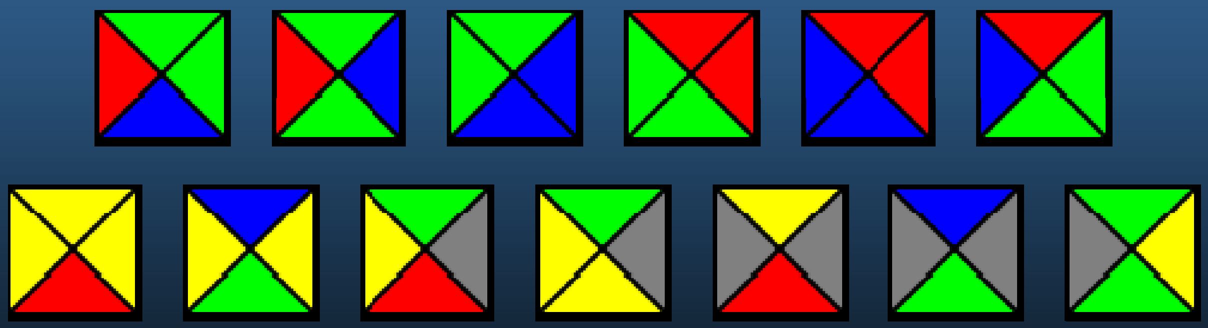
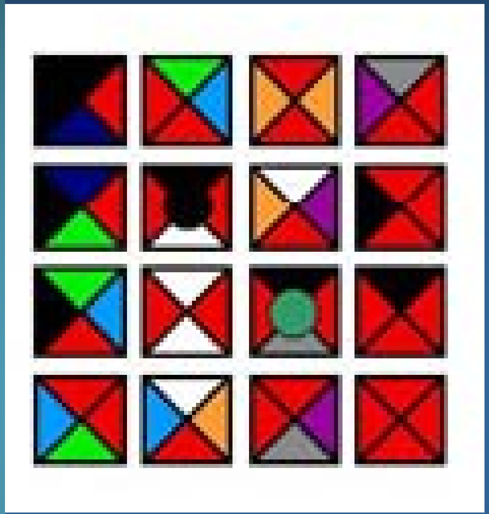
DNA-Based Computation and Algorithmic Assembly

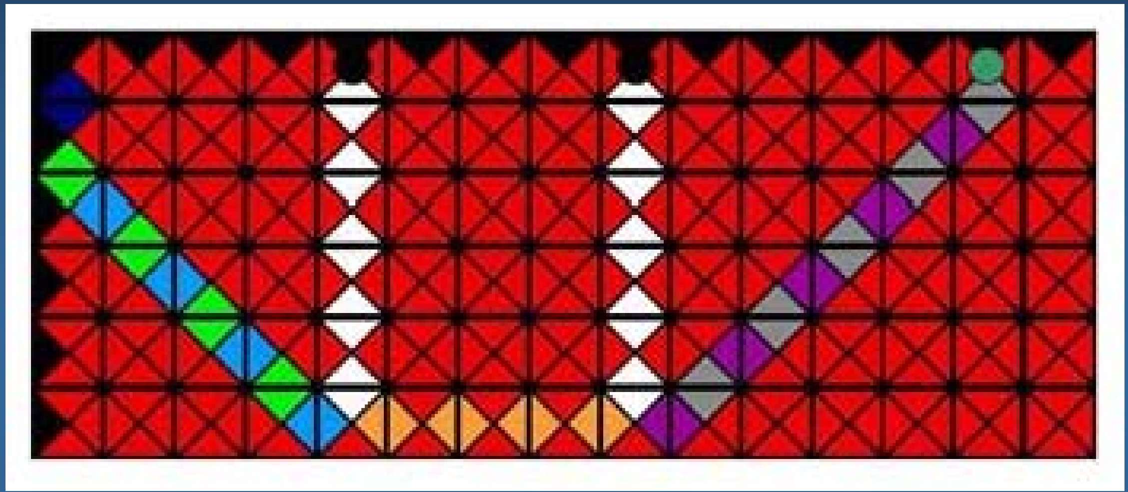
Wang Tile

- Wang tiles (or Wang dominoes) were proposed by mathematician Hao Wang in 1961.
- Equal-sized squares with a color on each edge which can be arranged side by side so that abutting edges of adjacent tiles have the same color.



