**Teresa Hawkin** and her partner, Victor Wilton, bought their first alpacas in 2007 and now run Rosecraddoc Alpacas in Cornwall.

We decided to focus on greys in 2009 and have started to see some success in the show ring. We keep a few patterned animals because of my interest in genetics and we like them. We have all had those "surprises" in our fields at birthing time and been left

# UNLOCK THE COLOUR POTENTIAL IN YOUR HERD

scratching our heads and muttering "where did that colour come from"? And some of us are passionate about a particular colour of alpaca be it brown, black or grey and so want to maximize the number of cria that are born this colour. A basic model of colour genetics can explain the little surprises and help us plan our coloured breeding programmes.

## THE BASIC THEORY

Don't panic, I promise not to bang on about chromosomes, alleles and all manner of other technical terms that will make your eyes glaze over. There are just two basic facts that we need to know and understand:

- Genes, like jeans, come in pairs. I never did quite understand that one – I know they have two legs but jumpers have two arms. So, **every alpaca carries two colour genes** - it receives one from each parent. These may be two of the same colour or two different colours.
- **Lighter colours are dominant over darker colours.** This doesn't mean that if you mate a white animal to a fawn animal you will always get a white – it's not quite as straightforward as that I'm afraid. What it means is that an animal will always physically appear the lighter of the two colour genes that it is carrying.

If we think about this for a moment, these two facts together tell us that for any alpaca in front of us, we know it must be carrying **one gene that is the colour the animal appears plus one that is either the same or a darker colour** that is "hidden" or "masked" by the lighter, dominant colour. So for example, an alpaca that appears white must be carrying a white colour gene, but it's second colour gene could be white, fawn, brown or black. A fawn alpaca MUST be carrying a fawn gene and the other gene could be fawn, brown or black. It can't be white which is a lighter, more dominant colour or it would appear white. For a brown animal it MUST be carrying brown and its second colour could be brown or black. Black animals are the most straightforward of all – they MUST be black and black.

## THE KEY

Identifying this second colour in your animals is the absolute key to predicting your possible mating outcomes and helping you avoid those surprises or breed for specific colours. However, it sometimes takes a little detective work to do this. The Herdbook is your best friend here. You can start by looking back through an animal's pedigree and try and allocate both colour genes to each animal on there to work out what is most likely carried by the animal in question. This isn't easy, especially once you hit an imported animal. You often end up with a couple of possibilities for an animal.

There are a couple of tricks that can help:

- If one parent is black you know that any progeny will have received a black colour gene from them. So if the female in question is fawn but her sire is black then she will be carrying a fawn and a black gene.
- If the animal has a number of progeny on the ground then the quickest approximation to its second colour is to look at the colours of the progeny. The animal must be carrying a second colour gene that is at least as dark as its darkest progeny. So for example, if you have a fawn female and she has thrown a brown cria then she must be carrying brown or black as her second colour, because if she'd been fawn/fawn she would have thrown a fawn colour, which is lighter than brown and the cria would have been fawn. If she has thrown a black cria, you know that she must be carrying black. Remember it takes two black colour genes to make a black animal, one from each parent.

Be warned, you won't be able to sit down and complete this exercise in an hour. Some will be straightforward, some will take a little work, some will take a lot and some you may not be able to map at all. I only have a small herd and still have the odd animal that is keeping me guessing. I suggest you try it out on a couple of animals to start with.

## PREDICTING COLOUR

OK, so you've had some sort of attempt at mapping out the colour genetics of your herd, or at least an animal or two. So what now? How do you go about predicting what the outcome of any mating might be?

One colour gene is passed from each of the parents to the cria but either can be passed and in any combination. Punnet squares, please bear with me, are used to help with this. These are just a type of table that is used to make sure you have listed out all the possible combinations in an orderly way without missing one. Simply use the colour genes of the two animals to be mated to label the columns and rows of the table. Then go to each box inside the table and list the colours from the corresponding row and column labels. We tend to use the first letter of the colour rather than write it out (W=White, F=Fawn, B=Brown and we use little b=black). And it helps if you list them with the paler colours initial first, then you know that this is the colour the animal appears.

By way of an example, imagine we have a fawn female that has both colour genes as fawn (F/F) and that she is mated to a brown male that has both his colour genes as brown (B/B). The possible outcomes are:

| | | Female | |
|---|---|---|---|
| | | F | F |
| Male | B | F/B | F/B |
| | B | F/B | F/B |

So the resulting cria would most definitely be fawn, but carrying both fawn and brown genes (F/B). It would appear fawn as this is the lighter of the two genes.

