4.1 – Genetics Put Simply

Within our Breed, as purists around the world are so very well aware, there are major disorders which have the potential to cause great distress to Golden Retriever owners and breeders.

In most countries, it has become the norm for sires and dams to have their hips x-rayed prior to mating. In countries such as Australia, breeders are also conscientious in testing for elbow dysplasia, heart defects and many submit their dogs to regular eye certification.

Whilst the most common areas of concern involve the eyes, hips, elbows and heart, there are a number of others. Included are atopy, ectopic ureter, diabetes mellitus, histiocytosis, hypothyroidism, idiopathic epilepsy, portosystemic shunts, Von Willebrand's disease. Space does not allow us to include information about all of these diseases, however details of any significant breed health issue not found in this chapter, can be accessed via the internet websites for a number of Specialist Breed Clubs.

The author gratefully acknowledges the following highly-respected specialist vets from Australia – Dr Bruce Robertson, Dr Bob Wyburn and Dr Karen Hedberg all of whom have most generously donated their valuable time by providing the comprehensive articles which appear in this chapter. These articles are both relevant and right up to date when going to print.

In addition, sincere thanks go to Ms C Sharp, Ms Anney Doucette and Ms Marcia Schlehr for their most informative articles on genetics and coat colour. No doubt the readers will find these both educational and interesting.

- Atoms are the smallest particles of an element.
- Groups of atoms are called molecules.
- DNA is the molecule responsible for the hereditary instruction in cells.
- Crick and Watson discovered that DNA is a molecule shaped like a double helix (a twisted rope ladder with rungs in between).
- DNA makes copies of itself by first splitting its two strands apart like a zipper and then adding the appropriate As Cs Ts and Gs to each of the single strands until there are two identical DNA molecules.
- The nucleotide bases- rungs on the DNA ladder- are called A C T and G. They are like a four-letter alphabet that combine to instruct cells how to make specific proteins.
- Sometimes errors in copying DNA occur, and this leads to mutations, or permanent changes in the DNA.
- Genes (sequences of DNA) can rearrange themselves on chromosomes.
- Genes come in small medium large and extra large lengths.
- During the reproduction of the sex cells (meiosis) chromosomes swap genetic information.
- Stretches of DNA that code for proteins are called exons, and stretches of DNA within genes that don't code for anything are called introns.
- Some non-coding sequences of DNA get repeated, sometimes at different locations on the chromosome and sometimes over and over again at the same location.
- DNA is the code of life which underlies heredity.
- Genes are stretches of DNA.
- Genes are passed from one generation to the next.
- Traits are determined in pairs and each generation gets one form of the pair from one parent and the other from the other parent.
- One form of the trait tends to be dominant and the other tends to be recessive, disappearing in some generations.
- Genes are arranged likes beads on a string. Some are sex linked.
- Some genes can jump from location to location on a chromosome and from one chromosome to another.
- All living things are made up of cells.
- Everything living other than bacteria has a nucleus and fall into the category of eukaryotes.
- The cell has tiny inner structures called organelles that act like its organs and carry out various functions so the cell can thrive.
- When cells divide to reproduce so does the heredity information in the chromosomes. This process is called mitosis.

- When the cells reproduce they divide twice giving the offspring half the chromosomes from the mother and half from the father.
- Proteins are essential for many jobs in animals.
- Proteins are made of chains of building blocks called amino acids.
- Females have two X chromosomes and males have one X and one Y.
- To start the manufacture of proteins, messenger RNA copies the sequence of a specific gene in the nucleus of a cell and then travels outside of the nucleus to the ribosomes, where the protein is manufactured.
- Ribosomes, the protein factories of the cell, read three-letter words called codons from the messenger RNA to see which amino acids to assemble into a chain to create the protein.
- After proteins are assembles, they fold up into specific shapes, which dictate their functions.
- Some copying errors in genes can cause genetic diseases.
- Living things are made of cells, cells contain chromosomes, chromosomes contain genes and genes are made up of DNA.

Rockgold (Australia) puppies. *Photo courtesy of Hilary Larsen.*

Photo courtesy of Sarah Middelton.

Dewmist Lady Sings The Blues by Swe Sh Ch Gatchells Prince of Thieves out of Swe Sh Ch Nord JW'03 Dewmist Leading Lady, bred by H Fryckstrand owned by A & V Donskov. Photo courtesy Mr H Fryckstand.

4.2 – Monitoring Eye Health in the Golden Retriever: How well do Australian and New Zealand dogs rate?

*The following article appears with kind permission of the Author Dr Bruce Robertson, Australia. In a popular Breed such as the Golden Retriever, there are many factors affecting the health and viability of each puppy in a litter, no matter how carefully the breeding has been planned. As every conscientious dog breeder knows, the aim in deciding on a particular mating combination and allowing such precious puppies to be born, is **first and foremost** to do everything possible to ensure that each puppy will start life and then grow on as a healthy specimen of the Breed, giving its new owners years of satisfaction and joy.*

Of course, for any aspiring owner/breeder who has invested considerable time and money to select a foundation bitch from quality breed lines and then shown her successfully until she is old enough to carry her first litter, it is likely that other equally discerning breed fanciers will express interest in the outcome, especially if she has been mated to an outstanding young male or a well proven sire. As a result of that added scrutiny there will be a lot more hanging on whether or not the combination has worked, hopefully producing two or three puppies that look promising enough at 8-12 weeks to be sold on to show homes.

That may seem obvious since one would expect that whatever the owner's reason for breeding a litter, it goes without saying that everyone involved in the exercise hopes (or assumes) that the pups will all be perfectly healthy by the time they are ready to leave home. Why, then, am I drawing this distinction between the litter bred by a novice owner from a basically sound 'pet' bitch (expecting the progeny also to go into pet homes), and the litter born to a bitch with a good show record of her own, where there is a lot more interest in the outcome and expectations are running high that she may produce a top winner?

The answer to this question is important, in the long run. Without going into the finer points of what constitutes in-breeding, line-breeding or out-crossing, we should recognise that the genetic effects are always going to be greater in the second example than the first, simply because in the random breeding of a 'pet quality' bitch, concentration of the genotype is not going to happen (especially if both sire and dam are themselves unrelated) and the resulting puppies are likely to be de-sexed. There are implications and potential risks in *c*arrying *known* breeding stock through generation after generation, simply because the natural inclination to line-breed will concentrate the genes common to both parents. While the owners of the show bitch we are talking about may well select carefully, they cannot be sure that over subsequent generations, breeders are going to be equally aware of the importance of genetic diversity.

That is why any fancier who shows quality animals with the intention of carrying on a line generation after generation, cannot afford to turn a blind eye to the possibility of discovering a new threat to health – be that one causing musculoskeletal lameness, poor sensory perception (vision, hearing etc.) or just a small matter of un-naturally slow growth or incorrect dentition. Fortunately Golden Retrievers have few major health issues, but it is important for every active breeder to take whatever steps he/she can, within reason, to ensure that the professionally supervised and quality controlled **health surveillance schemes** on offer to Australian and New Zealand owners are used to the breed's maximum long term advantage.

As a specialist veterinarian who (as a successful dog breeder himself) has made a professional career out of assisting clients from a wide spectrum of pedigree breeds work their way through potentially damaging inherited conditions as they aim for ever-higher quality and reliability, the widely recognised popularity of the Golden Retriever breed has always struck me as being exceptional, for two reasons. Firstly the way in which this breed came to prominence in the first place, from a reputedly narrow genetic base of only a handful of historically significant individuals that then gravitated to a recognisable breed type within a period of only thirty years. Secondly the fact that since then, breeders all over the World have exported and imported, crossed and recrossed on this theoretically narrow gene pool, yet they have produced an unexaggerated 'international type' Golden Retriever that varies very little within the agreed consensus for what is acceptable in head and expression, size, structure and angulation, movement and coat colour.

It might come as news to many of today's enthusiasts to be told that this is not typical of pedigree dogs in general – there may be only a handful of popular breeds possessing the underlying predictability and

the comparative freedom from serious genetic disease risks that the Golden Retriever has so compellingly demonstrated over the last 70 years. Surely, this is an advantage worth protecting, at all costs! As every experienced breeder and specialist judge knows, maintaining a line that stays close to 'correct' breed type generation after generation becomes increasingly difficult, especially when the underlying requirements for good temperament, basic intelligence and reproductive capacity need to be kept in mind as well.

That is why it is important to ensure that any potential threat to breed health and function is able to be picked up and then closely monitored – not necessarily to remove every 'affected' individual from the breeding pool but certainly so that we have **accurate incidence data** that truly represents the wider breed population, including not only those retained for future breeding but also their siblings, as far as possible.

Fig. 1: A mature Golden Retriever showing normal globe size and position, with correctly fitting eyelids.

What does this mean then, as a measure of how successful breeders across Australia and New Zealand have been in their attempts to restrict the incidence of painful or vision-threatening inherited eye conditions? Before we look at the actual figures being generated annually under the only regulated eye assessment system breeders have ever had access to, the **AVA-ANKC Australian Canine Eye Scheme (ACES)**, there are a few important points that should be re-stressed from my Chief Panellist's Summary Report on the Golden Retriever released in 2009, that I believe is available on the NGRC's website.

(1) While the total numbers of adult Goldens processed by the ACES Examining Panel (registered eye specialists only) across all States and Territories have been quite good year by year, even with an annual sample size of approx. 15-20% of ANKC litter registrations we have no way of knowing whether this represents what is *actually occurring* in the pet-owned population, State by State.

(2) While it is clear that the great bulk of ACES returns have come from the more populous States of NSW, Victoria and to a lesser extent Queensland where there are at least four ACES Panellists listed, we do not have enough information to be sure that breeders in the smaller population States (SA, WA, Tas and NT; the ACT being covered within NSW) are actually processing results through the national eye scheme that are in proportion to their State's share of ANKC annual litter registrations. If that is not the case and for whatever reason these breeders either neglect to test or continue operating *outside of* the quality-assured national eye scheme, then obviously this distorts the figures with a significant Eastern States bias, which then begs the question "how accurately do the annual ACES breed figures represent the breed as a whole, across Australia?".

(3) One would have thought that the breed clubs in each State would be encouraging the National Golden Retriever Council to ensure that for any health surveillance scheme to be able to produce meaningful results, as far as humanly possible all States should be expected to contribute – with current reports from active breeding stock at least, appearing in the annual summary of results. Where there are obstacles to seeing this ideal achieved, then certainly as far as ACES is concerned there are mechanisms within the Rules able to resolve that situation in a positive way, so that *all breeders across Australia* share not only the costs but also the benefits of accurate monitoring.

I have restricted these comments to Australia even though I am well aware that the Golden Retriever breed is equally strong in New Zealand, where they have produced many outstanding specimens over the last thirty years. New Zealand breeders do subscribe to regular eye testing of a selection of their breeding stock but only on an ad hoc basis – as yet there is no organised system of data collection and reporting of results, only a one-page veterinary certificate handed to the owner who may act on that or reject it, as they wish. It would be great if the well established ACES reporting standards could be extended to cover the North and South Islands of New Zealand, and this is the plan that both the AVA and NZVA are working to – once again aiming to ensure that we have the widest possible sample size.

Bearing those qualifying comments in mind, readers may place as much emphasis as they choose on the various eye conditions reported in my annual breed summaries over the first five years since ACES was launched. Since one of the reasons for introducing a standardised **quality controlled eye scheme** was so that meaningful comparisons can be made with other breed populations overseas, all I can do is to point out the trends showing up in Australia to date, leaving it to the readers to compare those observations with reports emanating from Northern Hemisphere eye schemes over the same period.

INCIDENCE OF RECOGNISED EYE DEFECTS REPORTED OVER THE FIRST FIVE YEARS ON OFFICIAL ACES RETURNS

Note: Since the vast majority of routine ACES testing has been carried out in the more highly populated eastern States (NSW, Vic., Qld.), these figures may not accurately represent the Australia-wide picture. The percentage figure shown in bold is the number of ACES adult submissions for the year *divided by* the annual litter registrations for Golden Retrievers reported by the ANKC for all breeds on its official web site. So as to report this sample size as accurately as possible year by year, since the majority of adults submitted for their first adult ACES exam are between one and three years of age, I have used the litter registration figure from *two years previously*, that being the period when most of these dogs were born.

Abbreviations: HC – posterior polar subcapsular cataract; MRD – multifocal retinal dysplasia; geogr. – geographic form of RD as opposed to multifocal; PPM (i-l) – persistent pupillary membrane, iris to lens.

