

Artificially Selecting for Intelligence in Dogs to Produce Human-level IQ Within 100 Generations

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Abstract—Artificial selection is a well-known phenomenon of selecting for certain physiological characteristics of various species of plants and animals, and it is something that human beings have been doing for thousands of years. A perfect example of this is the union and development of dogs under human stewardship since the beginning of the agricultural era of society. In that time, approximately 6,000 years [1], dogs have been artificially selected in such a way as to produce thousands of different breeds. From the stout Dachshund, a dog breed produced for the purpose of hunting den-dwelling animals, to the highly intelligent Border Collies who were bred to help sheep herders herd their flocks; the many different canine breeds have served humanity in a multitude of capacities for many generations. In this paper, using the concept of artificial selection,¹ it is determined with mathematical and statistical evidence how humans could artificially select for canine intelligence to such a degree as to produce canines with human levels of intelligence within a relatively short amount of time—600 years.

Keywords— Artificial selection, intelligence quotient, IQ, genetics, evolution, selective breeding, canine.

I. INTRODUCTION

It is well-known that not only is artificial selection possible, but very powerful. That being said, what if humans were to take this concept to its absolute extreme, and in a direction that has more or less never truly been broached in any significant manner? To some degree, various dog breeds have been bred for increased levels of intelligence, such as the Border Collie, or the German Shepherd, but never have they been bred to produce levels of intelligence that would approach perhaps tens of times higher capacities than a typical pet [2]. If one were to roughly compare the extent to which Border Collies have had their intelligence improved, it equates to a dog with the intelligence of a three-year-old child, or about 40% more intelligent than an average dog—which is to say that an average Border Collie can be considered a genius of the dog world; this means they would equate to a human with an IQ of 140 or higher *on average*.

II. BACKGROUND

The Border Collie dog breed, which will be the main focus of this experimental design, was bred from other more standard dog breeds, reaching its unique breed statistics and characteristics within only a few hundred years. It is surmised,

in fact, that the Border Collie breed has only been in existence since approximately the 1890's, and that all modern-day Border Collies can have their lineages traced back to one canine in particular—a one “Old Hemp [3].”

The story of Old Hemp is an important one, in that it represents the power that a single outlier specimen can have on the direction of an entire species of animal. Old Hemp was a veritable genius among his other canine peers, with a natural predisposition toward herding animals, a keen eye and ear to the direction of his master, and an ability to act independently and problem solve that far outstripped any other canine at the time. It is believed that he sired over 200 pups in his time, a point of critical importance, as this provided more than adequate genetic diversity to allow for future generations of canines just like him to survive and thrive.

This, hearkens to yet another important point in the experimental design discussed in this paper—the minimum number of specimens required at any level in order to provide for enough genetic diversity for proliferation. One of the earliest attempts at tackling this question was conducted in the 1980's by Australian geneticist Ian Franklin and American biologist Michael Soule [4]. They derived the minimum number of specimens—what they called the M.V.P.—to be around 50, but this does not take into account human intervention. Human intervention would drastically reduce this number, as selection could be more appropriately biased for maximum genetic diversification amongst the population, as well as maximization of the number of offspring of each generation. If, for instance, it is assumed that a Border Collie female will have ten pups per litter, and they have two litters of pups over the course of their lives, this would mean that the first generation of pups in a female population of ten Border Collies would yield an expected value of 200—coincidentally the number of pups sired by Old Hemp. Using these numbers as our guide, we can assume that an artificially selected group of specimens can have adequate genetic diversity with a male and female population of nine specimens each respectively.

For better or for worse, the concept of selective breeding was also the main driver behind the many royal families' breeding practices during the Medieval times [5]. The intent was to create and maintain a bloodline that was “superior,” in some way, shape, or form, one deemed worthy of leadership over many others. While at the time, those royal families had no scientific understanding for how this selection process could

¹ Also known as selective breeding.

most effectively be implemented, nor did they understand the many dangers involved in consanguinity of breeding practices and the lack of genetic diversity that comes along with it, this new information has come to light in recent years. Thus, new methodologies can be developed.

If, for instance, this same idea were to be implemented today, where a lineage of human beings decided to start selectively breeding for intelligence, then there are multiple avenues said lineage would be able to take. The first avenue would be for the most intelligent of each generation to have children with other highly intelligent lineages of people who share a common end goal. The rest of the children in that genetic lineage who are not selected in such an intelligence program could indeed have children with other families, that do not necessarily need to be of any genetic “royal” line. Further, each generation can make such a decision—it is never made unilaterally.

Depending on where these people are in the process, this could represent a very powerful genetic line onto which other lineages could attach, if they so desired. In that it is entirely the decision of the lineages of these families as to what they want to do with their development, free will is entirely respected, and moral issues and/or ambiguity are thus minimized.

