1. Briefly define (5 points each):
   a) Environmental Variance

   b) Clade Distance

   c) Population tree
2. A sample of individuals from a single deme is surveyed at an autosomal locus with two alleles as follows:

<table>
<thead>
<tr>
<th>Genotype</th>
<th>AA</th>
<th>Aa</th>
<th>aa</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>34</td>
<td>52</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

a. (5 points) What is the correlation of uniting gametes?

d. (6 points) Test the null hypothesis that the correlation of uniting gametes is zero.

c. (4 points) What inference would draw from the test result in part (b) about the system of mating of this deme?
3. (5 points) A neutral mutation occurs at an autosomal locus in an ideal population of stable size. What is the probability of the new mutation being lost in the next generation after it occurred by genetic drift in populations of ideal size 100, 500, and 1000?

4. Population 1 is fixed for the \( A \) allele at locus 1 and the \( B \) allele at locus 2. In contrast, Population 2 is fixed for the \( a \) allele at locus 1 and the \( b \) allele at locus 2. A 50:50 mix of individuals from both populations is translocated into the same area as part of a conservation program.

a). (2 points) What is the linkage disequilibrium in the mixed population?
b). (2 points) Is the linkage disequilibrium calculated in a) at its maximal value in magnitude? Justify your answer with a quantitative calculation.

c). (6 points) The AA and aa genotypes each have distinct phenotypes for a trait associated with 100% disassortative mating whenever a mate choice is available. The genotypes at locus B have no impact on mate choice. Given that the A and B loci are on different chromosomes, what is the linkage disequilibrium between the loci in the second generation of offspring from the mixed population assuming discrete generations?
5. An aquatic snail species is distributed along the shore of a large lake, able to survive only in discrete lake shore habitats that have a rocky substrate. An effectively infinite number of these discrete habitats exists along the shore, with each one inhabited by 1000 snails. The snails are self-compatible hermaphrodites, and their local demes are ideal in every way except that their system of mating has an inbreeding coefficient (as a deviation from random mating) of 0.5.

a). (4 points) What are the inbreeding and variance effective sizes of the local demes?

b). (5 points) Suppose each deme releases gametes into the lake at a rate of 0.0001 per generation, and receives the frequency of 0.0001 of its gametes randomly drawn from all the gametes released into the lake, with all other gametes coming from the local deme. What is the average probability of identity by descent at an autosomal locus within a deme at equilibrium?

c). (6 point) Now assume that in addition to the 0.0001 of gametes entering the general lake population, each deme exchanges gametes with its neighboring demes at a rate of 0.005 per generation (split 50:50 between the two neighbors) and receives a symmetrical input. What is the equilibrium value of $f_{st}$?
6. A mitochondrial haplotype (A) is found that interacts with smoking to yield a metabolic disease (md) as follows:

<table>
<thead>
<tr>
<th>MtDNA type</th>
<th>A</th>
<th>not A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoker</td>
<td>md</td>
<td>no md</td>
</tr>
<tr>
<td>Non-smoker</td>
<td>no md</td>
<td>no md</td>
</tr>
</tbody>
</table>

Assume that smoking status and the mitochondrial genotype are statistically independent.

a) (2 points) In a random-mating Chinese population, the frequency of the A haplotype is 0.0625 and 80% of the adult population are smokers. What is the frequency of the metabolic disease in this adult population?

b) (3 points) Which single factor (the mitochondrial A haplotype or being a smoker) is more predictive of developing the metabolic disease in this Chinese population in terms of the probability of the disease given one specific factor?

c) (2 points) In a random-mating US population, the frequency of the A haplotype is 0.25 and 20% of the adult population are smokers. What is the frequency of the metabolic disease in this adult population?

d) (3 points) Which single factor (the mitochondrial A haplotype or being a smoker) is more predictive of developing the metabolic disease in the US?

e) (3 points) Do the more predictive factors in these two populations share any common attribute, and if so, what is it?
7. A neutral, X-linked microsatellite locus in humans has a mutation rate of $10^3$ per generation.

a. (5 points) In a population of inbreeding effective size 1000 and variance effective size of 1500, calculate the average time in generations it would take for a sample of 5 X-chromosomes to coalesce to a common ancestral DNA molecule at this locus.

b. (5 points) Assuming an infinite allele model of mutation, what is the equilibrium expected heterozygosity at this microsatellite locus?

c. (2 points) What is the rate of neutral evolution at this locus?
8. (15 points) Most genetic textbooks describe the sickle cell allele at the hemoglobin β-chain locus as being recessive. In what sense is this an accurate description, and in what sense is this an inaccurate or misleading description?