(i) Year ending June 2007

Breed	Sch.1.	Sch.2	Repeat Defects	Litter Screening
Golden Retriever (330, 10.0%) 292 showed no eye defects	HC 9 MRD 4	nil	distichiasis 10 punctal atresia 5 retinal folds (MRD?) 3 PPM (i/i) 1	5L – all unaffected

(ii) Year ending June 2008

Breed	Sch.1.	Sch.2	Repeat Defects	Litter Screening
Golden Retriever (491, 16.8%) 432 showed no eye defects	HC 12 MRD 6	nil	distichiasis 9 lid apposn/puncta 6 retinal folds (MRD?) 4 corneal lipidosis 4	3L – all unaffected

(iii) Year ending June 2009

Breed	Sch.1.	Sch.2	Repeat Defects	Litter Screening
Golden Retriever (578, 20.11%) 510 showed no eye defects incl. 20 normal on gonioscopy	HC 15 MRD 15	nil nil	distichiasis 6 lid apposn./puncta 5 corneal lipidosis 4 iris cysts 2, PPM 3 nuclear/cortical cataract 11 goniodysgenesis (>33%) 4 retinal scars (non-congen) 8	7L, 6 unaffected 2P MRD geographic

(iv) Year ending June 2010

Breed	Sch.1.	Sch.2	Repeat Defects	Litter Screening
Golden Retriever (490, 18.05%) 442 showed no eye defects incl. 42 normal on gonioscopy	HC 11 MRD 7	nil	distichiasis 6 lid apposn./puncta 7 corneal lipidosis 6 iris cysts 0, PPM 2 nuclear/cortical cataract 1 goniodysgenesis (>33%) 8 retinal scars (non-congen) 10	6L, all unaffected early PPM scars

(v) Year ending June 2011

Breed	Sch.1.	Sch.2	Repeat Defects	Litter Screening
Golden Retriever (513, 18.63%) 475 showed no eye defects incl. 36 also normal on gonioscopy Gonioscopy requested: 48	HC (PPC) 11 MRD 9 (2 geogr, 1 detached)	nil	distichiasis 0 lid apposn./puncta 0 corneal lipidosis 6 iris cysts 1, PPM 1 goniodysgenesis (>33%) 12 lenticonus 1, retinal scars 4	3L, 2 unaff PPM (i-l)

From these published results, accessible to anyone on the ANKC's website and which as I have said only begin to offer a meaningful sample for breeders residing in the Eastern States who are submitting adults at the recommended examination frequency, there are still some useful observations to be made:

(1) The appearance of **hereditary cataract** and **multifocal retinal dysplasia** in significant numbers year by year, justifies their continued inclusion under **Schedule 1** (defects proven to be inherited). The most common type of inherited cataract in this breed is the **posterior polar subcapsular cataract** or 'star cataract', well known to breeders everywhere, and this is the type accounting for well over 90% of the lens cataracts reported by ACES Panellists – the others being perinuclear or nuclear cataracts and a few focal or peripheral cortical opacities, being reported randomly as well.

An important note at this point to avoid genuine confusion:

The reader might wonder why I make no reference to the term 'juvenile cataract' when it is still commonly used in articles on hereditary eye disease written in good faith by experienced breeders, especially those in North America. The reason is because this term has long been relegated to the waste basket by the international veterinary ophthalmology community, who for over ten years now have elected to classify canine cataracts according to (a) their known cause and (b) their precise location within the lens. That is why the term **hereditary cataract** is used as the major classification, with the principal type of cataract known to be inherited varying from breed to breed – in the Golden Retriever the PPSC (described according to its precise location) is clearly the most important cataract type known to be inherited, although there are others, as mentioned above. The term 'juvenile cataract' came into use about 40 years ago when veterinary ophthalmology was in its infancy in North America, and all it ever meant was a *cataract occurring under 7 years of age*, to distinguish lens opacities observed in immaturity (which obviously covers most of the likely inherited cataracts across all breeds) from the mature age or senile cataract seen in any older dog. In fact a lot of those were technically not true cataracts, by definition – often they were age-related **lens nuclear sclerosis**.

(2) Even after many years of selecting against the PPSC or star cataract, because nobody knows the true inheritance mode or what actually causes the developing lens fibres advancing from the front of the lens around to the posterior lens pole, to then fail to anchor their terminations right at the posterior lens suture line as they are meant to do, we have not yet unlocked the key to ultimate control of this vision-threatening opacity. In a normally developing animal, many thousands of lens protein fibres come together layer by layer as they approach the posterior lens pole, to then anchor each termination firmly on the 'Y' shaped posterior suture line, which in the normal adult becomes virtually invisible. Whether in the cataract-affected dog the fibres never quite reach the suture line or do reach it and are then 'dragged back' slightly before becoming firmly anchored, the end result is the classic appearance of a triangular shaped opacity or scar, centred around the three arms of the Y suture line and (as confirmed by an ophthalmologist using a slit lamp biomicroscope) *always* situated right at the back of the lens, just in front of the posterior capsule.

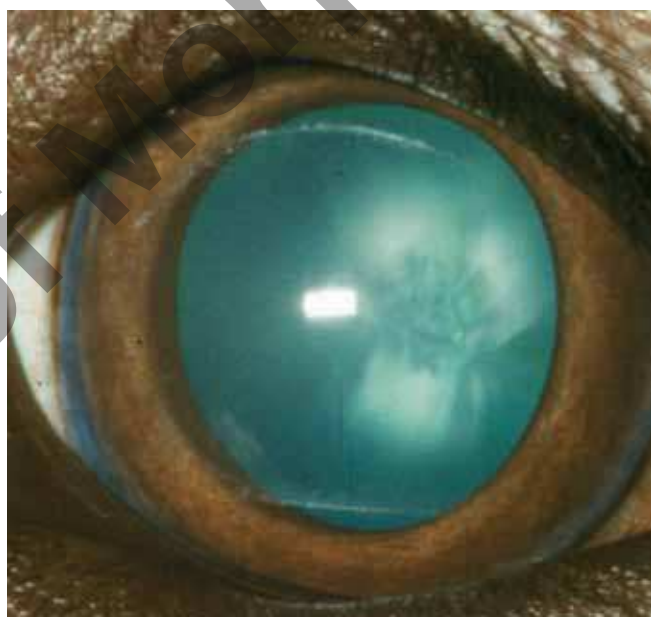


Fig. 2 : A posterior polar subcapsular cataract (with extensions) is a significant threat to vision.

Because of the difficulty being sure that every case with a small opacity at or near the back of an otherwise clear canine lens does in fact fit the set of criteria essential for a PPSC diagnosis, all of the fully qualified veterinary eye specialists who have served on the founding ACES Panel agree that this is not an exercise for the uninitiated, especially a general practitioner who lacks the highly specialised biomicroscopy equipment and has never received any formal training in its use.

All of the specialist eye examinations that have generated the above reported incidences of PPSC as a small but significant ongoing threat to vision (in both Golden and Labrador Retrievers) can be relied upon to have been carried out precisely – in

a quiet, darkened room and in accordance with correct ophthalmic examination procedures. It is because we can only offer those guarantees on behalf of the 16 State-registered veterinary eye specialists currently serving on the ACES Panel (all of whom participate in regular diagnostic review sessions) that we can offer such assurances, on behalf of those breeder clients *who elect to use the scheme*. That is not to say that a veterinarian with less formal training in ophthalmology or a lower qualification cannot do this job equally well, but our national quality assurance dictates that unless everyone is prepared to satisfy the training requirements set out in ACES Rules and also agrees to participate in diagnostic review sessions, the Ophthalmology Chapter of the **Aust. & NZ College of Vet Scientists (ANZCVS)** is not willing to back up their skills or admit them as full ACES Panellists – as a safeguard to owners, everywhere.

The presumed inheritance mode for the PPSC type of lens cataract has been described as a weak dominant (as opposed to a simple recessive) and this does seem to fit the low level incidence that is observed worldwide. If the causative genetic pattern was inherited as a recessive, we would have many more carriers in the wider population and the number of affected dogs would be far greater than it is. By definition, a dominant gene needs only one parent to pass it on, and this is why in every case of PPSC diagnosed in my practice experience, a re-assessment of both parents even at 8 years of age has revealed tell-tale posterior lens pole opacities in either the sire or dam. That can be a shattering discovery of course, especially in a popular breed line where the owner of that particular animal has always followed a systematic eye examination and selection process.

This presents something of an ethical roadblock obviously, and we are fortunate that as a result of breeder vigilance over the years, the posterior polar subcapsular cataracts that we see tend to be fairly small and not as threatening to vision as some of the larger ones - still seen now and again. The answer to this problem will come with the development of a reliable DNA test able to identify markers associated with the dominant gene, which will immediately label any 'affected' dog at an age early enough for him or her to be removed from the breeding pool altogether – end of story.

(3) I am sure that no long-standing member of any Golden Retriever Club needs to be reminded that **Multifocal Retinal Dysplasia** or **MRD** is a potentially contentious issue, especially in Northern Hemisphere countries where vision-threatening lesions have been well described for a decade longer than we have been recording them in Australia, and where it is common to hear reports of focal dysplastic lesions scattered right across both retinas, or alternatively much more spectacular areas of 'geographic' retinal dysplasia, which of course has a very damaging effect on vision.

The good news for us is this – for some as yet unexplained reason, in almost all the adult Goldens reported by ACES Panellists as having classic MRD signs on an indirect ophthalmoscopy exam, the areas of disruption have been quite localised and therefore probably not causing enough damage to the light-sensitive photoreceptors to affect the combined vision from both eyes. Over five years, ACES Panellists have reported only a small number of geographic cases and the multifocal lesions tend to be less spectacular than what is commonly reported by the overseas eye schemes.

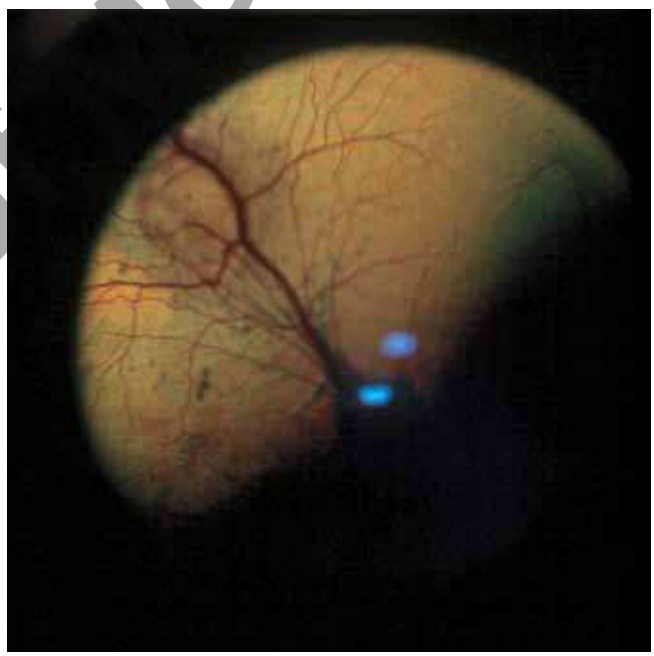


Fig. 3 : Multifocal retinal dysplasia lesions across the central tapetal fundus of a Retriever eye, with a larger area peripherally, suggesting a coincidental or prior retinal detachment.

So what does 10 or 15 MRD cases mean, apart from the caution I have expressed about sampling accuracy and some cases perhaps being incorrectly diagnosed, or not being reported through the national ACES database because owners operating outside of the Scheme are not sharing results?

If these findings *are* in fact representative on a national scale, then it would be very helpful to our understanding of this obscure vision-threatening condition to try to find out whether MRD does express itself somewhat differently in a Southern

Hemisphere environment, and if so why that might be. While there is no doubt that the risk of MRD appearing is inter-generational and is in some way inherited, could there be some random genetic factor that has an additive effect on the severity of retinal lesions? Could there be environmental mediators that are absent in a less industrialised climate? Perhaps the reason we don't see the spectacular MRD signs is simply because breeders have been careful to import only unaffected animals – could this measure alone have succeeded?

It would be great if research could be done locally to establish the truth of this, so that once we can be sure that what we are reporting is reliable information across all Australian States, it would be a feather in the cap of the breed clubs if the National Golden Retriever Council could help fund a Fellowship candidate's supervised research project that would allow these facts to be published.

(4) Incidental variations being reported by ACES Panellists year by year:

Given the thousands of Golden Retriever exams that have been reliably reported, we have seen only a low incidence of the following defects: focal **lens cataracts**, **distichiasis** (lid margin lashes), **corneal lipidosis** (covering a range of known metabolic changes in the cornea that result in dense opacities), **persistent pupillary membranes** (iris to iris or iris to lens) and **lacrimal system defects** (causing blockages, tear overflow or inadequate drainage for a range of different reasons).

