Solutions to exercise sheet 5

Sex, Ageing and Foraging Theory

1 Maintenance of sexuality

a. In line 133, we set the probability of sexual reproduction of a random individual in the population to 0. This operation happens in the 200th generation.

b. Figure 1 shows the survival probability of an individual as a function of its number of deleterious mutations under six different strengths of epistasis, ϵ. Four different qualitative cases can be observed: (i) When $\epsilon = 0$, the survival probability does not depend on the number of deleterious mutations, i.e., mutations are neutral; (ii) When $0 < \epsilon < 1$, the effect of each new mutation is reduced as the number of deleterious mutations increases. This is a case of negative epistasis, i.e. the combined effect of deleterious mutations is weaker than the sum of their individual effects. (iii) When $\epsilon = 1$, each mutation decreases the survival probability equally by a factor of $1 - s$. Finally, (iv) when $\epsilon > 1$, the effect of each extra mutation increases as the number of mutations increases. This is a case of positive epistasis. When $\epsilon >> 1$, there is a sharp transition in survival probability, which goes from 1 to 0 over a few mutations. This sharp transition occurs when individuals carry about K deleterious mutations, as seen in Fig. 2.

   The accumulation of deleterious mutations is more detrimental in the case of strong epistasis. Since asexual are more prone to accumulate deleterious mutations, strong epistasis should disfavor asexuals and thus help maintain sexual reproduction.

c. In the absence of epistasis ($\epsilon = 1$), an asexual mutant introduced in the population at the 200th generation is able to invade and its lineage quickly replaces sexuals (Fig. 3). Under strong epistasis ($\epsilon = 75$), asexuals are able to initially increase in frequency owing to their two-fold demographic advantage (Fig. 4). Due to epistasis however, asexuals quickly suffer a steep fitness reduction due to accumulating more mutations than sexuals. As a result, asexuals eventually go extinct.

d. When there are fewer loci, asexuals are able to invade and replace the sexual population even when epistasis is strong. This is because when there are fewer loci, the total rate of deleterious mutation per genome is lower so that deleterious mutations accumulate more slowly. In other words, larger genomes favor the sexual reproduction over asexuality.

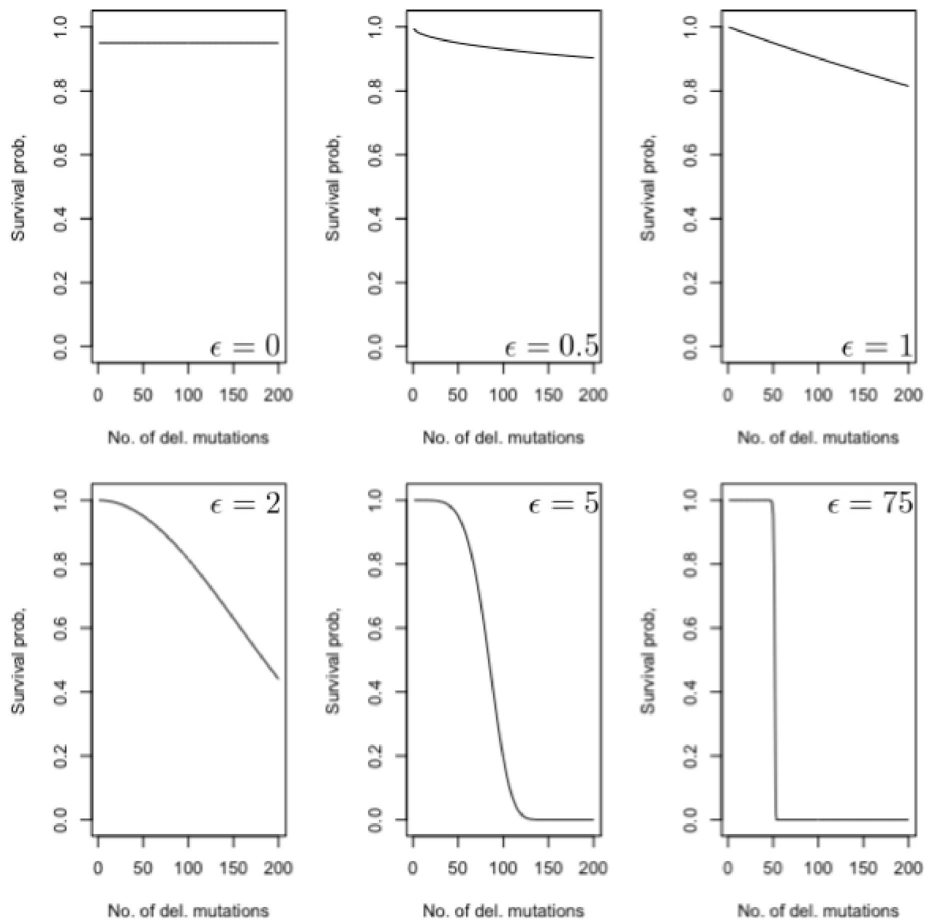

Figure 1: Survival probability as a function of the number of deleterious mutations for six different values of epistasis, ϵ. All plots have $K = 50$ and $s = 0.05$.

