JUST ASK A SCIENTIST!

Question

I have hi-fin swordtails, but when I breed them most fry show standard fins. When a male hi-fin and a female hi-fin are crossed, what percentage should have the hi-fin trait, and why won't 100% of the offspring be hi-fin?

Michi Tobler

Swordtails and platyfish are incredibly popular because of the high diversity of interesting color and fin traits that can be combined in fancy breeds. Some of these traits breed true, meaning that if two individuals having the trait are crossed, the offspring will also exhibit that trait. Other traits—like the high fin trait in swordtails and platyfish—do not breed true. The reason why some traits breed true and others do not depends on the underlying genetics; i.e., how exactly specific genes influence how a fin develops. The first person to figure out how different traits are inherited was an Augustinian friar named Gregor Mendel, who lived in what is now the Czech Republic and was obsessed about whether his peas have wrinkles or not in the 1850s and 1860s.

To better understand the problem, let's quickly dive into some basics about genetics. Our genomes are made up by thousands of genes that control the development of our bodies. Each gene resides at a specific location on a chromosome and is characterized by a specific DNA sequence *(Figure 1, page 18)*. Now if we look a specific gene in many individuals within a population, we are likely to discover that not all individuals have exactly the same DNA sequence, but there are minute variations. We call these different variations of the same gene an allele (indicated by different colors in the figure). Since most animals have two sets of chromosomes, they also have two copies of each gene. If both copies have the same allele, we call an individual homozygous at that particular gene. However, the two copies may have different alleles, in which case we call an individual heterozygous at that particular gene. When an individual has two different alleles at a particular gene, some alleles may be dominant over others, meaning one can override the effect of the other.

Now let's apply this to our hi-fin swordtails. Whether an individual exhibits a high fin or a normal fin is controlled by a specific gene in the genome that controls the growth of the dorsal fin during development. At that specific gene, there are two possible alleles. A so-called "wildtype" allele that produces a normal dorsal fin, and a "hi-fin" allele that produces a large dorsal fin. If an individual has two wildtype alleles, it develops a normal dorsal fin, and if it has two hi-fin

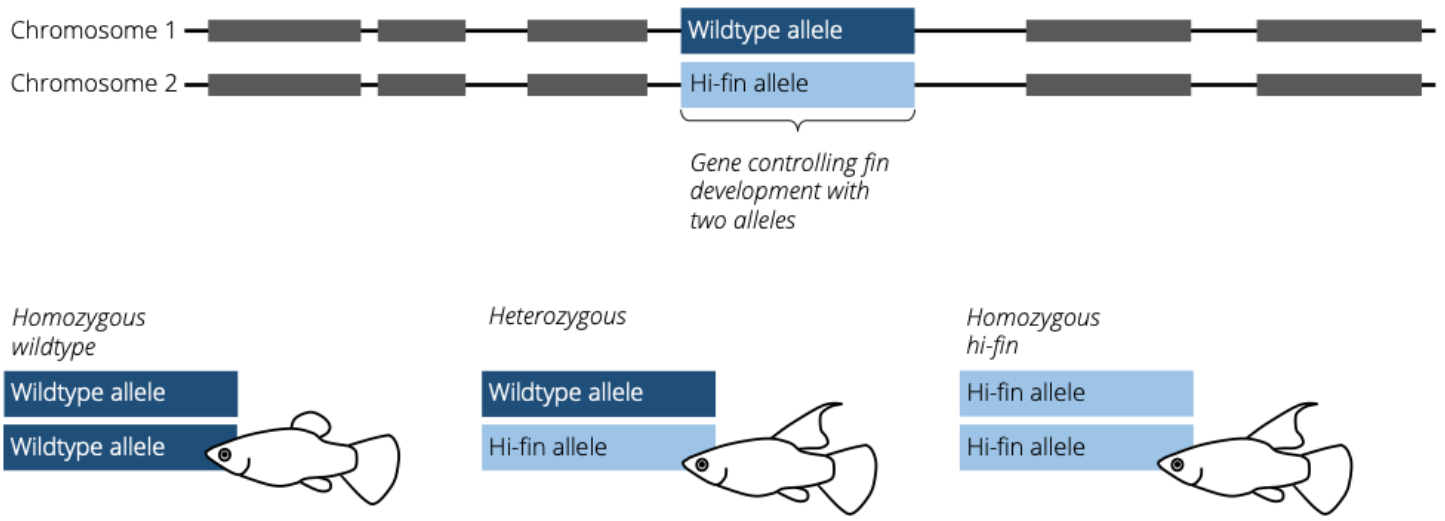

Figure 1 The top portion depicts two hypothetical, paired chromosomes. They both have the same genes, indicated by the boxes. At each gene, an individual may have two identical alleles, or it may have two different alleles, as indicated by the different colors for the gene that controls the development of the dorsal fin. The bottom portion shows how different allele combinations give rise to different fin morphologies. In this specific case, the hi-fin allele is dominant over the wildtype allele. Having a single copy of the hi-fin allele is sufficient for the development of a large dorsal fin.

