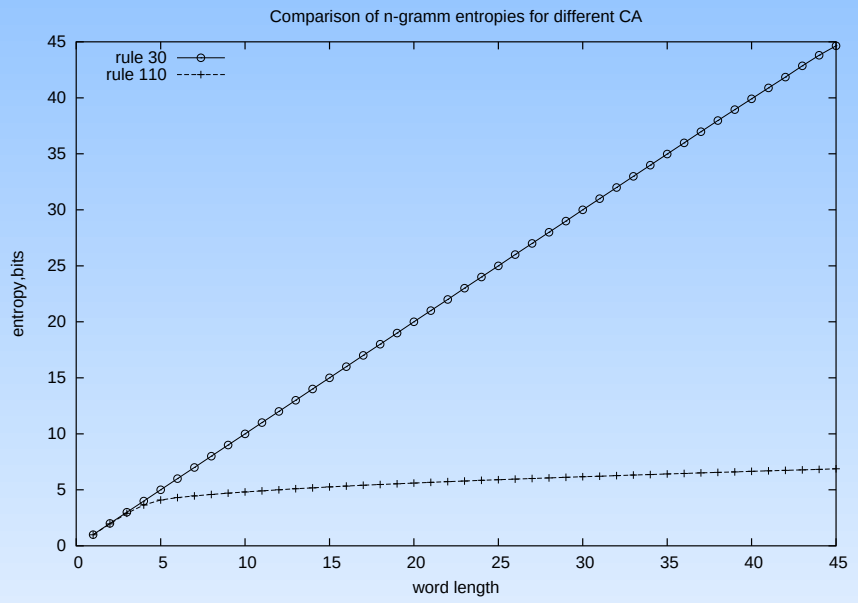

- Entropies show distinction in extensive part (just a multiplies), and also in subextensive one (qualitative – zero vs. growing function)
- Predicting future is impossible in CA30 – too fast information spread
- May be viewed as learning initial conditions

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- *Mathematica*'s `Random[Integer]` uses CA30

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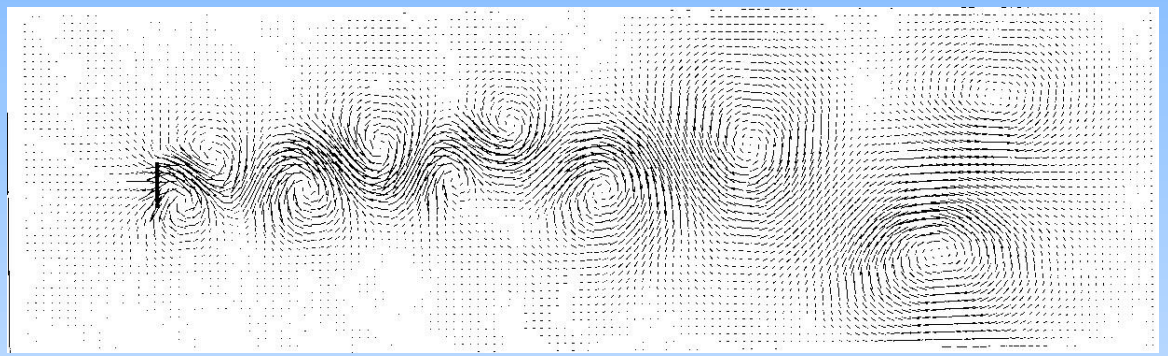
  Example: simulating turbulence with CA



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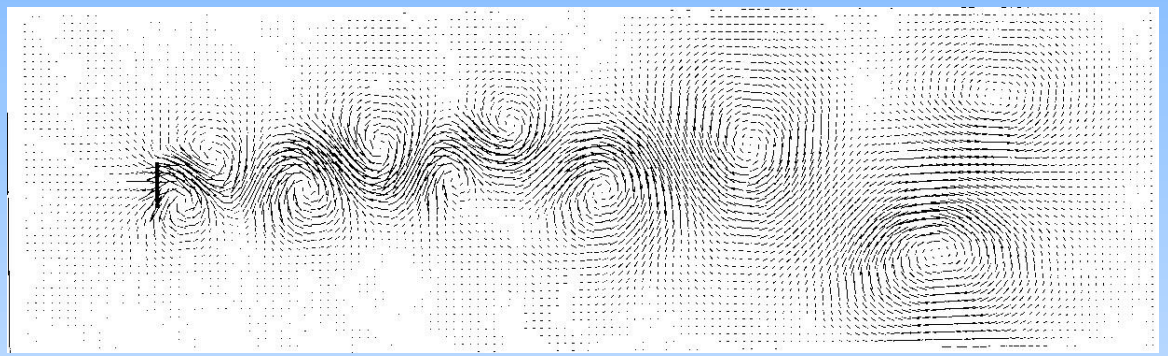

