Name: _____

Complex Adaptive Systems (CS 423/523) Midterm
March 21, 2019

The exam is worth 120 points. You may not use books, notes or calculators for this exam. You may use the back of the exam or ask for blank pages for scratch paper. You don't need to simplify powers or fractions. Write your answer in the space provided. Write clearly legible letters for multiple choice or **True** or **False** in the blank provided. Short answers should fit in the space provided. There are several longer questions toward the end, so be sure to leave sufficient time to complete those.

1. Order the following strings <u>from lowest to highest</u> Shannon Entropy.
   Assume that all strings are the same length.
   a. A string of zeros and ones in which the probability of zeros and ones is equal.
   b. A string of zeros and ones in which the probability of zeros is twice the probability of ones.
   c. A string of zeros, ones and twos in which all are equally probable.
   d. A string of all ones. 1. _____ (4)

2. A system with high **effective complexity** will always have higher entropy than a system with low effective complexity. True or False? 2._____ (2)

3. The Algorithmic Information Content (AIC, or Kolmogorov Complexity) of an object is defined as the length of the shortest computer program that can generate a complete description of the object and halt. True or False? 3._____ (2)

4. Given these 2 bit strings:

S1 = 11001100110011
S2 = 10100100010000

4a. Which has greater Shannon entropy?

a) S1
b) S2
c) S1 and S2 have the same Shannon entropy
d) it is not possible to know which has higher Shannon entropy 4a._____(2)

4b. Which has greater Effective complexity?

a) S1
b) S2
c) S1 and S2 have the same Effective Complexity
d) It is not possible to calculate which has higher Effective complexity 4b._____(2)

/12 pts

4c. Explain your answer for 4b. 4c._____(3)

_____

_____

4d. A string with no discernable regularities has higher effective complexity than a string with a simple repeating pattern. True or False? 4d._____(2)

4e. Is the transfer entropy from S1 to S2 higher or lower than the transfer entropy from S1 to itself? Write higher or lower in the blank and explain your answer below.

4e._____(5)

_____

_____

_____

5. Answer **True or False** for the following, given R = population growth rate and x = population size relative to carrying capacity.

a. In the logistic map, adding a constant number to R will cause the number of observed values of x (the periodicity of x) to double. 5a._____(2)

b. For some values of R, a value of x in the distant future can be predicted even if the initial value of x is not known with high precision. 5b._____(2)

c. Chaotic dynamics can be generated by deterministic equations. 5c._____(2)

d. Populations governed by the logistic map always exhibit sensitive dependence on initial conditions. 5d._____(2)

/18 pts

6a. (4 points) Fill in the rule table for Wolframs Cellular Automata Rule 122.

Current state	Transition state of the center cell (0 or 1)
000	
001	
010	
011	
100	
101	
110	
111	

Hint: To translate Rule 122, remember that the transition state for 000 is the least significant bit (corresponding to 0 or 1) and the transition state for 111 is the most significant bit (0 or 128).

6a. answer in table (4)

6b. (6 points) Given Wolfram's Rule 122, and a 1 D CA with the initial condition given below, show the state of the CA for the next 3 time steps.

0	1	1	1	0

6b. answer in table (6)

6c. How many *different rule tables* (like the one in 6a) transition to 11111 in one time step given an initial condition of 00000? 6c._____(2)

6d. Given a CA with alphabet {0,1} and neighborhood size 7 (meaning neighbors are considered from a radius of 3), how many entries are needed in the rule table to specify every possible transition? 6d._____(2)

6e. How many possible *different* rules can be specified from the CA in 6e? You may leave exponents in your answer. 6e._____(2)

/16 pts

11. Explain under what conditions ants or bees can acheive optimal decision making according to the Marshall optimal decision making paper.