Now imagine that this cria then went on to be bred to another brown (B/B) male:

| | | Female | |
|---|---|---|---|
| | | F | B |
| Male | B | F/B | B/B |
| | B | F/B | B/B |

Interestingly, it would stand a 50/50 chance of throwing a fawn (F/B) or a brown (B/B).

**Fig 1: What We Expect!**
Dark grey father, both threw black genes and one threw greying gene, could have equally produced a black.

**Fig 2: What We Expect?**
Father was actually a fawn male but carrying brown or black.

**Fig 3: What We Didn't Expect!**
Father was black, mother was brown carrying black. Father threw black, mother threw brown or black and both threw a dilution gene.

**Figs 4a/b: Breeding To The 2nd Colour**
This brown female is also carrying black which she passed to the cria. The sire, our silver grey male, passed a black and a greying gene to the cria. This young grey is out of the brown female in Figs 2 & 3 and our silver grey male (she is also carrying black).

> Some will take a little work, some will take a lot and some you may not be able to map at all. I only have a small herd and still have the odd animal that is keeping me guessing.

So you can see from this that you have two fawn animals in your field – one which will only ever throw you fawn cria when put to a brown (B/B) male and the other, which would throw you fawns and browns in equal proportions. Hence, knowing the second colours of these animals will help you choose suitably coloured males for them. If you have a fawn animal that is only ever going to throw you fawns you may want to put the best fleeced fawn animal on her that you can. Or you may deliberately decide to breed to her second colour as part of a longer term colour breeding plan and put a brown male on her with a view to producing more fawn females carrying brown. And by then putting a brown male on the fawn females carrying brown you will produce more browns (50%).

Of course, life often gets more complicated than that and there are probably very few animals out there that carry two of the same colour genes. But the model still works – you just need to know both colour genes for each animal. Imagine a fawn female, also carrying black (F/b) that is mated to a white male who is also carrying brown (W/B):

| | | Female | |
|---|---|---|---|
| | | F | b |
| Male | W | W/F | W/b |
| | B | F/B | B/b |

The cria from this mating would stand a 50% chance of being white (either W/F or W/b), 25% of being fawn (F/B) and 25% of being brown (B/b). Now you are starting to see why we hear comments like "he's white, but is known for throwing colours". It is because of that hidden 2nd colour.

## DILUTION GENES – A SPANNER IN THE WORKS

I am now hearing cries of . . . "so how come when I mated my brown female to a black male I got a light fawn cria?" Or, "I mated two blacks together and got a beige!" I have had similar things happen to me, see Fig 3, and dilution genes are the culprit. Dilution genes are more common than originally thought and when an animal inherits two dilution genes, one from each parent, its coat colour is significantly lightened. Understanding that **both** parents have had to pass a dilution gene for this to happen is significant – it tells us that they are both carrying a dilution gene. Note it on your herd mapping immediately.

You can avoid these dilute animals being repeated by ensuring that any animal carrying a dilution gene is only mated to an animal that isn't. If you are desperate to pair the animals for other reasons, the news isn't all bad. Remember, genes, like jeans, come in pairs so an animal carrying a dilution gene will also carry a non-dilution gene. Hence the dilution gene will only be passed half the time, and only one in four cria from parents both carrying a dilution gene will be dilute. Again, the herdbook can be used to look at animals' progeny to highlight any unexpectedly light cria being produced, the colour of the mother will need to be checked also, just in case they were mated to a light fawn, and hence the likelihood of a dilution gene being present.

And here's the thing. There is no need to discard these lighter animals if your aim is to breed dark colours. A dilute animal can still be a valid part of your breeding programme as it will breed based on its two underlying colour genes, provided its mate isn't also carrying a dilution gene. So your light fawn or beige animal bred from those browns or blacks will still breed like a brown or a black would.

Dilution genes occur in lighter animals, fawns and whites, too but are just not as noticeable.

## PATTERNS

If you're breeding for solid colours don't turn the page at this point – you might miss out on some useful advice on how to make best use of those animals bearing the odd white patch, we all have them.

Remember from earlier, genes come in pairs so an animal with a pattern gene will also have a "solid" or non-pattern gene, these are in addition to the normal two colour genes. Hence, over time/a number of matings, patterns are typically thrown 50% of the time when a patterned animal is mated to a solid animal. The majority of the pattern genes are dominant so if the animal is

Fig 5: Our Inkspot Paint
This female is brown, carrying black and a white spotting gene.

carrying them, they will be visible. There are exceptions which I will deal with as we go along.