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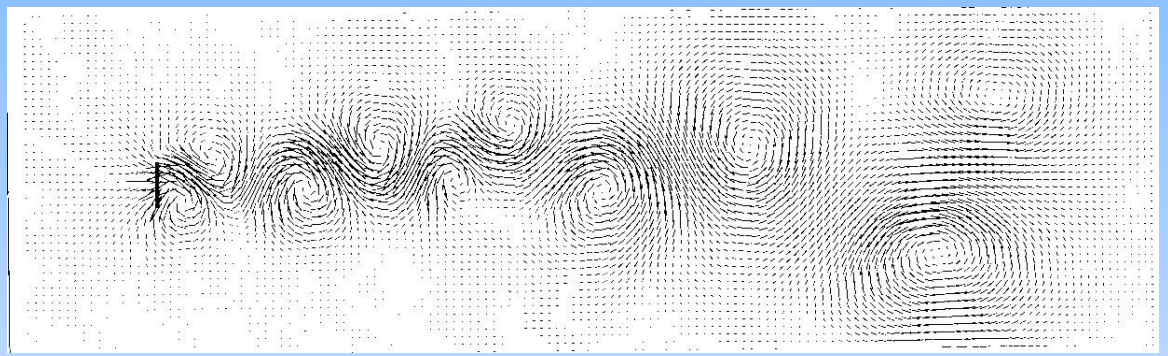

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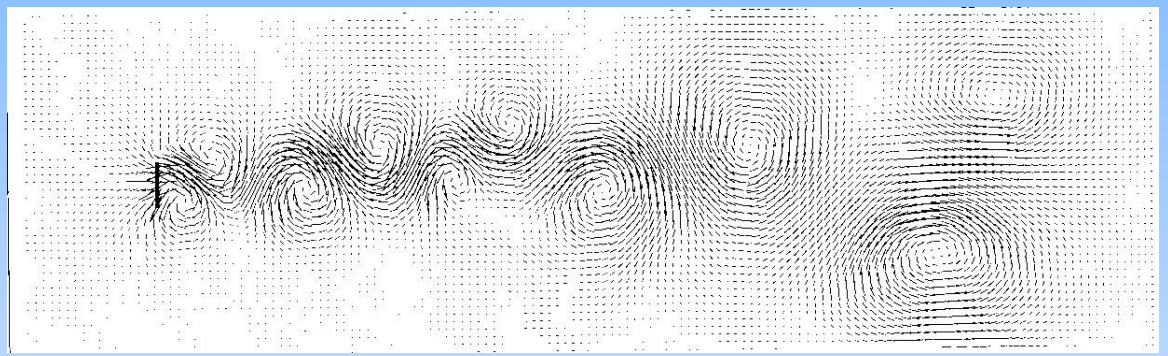

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  (But electron moving 1cm at the nearby star is felt 10^{-5} sec later.)

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- Not rigorous definition

  . . . [T]he greatest complexity lies . . . in systems that neither stabilize. . . , nor exhibit close to uniform randomness forever.

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- Logical depth – the number of computations; CA's are complex in this measure.

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- Programs as models – as good as equations as models

  . . . [T]raditional matematic[s] . . . say[s] that the motion of a planet is governed by . . . differential equations. But one does not imagine that this means that the planet itself contains a device that explicitly solves [them].