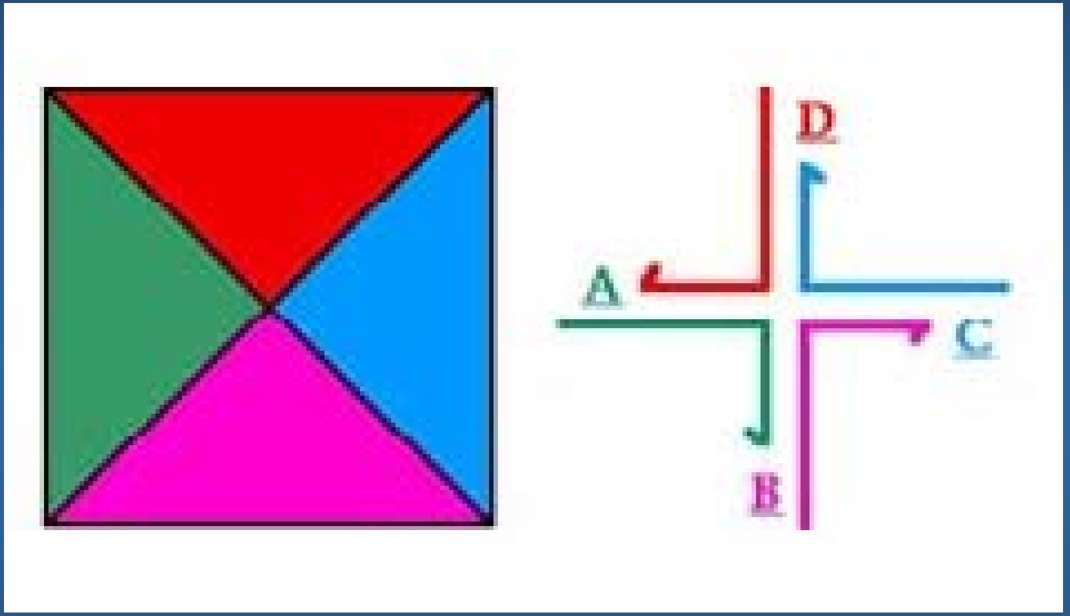
Wang Tile



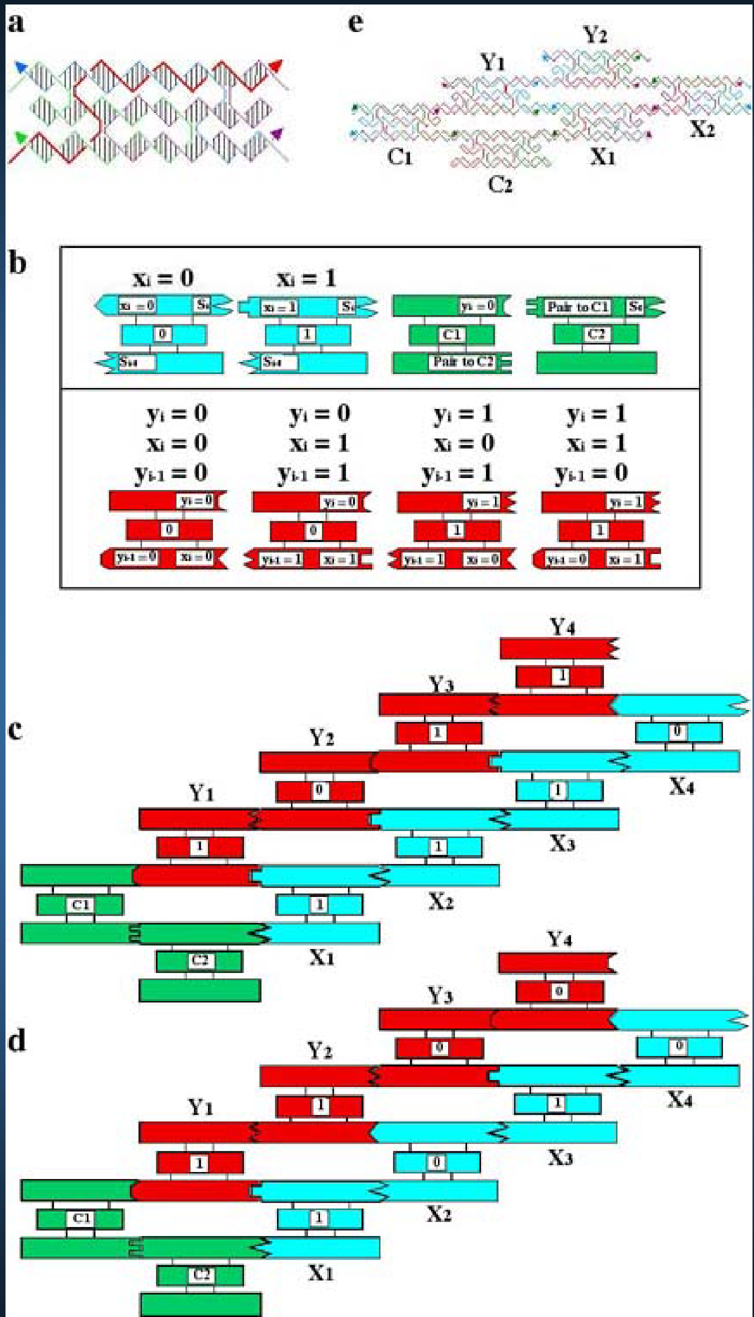


