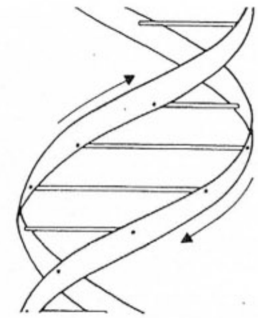
Genetic Improvement Factors Affecting Its Rate



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This, the fifth in a series on genetic improvement, ties together much of the information presented in the four preceeding articles. Because it is technical, it requires a little extra time and effort on the part of the reader—the rewards, however, could be substantial. The payoff comes when breeders understand the theories behind genetic improvement, put those theories to practice in their herds, then reap the benefits through subsequent calf crops.

In the previous four articles we have discussed the foundation for making improvement in purebred cattle. Most breeders want to improve their herds, and hopefully, from our discussion, we all have a better understanding of the genetic principles that both help and hinder our efforts.

Perhaps more critical to economic success, however, is not improvement alone but **rate** of improvement. If you have a strong market in your area for 1000-lb. yearling bulls but yours weigh only 800 lb., how rapidly can you increase your average up to 1000 lb.? This is a fairly simple question with a fairly complex answer. To begin answering this question, let's look at the important components in the form of an equation:

$$\text{annual genetic progress for a trait} = \frac{\text{heritability } (h^2) \times \text{selection differential (SD)}}{\text{generation interval (GI)}}$$

If we take the time to discuss each element in this equation, its application becomes more clear.

Heritability Differs Among Herds

First, although we have already discussed heritability, it is worthwhile to point out a few additional facts on the subject since it is obviously so important in determining rate of progress. Perhaps the most striking thing about heritability is that it may be different in different herds—even for the same trait. We mentioned earlier that heritability can be expressed as a ratio of genetic variance to phenotypic variance, symbolically:

$$h^2 = \frac{\text{genetic variance}}{\text{genetic + environmental variance}}$$

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Although this is not intended to be a mathematics lecture, a closer inspection of this ratio makes it apparent that h^2 will change if either the numerator or the denominator changes. Normally, the part which changes from one herd to the next is the environmental variance.

Considering yearling weight, for example, a small environmental variance can be brought on by treating all calves identically from weaning to one year of age. Such would be the case if all calves were weaned as a group and tested in the feedlot as a group. By so doing, all calves are exposed to more identical environments than would be the case if some were pulled out and tested in the show barn. As a consequence, more of the difference between any pair of animals would be due to genetic rather than environmental causes.

When the environmental variance is minimized, the coefficient of heritability is maximized. Of course there are certain limits to the amount by which the environmental variance can be reduced; consequently, none of the quantitative traits in beef cattle show 100% heritability.

If you have a strong market in your area for 1,000-lb. yearling bulls but yours weigh only 800 lb., how rapidly can you increase your average up to 1,000 lb.? This is a fairly simple question with a fairly complex answer.

Improves Accuracy of Selection

Now, maximizing heritability does not make the herd any better genetically, so why bother? There is a very good reason for maximizing heritability. Namely, it serves to improve our accuracy of selection based on records. Accuracy is no more than the correlation between the estimated breeding value and the true breeding value of an animal. Accuracy can also be thought of as the association between an animal's phenotype (what it appears to be on the outside) and it's genotype (what it really is genetically).

If we are selecting animals based only on their individual record, with no information from relatives, the accuracy is simply the square root of heritability. For example, if h^2 is .50, accuracy = $\sqrt{.50}$ = .71. If h^2 = .60, accuracy = $\sqrt{.60}$ = .77. Perfect accuracy would occur only if h^2 = 1.0. Of course, even if h^2 is substantially less than 1.0, accuracy can be better than $\sqrt{h^2}$ if information from relatives, such as progeny, is used since the progeny of a bull tell us a little bit more about the true breeding value of that bull.

Since most of us would prefer to make the fewest possible mistakes in our selection of animals to be parents, good management practices which maximize heritability in the herd are probably worth the effort.

What Selected Differential Means

The second component in our equation for genetic progress is selection differential. Selection differential is simply defined as the amount (pounds, inches, etc.) by which the selected group of individuals exceed the group from which they came. For example, if your entire group of yearling heifers have an average yearling weight of 700 lb. and your selected replacement heifers from this group have an average weight of 800 lb., your selection differential for yearling weight is 800 – 700 = 100 lb. When this selection differential is multiplied by heritability, as it is in our equation for genetic progress, we get an estimate of how much of this superiority is due to genetic superiority. Now, hopefully, our equation is beginning to make sense.

There are several things which affect the size of the obtainable selection differential. The most obvious of these is the number of replacements needed. If a breeder needs to save 20% of his heifers for replacement, he will be able to obtain a larger selection differential than if he needs to save 50% of his heifers for replacement.

Variation Makes Progress Possible

The second factor is the amount of variation present for that trait in a herd. Obviously, if all the heifers weigh exactly 750 lb., it will be impossible to select any which are above average. Although we as breeders tend to cuss at a calf crop with a lot of spread from top to bottom, without this variation we might as well sell the cows and join the carnival because genetic improvement would be next to impossible.