III. METHODOLOGY

For the purposes of this experimental/engineering design, it will be assumed that dogs currently have, on average, an IQ of 25 [6], and that the standard deviation of said IQ is proportionally shrunk down to the equivalent for canines with this IQ—3.75. That is, human IQ is 100 on average, with a standard deviation on a typical classical IQ test of 15. Dividing 15 by 4 yields 3.75. While, in truth, it is more likely that the average Border Collie IQ is roughly 35—the equivalent of a 140 IQ human—for simplification purposes it will be estimated at 25. It will also be assumed that adequate genetic diversity is accomplished through human stewardship of the process. The process for selecting is conducted as follows:

1. Raise a female Border Collie to the age of six years, being sure to note their intelligence. There are many ways to do this, however, a standardized test of intelligence would need to be derived. In addition to this, the intelligence test would need to be significantly modified through each intellectual epoch of the process—from canine levels of intelligence, to ape levels of intelligence, to dolphin levels of intelligence, and eventually to human standards, for example [7].
2. Once the Border Collie reaches four to six-years-old, breed with another experimentally selected, intelligent male Border Collie.
3. It is expected that each litter of puppies will be approximately ten in size. Once the puppies have reached the age of two months, conduct an intelligence test on them to determine the most intelligent of them [8].
4. Select the single most intelligent pup of the litter for follow-up in the next stage of the experimental selection

process. Of course, depending on the number of pups in each litter, and their intelligence standard deviations from the norm of that generation, more than one pup could be selected. That is to say, if, for instance, two pups have a tested intelligence that is two standard deviations above that generation’s norm, then both can be selected for future breeding. It must be noted, however, that the likelihood of this happening is low, roughly $100 * (.003)^2 = 0.0009\%$ chance, or 1:1100.

5. Do this with both nine male genetic lines and nine female genetic lines that are separate from one another. This will ensure that artificial selection will be maximized, and that genetic diversity is adequate. While conducting the process, selected canines ideally would not be made to breed with non-selected canines, as this would hamper/slow the process dramatically. This is because, combining two normal distributions creates yet another normal distribution. If the normal distribution of IQ of the non-selected canine is of average intelligence, and the *selected* canine is well above average, then the new normal distribution of the next generation of puppies would be roughly exactly in between the two normal distributions, which, as stated, would slow the process.

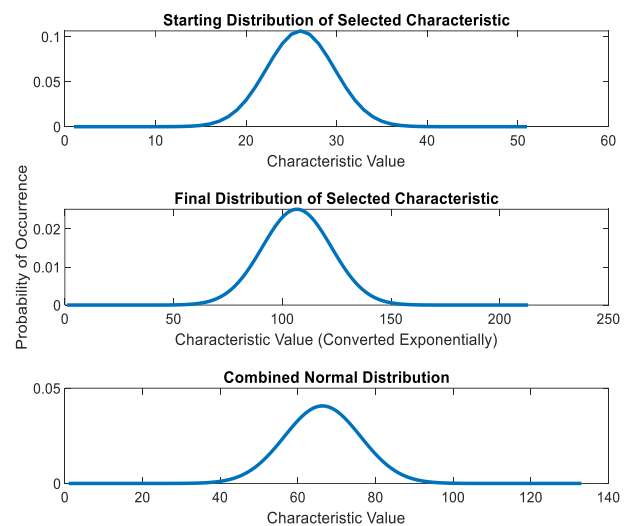


Figure 1: Figure showing combined normal distributions.

6. Additionally, if canines are made to breed with siblings, other genetic problems emerge. Therefore, this should actively be avoided [9]. This is not to say that the selected canines are barred from breeding with non-selected canines. It is only to say that the non-selected litters will not be used for the purposes of the selective breeding process, unless pups are tested within the desired intelligence range.

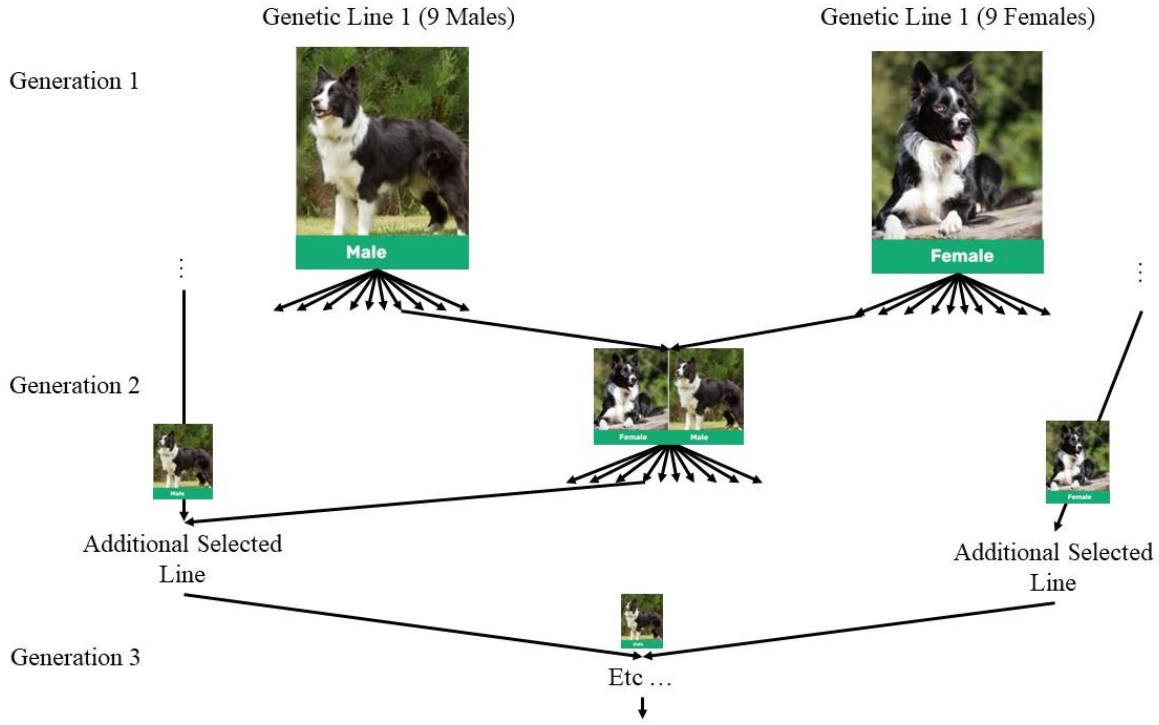


Figure 2: Border Collie Generational Selection Illustration.