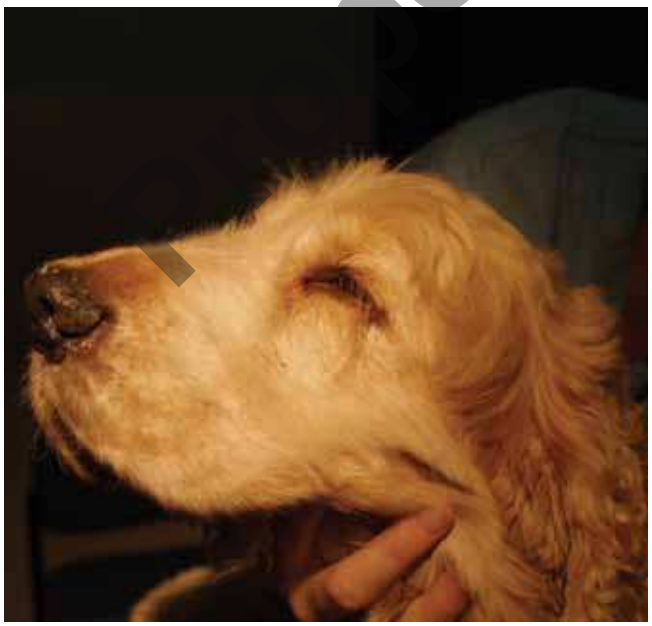


Fig. 4: Long upper lid lashes can cause corneal irritation, tearing and ulceration in ageing dogs.

Fig. 5: While this is an extreme case, variations in skull proportions or position of the bony orbit may lead to deep-set eyes, mild spastic entropion and prolapse of the third eyelid, or 'haws'.

There is little to be gained by dwelling on these therefore, except to stress the importance of continuing to record the appearance of all of these minor defects because as we know from what has happened in other breeds internationally, a shift in the popular 'style' or head shape can bring with it unexpected complications such as small, deep set eyes, overly long lid apertures and as a result of that, changes to the overall eyelid 'fit' that render the tear drainage system ineffective.

As any experienced breeder knows, simple awareness of a problem is already more than half of the solution. For that reason, the only way we can be sure that none of these minor defects is becoming a potential threat is to adopt a policy of regular eye testing up to a sensible mature age.

Finally, two issues that are receiving a lot of attention, both here and overseas:

(i) Primary glaucoma in Golden Retrievers and the diagnostic value of the gonioscopy test

I have addressed this topic in a recent response to the National Golden Retriever Council but will repeat some of the important points here, for the benefit of a wider readership. As yet we have not completed the full review of Golden Retriever returns to June 2011, and that will tell me the number of gonioscopy tests being done, and in which States.

Veterinary ophthalmologists do report cases of primary glaucoma undergoing treatment in their practices, usually in older animals and of course most of these are owned as pets. Once an animal develops glaucoma in one of both eyes, the success of pressure control therapy and other longer term treatment is somewhat less than

50%, so that eventually most of these dogs lose vision or need to have a painful, blind eye surgically enucleated.

The **gonioscopy test** uses a specialised corneal lens or set of mirrors to enable us to visualise the 'filtration angle' tucked in behind the edge of the cornea, where we can magnify the structural changes that restrict the free drainage of aqueous fluid from the anterior chamber of the eye, leading to a rise in intraocular pressure that can blind the patient. Glaucoma is a complex disease process in both humans and dogs, and pressure regulation is not the only consideration. We do know from human and canine studies that damaging 'pressure spikes' can be controlled, and one way to do this in pedigree dog breeds is to select for the best possible outflow capacity. That is the purpose of the gonioscopy test because it shows us both angle narrowing and the obstructive structural changes that we interpret as **goniodysgenesis**, present to varying degrees in both eyes.

Since attention has been drawn to this hitherto unrecognised cause of blinding eye disease in older Golden Retrievers, a number of Australian breeders have responded by submitting more than 150 adults of breeding age for an ACES exam *with* gonioscopy testing included. The best time to request gonioscopy testing is before a planned breeding of course, and after the eye is developmentally mature at around 18 months of age. If the filtration angle is open and functional over 240° to 360°, gonioscopy should not need to be repeated for the rest of the dog's life.

Based on reported results from other breeds in which genetic selection depended on a diagnosis of structural normality recorded in both eyes of a mature animal (as an arbitrary indicator of its ability to drain the aqueous fluid and maintain normal pressures), we do know that the degree of malformation can be reduced significantly (along with the predisposition to glaucoma) if breeders are encouraged to select for dogs possessing a more 'open' aqueous outflow pathway.

Fig. 6: Acute primary glaucoma (mixed breed), in which increasing intraocular pressure plus other changes will result not only in permanent blindness but also severe, persistent eye pain.

While some dogs show angle dimensions that are less open in profile (i.e. a narrow exit pathway showing between the inside of the peripheral cornea and the anterior face of the iris), it is not clear whether these are genuine anatomic variations or only functional differences. The narrow space (through which the aqueous fluid escapes) extends around the iris outer circumference for a full 360° and appears on high magnification like the edge of a forest of mature trees, with open spaces between 'pillars' of the primitive pectinate ligament. Some of these may be thickened or continuous, forming sheets of tissue that drastically reduce the number of openings or 'flow holes' through which aqueous fluid needs to be able to pass freely. This developmental anomaly is termed goniodysgenesis, and the purpose of the gonioscopy test is to estimate the degree of goniodysgenesis around the circumference of both eyes, expressed as a percentage.

Of course when we rely on percentages as a predictor of likely disease risk, it is always going to be difficult establishing where the cut-off point needs to be – especially as a predictor of glaucoma when we know that there are a few other age-dependent factors that may come into play, tipping the balance as to whether an otherwise healthy animal suffers a blinding angle obstruction or not.

From the gonioscopy percentage figures reported above for the year to June 2009, 2010 and 2011 however, ACES panellists were clearly of the view that evidence of narrowing or goniodysgenesis over *more than one third of the combined filtration angle circumference for both eyes* is abnormal and therefore should be seen as posing a significantly higher risk. Time will tell whether this arbitrary division is enough to protect the wider breeding population, and until we have access to a lot more gonioscopy test results from a wider range of breed lines it will not be possible for the ACES Panel to advise the NGRC on exactly what should be accepted as the borderline percentage of goniodysgenesis – before any thought can be given to conducting an ANKC Breed Survey that might eventually lead to the imposition of unpopular litter registration restrictions, Australia wide.

(ii) **Pigmentary Uveitis in the Golden Retriever as another cause of vision loss**

Over the last five years there have been increasing reports stemming mainly from North America, of a breed-specific tendency for a highly inflammatory eye disease affecting individual Golden Retrievers – causing a rapid onset of signs, usually unilaterally but sometimes in both eyes. These include conjunctival swelling, redness or cloudiness of the globe and hypopyon (pus) within the anterior chamber, which on a detailed eye examination proves to be an acute **anterior uveitis** where the main presenting sign is engorgement of the iris and ciliary structures within the globe.

The underlying reason for these sudden changes has yet to be confirmed, but it is likely to be some external cause or invading organism that is somehow priming or exacerbating the animal's normal immune responses, because once again, there are few records of this painful condition being observed amongst Australian owned or bred Golden Retrievers. Certainly there has been no sudden increase in the referral of acute uveitis cases to the eye specialists in each capital city.

This is an interesting condition not only because of its severe pain and ability to cause permanent vision loss, but also because even if the early signs are detected soon enough for emergency anti-inflammatory treatment to begin to deliver results, the damage done to the pigmented layers of the iris and ciliary body (behind the lens) cause these melanin-rich lining cells to release massive numbers of melanin granules. The pigment granules circulate within the anterior chamber fluid and over time, exacerbate the eye's inflammatory response as they accumulate within delicate structures and begin to clog the aqueous outflow pathway; also causing adhesions to other key structures, including the lens. Essentially this is a pigment dispersion syndrome, where ultimately the risk of permanent blindness due to irreversible glaucoma becomes extremely high.

Although we have not recorded many cases of pigmentary uveitis or acute glaucoma amongst Australian Golden Retrievers to date, it is a classic example of why routine observation of our dogs' eyes is so important. Anything that appears abnormal or has altered the size, shape or colour of a canine eye should firstly be examined by a general practitioner, who will refer the case for immediate specialist assessment if the eye signs are anything other than routine. Pet owners should always be reminded of the importance of routine eye care as well, because much of what we see in eye referral practice is perhaps more common in an urban environment than it is in the sort of semi-rural or outdoors situation found in a well-managed hobby breeder's kennel.

Early observation is usually the key to successful treatment of a potentially serious eye condition, and the more information we have about what is normal or abnormal in the eyes of any given breed, the better we will be able to predict the possible future risks and then manage them. This breed continues to lead the way in exercising responsible policies for the monitoring of any likely health risks, and I encourage owners and breeders everywhere to keep up the good work!

Dr Bruce Robertson BVSc, Cert.V.Ophthal (RCVS), FACVSc (Ophthalmology)

Chief Panellist, AVA-ANKC Australian Canine Eye Scheme

[Photo credits: eye specialist members of the ANZCVS Ophthalmology Chapter]

4.3 – Hip and Elbow Dyslasias in Golden Retrievers

The following article appears with kind permission from the author Dr RWyburn (Australia).

Canine hip dysplasia (HD) is a genetic disease that is inherited in a rather complex manner because it is influenced by more than one gene. The mode of inheritance is polygenetic. It was first recorded back in the 1930s but its incidence has increased as the popularity of breeding and showing dogs has increased. Whether this is coincidence or whether there is some relationship has not been established. In a number of breeds, including Golden Retrievers, the disease is present in some degree in over 80% of individuals. Any control programme that is put in place should require that all individuals which are to be bred from have their hips scored and a score should be set above which breeding is not recommended.

Obviously the ideal situation would be to breed only with dogs that have a 0 score. However this is unacceptable as doing so would exclude most of the breed. A compromise has to be reached which will allow the retention of sufficient breeding stock but which will decrease the severity and incidence of the disease. It is up to the breed society to set standards which are acceptable for breeding. The average hip score for Golden Retrievers in Australia is 15.85 so the following criteria could be adopted as indicating suitability for breeding. If the score for any one hip is greater than 8 or if the score for any one of the 9 features listed on the score sheet is greater than 3 the dog should not be bred from. As the breed average score drops so will the score that is acceptable for breeding.

Such a control programme can be taken a step further by recording the hip status of offspring so that it can be determined which sires are tending to reduce the hip scores of their progeny.

The Scoring System

HIP SCORE	Hip	Right	Left
Norberg Angle			
Subluxation			
Cranial acetabular edge			
Dorsal acetabular edge			
Cranial eff. acet. rim			
Acetabular fossa			
Caudal acetabular edge			
Fem neck exostosis			
Fem head recon touring			
Total Score			

The 9 items listed on the scoring sheet are all details of the anatomy of the hip joint that can be seen on an x-ray film. Of these features 8 are scored out of 6 with 0 being normal. One of these, the Caudal Acetabular Edge, is scored out of 5. Therefore the worst possible score for each hip is 53 with the worst combined score being 106. The figures I have currently available show the best score for the breed is 0 and the worst 101

The Grading System

There is not a direct relationship between scoring and grading which causes considerable confusion. The grading is done on the worst hip only. Because of differences in the assessment methods it is possible, though uncommon, for dog with a relatively low score to have a relatively high grade. Generally speaking it is considered acceptable to breed from dogs with grades 0, 1, 2, and 3 and not from grades 4, 5, and 6. It is probable that the grading system will stop being used sometime in the near future.

Hip Dysplasia

The hip joint is a ball and socket joint with the ball (femoral head) being on the proximal end of the thigh bone (femur) and the socket (acetabulum) being on the pelvis. If the hip joint is normal the ball is a neat fit in the socket. Generally all newborn puppies have normal hip joints but in those that have HD an abnormality develops during growth. The problem appears to be in the growing of the socket. For the socket to grow bigger as the dog grows requires quite a complex process because it is difficult to grow a hole. With the acetabulum this is achieved by the three bones that make up one side of the pelvis (ilium, ischium and pubis) joining at the acetabulum thus forming a complex pattern of growth zones. If the acetabulum is to develop correctly the growth rate at these different zones has to be precisely matched. If it is not, the acetabulum will become distorted so that the ball is no longer an accurate fit and this is hip dysplasia. Some recent research suggests that dogs with HD have problems with other bone growth zones but because these are mainly involving single bones they do not cause problems.

Hip dysplasia in itself does not commonly cause lameness. It only does so if it is of such a degree that the hip dislocates and this is uncommon. So many dogs, particularly younger dogs, with hip dysplasia show no signs of lameness. This combined with the fact that it is a developmental abnormality is the reason why we have to resort to assessing dogs for hip dysplasia from an X-ray taken when the dog is at least 12 months of age.

With dogs that have HD the ball is not a neat fit in the socket so the joint is subject to excessive wear and tear.