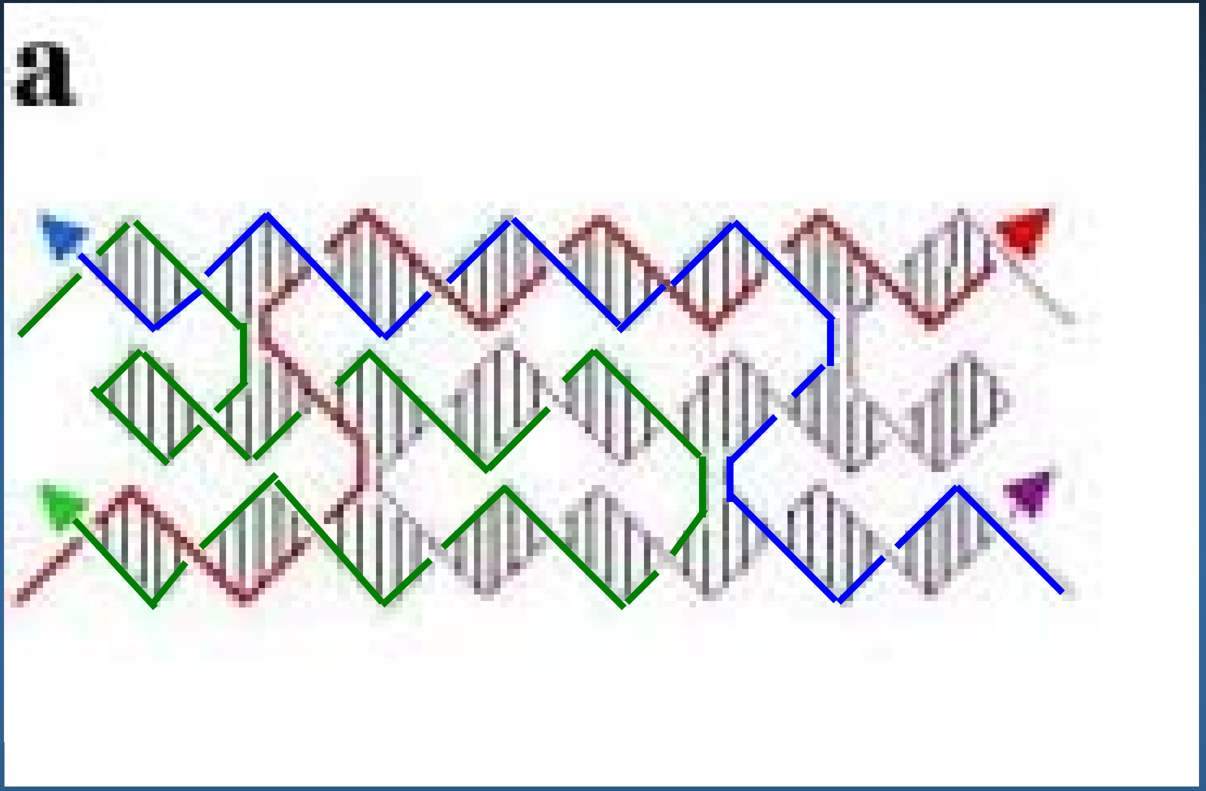
- In a sense, Wang tiles have computational power equivalent to that of a Turing machine.

