EE 193/COMP 150: Computing with Biological Parts
Spring 2019
Quiz #1 (bio & morphogenesis backgrounders)

Name:

1. The central dogma of biology is that (pick one):
   - a) DNA codes for the generation of RNA, which codes to create proteins
   - b) life proceeded by evolution rather than by divine creation
   - c) DNA is formed from two identical strands in a double helix
   - d) proteins fold into intricate shapes to precisely bind other molecules

2. Spoiler alert: the upcoming Game of Thrones season 8 will reveal that a White Walker has been captured and had its DNA sequenced. Its DNA has 6 bases (not only the usual A,G,C,T, but also X,Y), and its proteins are built with 39 amino acids. Assuming that the central dogma of biology holds for White Walkers, how many bases would they need in each codon, and why? What if White Walkers had only 36 amino acids?

See slides #9 and #10 in the biology backgrounder. In general, this is an encoding problem. For humans, with 4 bases, a single base could represent any of four different amino acids. Two bases gives 4*4=16 choices, and 3 bases gives 4^3=64 choices. It's the same idea as that in base 10, a three-digit number can represent anything in the range 0-999, or 1000 different numbers.

The White Walkers have a choice of 6 bases in each location, so it implements a code in base 6 rather than base 4. So a codon with two bases would give 6*6=36 possible amino acids, and one with three bases would give 6*6*6=216 choices. Thus, three bases are plenty to represent 39 amino acids. It would *almost* be enough for part (b) as well – except that we also need "start" and "stop" codons.

3. In general, with Boolean logic, it is true that AND (A, B, C) is equivalent to AND (AND (A, B), C); i.e., you can build a three-input AND gate with two two-input AND gates. However, biology may sometimes add its own constraints! Assume that we have a particular promoter, the AND2Prom promoter, that performs transcription whenever the transcription factors Px and Py are both present. Could we use two copies of this promoter (each in their own gene) to build a three-input AND gate (i.e., a system that produces a desired protein when every one of three particular input molecules are all present)? Why or why not?

No. Promoters are specific – if the AND2Prom promoter implements the AND of Px and Py, then that is what it does. It cannot, e.g., also implement the AND of two other proteins Pz and Pw. Thus, we could not use it to build the second AND gate above.

4. We would like to build a cell that glows green when protein PA is present, PB is absent, and PC is present (i.e., an AND-type function). You have the following promoters available:

- AProm: true whenever PA is present
- BProm: true whenever PB is present
- CProm: true whenever PC is present

- AND3Prom: true whenever the transcription factors P1, P2 and P3 are all present
- InvProm: true whenever the transcription factor P3 is absent

Assuming that you can build a gene with any of these promoters that produces as many output proteins as you like, show how you would build a cell with the desired property.

AProm generating protein P1
BProm generating protein P4, and then InvProm generating protein P2
CProm generating protein P3
AND3Prom generating GFP (green fluorescent protein)

5. Here are two theories for how morphogenesis happens:
   a) DNA is an explicit step-by-step recipe for how to assemble a body
   b) DNA provides a goal for what to build; a feedback mechanism keeps comparing the body's current shape with that goal and deciding how to alter the current shape via growth

   Which do you prefer? Back up your statement with two pieces of evidence.
   There were many answers for this one.