EXCERPTED FROM

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A NEW KIND OF SCIENCE

SECTION 6.3

Sensitivity to Initial Conditions

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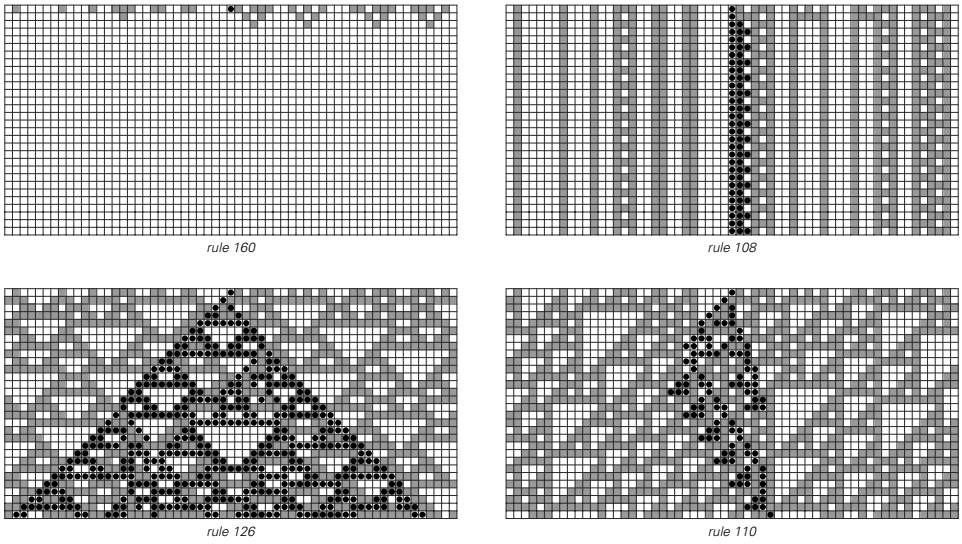
In the previous section we identified four basic classes of cellular automata by looking at the overall appearance of patterns they produce. But these four classes also have other significant distinguishing features—and one important example of these is their sensitivity to small changes in initial conditions.

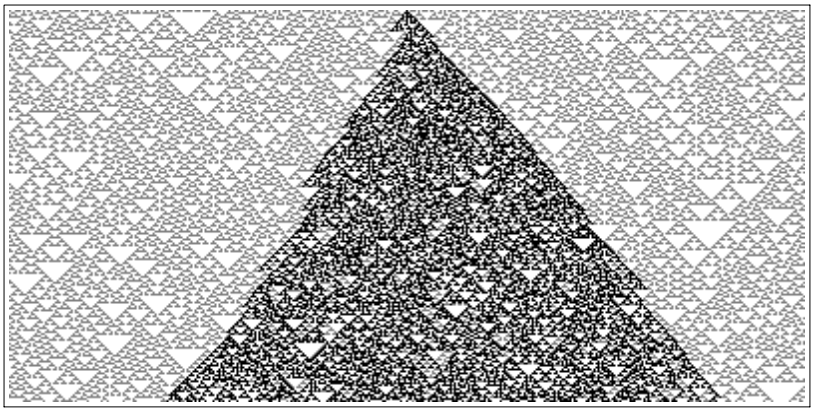
The pictures below show the effect of changing the initial color of a single cell in a typical cellular automaton from each of the four classes of cellular automata identified in the previous section.