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- In traditional science we try to make *predictions*; programs have to be executed to the end – they are not predictive (see the irreducibility section)
- Prediction works – we are not hit by moving trucks (Wolfram would probably argue that these are all simple cases)

Biology

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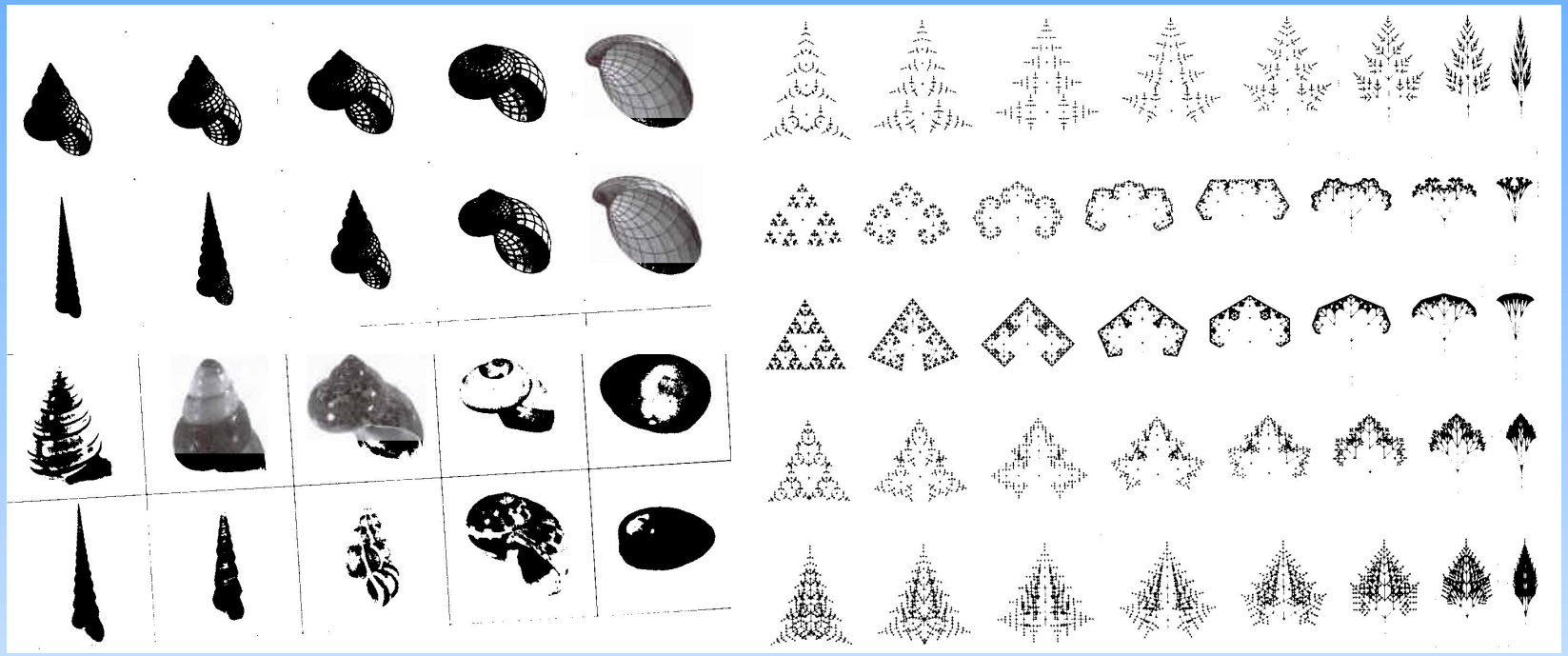
- Can explain things a posteriori – this is not predictive science

