Name: ______________________________ Time:

> CS523 Midterm Exam.
> This version of the exam is for students enrolled in *CS523: Complex Systems*. If you are enrolled only in *CS423: Introduction to Complex Systems* please ask for the corresponding exam. If you are enrolled in both CS523 and CS423 take this exam.

The exam is worth 15% of your final grade for this course. There are 25 questions each equally weighted (1 point each). The exam is 50 minutes long. The questions in each section refer specifically to the associated reading printed in **bold**. Mark the best answer by filling in the circle next to it. Explanatory comments will not be considered.

1. **Holland, J., Complex Adaptive Systems**

   (a) (1 point) Holland argues that a new mathematical framework is needed to analyse complex adaptive systems that emphasizes:

   ○ "Enumeration through Fourier analysis"

   √ **"Continuing adaptation through recombination of building blocks"**

   ○ "Strange attractors and fractal dimensionality"

   ○ "Lorenz analysis through computer simulation"

   ○ "Exhaustive search via computer simulations"

   (b) (1 point) Holland used which of the following as an instructive example of an adaptive complex system:

   ○ Youtube

   √ **The adaptive immune system**

   ○ Car engines

   ○ A ball falling to the ground

   ○ Linear systems

2. **Flake, G. The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation**

   (a) (1 point) Flake defines a limit cycle to be:

   ○ A strange attractor

   ○ Trajectories that converge to an ever expanding spiral

   √ **Movement that repeats itself over and over**

   ○ The root of chaos

   ○ Ergodic

(b) (1 point) Flake wrote the following about chaotic systems:

- ◯ "Chaotic systems are difficult to predict and therefore cannot be simulated."
- ◯ "Chaotic systems are random and therefore are not deterministic."
- ◯ "Chaotic systems do not depend on initial conditions and therefore can be easily simulated."
- √ **"Chaotic systems are completely deterministic and not random."**
- ◯ "Chaotic systems are completely deterministic and therefore random."

(c) (1 point) Which of the following does Flake describe as necessary for a system to be chaotic:

- ◯ Non-determinism, sensitivity to initial conditions, and conserving.
- √ **Determinism, sensitivity to initial conditions, and ergodicity.**
- ◯ Non-determinism, sensitivity to initial conditions, and ergodicity.
- ◯ Determinism, insensitivity to initial conditions, and ergodicity.
- ◯ Non-determinism, sensitivity to initial conditions, and conserving.

3. **May, R. Simple Mathematical Models with Very Complicated Dynamics**

(a) (1 point) May's reason for writing this paper was:

- √ **To show that simple non-linear systems can have dynamical behaviour that is not simple.**
- ◯ To show that complex non-linear systems can have dynamical behaviour that is simple.
- ◯ To show that all complex systems can be reduced to the Logistic map.
- ◯ To show that all complex systems can be reduced to simple systems through the May transform.
- ◯ To show that all simple systems can be reduced to complex systems through the May transform.

4. **Lorenz, E., Computational Chaos**

(a) (1 point) The methods Lorenz studies in this paper for approximating dynamical systems include:

- ◯ Simple non-linear substitution
- ◯ May's
- ◯ Lorenz's
- ◯ Pascal's
- √ **Euler's**

(b) (1 point) Computational chaos can be avoided by:

- ◯ Increasing the ODE solver step-size sufficiently
- √ **Decreasing the ODE solver step-size sufficiently**
- ◯ Fixing the ODE bifurcation rate
- ◯ Decreasing the ODE bifurcation rate
- ◯ Increasing the ODE bifurcation rate

5. **Gell-Mann, M. What is Complexity?**

(a) (1 point) The algorithmic information content (or AIC) of a string of bits is defined as:

- ◯ "The speed of the fastest program that will cause a standard universal computer to print out the string of bits and then halt"
- ◯ "The length of the longest program that will cause a standard universal computer to print out the string of bits and then halt"
- √ **"The length of the shortest program that will cause a standard universal computer to print out the string of bits and then halt"**
- ◯ "The length of the shortest string of bits printed by any program that halts"
- ◯ "The length of the longest string of bits printed by any program that halts"

6. **Crutchfield, J. Between Order and Chaos**

(a) (1 point) Crutchfield claims that "A completely ordered universe, however, would be..."