## GREYS

These may or may not be part of the family of white spotting genes, but since they are so significant, and my absolute passion, I shall deal with them separately. Silver greys are basically black animals (b/b) and rose greys are essentially fawn or brown animals. As such, rose greys could be carrying a range of colour genes (F/F, F/B, F/b, B/B or B/b) and so tend to throw a wider range of colours. Interestingly, whites could also be carrying the greying gene but the white fibres mixed with white wouldn't be visible. And it's not always obvious in some of the lighter fawn animals either.

The secret to breeding greys is to plan your matings in order to get the correct base colour (see Fig 4 – black for the silvers and brown, or as dark a fawn as is possible for rose greys, to ensure they look obviously grey. And if one of your animals is carrying a greying gene you stand a 50/50 chance of this being passed to the cria on top of its base colour. You will hear it said that rose grey is dominant over silver grey – this is only true in as far as fawn or brown is dominant over black, as previously discussed. Again, it will depend on the animals second colour. If you do the punnet squares for the base colours you will see that a rose grey, brown or fawn, carrying black could produce either silver or rose greys in equal numbers if put to a silver grey (b,b).

Whilst talking about greys, we must talk about the lethal gene. There is growing and compelling evidence that a grey x grey mating can produce a lethal grey/grey gene combination (just as in blue merle dogs). The punnet square below, irrespective of base colour, is for a grey (G/S) x grey (G/S) mating where G=greying gene and S=solid (or non-greying) gene:

| | | Female | |
|---|---|---|---|
| | | G | S |
| Male | G | G/G | G/S |
| | S | G/S | S/S |

In theory, this would give us our best chance (75%) of producing a grey cria but actually, the cria that inherits a greying gene from both parents (G/G) will not be viable. These normally result in what is often recorded as a non-pregnancy, but are most likely a re-absorption or abortion. This has been backed up by work on the Australian herd book where grey x grey matings resulted in grey offspring only something nearer 67% rather than the predicted 75%. It is a matter of interpretation as to whether you look at the overall picture and say only 50% of offspring will be grey (allowing for the 25% of non-viable pregnancies) or whether you say that 67% of offspring hitting the ground will be grey...

Let us also mention here the white faces/tuxedo patterns seen on many classical grey animals. It is likely that this is the result of the tuxedo gene, as seen in other coloured animals with the white face/throat/feet markings. It is thought that it sits very close to the greying gene on the same chromosome, oops, sorry – that word just slipped out, so is more often than not passed to the cria with it, BUT NOT ALWAYS. Hence we occasionally get a modern grey/roan animal without the tuxedo gene and hence without the white face/throat/leg markings. I may be a little biased, but this is why it would make sense to revert to the mixed grey/roan show classes. Modern greys/roans deserve to be recognized but given the current small number of greys at many shows, it is unlikely that we will produce them in sufficient numbers to warrant their own classes.

## WHITE SPOTTING GENES

These include the tuxedos already mentioned, pintos, white or white/spotted ring round the neck, paints, the stereotypical multi, some spotted animals, etc.

The thing to remember is that these animals are genetically speaking, a coloured animal, with two colour genes following the model we have previously outlined, with an overlay of white over their base colour. It is sometimes difficult to visualize this - consider the age old childhood debate in the back of the car on Friesian cows and whether they are black animals with white markings or white animals with black markings. This is especially difficult to imagine with the more spotted animals (see Fig 5) or speckled animals, which look white with speckles/spots of colour typically appearing to have been sprinkled along the backline and spreading downwards. Look closely at my own spotty girl, an "inkspot" paint (Fig 5). She is a brown animal, look at her head and legs, with a white pattern overlaid. Think of the white as a sheet/coat of very open lace laid over her neck and back.

These white-spotting animals, with a little knowledge, can still be used in a solid colour breeding programme as when bred to solids will produce solids 50% of the time. Even more interestingly, **grey animals seem to have the capacity to reduce the multicolour/white-spotting factor and increase the likelihood of solid offspring.** Liz Paul's research based on the Australian herdbook suggests that grey x multi matings produced as little as 14% multi-coloured offspring. The actual results were 43% solid colour, 32% solid white, 14% multi and 12% grey progeny. So if you have a multi and you don't want to produce more multis, consider putting a grey on it. The same effect was also noted by George Davis of New Zealand in his 1996 paper. See the results of my grey male across my spotty girls in Figs 6, 7 and 8.

Fig 6: Her Brown Cria
She passed her brown gene but not the white spotting gene. Sire was our silver grey, who passed a black gene but not his greying gene.

Fig 7: Her Grey Cria
Out of the same sire. This time he passed a black gene and his greying gene whilst she passed her black gene and not her white spotting gene, producing a classically marked grey.

Fig 8: Her Patterned Cria
Again, out of the same sire. This time he passed his black gene, whilst the mother passed her brown gene and the white spotting gene.

