Update on Self-Reproducing Automata
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Since *IBRI Research Report* #36 was printed in 1987, its contents were published (in a slightly edited form) in *Perspectives on Science and Christian Faith* 40, 1 (March 1988): 24-31.

In the March, 1989 issue of the same journal, Dr. John Byl, of the Department of Mathematical Sciences at Trinity Western University, Langley, British Columbia, took up the challenge offered in my conclusion and designed a much simpler self-reproducing automaton than that of Langton. See his letter, *PSCFI* 41, 1 (March 89): 26-29 for details.

Briefly, Byl has designed a cellular automaton with simplified structure and transition rules which reproduces in only 25 time-steps. The initial configuration looks like this:

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 22
2632
2642
 25
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With an array of only 12 cells, with 36 special transition rules and 7 default rules, Byl uses my estimates for the probability of this automaton arising by chance in the known universe to get a timespan for formation of only 5×10^{-45} seconds as against my value of 3×10^{139} years for the Langton automaton. This would seem to make the random production of a self-reproducing automaton quite likely somewhere in the history of our vast universe. Byl has made an important step forward in the search for the simplest possible self-reproducing automaton, but his conclusion regarding the ease of its formation does not follow.

Realizing that the Langton automaton was quite unlikely, I made a number of very generous concessions in the probability calculation in order to simplify it and to avoid haggling. In the interests of realism (though not wishing to appear stingy) I must take some of these back.

1. It was assumed that all relevant atoms in the universe were already in 276-link chains (or for the Byl automaton, these would be 55-link chains). This is certainly not the case. The actual number of 55 (or larger) atom molecules is an astronomically small fraction of the atoms involved. As yet I do not know how to calculate this fraction.

2. It was assumed that these chains were trading atoms in such a way as only to make *new* combinations. This will probably not make more than an order of magnitude difference in the result.

3. It was assumed that these traded atoms were moving at a speed appropriate for a temperature of 300 degrees Kelvin (about 80° F). But few of the atoms in the universe are in such a temperature regime. Those in much colder regions will be moving around much more slowly, so that fewer combinations will be formed. In any case, life would not survive in such areas even if it could form, and it is not likely there would be much

transport form such regions to warmer regions, as the mass movement is nearly all in the opposite direction (outward from stars). On the other hand, those atoms in much hotter regions will have much faster atomic motions, but that very motion will disrupt any long-chain molecules.

It seems best to restrict our calculations to that fraction of matter in "life zones" around stars. Taking our solar system as an average, this fraction amounts to the ratio:

$$F = M_{earth}/M_{sun} = 3 \text{ x } 10^{-6}.$$

Thus the fraction of atoms making such combinations is reduced by a third of a million.

Here on earth, it is only the material near the surface that is in a temperature/pressure regime for life to function . This fraction of the total earth's mass is something like that of a think shell at the earth's surface (say 1 to 6 miles thick), which gives us a further reductio of 10^{-3} to $2 \text{ x } 10^{-4}$.

4. It appears that an error was made in calculating the complexity of the Langton automaton which was also carried over to the Byl model. The transition rules were represented as one digit per rule (the result), but in fact a label is necessary for each rule to identify it. In Byl's automaton, each of the seven default rules needs one digit (the current value of the cell) to distinguish among them. The non-default transition rules depend upon the current values of the founr neighboring cells, which thus require a four-digit label for each. Adding in this complexity raises the number of combinations from Byl's value of $6 \text{ x } 10^{42}$ (page 28 of his article) to $2 \text{ x } 10^{173}$. Without even taking back the concessions discussed in items 1-3, above, this gives a formation time of $3 \text{ x } 10^{79}$ years again, and random formation appears to be out of the question.

I would appreciate correspondence from readers on possible improvements to this model calculation, as I believe the determination of minimum complexity for any reasonable analogs to life is desirable in working through the basic questio of life's origin.