This excessive wear and tear results in the development of degenerative joint disease (arthritis). It is the arthritis that causes the lameness. Other factors can impact of the degree of wear and tear the joint is subjected to. The two main ones are the weight of the dog and the amount and type of exercise the dog takes. Obviously the heavier the dog the more stress is put on the hip joint so large heavy dogs are more likely to become lame because of hip dysplasia than small light ones. Dogs that get a lot of exercise at fast gaits such as galloping behind a car or bicycle and dogs that do a lot of jumping or turning and stopping such as when fetching balls or sticks stress the hip joints and are therefore more likely to become lame. A normal hip joint can sustain these sorts of stresses without developing arthritis. So the age at which a dog with HD shows signs of lameness and the severity of the lameness is influenced by an inherited component. That is the degree of developmental abnormality of the joint. Then there is the environmental influence which is the degree of stress the joint is subjected to.

Outcomes

Now addressing the question of how successful the hip dysplasia control programme can be. Progress will be painfully slow for a reason. If only those dogs with a 0 score were bred from there would be a rapid decline in the incidence of hip dysplasia as has been demonstrated by some experimental breeding programmes carried out in Sweden. This approach, however, is socially unacceptable as it would eliminate a large percentage of animals from breeding. As a compromise is reached which acknowledges that dogs with some degree of hip dysplasia can be included in a breeding programme the control scheme is slowed but control is much better than allowing the disease to become even more widely distributed.

Elbow Dysplasia

Elbow dysplasia is a disease with a high inherited component, which primarily affects intermediate and large breed dogs. The incidence in Golden Retrievers is not as high as in some other breeds. Typically, both elbows are affected. However, unilateral elbow dysplasia is not uncommon.

Development

The elbow joint is formed by three bones (radius, ulna, and humerus) which must all grow synchronously and fit perfectly. The radius and ulna are paired bones with the radius being the main weight bearing bone. The normal elbow joint is characterized by a smooth transition from the ulnar articular surface to the radial surface. In a dysplastic elbow the edge of the ulnar surface lies above the level of the adjoining radius, creating a step between the radius and ulna and causing incongruity of the joint. The height of the step may vary from barely noticeable to 4 mm or more. When this occurs the weight bearing force on the ulna is increased, resulting in excessive pressure on the medial coronoid process. This leads to fragmentation of the coronoid process. This usually occurs between 5 and 7 months of age. A superficial to deeply grooved “kissing lesion” is often present on the humeral articular surface opposite the fragment. A cartilage flap or OCD (osteochondritis dissecans) lesion may also develop. Secondary arthritis becomes evident at 6-7 months. Compensatory adjustments during growth may occur in some dogs, tending to minimize unequal growth rates between the three bones and moving the ulna distally to better conform to the radius. . If the ulnar surface lies below the radial one, excessive force is then placed on the anconeal process at the top of the ulnar articular surface. This force will cause a failure of ossification, leading to an ununited anconeal process.

Clinical Signs

Affected dogs are frequently lame or have an abnormal gait. The gait is often characterized by excessive paddling or flipping of the front feet.

The animal may either hold the elbows out or tucked in and often stands with the feet rotated outward. Many sit or lie down much of the time, or play for shorter periods of time than other dogs of comparable age. They are often described as quiet or even lazy. Frequently, they are stiff when rising and tire easily. Exercise typically makes the lameness worse. In dogs with bilateral elbow dysplasia, the lameness may seem intermittent or shift from one front leg to the other. When both front legs hurt, dogs do not limp constantly. Rather, they shift weight off their elbows by

altering their gait and stance. These dogs will only “limp” when one elbow is more painful than the other. On examination, manipulation of the elbow is often resisted. Swelling and crepitus (grating) may be palpated. The swelling may be worse after exercise. In some cases, the joint will be thickened. Muscle atrophy may also be present.

Diagnosis

The routine monitoring for the presence of elbow dysplasia is carried out from a lateral x-ray of the flexed elbow joint taken when the dog is over 12 months of age. Correct radiograph technique is critical for making the diagnosis. The grade is derived by measuring the amount of new bone that has developed as a result of arthritis. Unlike the grading systems for hip dysplasia the system for elbow dysplasia is used internationally.

Advice

It is generally considered that dogs with grade 3 elbow dysplasia should not be used for breeding and that dogs with grade 2 should be considered a serious risk

Reference: World Small Animal Veterinary Association web site.

R S Wyburn BVMS, DVR, PhD

4.4 – Ectopic Ureter in Golden Retrievers

Published with permission. By Dr Karen Hedberg BVSc 2003

Ectopic Ureter is an inherited genetic condition in the Golden Retriever. Breeding experiments carried out by Boyd Jones [Massey University, NZ] in Golden Retrievers have indicated that it is an inherited condition in the breed.

It does occur in other breeds, including the Labrador Retriever and the Soft Coated Wheaten Terrier, but generally with a very low incidence.

Ectopic Ureter is a condition whereby one or both ureters, coming from the kidneys, by-

pass their normal insertion into the bladder and instead terminate in the genital tract. In the female, this is through the floor of the vagina adjacent to the proper opening of the urethra. The result is a continuous flow of urine from the side that is ectopic.

The condition can affect one or both ureters but there can also be a conglomeration of other congenital defects of the urogenital system associated with the ectopic ureter. The problem can be a simple ectopic ureter, but can include the following abnormalities:-

- mega-ureter - grossly dilated and enlarged ureter
- hydronephrosis -replacement of the kidney tissue by large fluid filled cystic areas.
- under developed bladder.

I have seen a number of cases with kidney abnormalities from hydro-nephritis to small, under developed, lobular kidneys (usually associated with bilateral mega- and ectopic ureters). Persistent hymens are sometimes observed, with associated infertilities in older affected bitches.

Theoretically, there can be associated kidney problems in older males and females if there is hypoplasia (under-development) of one or both kidneys; this could be a problem in old age.

Diagnosis

Affected animals usually show up before one year of age, the vast majority by 6 to 8 weeks of age. The affected female puppies do not grow as rapidly nor are as active as other litter members, as they are very prone to bacterial infections. Severely affected puppies are noticeably "wet" with urine scalding and staining by 3-4 weeks of age.

It is 8 to 9 times more common in females than in males since the prostate gland in males acts as a muscle sphincter, and therefore the dog may not have any dribbling of urine, but may show up at a later age eg 5-6 years.

Almost all females affected by ectopic ureter will show up at an early age although there have been a few cases without urinary incontinence *[Osborne & Oliver, 1977; Jones, 1980].*

Positive diagnosis can be made with the use of intravenous radio-opaque dyes that can show the ureter bi-passing the bladder.

Differential Diagnoses

Not all cases of leaking urine are due to ectopic ureter. Puppies that develop cystitis can leak urine, but these cases usually respond very well to antibiotics and within a few days, the problem resolves.

Equally the parasympathetic system can occasionally be a fault in a very young animal and one may see urine leakage. These puppies leak urine intermittently, and generally respond very well to Sudafed (epinephrine hydrochloride) type drugs, often given at quite a low dose for several weeks while the urinary tract system matures.

The other type of "leaking" can be due to a lack of hormones and/or dietary concerns. Once dietary issues are covered one can try Propalin on immature bitches and this can assist in those cases.

If despite trying to eliminate these alternative causes of leakage, the puppy continues to leak urine, one is back to the Ectopic ureter scenario.

Genetic Aspects

It appears that the inheritance pattern for ectopic ureters is polygenetic - more than two genes are likely to be involved. If it was a simple recessive condition it would be relatively simple to control.

While cases have been recorded elsewhere in the world (in the UK, NZ and the USA) we (this clinic and the University of Sydney) have recorded more than fifty cases in New South Wales. The incidence of affected offspring arising from a heavy carrier-to-carrier mating has been found to approximate between 1:6 and 1:8, that is about one puppy per litter.

Because the condition is polygenetic it is going to be extremely difficult to control. Genetic analysis shows that most of the major bloodlines have carriers present in them and it would be ridiculous to suggest that all

relatives of affected puppies, that is parents, litter mates, etc ought to be removed from breeding programmes. It is as hard as trying to remove hip dysplasia from the breed with even less solid evidence of the mechanics of inheritance.

Suggested Means of Reducing the Incidence

Despite the difficulties noted, I feel that there are a number of ways in which the problem can be minimised:

(1) Severely affected puppies usually need to be put down. They can show up as early as 3 to 4 weeks of age. The treatment to surgically correct the problem is both difficult and costly and not always very successful. A lot of heartache to the breeder and/or the new owner can be avoided this way.

Alternatively, one can try opening up these puppies at around 6-8 weeks and assessing the severity of the problem. If both ureters are affected (ie. ectopic), if there is bilateral megaureter or obvious kidney abnormalities, then I suggest the puppy be euthanaised.

If only one side is affected, and the kidney normal, the ureter can be redirected into the bladder. Alternatively the kidney and ectopic ureter from the affected side can be removed. I usually desex these puppies at the same time.

(2) A carrier dog and bitch is probably necessary to produce an affected pup.

(a) The Dog: If he produces affected puppies from 3 or more different bitches of varying bloodlines, I would suggest that he be withdrawn from general public use. If he is producing the condition regardless of bloodlines, he is obviously going to produce carriers.

(b) The Bitch: If she produces this condition with more than one stud dog of different bloodlines, I would suggest discontinuing to breed with the bitch.

(3) Litter Mates to affected puppies:

It is very hard to determine whether there are any abnormalities of the ureters or kidneys especially at an early age. Special radiographic techniques(using radiographic dyes to highlight the ureters and their placement) are available if you really wish to check the puppies, but it can be difficult to get good, reliable results, nor is it cheap to do. The vast majority are perfectly normal.

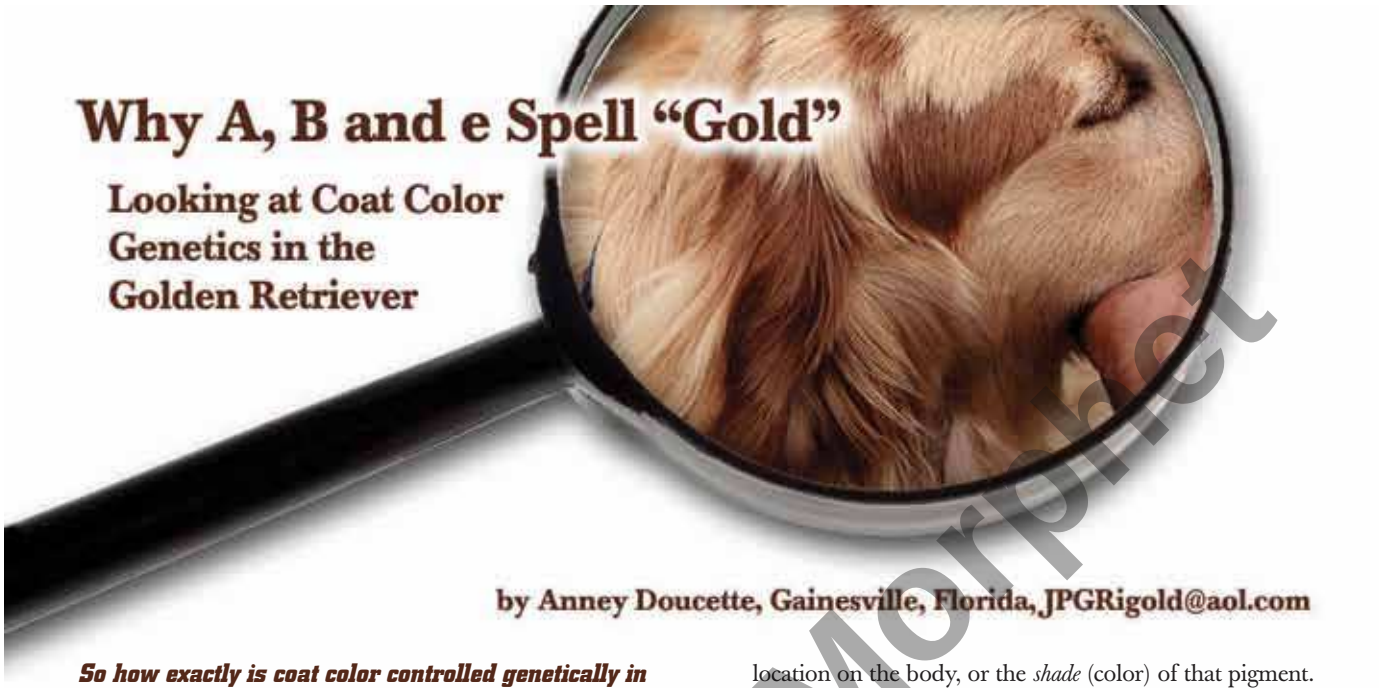
I would suggest breeding with care from these puppies - obviously they are/could be carriers but the only proof of their genetic status will be seen with their eventual progeny. Ideally these puppies should be outcrossed to avoid inadvertently doubling up on the problem.

