Purebred Dog Breeds into the Twenty-First Century:

Achieving Genetic Health for Our Dogs

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What is a Canine Breed?

What is a breed? To put the question more precisely, what are the necessary conditions that enable us to say with conviction, "this group of animals constitutes a distinct breed?" In the cynological world, three separate approaches combine to constitute canine breeds. Dogs are distinguished first by **ancestry**, all of the individuals descending from a particular founder group (and only from that group) being designated as a breed. Next they are distinguished by **purpose** or utility, some breeds existing for the purpose of hunting particular kinds of game,others for the performance of particular tasks in cooperation with their human masters, while yet others owe their existence simply to humankind's desire for animal companionship. Finally dogs are distinguished by **typology**, breed standards (whether written or unwritten) being used to describe and to recognize dogs of specific size, physical build, general appearance, shape of head, style of ears and tail, etc., which are said to be of the same breed owing to their similarity in the foregoing respects.

The preceding statements are both obvious and known to all breeders and fanciers of the canine species. Nevertheless a correct and full understanding of these simple truisms is vital to the proper functioning of the entire canine fancy and to the health and well being of the animals which are the object of that fancy. It is my purpose in this brief to elucidate the interrelationship of the above three approaches, to demonstrate how distortions and misunderstandings of that interrelationship now threaten the health of all of our dogs and the very existence of the various canine breeds, and to propose reforms which will restore both *balanced breed identity* and *genetic health* to CKC breeds.

In order for canine breeds to fulfill their destinies effectively, the three distinct axes along which breeds are distinguished must have equal importance and consideration, otherwise serious problems arise. Breeds cannot be distinguished by ancestry alone, by purpose alone, or by typology alone. Unless these three vectors of breed identity interrelate fully and cooperatively, the fullness of that identity is missing or marred. Unfortunately, this full and cooperative interrelationship is a rarity in our contemporary dog world. The criteria of ancestry are applied rigidly and mechanically; the criteria of purpose and utility are subordinated or not considered at all; the criteria of typology are applied in a highly exaggerated, obsessive fashion. The interaction of the three approaches is seldom considered and almost never is a sustained effort made at the integration of the three.

The Origins of Dog Breeds

Canine breeds come into existence in many different ways and their beginnings are very often shrouded in obscurity. Let it not be thought that the three or four hundred-odd dog breeds now extant are the only ones possible, or that there cannot be any more truly new breeds. Such is the genetic plasticity of the dog that there is no end to the possible unique variations of which the species is capable. New breeds are born and old breeds die periodically. The genetic transformation of the dog goes on ceaselessly, and for that reason it is impossible that any breed should remain frozen, with all its characteristics fixed and unchanging, for any appreciable length of time. It must be realized that canine breeds are manmade, created by artificial election out of the endless diversity of the canine gene pool. Breeds must not be confused with species or even subspecies, which occur naturally under the influence of natural selection; dog breeds are only unstable manmade varieties which would not survive unchanged in the natural world without human management.

An important characteristic of breeds is that they are created by breeders -- not by registries or protective organizations such as The Canadian Kennel Club. The origin and course of a canine breed is in the hands of its breeders, first, last and always. It is the business of cynological associations to facilitate and support the work of dog breeders and not *vice versa*. The purposes of the Animal Pedigree Act, under which CKC is incorporated, are the promotion of breed improvement and the protection of those who breed and purchase animals; such is the mandate of the Act and therefore of the Club [Animal Pedigree Act, §3(a,b)]. All else is secondary.

Ordinarily a breed has already existed for an appreciable length of time before it reaches the point of becoming a recognized breed served by a registry. Nonetheless, the event of its "recognition" by a registry such as CKC is always a crucial one in the history of a breed. As things now stand, breed recognition is far more crucial (and ultimately damaging to the welfare of the animals) than it need be or ought to be, but more of that anon. First let us examine what is needed to start a new and unique canine breed.

Four essential characteristics usually distinguish the origin in the genetic sense of a new breed (as opposed to the discovery, popularization and "recognition" of, for example, an autochthonous breed which may have existed in a particular region for a long time without connection to formal cynological structures). The first and most crucial characteristic is the ***founder event*** in which a finite number of individual canines is chosen to contribute genetic material to found a new and unique canine population. They may all be quite similar, or they may be widely divergent one from another (as when Bulldog and Mastiff specimens were used to create the Bullmastiff breed). What matters is that a finite and sometimes quite small number of individuals are selected from the existing canine population and set apart so that their genetic material alone forms the gene pool for the new breed. That is in fact the next characteristic: ***isolation***. If the founder group continues to exchange genetic material at random with the general canine population, a new breed will not result. Without genetic isolation of the new founder group, the differentiation that creates a new breed cannot take place. The logical consequence of this isolation is the next characteristic: ***inbreeding***. If the founder group is of small or moderate size, such inbreeding cannot help but occur. Even if the founder group should be quite large, ordinarily those who guide the breeding which creates the new breed will find it necessary at some stage to employ a strong degree of incest breeding or inbreeding, to facilitate the weeding-out of undesired characteristics and the fixation of desired traits. Particularly if individuals of widely divergent type and physique are involved, inbreeding will be required to set up a stable genome in which random variability is kept within limits defined by the breeders. The final essential factor is ***artificial selection***, since inbreeding alone will not serve to fix type characteristics and to eliminate unwanted traits. The breeders must select among the individuals produced in early generations so that only hose displaying the desired characteristics are allowed to produce subsequent generations. Without the four factors of the founder event, isolation, inbreeding and artificial selection, new breeds ordinarily do not come into existence. These four tools are used to define a new genome which, hopefully, contains only the traits desired by the creators of the new breed and is able to reproduce itself, with its distinguishing characteristics, to a fair degree of stability and consistency.

The Healthy Continuation of Breeds

Purebred dogdom is even now in serious trouble through a general failure to distinguish between what is necessary *to establish* a breed and what is desirable to continue that breed in perpetuity. Most registered breeds are less than a century old as registered breeds; many are but fifty or sixty years old. Yet nearly all breeds now show levels of expression of genetic defects that must be considered unacceptable. Over 500 distinct genetic defects have been cataloged in various breeds of purebred dogs and more continue to come to light regularly. Some of these have reached very high levels of incidence, creating problems for breeders and dog owners, threatening the health of entire breed populations. What is worse, in many instances organized control programs seem relatively ineffective. Although such programs successfully identify affected animals, in some cases individuals with several generations of "clear" ancestry stubbornly continue to produce affected stock. Let us try to examine what has gone wrong and what must be done to correct the situation.

First of all it must be recognized that practices which were essential for the differentiation and establishment of a new breed may not necessarily be desirable for its continuation over time and may in fact be prejudicial to a breeds continued existence over the long term.

Let us take isolation, for example. Without genetic isolation, it would not be possible to control the genome of a new breed still few in number. It takes time and careful breeding to fix a new combination of characteristics; while that is being done, the regular addition of new genetic material would generally be counterproductive. Yet in the long term, if genetic isolation is maintained, it will necessarily lead to degeneration through genetic drift.

Similarly inbreeding, if it continues to be practiced after the need for it is past, will lead to a steadily increasing state of homozygosity which may well destroy the genetic health of the new breed. Even artificial selection, if carried on too strongly for too long, can combine with isolation and inbreeding to reduce drastically the effective breeding population, thus eroding the genetic health of the breed.

The Fallacy of Breed Purity

The present structure of The Canadian Kennel Clubs studbook registry (and others like it) embodies a fallacy which is directly responsible for the current genetic crisis in purebred dogs: the fallacy of breed purity. The ideal of the purified lineage is seen as an end in itself; accordingly, the studbook has been structured to reflect and to enforce that ideal rigidly and absolutely. This insistence on absolute breed purity arises from nineteenth-century notions of the "superior strain" which were supposedly exemplified by human aristocracies and thoroughbred horses; this same ideal, pushed to an illogical conclusion on the human plane, resulted in the now discredited "scientific racism" of the Nazis, who tried through selective human matings to breed an Aryan superman. The idea of the superior strain was that by "breeding the best to the best," employing sustained inbreeding and selection for "superior" qualities, one would develop a bloodline superior in every way to the unrefined, base stock which was the best that nature could produce. Naturally the purified line must then be preserved from dilution and debasement by base-born stock. There is no support for this kind of racism in the findings of modern genetics -- in fact, quite the opposite: population groups that are numerically limited and closed to new genetic inflow are now thought practically certain to be genetically inferior. Certainly towards the close of the nineteenth century it became embarrassingly obvious that the human aristocracies of Europe were degenerating rapidly under their own version of the "closed studbook."

The ideal of breed purity as applied to purebred dogs has resulted at the end of the twentieth century in a subculture that holds "purebred" registered animal stock to be qualitatively superior to crossbred or "mongrel" stock. (The word "mongrel" is in fact part of the vocabulary of racism, being applied equally to canine stock of no recognizable breed, to animal crossbreeds and to persons of mixed race!) In this subculture -- presided over in Canada by the CKC -- it is thought to be of paramount importance that purebred stock be maintained unsullied by any genetic influence external to the supposedly superior strains that are produced by registered breeding in a closed studbook from a small group of foundation stock. New members of the CKC are required to subscribe to "Conditions of Membership" whereby they promise to have nothing to do with "dogs which are not purebred" (with the exception of family pets and boarders), "purebred" being specifically defined as referring only to dogs "registered individually or eligible for registration in records of the CKC." Litters which are made the subject of complaints that they may not be purebred are investigated and in many cases ceremoniously withdrawn from the registry by resolution of the Clubs Board of Directors. Whether you like the word or not, this is effectively a special variety of racism in concept and in practice.

Not all dog breeders are in agreement with the proposition that breed purity is more important than anything else, particularly when they are confronted with the problem of breeding dogs to demanding performance standards. Mostly such dissenters are obliged to carry on their breeding without the benefit of centralized pedigree record keeping and official certificates of registration -- for example, those who breed "Alaskan huskies", the high-performance racing sled-dogs that dominate both short and long distance dogsled racing, keep pedigree records and maintain sophisticated breeding programs, but only as individual breeders. Yet sometimes even participants in established purebred registries engage in a subtle kind of rebellion, quietly breeding according to their own judgment in defiance of formal restrictions. Thus the Racing Greyhound Club of Australia, when it recently subjected a broad sample of stock from its registry to DNA testing, is rumored to have discovered that many pedigrees failed to match DNA ancestry findings and that considerable interbreed crossing had apparently occurred. Similarly most Siberian Husky fanciers are aware that some CKC bloodlines may have received surreptitious infusions of genetic material from non-purebreds or from other breeds. In some circles one even gets the distinct impression that "its OK to crossbreed occasionally if you have a good reason for doing it and you manage it in such a way that no embarrassingly obvious mongrels are produced" -- i.e., "just don't get caught!" Thus the sanctity of breed purity may sometimes be less than inviolate in actual practice.

