Breeding Icelandic Sheepdog
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Icelandic Sheepdog breeders should have two high priority objectives: The survival of the breed and the health of the breed. In this article I will explain that maintaining genetic variation is necessary to reach our ultimate goal: Securing a future for the breed.
From this point of view, we should value variation in our breed. We are for example very lucky still to have various coat colors in our breed. Let us preserve that variety!

Part one

Genetic variation
The more, the better!

History
Iceland is a small country and being an island far from the continent, it is also isolated. This has had big implications for the only dog breed that originates from this country: the Icelandic Sheepdog.
Because Iceland is small, the population of Icelandic Sheepdogs has never been large during the past centuries. As a result of the isolation, the population of dogs remained pure, but this also limited the exchange of genetic material. In other words: only a small number of dogs contributed their genes to breeding and few new genes entered the breeding population. This has been the situation in the past and this has implications for the current population and for the breeding future. Although Iceland is not so isolated nowadays, breeders want to keep the

breed pure, which limits the size of the population and keeps the breed isolated from new genes, even when the breed is spread over many countries in Europe and America as it is now.

At the start of the official registration of pedigrees for Icelandic Sheepdogs in 1967, we can identify around twenty "founders". These are both male and female dogs that have contributed to the starting population of purebred Icelandic Sheepdogs. According to the research of Pieter Oliehoek which he carried out in 1999, after thirty years most of the then existing dogs descended from only three of these founders. This means that in a relatively short breeding period, in which on the one hand the number of Icelandic Sheepdogs around the world *increased* a lot, the genetic variation in the breed *decreased* a lot. This situation remains unchanged in 2012, although breeders have improved their breeding habits. The fact of the matter is that genes once lost from the population cannot be recovered.

A group of people concerned about the breed started an international cooperation to maintain the Icelandic Sheepdog. This Icelandic Sheepdog International Cooperation (ISIC) has been working on the future of the breed since 1997 and strives to do this together with all the Icelandic Sheepdog breed clubs in the world. Naturally, one of the main topics for ISIC is maintenance of genetic variation. This breed can only survive when decreasing genetic variation is slowed down as much as possible. For the sake of the health of the breed, all associated breed clubs are convinced that maintaining genetic variation is top priority.

Health

Genetic variation is directly related to the health of the breed. A low variety of genes in a population means that the dogs have many ancestors in common, instead of many different ancestors. The more the dogs are related, the higher their vulnerability for (the development of) diseases. With increasing close relationships in a breed, diseases will arise and fertility will go down. The population will become more vulnerable to diseases that are caused by immunity deficiencies or to inherited disorders. The fertility of the population will go down: the average litter size will decrease, the life expectancy of the dogs will be lower, etc.. For this reason, preservation of genetic variation is important for a healthy breed.

Unfortunately there are mechanisms that diminish the genetic variation in a population just by chance, there's nothing we can do about that. These are general mechanisms, that happen in every population, so also in our breed. One mechanism is called **bottleneck**. A bottleneck is a period in the history of a population in which only a few animals contribute to the next generation. An example is the distemper disease, which arrived in Iceland in the nineteenth century and resulted in the death of a lot of dogs. Few dogs survived and only these dogs were able to produce offspring. This meant that the complete next generation descended from this small number of individuals, and only the genes of these dogs were passed on to the next generation. All the other genes disappeared from the population.

Each bottleneck will decrease the genetic variation in the population by **genetic drift**, the loss of genotypes by chance. In a small population it is possible that just by chance some genes pass on to the next generation and other genes do not, which means that they disappear from the population. Once disappeared, a gene will never come back. Small populations suffer from decreased genetic variation through this autonomous process, which we cannot influence, we can only have a hand in the size of the population.

