

PLEASE: If you draw pictures to help answer these questions, draw BIG pictures. They are impossible to grade otherwise.

1. A standard lab strain of mice has the following arrangement of genes on its first chromosome (where capital and small letters represent different alleles of the same locus):

A-B-C-centromere-D-E-F-G-H (type 1)

a-b-c-centromere-d-e-f-g-h (type 2)

- (a) (2 pts) If we have an animal which is heterozygous for the two chromosomes shown, and a homologous (normal) crossover happens in the segment between the E and F loci, what will the two recombinant daughter chromosomes look like? Be sure to show whether each locus has the capital or small allele, and where the centromeres are.

*A-B-C-cen-D-E-f-g-h*

*a-b-c-cen-d-e-F-G-H*

- (b) (2 pts) An inversion occurs which reverses the E-F-G part of the chromosome, so that the arrangement (call it type 3) is now:

*a--b--c--centromere--d--g--f--e--h*

If we have an animal which is heterozygous for type 1 and type 3, and a crossover takes place in the segment between the E and F loci, what will the two recombinant daughter chromosomes look like? *You will need to draw a loop structure to predict this. The chromosomes attempt to pair every homologous part, even if this requires some twisting. Draw one chromosome as a U shape, and lay the other along it so that A pairs with A, B with B, etc. all the way along. The second chromosome will have to twist to line up. After crossover the results are:*

*A-B-C-cen-D-E-f-g-d-cen-c-b-a*

*H-G-F-e-h*

*The first chromosome will snap during cell division, and the second one has no centromere and will tend to be lost. The resulting gametes are likely to die. Two non-recombinant gametes will also be produced; these should be fine. One has the original gene order and the other has the rearranged one.*

*These twists can be seen under the microscope in Drosophila polytene chromosomes.*

- (c) (2 pts) What does this predict about the fertility of the animal in part (b)? Will it be higher, lower, or the same as in part (a)? *The (b) animal will have reduced fertility. Whenever a crossover occurs anywhere between loci D and F, two of the resulting gametes will be inviable due to chromosomes with too few or too many centromeres. Many students said 50% fertility and I did not mark it wrong, but a crossover will not always happen so the reduction is less than 50%.*
  - (d) (2 pts) Which is generally worse, a big non-centromere-containing inversion or a small one? Why? *The loop structure is not harmful in itself, but whenever a crossover occurs within it, half of the gametes are inviable. A large inversion is therefore worse than a small one because the chance that it will have a crossover is higher. A very small inversion may not be able to loop, and will be harmless.*
2. Humans have one chromosome less than other great apes, because two chromosomes have become fused together. The centromere of one chromosome was lost in the fusion, but assume for this problem that no genes were lost.
    - (a) (2 pts) What difficulties would a heterozygote for the old (24 chromosomes) and new (23 chromosomes) arrangements encounter? *It would be difficult for a heterozygote to segregate its chromosomes properly in meiosis; some gametes would probably end up with too many or too few and be inviable. Note that this is a segregation problem and does not rely on recombination. Many students said meiosis will always fail, but in fact the chromosomes will segregate correctly by chance about 50% of the time. A completely unpaired chromosome could cause meiotic arrest, but all of these can pair with something; they just don't segregate well with only 3 centromeres.*
    - (b) (2 pts) What problem would the new chromosome face in becoming established in the population? It may be useful to know that most human chromosomes contain genes which are severely harmful if present in zero or three

copies. Because some gametes would end up with too many or too few chromosomes, and this would likely be severely harmful, fertility would be reduced in heterozygotes. Since a new chromosome rearrangement, like any new trait, will mainly be in heterozygotes, it will tend to be lost by natural selection. In other words, chromosome rearrangements are underdominant.

- (c) (3 pts) Suggest a situation which could have helped the new chromosome become established. *Natural selection in favor of the new rearrangement. Meiotic drive. Small population size and/or intense inbreeding to rapidly produce homozygotes. In some groups, asexual reproduction or self-fertilization could also help, but these have never been observed in primates. Finally, if individuals with the new chromosome arrangement could somehow preferentially mate with each other, this would reduce production of heterozygotes and improve the new arrangement's chances.*
3. Wheat and rye are not in the same genus, but it is possible to cross them. We cross a tetraploid (4N) strain of wheat with a diploid (2N) rye. The resulting hybrids are sterile. However, if the parent plants are treated with colchicine, a drug that causes doubling of chromosome number via meiosis failure, fertile hexaploid (6N) plants, called "triticale," are produced.
- (a) (2 pts) What is a likely reason for the sterility of the original hybrids? (Be sure your explanation does not also predict sterility of triticale.) *The result of diploid wheat gametes and haploid rye gametes mating up is a triploid. It will have a very hard time segregating its chromosomes in meiosis because three chromosomes can't be divided evenly among two daughter cells. Most gametes will end up with imbalanced chromosome sets and will be inviable. This is not a problem for triticale as it has six chromosome sets, which can divide evenly.*
- (b) (3 pts) Why are fertile hybrids between two distantly related **diploid** plants frequently tetraploid rather than diploid? (Hint: What advantage would tetraploidy give them in meiosis?) *If the chromosomes of distantly related species have diverged too much they may not match up in meiosis, again leading to bad gametes. (This is particularly likely if the number of chromosomes differs, as in human/chimp or horse/donkey, or if inversions or translocations are present in one species.) Doubling the entire set of chromosomes means that every chromosome now has a good pairing partner and meiosis will go better.*
- The remaining problem, which some hybrids can overcome and others cannot, is that 4x copies of every gene instead of 2x can cause trouble. Tetraploid humans are very unhealthy, though one survived for 26 months.*