If there is infertility, the problem will be self-limiting but if the bitches produce affected pups in their first litter, one should think very carefully of including them in a breeding programme. If the dogs produce affected puppies with more than one bitch, again one should give careful consideration to a withdrawal of that dog from breeding.

Preferably where there is an affected puppy in a litter, you ought to select a puppy you may wish to keep, breed it with care. Ideally, sell the rest as pets which will then limit the problem.

Rockgold (Australia) puppies. *Photo courtesy of Hilary Larsen.*

4.5 Colour Inheritance



by Anney Doucette, Gainesville, Florida, JPGRigold@aol.com

So how exactly is coat color controlled genetically in the dog?

The coat color of every breed of dog is controlled by a combination of nine genes. A *gene* is a sequence of DNA that programs for a specific physical trait. Every dog has these nine coat color genes, no more, no less, and no special genes exist only for certain breeds. Each organism inherits two copies of each gene, one from each parent. Those "copies" or inherited units are called *alleles.* Alleles are different forms of the same gene, and allow for variation in the appearance of the same trait within a species. While a single animal can only possess two alleles per gene, the gene itself might have many more alleles, or forms, present across a species. This concept of only two alleles per gene for an individual animal, but multiple alleles per gene for a species, is important in understanding coat color genetics of the dog.

Generally each allele is either *dominant* or *recessive* to the other alleles at the same gene. Conventional nomenclature abbreviates dominant alleles with a capital letter, recessive alleles with a lowercase letter. Since an animal can only possess two alleles at any gene, an animal that is *homozygous dominant* would be labeled "XX" (homozygous meaning "same alleles"), since both of its alleles at the "X" gene are dominant. If the animal was recessive at this gene the notation would be "xx." If the animal had one dominant allele and one recessive allele at that gene, he would be labeled "Xx" which is called *heterozygous dominant* ("different alleles"). Animals which are heterozygous dominant at a gene will physically display the dominant form of the trait, but "carry" for the recessive form of the trait, and can pass the recessive allele onto its offspring. If a gene has more than two alleles, there is usually a hierarchy of dominance among the set of alleles, and they are differentiated by a superscript letter such as x^a, x^b, etc.

Another important term is *locus* (singular) or *loci* (plural), which you can take to mean the "location" of a gene along a *chromosome* (a cluster of DNA in the cell nucleus). The term "locus" is often interchangeable with the word "gene."

The nine coat color genes of the dog code for one of two things: the *distribution* of pigment in the hair shaft and/or its location on the body, or the *shade* (color) of that pigment.

Hair pigment, also called *melanin*, in the dog is present in two basic formats: *eumelanin* (or "true" melanin) is black, brown/liver or grey/blue hair, *phaeomelanin* ("false" melanin) is any shade of red, yellow, gold, buff, etc.

In brief, the nine accepted gene loci of the dog are:

1. A Locus = The "Agouti" locus. This is the primary color gene in the dog species and controls the location of eumelanin versus phaeomelanin not only on the dog's whole body but also the distribution of pigment along each individual hair shaft. This gene has many alleles. It codes for solid black (dominant), sable (black-tipped hairs, i.e. Collie), black with tan points (Rottweiler), black saddle (Airedale terrier), salt and pepper/agouti (Schnauzer) or solid recessive red ("fawn" like a Great Dane, boxer, etc).
2. B Locus = "Brown Dilute." This one is simple. If a dog is recessive, all eumelanin (black) pigment is diluted to brown. Does not affect phaeomelanin. Examples are "red" Dobermans, "chocolate" Labradors and "liver" flat-coated retrievers.
3. C Locus = "Chinchilla." When recessive, causes fading of phaeomelanin (red) pigment to light cream or white but does not affect eumelanin (black) pigment. "Silver" Siberian huskies are an excellent example of this: they are sable but the red undercoat is washed out to white and the black tipping on the hair remains to give a "shaded" effect.
4. D Locus = "Blue Dilute." This one is also simple. If a dog is recessive, all eumelanin (black) pigment is diluted to a bluish grey shade. Does not affect phaeomelanin. Examples are "blue" Dobermans and all Weimaraners.
5. E Locus = "Extension Locus." When a dog is recessive at E, all eumelanin is converted to phaeomelanin. In other words, all black is turned to red. Does not affect skin color so nose, paw pads, etc., remain black. Examples are Golden Retrievers, Irish setters and yellow Labradors.
6. G Locus = Greying gene. If a dog is dominant here, it will be born with nearly black eumelanin, and fade to grey as the dog ages. Only affects black pigment. Examples are Old

Color Mutations: What happens?

A mutation is any spontaneous change in the chemical structure of an organism's DNA. Mutations are totally random in frequency and can be either somatic (mutation of a non-sex cell, such as a skin cell, bone cell, intestinal cell, etc) or germline (mutation of a sex cell – a sperm or egg). The frequency of mutation is actually extraordinarily low, thanks to the body's own mechanisms of cell regulation. Since many mutations will terminate a developing embryo or only affect one cell out of the trillions of cells in the mammalian body, it is unusual to notice a mutation at all. However, some notable exceptions are observed in the coat color of the Golden Retriever.

A somatic or "point" mutation is the most common. This is when one somatic or body cell spontaneously mutates from one form to another. If you find one or two black hairs on your Golden Retriever, it is because one melanocyte (pigment-producing skin cell) mutated from ee (yellow) to Ee (black). Since it is not a sperm or egg cell, this mutation is not inheritable. A large dog has literally billions of hair-producing cells, so finding a few mutated black hairs is not unusual at all.

A germline mutation is a spontaneous change in the DNA of a sperm or egg cell, and will cause the same mutation to be inherited in any offspring resulting from that particular mutated egg or sperm. It is important to remember that in the case of dog coat color genetics, actually witnessing an organism displaying a germline mutation is exceedingly rare. A male dog will produce trillions of sperm cells in his lifetime, the chance of one carrying a color gene mutation actually fertilizing an egg which develops into a viable offspring is infinitely small. In theory a Golden Retriever sperm cell could contain a mutated dominant E allele and result in a solid black purebred Golden Retriever, but this chance is so remote it has never been observed.

Here are some samples of somatic mutations in color in Golden Retrievers.

1) BLACK SPOTS

These photos show purebred Goldens with black spots. These are somatic mutations from "ee" at the E locus (yellow) to "Ee" (black, as expressed by the A locus). The origin of the spot is one mutated melanocyte which then divided into a clump of skin cells. The larger the spot, the earlier the mutation in the embryo's development. The photo of the same dog with the spot on his side as a puppy demonstrates that spots are fully developed at birth and will not get appreciably larger as the dog matures. These spots are not inheritable.

Why A, B and e Spell "Gold", *continued*

English sheepdogs, Kerry blue terriers and Yorkshire terriers.

7. M Locus = Merling gene. If a dog is dominant here, the portions of the coat that are eumelanin (black or brown) will be broken up into a random pattern of normal and diluted pigment. Does not affect phaeomelanin. Obvious examples are merle collie-type dogs, Harlequin Great Danes and "dapple" Dachshunds.
8. S Locus = the "Spotting Series." Doesn't affect the shade of pigment, but controls the distribution of non-pigmented (white) hair throughout the body. There is a sliding scale of dominant to recessive at this locus, the most dominant allele being that for solid color, the next recessive being limited white markings (toe tips, tail tip, star on head or chest), then "Irish" or "collie" pattern (white blaze on face, collar, chest, belly, legs, feet and tail tip), then piebald or parti-colored (colored patches on a predominantly white coat), then extreme white being the most recessive (color found in small amounts generally on the head and along the spine or tail).
9. T locus = the Ticking gene. Dogs dominant at the T locus display ticks or "freckles" of color on otherwise white fur. The ticks are whatever color normally would be on that area of the body if the white fur was not there. Ticks can be modified in their appearance, from very small (individual hairs) and irregular, to large and with great conformity (clear "spots"). Examples of ticking are "roan" English cocker spaniels, "belton" on an English setter, the "spots" of Dalmatians, and all manner of freckles commonly seen on partially white sporting and herding breeds.

There is some argument on what genes might code for brindle and black mask. Many put these in control of the E locus, others propose they are programmed by separate, unknown genes altogether.

So what exactly makes the Golden Retriever, well… golden?

The answer to this is pretty simple; 100% of Golden Retrievers are recessive at the E locus, so all of their eumelanin is washed out to phaeomelanin, even down to their whiskers, which are also blonde in color.

EE = Dominant – normal eumelanin (black) pigment expressed.
Ee = Heterozygous dominant – normal eumelanin (black) pigment expressed.
ee = Recessive – all eumelanin (black) pigment replaced with phaeomelanin (yellow) pigment. All Golden Retrievers are "ee."

It is interesting to note that among geneticists, dogs recessive at E are termed "yellow," whereas dogs that are solid red from the A locus (but dominant at E) are termed "red" or "fawn." It is the same pigment (phaeomelanin), but called different names based on what gene you are seeing in action.

Color Mutations, continued

2) DOG WITH SPOTTED EAR

This photo shows a purebred Golden with dark red splotches of fur on its head and ear. The owner reported that this fur was decidedly a dark red, Irish Setter-like color and not chocolate-brown. As the original mutated cell multiplied as the embryo grew, these mutated cells sifted in with the "normal" skin sells around it to give a mottled appearance.

There is no clear explanation genetically for the change in color of the hair. Did the cells mutate from AA (black) to $a^{y}a^{y}$ (sable), giving a clear red color? Did the modifying genes controlling the shade of the yellow "turn up" and darken the hair in only that area? It is not likely that these skin cells mutated from BB (black) to bb (brown) because even if that were the case, the dilution to brown would not affect a yellow coat (the recessive brown alleles only dilute black fur).

This dog is clearly not a mixed breed because any change in hair color would be over the dog's whole body, not localized to one area.

3) "MERLE" PUPPY

This is a very interesting observation. This Golden puppy shows a distinct mottled or "merle" pattern over its entire body of dark and light gold. While it seems impossible that merling would have any effect on a yellow coat, "yellow merles" – which look very much like this pup – are sometimes observed in Australian shepherds, Border collies and Catahoula leopard dogs, breeds which carry both the dominant merle allele and the recessive E (yellow) allele. Is this puppy an extraordinarily rare result of a germline mutation (in that, either the father's sperm or the mother's egg was mutated from "m" non-merle to "M" merle)? Did a somatic cell mutate so early in the pup's embryonic development as to cover nearly the entire body of the dog? Or are we looking at something totally unknown?

Why A, B and e Spell "Gold", *continued*

So all Goldens are actually black dogs, under that gold coat?

Yes! If it weren't for those recessive alleles at the E locus, Goldens would be solid black, from the A locus alleles that programs for solid black. The frequency of the recessive "e" allele at the E locus is 100% across the board for the Golden Retriever breed, hence there is no likelihood of getting a black puppy from breeding two purebred Goldens.

But wait, you said Goldens and Irish Setters are the same genetically, why are Irish Setters a dark mahogany and some Goldens so blonde they almost appear white?

There are two scenarios that affect what shade of yellow an "ee" dog is. *Modifier genes* act on the E locus gene to change its shade (we do not know how many modifier genes exist). Picture a room full of light bulbs each connected to a toggle on/off switch. The room is the E locus and the light bulbs are the modifier genes that change the brightness of the room. Neither "on" (lighter) nor "off" (darker) are dominant or recessive, as they both work equally well. The more light bulbs you have switched to "on" the lighter the room is, the more you have switched to "off," the darker the room. The modifier genes' on or off toggles are "added" in the offspring to give a unique combination to influence what shade the E gene exhibits. Thus, Irish setters have more toggles for darker pigment and Goldens have more toggles for lighter pigment, but they are all the same base color of yellow.

This also explains why breeding two darker Goldens will on average result in puppies as dark as or darker than their parents. The dark toggles of modifier genes add up from both parents in the puppies, giving the pups an even higher percentage of dark toggles among their modifier genes. The same is true in that light gold to light gold begets even lighter gold, and breeding medium golds together or a light gold and a dark gold together will give you a variety of shades in the pups.

Some Goldens probably carry recessive alleles at the C (chinchilla) locus. Recessive at this gene causes washing out of the phaeomelanin. It's quite likely that very light cream colored Goldens are recessive at C.

What about white spots?

White spots on Goldens can be either genetic or congenital (present at birth but not inherited).

The Spotting locus "S" controls extent of white on a dog. Most Goldens are going dominant/solid color at S. Some Goldens probably have a limited spotting allele which causes white chest spots, white hairs on the feet and head, etc. Much like the modifier genes for shade of yellow, amount of white appears to also be additive. So breeding two Goldens with a small amount of white will quite possibly yield puppies with greater amounts of white over the generations.