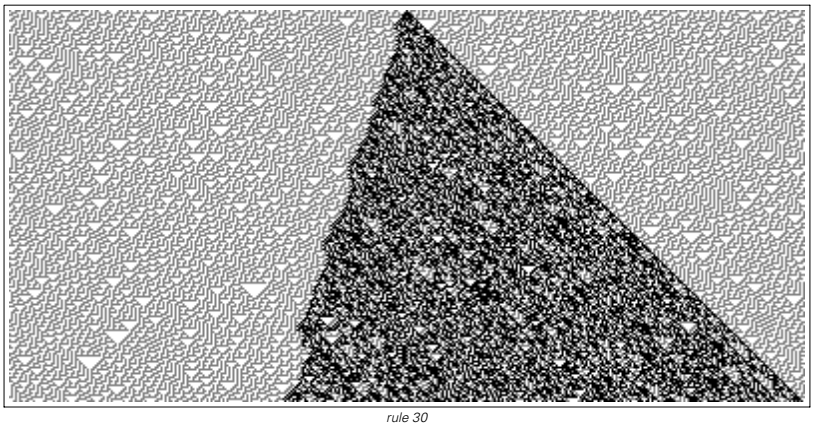
The effect of changing the color of a single cell in the initial conditions for typical cellular automata from each of the four classes identified in the previous section. The black dots indicate all the cells that change. The way that such changes behave is characteristically different for each of the four classes of systems.

The results are rather different for each class.

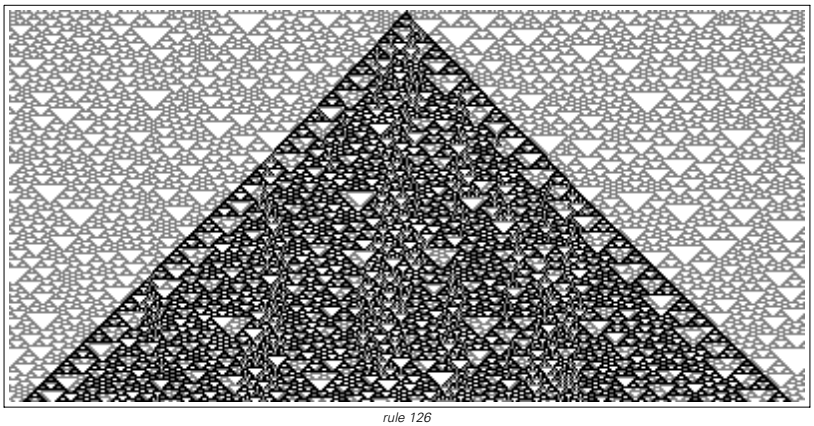
In class 1, changes always die out, and in fact exactly the same final state is reached regardless of what initial conditions were used. In class 2, changes may persist, but they always remain localized in a small region of the system. In class 3, however, the behavior is quite different. For as the facing page shows, any change that is made



rule 22



rule 30



rule 126

The effect of changing the color of a single initial cell in three typical class 3 cellular automata.

typically spreads at a uniform rate, eventually affecting every part of the system. In class 4, changes can also spread, but only in a sporadic way—as illustrated on the facing page and the one that follows.

So what is the real significance of these different responses to changes in initial conditions? In a sense what they reveal are basic differences in the way that each class of systems handles information.

In class 1, information about initial conditions is always rapidly forgotten—for whatever the initial conditions were, the system quickly evolves to a single final state that shows no trace of them.

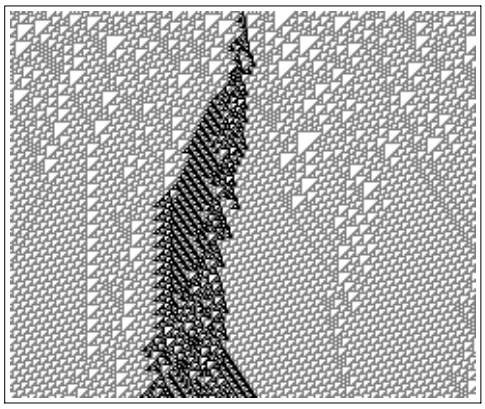
In class 2, some information about initial conditions is retained in the final configuration of structures, but this information always remains completely localized, and is never in any way communicated from one part of the system to another.

A characteristic feature of class 3 systems, on the other hand, is that they show long-range communication of information—so that any change made anywhere in the system will almost always eventually be communicated even to the most distant parts of the system.