Population geneticists insist that limited populations under strong artificial selection, subjected to high levels of incest breeding - such as our own CKC purebreds -- simply cannot maintain genetic viability and vigor in the long term without the periodic introduction of new and unrelated genetic material. They are referring, moreover, to true outcrossing, the introduction of stock unrelated to the breeding line, not merely the use of a dog which might be from someone else's kennel but is derived from exactly the same foundation stock some generations back.

The Demise of Typological Thinking

DNA research has radically changed zoological concepts of species, subspecies and varieties. In the nineteenth century and the first half of this century it was thought that a species could be represented by a type specimen, that the vast majority of individuals of a species were virtual photocopies of the type specimen, genetically speaking, and that the genetic norm for most species was homozygous at most loci. In the mid 1960s the credibility of that idea was shattered as electrophoresis protein studies revealed extensive protein polymorphism that had not been previously suspected [Carson 1983]. Today the concept of a species in a satisfactory state of genetic health invokes a state of "dynamic balance" in which the species genome contains an array of genotypes with a high degree of heterozygosity, with multiple alleles at many gene loci. Natural selection is now thought to favour heterozygotes in a way which tends toward a high state of natural variability, preserving the greatest variety of possibilities with which a species can meet new environmental challenges. Conversely, species which have lost most of their genetic diversity, often through accidental population "bottlenecks" similar to those which regularly occur in purebred dogs, are held to be in high risk of extinction through the loss of adaptive capability. (The most notorious example is the cheetah, which is almost totally homozygous and is thought to have undergone at some time a bottleneck reducing its population to a tiny handful of specimens.)
There is no reason why dog breeds also cannot be maintained in a balanced state of heterozygosity, analogous to that of healthy wild animal species, if typological thinking in the dog fancy could somehow be replaced (or at least tempered) with population thinking. Fanciers will generally admit that no dog conforms perfectly to its breed standard. Thus the concept of the perfect type specimen, to which an entire breed ought to conform as closely as possible, is really as foreign to dog breeds as it is to animal species in the wild.

The fanatical pursuit of breed type to the exclusion of other more important factors (more important to the dog, to his owner, and to his veterinarian) has led to a distinctly unhealthy situation in most breeds. Since the majority of breeders within CKC seem to direct their efforts toward the production of a winning exhibition specimen, and since many breeders therefore breed their females to the males that do the most winning at dog shows, a situation has arisen in which continued effort to produce show winners leads consistently to greater and greater exaggerations of "type", that being the factor most susceptible to the off-the-cuff three-minute analysis of the breed ring. It is an accepted fact that strong incest breeding is the fastest route to this kind of "success"; here is one successful show breeder's recipe for "excellence" [de Boer and de Boer, DOGS in Canada, April 1994]:

"My approach would be to identify an outstanding, dominant stud dog. Let's call him 'Shadrack.' To improve the odds I'd buy or lease three bitches whose grandsire on the dam's side was the same as Shadrack's sire. Let's call the grandsire 'Fashion Hint.' I would breed the Fashion Hint bitches to Shadrack. Assume, in this first generation, that I get three nice bitches. For the second generation, I'd breed them to a half-brother of these three bitches (Shadrack's son, also a dominant sire). For the third generation, several 'mix and match' options include going back to Fashion Hint or Shadrack. I could also do brother-to-sister or father-to-daughter breeding." Thus the quest for more and more refined breed type leads directly to a state of advanced homozygosity, rising inbreeding coefficient, low effective breeding population and consequent impoverishment of the gene pool in most CKC breeds, through rampant uncontrolled incest breeding.

The show ring has also been largely responsible for the decline of breed purpose, working ability and temperament in a great many breeds, notably sporting breeds, herding breeds and sleddog breeds. The quick and easy gratification of blue ribbons and gilt trophies all too readily supplants the hard work necessary to preserve and advance canine working abilities. If our dog breeds are to conform to the ideal of "a sound mind in a sound body" (as advocated by the proponents of the Advanced Registry), the fancy must find some way of ensuring that less dog-breeding takes place along the lines of least resistance and cheap gratification, so that greater attention is paid to working characteristics, temperament and trainability. A balanced outlook on breed identity must be restored by integrating canine function with the ideals of conformation, beauty and "type." All kinds of dogs, toy breeds not excepted, can perform useful functions and respond to training. Those aspects of the fancy should be accorded an importance at least fully equal to that of type and conformation instead of being regarded as merely optional. For example, breeding and exhibition of utility breeds such as gundogs and sleddogs merely for sale as pets and for dog shows, with no effort made to maintain and advance their working capabilities, is an obvious abuse which must lead inevitably to mental and physical degeneracy in those breeds.

Abandoning Natural Selection

The breeder of domestic stock often assumes that he has abandoned the realm of natural selection and that only artificial selection plays a significant role in his breeding programme. Nothing could be further from the truth. The breeder may attempt to abandon natural selection; natural selection, however, will not abandon his stock. As one geneticist puts it:

"Man-imposed characteristics, however, like the flower colours and forms selected by the plant breeder, usually do not perturb the deep-set genetic variability systems of the species. Most such changes are reversible when a less restricted gene pool is restored. The 'balance' system appears to be retained by natural selection, which, perhaps paradoxically, pervades most systems of artificial selection."

(Hampton L. Carson, The Genetics of the Founder Effect. l983)

Those who attempt to set aside the balanced genomes arrived at by natural selection must struggle thereafter to attain and to maintain fitness in their stock. There is more to this than mouthing platitudes about "soundness." Artificial selection alone, such as that used to produce winning exhibition dogs, involves breeding in a way which flagrantly disregards most of the gene loci in the canine genome. Since genes assort in groups on chromosomes (a phenomenon known as "linkage"), inbreeding and selection for desired traits of superficial appearance unavoidably affect many other genes which are inadvertently selected and often fixed in a homozygous state in total ignorance of what is happening. This may be a major factor in the current prevalence of genetic diseases. Thus natural selection, baulked for a season by artificial selection, high-level nutrition, and advanced veterinary care, reasserts its primacy at a deeper and more serious level when the new genome as set up by the breeder proves flawed through genetic unsoundness, so that healthy and hardy animals can no longer be produced, however typey and attractive to the eyes of the judges the result may be.

Declining vigour caused by the inadvertent fixation of sublethal and subvital alleles will not be made up for by breed points. Fitness criteria may not be replaced with impunity by aesthetic criteria. The animal's environment is the ultimate arbiter of its fitness and will not be denied its say. You may vaccinate the dog and dose him with antibiotics, feed him with vitamins and minerals as you like, enclose him in a sterile pathogen-free laboratory environment if it comes to that! Still natural selection may not be avoided; it only emerges at a deeper level. In a sense the dog's environmental includes his own physical body; if the genes which blueprint his physiology are flawed, then the dog is doomed regardless of his beauty and classic breed type. The truth is that the "superior strain" cannot be produced by manmade breeding programmes and artificial selection; the breeder's decisions are subject to nature's veto at all times.

With what, then, will the breeder replace natural selection? If he replaces it with profit, the degeneracy of his stock will in the end put him out of business as veterinary costs and death eat up his profit margin. If he replaces it with beauty contests, in the end his beautiful contest winners will engender weaklings and degenerates. If he replaces it with screening programmes for the "elimination of genetic defects," in the end his stock will succumb to inbreeding depression as bitches fail to whelp naturally and puppies die in the nest. If he replaces it with veterinary care, in the end his stock will die prematurely of incurable cancer, or the young will fall prey to viral diseases despite repeated polyvalent vaccinations. If he replaces it with work and austerity, his stock may endure awhile longer, but in the end it will turn out to be afflicted with genetic ills that slipped through his demanding programme, or its performance will mysteriously decline as the inbreeding coefficient creeps upward. In the end, natural selection cannot truly be replaced with artificial criteria. The breeder must find a way to work with natural selection, within the framework of what is now known about the biological operation of the natural world. We in the canine fancy must begin to take lessons from wildlife biologists, from evolutionary biologists, from population geneticists.

In our quest for breed purity, the superior strain, and classic type, we have made a sad mess of our dogs - with unhappy, neurotic temperaments, epilepsy, blindness, deafness, immune system weakness, skin diseases, blood disorders, endocrine system malfunctions, crippling blood disorders, deliberate deformity, and often even the inability to reproduce their kind without breeder and veterinary intervention. How clever we have been!

Can we not now take a clear-sighted view as the millennium turns slowly over, of what we have done - of our own pitifully-flawed creation in our world of purebred dogs and, like mature, intelligent people, clear away the

mess and try to do better? Can we not learn from bad experience? If we would be truly clever, we might attempt to imitate more closely the methods of nature, to work within the natural system, albeit for our own ends. That would indeed be clever. I think that that is now possible, if we would but step outside our own incestuous little purebred world and learn something of what people working in other zoological fields of endeavour have already learnt.

A Century of Nineteenth-Century Dog Breeding

How, then, may we set about correcting the accumulated errors of over a century of what we might call nineteenth-century dog breeding? First of all it might be wise to attempt a short-list cataloguing the errors and abuses of which we are aware, the areas known to be deficient in one way or another.

- Dog shows must come high on the list. They began as an arena for the evaluation of breeding stock, they continued in the form of the "bench show" as a public showcase for purebred dogs. Both functions are now illserved if not virtually abandoned. Championship shows are now just that, mills for the production of Champions, Best in Show and Group winners, little more. They contribute almost nothing to the true welfare of dog breeds; they have few lasting positive values to offer breeders, only ephemeral fads and fashions.