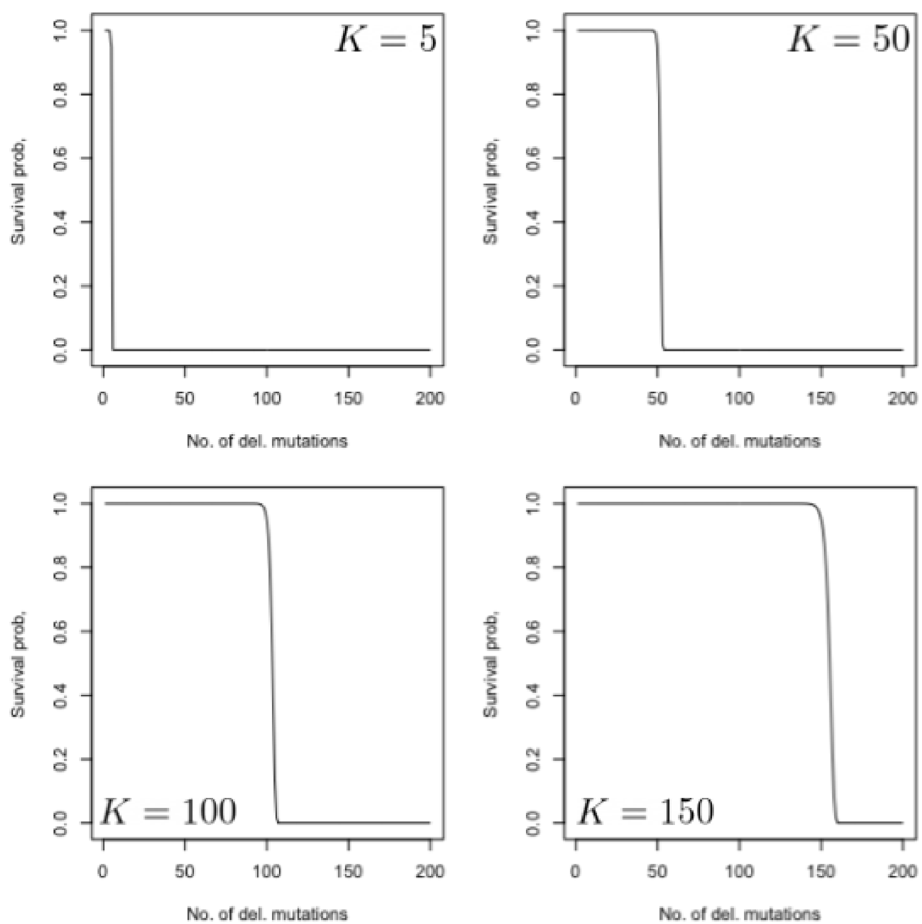

Figure 2: Survival probability as a function of the number of deleterious mutations for different values of K. All plots have $\epsilon = 75$ and $s = 0.05$.