Wang Tile and Branched Junctions



The sticky ends on the branched junction can emulate a Wang tile.


a
e
Y2
Y1
X2
C1
X1
C2
b
xi = 0
xi = 1
yi = 0
yi = 0
yi = 1
yi = 1
xi = 0
xi = 1
xi = 0
xi = 1
yi-1 = 0
yi-1 = 1
yi-1 = 1
yi-1 = 0
c
d
Y4
Y3
Y2
Y1
X4
X3
X2
X1

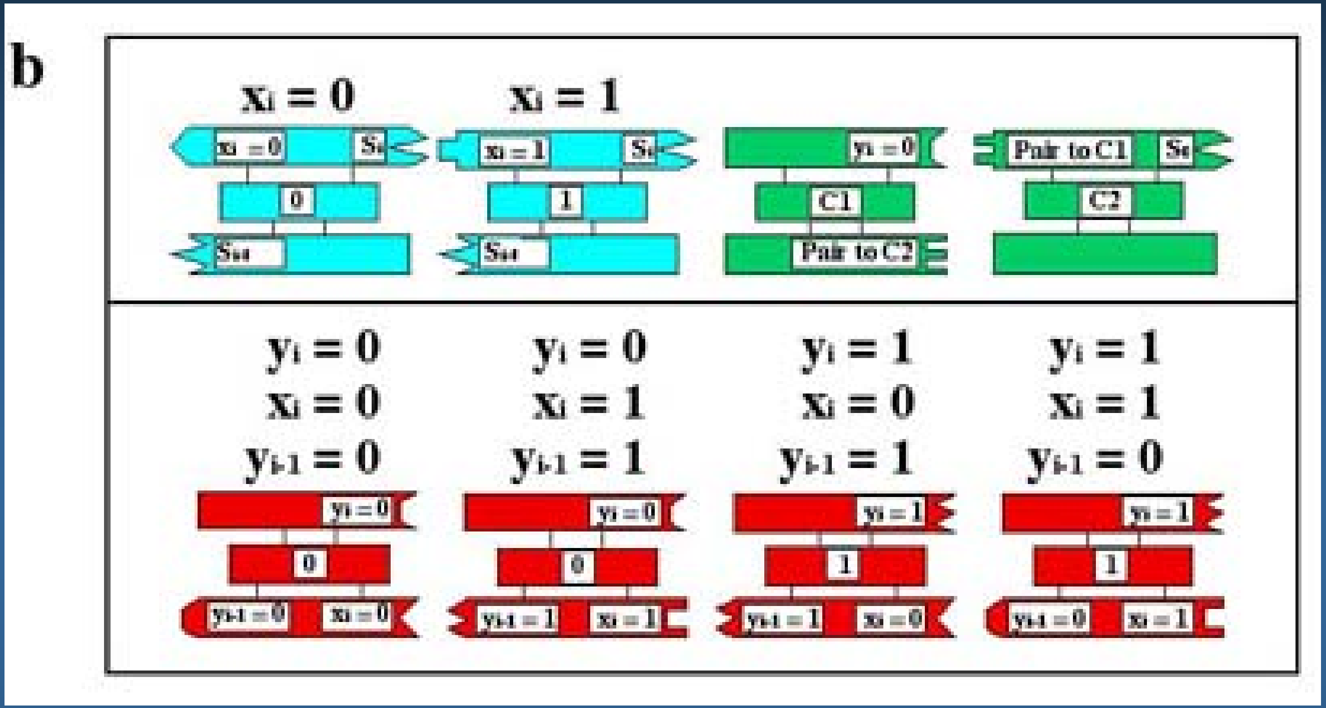


(a) shows a triple crossover (TX) molecule, whose topology produces a reporter strand that is drawn with a thick red line. Each of the components is a similar triple crossover molecule.

