Name:
Student Number:

BIOLOGY 4FF3

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

THIS EXAMINATION PAPER INCLUDES 5 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 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. Suppose that the next space probe that is scheduled to land on Mars were to discover life there! Imagine that that probe were to send back to Earth one datum revealing that organisms on Mars use a genetic code that involves 8 rather than 4 nucleotide bases. Please quantify the information that scientician Ian Formation would acquire if he were the fortunate person to receive that datum.

2. Champion-cattle-producer Gigi Netics raises pigs on a farm that is situated near the nuclear reactor in Pickering. Among the 16 female pigs that reside on the farm, some contain the homozygous genotype for the red (*R*) allele and the rest contain the homozygous genotype for the blue (*B*) allele. One male pig resides on the farm, a homozygous red individual. No purple pigs (*RB*) reside on the farm. Two individuals from the 16 available female pigs are chosen and crossed sequentially with the lone male (*i.e.*, one female is led to a cosy barn in which 'mood music' is playing, then, a little later, another is brought in); eventually, each produces one offspring.

a) Please list the different phenotypes that could be produced.

b) In the mating protocol that is described above, the probability for obtaining 1 purple piglet and 1 red piglet is equal to the probability for obtaining 2 piglets with the same colour (*i.e.*, 2 red or two blue). Using this information, please determine the phenotype proportion that is exhibited among the adult female pigs on the farm (*i.e.*, red:blue = x:(16 – x)).

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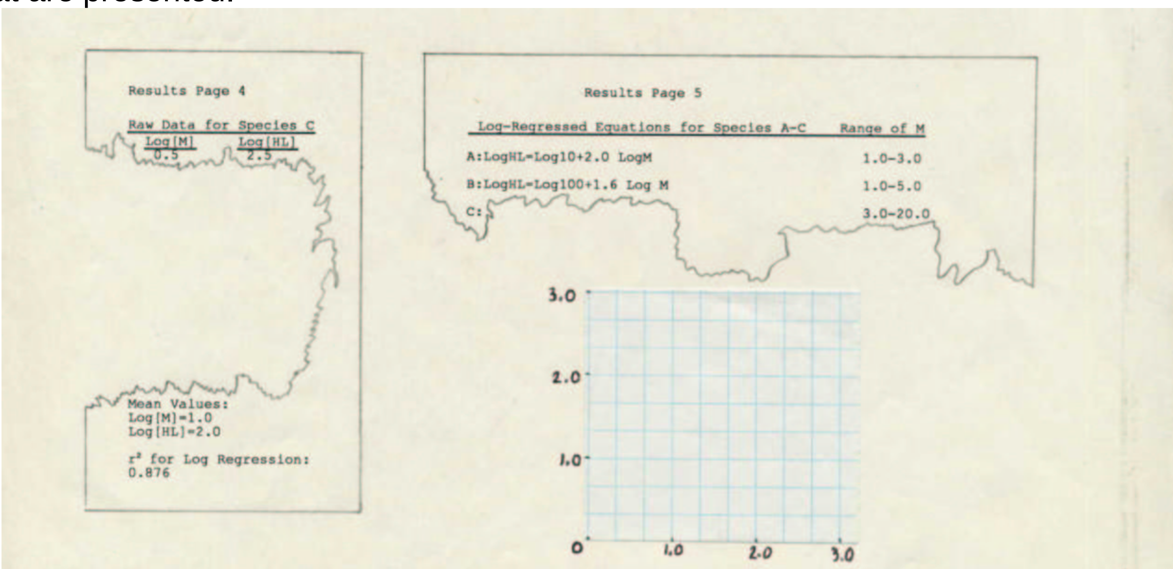
3. Using as few words and equations as you can, please propose:

a) a method for estimating the length for the enamel ridge on the occlusal surface on an elephant tooth, using stereological analysis;

b) a method for determining the fractal dimension for the cristae in a mitochondrion, using micrograph images, Microsoft © PowerPoint, and some algebra.

4. Introductory Computational Biology student Al Ometry's dog ate Al's report on *Hornithorhynchus hypotheticus*, the horny, duck-billed dinosaur! The remaining pieces (that even the dog rejected) are shown below. Please use them to solve the problems that are presented.