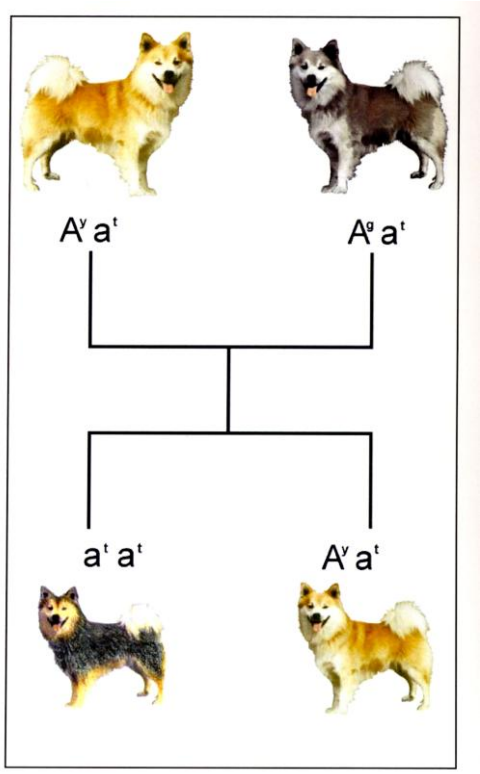

Fig. 1 parents and offspring with the genes for coat color

Figure 1 shows the influence breeding can have on the genes in the next generation. At the top of figure we see the parents of the litter: a red father with the color genes A^y and a^t and a grey mother with the color genes A^g and a^t. Both parents pass their genes on to their offspring, but each puppy gets only one gene from the father and one from the mother. In this case two puppies were born. One black and red puppy, and one red puppy.
The black and red puppy received one a^t from the father and one a^t from the mother. The red puppy received the A^y from the father and the a^t gene from the mother. In this case, the gene for the grey color A^g was not passed on to the next generation. In this way the A^g gene and with that gene the grey color can disappear from the population.

People can influence genetic variation by two other mechanisms, namely **selection** and **inbreeding**. People select animals for breeding and this means that these animals contribute their genes to the next generation and further. Animals that are not selected, do not. In this way selection has a large influence on the genetic variation of the next generations.

We talk about inbreeding when two individuals used in breeding are more related to each other than to the average population. In case of inbreeding, the offspring has more ancestors in common than necessary in the population. With the inbreeding coefficient we can measure the probability that dogs inherit identical genes by descent from the common ancestor. In this way inbreeding is responsible for the increase of homozygote gene pairs.

As shown above people can influence genetic variation by selection and inbreeding. Of course one breeder will not immediately decrease the genetic variation of the population by doing so, but all the breeders together can have an impact, for instance by selecting for the same traits.

Even so, in general we can state that people diminish genetic variation by selection and inbreeding.

Inbreeding and litter size

Type of mating	numbers	Inbreeding %	Litter size
I	**412**	**1.8**	**4.3**
II	**137**	**9.2**	**4.1**
III	**136**	**16.8**	**3.8**
IV	**25**	**29.6**	**3.7**

Type I = parents less related than cousins - inbreeding coefficient < 6.25%
Type II = parents related as cousins but less than half sibs - inbreeding coefficient > 6.25%, < 12.24%
Type III = parents related as half sibs but less than full sibs - inbreeding coefficient > 12.24%, < 25%
Type IV = parents related as full sibs or parents to progeny - inbreeding coefficient >25%

Table 1. The relationship between inbreeding and litter size in Icelandic Sheepdog (Per-Erik Sundgren 2006)
Type of mating: relationship between parents of a litter
Numbers: number of litters
Inbreeding %: inbreeding coefficient in percentage
Litter size: average number of puppies per litter

Table 1 shows the relationship between inbreeding and litter size. Per Erik Sundgren has investigated the ISIC database with Icelandic Sheepdogs. He looked into the inbreeding coefficient of breeding pairs in relation to the number of offspring. He clearly showed that on average more related parents produced less puppies.

