ALL IN THE GENES

PART 1: THE "IN"/"OUT" BREEDING HOKEY COKEY

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When it comes to the subject of trout and salmon genetics, there should probably be a medal awarded for the "biggest misconceptions spoken as if they were true facts". On second thoughts, that might get a pretty close run from a few other topics just within fly fishing itself! I hope that, at least with respect to genetics and conservation, this two-part offering (second installment later in the magazine) will help to set some of that misinformation straight – using some simplified examples to cut through the technological jargon. Because the inheritance of genetic material is fundamental to what we will talk about, it is sadly(!) necessary to cover some very basic ideas surrounding genes...

JARGON AND DEFINITIONS

First of all, what is a gene? In brief, it is a region on one of the strands of DNA inside living cells that contains the code to produce a particular protein or particular set of instructions to perform a function in that cell. It is probably easiest to think of each gene as a drawer in a filing cabinet that contains the specific instructions needed to produce a characteristic. The combined action of genes and their interaction with the environment determine the characteristics of living things. A few characteristics are controlled by just a single gene (e.g. eye colour in humans), but many rely on multiple genes. To complicate matters further, some single genes can influence a number of different characteristics...

Another necessary piece of jargon describes the long strands of DNA inside cells that are called chromosomes. If genes are the drawers, then chromosomes are the filing cabinets. Trout (and humans) have two complementary sets of chromosomes and this condition is called "diploidy". One set is inherited from the mother and one set is inherited from the father and the whole collection occurs as a series of corresponding pairs. Figure 1 shows just one pair as an example. In brown trout there are around 40 pairs (80 chromosomes; although some local strains have a few more or a few less) whilst humans only have 23 pairs (46 chromosomes).