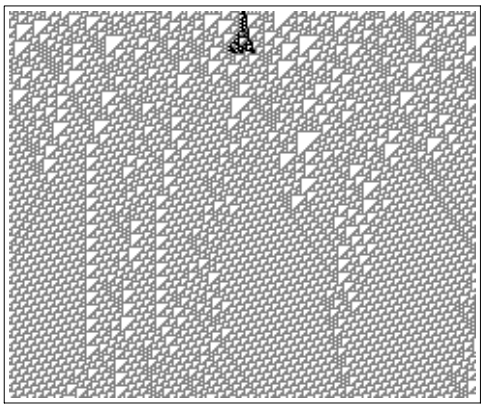
Class 4 systems are once again somewhat intermediate between class 2 and class 3. Long-range communication of information is in principle possible, but it does not always occur—for any particular change is only communicated to other parts of the system if it happens to affect one of the localized structures that moves across the system.

There are many characteristic differences between the four classes of systems that we identified in the previous section. But their differences in the handling of information are in some respects particularly fundamental. And indeed, as we will see later in this book, it is often possible to understand some of the most important features of systems that occur in nature just by looking at how their handling of information corresponds to what we have seen in the basic classes of systems that we have identified here.

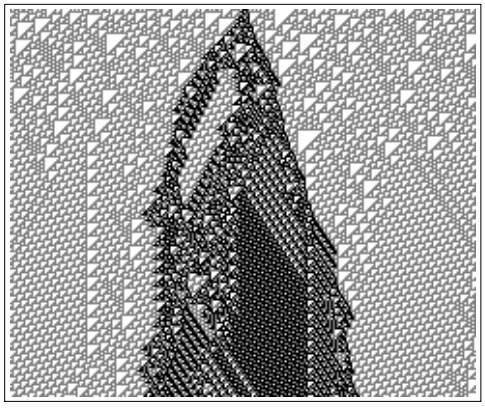
The effect of small changes in initial conditions in the rule 110 class 4 cellular automaton. The changes spread only when they are in effect carried by localized structures that propagates across the system. ▶