- Breed purpose and the cultivation of canine utility have a low status in the fancy compared to what one author called the glitz and hype of the show world. Those who concern themselves with the working ability of their dogs exist mostly in ghettos where little communication takes place with other branches of the fancy.
- Obedience work, begun as a way of initiating dog owners into the fascination and technique of training one's pet to be a pleasant, well-behaved companion, has become largely ritualised and sterile. The pursuit of "Club 200" (the perfect point score) has become an obsession. Intelligent and useful training on the owner's part, intelligent obedience on the dog's part, are now beside the point. What matters all too frequently now is the minutely-perfect performance of a set ritual. Here again we find a canine ghetto.
- The worship and exaggeration of type, as already noted, is responsible for a multitude of ills.
- Modern registries based on a rigidly-closed studbook are throttling the genetic health of all registered dog breeds. Genetic impoverishment is now a real and present threat. Many breeds now bear a genetic load of defects which has grown totally unmanageable as their respective gene pools have become more and more narrow through imprudent breeding and selection practices.
- Incest breeding, once a convenient tool for the rapid fixation of type in newly-registered breeds, has become virtually standard practice for those who seek success in dog breeding. The net effect has been the decimation of gene pools, widespread homozygosity and the unintended fixation of unknown scores, hundreds or thousands of alleles, many of which are proving to be harmful or lethal to the animals that bear them.
- The CKC, born in the height of the Victorian era, seems to cling to cumbersome structures, making it difficult for the Club to respond in a timely fashion to external challenges or internal needs. The entire By-Law and Amendment structure could do with modernisation. Many members feel there is little justification for such practices (for example) as the three-year member apprenticeship proviso, under which new members (or old ones who for whatever reason have let their membership lapse for a year or more) are completely disenfranchised for anywhere from three to five-plus years (inasmuch as elections and referenda are triennial), costing the Club dearly in lost members and wasted talent. Many members also feel that Board of Directors initiatives are frequently arbitrary and undertaken hastily, with insufficient grassroots consultation, while initiatives from the general membership must go through a slow and cumbersome multi-stage routine before they can be acted upon. One feels a general atmosphere within the Club of elitism and ultra-conservatism, as if those in power felt that only they themselves, the "old hands," knew what is good for purebred dogs and the fancy, and that newer members should not be entrusted with the franchise.
- Breed clubs seem to possess little real power to represent breeders or their breeds effectively. Special measures which they may feel essential for the health, development, and protection of the breeds whose breeders they represent must be put through the centralist CKC system and approved by the Board before they become effective; often such measures have little chance of approval because they

are felt to conflict with the rigid all-breed norms of the Club. Since breed clubs have relatively little real power, they often tend to be less than fully representative of all breeders of a particular breed. Frequently they are more or less run by cliques; they waste much time and effort in wrangling and personalities, being perhaps inadequately supervised and not taken terribly seriously.

- Breeders, as well, are sometimes far from free to make their own responsible decisions for the best interests of their own dogs and bloodlines being closely constrained by CKC Bylaws and by the Animal Pedigree Act. Little discretion is given them regarding matters such as the withholding of registration papers, delaying registration of stock until it reaches physical maturity, the introduction of new genetic material when in their judgment it is needed for genetic health, etc.

Many of the abuses and deficiencies not rooted in outmoded attitudes such as racism and elitism arise from misunderstandings of genetic realities. Let us now examine briefly a few points of up-to-date genetic theory as they relate to purebred dog populations.

Lessons from Population Genetics

Gene Frequencies

Much of the work of population genetics involves estimating or calculating gene frequencies, which quantify the relative commonness or scarcity, within a particular population, of alleles at a particular gene locus. If there is only one version of a gene in the population, then the entire population is necessarily homozygous for that gene. Gene frequencies are expressed as decimal fractions which must add up to unity, so a gene without alternative alleles has a frequency of 1.0. The gene frequency figure is a ratio of the number of copies of alternate versions of a gene in the population, independent of the number of animals involved and of whether they have the gene in homozygous or heterozygous form. An individual may have two copies of the same allele or it may have one or none. For example, if a locus has two alleles, and the population involved consists of fifty animals, and there are 25 copies of one allele, then the frequency for that allele is 0.25; therefore the frequency of the other allele must be 0.75, with 75 copies of it in the same population. It must be emphasised that gene frequency by itself says nothing about relative heterozygosity or homozygosity; it deals only with quantitative aspects of alleles in the population, not the diploid genotype of individuals.

Founder Events

Perhaps the most crucial concept in population genetics for dog breeders is the founder event, for its theory describes perfectly what takes place when a breed is "recognised" by CKC or a similar registry. Whatever may be the state of genetic balance or the frequency with which particular alleles are found in the general canine population, it all changes when a founder event occurs. In nature such events happen when individuals of a species occupy and reproduce in territory new to the species, losing contact with the source population of the migrants (as when small birds are deposited by hurricane winds on mid-ocean islands). The founder event describes the establishing of a small population, although later on it may grow to be a large one. When a finite number of individuals found a new population group, the genome of the new group will necessarily reflect the genes brought to it by the founder animals; gene frequencies within that population will reflect the gene frequencies within the founder group rather than that of the source population. In this way, when a founder event occurs, a gene quite rare in the source population may have a much higher frequency in the new population; conversely, genes common in the source population may be infrequent or even absent from the new population. It all depends on the genes of the founders! Thus a genetic defect extremely rare in the overall canine population can come to be common in a particular breed simply because one or more individuals of a small breed foundation carried that gene.

Hardy-Weinberg Principle

The Hardy-Weinberg Principle states that under certain specific conditions (random mating, very large population group, no mutations, absence of selection pressure, for example), the relative allele frequencies of genes at a given locus will not change from generation to generation and can be described by an equation,

allowing the geneticist to create a mathematical model of gene frequencies within the population. Without trying to explain the equation and its operation here, we can still say in general that the net result is that heterozygote organisms will be much more numerous than homozygotes in a Hardy-Weinberg population. Many natural populations can be described in this way, although purebred dog populations cannot, since they are subject to inbreeding, artificial selection, non-random mating and small populations. Nonetheless, the principle has a certain significance, in that the overwhelming preponderance of heterozygotes in natural populations means natural selection tends to favour the heterozygote. Thus the natural genetic balance systems of most species include a high degree of heterozygosity [Carson, 1983]. When we as dog breeders use incest breeding and artificial selection to fix characteristics arbitrarily, we are therefore quite likely to upset the natural genetic balance of the canine species in our breed populations. Moreover, the natural preponderance of heterozygotes is rendered even more important by overdominance effects, described below.

Genetic Drift

Small populations, such as most purebred dog breeds, are subject to a condition known as genetic drift. This is a situation in which gene frequencies change at random from generation to generation, varying from statistical expectations because of sampling error. (Sampling error occurs when too small a number of trials departs from the expectations of probability, as when someone flips a coin six times and gets five heads and one tail - if he flipped it 600 times, the results would be close to 300 heads, 300 tails, but in a small sample, chance can cause a departure from the expected result.) This happens also when gametes unite to form zygotes in reproduction; the union of gametes is at random by hazard. A dominant black dog, whose dam was white, when bred to a white bitch should in theory produce equal numbers of white and black pups, but few breeders would be very surprised to see 2 whites and 6 blacks, or vice versa. Yet when such sampling errors occur in small populations, over subsequent generations gene frequencies can change, taking a random walk that leads finally to the loss of one allele and the fixation of the other! The smaller the population, the fewer generations this result is likely to take. In a very large population, it will not happen at all. Genes are lost and other genes fixed completely at random in this way by genetic drift.

Generation Time

Since in limited, genetically isolated populations such as CKC breeds a certain amount of genetic diversity is lost with each reproductive event through the action of genetic drift, inbreeding and artificial selection. The number of generations from the founder event becomes an issue. The average time between one generation and the next is a convenient yardstick to help us realise the relative rate of genetic attrition. A few instances exist in which certain bloodlines - working dogs, usually - are bred conservatively enough that the generation time is as much as an average six or seven years.
But this appears to be exceptional. Many exhibition lines seem to operate on the following model: "Phoo-Phoo" starts his show career at six months of age in Junior Puppy class, is heavily "campaigned" and has all his Championship points by ten months of age. The owners' immediate "bragging ad" in "DOGS in Canada" or the breed club newsletter recounts his triumph, adding that "puppies from Ch. (subject to CKC confirmation) Phoo-Phoo are eagerly awaited next month". In such lines the average generation time may be two years or even less. This reproductive rush has two implications: first, a greatly accelerated rate of loss of genetic diversity; second, an implicit selection for early maturity which carries with it an elevated risk of joint disease and a lowering of average longevity.

Effective Breeding Population

The population figure that matters in situations such as random genetic drift is not the total number of individuals alive at any one time. Nor is it even, as one might think, the actual number of individuals that contribute progeny to the next generation. Variations in breeding population from one generation to the next have a marked effect, such that the effective breeding population, especially where variations in number are extreme, tends to be only modestly greater than the lowest number. Another factor which makes a great difference and is crucially important in purebred animals is the sex ratio of successful reproductors. The effective breeding population can never be greater than four times the number of males, no matter how numerous the females may be, since gametes must come from both sexes. Thus anything that limits the number of males in use drastically restricts the effective breeding population. Overuse of popular sires is a tremendous factor in the genetic impoverishment of purebred dogs. One of the major drawbacks of the proposed CKC Advanced Registry is the virtual certainty that the existence and promotion of a few "elite" sires, titled, temperament-tested and

certified "clear" of major hereditary diseases, will further dramatically reduce the effective breeding population in many breeds, causing further declines in breed vitality and viability and leading to the loss of vitally-needed breeding lines which happen not to be among the elite group.

Linkage Disequilibrium

Genes found on the same chromosome will fail to assort independently in accordance with Mendelian principles. Such genes are said to be in a state of linkage disequilibrium. This simple fact has a devastating effect in artificial selection, since it means in practice that when a breeder selects for or against any single-gene trait whatever, whether he is aware of the fact or not he is also selecting for or against every other gene located on the same chromosome. This is how genetic defects become rapidly fixed in inbred populations subjected to artificial selection. Since dogs have only 78 chromosomes (diploid number) but many thousands of genes, obviously linkage disequilibrium can be tremendously influential. Genes that are linked eventually become unlinked over time (except in certain special situations) through crossing over, a process whereby chromosome pairs exchange segments of their DNA structure during meiosis. The unlinking process however, is slow and unpredictable; it offers little hope of remedying the linkage disequilibrium problem in a few generations and of course is no help at all where deleterious alleles have already become fixed.