How to maintain a healthy population?
We have seen that the size of the population is important. In a large population it is easier to maintain genetic variation and thus to diminish loss of genes. We are happy that the Icelandic Sheepdog population is large enough nowadays when we consider the breed as one population worldwide. For this reason the cooperation between the breed clubs in ISIC is very important, because we can only realize a large population by a joined effort.

Besides size, the keyword is relationship. We should aim for random mating, to make sure that the relationship between animals in breeding is as low as possible. In practice it is not possible to realize random mating in a dog breed, but we can try to avoid inbreeding. We should avoid this as much as possible and try to combine parents that are not more related than average for the population.

To make sure that many genes are passed on to the next generation, we need to use many different individuals in breeding. All individuals with different genotypes that take part in

breeding combined, are called the effective population. When we combine 50 males and 50 females in breeding, we cannot state that the effective population size is hundred. The effective population size depends on the differences in genotype of the breeding stock. When the 100 breeding dogs are related to each other, the effective population size will be much lower than hundred. The aim is to realize a large effective population. In practice this can only be achieved by using many unrelated individuals in breeding. The consequence of this is that one individual parent should not have many puppies.

Based upon the above the breed clubs in ISIC have formulated breeding recommendations for the Icelandic Sheepdog. The objective is to maintain a healthy breed for the future. Several experts in dog genetics have assisted ISIC with calculations for our current population of Icelandic Sheepdogs. The result of the calculations is formulated in recommendations for breeders all over the world that want to contribute to the future health of the breed.

The following are the recommendations for studs:
One stud should not father more than 8 litters during his lifetime. As a father he should have less than 35 puppies. When his sons and daughters are used in breeding, the number of his grandchildren should not exceed 70 puppies in total.

The following are the recommendations for dams:
One dam should not have more than 5 litters during her lifetime. As a mother she should have less than 25 puppies and as a grandmother not more than 70 puppies in total.

Finally, we have to state that these international recommendations are agreed upon by all the breed clubs. Once a year representatives of the clubs come together to discuss breed matters and to evaluate the situation in the breed. Each breed club writes a report about the situation in its country. In this way ISIC tries to maintain as much genetic variation in the breed as possible.

Data base
For breeders that want to take their responsibility, information about individual dogs and their pedigrees is required. Therefore ISIC is working on a database with pedigrees of all the Icelandic Sheepdogs in the world. There currently is a database available (it is the one that Per Erik Sundgren and Pieter Oliehoek used for their research) but not all dogs are included in there. The most important improvement for the future should be making sure that this database is available for breeders. The database will provide information about the size of the population and the relationship of individuals compared to the average relationship in the population.

Maintain genetic variation
Maintenance of genetic variation in a population means prevent losses and maintain variety. For breeding this will read as: include as much as possible and exclude only what really should not be included. This brings us to the variety of coat colors in our breed. See part two…

Part two

Variety in coat colors
Let's keep them!

Fortunately many colors are allowed for Icelandic Sheepdogs and in reality we see dogs with many different colors, as the image below shows. The breed standard clearly states that several colors are permitted, but a single color should always be predominant. White accompanies the predominant colors, but should not be predominant itself. The colors mentioned by the standard are various shades of tan, brown, grey and black. A wide variety of colors and color patterns is characteristic for our breed. When we realize that each color pattern is caused by one or several different genes, the relation between coat colors and genetic variation becomes clear. It is important for the future of our breed to maintain all these coat colors and color patterns, because then we can preserve the variety of genes responsible for these patterns as well.

Image 1. Colors in one litter

Image 2. Club event in The Netherlands

Dominant and recessive genes
With the future of our breed in mind, it is undesirable to breed for one color only. Independent of the inclination one can have to prefer one color above others, good breeding practice is: use breeding stock with various coat colors.

Some colors are common, other color patterns are rare. This normally has nothing to do with preference, but is caused by dominant and recessive genes. When a dominant gene is responsible for a color pattern, this pattern will be more common because every dog with one such gene will show that pattern. An example of this is the tan pattern. Red and yellow (various shades of tan) dogs are common in our breed. The gene responsible for this coat color is dominant over most of the other color genes in our breed.