$y_i = XOR(x_i, y_{i-1})$

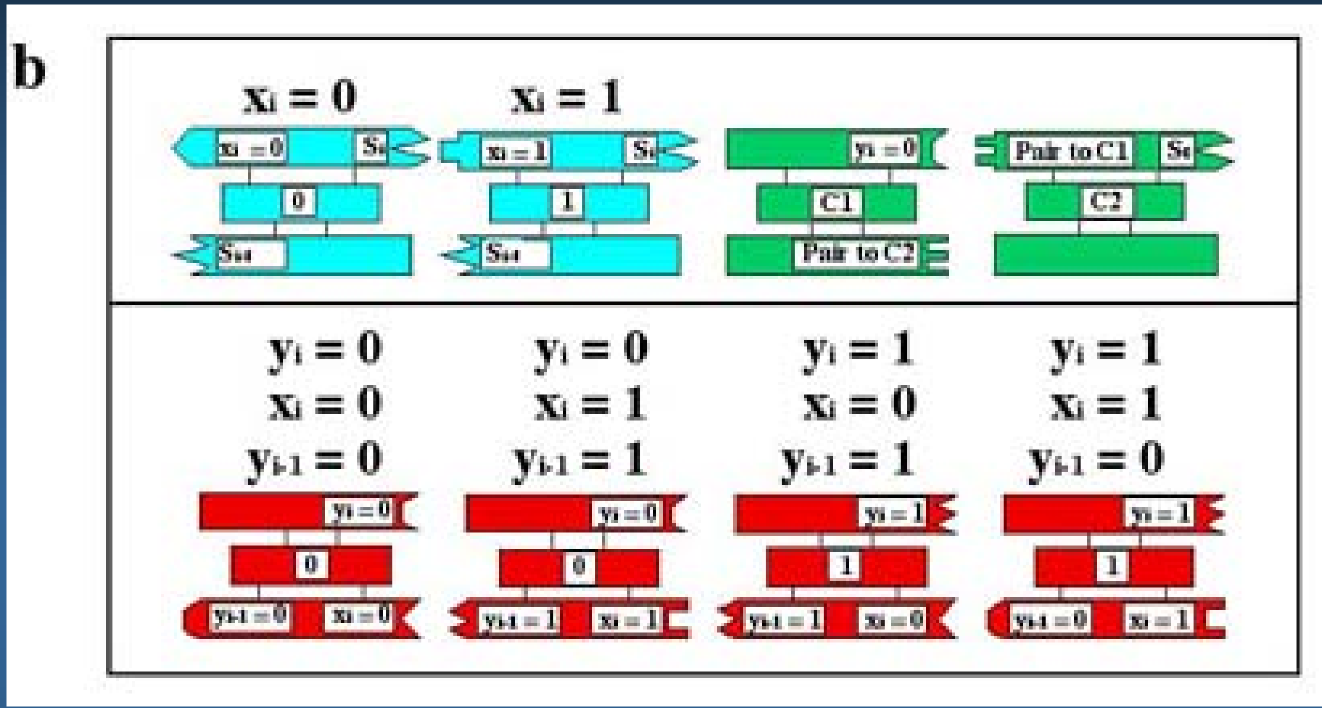
- The XOR operation reports a 1 if the two inputs are different, 0 and 1 or 1 and 0, and it reports a 0 if they are the same, 1 and 1 or 0 and 0.

[Y(i-1), X(i) -->Y(i)] $y_i = XOR(x_i, y_{i-1})$



- The input X(i) tiles are drawn in light blue. Their value is shown at the center of the tile.
- '1' tile contains EcoR V site on the reporter strand
- '0' tile contains Pvu II site on the reporter strand.

[Y(i-1), X(i) -->Y(i)] $y_i = XOR(x_i, y_{i-1})$



- The sticky end (drawn as a geometrical shape) that corresponds to, say, X(i) = 1 is the same both for the second Y tile [Y(i-1) = 1; X(i) = 1; -->Y(i) = 0] and for the fourth Y tile [Y(i-1) = 0; X(i) = 1; --> Y(i) = 1].