alleles, it produces a large dorsal fin. The hi-fin allele is also dominant over the wildtype, which means that heterozygous individuals (those that have one wildtype and one hi-fin allele) also exhibit a large dorsal fin *(Figure 1).* Traits that are inherited in this fashion typically breed true, and the proportion of hi-fin offspring is dependent on the genetic make-up of the parents. If both parents are homozygous for the hi-fin allele, all offspring will be hi-fin (and they all would be homozygous, too). If one parent is homozygous for the hi-fin allele and the other homozygous for the wildtype allele, all off the offspring will be hi-fin as well, but they will all be heterozygous for that particular gene. If both parents are heterozygous, 75% of the offspring will be hi-fin (25% homozygous for hi-fin, 50% heterozygous) and 25% will have normal fins (i.e., they are homozygous for wildtype). Check out *Figure 2* for different scenarios. The bottom line is that we can calculate the expected proportion of offspring traits, if we know the genetics of the parent, and as soon as at least one parent has one hi-fin allele, 50% of offspring will express large dorsal fins.

So much for the theory. As you have accurately observed, this does not really hold true for the hi-fin gene! If it did, this trait should breed true, and once you have a strain that is homozygous for hi-fin, all the offspring should have large dorsal fins. Here is the snag: having two hi-fin alleles turns out to be deadly. We don't know why, but for some reasons individuals that have two copies of the hi-fin allele do not develop properly and are never born. So, all the fish that have large dorsal fins are in fact heterozygous, they have one (dominant) hi-fin allele and one wildtype allele. Even if you breed two hi-fin fish with each other, at least one third of the individual will always exhibit a normal dorsal fin *(Figure 3, page 20).* If you breed a hi-fin individual with a partner that has a normal fin, 50% of the offspring are expected to show large fins. All the other crosses highlighted in the previous hypothetical