_____

_____

_____

_____

11. _____ (6)

12. The Central Dogma states that DNA is transcribed into RNA which is translated into proteins which are largely responsible for an organism's phenotype. T or F? 12._____(2)

13. List and <u>briefly</u> explain 3 reasons that Evolutionary Theory may need a rethink.

1. _____

_____

2. _____

_____

3. _____

_____

13._____(6)

14. Andreas Wagner argues that in mutationally robust systems, mutations often do not result in new phenotypes; therefore, mutational robustness reduces genetic variation in a population over time. True or False? 14._____(2)

/16 pts

15a. Melanie Mitchell demonstrates that a GA can evolve a CA ruleset that correctly classifies any input bit string as majority ones or majority 0s.

True or False? 15a._____(3)

15b. λ describes the fraction of ones in the transition states of a CA table. Which of the following are true?

a. For the "majority rule" λ is ½
b. As a rule set is evolved for density classification in Mitchell, λ increases monotonically
c. As a rule set is evolved for density classification in Mitchell, λ is initially close to ½
d. As a rule set is evolved for density classification in Mitchell, there are no systematic changes in λ

List all true statements 15b._____(4)

16. Bob is the world's simplest organism.
Bob's genome consists of a single codon (3 base pairs): AAA.
Helpful hints:
There are 4 base pairs: A, G, C, T.
There are 20 amino acids.
The amino acid Lysine is encoded by 2 codons: AAA and AAG.

16a. How many genomes of the same length (3 base pairs) are 1 mutation away from Bob? 16a._____(2)

16b. How many are 2 mutations away? 16b._____(2)

16c. How many are 3 mutations away? 16c._____(2)

16d. How many possible genomes of length 3 are there? 16d._____(2)

16e. How many distinct phenotypes can possibly exist among Bob and 3 generations of his offspring (Bobs children, grandchildren and great grand children)? 16e._____(2)

16f. How many genomes are in Bob's neutral network (include Bob in your count)? 16f._____(2)

17. Software mutational robustness is defined as the fraction of random mutations to software that leave a program's behavior unchanged with respect to what? (Answer with a few words below).

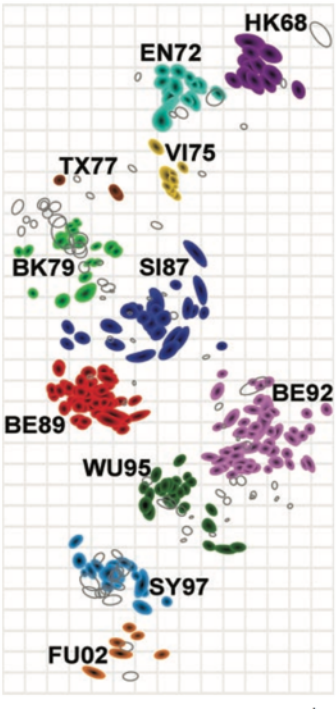
_____

17._____(3)

18. Gell Mann says that much of the effective complexity in the universe arises from Frozen Accidents. Frozen accidents make it difficult for the innate immune system to classify different types of pathogens. True or False?

18._____(2)

/24 pts



19a. In the antigenic map of Smith et al. (shown to the left), the distance between points indicates what?

a. Time
b. Antigenic distance (corresponding to differences in virus phenotype)
c. Genetic distance (corresponding to differences in virus genotype)
d. Geographic distance

19a._____(2)

19b. Smith et al showed that small changes in virus genotype

a. usually generated small changes in phenotype
b. usually generated large changes in phenotype
c. occaisionally generated large changes in phenotype
d. never generated any changes in phenotype
e. always generated some change in phenotype

List ALL correct answers (and no incorrect answers) 19b._____(4)

19c. Is mutational robustness in the flu virus advantageous or disadvantageous for humans? Breifly explain in the space below.

_____

_____

_____

19c._____(4)

/10 pts

20. Mitchell lists 4 ways that information is communicated and processed in complex adaptive systems. List three of them and explain what they mean, using a system we've studied in class (e.g., a GA, CA, ant colony, or immune system), to provide concrete examples of how information is communicated and processed.

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

20._____(12)

21. You probably studied things that I did not ask about. Provide a question that I did not ask, and answer it with a figure or a few sentences. Your grade depends on you asking a non-trivial question, and a correct answer.

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21._____(12)

/24 pts

Final Score _____/120 pts
(of 122 possible points)