Overdominance

Situations exist in which a heterozygote individual enjoys a survival advantage over both the recessive homozygote and the dominant homozygote of the same gene; this is called overdominance or heterozygote superiority. As yet not much seems to be known about this mechanism and proven examples of specific overdominant genes are rare. Nonetheless this mechanism may be one reason (apart from their usually recessive nature) why genetic defects are persistently found in genomes despite their apparent fitness disadvantage in the homozygous state. While on this subject it is worth noting that population genetics offers mathematical models for various forms of selective breeding, including the selective elimination of individuals bearing homozygous recessive genes for harmful traits. These models demonstrate that the elimination from the breeding population of individuals homozygous for unwanted traits has only the smallest effect in changing the allele frequency! It has been calculated, for example, that to reduce the expression of the recessive albino gene in humans from one in ten thousand to one in one million, simply by prohibiting albino (i.e. homozygote) individuals from having children, would require nine hundred generations of such selective breeding to accomplish! This is one of several reasons why screening programmes, although perhaps profitable for the veterinary profession, are of questionable effectiveness, since they identify only affected (usually homozygous) individuals.

Heterosis

More commonly known as hybrid vigour, heterosis is a situation in which a cross of two or sometimes three highly-inbred bloodlines displays enhanced performance for some desired trait, as for example higher yield in corn. It works best in plant species capable of self-fertilisation, but has been amply demonstrated in domestic livestock species. It is worth noting that in practice many different inbred lines must be developed at the same time, that most of the inbred lines become so unfit that they must be discarded as they become non-viable, and that considerable random trial of different crosses must be done to establish which lines will actually yield the desired result. Although the seed-grower's methods are unsuited to purebred dogs, the overall principle is of interest, since it is thought that heterosis works because of the heterozygosity of the hybrid generation, probably through the action of both dominant and overdominant genes. Geneticists are now starting to realise that the balanced-heterozygote systems of many wild species involve a heterosis effect which gives them a high degree of fitness.

Inbreeding Depression

As genetic variability diminishes and homozygosity rises through inbreeding, a syndrome known as inbreeding depression sets in. It is characterised by a reduction in viability (survival of individual progeny), birth weight, fecundity (number of young) and fertility (reproductive success), among other things. Much of it is caused by the homozygous presence of rare, deleterious recessive alleles. Part of it may also be due to the relative absence of overdominant heterozygote combinations. As inbreeding depression becomes more severe, highly inbred lines tend to become extinct through the loss of ability to reproduce successfully and / or inability of the young to survive. It varies somewhat in intensity from species to species, due probably to variations in the number and

nature of lethal, sublethal and subvital alleles involved. Some wild mammals which show almost no juvenile mortality when bred in captivity without inbreeding, exhibit 100 percent juvenile mortality when inbred! A survey of captive breeding records for 44 species [Ralls & Ballou, 1979, 1982] showed that juvenile mortality of inbred young was higher than that of noninbred young in 41 of the 44 species for which records were analysed.

Genetic Load

The difference between the fittest genotype of a population and the average fitness of that population is known as genetic load. [Muller, 1950] It is, of course, caused by the presence of lethal, sublethal and subvital alleles. The more such alleles found in a population, the greater the genetic load. Genetic load is sometimes measured by the number of lethal equivalents, and the severity of inbreeding depression can be quantified in this way. Humans in general normally carry in a heterozygous state from 5 to 8 lethal equivalents per person - genes or combinations of genes any one of which, if homozygous, would cause the death of the organism. It should be emphasised that genetic load is present in every population, since never are all individuals maximally fit. The presence of lethal, sublethal and subvital genes is a normal state of affairs in all species. Homozygotes for such genes are usually so infrequent as to have little effect on species fitness. It is only when founder events and inbreeding occur that the gene frequency of deleterious alleles rises and genetic defects start to become a problem as the growing genetic load degrades the fitness of the inbred, limited population. Thus in the case of purebred dogs the problem does not inhere in the presence of "defect" genes, but in the registry and breeding practices of the purebred dog fancy!

Balanced Heterozygous Population Structure

In recent decades growing evidence from DNA studies of protein polymorphism conclusively disproved the "classical" view of species as being homozygous at most loci, with the phenotypes of all individuals of a species conforming to that of a type specimen. Population geneticists and evolutionary biologists now realise that typological concepts are useless in a natural world in which populations may best be described genetically not as individuals conforming to a type but as arrays of genetic variability. Some of the implications of the "balance view" are elucidated by one geneticist as follows:

Species that are diploid and cross-fertilised [this includes all mammals]... characteristically carry large stores of genetic variability in a balanced state in their populations... Genetic recombination naturally generates diverse genetic types from the large field of variability in the gene pool. In order to meet environmental challenges, natural selection in many such organisms tends to develop a system based on the higher fitness of heterozygotes. These are maintained under regimes of selection that exploit the advantages of heterozygosity for many alleles simultaneously. In these, the large amount of genetic variability is continually being recombined as balanced hybrid vigour is maximised...

The genetic system is not a fixed and frozen entity but is dynamic and variable... By its very nature, this genetic system is inimical to the perpetuation of sameness. At each reproductive event an enormous field of genetic variability is produced. Most of the variability is held in sexual populations by a complex balancing selection based on the superiority of fitness of heterozygotes...

The biological conserver, short of putting the DNA into liquid nitrogen, cannot hope to freeze the characteristics of any natural population, be it a deme (local population), a subspecies, or a species.

Hampton L. Carson. The Genetics of the Founder Effect, 1983

Efforts at artificial selection and breeding which attempt to defy this system of balanced heterozygosity and variability will almost certainly fall foul of the kind of difficulties we are now encountering in purebred dog breeds. It is hopeless to attempt to freeze the genetic characteristics of small populations and even the attempt, which is doomed to eventual failure, is quite costly in terms of the loss of hardiness and viability. Artificially selected populations, too, can and should be maintained in a state of dynamic heterozygous balance. Thus the entire problem of genetic defects would be minimised.

Assortative Mating

Assortative mating is a method of selective breeding capable of creating homozygosity for desired traits without having as great an effect on overall homozygosity as does inbreeding. It consists of mating phenotypically similar individuals that are not closely related. This method of selective breeding would be capable of maintaining a reasonable range of breed type in a balanced-heterozygosity breed system with an open studbook. Having now acquired a few of the more crucial concepts of population genetics, we are prepared to examine in a new light the nineteenth-century system of dog breeding and registration which we have inherited. As we prepare to enter the twenty-first century, perhaps we can conceive a renewed system which will serve our dogs and their breeders far better than the present one.

The Crux of the Problem

As we face the millennium, the one problem which most concerns the entire purebred dog fancy is genetic defects. Breeders used to worry about overshot/undershot bite and cryptorchidism. Not much else of a genetic nature was cause for concern; fanciers were a lot more worried about distemper, hepatitis and internal parasites. Breeding programmes concentrated on individuals' visions of canine excellence. Then in the 1960s the tip of the genetic iceberg emerged as concern grew about a joint disorder called hip dysplasia. A control programme involving the examination of hip xrays by a skilled scrutineer and the maintenance of a registry of animals "cleared" of the defect was established at the Ontario Veterinary College at Guelph, Ontario. Now after three decades of the OVC programme it has been pretty well established that "clear" animals with several generations of "clear" ancestry can nonetheless produce dysplastic progeny [Chidiac-Storimans 1995]! Hence the OVC control programme would seem to be of questionable effectiveness. As the generations of closed-studbook breeding have advanced, a panoply of other inherited problems has emerged in purebred dog breeds. There is no need to list them here; the list would be on its way to obsolescence in a month or so; veterinary research continues to define more inherited disorders regularly. Many breeders now run four-way screening programmes; some may screen for even more problems. Many breeders' selection programmes for various kinds of canine excellence must now be at a standstill - all the selection is going into the effort to produce stock "clear" for eyes, hips, elbows, blood disorders, endocrine dysfunction, etc. Yet thirty years of xrays have not eliminated hip dysplasia - it is now widespread in breeds in which it was not a problem thirty years ago.
In December 1994, **Time** magazine published a scathing indictment of the American Kennel Club and of purebred dogs and their breeders, targeting in a cover story the problem of genetic ills, suggesting that the best use of pedigree papers was for housebreaking the puppies and recommending that the public satisfy its desire for canine companionship with mongrels. Since then, most of us have known we have an untenable situation on our hands. Our reputation as breeders of purebreds is now in tatters; we are caricatured in the media as greedy, uncaring producers of degenerate animals. The CKC's main response to the situation was a Board policy statement that "reputable breeders will provide a detailed written guarantee of the present and future good health of the dog and will not hesitate to uphold their guarantees." The policy statement, far from helping the situation, only saddled breeders officially with a heavy responsibility without enacting measures which might assist them in living up to it.

It is time for us as dog breeders to stand up for ourselves and for our dogs, to reject the imputation that we ourselves are individually to blame for the problem of genetic defects, and to demand swift remedial action by the Club and, if necessary, Agriculture Canada. The crux of the problem is the closed studbook and with it, the ideal of breed purity, the worship of type and the preeminence of the championship show as goal and arbiter of most breeding programmes. Armed with the concepts of population genetics, we can now examine the last: century of nineteenth-century dog breeding, ascertain what has gone wrong, and establish ways and means to correct the situation.

Earlier we stated that the recognition of a breed by a registry was a crucial event in its history, more crucial than it need be. That is because the usual practice has been to open the registry to foundation stock for a limited period, to inspect and register a small population of foundation animals, and then to close the registry to new genetic inflow forever after, with the sole exception of animals of the same breed imported from other registries and derived from the same or closely-related foundation stock. In recent decades there has usually been no unique Canadian foundation stock except in the case of indigenous breeds; CKC merely accepts registered stock from other jurisdictions. (Actually the relationship of CKC foundation stock to that of other registries has never been clearly defined, so far as I know. CKC accepts registration papers of other studbooks which it considers to be "reliable." So long as the export pedigree shows three generations of registered, numbered ancestry; import stock seems to be eligible for CKC status without question. The criteria involved are clerical, not genetic.) Most of the breeds we are familiar with were founded from sixty to over one hundred years ago. In those days

Canada's population was much smaller than it is now; the canine population was correspondingly smaller, too. Thus the number of dogs accepted during the open-registry periods was rather limited.