$$P_{2,tot} = 1 - (P_0)^{litter\ size} \tag{1}$$

$$P_{2,tot} = 1 - (.977)^{10} \approx .208 \tag{2}$$

7. Any other genetic abnormalities can, and should be more or less ignored at least initially, as they will be washed out over the course of the process due to non-selection and the Law of Large Numbers, as long as step (6) is followed. That is, if a characteristic is not selected for, then the genetic propensity for it developing in future generations with a higher-than-normal probability is minimal.

IV. SIMULATIONS

In order to simulate this process in MATLAB, several loops were designed. Initially, what is required is to use a normal distribution heuristic for a random selection of the standard deviation value from the mean. This means, MATLAB can be made to randomly select a value for number of standard deviations from the mean based upon a normal probability distribution and input initial standard deviation and mean values. This process is carried out for an initial generation of canine pups. With a user-determined average size of each generation’s litters, this will probabilistically derive the average maximum intelligence a typical canine will achieve within each litter. For example, if a litter is ten in size, then the likelihood of having a pup with an IQ two standard deviations above the norm is

If the input litter size is instead 20^2 , then the final probability will change accordingly.

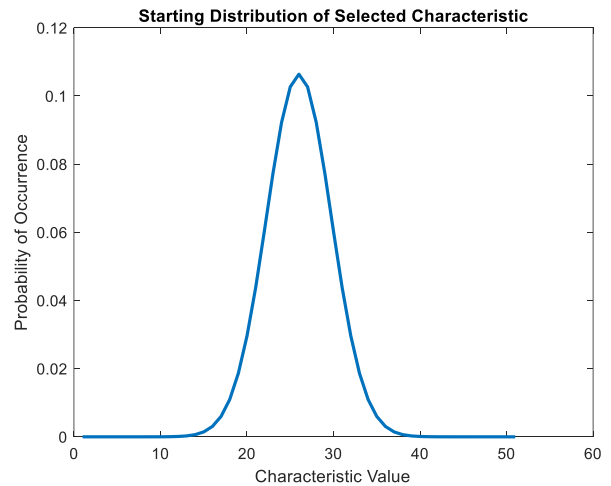


Figure 3: a representative normal distribution of the starting IQ of canines.

² If, for instance, it is expected that each Border Collie generation of bitches will have two litters instead of one.

Essentially, all input values are probabilistically determined in the real world, from the size of each litter, to intelligence, to the variance of intelligence, and more. Isolating for expectations however, meaningful results are derived.

Once the generational characteristic is determined, that process is carried out for a user-determined number of generations, taking the maximum of the selected characteristic from every generation and making it into the next generation's new mean for its normal distribution for the characteristic. Because of the stochastic nature of this experiment, in order to yield a number that is as close as possible to the expected average in the future, a number of simulations should be run, and the average of all those simulations taken, rather than a single point reference. This creates a series of three loops in total in order to give as accurate a solution as possible. The following parameters were used to determine the final characteristic value at the end of the simulation:

1. Number of Generations: 100
2. Starting Characteristic Value: 25
3. Number of "Children": 10
4. Starting Standard Deviation: (15/4)
5. Years Per Generation: 6
6. Number of Simulations: 100

It is important to note that (6) must be strategically chosen, as too large of a number will cause the simulation to take several seconds to even several hours to complete. However, it must be large enough to provide a reasonable average value. Therefore, 100 was selected. The outputs are as follows:

1. Total Time: 600 years
2. Final Characteristic Value (Raw Value): ~605 to 610.
3. Exponentially Scaled Final Characteristic Value: ~104 to 105.

What is meant by exponential scaling? Intelligence is normally distributed and exponentially derived. That is to say, an animal with an IQ of 25 is not simply $\frac{1}{4}$ as intelligent as an average human, but vastly less intelligent. If the IQ of 25 is normalized to 100, then that would mean the IQ of 100 would be normalized to 400. Using the following exponential function, one can determine the "multiples more intelligent," an animal with a higher IQ actually is:

$$\ln\left(\left[\frac{FV}{SV}\right] \times SV\right) + SV = CV \quad (3)$$

Where FV is the final characteristic value, SV is the starting characteristic value, and CV is the exponentially converted final characteristic value. In terms of raw numbers, this means that a canine with an IQ of 105 is, in reality, approximately 20 to 25 times more intelligent than a canine with an IQ of 25—or on the same order of intelligence as a human. The following figures show the progression of this process over the course of the chosen 100 generations:

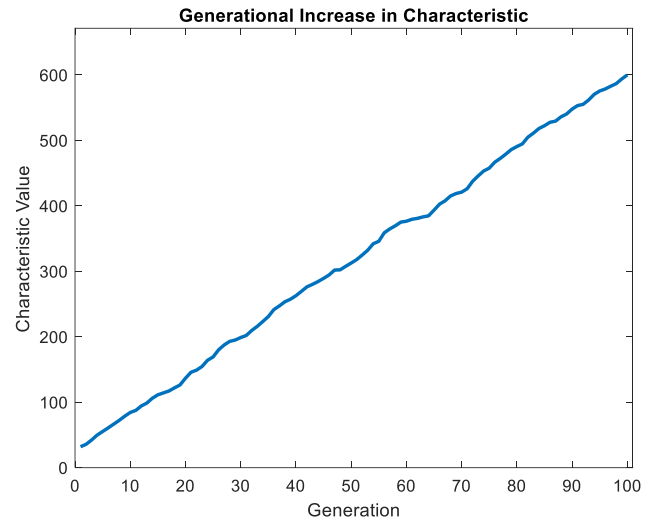


Figure 4: intelligence raw value change over the course of 100 generations of canines.

Note that the figure above does not have a perfectly linear progression of the characteristic value. This is, once again, due to the stochastic nature of normally distributed characteristics and probabilistic likelihoods of offspring having the desired trait.

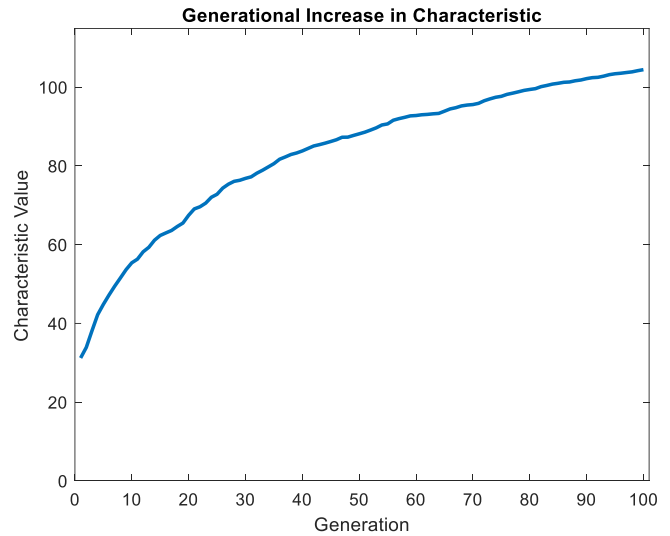


Figure 5: exponentially converted characteristic value over 100 generations.

Since, as stated before, this process is stochastic, doing many simulations in a Monte Carlo scheme is the best way to come to the true expected result. This is shown below.

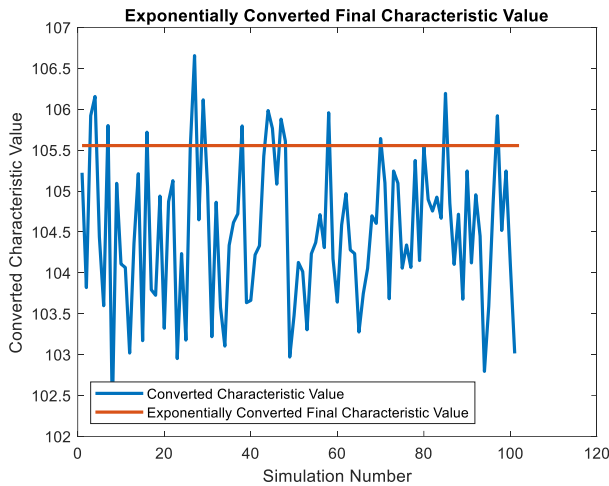


Figure 6: final value of each simulation, with the average value of all simulations shown by the red line.

V. DISCUSSION

One of the main issues, if not *the* main issue, with respect to conducting such a selection process is that of morality. This is an issue that must not be ignored, as it hearkens to the very nature of who we are as human beings. However, this moral conundrum can be broached in a variety of ways. Principally, the most important thing that must be considered is free will, not only of humanity to conduct such a process, but also the burgeoning free will of the subjects being developed. That is, allow for each representative of a lineage to decide what they want to do with their own line once they develop the ability to make said decision. This is a follow-up/corollary to the royal bloodlines explication in a previous section.

If, for instance, one genetic line decides that they instead want to start working on artificially selecting for bipedal nature, then they can do that along their lineage. If another decides they want to select for size, they can do that along their lineage, etc. But for such a choice to be made, there must first be a conscious awareness of such a choice, which requires a threshold level of intelligence that this process will help canines achieve, bare minimum.³

This idea also serves to challenge those perspectives of individuals such as Klaus Schwab et. al., who seek to reduce the population of the planet due to what they consider to be “dead weight” human beings with no capacity to produce anything of value [10]. These individuals also seek to reduce the human population by any and all means necessary, to include very unsavoury ones. Using a hypothetical case study of a man who is, based upon current testing standards, considered mentally slow, if he decides that he wants to conduct this process on his genetic line going forward, then in a matter of only a handful of generations his descendants would potentially have intelligence levels far above and beyond that of the average human of the time.

³ For future reference, this will be termed, “Internal Locus of Objection.”