Because nearly all Goldens are solid at the S locus, and Goldens with extensive areas of white (more than half their

Why A, B and e Spell "Gold", *continued*

body) are never observed, it is impossible to have a truly "white" Golden Retriever. Dogs that are so light in color as to appear white are simply extremely pale yellow, from modifier genes and/or the chinchilla gene.

It's actually quite interesting in that *melanocytes* – skin cells which produce color – originate along the neural crest (spine) in an embryo. As the embryo develops the melanocytes "fall" from the neural crest and settle in the farther regions of the body. This is why in dogs that have minimal white markings they are seen in areas *farthest* from the spine: tip of nose, paws, chest, tip of tail. White spotting like this can also be congenital, if the melanocytes fail to "fall" all the way around the body. This is not genetic.

This handsome dark gold dog shows a fairly large amount of white on the chest and also a white spot on his forehead. White markings such as this can be either genetic or congenital. In this animal, the markings are probably genetic (controlled by the S locus) since the white appears on both the chest and head, consistent with the limited white spotting alleles at that gene.

What about black spots?

If you find a few hairs, or a spot, of black on a Golden, it is because those melanocytes have mutated spontaneously from "ee" to "Ee" (most likely) or "EE" (really rare). So the hair is black not yellow. Depending on how early in an embryo this happens determines how big the spot is (earlier mutations yield a larger spot, because the one mutated cell has more time to multiply and divide into a larger area of skin). It's a popular notion that black hair on a Golden Retriever is derived from the breed's common ancestry with the Flat-Coated Retriever, but this is simply not true. These spots are *not* inheritable – they are mutations in the somatic or body cells, not the sex cells, so they are not passed on to the egg or sperm cells.

To sum up…and an interesting example…

We do not know the exact genotype (genetic code) for Goldens at all the coat color genes, but we can make a good guess:

A(A)BB(CC)DDeeggmmS(S)(tt)

Goldens are undoubtedly homozygous dominant at the B and D loci, and recessive at E, G and M. Some Goldens may carry an allele for limited white markings so it is unknown if 100% of the breed is dominant at the S locus. Goldens may or may not carry the ticking alleles at the T loci, they do not display enough white to witness ticking and make that determination. Some Goldens most likely carry recessive Chinchilla alleles at the C locus to cause the light cream coloration. Are Goldens solid black, or another pattern, as dictated by the A locus? The most simple conclusion is yes, they carry only dominant A alleles, but since all their black pigment is washed out to yellow because of the E gene, we cannot tell if Goldens have sabling or tan points. Except for Chesapeake Bay retrievers, no other retriever breed displays sabling, tan points, black saddles, etc, so it is probably safe to assume Goldens are also dominant at A.

With a good grasp of coat color genetics you can look at any dog and understand the possible genetics behind their coloration. A great example comes from a true story that happened only a few years ago. A breeder bred her Golden bitch via frozen semen. The bitch delivered one puppy that gave everyone a great surprise – he was solid black! Turns out, the same day the Golden bitch was inseminated, an English bulldog bitch was at the vet's office for the same procedure and the semen straws were accidentally switched (the bulldog did not take). The bulldog sire was a fawn and white piebald dog. Both the breeder and the vet were stumped as to why the puppy was solid black, but this is easily explained if you follow the rules of coat color genetics. The bulldog sire was fawn (a^y), a recessive allele at the A locus, piebald (s^p, a recessive at the S locus) and dominant at the E locus. The Golden was dominant solid black at A, dominant solid color at S, and of course recessive at E. So the puppy's genotype was Aa^ySs^PEe – solid black.

This article was reviewed by the Editorial Review Board.

This article was first published in the GRCQ News. With thanks to Anney Doucette and The Golden Retriever Club of America.

4.6 – Some Musings on Colour
with thanks to Marcia Schlehr

Why fuss about colour? The breed is the "Golden Retriever", is it not? What could be so complicated about that? Everybody knows what "Golden" colour is … don't they?

Webster's Dictionary says it is "of the colour and lustre of gold: bright yellow."

In the original Golden Retriever Standard, serving both the UK and the USA, the area of colour was allotted 20 points, of a total of 115 (and no points were given for gait or movement, oddly). Obviously, colour was considered an important matter in judging in the early days of the breed. The original statement frowned on both "cream" and setter-red. "Cream" is defined as "yellowish-white". Setter-red is recognized as a rich chestnut, reddish-brown, or as an artist would say, burnt sienna.

The Standard, circa 1923; Rich golden, must not be as dark as an Irish Red Setter or cream colour. The presence of a few white hairs on chest or toes permissible, but white collar, feet, blaze to be penalized. Minor white markings were quite common at the time, although selection was for as little white as possible. In 1926, "white… on the toes" was moved into the "to be penalized" phrase.

In the 1920s many felt that preference should be for coloring as uniform as possible: a dog that had neither darker shadings nor lighter areas. As the Standard was not specific, this opinion is understandable. However, one result was that deeper shades began to predominate as dogs with "cream" trimmings on under-pants, "pants" and tail featherings were passed over in favour of those without. The Standard did not specify that light shadings were allowable, but that pale(cream) "must not be".

In 1933 Mrs Charlesworth wrote (in Hutchinson's Dog Encyclopaedia): "The incorrect colours are cream or Red Setter or mahogany. Any colour between these feathers are a great characteristic of the breed and should be encouraged." So it can be gathered from this statement that it is the body colour of cream or of Setter red that was not desired, and that pale feathering is (has always been) quite allowable, although the UK Standard does not, and never did, say this specifically. This was an unfortunate omission.

In the 1930s in the UK some lighter coloured dogs made their mark in both work and show. The great dog Gilder (sire of nine champions) and his offspring especially could not be defined. These dogs were golden in their predominant colour, but had paler shadings and under-parts, feathering and tail plume.

But this was one of those "everyone knows that" items which writers of the Standard probably felt too obvious to need to be stated… just as gait was not described. It was taken for granted that everyone of any dog background at all knew (or should have known) how a sporting dog was to move (my, how times have changed…!).

In 1935/6 the UK Standard was altered. At whose initiative, is not known. The new wording read "Any shade of gold or cream, but not red nor mahogany" with the same caveat as earlier about white markings. The point allotment for colour was also decreased to 10 points, rather than the previous 20, and that extra 10 points then assigned to hocks (perhaps that was a greater concern at that point than was colour?). It seems clear, to this researcher, at least, that this change was meant to allow the paler(cream) shadings on golden dogs, and not intended to include dogs that were wholly cream without "golden" to them. Very few, if any, of the dogs of that time, the mid-thirties, could be called "true creams" – all had obvious definite golden colouring on their bodies.

But what about the legendary Gilder? Some will say that his photographs show a dog we could call "cream". Yes, most of Gilder's published photos appear to show a very pale dog – but those photos are all of the dog at 9-10 years of age, when he had gone nearly white from age. An earlier photo of him at about two years of age and before coming into the ownership of Major Wentworth-Smith, who took the dog to his well-deserved reputation as a worker and sire, shows a definitely golden dog.

The revision in the Standard in 1936 did allow for dogs colouring that was lighter than was popular in the 1920s to be recognized. Although the War stopped Ch Hazelgilt (a Gilder son) from completing his Dual Championship title, after the War the Torrdales and the Boltbys made the lighter dogs a force to be reckoned with. Stubblesdown Golden Lass, a true gold with lighter shadings, completed her Dual title, and the Stubblesdowns, Wynfords and Holways dominated the field. By the 1960s Goldens showed a beautiful range of golden colourings, and UK exports went to all corners of the world.

The Stenburys, to name one influential strain, produced some lovely, elegant animals, and through generations of rather close breeding, paler and paler dogs. They were influential in the Scandanavian countries – where now the palest dogs are the most popular. Ch Boltby Skylon, a top show dog and sire of the 1950s, was light, but had definite colour on this body. His contemporary, Ch Alresford Advertiser was a lovely golden colour with lighter trim. Ch Cabus Cadet appears pale in his black and white photos, yet the Beswick porcelain figures based on him are most definitely golden. The Champions Camrose Cabus Christopher and Cabus Botby Combine were lighter dogs, as was Ch Styal Scott of Glengilde. Importantly, such dogs of high degree of breed type and show ring success encouraged rising popularity of the pale colouring both at home in the UK and in the increasing number of exports.

In the USA, however, the Standard until 1955 was precisely the same as the UK standard of 1932, before the addition of "cream" as an allowed colour. The phrase was "A rich Golden, must not be as dark as an Irish Red Setter or cream colour." The majority of dogs brought to the USA in those early years (the 1930s) were mid- to dark shades (as most were in the UK at that time) and those were the foundation of the breed in North America. Deep shades predominated, although some outstanding individuals were of bright golden (such as Ch Rockhaven Rory, FtCh Goldwood Tuck) – but still specifically "golden" not "cream" by any means.

The 1955 revision of the AKC Standard was a complete overhaul of wording. The intent was not to change the "ideal" of the breed in any way, but to clarify and enlarge upon numerous areas that were vague or even omitted from the original version, such as gait and angulation. In this revision we also have, for the very first time, a complete description of colour and markings, as well as of coat texture and patterning, i.e. distribution and amount of feathering, that was absent from the earlier version.

"Coat and Colour: Dense and water repellent with good undercoat. Texture not as hard as that of a shorthaired dog nor as silky as that of a setter. Lies flat against body and may be slightly wavy. Moderate feathering on back of forelegs and heavier feathering on front of neck, back of thighs and underside of tail. Feathering may be lighter than rest of coat. Colour, Lustrous golden of various shades. A few white hairs on chest permissible but not desirable. Further white marking to be faulted."(1955)

So for the first time, specific mention is made in a Standard of the allowable light shadings on a Golden dog : a feature which many years earlier had been described by one of the earliest active Goldens as "a great characteristic of the breed".

This Standard later underwent another careful study culminating in the revision effective in 1982. (Reformatted in 1990 but essentially unchanged, this is the current AKC version). The colour statement in this Standard reads:

"Colour – rich, lustrous golden of various shades. Feathering may be lighter than rest of coat. With the exception of greying or whitening of face or body due to age, any white markings, other than a few white hairs on the chest, should be penalized according to its extent. Allowable light shadings are not to be confused with white markings. Predominant body colour which is either extremely pale or extremely dark is undesirable. Some latitude should be given to the light puppy whose colour shows promise of deepening to maturity. Any noticeable area of black or off-colour hair is a serious fault."

As more judges and exhibitors come into the Fancy who have no real depth of background in the breed, it becomes necessary to be even more explicit in the Breed Standard. Areas that were "taken for granted" earlier can no longer be assumed to be common knowledge, but must be stated (the fact that puppies are often lighter that what they will be at maturity, for instance.) This rather lengthy paragraph was aimed largely at questions raised by newcomers, and by judges with little or no background in this breed. The characteristic light shadings are not "white markings" : white markings are, as noted in the earliest Standard, on the chest, feet, tail tip, or a blaze on the face.

One of the reasons for early dislike of extremely pale dogs was simple – it was difficult or impossible to detect white marking on dog whose legs and feathering were effectively so pale as to be indistinguishable from white. Today, white markings of any extent are so rare that they are far less of a concern, but still, the possibility remains that a white splash on chest and feet could be unnoticed. Other concerns by practical hunting men were that pale dogs would "turn away" waterfowl by their obvious colouring; and also, that pale dogs showed the dirt more than those dogs with deeper colouring. You may decide for yourself as to the validity of these claims.

Perhaps it would be helpful to define some basics regarding colour. By definition, the colour "golden" must have a noticeable component of yellow, as of the metal, gold.

This can range from a very deep, concentrated hue right through to a bright coppery yellow to a bright true gold, a light gold, a lighter pale gold. Knowledgeable breeders of years past defined "ideal" colour as that of "a newly minted gold coin": a guinea in the UK. Pity, that we no longer have gold coins in common use!

These shades will add to various degrees "luster" to the coat. The AKC Standard states "Lustrous golden". Luster is a type of reflection due to the type of, and placement of, pigment within the hair shaft. Cream and white hairs are far less lustrous, as the light is absorbed into the hair shaft rather than being reflected. (This is why polar bears are white – with no pigment granules in the hair shaft, light travels down the hair shafts and is absorbed as heat by the bear's black skin). "White" is an effect brought about by fewer pigment granules within the hair, as well as paler pigment and even, perhaps, the shape of the pigment granules.

During the 1960s-1970s and continuing on, the very pale dogs became more numerous in the UK and in Canada (via imports). Some influential kennels such as Chrys-Haefen, Skylon and Kyon in Canada bred, imported and showed light dogs and creams with success. The Swedish import "Shea" (Ch Mjaerumhogda's Kyon Flying Surprise) put his defining stamp of type and structure on Goldens in the eastern half of Canada. Some called him "cream", others described him as "pale gold". He did have a body colour that was slightly deeper than the paler extremities.

