Due: Workshop+1d

Physical Chemistry II

Exercises Set 4

1. Conceptional

a. List the idealization made by modeling natural systems by discrete binary cellular automata CA.

b. How many instructions for survival are possible for such a CA, taking account only of the status of nearest neighbors, encoded in ☐☐☐ bytes?

c. How does that number scale when also the next-to-nearest cells are included, i.e., in ☐☐☐☐☐ bytes?

d. Read the tutorial about Fractal Dimension & Structures. What is a fractal structure? What geometrical properties make them different from other materials? Are fractal structures found in nature?

2. Cellular Automaton #150

Consider the CA given by the propagation rule encoded by the decimal 150.

a) Decode the rule and draw the "code bar" with the ordered set of (3-bit) bytes $\{p_i, q_i, r_i\}$ defining geometrically the population conditions for the CA with increasing time step $i \rightarrow i+1$.

b) Encode the in formal logics those conditions $\{p_i, q_i, r_i\}$ of the code that lead to $q_{i+1}=1$ (occupied).

c) Take each byte $\{p_i, q_i, r_i\}$ of the code bar by its numerical value, empty bit=0 and filled bit=1. Deduce a purely numerical condition on the population $q_i \rightarrow q_{i+1}$.

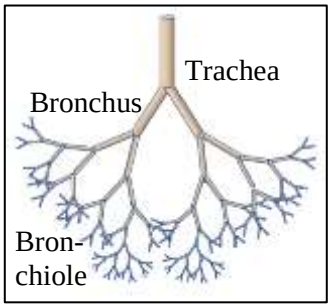
3. Construct Cellular Automaton

The geometrical pattern of the discrete 1D CA#20 was discussed in class. Plotting the time evolution on a 10x10 – (t, x) grid, it produces a linear, staircase-like trail tending to the right. For each of the tasks below, draw the ***code bar*** with the ordered set of bytes

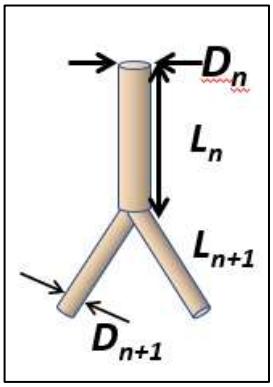
defining geometric survival conditions for the CA. In each case, start with the single seed cell (t=0, x=5) occupied (alive) at time zero in the center of the array. Follow the prescribed time evolution by shading cells occupied in sequential time steps.

a) Design a new CA# LL that produces a mirror image of the CA#20 pattern, i.e. one tending to the left. Demonstrate the CA#LL pattern by marking the evolution for at least 4 time steps.
b) Design a new CA#LR by combining CA#20 with CA#LL in an inclusive logical OR of both sets of survival codes.
c) Shade the pattern for CA#LR for 8 time steps. Discuss the nature of evolved pattern (symmetry, repetition, density of area cover).

4. Fractional Respiratory System (AC)



Consider the fractal model of the human respiratory system pictured in the drawing. Doubling of the number of tubes and an associated reduction in diameter $\boldsymbol{D_n}$ and length $\boldsymbol{L_n}$ by a factor $\boldsymbol{R}$ repeats at each of $\boldsymbol{N} = 24$ levels. Use data for a typical human, i.e., $D_0 = 2$ cm, $D_{23} = 0.2$ mm.



From the data given above, calculate

a) the ratio D_n/D_0,

b) the scale factor R,

c) the total number of tubes,

d) the total combined length of all tubes, and

e) the total combined volume of all tubes.