The main barrier here, above all else, is the proper advertising and advocacy for such cultural moves. Being that these ideas are seemingly taboo in so many cultural circumstances, the zeitgeist needs to be shifted as such, which is one of the primary purposes of this paper. It is a kind of “Overton Window” of social paradigm that not only hampers our ability to move forward on this idea, but also hampers our ability to simply discuss and therefore rebut the perspectives of individuals such as Klaus Schwab in formal settings [11].⁴

It is also very important to note, however, that IQ is a relative measurement, as stated before. That is to say, it is a measurement of how an individual sample stacks up against the distribution of an entire population. Converting the IQ from one species to another is difficult, and very much an imperfect science. This is not even mentioning the tremendous difficulty in extrapolating the progression of artificially selected intelligence over hundreds of generations. This is merely a theoretical estimation.

VI. THE FLYNN EFFECT AND HUMANS

To the point mentioned immediately previous, coevolving factors could very well be in play that slow—or even accelerate—the process beyond what science can currently predict. If one looks at the Flynn Effect as measured in human populations [13], it has been empirically determined that average human IQ has been increasing by three points per decade for the last few hundred years, though it does appear to be slowing in current times, and with no well-understood reason. It could be for any number of possible exterior factors. Not only could there be coevolving factors slowing down the process, but it could also be the very exponential nature of IQ, and how its measured increase necessarily slows as the raw values increase. This would mean, perhaps, that IQ increases could be a measure of the efficiency of the cerebral cortex and how well-folded it is within its volume, rather than an increase in cranial volume itself, but in-depth discussion on anatomy is beyond the scope of this paper.

This is to say, an increase in cohort intelligence does not necessitate an increase in overall cranial volume, but rather an increase in the density of the brain matter itself. This is exemplified well in the brains of highly intelligent birds, such as crows or ravens [14]. These birds have brains that, on average, are approximately the size of a walnut, but have a level of intelligence that is roughly on the order of that of a seven-year-old human. A modern-day canine has a brain volume that is several times this, though is only a fraction as powerful. Then, beyond this, the parts of the cerebral cortex that are over- or underemphasized also play a part. Dolphins, for example, are believed to be the second most intelligent species on planet Earth, after humans [7]. Their brains, though slightly more massive on average than that of a human, have evolved in a different way, where they seem to have overdeveloped prefrontal cortices, rather than simply an oversized brain in general. To be even more specific than the cerebral cortex being

⁴ Noted from the title of [12], differing perspectives on this topic are considered conspiracy theories.

the portion of the brain dedicated to higher level thinking, the *prefrontal* cortex is known to be the seat of reason [15].

Then, let us go one step farther. While a stabilized distribution of a particular characteristic of a population cohort may most closely resemble a normal one, this is not to say that one that is actively undergoing artificial selection would reveal the same result. That is to say, perhaps, as intelligence is being artificially selected for canines, the distribution is being “drug” into a new mean location. This means that one could envision a normal distribution being converted into something more closely resembling a typical Poisson distribution.

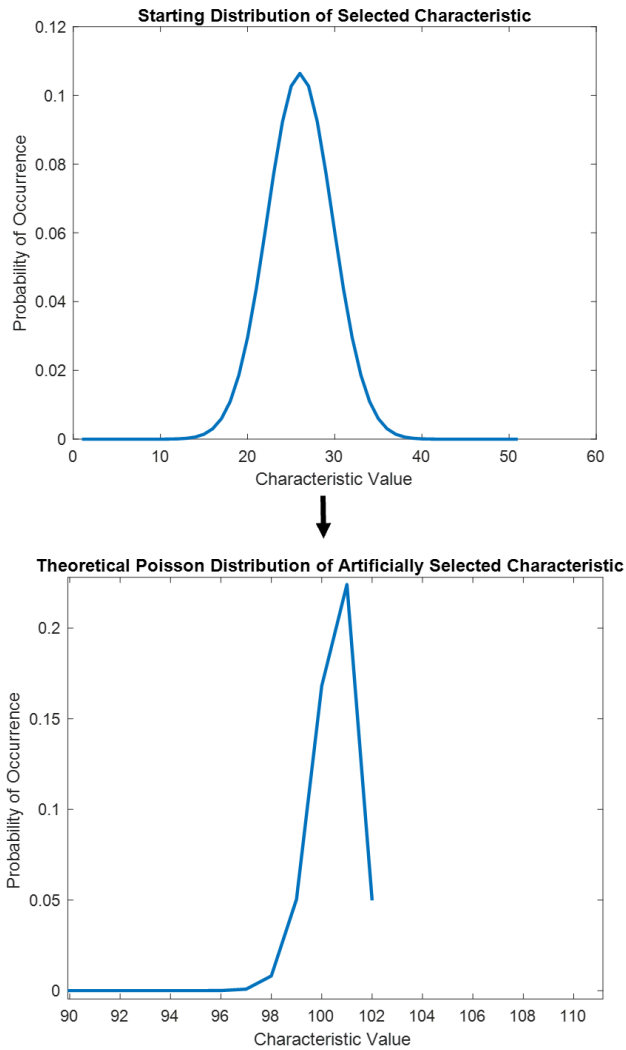


Figure 7: figure showing the hypothesized conversion of a Normal distribution into a Poisson distribution through artificial selection processes.

