Evolution Puzzles
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Consider a fictional disease called 'DISEASE X' which is passed on genetically. You only develop the disease if you have two copies of the gene ie. AA. The other harmless version of the gene is labelled B. If you develop the disease you are unable to have children.

Q1. If your parents both have only one copy of the gene – so they both have AB – what is the probability that you inherit the disease?

From two AB parents, you have an equally likely chance of inheriting AA, AB, BA or BB. Therefore, the probability that you inherit the disease (AA) is 1/4.

Q2. If the prevalence of the gene in the general population is 20%, and you have one copy – so you have AB – what is the probability that your child develops the disease?

Your child can only develop the disease (AA) if your partner is AB. There is a 1/5 chance of your partner being AB, then a 1/4 chance of your child developing AA by Q1. The probability your child develops the disease is 1/4 * 1/5 = 1/20 overall.

Q3. If you select two people at random from the general population, what is the chance that their child will develop the disease?

For the child to develop the disease, they both need to be carriers of the gene (AB) which occurs with probability 1/5 * 1/5 = 1/25. Then we can use the result from Q1 which gives the chance of their child having the disease as 1/4, so overall 1/25 * 1/4 = 1/100.

Q4. If you are a carrier of the gene (you have only one copy of it, i.e. you are AB), what is the chance that it is passed onto your offspring and continues in the population (ie. your children are also carriers)?

If you have children, then your partner must be either AB or BB. Only AB in your offspring would see the disease passed on and continue in the population. The chance of your partner having the gene is 1/5, and 2/4 of the possible genes for your offspring would see the disease continue in the population, giving the probability as 1/5 * 2/4 = 1/10. The chance of your partner being BB is then 4/5, and 2/4 of the possible genes of your offspring would see the disease continue in the population, giving the probability as 4/5 * 2/4 = 2/5 = 4/10.
The total probability is 1/10 + 4/10 = 5/10 = 1/2.

Q5. Finally, if you are a carrier of the gene, what is the probability that your grandchildren are also carriers? *Assume that the prevalence of the gene in the general population stays at 20% in your children's generation.*

By Q4, there is a 1/2 chance that your child is a carrier of the disease and then a further 1/2 their children (your grandchildren) are also carriers, giving a probability of 1/2 * 1/2 = 1/4.
By looking at Q4 again, we can see that there is a 1/4 chance that your child is BB. There is then a 1/5 chance that their partner is AB and a further 1/2 that their children are carriers, giving a probability or 1/4 * 1/5 * 1/2 = 1/40.
The total probability is 1/4 + 1/40 = 10/40 + 1/40 = 11/40.