- √ **"Dead"**
- ◯ "Complex"
- ◯ "Unpredictable"
- ◯ "Chaotic"
- ◯ "Inevitable"

(b) (1 point) Crutchfield describes the complexity of dynamical systems in terms of:

- ◯ "Evolutionary building-blocks and the Ackley function"
- ◯ "The Feigenbaum exponent"
- √ **"Intrinsic computation"**
- ◯ "The holographic principle"
- ◯ "Abstract syntax trees"

7. **Hughes, A. The Central Dogma and Basic Transcription**

   (a) (1 point) In Hughes' analogy between cell biochemistry and computer programs DNA is:

   ◯ "The program output"

   ◯ "The running program"

   $\surd$ **"The program stored on disk"**

   ◯ "The input to the program"

   ◯ "Used to string together sugar molecules"

8. **Losos, J. Evolutionary Biology for the 21st Century**

   (a) (1 point) The purpose of this paper is to:

   $\surd$ **Describe the broad impact of evolutionary theory on society**

   ◯ Describe the impact of evolutionary theory on computation

   ◯ Describe the Fundamental Theorem of Genetic Algorithms

   ◯ Describe Darwin's Theory of Natural Selection

   ◯ Describe Watson and Crick's discovery of the structure of DNA

9. **Forrest, S. Genetic Algorithms: Principles of Natural Selection Applied to Computation**

   (a) (1 point) Forrest describes two uses of genetic algorithms:

   $\surd$ **Solving optimisation problems and modelling evolutionary processes**

   ◯ Solving optimisation problems and proving theorems

   ◯ Modelling evolutionary processes and proving theorems

   ◯ Automated design patterns and proving theorems

   ◯ Automated design patterns and solving optimisation problems

   (b) (1 point) Genetic algorithms...

   ◯ Are inspired by biological evolution but includes a crossover operator which is not biological

   ◯ Can always find the global optimum

   ◯ Are unrelated to biological evolution

   ◯ Are more complex than biological evolution

   $\surd$ **Are simpler than biological evolution**

10. **Floreano, D. Evolution of Adaptive Behaviour in Robots by Means of Darwinian Selection**

   (a) (1 point) The GA in this study operated on what aspect of the robots:

   ○ Their actuators

   ○ The simulated annealing process

   ○ Their network of robot interactions

   √ **Their neural networks**

   ○ Their behaviour coefficients

11. **Weimer, W. Automatically Finding Patches Using Genetic Programming**

   (a) (1 point) The population being evolved in this paper is made up of:

   √ **Programs**

   ○ Patches

   ○ Testcases

   ○ Mutation

   ○ Mappings between programs and outputs

   (b) (1 point) The fitness function used throughout the paper is based on:

   ○ Programs

   ○ Patches

   √ **Testcases**

   ○ Mutation

   ○ Mappings between programs and outputs

12. **Neumann, J., Theory of Self Reproducing Automata**

   (a) (1 point) Von Neumann compares which two systems:

   ○ Genetic algorithms and electronic computing machines

   √ **The central nervous system and electronic computing machines**

   ○ Ant swarms and electronic computing machines

   ○ The adaptive immune system and electronic computing machines

   ○ Dynamical systems and electronic computing machines

13. **Wolfram, S. Cellular Automata as Models of Complexity**

   (a) (1 point) Wolfram speculates that:

   ◯ Since most natural systems are more complex than a 1D cellular automata, and cellular automata exhibit complex and chaotic behaviour, it follows that many natural systems can be understood without simulation.

   ◯ Since most natural systems are more complex than a 1D cellular automata, and cellular automata exhibit complex and chaotic behaviour, it follows that many natural systems are also simple.

   ◯ Since most natural systems are more complex than a 1D cellular automata, and cellular automata are simple, it follows that many natural systems are also simple.

   ◯ Since most natural systems can be simulated using a 1D cellular automata, and cellular automata are simple, it follows that many natural systems are also simple.

   √ **Since most natural systems are more complex than a 1D cellular automata, and cellular automata exhibit complex and chaotic behaviour, it follows that many natural systems can only be understood through simulation.**

   (b) (1 point) Which of the following is true:

   ◯ Class 1 and 2 cellular automata are chaotic

   ◯ Class 2 cellular automata are complex

   ◯ Class 3 cellular automata are analogous to fixed points in a dynamical system

   ◯ Class 4 cellular automata are equivalent to regular languages

   √ **Class 3 and 4 cellular automata are not equivalent to regular languages**

14. **Project 1: Dynamical Systems**

   (a) (1 point) You were asked study which two types of dynamical system:

   √ **A map and a flow.**

   ◯ A system of differential equations and a flow

   ◯ A system of difference equations and a map

   ◯ Two systems of difference equations

   ◯ Two flows

(b) (1 point) You were asked to determine whether the dynamical systems were:

- ◯ Bound by the Feigenbaum exponent
- ◯ Bound by the Feigenbaum constant
- √ **Dissipative or conserving**
- ◯ Expanding or Dissipative
- ◯ Always less than the Lorenz exponent

15. **Project 2: Genetic Algorithms**

(a) (1 point) You were asked to implement which of the following as a way to preserve diversity and prevent premature convergence:

- ◯ Island selection
- ◯ Island mutation
- ◯ Island crossover
- √ **An island GA.**
- ◯ None of the above.

(b) (1 point) The Mann-Whitney test produces which of the following:

- ◯ Hawking's constant
- ◯ Feigenbaum's constant
- ◯ Lord May's constant
- √ **A p-value**
- ◯ None of the above