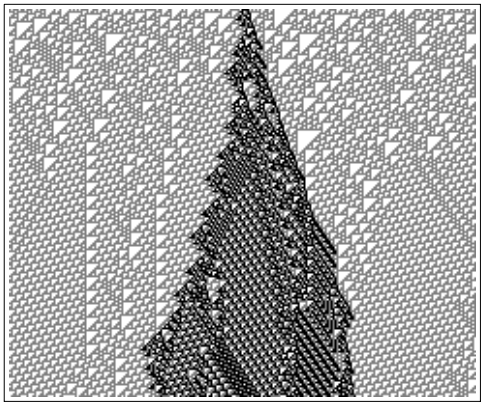
1 cell changed



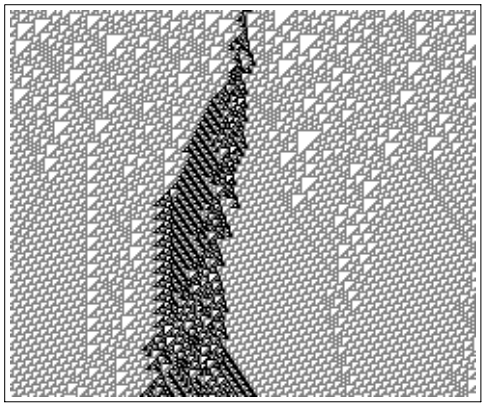
2 cells changed



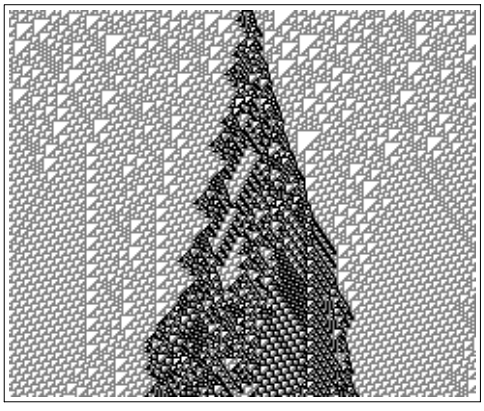
3 cells changed



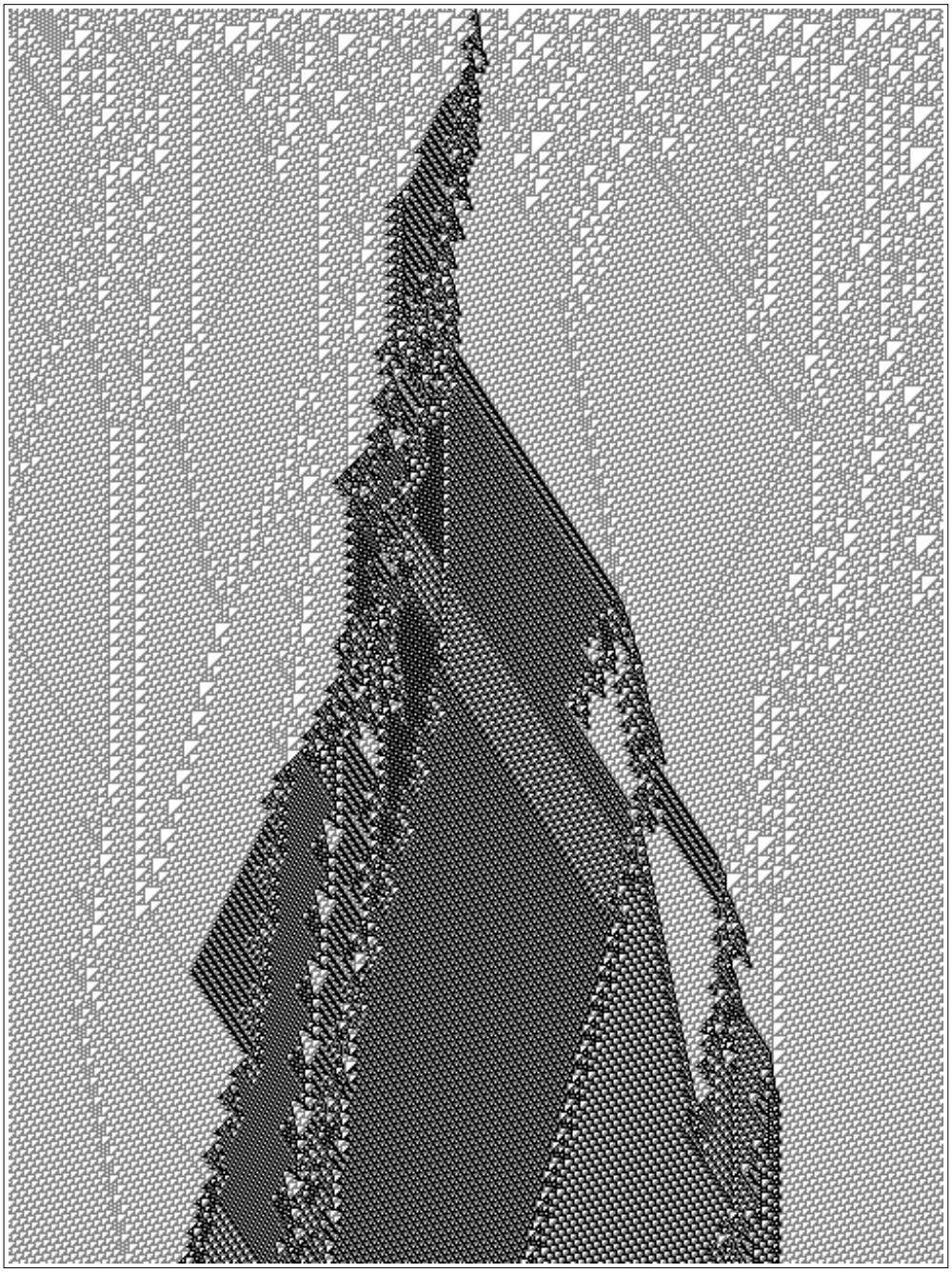
4 cells changed



5 cells changed



6 cells changed



1 cell changed