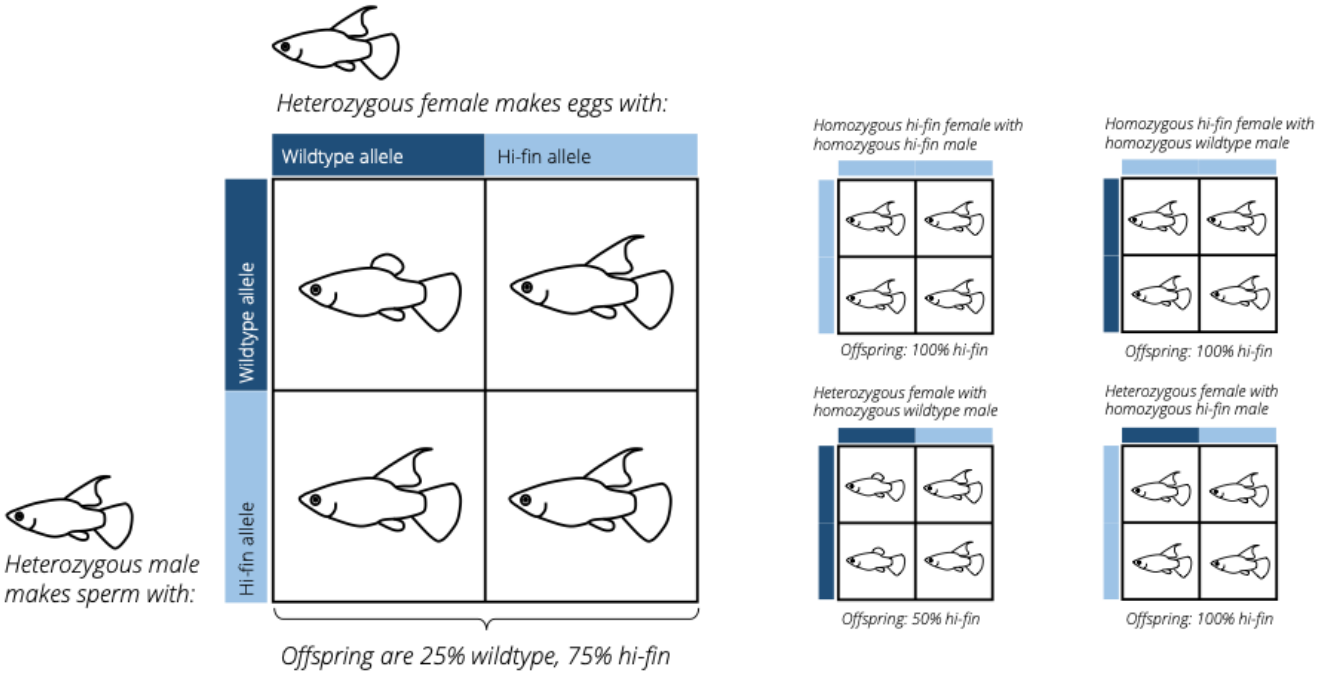

Figure 2 We can predict the outcome of different crosses if we know the genetic background of the parents. A heterozygous female will produce eggs that either contain a wildtype allele or a hi-fin allele. Similarly, a heterozygous male will produce sperm that either contain a wildtype allele or a hi-fin allele. Making all possible combinations of sperm and eggs (big square), we find that there will be one offspring that inherits two wildtype alleles, one offspring that inherits two hi-fin alleles, and two offspring that are heterozygous (having one of each allele). With hi-fin being dominant, we should consequently observe that 75% of the offspring exhibit large dorsal fins and 25% normal dorsal fins. This exercise can be repeated for crosses with parents that have different genetic backgrounds (small squares). As soon as at least one parent has one hi-fin allele, 50% of offspring will express large dorsal fins.

examples are not possible, because they involve individuals with two copies of the hi-fin allele, which do not exist.

In summary, there is a simple genetic reason that the hi-fin trait does not breed true in swordtails and platyfish. As soon as desired traits are only present in heterozygotes, any crosses will always also yield some offspring that do not exhibit the desired trait. The situation can get much more complicated though, because most traits are not controlled by a single gene, but by many. Depending on patterns of dominance and the interactions among genes, predicting how offspring will look like in different crosses becomes increasingly difficult.

"Just Ask a Scientist!" will hopefully be a regular component of Livebearers in the future. However, this requires your input. Have you ever wondered about the meaning of observations you made in your fish tank? Do you have questions about the behavior, reproduction, ecology, or evolution of livebearers? Submit your questions directly to Michi tobler@ksu.edu. He will do his best to answer your question or find somebody that can.

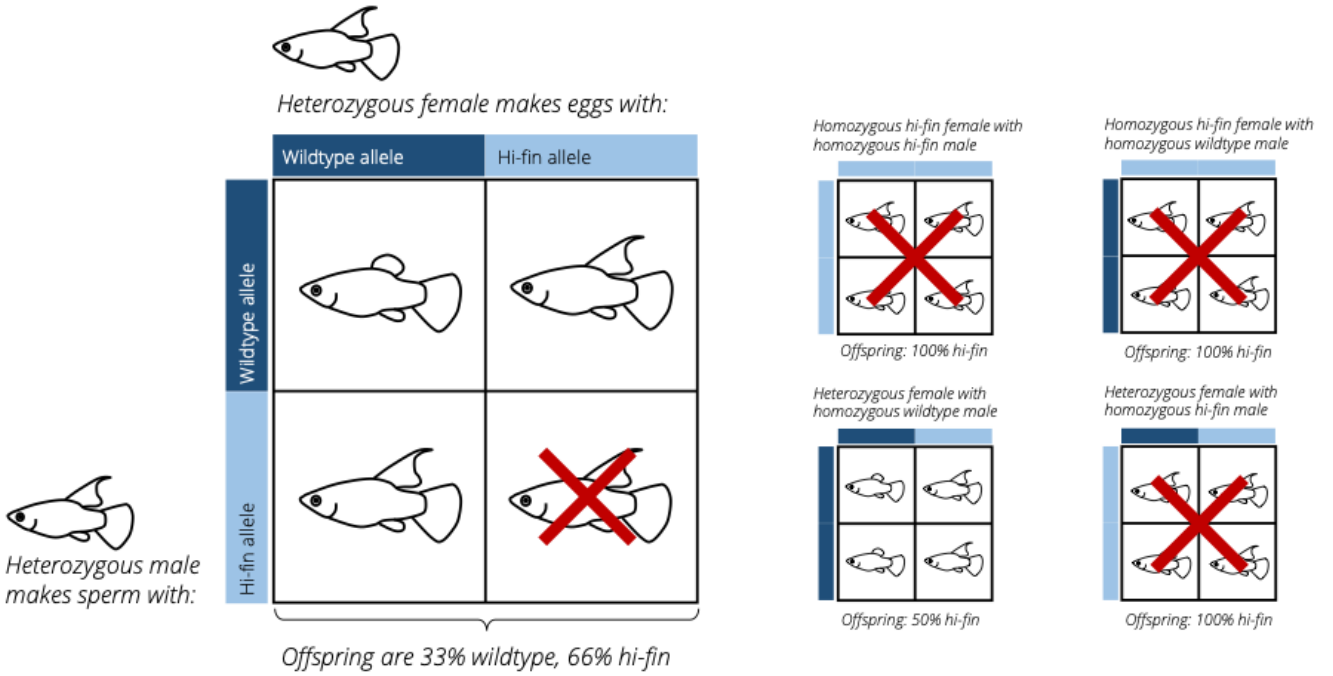

Figure 3 Possible crosses of fish that have a hi-fin trait. Since individuals with two hi-fin alleles never develop, only 50-66% of offspring are expected to have a large dorsal fin. Most crosses showcased in the hypothetical example of Figure 2 are not actually possible.