FIGURE 1

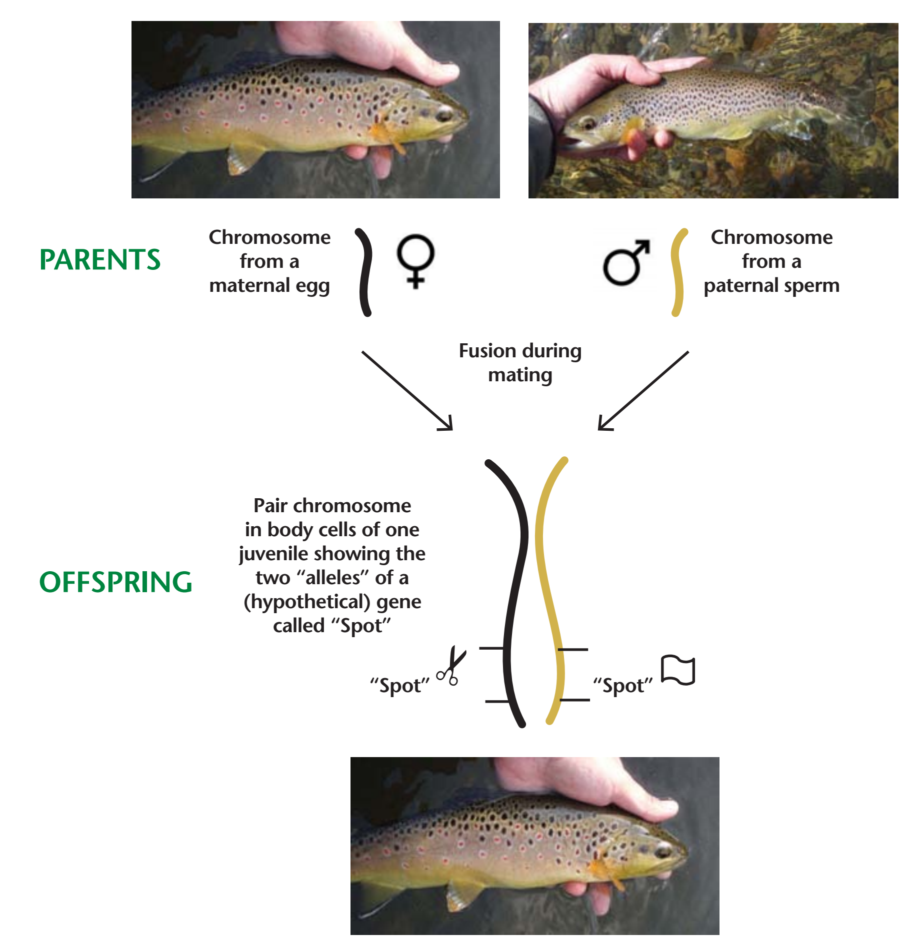


Figure 1: The pair of chromosomes derived from parental egg and sperm fused in an individual offspring. The annotated regions on each chromosome indicates the DNA code that controls spotting pattern under the influence of two alleles of that gene ("scissor" and "paper"). The offspring in this case will conform to the coding of the dominant "scissor" allele (see main text).

Figure 1 also gives a highly simplified representation of how a fictional single gene called "Spot" could have two alternative versions (one version called "scissors" and one called "paper"). These different versions are called "alleles". Alleles would be the various alternative documents of written instructions that we could choose to stick in a particular drawer in the cabinet. For example, the instructions in a drawer dedicated to eye colour might specify a blue pigment whilst an alternative set of instructions could specify a brown pigment.

HANDY GLOSSARY OF TECHNICAL TERMS

Chromosomes
The "filing cabinets" that hold genetic information. Out of each pair that you have, one comes from your mum and one from your dad.

Genes
The drawers in the filing cabinets (i.e. the location on each chromosome that genetic information is "filed" for a particular characteristic)

Alleles
The various alternative "files" that can be placed in each drawer (e.g. the alternative instructions for blue, brown or green eye colour)

Dominant allele
When a pair of "filing cabinets" hold different alternative "files" – the dominant allele is the one that is actually put into action

Recessive allele
The one that is "over-ruled" by a dominant allele

In the case of our imaginary "Spot" gene, let's say that it controls the appearance of the spots on a trout's flank. We will also imagine that the "scissors" allele (version) of "Spot" produces large round spots with a white outline. Our second "Spot" allele (version) will be called "paper" and contains the code that produces small, dark flecks.

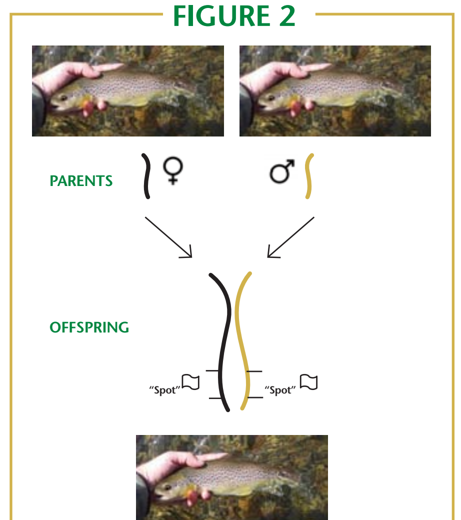
In offspring, one allele is inherited on a chromosome from the mother's egg and the other allele from a chromosome in the father's sperm. The important point here is that egg cells and sperm cells are special – since they only carry half of the full set of chromosomes (this condition is called "haploidy"). The reason for this is that, when they combine during fertilisation, the two half sets of chromosomes in the eggs or sperm (haploid cells) combine to produce the full paired set in the embryo (diploid cells) when the egg and sperm fuse together. As the ways in which each "half set" of chromosomes is assigned to individual eggs and individual sperm is a somewhat random process, there can be a large amount of variation in the collection of alleles present in different egg cells from the same mother (or different sperm cells from the same father).

DOMINANT AND RECESSIVE ALLELES – IMPORTANT

Often, when two different alleles are present in an embryo – one of those alleles will be "dominant" to the other. This means that it will be the one that is actually expressed in the organism. The process could be viewed a bit like a game of "stone, scissors, paper" where one option will "beat" another. Whilst other, more complicated, interactions of alternative alleles do exist, it is not useful to consider them here! So in our example of Figure 1 – the "scissors" allele of the "Spot" gene will be dominant to the "paper" allele. Because of that dominance, this offspring will have the large spots with white rim encoded by the "scissors" allele. A simple comparable example in humans is brown eye colour being dominant to blue eye colour.