With one envisioning the normal value being “pushed” upward through time, this also explains the well-known concept of Regression to the Mean [16]. There may be a period of stabilization required, where other coevolving attributes are balanced out, and physiological infrastructure adequately developed.

VII. MORE EMPIRICAL DATA IS NEEDED

The simple fact of the matter is, more empirical data is needed [17]. While selective breeding is a time-honoured tradition in human history, and has been carried out many a time with canines, the empirical data sets on its execution are sparse. That is, while there is the physical evidence that it works, manifested in the many different canine breeds, the numbers behind it, such as the various distributions shown in this paper, are hard to find, if not non-existent. It is not only important, therefore, to produce and save such valuable data going forward, but also to have the courage to tackle potentially controversial scientific principles in order to advance the discussion, and humanity. This is because these same concepts can be extrapolated to any biological being, *including humans*.

VIII. OTHER SELECTIONS

It will no doubt be an absolute necessity to select for other physiological traits in addition to canine intelligence because, what good is having a human level of intelligence if your average lifespan remains as only 14 years? In this regard, the very next selection that could be carried out is that of longevity. The unfortunate reality is that, if longevity and intelligence do not coevolve in some way, then canines will first be highly intelligent, and afterward will have extended lifespans. This will yield a difficult period in their evolution and development, one that would likely yield much in the form of existential crises.

While there is some empirical data to support longevity and intelligence being correlated among human beings, it is still as of yet unknown if this is simply due to humans of higher level of intelligence taking better care of themselves, or if there truly is a physiological link between the two characteristics. Though, thus far, the evidence suggests it is most likely the former [18].

With canine life expectancy having a standard deviation of 2.36 years—a relatively high level of variability—it can be effectively and swiftly selected for as well [19]. In addition to this, due to the very nature of normally distributed characteristics, while selecting for one trait, any variation in other desired traits becomes a “wash” over the course of many generations. This means that, once, say, the IQ of the new canine breed stabilizes after the selection process has been concluded, the mean IQ would stay the same across generations (minimal genetic drift) from that point without artificial selection efforts. Therefore, selecting for a non-coevolving characteristic such as longevity could be conducted with relative ease. Though, if indeed intelligence is correlated to lifespan and vice versa, this might not even be necessary to any significant degree.

In practice, we find, selecting for longevity is a rather complicated, and much more difficult endeavour than selecting for intelligence. This is because, one does not know the actual longevity of a particular sample individual until they have passed away, but one can know the intelligence of an individual specimen only weeks after birth. This means, the parameters of selection for longevity would have to be slightly modified. In this regard, if it is assumed that the standard deviation of a canine’s life expectancy is 2.36 years, then if the canine reaches

an age that is two standard deviations above the norm, this can be assumed to be the first requirement for an individual to be a candidate. The next requirement is that the specimen be male, because female canines cannot reproduce past a certain age typically. This, however, can be mitigated if at the outset of the study all female canines have some of their ova harvested and frozen for future use. Then, once the female canine has reached an age past that set limit of two standard deviations above the norm, that specimen can have its ova used for future generation insemination.

If semen specimens are also taken from male canines in the same manner, then the same process can be conducted. This means despite not having knowledge of when a specimen will pass on, their genetics will be carried forward.

IX. EXCURSIONS

As discussed in the previous two sections, there are a great many other physiological characteristics that ought to be explored as potential future excursions for this process. That being said, the code developed for this paper in order to produce the numbers provided can have its inputs changed to whatever values, for whatever characteristics, for whatever species the user desires. So let us use the following parameters for such a process to be conducted on humans:

1. Number of Generations: 10,000
2. Starting Characteristic Value: 100
3. Number of "Children": 8
4. Starting Standard Deviation: 15
5. Years Per Generation: 20
6. Number of Simulations: 100

These numbers were selected because, on average, human IQ is 100, and there have been roughly 10,000 generations of humans—derived from the fact that each generation is on average 20 years, and modern humans have been in existence for approximately 200,000 years. Additionally, eight children per generation is an optimistic value, chosen from the author's desire to have more human beings alive in the future, especially those contributing to anti-dysgenics [20]. The number of 100 simulations was selected because it provided the best balance of fidelity and simulation run time. This excursion yields the following outputs:

4. Total Time: 200,000 years.
5. Final Characteristic Value (Raw Value): ~215,650.
6. Exponentially Scaled Final Characteristic Value: ~870.

It also yields the following final normal distribution:

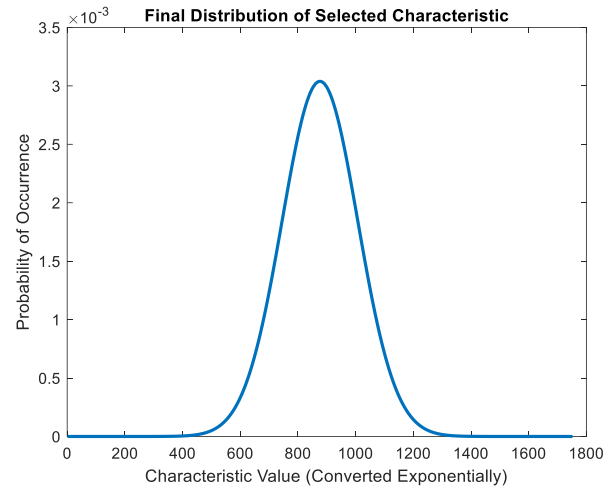


Figure 8: final normal distribution for human IQ with artificial selection over 200,000 years.