Al used the symbol HL for horn length [mm] and M for body mass [tons]. Al measured M with greater accuracy. Al used logarithms to the base 10 (written carelessly with and without [ ]s).

a) Please state functions relating M and HL for species A and B, using what remains from the results that Al obtained.

b) Al can remember two statements that were included in the results; these statements now reside in his dog's gut but reasonable facsimiles are presented below. Please assess whether each is accurate and explain your assessment, using as few words as you can:

i. As M increases, the variable HL scales to a greater extent for Species A than for Species B.
ii. The horns on Species B are shorter than the horns on Species A.

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c) Al can remember one conclusion that he drew:
"The horn length for a member in Species A will be the same as the horn length for a member in Species B, when Log[M] = 2.5 "
Please assess whether this statement is accurate and explain your assessment, using as few words as you can.

d) Al recalls that the best-fit lines that he obtained by conducting least-squares regression analyses on logarithmically transformed variables for Species A and Species C intersected at M = 1.0. Please use this information and the available evidence to derive an equation relating HL and M for Species C (hint: two points may be used to define a straight line).

5. In turtle populations, the gender for a developing individual is determined by the temperature at which the embryo is incubated. Field-work indicates that the % females F(T) in a particular population may be calculated using the equation

$F(T) = 100 / (1 + e^{r(C - T)})$,

wherein C is a constant and T is the temperature in degrees Celsius. Computational Biology student Lonnie Gistic determined that C = 25 degrees Celsius and F(23) = 25% females. Please use this information to predict the temperature at which the population will comprise 75% females.

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) please determine the maximum probability for surviving until t = 4 and the corresponding final energy Q_f (*i.e.*, at t = 4) for an organisms that were to begin with energy Q_i = 2 units at time t = 1.

b) please determine the final energy Q_f (*i.e.*, at t = 4) for an organism that were to choose the other patch at t = 1 and optimise its probability for surviving until t = 4.

c) suppose an organism were to reproduce immediately after t = 4; if gamete production were directly proportional to energy, then please predict which among the two scenarios above (*i.e.*, a or b) would be expected to provide optimal reproductive success – for this scenario, expected reproductive success may be considered as involving the probability for the organism to survive until t = 4 and the gametes that it would possess upon doing so.

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7. The noo noo grub *Cole rutstonei* exhibits two phenotypes. A field biologist observes that matings in which at least one parent exhibits the 'jaded' phenotype produce jaded offspring, whereas only matings in which both parents exhibit the 'raquetted' phenotype produce raquetted offspring. The alleles at the locus that encodes these phenotypes are inherited in a Mendelian manner. Suppose that you were provided with data concerning one population:

Phenotype	Frequency
jaded	53
raquetted	834

Assuming that the population were in Hardy-Weinberg equilibrium and population size were to remain constant, please predict how many heterozygous individuals would be present in the next generation.

8. Lawyer Claudette S. Ticks enjoys conducting phylogenetic systematic analyses when she has spare time from defending mass murderers (well, nobody's perfect). Her most-recent project involves constructing a cladogram for Amoralidae, a Family containing 'reptilelike' creatures (well nobody's perfect) with long, black capelike body plumage and white-tuft head covering. Please use the Latin binomial names and character states that are provided below to help Claudette construct a cladogram (using *Computational biologistum* as the only outgroup), then please calculate the probability for it.

Computational biologistum	blood	true	scrupulous	0	A	*
Advocatus ambulanchaseroi	bile	deceitful	amoral	0	A	$
Barristori ignoramus	bile	deceitful	amoral	0	A	$
Constabalus traficcus	bile	deceitful	amoral	0	A	*
Justopeacious bribarius	bile	true	scrupulous	1	T	*
Solicitorus hypersalarus	bile	true	scrupulous	1	T	*

9. Please determine the probability for finding the subsequence GATTACA in DNA sequences with unbiased composition comprising 10, 100, 1000, 10000, and 100000 nucleotide bases.

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10. Congratulations, you are a Computational Biologist! I hope that you enjoyed the course as much as I did!

a. Please define Computational Biology, citing any sources that you use (in case you thought that you could elude this problem).

b. The default marking scheme for this examination is 10 points per problem (10 x 10 = 100 points). Please feel welcome to provide an alternative marking scheme for this examination, subject to the following conditions: total credits must sum to 100 points; no problem may be allotted less than 5 or greater than 15 points; the maximum credit that could be earned for each problem must be divisible by 5 (with no remainder); and this problem (*i.e.*, 10) may be allotted only 5 marks. If you provide an alternative marking scheme, then it will be used to evaluate your examination. If you opt for the default marking scheme, then part a to this problem may earn a maximum credit = 10 points and this part contributes nothing to your final mark.

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