The canine species possesses tremendous genetic diversity as a whole. Like most species, that diversity includes a genetic load, a wide variety of more or less deleterious alleles, probably quite a few of them held in a state of heterozygote superiority, so that although natural selection tends to eliminate homozygote recessives when they segregate, the bad alleles themselves maintain a strong presence due to the selective advantage of the superior heterozygote. What happens when a founder event occurs? Then it is possible that bad alleles, uncommon in the canine population as a whole, may achieve a much higher frequency of occurrence owing to their presence in a small founder population - especially since the foundation stock of a newly-recognised breed will already be considerable inbred from the breed development process. Inbreeding and selection together raise homozygosity levels dramatically through the wholesale elimination of alleles from the genome. Those alleles may be unwanted by the creators of a new breed; nevertheless their elimination raises the allele frequency of whatever remains.

An Example from One Breed

Thus the recognition of a breed creates a founder event when the registry is opened; a limited number of breed foundation animals are selected, often from a population which has already undergone considerable inbreeding and selection. Let us take for an example the Siberian Husky breed. Registered in 1939, the initial CKC population consisted of 47 animals, all belonging to or bred by one kennel! Of those 47, nine were foundation stock of the kennel whose dogs were registered. Two of those were males imported from Siberia - littermate brothers! The other seven were mostly related to one another. (Two were seven-eighths Siberian and one-eighth Malamute.) The other thirty-eight were all progeny and grand-progeny of the founders. Of the nine foundation animals, two were not bred from at all. Two were mated - once only - to each other: one only of their progeny contributed to further breeding. Of the two Siberia import males, one brother was always bred to the same bitch, producing a large number of progeny of identical pedigree; the other brother was usually bred to daughters of the first brother. Today Siberian Husky lines that trace directly back to the Canadian foundation stock owe 25% of their pedigree lines to the first brother, 15% to the second brother, and 27% to the first brother's invariable mate! Two-thirds of the genetic heritage of these modern Siberian Huskies derives from only three foundation animals! This is not an exceptional situation, it is a fair example of the early breeding history of CKC breeds.
In the case of the Siberian Husky, then, (which happens to be my breed, with whose early history I am reasonably well familiar), The Canadian Kennel Club opened a registry in 1939, inspected one kennel's dogs and admitted four dozen closely-related individuals to the registry, which was then closed permanently. No effort was made to ensure a broad foundation, nor a numerous one, nor a genetically diverse one.

Just how permanently the registry was closed I recently found out when I imported from Russia a dog bred to the Siberian Husky standard! The dog was born in the Ural Mountains well within the boundaries of Siberia from parents of Chukotkan village origins; he had three generations of known ancestry (without registration numbers since there is no official "Siberian Husky" registry in Russia). I was immediately told that the Club "did not know what to do" about my application to register the dog, that the protocols used to register breed foundation animals in 1939 were no longer valid, and that my dog "should not be used for breeding because it would probably be a long process," in spite of the fact that the dog had a valid FCI Export Pedigree from the Czech Republic (through which he was exported). A year and a half later after repeated in camera discussions, the import was refused recognition by the Board and Registration Committee on grounds of inadequate information (no ancestral registration numbers). Repeated calls for Club inspection of the import and offers to submit the animal to DNA tests and progeny testing were ignored. The registry is closed - even to new Siberia imports!

For the past fifty-six years, then, all Siberian Huskies bred in Canada have stemmed from the 1939 registrations, or from American imports, which mostly stem from the same dogs CKC registered, plus perhaps three additional animals. The original foundation animals were poorly utilised and subsequent generations were so closely inbred that the two Siberia import males plus one bitch are even today still statistically equivalent to grandparents of every single Siberian now registered!

Thus the original founder event in my breed plus the closed studbook has resulted in a state of forced inbreeding for Siberian Huskies. There is no such thing as an outcross mating in Siberians in any genetically meaningful sense. A sire can be found, perhaps, who may have no ancestors in common with a bitch for the last 5 or 6 generations - if one knows all Siberian bloodlines well enough and doesn't mind going a few thousand miles to find him - but he will not be an outcross, because all of his ancestors and all of the bitch's ancestors are the same

animals, once the pedigree is taken back far enough. It would be difficult to calculate inbreeding coefficients for fifteen to thirty generations of ancestry; software to handle calculations of that nature doesn't seem to be generally available to breeders. (After all, a thirty-generation pedigree would contain over two billion names.)

Thirty generations of breeding all going back to ten dogs or fewer represents an impressive feat of sustained inbreeding! Predictably enough Siberian Huskies, which eighty-five years ago were probably the toughest, hardiest variety of dogs on earth, now suffer from the same gamut of genetic defects that afflicts other breeds. Few if any registered Siberians are now able to perform as sleddogs on anything approaching the level of the 1910 dogs imported from Siberia. Probably this is mostly due to the decline in heterozygosity and loss of vitality through inbreeding. What is worse, unmistakable signs of inbreeding depression are surfacing in the breed: rising numbers of Caesarean births, smaller litters, lower birth weights, delicate nestlings prone to infection, etc. Breeders of domestic livestock - cattle, poultry, sheep - manage to run registries and maintain breed type without imposing the concept of absolute breed purity. They inbreed to fix desirable traits, as do dog breeders. Livestock breeders, however, do not try to pretend that they can inbreed forever without ill effects. Thus when inbreeding depression or genetic defects threaten, they outcross - repeatedly, if necessary. They can do so because they do not have closed studbooks. I do not suggest that we slavishly copy the procedures and registry structures of livestock associations, because I think they, too, might benefit from some restructuring in the light of modern genetic knowledge. Nonetheless I would make the point that we in the canine fancy are in a minority when we cling to absolute ideals of breed purity and insist on rigidly closed studbooks.

As a dramatic contrast to the foregoing example of the CKC's Siberian Husky breed foundation, let us examine for a moment the standards which Agriculture Canada now applies to new domestic animal breeds in this country, as set forth in a three-page leaflet entitled "Establishment of a New Breed of Animals in Canada." Agriculture Canada now requires that breed foundation stock (that is to say, the first generation of registered animals of a new breed) be selected from the third filial generation (F3) or later of the "evolving breed" which precedes the actual, registered new breed. It lays down no parameters for the founder generation of the evolving breed, but it does state:

The standard used for the creation of a new breed is as follows:

- Minimum number of animals to constitute the foundation stock of the new breed (F3): 200 animals (unique genotypes).
- In order to reach the required 200 F3 animals and in order to provide a sufficiently wide genetic base, it is recommended that the minimum number of animals to be produced in each F level be:

  Fl : 60 animals
  F2: 100 animals

It also stipulates that "the F3 generation is the earliest generation to become eligible for inspection as foundation stock... In practice most evolving breeds will evolve over many generations before having developed a significant population of foundation animals."

These modern standards are at least somewhat influenced by population genetics considerations, in an attempt to establish a basis for genetic health and stability for new animal breeds in Canada. Yet (in all probability very few of our existing CKC dog breeds, which are arguably of much greater economic importance than any new breed, would come anywhere near to the foundation stock numbers now enforced by Agriculture Canada. The sole exceptions would probably be breeds, like the Canadian Eskimo Dog, accepted for registration during the last decade or two. As for the Siberian Husky, its actual genetic founders (those whose genes contributed to future generations, leaving aside those which did not reproduce) numbered 6 only; the Fl generation which actually reproduced numbered 8 individuals; the F2 generation which actually reproduced numbered just 5 animals; no F3 animals were registered in the first year of CKC registrations -- original founders. F1s and F2s were all registered together in the first year.

Thus it is obvious that the Siberian Husky, at least, could not begin to satisfy current Agriculture Canada standards for an appropriate number and variety of foundation stock to establish a new breed, when traced to its historic foundation. In all probability, few CKC breeds could do so. Yet the registry norms that are rigidly enforced by CKC, backed up by Agriculture Canada make the acceptance into the studbook of badly-needed new

foundation stock a complete impossibility! Presumably Agriculture Canada has good and sufficient reasons justifying its standard for new breeds -- that being the case, then it is a curiously irrational situation that older, existing registered breeds not only are exempt from any such standard, but are actually prohibited from enlarging their founder group by the acceptance of unrelated primitive stock.

The Holistic Breed

Now I would like to evoke a vision of the future -- but not the distant future. I want to describe how dog breeds might be in the twenty-first century. Instead of all breeds being subjected to arbitrary structures not equally well suited to them all, each breed would get whatever special measures its breeders thought necessary. Instead of a fragmented canine fancy with ghettos of show, fanciers, obedience buffs, and working-dog specialists, dog breeds would have the benefit of a holistic outlook, integrating the various aspects of canine: activity and producing well-rounded, versatile, mentally stable animals. Let me stress that the suggestions which follow will be fully practical and down-to-earth. They involve no technology we don't already possess. They require no knowledge that isn't already generally available. All that is needed is a proactive attitude and the will to make necessary changes in an obsolescent structure. This vision *could* become a reality within ten years time.
At the beginning of this brief I stated that the three distinct axes along which breeds are distinguished -- ancestry, purpose, and typology -- had to relate fully and cooperatively, or the fullness of breed identity would be missing or marred. Let me now describe how such a relationship might he achieved.

To begin with, we absolutely must open CKC stud books, in every breed, to new genetic inflow. There can be no long-term genetic health in small populations such as our registered breeds without the periodic infusion of new genetic material. The one big "sacrifice" we shall have to make, if it is really a sacrifice, is to abandon racist attitudes and the concept of rigorous breed purity. We must recognize that first of all, a dog is a dog, species *Canis familiaris*, and that is his true identity. He is a dog first, before he is a Siberian Husky or a Foxhound or a Doberman; breed identity is subordinate to species identity. We must stop treating breeds as if they were species, abandon the rigidity and narrow typological thinking which has heretofore characterized the canine fancy. We must recognize that dogs are unique individuals and that there is no positive value in trying to create groups of dogs which are all clones or photocopies of a type specimen represented by a breed standard. This should not be too hard, since breeders and judges have never been able to arrive at agreed and consistent interpretations of breed standards anyway. Why, then, should we pretend that a standard, which as it now exists evokes a different imagistic interpretation in the mind of each individual breeder and judge, describes a single ideal type?