As previously stated, this process can be conducted for any variable values that the user desires. The MATLAB code will be provided in attached appendices.

X. CONCLUSIONS

For thousands of years, canines have been exalted in human society, hailed as “man’s best friend,” and for a multitude of very good reasons. Canines, without a shadow of a doubt, have been responsible for more human lives saved than can be counted, providing love, compassion, companionship, friendship, loyalty, and much, much more to many a human soul in desperate and dire need. Humanity would be remiss if we did not reciprocate the canine’s immense and positive impact on our civilization by building them the same capacity, so that they may develop accordingly. In our gratitude, simply put, canines more than deserve to have society and intelligence of their own, and they will have it in due time. We will make sure of it.

And for humans, if such a process were conducted in contemporary society, the change would be so gradual that few would notice. That is, unless there is a bifurcation in species.

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APPENDIX I: MATLAB CODE

```

[21] Initialization
[22]
[23] clc
[24] clear all
[25] close all
[26]
[27] % Generational increase in normally distribut-
[28] % ed characteristics.
[29]
[30]
[31] Input Prompts Section
[32]
[33]
[34] format longG
[35] prompt3 = 'Number of generations: ';
[36] generations = input(prompt3) - 1;
[37] prompt4 = 'Starting average value of normalized characteristic: ';
[38] start = input(prompt4);
[39] SS = start; % Placeholder variable for intermediate
changes required in code.
[40] SSS = SS; % Maintain initialized characteristic value.
[41] m = 1; % Start of average value vector counter.
[42] prompt5 = "'Children" per generation: '; % Children in quotes because
this can be done with any characteristic.
[43] sample_number = input(prompt5) - 1;
[44] conv_start = log(start/start)*start + start;
[45]
[46] if sample_number <= 1
[47] sample_number = 1;
[48] else
[49] end
[50]
[51] if generations <= 1
[52] generations = 1;
[53] else
[54] end
[55]
[56] n = 1;
[57] p = 1;
[58] q = 1;
[59]
[60] prompt6 = 'Standard deviation of normalized characteristic: ';
[61] st_dev_char = input(prompt6);
[62] st_dev_char2 = st_dev_char;
[63] prompt7 = 'Years per generation: ';
[64] years = input(prompt7);
[65] prompt8 = 'Number of simulations you want to carry out (gets you an
average): ';
[66] simulations = input(prompt8);
[67] sim_vector = 0:simulations;
[68] total_time = (generations+1)*years;
[69] converted_char_vector = 0:generations;
[70] start_vector = 0:generations;
[71]
[72]
[73] Loops Section:
[74]
[75]
[76] for k = 0:simulations % Simulation loop.
[77]
[78] j = 0;
[79] q = 1;
[80]
[81] for j = 0:generations % Generational loop.
[82]
[83] children_of_generation = 0:sample_number;
[84] n = 1;
[85] i = 0;
[86]
[87] for i = 0:sample_number % "Children" loop.
[88]
[89] %st_dev_char2 = st_dev_char*rand;
[90] children_of_generation(n) = st_dev_char2*randn(1,1) + start;
[91] n = n+1;
[92]
[93] end
[94]
[95] start = max(children_of_generation);
[96] start_vector(q) = start;
[97] converted_char = log(start/SSS)*SSS + SSS;
[98] converted_char_vector(q) = log(start/SSS)*SSS + SSS;
[99]
[100] % With each generation, a characteristic (e.g. IQ) is typically
[101] % renormalized to its central standardized point. In the case of IQ, this
[102] % is supposed to be re-adjusted to 100 with every generation. Doing this
[103] % negates the necessity of re-adjusting the standard deviation between
[104] % generations (possibly).
[105]
[106] q = q+1;
[107]
[108] % Not commenting st_dev_char out assumes that the cranial size stays
the same.
[109] % If this is turned on, then we can assume the cranial size is increasing.
[110] % It can be assumed that over time, as artificial selection is being
[111] % carried out, that the normal distribution of the characteristic would
[112] % turn into more of an inverted Poisson distribution.
[113]
[114] % st_dev_char2 = (0.9)*st_dev_char;
[115]
[116] % This assumes that the standard deviation increases by half the
[117] % difference between the scaled standard deviation of the new char-
[118] % acteristic (e.g. IQ) number and the total old standard deviation.
[119] % If standard deviation remains the same as the original, then the
[120] % numbers grow exponentially, rather than taper. Perhaps we can
[121] % determine the new standard deviation based upon where the
[122] % characteristic settles after artificial selection has ceased
[123] % (regression to the new mean).
[124]
[125] % We need to gather empirical data from artificial selection (selective
[126] % breeding) studies with respect to certain characteristics in order to
[127] % determine how the standard deviation is affected from generation to
[128] % generation.
[129]
[130] end
[131]
[132]
[133] % This portion creates a Monte Carlo Simulation to converge more
[134] % accurately on the true answer.
[135]
[136] sim_vector(p) = start;
[137] start = SS;
[138] st_dev_char = st_dev_char2;
[139] conv_sim_vector(p) = converted_char;
[140] % converted_char = conv_start;
[141]
[142] p = p + 1;
[143]
[144] end
[145]
[146] S = sum(sim_vector);
[147] Conv = sum(conv_sim_vector);
[148]
[149]
[150] Plotting Section:
[151] average_val = S/k;
[152] conv_avg_val = Conv/k;
[153] avg_val_vector = 0:length(sim_vector);
[154] conv_val_vector = 0:length(conv_sim_vector);
[155]
[156] for l = 0:length(sim_vector)
[157] avg_val_vector(m) = average_val;