Simple programs in biology



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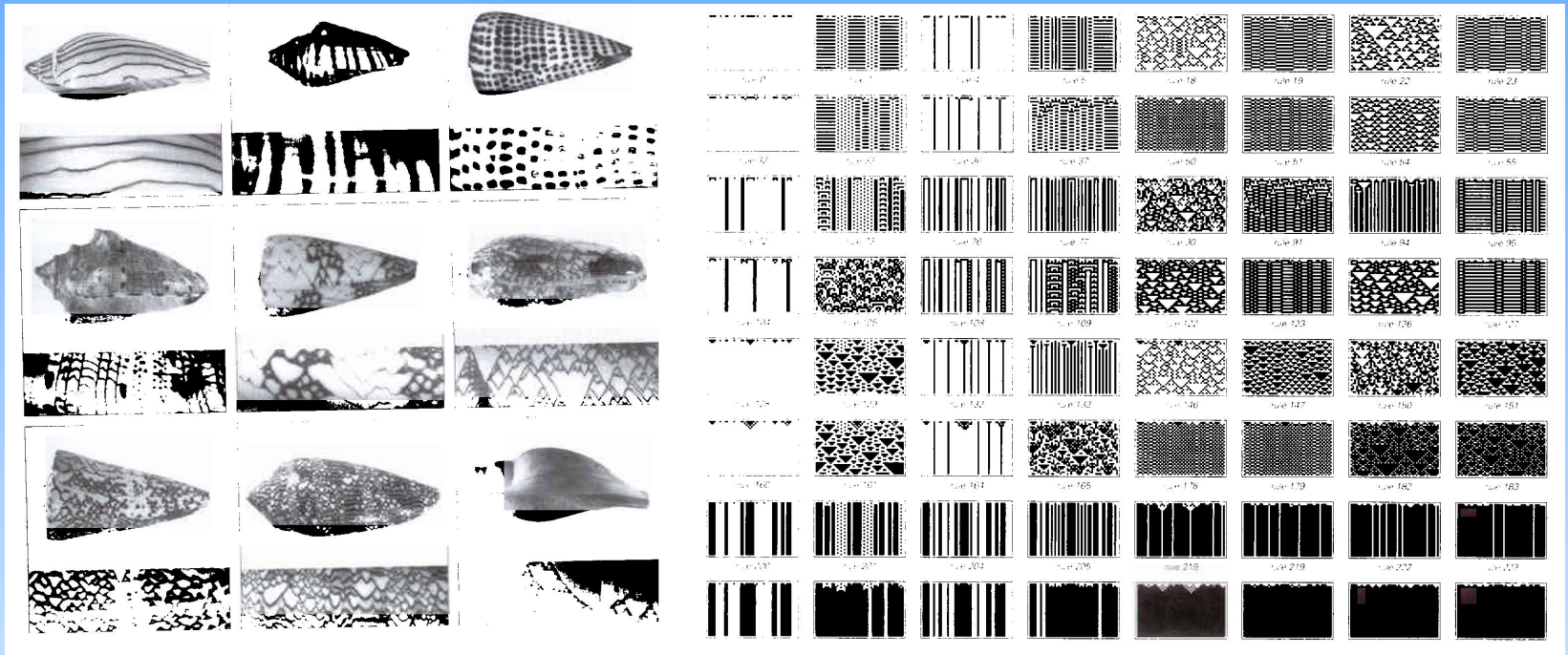