When a recessive gene is responsible for a color pattern, that pattern will be more rare because a dog will show the pattern only when it has two identical genes for that pattern. An example of this is the brown color. Chocolate brown dogs are rare, they must receive the genes for brown from both parents. Only in that case we can see the brown coat color on the dog.

Breeding with dogs that have a dominant color pattern will often surprise the breeder, because the pups can have several different colors. This is because hidden behind the dominant gene of the parents, there can be a recessive gene present. On the other hand, combining two dogs with the same recessive color pattern will only produce pups with the same pattern as the parents.

Hair colors

The color of the coat is based on the color of the hairs and this depends on the pigmentation in the hairs. Hair color is the pigmentation of hair follicles due to two types of melanin:

- eumelanin (responsible for black and brown shades)
- pheomelanin (responsible for all the red shades)

All hair colors and coat colors are mixtures of these two pigments. The amount of the pigments affect the color (black versus grey, red versus yellow) and the distribution of the pigments affect the pattern. White is not a different color. Hairs become white where no pigments are present - white is lack of pigmentation.

One hair can have pigmented bands. Often we find hairs that are very light, almost white, near the skin, followed by a broad red band and ending in a black tip. Also on the coat as a whole, the pigments are scattered in patterns. We can find parts with red hairs, parts with black hairs and white markings. The distribution of the two pigments in the coat of dogs is controlled by a number of genes. Some genes influence especially eumelanin (black pigment) distribution, other genes effect the pheomelanin (red pigment) pigmentation. Also the intensity of the pigmentation is influenced by genes.

Color genes in Icelandic Sheepdog

When we want to look at the inheritance of coat colors in Icelandic Sheepdog, we have to mention some general genetic principles first. Each single gene has its own location on the chromosome. This spot is called a locus and each locus derives its name from one original character, for example locus A (A from agouti) on one of the chromosomes. On this locus one gene will be present. Because a puppy receives one chromosome from each parent, there will be two chromosomes with locus A, and on each chromosome one of the A genes will be present.

The A genes, the possible genes on locus A, are called alleles. The dominant allele is written in upper case: A. The recessive allele is written in lower case: a.

We can distinguish several loci in dogs with genes that influence the coat colors. Most dog breeds have a selection of colors and also a selection of possible genes on these loci. Here we will discuss only the genes that influence the colors in Icelandic Sheepdogs. We will discuss 5 loci with more than one possible allele that are responsible for the color patterns in our breed. This will be A, the agouti locus; B, the black/brown locus; E, the extension locus; I, the intensity locus; and S, the spotting locus.


Photo 1. Red Icelandic Sheepdog with black mask


Photo 2. Yellow Icelandic Sheepdog with black mask

Agouti locus

According to the standard, a common color pattern in our breed is called 'various shades of tan'. The dog has a red coat, from dark red, brown to yellow or light red on the back. Often with some black hairs in between and always with a black mask. The black mask is clearly visible on the puppy, but on the mature dog it will more or less disappear. Responsible for this color pattern is the gene A^y on the agouti locus. The A^y gene allows the red pigment to express itself and spread out over the body of the dog. The black pigment is only allowed on the tips of some hairs and on some small parts of the coat. Photo 1 and 2 show this pattern.

Both dogs on photo 1 and 2 carry the A^y allele on the agouti locus. The difference in color is due to another gene, located on the intensity locus on another chromosome. The I genes affect the intensity of the red pigment only. The red dog shows intensive red pigmentation, on the yellow dog the intensity of the red pigment is less, resulting in a yellowish color. Both dogs have a black mask. The I genes do not affect the black pigment. The dominant I allele is responsible for the red color. The recessive i allele produces the yellow color when there are two identical alleles (i i) present.


