

1. Why is there more rain at the equator than at either 30°N or 30°S. Be sure your explanation includes a description of the mechanisms driving global circulation patterns. [5 points]
2. On average, what direction does the wind come *from* in Zambia (Africa, 15°S)? [4 points]
3. The environment is constantly changing, and organisms must respond phenotypically to these changes. Two possible responses are a developmental switch and acclimation. How do these two responses differ and what environmental circumstances would favor one over the other? [8 points]

4-9. Brine shrimp (*Artemia franciscana*) are almost the only animals that live permanently in the highly saline waters of the Great Salt Lake. (The others are a brine fly and a water boatman.) Many tons of brine shrimp eggs are harvested every year by a local industry that brings millions of dollars into Utah's economy. The eggs are used as food for aquarium fish and for edible prawns which are cultivated commercially in southeast Asia.

You have been studying genetic variation in the brine-shrimp *sodium pump* (Na/K-ATPase), a central part of the system that moves sodium and chloride ions out of cells. (Recall that salt is sodium chloride, *NaCl*.) All animals have a sodium pump that is homologous to the one in brine shrimp, but this one is remarkable for its ability to help brine shrimp cope with the tremendous osmotic stress of living in a nearly saturated salt solution.

Using protein electrophoresis and DNA sequencing, you survey the sodium-pump genes and proteins of 1000 adult brine shrimp collected at the north end of Antelope Island in the Great Salt Lake. You find an amino-acid polymorphism in this protein, with two alleles (**A₁** and **A₂**) at intermediate frequencies. Your assays reveal the diploid genotypes of each of the 1000 adult brine shrimp in your sample:

genotype	number
A₁A₁	162
A₁A₂	476
A₂A₂	362
	1000

4. What is the frequency of allele **A₁** in your sample? [3 points]
5. What is the frequency of **A₂**? [2 points]
6. Do your data suggest that brine shrimp mate randomly with respect to their genotypes at the sodium-pump locus? *Briefly explain.* [10 points]

The next year you repeat your survey and find the following genotype frequencies:

A₁A₁	88
A₁A₂	424
A₂A₂	488
	1000

7. What was the *change* in the frequency of **A₁**? [10 points]

Impressed by this result, you carry out a *geographic survey* of sodium-pump allele frequencies at several different locations around the Lake. You find quite a bit of variation from place to place. In particular, you find *high frequencies* of A_1 near the mouth of the River Jordan and southwest of the Bear River Wildlife Refuge (both places with relatively *low salinities*, owing to continual inputs of fresh water), and you find a *low frequency* of A_1 in the North Arm of the lake, where the *salinity is high*.

location	p (A_1)	
River Jordan	0.5	
Bear River W.R.	0.6	
Antelope Is. St. Park		<- from your second-year study, above
North Arm	0.2	

The Lake reached historic high water levels in the early 1980s (when we had record-breaking rain and snow). Because the volume of water was high, the average salinity was low. Since then, the water level has been dropping and the salinity has been increasing in most parts of the lake. Putting these facts together, answer the following question about the allele-frequency change you observed at your Antelope Island study site.

8. Of the four major evolutionary processes or "forces", which one is *most likely* to have caused this change, which two are relatively *unlikely* to have been significant causes of the change, and which one is a "*maybe*"? Circle your answers, then *briefly* explain your *reasons* for thinking so. [40 points]

mutation	likely	maybe	unlikely
migration	likely	maybe	unlikely
genetic drift	likely	maybe	unlikely
natural selection	likely	maybe	unlikely

9. How might you *test* your hypothesis, outlined in question 8, above? What additional observations, or experiments, might help you to establish the cause of the allele-frequency *change* you observed in the waters around Antelope Island, and the allele-frequency *differences* you found at different sites around the perimeter of the Lake? [8 points]

10. Tropical alpine daisies fold up their leaves at night (Lissy showed slides of some from the Andes and Jon showed overheads of some from Hawaii and Africa). Give ONE proximate (mechanistic) and ONE ultimate (adaptive) reason why, and describe an experiment to test each hypothesis. Your answers can be somewhat speculative. [10 points]

Proximate:

Ultimate: