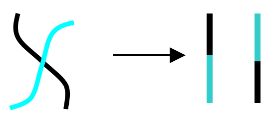
Advanced Rabbit Genetics

By Amy Hinkle

First, let's talk a bit about gene linkage and how it works. Different groups of alleles reside on different places on the chromosome, called loci. For example, the agouti, tan pattern, and self alleles all will reside on the same locus. Same as both dense and dilute will reside on the same (but different than the A) locus. In normal Mendalain genetics, it is *assumed* that the loci are on separate chromosomes. This means they can each have an equal chance of being passed on as only one chromosome from each parent is passed on; this is why there is one copy of each gene from each parent. However, this is not always the case.

There are many *many* loci per chromosome, and if they are close enough together, they oftentimes get passed on together. The closer they are the more often this occurs. This is called "linkage" because the genes are "linked" via the same chromosome.

Now, there are plenty of times where two genes being on the same chromosome doesn't really matter, because they are on loci that are very far apart. A chromosome will have "crossing over" events. Crossing over is when a chromosome pairs with its partner chromosome (remember: chromosomes come in pairs just like genes do) and they exchange data. Here's a picture to help:



As you can see, it actually "swapped" bits of itself with its partner chromosome. Usually, loci are far enough apart that this sort of thing occurs, and so even if two loci for coat color happen to be on the same chromosome, it is still basically a random 50/50 shot at getting each. However, sometimes, they are pretty close! This is when we talk about linkage.

When someone talks about a "crossover percent" or a "map unit", these are ways of saying how close the two loci are. This number is the gene's chances, the percentage, of being *passed on independently*, as "normal" genes would be. So if there is a map unit of 35, this equals a crossover percent of 35%, meaning that the genes will be passed on independently of one another *only 35%* of the time, not like the random chances you would expect. Remember, this is two different genes from two different loci, this is not the gene pair. For example, this is not saying that both agouti and self (Aa) will come from one parent. Instead, it means if you have a chocolate allele linked with a light chin, 65% of the time those genes will be passed on together, which is "bad" because chocolate points are not recognized and you'll have a higher risk of that occurring than if each was passed on independently of one another.

In rabbits, there are a few instances of this linkage in coat color. The B (black/brown) and C (color) loci are linked. Cross-over between B and C is approximately 35%, or 35 map units apart. So, as in our example above, 65% of the time the B and C alleles are passed on together. [1]

Another color linkage group is the En (English Spot aka Broken Pattern), Du (Dutch) and Angora coat loci, with a crossover percent between Angora and Du of approximately 13%, or

13 map units. Linkage between Du and En loci is about 13 map units as well. Linkage between the Angora and En loci is, therefore, 26 map units. [1]

Yet one more linkage group is between the A (Agouti) and W (Wideband) loci at 30%. [2]

Here is an example to help illustrate what this means:
Sire: Chocolate Chinchilla, relevant genotype: $bbc^{ch3}c$
Dam: Chestnut, relevant genotype: BbCc
Now, say that for the sire, his chromosomes obviously have to be bc^{ch3} and bc.
The dam could have the chromosomes BC & bc or Bc & bC
Since 65% of the time, these pairs will be passed on together, it will skew the normal ratios of probability for certain colors that you could get, as if it is the first set for the dam, she's not going to often pass on a Bc or a bC, and vice-versa if the second set.

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I'm going to switch topics a bit now with some brief mention on genes and patterns not often talked about in detail.

First, a bit about varying non-standard coat types. The rex gene does not actually create a coat lacking in guard hairs as is commonly taught, instead, these hairs are extremely shortened making them barely distinguishable. Also, the rex, while independent of angora, when both are present in recessive form it creates a compromise between the two characteristics. [3] The rabbits will have fur longer than normal but shorter than angora, and it will be curled at the end. Whiskers are also curled. There is also a wuzzy mutation that causes normal hair to be curly and easily matted, and the characteristics of the hair fibers itself are different from standard. It starts to manifest around day 10 and creates a very unkempt appearance. [4]

There are also interesting coat patterns that can be created with varying combinations, for example what we see in the Hotot breeds. The dwarf hotot is caused by a combination of the broken and dutch genes. There are actually two variations of dutch, du^d ("dark dutch") which creates more what we think of as the classic Dutch, and du^w ("white dutch") which is responsible for patterns as seen in the Hotots. A classic Dutch rabbit will have the genotype of $du^d du^d$ or $du^d du^w$ and various modifires play a role to the exact pigment placement, much as it does with the large variance seen in the broken pattern. A Hotot, however, will be a mixing of both the broken gene and the dutch, is $En\_du^w du^w$. [5] There are other combinations which could produce a Hotot colored animal, such as $EnEndu^d\_$, and this likely explains why some breeders rarely ever get mismarks like "broken dutch" and some often do, because of exactly which alleles are creating the Hotot. And indeed it seems to hold true that breeding a brown eyed Hotot (no eye bands whatsoever) with a broken dutch Hotot produces largely properly banded offspring.

Works Cited
[1] Castle, Sawin. Genetic linkage in the rabbit. *Proc Natl Acad Sci* 27(11): 1941
[2] Sawin. Linkage of wide-band and agouti genes. *J Heredity* 25(12): 1934
[3] Castle & Nachtsheim. Linkage and interrelations of three genes for rex (short) coat in the rabbit. *Proc Natl Acad Sci* 1933
[4] Crary & Sawin. Inheritance and hair morphology of the wuzzy mutation in the rabbit. *Journal of Heredity* 50(1)
[5] Castle. Genetics of the dutch coat pattern in rabbits. *J Experimental Zoology* 68(3)