Photo 3. Black and red

The recessive gene a^t on the agouti locus is responsible for the black and tan pattern. When the two a^t a^t alleles are present, the black pigment is allowed to spread over the largest part of the body. The red pigment is restricted to small areas, the so called tan markings: in the face, on the legs and below the tail. Photo 3 shows an Icelandic Sheepdog with this color pattern. The intensity genes can influence the red color in this color pattern also. Therefore we can find black and red dogs, as well as black and yellow dogs.


Photo 4. Recessive black and white Icelandic Sheepdog

On the agouti locus a third allele is possible. This allele, a, is quite rare in the population of our breed. This is due to the fact that it is recessive to both A^y and a^t alleles. The a allele is responsible for the recessive black color. The dog in photo 4 has the double a a alleles, which allows the black pigment to spread over the entire dog. To distinguish the aa dog from a dog with a^t, you should look below the tail. Only the aa dog is completely black below its tail. This dog has white markings, but no traditional tan markings.

Cream


Photo 5. Litter with five red puppies and one cream

Our breed has another remarkable color which is rare as well: cream. This color pattern is the result of the recessive allele e on the extension locus. As said before, a black mask is normal for Icelandic Sheepdogs. Most of our dogs have the E^m gene, which is responsible for the black mask. There is one exception: the cream puppy, that is born without a black mask (see photo 5). Because E^m and e are the two alleles that are possible on the E locus in our breed, the ee dogs will be the only dogs that do not have the mask gene. The ee color pattern is called cream because Icelandic Sheepdogs with this pattern have a very light red color. The e allele suppresses the black pigment. A cream dog does not have any black hair. The e allele fades the red pigment into a light yellow, almost beige color. Cream dogs are not white, though they can have white markings just like other Icelandic Sheepdogs.

Black and brown


Photo 6. Brown with red and white Icelandic Sheepdog

Chocolate brown dogs receive their color from the black pigment eumelanine. The eumelanine can express as black or as brown. The gene that is responsible for eumelanine to produce the brown color, is b on the B locus. Besides the black pigment that becomes dark brown, also the pigmentation of the nose and eyes is affected. Brown dogs have a brown nose and often lighter colored eyes. The dominant B gene is responsible for the black pigment to become black, and also the nose to become black. The recessive b gene will produce a brown color where the dog would have been black with B. The B and b alleles will not affect the red pigment.
The dog in photo 6 has the tricolor pattern, with the black parts turned into brown. The red parts are not affected, nor are the white markings. This dog has the a^t pattern on the agouti locus and the brown bb pattern on the black/brown locus.

When a red dog with the A^y gene happens to have the bb genes for brown, the black hairs will become brown as well. Since the red dogs do not have many black hairs, this will not be easy to see. The best way to recognize these dogs is by their brown noses.

White markings
According to the standard, all the above mentioned color patterns should be accompanied by white markings. The standard asks for a white blaze, collar, chest, white socks of varying length, and white tip of tail. All these markings are peripheral white.
During pregnancy, the coat colors of the puppy develop. The pigmentation of the puppy starts from the spine and pigment cells migrate all around the body across the skin. The most distant areas are reached last. These are the tip of the tail, the feet, the middle line of the belly, the neck and the muzzle and chin. Here we often find small spots without pigmentation: peripheral white markings. After the puppy is born, it is possible that the pigmentation of the skin continues; the peripheral white spots can become smaller and even disappear when the

puppy is mature. The dog in photo 7 shows the typical white markings on the head that are peripheral white. Small blaze, part of the muzzle, white chest and collar. These markings are more or less symmetrical. The dog in photo 4. shows the white socks and the white tip of tail.

 Photo 7. Peripheral white on a black and red Icelandic sheepdog

Many Icelandic Sheepdogs have white markings, according to the requirements of the standard. Sometimes the white spots are very small or have disappeared – see for instance the dogs in photo 1 and photo 3. It is probable that minor genes are involved in the size of the white peripheral markings, but it is not yet clear which genes exactly. We only know that these genes are not located on the spotting locus.