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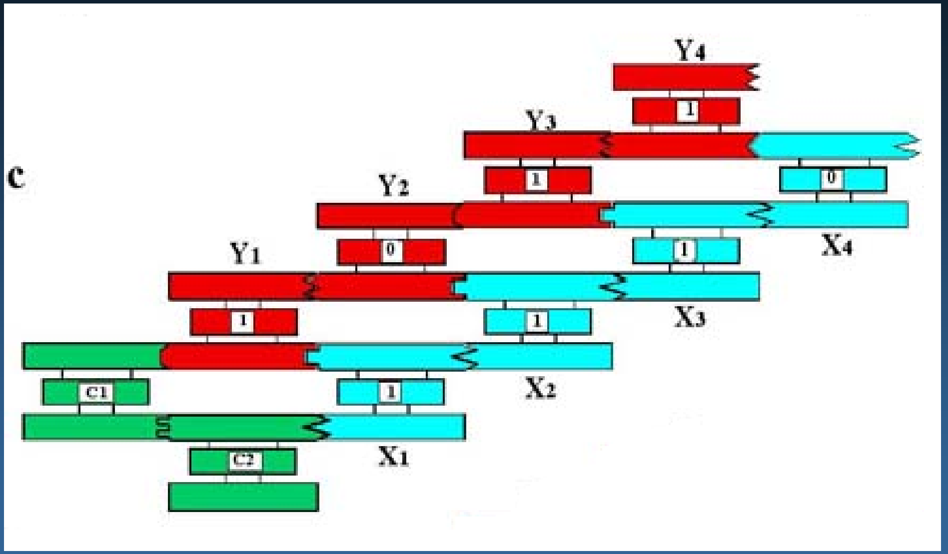
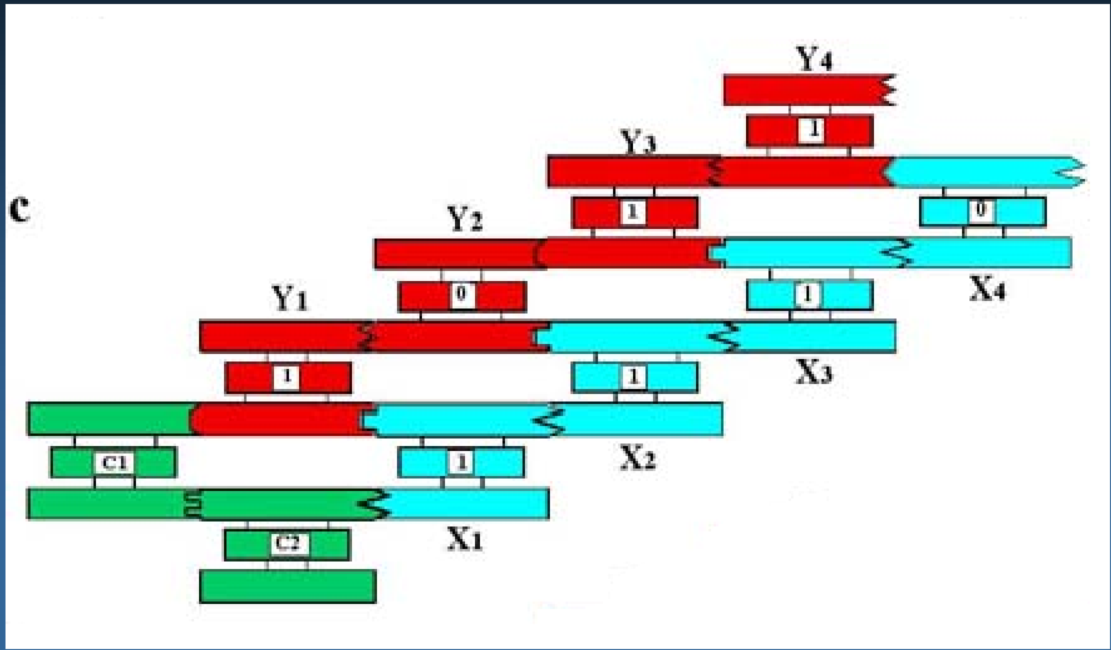