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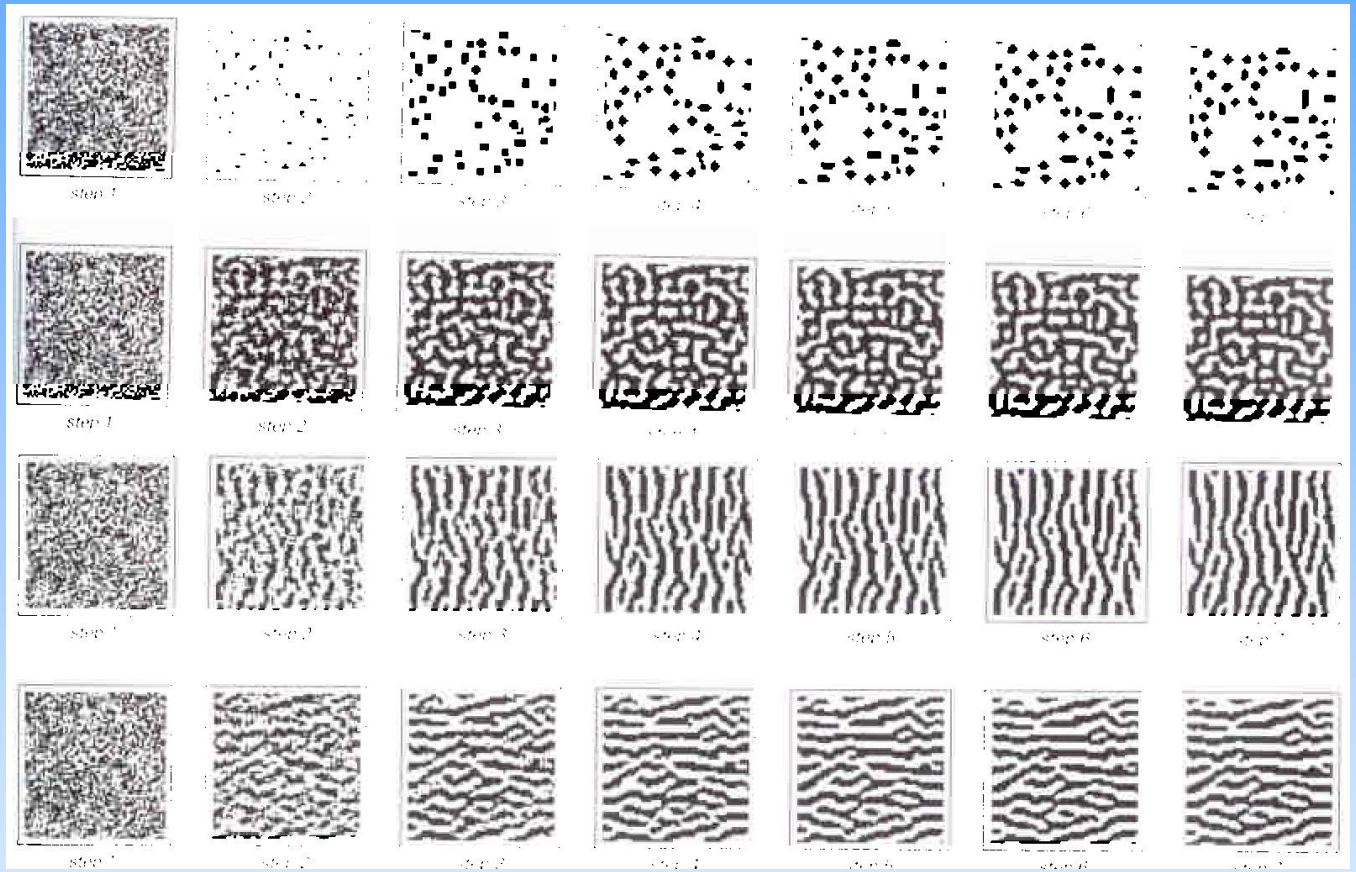

Reaction–diffusion process

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- The Second Law is an important and quite general principle—but it is not universally valid.

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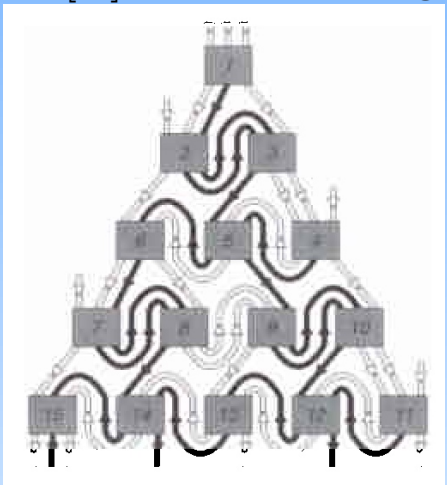

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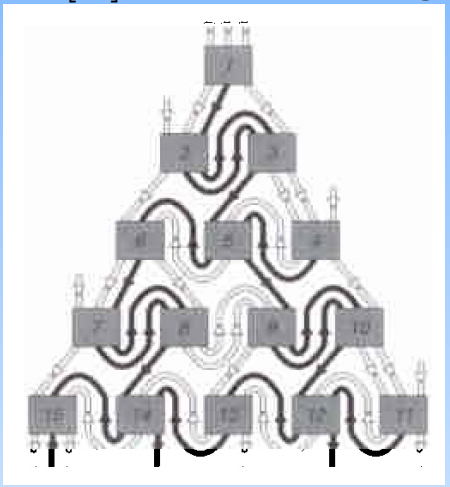