Spotting locus

Some Icelandic Sheepdog have large white markings, that are often irregular and/or have patches of color on a white background. This pattern is called pied or piebald spotting. The responsible recessive gene s^p is one of the two alleles on the spotting locus that we find in Icelandic Sheepdogs.

The dominant allele is S, S for solid, this allele allows the two pigments to express themselves all across the skin. Dogs that have two S alleles, will show a solid color with peripheral white markings only. Dogs that have two s^p alleles, will show piebald spotting, see photo 8 and 9.

Photo 8. irregular white markings on a red Icelandic Sheepdog

Characteristic for piebald spotting is the distribution of patches on the white background, which is random and hardly symmetrical. This distinguishes the piebald pattern from the peripheral white pattern.

How the dog with Ss^p looks in our breed is not yet clear because this varies in other breeds. In a number of breeds, the Ss^p dogs have the same color pattern as the SS dogs, as you should expect from a dominant and a recessive allele. But in some breeds, for example in Shetland

Sheepdogs, the Ss^p dogs have more white than the SS dogs, especially on the belly and the legs. This has been discovered by DNA research. Unfortunately no DNA research for coat color inheritance has been done in our breed so far.

Predominant white

In general the amount of white on a piebald dog can vary. The white markings either cover the ventral surface of the body or most of the body. Both piebald spotting patterns are available in our breed. See photo 9 for the white background with a piebald pattern of red patches.


Photo 9. Piebald spotted Icelandic Sheepdog

Though the standard requests white markings, the standard does not want the white to become predominant. At least half of the dog should have pigmentation. This is important for the sake of the health of the breed. Remember that white is not a color, but is lack of pigmentation.

Lack of pigmentation in general can cause several health problems. Problems related to lack of pigmentation that have occurred in dog breeds are deafness, blindness (blue eyes), and UV sensitivity. At the moment we do not have these problems in our breed, but we do not want them in the future either. Therefore we need to be careful with a lot of white in our breeding stock, especially on the head. As you can see in photo 9, this Icelandic Sheepdog has a lot of white, but has pigmentation around the eyes and on the ears, which is important to prevent problems. The dog in photo 8 has more pigmentation on the body, but the right eye is located in a white part of the head. Fortunately the eyes of this dog are dark brown, which means that they are well pigmented. When breeding with dogs like the ones in photo 8 and 9, we should avoid increasing the white. Instead we could combine those dogs with well pigmented Icelandic Sheepdogs that have only peripheral white markings. Again an important reason not to breed for one color, but to combine various coat colors in breeding.

Recommendation

Icelandic Sheepdog breeders should have two high priority objectives: The survival of the breed and the health of the breed. In this article I have explained that maintaining genetic variation is necessary to reach our ultimate goal: Securing a future for the breed. From this point of view, we should value variety in our breed. We are very lucky still to have various coat colors present in our breed. Let us preserve that variety! This means include all colors in breeding, and do not breed exclusively for one color.

Table 2. The color genes for the dogs in the photos

	A	**B**	**E**	**I**	**S**
Photo 1	A^y / -	B / -	E^m / -	I / -	S / S
Photo 2	A^y / -	B / -	E^m / -	i / i	S / S
Photo 3	a^t / a^t	B / -	E^m / -	I / -	S / S
Photo 4	a / a	B / -	E^m / -	?	S / -
Photo 5	A^y / -	B / -	5 x E^m/- 1 x e / e	?	S / -
Photo 6	a^t / a^t	b / b	E^m / -	I / -	S / -
Photo 7	a^t / a^t	B / -	E^m / -	I / -	S / -
Photo 8	A^y / -	B / -	E^m / -	i / i	s^p / s^p
Photo 9	A^y / -	B / -	E^m / -	I / -	s^p / s^p