```

```

[158] conv_val_vector(m) = conv_avg_val;
[159] m = m + 1;
[160] end
[161]
[162] hold on
[163] figure(1)
[164] plot(sim_vector,'LineWidth',2)
[165] title('Simulated Final Characteristic Value')
[166] xlabel('Simulation Number')
[167] ylabel('Characteristic Value')
[168] plot(avg_val_vector,'LineWidth',2)
[169] legend({'Characteristic Value','Average Characteristic Value'},'Location','southwest')
[170] hold off
[171]
[172] figure(2)
[173] plot(conv_sim_vector,'LineWidth',2)
[174] hold on
[175] title('Exponentially Converted Final Characteristic Value')
[176] xlabel('Simulation Number')
[177] ylabel('Converted Characteristic Value')
[178] plot(conv_val_vector,'LineWidth',2)
[179] legend({'Converted Characteristic Value','Exponentially Converted Final Characteristic Value'},'Location','southwest')
[180]
[181] figure(3)
[182] x = 0:length(sim_vector);
[183] y1 = poisspdf(x,3);
[184] y2 = flip(y1);
[185] bar(x - (length(sim_vector) - average_val),y2,.2)
[186] title('Theoretical Poisson Distribution of Artificially Selected Characteristic')
[187] xlabel('Characteristic Value')
[188] xlim([min(children_of_generation)-(0.1*min(children_of_generation)) (1.1*max(children_of_generation))])
[189] ylabel('Probability of Occurrence')
[190]
[191] figure(4)
[192] qq = 0:length(conv_sim_vector);
[193] y1 = poisspdf(x*2,3);
[194] y2 = flip(y1);
[195] plot(y2,'LineWidth',2)
[196] %bar(qq - (length(conv_sim_vector) - conv_avg_val),y2,.2)
[197] title('Theoretical Poisson Distribution of Artificially Selected Characteristic')
[198] xlabel('Characteristic Value')
[199] % xlim([min(children_of_generation)-(0.1*min(children_of_generation)) (1.1*max(children_of_generation))])
[200] ylabel('Probability of Occurrence')
[201]
[202] figure(5)
[203] plot(start_vector,'LineWidth',2)
[204] xlim([0 generations+2])
[205] ylim([0 1.1*average_val])
[206] xlabel('Generation')
[207] ylabel('Characteristic Value')
[208] title('Generational Increase in Characteristic')
[209]
[210] figure(6)
[211] plot(converted_char_vector,'LineWidth',2)
[212] xlim([0 generations+2])
[213] ylim([0 1.1*(max(converted_char))])
[214] xlabel('Generation')
[215] ylabel('Characteristic Value')
[216] title('Generational Increase in Characteristic')
[217] hold off
[218]
[219] figure(7)
[220] xx = 0:ceil(SSS*2);
[221] plot(normpdf(xx,SSS,st_dev_char),'LineWidth',2)
[222] title('Starting Distribution of Selected Characteristic')
[223] xlabel('Characteristic Value')
[224] ylabel('Probability of Occurrence')
[225]
[226] figure(8)
[227] yy = 0:ceil(conv_avg_val*2);
[228] plot(normpdf(yy,conv_avg_val,(conv_avg_val/SSS)*st_dev_char),'LineWidth',2)
[229] title('Final Distribution of Selected Characteristic')
[230] xlabel('Characteristic Value (Converted Exponentially)')
[231] ylabel('Probability of Occurrence')
[232]
[233] figure(9)
[234] t = tiledlayout(3,1)
[235] nexttile
[236] plot(normpdf(xx,SSS,st_dev_char),'LineWidth',2)
[237] title('Starting Distribution of Selected Characteristic')
[238] xlabel('Characteristic Value')
[239] %ylabel('Probability of Occurrence')
[240] nexttile
[241] plot(normpdf(yy,conv_avg_val,(conv_avg_val/SSS)*st_dev_char),'LineWidth',2)
[242] title('Final Distribution of Selected Characteristic')
[243] xlabel('Characteristic Value (Converted Exponentially)')
[244] ylabel('Probability of Occurrence')
[245] nexttile
[246] avg_avg = (conv_avg_val + SSS)/2;
[247] zz = 0:ceil(avg_avg)*2;
[248] plot(normpdf(zz,avg_avg,(avg_avg/SSS)*st_dev_char),'LineWidth',2)
[249] title('Combined Normal Distribution')
[250] xlabel('Characteristic Value')
[251] %ylabel('Probability of Occurrence')
[252]
[253]
[254] Other Output Section:
[255]
[256] fprintf('Simulation Average Characteristic Value')
[257] average_val
[258] fprintf('Exponentially Converted Actual Characteristic')
[259] exp_conversion = log(average_val/SSS)*SSS + SSS
[260] fprintf('Total Time')
total_time

```