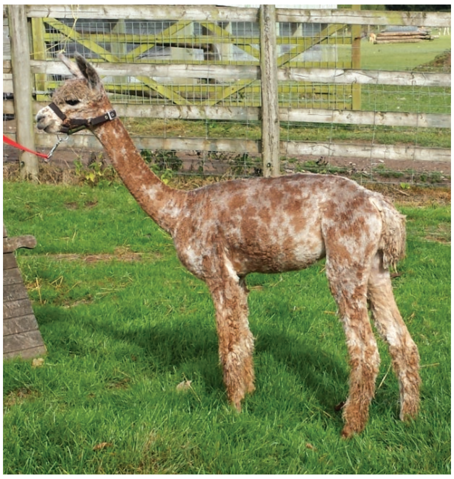

Fig 9: Leopard Appaloosa

Consider the age old childhood debate in the back of the car on Friesian cows and whether they are black animals with white markings or white animals with black markings

For those of you out there that breed whites, don't think you get away scot free. Be warned, many whites are actually white spotted animals, you just can't see it, hence the occasional fawn with a white face. And whites can also sometimes even carry the grey gene, which again wouldn't be visible but might suddenly show up when the animal is bred to a coloured animal.

## DARK SPOTTING GENES

These are different to the white spotting genes. Animals carrying the dark spotting gene are characteristically a light colour but not white, e.g. light fawn or silvery grey, with dark spots. This spotting gene is often called the "leopard" gene. Appaloosas (Fig 9) and Harlequins (Fig 10 -12) are classic examples.

Little study has been done on appaloosa genetics in alpacas but in horses, it is known that it is not a single gene but rather a complex string of genes and that modifying genes form part of this string and must be present if the pattern is to be visible. These modifying genes are responsible for the extent and amount of spotting that is seen - from a few spots to many. It is likely that something similar occurs in alpacas. This is why appaloosa patterning can appear to skip a generation and why we find instances of solid animals throwing appaloosas. An animal may appear solid due to the lack of the modifying genes but may still be carrying the leopard gene. When mated to another animal who can supply the modifying genes the spots can be seen in the offspring and an appie is born.

It is also thought that in some instances, white can mask the dark spotting genes.

Overall, appaloosas tend to follow the prediction and produce appaloosas approximately 50% of the time.

Harlequins are rarer and again an example of the dark spotting or leopard gene. Animals tend to be born with a light basecoat (typically fawn, although they can be light grey) with lots of small black spots, but shade between 3 and 8 months of age to a roan effect. They typically retain the

spots/speckles on their faces and sometimes in the groin area. Even less is known about harlequins but my own theory is that dilution genes have a role to play. They are often born to black or sometimes dark brown parents - and black spots on a black animal would just simply, not be visible. This would account for their rarity compared to appaloosas as it would require both parents to also be carrying a dilution gene and pass them, along with the dark spotting gene to the cria. I have mated my harlequin male this summer to one of my dark brown females which I know to be carrying black ***and*** a dilution gene and I can still only rate my chances of producing a harlequin cria somewhere between 12% and 25%... but isn't half the excitement in the anticipation?

**Credits/Sources:**

Genetics for Alpaca Breeders (plus various other articles/lectures), D. Andrew Merriwether

Theory of Colour Inheritance in Alpacas, Elizabeth Paul

The Status of Grey Alpacas in the Australian Herd, Elizabeth Paul

The ABC's of Llama Color, Debby Ulrich

Synthesis of a Miracle, Mike Saffley

**Fig 10: Harlequin Cria**
Spotting clearly visible.

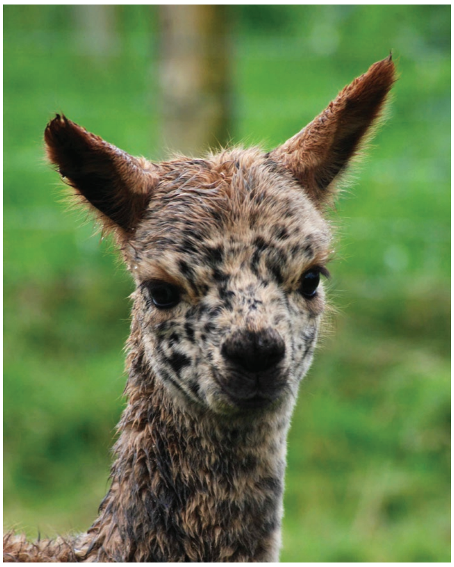

**Fig 11: Harlequin Adolescant**
Shaded to a roan effect

**Fig 12: Harlequin Adult**
Darker again but speckled face still visible.