When does "cream" become white? Any interior decorator can show you multiple variations of "white". Put any of them against fresh-fallen snow, and the differences are quite obvious. Yet all are termed "white". In art, white is defined as the absence of colour. Not necessarily the absence of pigment, as there are pigments (zinc white, lead white, Chinese white) that are used to depict white. In physics, "white" light is a balance of all the visible wavelengths of light. Webster's Dictionary defines "cream" as "yellowish white"… so by definition, if a dog is "cream", then it is "yellowish white". And several breeds of dogs commonly called "white" are actually genetically, the same as cream in the Golden Retriever.

In dogs, there are at least three common genotypes of white. One is the result of extreme white spotting. White spotting is the failure of the pigmented areas to cover or fill-in the entire dog, leaving white areas, and is governed by several genes on the S locus. This white-spotting may be so extensive as to produce a dog with no visible coloured markings, or with very small areas of colour (Sealyham Terrier, White Bull Terrier). Homozygous merle ("white merle") can produce a similar effect. Neither white-spotting nor merle is of concern in the Golden Retriever as those alleles are not known to exist in the breed.

Another type of white is actually an extremely pale cream (White German Shepherd [recognised as a separate breed, the White Shepherd, by UKC] West Highland White Terrier, Kuvasz). Often these breeds will show cream or "biscuit" shadings on the ears and perhaps a dorsal stripe or band of pale colour. "Ivory" is an accepted colour for Kuvasz in Europe, and cream or "biscuit" is accepted in the Samoyed. The Great Pyrenees breed has both types of white – all Pyrs have extreme head markings white spotting, and some also have the extreme pale cream, typically shown as yellow head markings on the white dog. All of the white-cream dogs mentioned can have dark pigment in the eyes and skin; they are most definitely Not "albinos", which lack all pigment (in hair, Skin, and iris of eyes).

Researchers have found that white German Shepherds are e/e(as are Goldens) which converts all dark pigment in the hair to yellow or red(phaeomelanin) and disallows formation of dark(brown or black pigment; eumelanin). But they also have something else that makes that yellow very, very pale i.e. cream. So far this gene has not been pinpointed. Dr C. C. Little postulated that this type of white might be due to a double dose (hymogygous form) of what is called the "chinchilla" gene, at the C locus- but this is uncertain at the moment. (C would be for full depth of colour, c for an intermediate depth, c(ch) for pale colour). Whatever it is , its action is to change the expression of the yellow pigment so that it appears white, or nearly so. This may be by altering the number of pigment granules in the hair shaft, altering their arrangement and consequently how they reflect light, or in some other fashion. More research is needed to explain the precise mechanism. But it is apparent that there is indeed something additional that makes some Goldens very pale dogs instead of "rich lustrous golden."

Are there other genetic forms of "golden", that is, yellow–red coat colour? Yes.

Notably, some variation of sable or fawn (same colour genetically, different names in different breeds). This is due to an allele at the A locus. A controls certain patterns of yellow-red and black. A is for solid colour; a(y) is sable; a(t) produces tan pattern(as in Dobermans) a(g) is agouti, "wild" or wolf-coloured with banded hairs.

Dogs of sable colouring are born rather "mouse coloured", greyish tan hair with darker tippings. As the pup matures, the colour may clear to an apparently pure red (Basenji) or yellow (Wheaten Terrier, 'golden sable' Collie). Or, it may retain the black tippings to lesser or greater degrees (mahogany sable Collie, Belgian Terveuren, Malinois).

Even if some sables/fawns may appear similar in colour to the Golden at maturity, the affect that they show black hair at birth is the give-away. Golden puppies are always born some shade of yellow, from very pale cream that appears white, to deep chestnut red; and generally

show a darker shade of that same colour on the ears. The coat also darkens with maturity- it does not lighten. Well, at least not until aging changes might lighten the coat through natural graying or silvering.

Sable/fawn is rare in Sporting/Gundogs. It does exist in some American Cockers, although this is a subject of much discussion within that breed. Some feel it is "foreign", others feel that sable has been in the breed for decades, even centuries. In Irish Setters, years ago, there were reports of the occasional Irish Setter with black shadings in their coats.

In Goldens, because the homozygous ee prevents ANY black pigment in the hair, a Golden may carry any of the A series alleles, and they cannot be expressed. Well, until some crossbreeding brings in E to allow black hair-a Golden x. A sable Collie has produced both sable and black and tan offspring. Crosses with other breeds often produce solid black puppies as well. It is possible that these "hidden" patterns of light and dark may be responsible for much of the lovely variations of shading seen through the Golden Retriever breed. The A series alleles affect yellow-red pigment much less than if dark (black) pigment were present, but still may have some effect.

It is possible for solid black puppies to be born to Golden Retriever parents? For all practical purposes, no.

The only way this could happen was if an e gene was to mutate to a dominant E, which allows for the formation of black pigment in the hair. This would be an extremely rare occurrence. None such has ever been verified by DNA testing.

What about skin pigmentation? That is, the pigmentation of the nose, eye-rims, lip edges, foot pads and sometimes toenails. This is governed by the B locus. Dogs that are BB or Bb will have black pigment; dogs with bb will have brown (chocolate, liver, or lighter brown). "Black", however, can vary considerably, from a jet-black all the way to a very brownish charcoal. Goldens with black pigment often vary considerably in depth of nose colour (and eye-rims and lip-edges), and those with "snow-nose" may fade to a shade of brown in cold weather. However, these dogs will almost always retain a black edging to the nose, and dark eye-rims. Early in Golden history, brown (liver) skin pigment was not unknown in the breed, but over the years has been virtually eliminated.

Keep in mind that aside from dogs that are bb (or in other breeds may have dilute factors), the usual factors that affect coat colour in the Golden do not affect the skin pigmentation. Very dark red dogs may have very black skin pigmentation, or very "faded". And very pale dogs often have the rich, jet-black "trim" that is so attractive.

Obviously, there are modifiers that affect the skin pigmentation that are unrelated to the hair colour.

While the Golden's genetic colour formula is relatively simple compared to many other breeds (let's not even consider Poodles or Greyhounds!), there is still quite enough to provide a rich range of variation. And as long as a particular dog's colouring is within this allowed range, differences in coat colouring are far less critical than basic structure, soundness, and breed character and "type".

Magpie Waltz 7weeks. *Photo courtesy of Mrs J Hodges.*

4.7 – The Price of Popularity: Popular Sires and Population Genetics

This article first published in "Double Helix Network News", C. A. Sharp (Editor). Consider the hypothetical case of Old Blue, Malthound extraordinaire. Blue was perfect: Sound, healthy and smart. On week days he retrieved malt balls from dawn to dusk. On weekends he sparkled in malt field and obedience trials as well as conformation shows, where he baited to – you guessed it – malt balls. Everybody had a good reason to breed to Blue, so everybody did.

His descendants trotted in his paw-prints on down through their generations. Blue died full of years and full of honor. But what people didn't know was that Old Blue, good as he was, carried a few bad genes. They didn't affect him, nor the vast majority of his immediate descendants. To complicate the matter further, some of those bad genes were linked to genes for important Malthound traits.

A few Malthounds with problems started showing up. They seemed isolated, so everyone assumed it was "just one of those things." A few declared them "no big deal." Those individuals usually had affected dogs. All in all, folks carried on as usual.

Time passed. More problem dogs turned up. People made a point not to mention the problems to others because everyone knows the stud owner always blames the bitch for the bad things and takes credit for the good. Stud owners knew it best to keep quiet so as not to borrow trouble. Overall, nobody did anything to get to the bottom of the problems, because if they were really significant, everybody would be talking about it, right?

Years passed. Old Blue had long since moldered in his grave. By now, everyone was having problems, from big ones like cataracts, epilepsy or thyroid disease to less specific things like poor-keepers, lack of mothering ability and short life-span.

"Where can I go to get away from this?" breeders wondered.The answer was nowhere.

People became angry. "The responsible parties should be punished!" Breeders who felt their programs might be implicated stonewalled. Some quietly decided to shoot, shovel and shut-up. A few brave souls stood up and admitted their dogs had a problem and were hounded out of the breed.

The war raged on, with owners, breeders and rescue workers flinging accusations at each other. Meanwhile everybody carried on as always. After another decade or two the entire Malthound breed collapsed under the weight of its accumulated genetic debris and went extinct. [Sound a bit like "THAT" BBC show !!!!]

This drastic little fable is an exaggeration -- but not much of one.

Here's a similar, though less drastic, example from real life: There once was a Quarter Horse stallion named Impressive. The name fit. He sired many foals who also exhibited his desired traits. But when they and their descendants were bred to each other, those offspring sometimes died. Impressive had been the carrier of a lethal single-gene recessive trait. No one knew it was there until they started in-breeding on him. The situation of a single sire having this kind of drastic genetic effect on a breed became known as the "Impressive Syndrome."

Many species and breeds of domestic animals, including dogs, have suffered "Impressive Syndromes" of their own. But cases like that of Impressive are only the tip of the iceberg. A single-gene recessive becomes obvious in just a few generations. But what about more complex traits?

This is not to say that those popular sires we so admire are bad breeding prospects. Their many excellent traits should be utilized, but even the best of them has genes for negative traits.

The problem is not the popular sires, but how we use them. For a century or more, in-breeding has been the name of the game. (For the purposes of this article, "in-breeding" refers to the breeding of dogs related to each other and therefore includes line-breeding.) By breeding related individuals, a breeder increased his odds of producing dogs homozygous for the traits he wanted. Homozygous individuals are much more likely to produce those traits in the next generation.

When a male exhibits a number of positive traits and then proves his ability to produce those traits he may become a popular sire, one that is used by almost everyone breeding during his lifetime, and maybe beyond, thanks to frozen semen Since the offspring and grand-offspring and so on are good, breeders start breeding them to each other. If the results continue to be good, additional back-crosses may be made for generations. Sometimes a sire will be so heavily used that, decades hence, breeders may not even be aware of

how closely bred their animals are because the dog no longer appears on their pedigrees.

This is the case in Australian Shepherds. Most show-line Aussies trace back, repeatedly, to one or both of two full brothers: Wildhagen's Dutchman of Flintridge and Fieldmaster of Flintridge. These, products of a program of inbreeding, were quality individuals and top-producing sires. They are largely responsible for the over-all quality and uniformity we see in the breed ring today--a uniformity that did not exist before their birth nearly three decades ago.

Working lines have also seen prominent sires, but performance traits are far more complex, genetically and because of the significant impact of environment. They are therefore harder to fix. Performance breeders will in-breed, but are more likely to stress behavioral traits and general soundness than pedigree and conformational minutiae. The best working sires rarely become as ubiquitous as the best show-line sires.

Not every popular sire becomes so because of his ability to produce quality offspring. Some have won major events or are owned by individuals with a knack for promotion. Such dogs may prove to be wash-outs once their get is old enough to evaluate. But a lot of breeders have been using the animal for the few years it takes to figure that out, the damage may already have been done.Use of even the best popular sires, by its very nature, limits the frequency of some genes in the breed gene pool while simultaneously increasing the frequency of others. Since sons and grandsons of popular sires tend to become popular sires the trend continues, resulting in further decrease and even extinction of some genes while others become homozygous throughout the breed. Some of these traits will be positive, but not all of them.The owners of Old Blue, the Malthound in the opening fable, and those who owned his most immediate descendants had NO IDEA what was happening under their noses. They were delighted to have superior studs and even more delighted to breed them to as many good bitches as possible.Dog breeding and promoting is an expensive proposition. One usually winds up in the hole. But owning a popular sire can change that. The situation looks like a winner for everyone--the stud owner finds his financial burden reduced while breeders far and wide get to partake of his dog's golden genes.

No one breeding dogs wants to produce sick dogs. A small minority are callous and short-sighted enough to shrug genetic problems off as the price you pay to get winners, but even they do their best to avoid letting it come to general attention.

***

We need a total re-thinking of how we utilize stud animals.

No single dog, no matter how superior, should dominate the gene pool of its breed. Owners of such sires should give serious consideration to limiting how often that dog is used, annually, through its lifetime and on into the future, if frozen semen is stored. The stud owner should also look not only at the quality of the bitches being presented, but their pedigrees. How much will the level of inbreeding be increased by a particular mating?

The bitch owner also needs to think twice about popular sires. If you breed to the stud of the moment and everyone else is doing the same, where will you go when it comes time to make an outcross?

***

Finally, the attitude toward genetic disease itself has to change.

***

It must cease being everyone's dirty little secret. It must cease being a brick with which we bludgeon those with the honesty to admit it happened to them. It must become a topic of open, reasoned discussion so owner of stud and bitch alike can make informed breeding decisions. Unless breeders and owners re-think their long-term goals and how they react to hereditary problems, the situation will only get worse.

