the properties of (Fe,Mg)O at lower mantle pressures and temperatures remain the weakest part of my argument, and this emphasizes the need for detailed studies of magnesiowüsite at high pressure and temperature.

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Simplifications of a Self-Replication Model

J. A. Reggia *et al.* (*1*) describe a simple system (called UL6W8V) that directs persistent self-replication of an informational figure in two dimensions; the process is guided solely by local interactions of the components of the figure throughout its life history. Each cell in a gridded plane exists in one of eight states: empty or occupied by O, L, #, or one of four axially oriented arrows. At each transition, the new state of each cell is determined by a rule based on the current states of the cell and its four immediate neighbors. The basic form of UL6W8V is six occupied cells in a loop of three corners and a branchpoint, with a two-cell arm. A specific stage is

V L
O O L>

With successive transitions, the string OOL> flows both counterclockwise around the loop and out the arm from the branchpoint. A daughter loop is constructed on the arm and the two loops separate, with new arms forming perpendicular to the original arm. Colony growth continues indefinitely, but loops are prevented from replicating into occupied space; in such collisions, the new arm does not form, and the information sequence L> circulating in the loop is erased (that is, converted to OO).

There is a family of simpler variants of the UL6W8V duplication cycle. (i) When the arrow arrives at the branchpoint, the choice of its orientation toward either direction of string flow is arbitrary. The variants use the anticlockwise orientation, which is simpler because it retains the orientation, with respect to loop neighbors, of a corner arrow. (ii) Generation time can be reduced from ten [as stated in (*1*)] to six transitions by incorporating the information sequence directly into the new arm; this regenerates the starting figure depicted above. (iii) The L state signaled left turns during daughter loop construction in earlier systems that lacked oriented states, but the arrow suffices for this function. Replacing L with O reduces to seven the number of states used, and the information sequence to a single character. (iv) The generation time in the seven-state system can readily be shortened, as above. (v) The # state serves a single role, as a pre-arm. An arrow, oriented toward the "probe" arrow that pops out from either side of a dividing loop pair, can also fill this pre-arm role, thus requiring only six states of three types of cell (empty, O, or arrow). (vi) The generation time of this six-state system can be shortened from ten to six transitions; however, the information arrow cannot be incorporated directly at the new arm tip, and arm formation cannot be simply advanced by a single transition to facilitate its incorporation at the new arm base. One solution is to advance probe formation by two transitions, with a relative single-transition delay of arm formation, timed with the use of a false pre-arm (an arrow pointing toward the loop) before the appearance of the correct pre-arm. These variants can be compared in terms of the number of state-change rules required for a duplication cycle: 28, 24, 22, 19, 21, and 20 for slow and fast eight-state models, slow and fast seven-state models, and slow and fast six-state models, respectively; UL6W8V requires 31 rules.

Post-duplication loop interactions can also be simplified. If the pre-arm is prevented from forming at collision, the probe is maintained and can be used for timing the insertion of a "jam" arrow between the two dividing loops. The jam promotes erasure in the targeted loop and decay of both itself and the probe. Its benefit is seen if one compresses the complete set of rules that describe colony growth by allowing the identity of certain cell neighbors to be ignored while contradictions are avoided. Model UL6W8V originally required 33 compressed rules for colony growth (*1*); use of the jam reduces this number to 23. The jam can be applied to the eight-state variants, but for the others, erasure is less elegant. However, erasure after collision is neither essential for colony growth nor necessarily desirable; if erasure is not demanded, the pre-arm and probe can simply decay upon collision. The fast seven-state system uses only 15 compressed rules for such colony growth.

Mutability can be conferred on these systems by incorporating the appropriate stochastic features. Small changes in the rule set can drastically alter such properties as generation time.

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