Canine breeds can and should be differentiated, bred and maintained on a dynamically balanced, heterozygous population basis without restriction to a closed, historic founder group. The closed studbook and the breed purity concept are, from a genetic point of view, simply unnecessary. Indeed, as we have seen, from the standpoint of maintaining a genetically healthy limited population, they are thoroughly counterproductive. Where is the logic in submitting each and every CKC breed to a registry system which guarantees ongoing, progressive genetic degeneration, loss of species vigor and hardiness, and saddles every breeder with the unwanted, unhappy responsibility of producing more and more unhealthy, flawed stock as time goes by? The notion that genetic disease can be controlled, much less eliminated, by screening programs and selection has not been borne out by general experience. Those who promote such a notion are engaging in a cruel, self serving deception. It may be that a breeder can sometimes improve his odds against producing defective stock in a given mating by screening the parents, but experience has proved that screening will not solve our genetic problems in any wider sense. Despite generation after generation of "clear" stock, bloodlines can still produce more and more affected animals. That is because our problems are inherent in the closed studbook/incest breeding system. In order to restore genetic health we shall have to adopt a different system.

It will be asked, "Just how will the opening of our studbooks to outcross stock bring about the elimination of genetic defects?" The answer is that it will not *eliminate* genetic defects. That need not be the end in view. If we could somehow eliminate all the various genes now known to produce harmful anomalies, plus all of those yet to be discovered, we would almost certainly find that the remaining genome was non-viable, that healthy reproduction and growth to maturity could not reliably take place. Genetic defects are not "eliminated" in nature. Instead random mating and behaviour patterns that discourage inbreeding take care of the problem by ensuring high levels of heterozygosity and the consequent rarity of defective homozygotes. If we take steps to set up similar patterns in purebred dogs, we shall be able to reduce the ***level of expression*** of defective genes greatly, which is all that is required. The end in view is healthy stock, not "racial purity." Purged and purified bloodlines would be weak for other reasons, as has been explained. As the mapping of the canine genome progresses and RFLP allozyme or microsatellite "markers" for common genetic defects are found, we shall probably then be

able to use DNA studies to recommend matings that will avoid the production of defective homozygous progeny -- provided that we have made enough genetic diversity available through outcrossing to give us the genetically distinct lines from which to choose! As things stand now, most breeds are so homozygous that it could prove extremely difficult to find matings which would avoid one genetic defect without reinforcing another!

New Structures for the Dog Fancy

Very well, then, if we eliminate the closed studbook, how shall we decide what stock to admit for registration? One must begin, of course, with the existing body of registered stock. Thereafter, one way of proceeding might be to strengthen and empower the breed clubs. They should be granted responsibility and autonomy: responsibility for the welfare of their breeds, and autonomy to make the judgments and decisions necessary to fulfill that responsibility. It should also be ensured that the breed clubs are fully representative of all breeders, by making breed club membership a requirement for anyone wishing to register stock he has bred or imported.
The first task of the breed clubs would then be for each of them to determine what sources of genetic inflow might best be employed in their breed. Breeders alone can command the collective expertise to make that decision and it ought to be theirs alone, but the designation of outcross sources should be obligatory, not optional. The Siberian Husky Club of Canada, for example, would have to decide where outcross animals might best be obtained for restoring heterozygosity to that breed; they might decide, for example, that dogs imported from Russia and perhaps even an occasional outstanding individual carefully selected from the present "Alaskan husky" gene pool of racing sled dogs (which was derived largely from 1910-era Siberia imports that remained in Alaska) are two logical sources. Breeds which do not have their origins in autochthonous populations would have to seek outcrosses in similar related breeds, as Spaniels (English Springer) and Spaniels (Welsh Springer), or Retrievers (Labrador) and Retrievers (Flat-Coated). They would then have to set up inspection and test-breeding procedures for admitting outcross animals. Once the outcross sources had been designated, selection of candidate animals would in most cases be best left to individual breeders, who might then apply to the breed club for preliminary inspection of their outcross -- which inspection ought not to be excessively rigorous. General soundness, reasonable temperament, proven working ability, approximate size and physique, and acceptable overall type should be adequate criteria, none of the foregoing to be rigidly interpreted. The outcross should then be registered provisionally by CKC, subject to breed club inspection of two generations of its progeny. The registry should remain permanently open to new outcross animals. It might prove desirable to set limits to the number of outcross dogs registered in any given year proportionate to the overall breed population, in order that small populations not be swamped by excessive outcrossing. Some regulation of the process would obviously be necessary, but the best regulation would probably be breed club oversight and guidance of the process, backed up by CKC supervision.

Advantage should be taken of DNA analysis techniques by using them to monitor heterozygosity and relative kinship in major breeding lines. (It would also be a good idea for the Club to offer DNA profile parentage certification.) This technology already exists and is in use: it is rapidly becoming much more affordable. Limits should definitely be set on inbreeding, preferably by the breed clubs, but CKC should decide maximum allowable limits of inbreeding as a default setting. Only by the outright prohibition of excessive degrees of inbreeding will it be possible to make the transition to a balanced-heterozygous state for purebreds; otherwise old ways will continue through inertia and persistent typological thinking. Assortative mating can and should become the norm for the preservation of type, mating individuals which are phenotypically similar but unrelated or at least not closely related. The Club would have to monitor registrations, possibly performing occasional DNA spot-checks, to ensure that inbreeding does not take place; otherwise many would continue to breed from whatever dogs were in their own backyard rather than seeking breed club advice to find suitable individuals from unrelated lineage.

A Healthy Balance, for Breed Identity

The responsibilities of the breed club should not end with the designation of outcross sources and the inspection of outcross candidates. If the fullness of breed identity is to be achieved overall in each population, then the breed clubs should take on responsibility for balancing the various facets of that breed identity. Realistic, meaningful and workable systems should be introduced for monitoring temperament, for proving working ability and trainability, and for evaluating, type and appearance. Championship shows would then become breed-club events, since the methods of evaluation and the various events required to test such qualities as temperament, vigor and endurance, working ability, and trainability would be breed-specific and under the breed clubs oversight. That is not to say that a number of breed clubs might not band together to stage events for several breeds simultaneously at the same venue, but the all breed show with all-rounder judges, under CKC rules for

CKC Championship points, would eventually be history. To ensure wholehearted support and participation by breeders, it would probably be necessary for CKC to evolve some means of making clear on the papers of every dog the extent to which that animal had been submitted to the testing and evaluation procedures of the breed club and with what result. Breed club input of information to the Clubs database could be done by e-mail on the day of the event. Strong incentives for participation should be arranged and breed clubs should be so structured that they could not be autocratically ruled by individuals or cliques.
Registration certificates produced by CKC would carry much more detailed information under the new system than they now do. The computer power is now available to make this quite feasible. A certificate of registration should once again carry a pedigree of at least four generations. A two-tier certificate system would be necessary, as no dog would be eligible for breeding registered progeny until it had been inspected and evaluated by the breed club. Rating and measurement protocols are already being worked out by proponents of the Advanced Registry proposal. Broodstock certificates should carry a summary of the breed clubs rating and evaluation of the animal, together with evidence of proof tests for temperament, working ability and trainability. All certificates should identify outcross lines and bear a quantitative estimate of the relative heterozygosity of the animal identified by the certificate.

Breed standards would require revision under the new system. The concept of disqualifications should probably be dropped in favour of a detailed rating system in which all breeding stock would participate. In the case of quantitative characteristics such as height and weight, a simple Bell curve statistical description of the desired mean and range ought to be sufficient, without disallowing occasional extreme examples. Working abilities ought to be clearly defined in the breed standard and a basic performance standard given where possible. Clearer and more detailed descriptions of desired temperament and of qualities bearing on trainability ought to be part of the new standards. Prescriptive minutia should be minimal; it should be sufficient merely to describe the general distinguishing features of a breed, without an excess of cosmetic and conformation restrictions, except where indispensable breed points are involved. Type stringencies should be relaxed considerably, allowing most breeds to become moderately heterotypic; if qualities of working ability, hunting instincts and similar traits achieve greater emphasis, there will be correspondingly less need for extreme type requirements to distinguish breeds. Standards should be holistic descriptions of the breeds they identify, brief statements of essential breed qualities, rather than typological blueprints. It is imperative to subordinate typological thinking to considerations of utility, genetic health and hardiness. First a dog should be healthy, balanced, of sound mind in a sound body, able to fulfill his breed purpose; after that can come points of beauty and type but never again in the bizarrely exaggerated fashion that now prevails in the breed rings of championship shows.

It might eventually be found desirable to quietly merge scarce and consistently unpopular breeds, as well as closely similar breeds, with populations nearest to them in general characteristics, possibly initially designating them as breed varieties. Reasonable numbers are necessary for the maintenance of a healthy population. The number of breeds recognized has continued to grow, yet the total number of dog owners in the country may not have grown proportionally. A rare breed is not the same thing as an endangered species; breeds can come and go without damage to the canine species as a whole. Breeds known to be of low viability due to their dependence for breed identity on anomalies such as achondroplasia, may have to be dropped from the registry unless evidence is advanced that they can be upgraded to certain minimum standards of health and structural soundness.

Can it Really Work?

I can hear someone objecting, after having thought about the idea of a breeding and registry system in which outcross breeding was actually encouraged, "Surely this system will produce some dogs which are not even recognizable representatives of their breeds! What happens then?" Typological thinking dies hard. I used to worry lest my Siberian breeding program should one day produce a dog or dogs whose ears were not fully erect. It never happened. Instead something much worse happened when I found that I was producing some dogs who ran a high risk of being unable to lead a healthy, normal canine existence, through endocrine malfunctions, immune system weakness, and the risk of blindness. To think I had worried about the possibility of a tipped ear, something which would not handicap or bother the dog in the least! Let me say the following, then, to those who worry that a balanced-heterozygous breed will engender "untypical" examples. It is far better that our breeding occasionally engender a dog deficient in breed type, than that we should consistently produce large numbers of dogs guaranteed to lead lives of suffering, creating anxiety, large veterinary bills, frustration and unhappiness for their owners. That is what we are doing now. Over sixty percent of Golden Retrievers, for example, will suffer from hip dysplasia, osteoarthritis or osteochondritis in their lifetimes. Is that to be preferred to the possibility of producing an occasional robust "mutt" lacking in breed type but who will nonetheless still make someone an excellent happy, healthy companion? I am sure that it would take awhile for all of us to learn how to breed in this

new and different way; I suppose we might produce occasional oddities in the process. Yet I am absolutely convinced that the good results we would quickly achieve would more than make up for the embarrassment of our failures. At the very least we should all have clean consciences once again, knowing that we were making our best efforts, using up-to-date genetic knowledge, to produce sane, healthy, robust canine companions. Let us not forget that as DNA mapping procedures advance (there are at least two canine genome mapping projects now under way) our tools are going to improve and our ability to predict what our breedings may produce will be greatly enhanced.

