**Answers to Problems and Discussion Topics**

to accompany

*Evolution,* Fifth Edition

Chapter 12

*All About Sex*

**1. Suppose a population of a hermaphroditic species is segregating two alleles, *A*0 and *A*1, at a single locus, where the three genotypes occur in the following frequencies: 20% *A*0*A*0, 40% *A*0*A*1, and 40% *A*1*A*1. After one generation, assuming no selection, what are the expected frequencies under the following three situations? What happens to the genotype frequencies after many generations in each of these situations?**

1. **Random mating.**
2. **Pure selfing.**
3. **Asexual reproduction.**
4. **In the same population, suppose a beneficial allele, *B*1, arises at a second locus that was initially fixed for the *B*0 allele. This allele arises in an *A*0*A*0 individual and then sweeps to fixation. Under each of the three scenarios (random mating, pure selfing, asexual reproduction), what happens at the *A* locus when the recombination rate is 0? What about if the recombination rate is ½ (free recombination)?**
5. **Suppose the beneficial allele, *B*1, arises in an *A*0*A*1 individual and then sweeps to fixation. Under each of the three scenarios, what happens at the *A* locus when the recombination rate is 0 or ½?**

*Answers:*

1. Frequencies become 16% *A*0*A*0, 48% *A*0*A*1, 36% *A*1*A*1 (Hardy-Weinberg proportions) and remain that way indefinitely.
2. Homozygotes increase and frequencies become 30% *A*0*A*0, 20% *A*0*A*1, 50% *A*1*A*1. After many generations, frequencies will be 40% *A*0*A*0 and 60% *A*1*A*1.
3. Frequencies remain unchanged at 20% *A*0*A*0, 40% *A*1*A*2, 40% *A*1*A*1 indefinitely.
4. If *r* = 0, fixation of the *B*1 allele will also cause fixation of the *A*0 allele and all individuals will become *A*0*A*0*B*1*B*1 under all three scenarios. If *r* = ½, fixation of the *B*1 allele will cause fixation of the *A*0 allele for both pure selfers and for the asexual population. However, for the outcrossing population fixation of the *B*1 allele will not cause a change in the frequency of the alleles at the *A* locus.
5. In the asexual scenario, the *A*0*A*1 genotype will fix regardless of the recombination rate. With *r* = 0, in both the selfing and outcrossing scenarios one of the two *A* alleles will fix, whichever one was linked to the *B*1 allele, and the population will consist of homozygotes for that allele. With *r* = ½, there will be no change in allele frequency in the outcrossing case. With *r* = ½ and pure selfing, the frequency of the *A*0 and *A*1 alleles will be equal after fixation (since the *B*1 allele is equally associated with both), so half the population will be *A*0*A*0 and half *A*1*A*1.

**2. The following shows a graph of fitness versus body size for males (M) and females (F) in a species of fish:**



* 1. **What does this graph indicate about the effect of body size on fitness in males and females?**
	2. **With dioecy (separate sexes), would you expect males or females to reach sexual maturity at a smaller body size in a species that stops growing at adulthood?**
	3. **Could the fitness relationships shown favor sequential hermaphroditism? If so, would the transition be male to female or vice versa?**
	4. **Suppose that temperature affects offspring development (as it does in in turtles), such that warmer temperatures result in larger adult body size. In that case, could temperature-dependent sex determination be favored? If so, which sex would you expect to be produced at cool versus warm temperatures?**

*Answers:*

1. Fitness increases with body size in both sexes, but faster in females.
2. There is a smaller advantage to continuing to grow before reaching sexual maturity in males, so we expect them to mature at a smaller body size.
3. Yes, it is better to be a male at smaller body sizes and a female at larger body sizes (curves cross). So, expect transition from male to female.
4. Yes. Eggs laid in environments that are warmer (giving larger adult body sizes) would be predicted to develop as females.

**3. Asexual, parthenogenetic species are typically found on the tips of the tree of life: their closest relatives reproduce sexually. Explain this pattern.**

*Answer*: This pattern suggests that asexual species are young and do not persist for very long. That is the pattern expected if asexual species become extinct much more quickly than sexual species.

**4. Populations of some species of fish, insects, and crustaceans consist of both sexually and asexually reproducing individuals. In a species that has several generations per year, what factors might maintain both reproductive modes, and why?**

*Answer:* Sexual reproduction is favored by changing environments, while asexual reproduction is favored in stable conditions. So sexual reproduction might be favored when changing seasons cause big swings in temperature and other factors, while asexual reproduction might be favored in seasons in which the climate is relatively constant.

**5. In many reptiles, including crocodiles and many turtles, sex is determined by temperature during early development. Many scientists expect that as Earth’s climate warms, the sex ratios in these species may become highly biased, further endangering these animals. Do some outside research and conclude whether this concern is warranted and what might happen to these populations as a result.**

*Answer*: (Answers will vary; no single correct answer.)

The concern does seem to be warranted. Changes in temperatures in the nesting range might skew sex ratio in these populations. This could reduce effective population size and increase their vulnerability to extinction. However, the risk may be ameliorated by several factors. Huey and Janzen (2008) point out that the species could adapt to temperature changes by shifts in thermal sensitivity and thresholds to sex determination. However, animals like tuatara may not have the necessary genetic variation to respond. Even if the genetic variation was present, the rate of change in the environment might still outpace their rate of adaptation. Organisms could also respond to temperature increases behaviorally, migrating north. The tuatara is an island species and cannot do this. They can, however, compensate by nesting in microhabitats that are cooler, although few such sites may be found.

Loggerhead sea turtles face similar challenges, although their sex determination may be influenced by an interaction between temperature and moisture level (Wyneken and Lolavar 2015). Sea turtles have the option to shift nesting grounds to more northerly beaches, but this is limited by their preference for the beach of their birth (philopatry) and use of coastal areas by humans. Since tuataras are restricted to a few islands, their continued survival may depend on intervention by humans, perhaps by moving them to new, cooler islands.

**6. What aspects of human behavior, physiology, and morphology might be explained by sexual selection? What are the alternative hypotheses, and how might we determine which is (or are) correct?**

*Answer*: (Answers will vary; no single correct answer.)

Many traits that may seem either adaptive or non-adaptive can be imagined as having been the product of sexual selection. For example, one can imagine human intelligence as evolving by runaway processes, where smarter women showed a preference for clever men. It would be more effective to think of these explanations as hypotheses to be tested against alternatives like adaptation in response to natural selection (smarter people are more likely to survive) or even genetic drift (human intelligence may be just a side effect of other aspects of human social evolution).

**References**

Huey, R. B., and Janzen, F. J. (2008) Climate warming and environmental sex determination in tuatara: the Last of the Sphenodontians? *Proceedings of the Royal Society of London B: Biological Sciences* 275(1648): 2181–2183.

Wyneken, J., and Lolavar, A. (2015) Loggerhead sea turtle environmental sex determination: Implications of moisture and temperature for climate change based predictions for species survival. *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution* 324(3): 295–314.