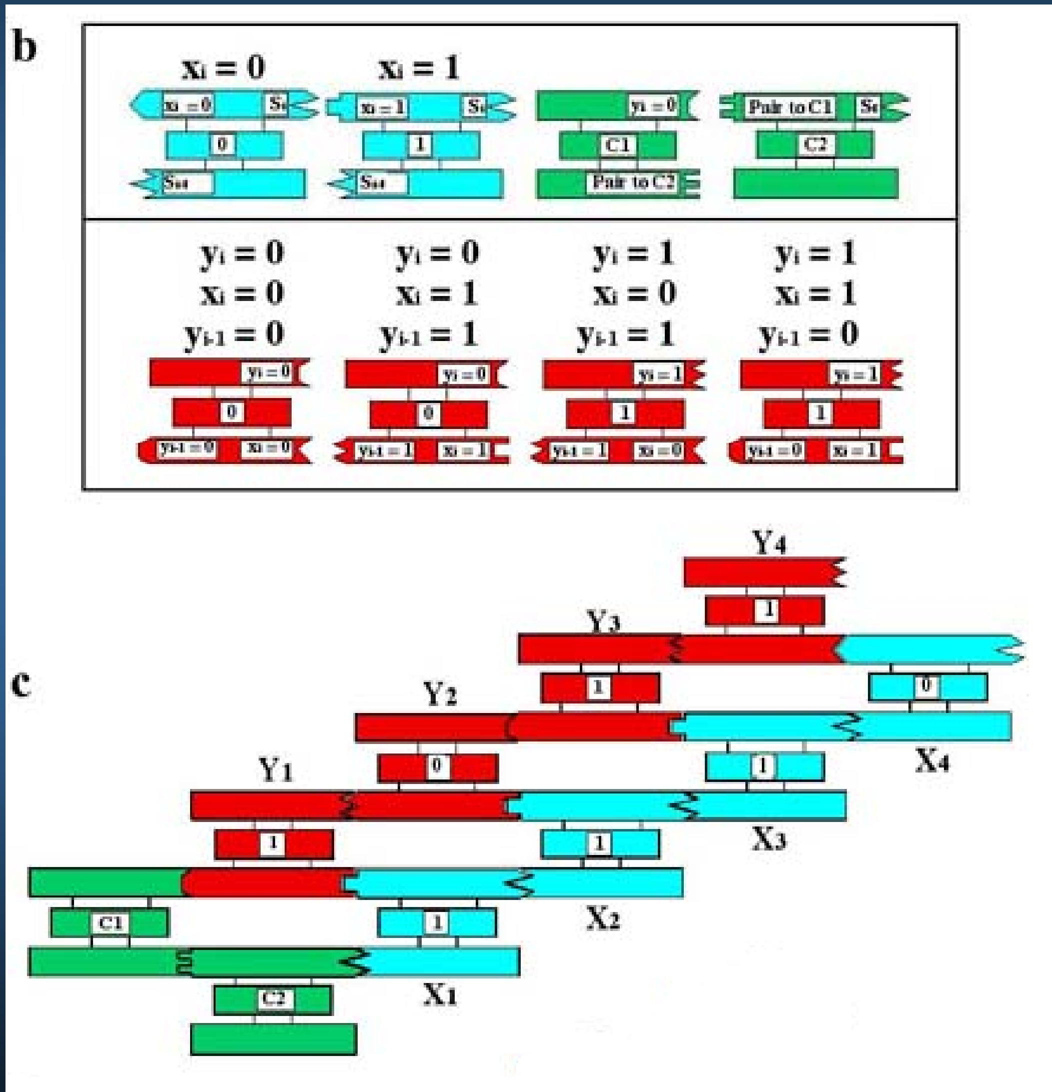
- <u>C's & X's</u>
  - To perform the calculation in parallel
    - One would allow the X(i) tiles to associate randomly, giving, for a four-bit problem, 16 different final answer strands.
  - To assemble the X and C tiles first in a cooling protocol
    - Longer sticky ends were assigned to those tiles connecting the X and C tiles, than to those involving the Y tiles.



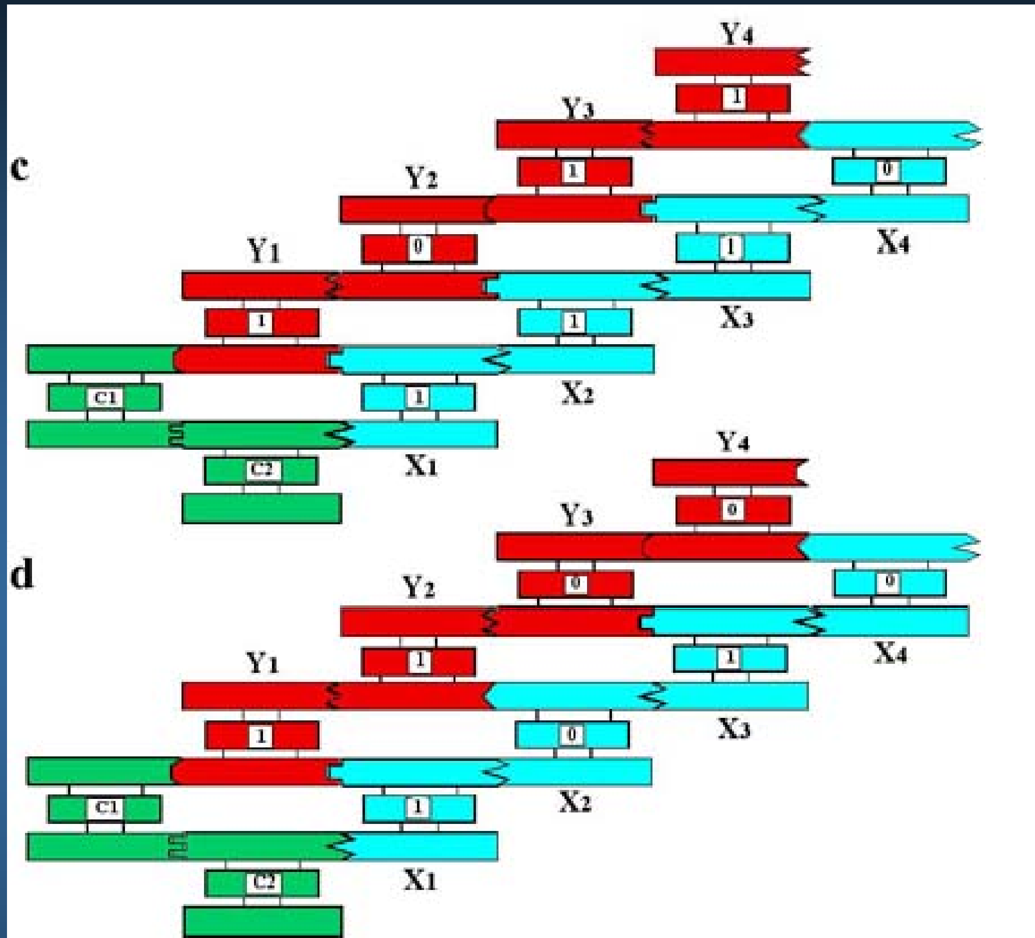
Y's

- The Y-tiles are connected to the X tiles
- The four possible Y answer tiles [Y(i)], corresponding to the two different inputs [Y(i-1), X(i)]are drawn below these tiles.

$y_i = XOR(x_i, y_{i-1})$



b
xi = 0
xi = 1
Pair to C1
C1
C2
Pair to C2
yi = 0
xi = 0
yi-1 = 0
yi = 0
xi = 1
yi-1 = 1
yi = 1
xi = 0
yi-1 = 1
yi = 1
xi = 1
yi-1 = 0
c
Y4
Y3
Y2
Y1
X4
X3
X2
X1



- The two calculations we performed are shown in (c) and (d).
- In (c), the inputs are X(1) = 1; X(2) = 1; X(3) =1; X(4) = 0. This should lead to Y(1) = 1; Y(2) = 0; Y(3) = 1; Y(4) = 1.
- In (d), the input values are X(1) = 1; X(2) = 0; X(3) = 1; X(4) = 0, leading to Y(1) = 1; Y(2) = 1, Y(3) = 0; Y(4) = 0.

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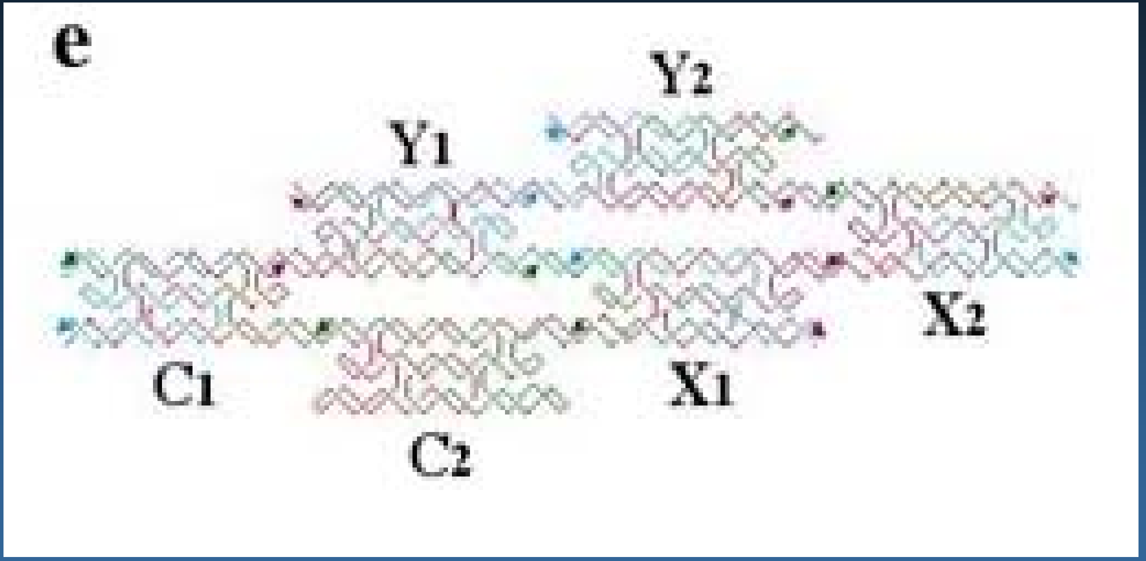

To extract the answer from the self-assembly, some means must be found to make a record of it. This is done by ligating the reporter strands together, as shown in (e). Once the ligation is complete, the strand is subjected to PCR and is treated with the appropriate restriction enzymes (partial digestion). The answers to the two calculations are then visible on a gel.

Gel Electrophoresis