As things now stand, the dog fancy is in a position which is frankly untenable. The CKC Board of Directors has unilaterally committed "reputable breeders" to the proposition of guaranteeing the "future genetic good health" of the dogs they sell. Yet those same breeders have no means of protecting themselves from the looming specter of financial ruin should they be held to such a guarantee, otherwise to the loss of public credibility. Other than the continued elaboration of screening programs and the Advanced Registry proposal, both of which are somewhat like applying an adhesive bandage to a severed artery, nothing is being done about making guarantees of genetic health a workable proposition. At present, purebred breeds -- all breeds -- show levels of genetic defects totally inconsistent with the practical maintenance of the Boards policy. Many honest, caring breeders are racked by torments of guilt and self-reproach brought on by the suffering of defective dogs, yet it is really no fault of the breeders themselves! The fault, as has been demonstrated in this brief, lies with the closed studbook and the inbreeding system. If the consensus of the Club is truly that purchasers of purebred dogs have a right to expect genetically healthy animals, then the Board has no choice other than to do everything in its power to change the existing system so that healthy animals may once again be reliably produced! That will never happen just through Advanced Registries, higher Championship point requirements, more screening programs, and Board policy pronouncements. The Club must take to heart the lessons of population genetics. It must open its studbooks to outcross stock on a permanent basis. It must take measures against the obsessive pursuit of breed type and the worship of breed purity, measures which will increase the health, utility, trainability and sanity of purebred dogs, measures which will balance the elements of breed identity. There are no credible "soft options" left.

One unfortunate reality which must be faced, however, in order to bring about any major changes involving the CKC will be the conservatism and resistance to change of the Board and of the "old hands" -- the ruling oligarchy of the Club. The CEO and the Board will almost certainly aggressively defend the *status quo* no matter how urgent the need for change. At present, for example, they turn down requests for the registration of new foundation animals with statements such as this one: "The CKC takes pride in registering dogs based on accurate and complete information and we will continue to strive for these high standards." Yet when that statement was written, the Club was still registering Canadian-bred litters whose parentage information was supported only by a signed registration application form filled out by the owners of the dam and sire. Under that system of information gathering it is regularly necessary for the Board to cancel litter registrations when it becomes evident that the parents of some litters are not both of the same breed. No one knows how many litters go unchallenged which, although purebred with both parents of the same breed, have their parentage misrepresented because the actual sire of the litter is not the dog entered on the application form. In the absence of DNA testing, how can the substitution of sires be detected?

Meanwhile the United Kennel Club, a "dissident registry" in Kalamazoo, MI, USA, which now registers about a quarter of a million dogs annually, has already instituted a process for the verification of parentage by DNA profiling! This is the first time that DNA profiling has been made routinely available to dog breeders, and UKC is the first canine registry in the world to offer such assurance of verified parentage. Innovations such as this make the Clubs defensive statements about its high standards sound rather hollow.

Anyway, those of us who seek reform will have to contend with a Club establishment which will attempt to make a virtue of the very things which most threaten the genetic health of CKC dog breeds: the closed studbook, the breed purity concept, the endless inbreeding, the constant refinement of type, the preeminence of the Championship show, Those who dare to challenge the existing system will have to put up with being made to look foolish or even villainous by the solemn pronouncements of the old guard. We should all realize that the Club establishment is unlikely to initiate serious action for change in the absence of grassroots pressure from the general membership. It is up to us to initiate serious dialogue along the lines outlined in this brief, to research ways and means to promote a different, healthier method of purebred dog breeding, and to raise the consciousness both of novices and of old hands regarding the genetic dilemma which now faces us.

Deep structural change cannot occur without widespread debate among fanciers, because new and different concepts sound threatening when they are first described. Once the reasoning behind them has been adequately discussed, the threat often disappears. Someone may ask, for example, "What about these open-ended Breed

Standards? A Bell-curve statistical description of a breeds height standard may be an adequate formula, but what if the mean is set at 22.5 inches and you don't disqualify the 25-inch dogs. Then maybe in a few years the mean may drift upward to around 24 inches, with hardly a single dog under 22 inches. What then?" My answer would be that the whole point of the balanced-heterozygous system is its healthy flexibility. A stubborn insistence on narrow tolerances in matters such as height at withers usually involves the sacrifice of other worthwhile qualities anyway, as too many otherwise good animals must be discarded only because they are a shade over standard. In the balanced system described, nothing at all need be lost. If the height mean of a 22.5-inch breed should drift upward to 24 inches, it would be because most of the breeders wanted a taller dog! Since the breed club would be advising breeders, measuring and rating dogs, maybe even suggesting matings, this sort of gradual change would occur only with the knowledge and acquiescence of the breed club, representing all active breeders. Under a heterozygous plan with mainly assortative matings, nothing whatever is lost in such a gradual change. Should the height drift upwards and, later on, the breeders decide upon a return to the original mean, a simple shift in the emphasis of assortative mating will accomplish such a return easily, smoothly, with no genetic loss and no disturbance of other traits.

The whole idea of a dynamically balanced heterozygous breeding system is the retention of as much healthy genetic diversity as possible. Such diversity makes it easy for a breed to develop and progress in whatever direction its breeders wish. It also ensures that genetic problems are kept to a minimum no matter what changes of standard may occur. In the statically balanced homozygous system now in force, the more homozygosity increases with time and selective breeding, the harder it becomes for major change to occur naturally and easily, and the more pronounced genetic problems become. Once an allele has been "fixed" in homozygosity, no amount of selection can change that trait; only radical outcrossing can restore the lost alleles and such outcrosses will always upset the static balance completely, necessitating years of remedial inbreeding and selection, probably creating new genetic problems. I am convinced that a system based on a dynamic equilibrium of healthy dominant genes must inevitably be better than one which throws away most of the healthy genetic diversity in order to achieve static stability for homozygous recessive traits.

It is worth noting that the new system, if carried out at all conscientiously, would mean more work per dog for everyone. Breeders would necessarily invest more time and effort in their breeding stock in order for it to pass breed club requirements. This is by no means a negative factor. One ongoing problem in our society is that of large numbers of unwanted pets. Another related problem for the purebred fancy is substandard dogs produced by the non-serious "backyard" breeder and the puppy-mill profiteer. The suggested reform measures would discourage exploitative factions and reduce considerably the overall number of purebred dogs, while raising greatly the overall quality levels and ensuring that practically all purebred dogs were valuable, cherished, and wanted by their breeders and owners. The new system would greatly increase the inherent value of purebred canine stock. Purebred would then mean much more than just a paper certificate!

A Canine Revolution?

The foregoing prescriptions may sound like a canine revolution. If so, the revolution would consist mainly of integrating many facets of the fancy which now exist in ghetto isolation, or of importing good ideas from other parts of the cynological world. In Europe, for example, many breed clubs have long held responsibilities for their breeds similar to those described above. The only really revolutionary features of this new vision of purebred dogdom are the permanently open studbook and the abandonment of incest breeding, and those represent simple, inevitable acquiescence to genetic reality. If there is one thing we can do which will be of lasting benefit to the dogs we breed, it is to endow each and every one with a healthy, heterozygous genetic outfit. If that is to become possible, the closed studbook must go and inbreeding must go. There are no effective alternatives.
These reforms would require considerable cooperative effort on the part of breeders, breed clubs and the CKC in order to bring them into being. A major part of the job would be to convince Agriculture Canada of the desirability and feasibility of these proposals, followed by amendment of the Animal Pedigree Act to facilitate them. Yet when we consider the threat to the very existence of purebred dogs posed by genetic disease, the economic loss caused by genetic defects, and their widespread unhappy effect, on peoples lives, can we deny that radical and decisive remedial action is required? The goals of a balanced-heterozygous breeding system producing healthy, hardy dogs and a balanced breed identity structure coordinating all the delightful activities of purebred dogdom, would be worth any amount of effort. Let us begin work now to bring those goals into existence! Future generations of breeders and fanciers will be grateful to us for so doing and what is more, we shall be doing the best and kindest thing for our very best friends - our dogs.

Postscript

Inevitably some will feel that the suggestions contained in this brief are unrealistic and impracticable, that ideas such as breed autonomy and balanced-heterozygous breeding "will never fly" in Canada. It may be that this brief is slightly ahead of its time; nevertheless, we are about to embark upon a new millennium. Already this country has seen the acceptance and adoption of many concepts that would never have been practicable fifty years ago. The Charter of Rights, settlement of aboriginal land claims, the Internet, the Quebec referendum -- none of these current realities would have been acceptable or seriously foreseeable in the first half of the twentieth century. Many breeders will reject outright the mere idea of deliberately trying to increase heterozygosity, after so many years in the pursuit of homozygosity through "linebreeding" and frank incest breeding. Others will be horrified by the thought of dismantling the apparatus of the CKC Championship Show. Almost everyone, myself included, will be nervous and dubious about increasing the power and autonomy of breed clubs, based on the past performance of many such clubs. Yet needs must when the devil drives! The genetic situation is dire and the present outlook for many breeds is grave. Something will have to be done. Just now most of the hope and effort rests upon research towards detection of DNA markers for major genetic diseases. Yet those who promote this approach to the problem of genetic defects invariably seem to have a very narrow outlook, treating each defect in isolation. The approach is no different from that of traditional hip x-rays and eye examinations, except that it may be more efficient. The proponents of disease marker detection do not, however, explain how we are going to deal with the problem of diseases which are already widespread throughout a breeds population, or how our gene pools will stand up to successive waves of severe culling as we strive to "eliminate" one widespread genetic disease after another in our small populations bred from tiny founder groups. The population genetics aspect of marker detection, screening and subsequent selection is simply being ignored. As we have already found to our sorrow, those aspects of breeding and genetics which we ignore as being inconvenient at the time emerge later to work us woe.

Now is the time when we must begin a full and open dialogue among ourselves on the topics that have been mentioned in this brief. Now -- before we embark upon a devastating new wave of genetic attrition which could be the "killer wave" that sinks the ship of purebred dogs.

