Name:
Student Number:

BIOLOGY 4FF3

DAY CLASS J. Stone
DURATION OF MOCK EXAMINATION: 3 Hours
MCMASTER UNIVERSITY MOCK FINAL EXAMINATION April 2004

THIS MOCK EXAMINATION PAPER INCLUDES 10 PAGES AND 10 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR MOCK INVIGILATOR.

SPECIAL INSTRUCTIONS:

- Any calculator may be used.
- all non-communicative aids accompanying the candidate may be used by that candidate only
- candidates may prepare solutions using wordprocessing software and submit those solutions by printing a hardcopy OR candidates may use a pen to write solutions in examination booklets and submit those booklets
- provide solutions to all 10 problems

1. In textbooks, journals, seminars, and even classrooms, scientists often state that DNA sequences contain information. The proteins that are encoded by genes may be considered as words in a language comprising 20 different letters representing amino acids.

a. Please quantify the information that is encoded when each single amino acid in a protein sequence is specified.

Scientists also often use a language analogy to 'explain' the codon basis for encoding amino acids (*i.e.*, three nucleotide bases), citing that, given 4 nucleotide bases with which to comprise 20 amino acids, 3 constitutes the minimum possible 'wordsize:'

$$4^1 = 4 < 20$$
$$4^2 = 16 < 20$$
$$4^3 = 64 > 20.$$

This explanation is adequate but lacks a theoretical rationalization. A Computational Biologist ought to seek an explanation with a little more oomph!

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b. Please calculate the quotient

(information that is encoded when each single amino acid in a protein sequence is specified) / (information that is encoded when each single nucleotide base in a sequence is specified)

(hints: you calculated the numerator moments ago and the denominator for problem set 1 – please note that the denominator can be derived in a single line with a single equation, so you might save time by thinking rather than pilfering through notes; please mind units in your calculation, as this will help you to answer the next question).

c. This ratio provides the minimum possible wordsize on the basis of information; please compare this prediction to the codon basis that is observed in nature and discuss any revelations.

2. Imagine conducting the pentahybrid cross (*Uu Vv Ww Yy Zz*) x (*uu Vv ww Yy zz*). Assuming that alleles for the 5 genes reside at independent loci (and that uppercase and lowercase letters indicate dominant and recessive alleles), please predict the proportion among offspring that would resemble (genotypically):
a. the first parent;
b. the second parent;
c. either parent; and
d. neither parent
(note: if you answered this question for problem set 2, then please answer it in phenotypic terms for this practice examination).

3. The stereology equation D = 6(V / S) was derived for the case in which objects were spheres (*i.e.*, by solving equations involving volume V and surface area S for diameter D and equating them). Please derive an equation for D for the case in which objects were cubes. You can verify whether your approach for the cube case is correct by deriving the sphere case and checking that you obtain 6(V / S).

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4. The following relations were culled from Peters, R. H. 1983. *The Ecological Implications of Body Size*. Cambridge University Press, England. All data are for herbivorous mammals, wherein M = body mass in kg.

Pulse rate H, or heart beats [s^{-1}]: $R = 3.61\ M^{-0.27}$

Locomotion W, or walking speed [m s^{-1}]: $W = 0.33\ M^{0.21}$

Home area T, or territory size [km^2]: $T = 0.032\ M^{1.00}$

a. Assuming that all home areas are circular ($T = \pi D^2 / 4$), please convert the home area equation to yield a power function relating D to M.

b. Please derive an equation which predicts how many heart beats occur during the time period that is required for an organism to walk across one diameter in the home area.

5. Brittle and Chrispy are championship show dogs belonging to Justin Time, a nuclear physicist. Unfortunately, the two pooches were too close to a window when the village power plant let off a little steam. Now Brittle is growing while Chrispy is shrinking, each exponentially! Initially, Brittle contained a mass N(0) = 2 kg and Chrispy contained a mass N(0) = 10 kg. Subsequently, Brittle doubled her N(0) in one week while Chrispy dwindled to half her N(0) in ten days.

a. Please calculate the growth rate r for each canine.

b. Please predict at what time t Brittle and Chrispy will contain the same mass N(t) and what that mass will be.

c. Please predict the time t at which N(t) for Brittle will equal twice the N(t) for Chrispy.

6. For the optimal foraging theory simulation and dynamical modeling exercise that we considered ($p_1 = 0$, $c_1 = 1$, $f_1 = 0$, $v_1 = 0$, $p_2 = 0.5$, $c_2 = 1$, $f_2 = 0.5$, $v_2 = 4$), a general pattern emerges in the results table: on any day, ascending (*i.e*. going up) the rows in the table, patch 2 initially constitutes the optimal foraging strategy (*i.e*., choice for maximising the probability for surviving until t = 4), whereas, in the remaining ascending rows, patch 1 constitutes the optimal foraging strategy. Explain this pattern using as few words as you can.

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7. Among individuals in a population, 20% contain the *GG* genotype, 60% the *Gg* genotype, and 20% the *gg* genotype.

a. Please calculate what commonly are called ‘allele frequencies’ for this population.

b. In this population, individuals exhibit bias in mating, choosing those that resemble themselves phenotypically. Assuming that *G* were dominant and *g* were recessive, please predict the genotypic and phenotypic percentages that would be found in the next generation.

8. Sister Matics, a nun who enjoys constructing cladograms, is perplexed. She is attempting to classify some strange plants that Gregor Mendel grew behind the monastery in Brno. Please use the Latin binomial names and character states that are provided below to help her devise a phylogenetic systematic classification (using *Aplantae comfortabolium* as the only outgroup).

Aplantae comfortabolium	0	@	#	$	%
Arbour ingtostudii	1	@	#	$	%
Barkus biggerthanitsbitus	1	&	#	~	%
Elastic similaritus	1	&	#	~	%
Leavus aloneii bile	1	&	*	$	+
Xylem phloemus	1	&	*	$	+

9. My mother yielded 3 females and 2 males in 5 independent births (disregarding order). Please calculate the proportion among many 5-child families that you would expect to observe for the gender count that my mother accomplished. You may assume that lawyers are human, but please state explicitly and justify any additional assumptions that you invoke.

10. Please determine the probabilities for finding the subsequences:

a. AA and AT in DNA sequences with unbiased composition comprising 100 nucleotide bases; and

b. AAA and AAT in DNA sequences with unbiased composition comprising 100 nucleotide bases.

c. Please compare the solutions that you provided for a and b, explaining similarities or differences.

THE END