C.A. Sharp is editor of the "Double Helix Network News". This article appeared in Vol. IV, No. 3 (Summer 1998). It may be reprinted providing it is not altered and appropriate credit is given.

***

With thanks to CA Sharp and 'Double Helix Network.' Published with permission.

What is the co-efficent of Inbreeding ?

The co-efficient of inbreeding (COI) is a Mathematical method to define inbreeding.

The higher the inbreeding co-efficient the more homozygous we can expect a dog to be. Inbred stock increases homozygosity thereby making them more predictable breeding stock The further back the inbreeding occurs the less important it will be in terms of affecting the COI. If a genetic defect is recessive both parents must carry the gene for the particular defect to occur therefore inbreeding increases the chance that this will occur. If a dog carries no defects no degree of inbreeding will cause a genetic fault to occur.

4.8 – Understanding Polygenetic Inheritance

This article was first published in "Working Aussie Source" by C.A.Sharp

Everyone knows this old game: You place beans or other markers on numbered squares arranged in a grid as someone announces numbers pulled at random from a box. The first person to form a line of markers across the grid in any direction yells, "Bingo!"

Breeding dogs is like playing Bingo, but instead of ranging beans on a card you are shuffling genes. When the right combination lines up, one or more of the puppies in your litter may exhibit a polygenetic trait: Bingo!

Polygenetic traits are probably the most difficult for breeders to understand. They are certainly the most difficult to control in a breeding program, whether you want the trait or you don't. The phenotype of the dog – what you see or the behavior you get – will spring from the combined actions of multiple genes. Sometimes, as with hip dysplasia, the genetic potential may be swayed by environmental effects.

Unfortunately, many inherited diseases, like HD, are polygenetic. It follows an irregular inheritance pattern: Some dogs will never produce HD, others may produce it occasionally, and some will produce it frequently. Some families will have it every generation, others may go for several generations with no cases at all. Excellent hips may produce dysplasia and affected parents may produce sound offspring. Whether a dog will produce HD or not depends on exactly what combination of genes it has and who it is bred to. Even though the environment plays a role, a dog won't have HD unless it has the genes to do so.

Thinking of the different genes that contribute to polygenetic traits as letters in the word BINGO may help you visualize what happens as they are passed from one generation of dogs to the next. For the sake of this discussion we will say that to produce a polygenetic trait, the dog must have particular alleles—or versions—of five different genes before it will have that trait. We will call them B I N G and O. If a dog has any combination of alleles at those genes other than BINGO, it will not exhibit the trait. BINGo won't do it and neither will BInGO. Dogs like these with an incomplete set are carriers of the trait, but they will only produce it if mated to a dog with the missing alleles.

You can breed BiNGO to BiNGO and never see the trait, but cross once to a dog that has I rather than i and there may be BINGO puppies. Obviously a dog with only one BINGO allele will produce the trait far less often than one that has all but one of them. In fact, a dog that just has just O might never be bred to one that has BING and therefore never produce the trait even though it is a carrier.

Though we don't think of it as such, coat color results from action of multiple genes. Some determine color (black, blue, yellow.) Others provide pattern (brindle, piebald, merle) The particular combination of color gene alleles determines what color dog you have. For example, an acceptably colored blue merle Australian Shepherd with tan points would have a genotype that could be described thus: a t - B- C- D- E- gg kk Mm s i -. Some genes must be dominant, others need two recessives. The ones with one allele and a dash may have two different alleles, provided at least one is the allele noted and the other is the same or recessive to it. Change a single allele and you can have an entirely different coloured dog: A pair of m's makes the dog a black tri; a dominant K deletes the tan points.

Maintaining desirable polygenetic traits is easier than getting rid of them, but even so you can breed a BINGO pair and wind up with a dud litter. Diligent selection for BINGO over many generations may ultimately lead to the trait becoming very common. Even so, the occasional non-bingo pup will occur because of a chance combination of the non-bingo alleles floating around in the gene pool in low frequency.

Completely eliminating a polygenetic trait can be extremely difficult if not impossible. If ancestors of your dog have produced an unwanted BINGO, some or all of the genes may come down to your dog. If Lucky is heavily linebred on the Old Granddad/Grandma cross and Gramps and Granny were known to have produced BINGO, there's a fair shot Lucky will carry at least some of the genes even if he doesn't have the trait himself. The more ancestors that have had or produced BINGO and the closer up they are in the pedigree, the more likely Lucky will at least be a carrier.

Unfortunately, there is much we do not know about polygenetic diseases. Some don't start until the dog is an adult and may already have been bred. Sometimes diagnosis is not clear-cut. We may not be able to predict which cases will be controllable and which crippling or lethal. And in most breeds we can only guess at the specifics of inheritance. While it is possible with careful,

diligent selection over generations, to clear a line of a trait, its absence doesn't mean that you have eliminated BINGO. Maybe you have only eliminated G.

A common breeder's dilemma is the discovery that one of your dogs is half-sibling to a dog with an undesirable polygenetic trait. With half-sibs, you know that the common parent had some part of BINGO. Therefore, your half-sib probably inherited something. Depending on what genes the half-sib's other parent has, it may have picked up a few more—possibly enough to have BINGO. Even without a complete BINGO it is a carrier. If you are going to breed a half-sib, the other side of its pedigree needs to be as clear of the trait as possible. Prospective mates for that dog will also need to be from families clear of the trait.

While inbreeding and linebreeding in and of themselves do not perpetuate unwanted polygenetic traits, the risk of doing so increases if you linebreed on dogs that carry the necessary alleles. When you do this, you can unintentionally increase the frequency of those genes in the group of dogs you use for breeding. Coefficients of inbreeding can tell you which crosses are less linebred, but COIs are only part of the picture. If the particular dogs in a pedigree that raise the COI are not problematic for the trait, the COI will have no bearing on whether or not you might get the trait.

Close inbreeding and heavy linebreeding on a BInGO dog will never produce an affected pup. But if you outcross to a line that happens to have G, you may "suddenly" have a genetic problem for which your line was "clear." This has been called "outcrossing surprise." Outcrossing will only help if the line you outcross to lacks BINGO alleles.

Eliminating BINGO alleles may not be merely a matter of heavy and consistent selection against the trait. It may be impossible. Geneticists have recently discovered that genes multi-task. Where we once thought dogs had 80-100K genes, today we know the number is actually more like 40K. Different parts of genes do different things. They may have different functions at different points in life, or do different jobs in different tissues. It is possible that N is beneficial when present alone, and only becomes a problem when the whole BINGO is there. Efforts to eliminate it might create more trouble than the trait you are trying to get rid of.

When the BINGO trait doesn't show up until later in life, the affected dog may have been bred. While it will pass along those alleles to its offspring, it is unlikely to pass the entire set since not all will be dominant. A dog can give only half of its genes to its offspring. If it is affected, those offspring will certainly receive some part of BINGO, but the pups won't have the trait unless the other parent provides whatever alleles are missing.

The individual genes that make up BINGO may be dominant, recessive, co-dominant, or incomplete dominant. These genes may have only a couple or several different alleles. Only one or several of the possible alleles may contribute to BINGO. Some genes may override the action of others. Genes may work in concert to produce the BINGO phenotype. If even one BINGO gene is on the X chromosome, you will see more males with the trait than females.

Let's take another look at coat color: Pretend that all other colors are possible in your breed but blue merle unacceptable. Since all colors can happen, the actions of other color genes may confuse the issue or make it impossible to know if a dog is genetically blue merle.

S (white spotting) has multiple alleles causing varying amounts of white trim, ranging from none to an entirely white dog. If the dog has two extreme white alleles, you may not be able to tell whether it is merle. Piebald or irish pattern dogs will have patches of color, but they may be very small. This kind of trait expression tempts breeders to conclude that perhaps it isn't important because the dog only has "a little bit" of the trait. However, the genes are there and it will reproduce like a blue merle even if you only see a tiny patch of the color.

This is an example of how a trait might be termed 'dominant with variable expressivity'. The color requires two dominant genes, however the variety of trait expression—big color patches, tiny ones or none, depends on another gene. These traits are not single gene; they are polygenetic. Therefore both parents of an offspring with the trait will have contributed alleles necessary to produce that trait. They are both carriers.

The most recessive allele of the E locus causes yellow color. If a dog with a blue merle genotype has two copies of the recessive e, you will not be able to tell that it is merle. This might be termed dominant with incomplete penetrance, meaning sometimes you get the trait and sometimes you don't. This also is a type of polygenetic inheritance and both parents contribute.

To put a BINGO spin on incomplete and variable penetrance, consider this scenario: B is dominant and INGO are not. Both B and O are vital to exhibiting the trait while IN and G are additive, causing variations in the presentation or progress of the disease. Some cases will be worse than others (variable expressivity.) Most will appear to be inherited in a dominant fashion, but every once in a while bINGO will be bred to BINGo, both of whom are normal, and BINGO will result (variable penetrance.)

Additive genes, like ING in the example above, are often referred to as "modifiers." These are genes that tweak a quantitative phenotype, like coat length, how tall a dog is, or how heavy its bone. Additive genes

may determine things like seizure threshold in primary epilepsy, or age of seizure or onset of cataracts.

Other modifying genes are qualitative: Several combinations of S alleles will give an irish pattern. Modifiers determine whether we have a collar, white legs, white up the stifle, or a blaze.

Individual genes may have any mode of inheritance. With color, we know the major genes and we know what they do to the dog. We recognize the phenotype and have a good understanding about how it can be inherited. For the most part, color is there to see before the puppies leave the whelping box. But coat color is the exception; with most polygenetic traits we know little of this.

It's only natural for people to seek the simplest answer to a question. It isn't uncommon to hear assertions made about polygenetic disease based on nothing but hope, that one or most of the genes involved are dominant. This is a dangerous mind game to play. The more genes are involved in a polygenetic trait, the less likely that all will have the same mode. Most mutations for diseases tend not to be simple dominant because both Nature and breeders select vigorously against them.

We have no way to evaluate how many genes are involved in these traits or by what mode of inheritance they transmit their individual contributions to the overall trait. It would be very shortsighted of to assume that a very few dominant genes are involved simply because it gives us the out of declaring that the unwanted result is the fault not of one's own dog, but of the one it was bred to. And since these traits usually arise in the offspring of normal parents, how on earth can we know which one of them gave what.

There is hope that someday science will come up with a way to determine genotype on polygenetic traits. Early research into canine genetic disease focused on single-gene inheritance. These traits were the easiest to track. Now that scientists can pick apart the very structure of the dog's DNA, they are beginning to identify polygenetic traits as well.

One of these is epilepsy in Belgian Sheepdogs and Tervurens. Researchers have discovered that in these closely related breeds, there is one gene with major impact and others which contribute to its expression. Efforts are underway to develop a screening test for that key gene. Controlling it may drastically reduce if not eliminate epilepsy in those breeds.

Once genetic tests are developed, we can work toward eliminating them even though we may not totally remove all the BINGO alleles from the breed. With a screening test, if you know the dog as B and G and the bitch has only I, you are safe to breed. But if the bitch has N and O as well as I, she isn't a good match for your dog. Even if you know the genotypes of the parents, you won't know how the BINGO alleles fell in the pups, so you would then screen any that were to be bred so the results could be compared with those for prospective mates. This way you will be able to avoid crosses that produce the disease. The point is not to totally eradicate all BINGO alleles, but to produce healthy pups. With screening tests, we will even be able to view genes for very serious diseases as a sort of fault rather than an automatic reason to take an animal out of the breeding pool.

Lacking any kind of screening test, the best breeders can do is evaluate risk and try to lower it via careful mating choices. That may mean never breeding an otherwise excellent individual because the risk is too high. Risk analysis will not totally prevent unwanted traits, but it is the best tool available at present. However, it is dependent on the open exchange of information between breeders about what dogs have had or produced disease.

Until genetic tests become available, breeders need to amass as much information as possible about both positive and negative traits. Not only in their own dogs, but their relatives, too. Careful study of pedigrees, including the vertical pedigrees which include siblings of the dog and its progenitors, noting which dogs had or produced a trait, how many of them there are in the pedigree and how close they are to the subject dog will provide the breeder with an idea of how likely a particular dog is to have or throw the trait.

With careful record keeping, diligent study of pedigrees, and—as they become available—genetic screening tests, a breeder can make progress toward desirable polygenetic traits and away from the undesirable. With a high level of honesty and cooperation between breeders, progress will come even faster. Some day nobody will have to yell "BINGO!" because of a bad line of beans.

The author, C A Sharp, would like to acknowledge Michele Betit for suggesting the BINGO concept on the EpiGenes discussion list.

With thanks to CA Sharp and 'Working Aussie'. Published with permission.

A litter of Styal babies, peas in a pod. Photo courtesy of Shirley Sullivan.