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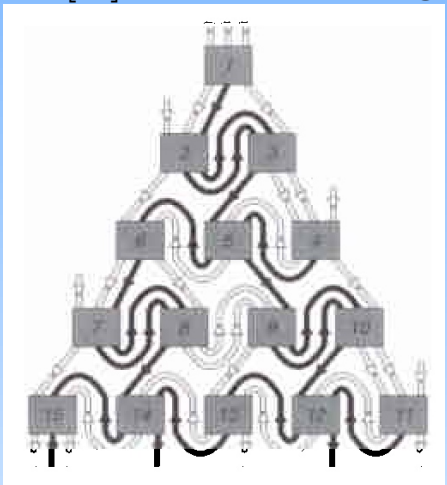

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- How is this all testable?

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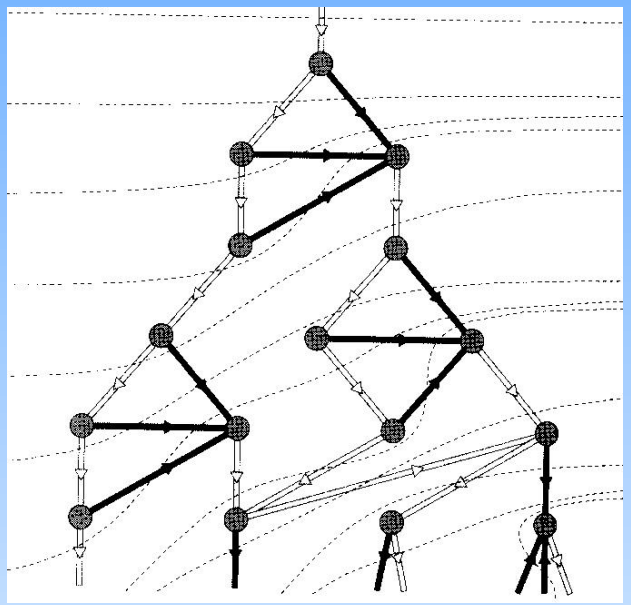

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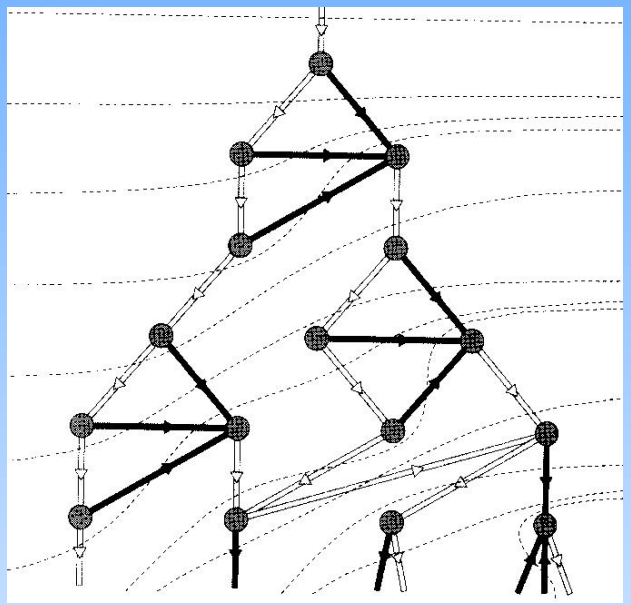

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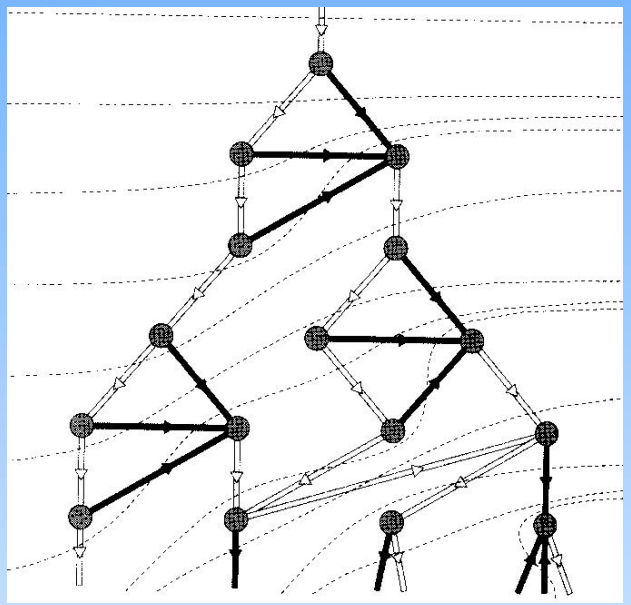