Alleles that are dominated by their alternative version are termed "recessive". The really important feature of "recessive" alleles is that, in order for them to be expressed, they must occur in identical matching pairs. This means that both the maternal egg and the paternal sperm must carry the same, recessive, allele. In our fictional example, in order for the flecked "paper" allele spotting pattern to be expressed, both of the chromosomes in the appropriate pair have to contain the "paper allele" (Fig. 2). It is important to bear in mind that parents can show a dominant trait (e.g. brown eyes in humans) as a result of having one dominant and one recessive allele in their genes. These parents will produce two kinds of eggs or sperm – ones with "brown eye" alleles and ones with "blue eye" alleles. So, in this way, it is perfectly possible for two brown-eyed parents to produce a blue-eyed child if both the egg and the sperm happen to be carrying the "blue eyed" allele. However, without going into too much detail, the mathematical combinations of options means that three out of every four offspring will be brown eyed and one out of every four will be blue eyed (on average!).

FIGURE 2



Double recessive alleles are required for fish to show the "paper" allele spotting pattern

INBREEDING DEPRESSION (SAY WHAT?)

Why is all this talk of recessive alleles important to wild trout? Well, when fish are domesticated, there is a risk that inbreeding can occur (where genetically similar/closely related individuals are artificially mated, often over several generations). A good number of genetic disorders and health problems are produced by recessive alleles (although not all recessive alleles are bad of course). When relatives interbreed, the probability that one or both parents carry two copies of damaging recessive alleles dramatically increases. Consequently, the risk that offspring will inherit matching pairs of damaging recessive alleles from their parents is also heightened. This is called "inbreeding depression" by scientists and is commonly referred to as "being inbred".

It is crucial to reduce the likelihood of lots of "double recessive" combinations when undertaking artificial mating of any domesticated animals. For this reason, it is necessary to refresh the breeding lines from new stock in order to avoid these inbreeding effects. Happily, in wild populations, the process of natural choice of breeding partner is adapted to avoid damage from inbreeding.

OUTBREEDING DEPRESSION (NO REALLY!)

The complete wild trout gene pool represents the ultimate "master library" of every single version of every single trout gene that could possibly be present in any lineages (whether domestic or wild). Both domestication and local adaptation in the wild involves selecting only a subset of the total gene library. BUT, during domestication, the characteristics that are selected are the ones that allow individuals to thrive in artificial conditions. These artificial conditions are broadly similar between different rearing facilities – and consequently result in the selection of relatively few alleles. In total contrast, natural selection in the wild produces fish that are specifically adapted to their local stream conditions. Conditions in one wild location can be vastly different from conditions at another – so this has produced a far higher degree of genetic variation across wild populations compared to all domestic strains. In addition, some wild breeding populations will exploit one part of the environment whilst other co-habiting wild populations will exploit another, very different, opportunity that is also present in the same area.

The difficult concept comes when we look at an individual, wild, locally-adapted population. Because it is finely tuned by adaptation to its unique surroundings, there may not be very much genetic variation between individuals. Surely, then, if we add fertile domestic stock fish – and increase the amount of genetic variation – this is a good thing? Surely it is the same as when we "refresh" inbred domesticated breeding lines with new blood? Au contraire Blackadder! What actually happens is that the additional genetic variation consists of alleles that are unhelpful for local survival and reproduction in that specific wild environment. The alleles that are added are those that are suited to domestication and actually reduce the fitness of the hybrid offspring of wild x stock fish matings. This concept is called "outbreeding depression". It is made even more complicated when you throw in the fact that many individual wild breeding populations overlap and spend much of their lifecycle (when they are not spawning) all mixed up together in various river and lake systems – and even in the sea if you are a sea-trout.

The reason that this is important is the subject of the next article...