If the more advanced reforms suggested in this brief prove too unpopular for implementation, then so be it. What cannot be done now we may perhaps achieve in time. But at the very least, an irreducible minimum of reform must take place soon if we are to have any hope for the future of our dogs. The most critical item is relaxation of the closed studbook to allow for admission of new foundation stock. We cannot go on selecting rigidly forever and a day from a closed foundation, particularly not if we are to embark upon an era of new selection criteria based on marker research. A breeds gene pool may be likened to a bank account: one cannot go on making withdrawals forever without an occasional deposit (no matter what deficit-spending politicians may think). That some breeders are dead set against outcrossing does not imply that the rest of us should be prevented from introducing new genetic material if we feel it is needed in our own bloodlines. Likewise I think that the restoration of balanced breed identity is also a high priority item, which many people in the fancy are already well-prepared to welcome. Fanciers interest, for example, in useful working dogs instead of mere beauty contestants has never been higher than it now appears to be.

It must also be pointed out that it would be extremely unwise for the CKC to ignore the need for genetic renewal. The Clubs adoption of a hard-line position would carry a high risk of major schism within the ranks of purebred dog breeders. Already independent breed associations and alternative registries exist, promoting genetic excellence and asserting the need to "protect their breed from the kennel clubs"! CKC terms these organizations "dissident registries" although the associations themselves seem to feel it is questionable who is more dissident in view of the hostile position CKC adopts towards their pedigrees and stud books! In any case, the absence of a proactive, cooperative and open-minded response from the Club to the genetic crisis will almost guarantee the creation of alternative associations and stud books, dedicated to the pursuit of genetic excellence on a more practical basis than that offered by CKC. This author, for instance, fears that in order to incorporate new Siberia import stock into his bloodline of working sled dogs he may ultimately be obliged to adopt an "evolving breed" scenario under an independent association. Schism of this kind is perhaps in no ones best interests, but may be unavoidable should the CKC prove intransigent in refusing to reopen stud books to new foundation, as it has done to date. If more "dissident registries" should in fact arise and succeed in producing canine stock to a higher standard of genetic excellence than can be done within CKC, it would greatly damage the Clubs credibility in the public eye.

What is of paramount importance is that we all recognize the true dimensions and gravity of the problems we now face. It is far too easy to ignore genetic diseases, to make excuses, to pay the vet bills and say nothing for fear that others will accuse one of breeding defective stock -- I think practically all of us live in fear of the smear tactics that are so common in the dog world. Yet the truth is that we are all breeding defective stock; the system

itself virtually guarantees that. If we believe that to breed defective stock is a bad thing, then we simply must discuss ways and means of altering that system to allow us to restore genetic health. Too many breeders are now reluctantly deciding that "health must be the paramount concern" and abandoning their usual selection criteria in favour of breeding for hips, eyes, blood, etc. A few decades of that sort of breeding will surely do greater harm to breed characteristics than could ever be done by outcrossing. We must now seek to evolve a system which will naturally, almost automatically, produce healthy animals -- so that we may continue on with, or return to, our selection for temperament, working ability, conformation and breed type. Most of all, it is imperative that we start now to discuss and work on the new structures that are needed to facilitate genetic health for our dogs. The next millennium, close as it is, may be too late.

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Glossary

In the hope of helping the reader to understand certain genetic and other terms which may be unfamiliar, I have included this Glossary. It does not explain terms or concepts that have already been explained elsewhere in the brief, as for example, the concepts treated in the section headed "Lessons From Population Genetics." I have included here mostly terms which are technical enough to be omitted from most dictionaries. If the reader finds other unfamiliar words in the brief, their definitions will be found in any good collegiate dictionary.
achondroplasia - a genetic syndrome producing skeletal development resulting in a semi-dwarf phenotype with shortened and distorted limbs; occurring in some breeds (Alaskan Malamutes. e.g.) as a genetic defect, it is selected for as a breed point in others (Basset Hound, e.g.).

allele - an alternative form of a given gene producing a difference in the trait controlled by that gene; some genes have only one allele, some have two, some have multiple alleles for the same trait.

allozyme - enzymes differing in electrophoretic mobility (i.e., which migrate different distances through the substrate when an electrophoresis test is performed) as a result of allelic differences in a single gene; allozyme variation thus indicates genetic variation. One of the oldest lab tests for genetic analysis.

autochthonous - "sprung from the earth," native to a particular region from a very early time. The Siberian sled dog is an autochthonous dog in Siberia. (Pronounced "aw-TOC-thun-us.")

chromosomes - structures within the nuclei of living cells which are made up of nucleotide sequences, the biochemical information carriers which we call genes. All genes exist as tiny portions of chromosomes; although we may speak of particular genes individually, in isolation, they do not exist as separate entities, but are always found as subunits of chromosomes.

cynological - of or pertaining to the knowledge and study of dogs.

deleterious · harmful or injurious.

diploid - the body cells of most complex animal organisms such as birds and mammals all have their chromosomes in pairs derived from sexual reproduction, such that one chromosome of a pair comes from the father, the other from the mother. The sex cells from only one parent have only half the number of chromosomes of cells in other parts of the body: the normal chromosome number is known as the diploid number, the chromosome number of sperm and egg cells is called the haploid number.

disequilibrium - imbalance or instability.

dominant - said of an allele which by itself alone will produce a particular phenotype regardless of which other allele may be present on the other matching chromosome of the diploid pair; thus it takes only one copy of the chromosome to cause a dominant trait to be expressed in the phenotype.

electrophoresis - one of the most useful lab techniques for revealing genetic variation. which came into widespread use in the 1960s. It involves placing sample material (blood, e.g.) on a gel substrate. An electrical field is then applied between the two ends of the substrate, causing protein molecules to migrate through the gel. Proteins with different ionic charge will travel different distances across the substrate. Staining subsequently makes bands of protein in the substrate visible, so that various samples can be "read" in much the same manner as a supermarket bar coded label.

expression - not all genes possessed by an organism will result in detectable physical traits or differences in that organism; the genes that do are expressed. Dominant genes are always expressed, but recessive genes may be present for many generations without physical expression in the phenotype.

fecundity - the number of progeny produced by animals when reproducing.

fertility - the relative degree of reproductive success, i.e. the frequency with which mating is followed by pregnancy.

gametes - the sex cells of sexually reproducing organisms, i.e. spermatozoa and ova.

genome - the total genetic information possessed by an individual, a breed or a species.

genotype - the invisible genetic makeup of an individual organism, which includes alleles which may be recessive and therefore have no visible physical expression.

heterotypic - displaying different types. A breed which has more than one distinct and recognizable set of "type" characteristics is heterotypic.

heterozygote - an organism that possesses different alleles at a given gene locus.

heterozygous - possessing different alleles at a given gene locus.

holistic - relating to or focussing on the entirety of a thing or an organism and the interrelationship of its component parts, instead of emphasizing different aspects or parts in isolation without considering their interactions.

homozygote - an organism that possesses identical alleles at a given gene locus.

homozygous - possessing identical alleles at a given gene locus.

inbreeding coefficient - a number used to quantify the probability that an organism will have identical alleles from the same ancestral source, usually computed by analyzing the pedigree for "loops" in which the same ancestor is found on both the male and female sides of a mating.

lethal - likely to cause or capable of causing the death of an organism. A lethal gene is one which could either cause an aborted fetus or the death of the organism at some later stage of its life.

locus (pl. loci) - the physical location of a given gene on a particular chromosome.

meiosis - the kind of cell division which produces spermatozoa and ova or gametes and which reduces the chromosome number to half the normal complement.

microsatellite - a kind of DNA testing which detects short DNA sequence variations at particular highly variable sites; used in so-called "DNA fingerprinting."

phenotypic - the visible physical expression of an individual organisms invisible genetic makeup.

polymorphism - difference or variation in form, diversity. Molecular geneticists study protein polymorphism, different forms of proteins in an organism indicating different alleles. Polymorphism studies show that from 20 to 50 percent of gene loci in most species have two or more allele forms.

recessive - a gene which contributes to the phenotype only if it is present in homozygous form. It takes two identical copies of a recessive gene to produce the trait it governs in the phenotype. In practice many genes are neither clearly dominant nor recessive, in which case geneticists speak of variable expressivity or incomplete penetrance.

RFLP - "restriction fragment length polymorphism" -- a DNA analysis technique which involves the use of enzymes to break the DNA chain at specific nucleotide sequences: the resulting "restriction fragments" are then analyzed by the use of electrophoresis and blotting techniques. RFLPs are used as markers for known genetic traits and can be employed for genome mapping.

sublethal - having known deleterious effects which by themselves will not usually cause the death of the organism but which handicap it in some way. Several sublethal genes may nevertheless combine to form a "lethal equivalent."

subvital - having known effects which work to reduce the overall vitality and health of the organism.

typology - the study of types or groups of distinguishing characteristics. Typological thinking involves emphasis on visible superficial characteristics, often mere cosmetic traits which have little to do with the health and viability of the animal possessing them.

viability - the relative survivorship of the fertilized ova resulting from a reproductive event. Nonviability may involve ova which simply fail to develop, fetuses which abort, nestlings which die or juveniles which fail to survive to maturity.

Afterword

The author most sincerely hopes that the foregoing brief has in one way or another stimulated or inspired your thinking about the breeding and selection of purebred dogs into the twenty-first century. Our fancy badly needs a responsible long-term perspective, both for our own good as breeders and for the good of our animals.
If you should wish to comment on this brief, or if you should have some urgent unanswered question, the author will be happy to receive your letter at the address given below.

Should you feel indignant or upset after reading this brief, please put it aside for a few days, then read it again. I have introduced some ideas which, although they are becoming commonplace in other parts of the dog world, have largely failed as yet to reach Canada. Those who have accepted the gospel of breed purity inbreeding, and type above all, as published in a multitude of magazine articles and "how to breed" books, may well feel betrayed or insulted! It is not my wish to insult or to upset anyone, but I have nothing against disturbing complacency. We shall all have to rise above our own narrow individual interests and perspectives if we are to save our purebred dog world from genetic disaster.

If this brief -- as I hope it will -- leaves you feeling that The Canadian Kennel Club should be approaching the matter of genetic health in purebreds in a different way or should be considering new ideas, I hope that you will make your feelings clearly known to the Board of Directors by writing to the CKC Director for your region, whose name and address will be found on Page 2 of the "CKC Official Section" which is mailed every month to CKC members along with their copy of "DOGS in Canada."

In closing, I wish the best to all of us as we carry our breeding programs forward into the twenty-first century.

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