- Can recover time dilation and other spatial properties
- Cannot get $E = mc^2$ and other non-spatial aspects

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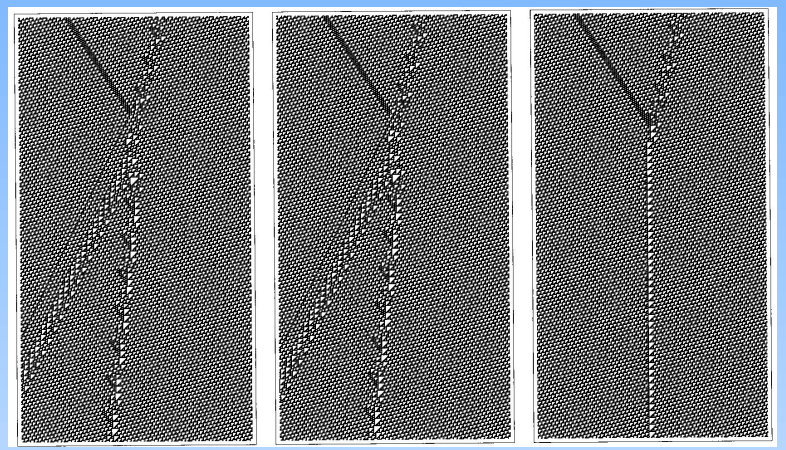

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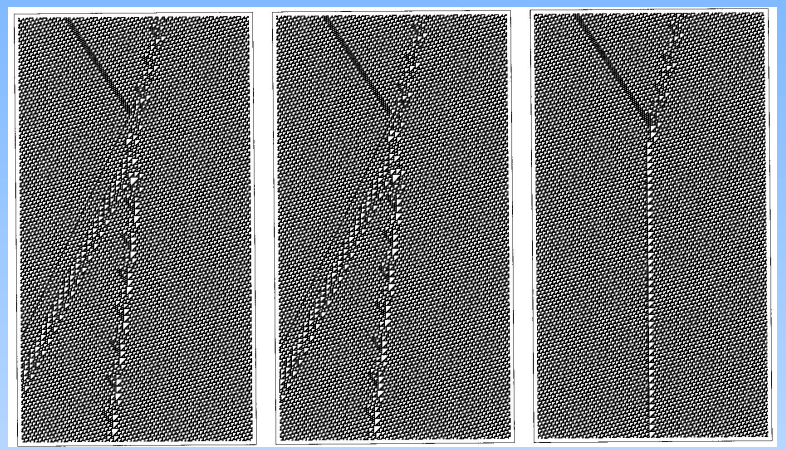

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- Gravity is changing the pattern of connections and getting curvature – the number of nodes within a given distance from the center depends on the Ricci scalar

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- Some interesting properties of physics are obtained