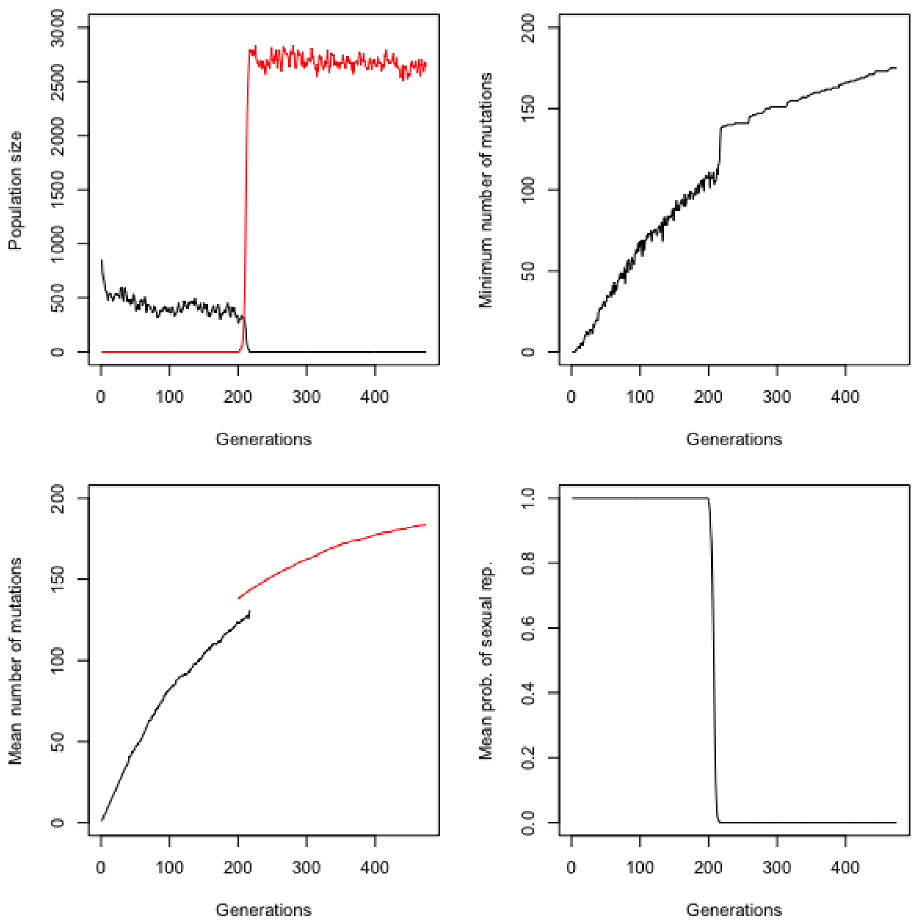

Figure 3: Invasion and substitution of asexuals in a sexual population in the absence of epistasis, $\epsilon = 1$. In each graph, the black curves represent quantities measured in sexuals, while the red curves represent the same quantities measured in asexuals.

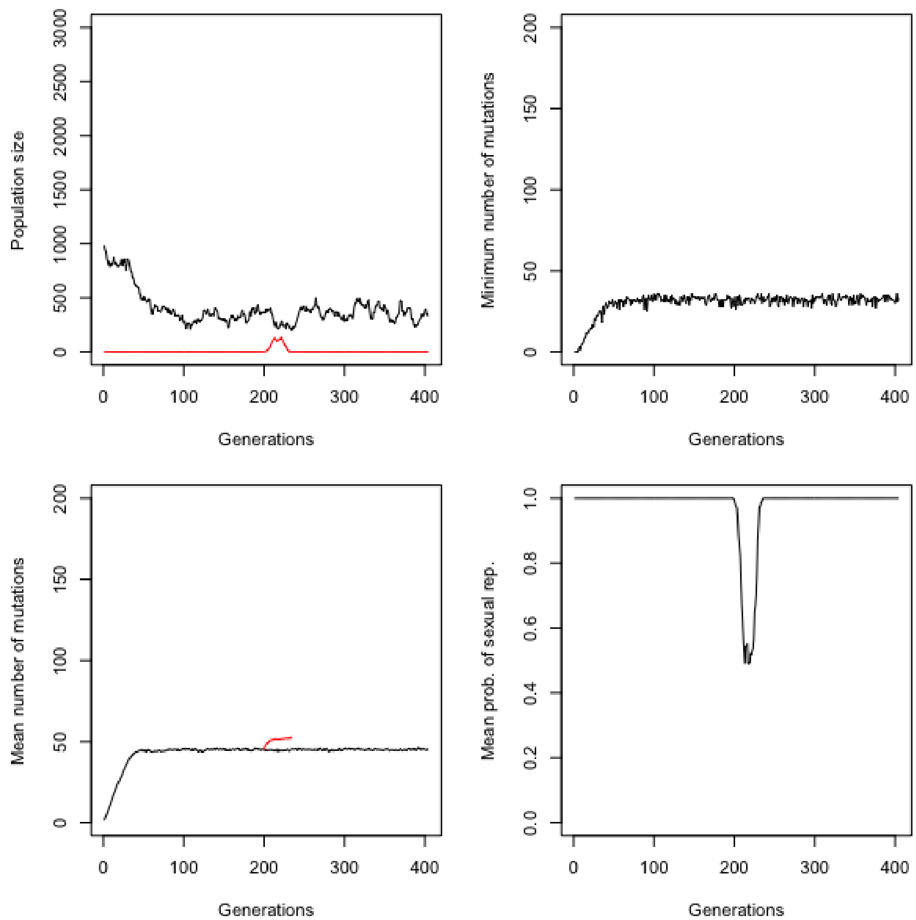

Figure 4: Asexuals fail to invade a sexual population under strong epistasis, $\epsilon = 75$.