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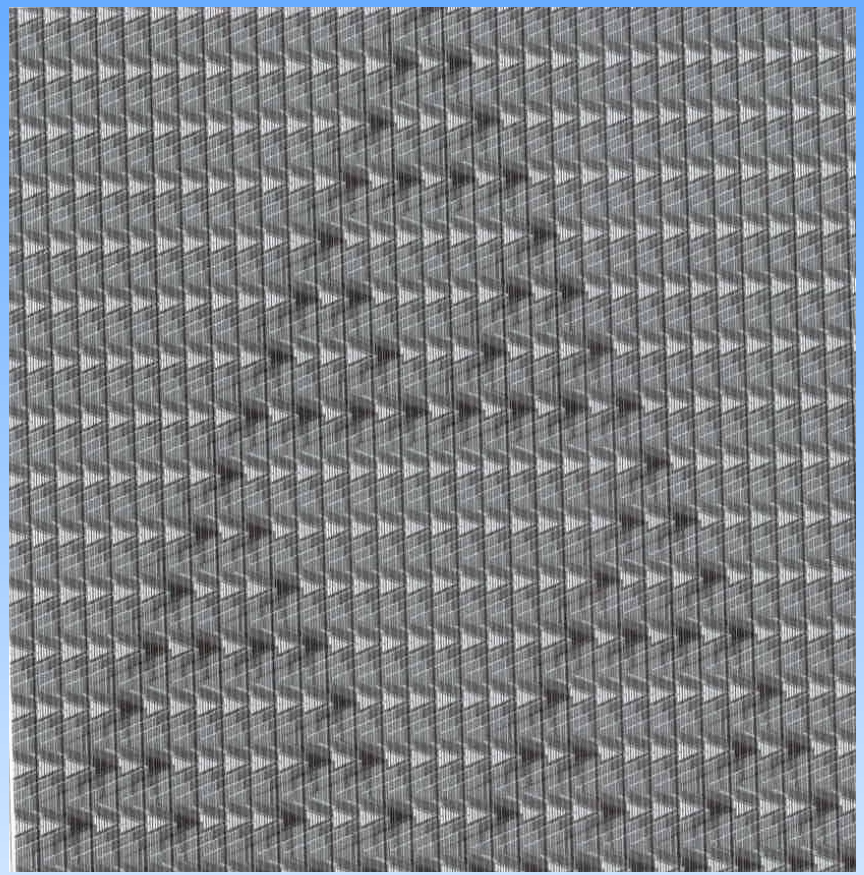
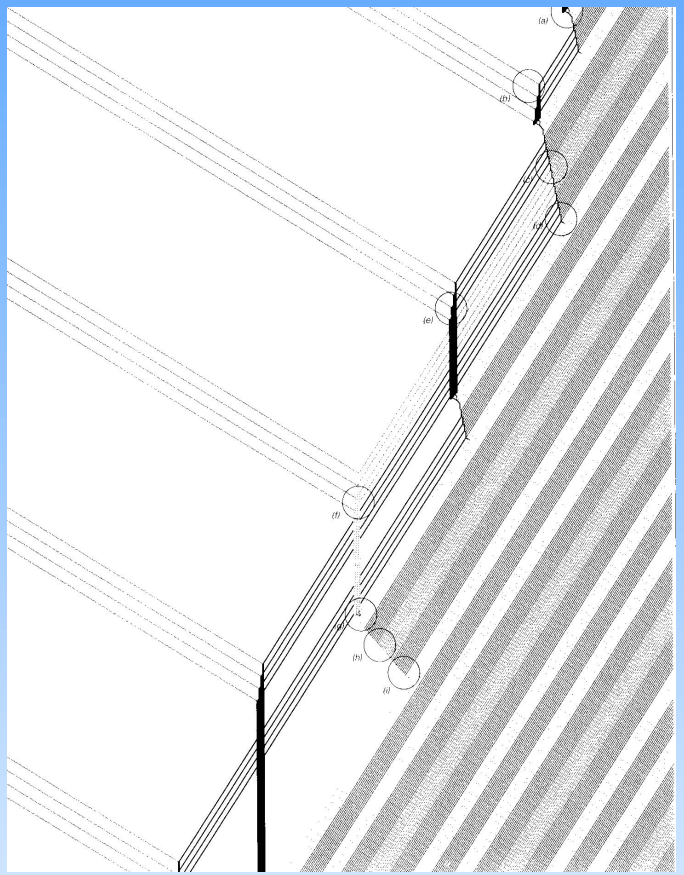
- There are universal computers among almost all very simple ones
- Threshold for universality is low – possibly all class 4 CA's are in it (localized structures allow controlled information transmission)

> I suspect that in almost any case where we have seen complex behavior . . . it will . . . be possible to show that there is universality.

Universal cellular automata





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- Related to Gödel's undecidability (does the pattern die out?)

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- Maybe we should ask about all possible input–output relations? If mutual information between them can get infinite, we can encode all computations and get universality

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- Free will is described
- Bleak human future

Last addition to understanding ANKOS

- Most systems are irreducible, but random only instrinsically
- Most systems are as complex as they get
- They cannot be predicted at all
- Traditional science is useless for them
- But aside from stating the uselessness, ANKOS does no better.