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The third factor affecting the size of the selection differential is the one which is the most discouraging to cattle breeders—the number of traits being considered for selection. While every breeder would undoubtedly like to make maximum progress in each and every trait, we know that certain sacrifices must be made if more than one trait is being considered for selection. How many times have you thrown up your arms in disgust because that 1400-lb. yearling bull is only a frame score three, or is post-legged, or has only one testicle?

More than One Trait Affects Value

These types of problems are universal and they offer no easy solutions. Unfortunately, the economic value of beef cattle cannot be summarized into one trait. This cuts down our selection differential for each trait as the following numerical example illustrates. Let's suppose that we've collected the following data on 10 heifers:

Heifer No.	Yearling Weight	Hip Height	Conformation Score
1	900	45	13
2	890	48	14
3	880	45	14
4	870	47	15
5	860	49	16
6	850	46	17
7	840	44	17
8	830	44	16
9	820	45	14
10	810	43	14
	Average 855		

If we need two heifers and if we ignore hip height and conformation score and select only for yearling weight, we would select heifers 1 and 2. The selection differential would be 895 – 855 = 40 lb. Let's set heritability at .50 and generation interval at 5. Plugging into the equation for genetic progress we have:

$$\text{annual progress for yearling weight} = \frac{.5\ (h^2) \times 40\ (SD)}{5} = 4 \text{ lb.}$$

Now, let's expand our selection program to include two traits (yearling weight and hip height) and see what progress we can make in yearling weight. If we set independent culling levels at 870 lb. for yearling weight and 47 inches for hip height we have only two heifers (2 and 4) which meet both these criteria. Now, checking annual progress for yearling weight we have:

$$\text{annual progress for yearling weight} = \frac{.5\ (h^2) \times 25\ (SD)}{5} = 2.5 \text{ lb.}$$

So, by adding a second trait, (hip height) we have reduced annual progress in yearling weight from 4 lb. to 2.5 lb.—a significant reduction.

More Traits Mean Slower Progress

Let's continue by checking annual progress in yearling weight when we include all three traits in the table. To obtain two heifers we need to set our independent culling levels at 860 lb. for yearling weight, 47 inches for hip height and 15 for conformation score. The only two heifers which meet all these criteria are 4 and 5. Now, using our formula, what annual progress can we expect for yearling weight?

$$\text{annual progress for yearling weight} = \frac{.50\ (h^2) \times 10\ (SD)}{5} = 1 \text{ lb.}$$

Considering all three traits, we advance one pound per year in yearling weight compared to 2.5 lb. per year with two traits and 4 lb. per year when only yearling weight was included. Keep in mind that this is progress due to selection of females only.

The preceeding example may have been a bit lengthy but it serves to illustrate how selection for more than one trait tends to slow progress for **each** trait. It does this, of course, by reducing the selection differential.

Same Principle Applies to Bulls

Up to this point we have discussed selection differential with regard to heifers. The same principle applies to the selection of bulls. Many of us have heard the statement that "from 85-90% of the genetic improvement made in a herd is due to the selection of bulls." The truth in this statement lies in the fact that our selection differential for bulls is generally much larger than for females. While we may have to keep the top 40 or 50% of our heifers each year as replacements, we need only keep the top 1-2% of our bulls. If we look at the overall picture which includes many A.I. sires, we may be using the top .5% of the bulls in the entire breed which drastically improves our selection differential. Even if many traits are considered, as is usually the case, the opportunity to select one or two bulls from the entire population of Angus cattle gives all of us the freedom to be very particular.

Since most of us would prefer to make the fewest possible mistakes in our selection of animals to be parents, good management practices which maximize heritability in the herd are probably worth the effort.

Interval Based on % Replacement

The final component in our equation for genetic progress is the numerator: The generation interval. The generation interval can be defined as the number of years it takes to completely replace your breeding herd. In our numerical example we used the value of 5.0 for our generation interval. This assumes that 20% (one-fifth) of the herd will be replaced each year by progeny of the herd. Generation interval may also be defined as the average age of the parents when the progeny are born.

While every breeder would undoubtedly like to make maximum progress in each and every trait, we know that certain sacrifices must be made if more than one trait is being considered for selection. How many times have you thrown up your arms in disgust because that 1,400-lb. yearling bull is only a frame 3, or is post-legged, or has only one testicle?

So, how does this affect rate of improvement? Younger cattle certainly don't have better heredity simply because they're younger. Presumably, they have better heredity because they have been *selected.* Recall from our discussion above that in order for selection to be at all rewarding, a real selection differential must be obtainable. The generation interval describes, in essence, the proportion of the herd which has most recently been selected (has benefited from our selection differential). To point this out more clearly, recall our equation for annual progress:

$$\text{annual genetic progress} = \frac{h^2 \times SD}{GI}$$

Earlier, we interpreted the numerator (h^2 x SD) as being the expected *genetic* superiority of the selected individuals. Now, instead of writing our equation in the traditional form, let's rewrite it:

$$\text{annual genetic progress} = (h^2 \times SD) \times 1/5)$$

Fraction Indicates Selected Individuals

We multiply by the fraction (one-fifth) because this represents the proportion of the population which is composed of selected (improved) individuals. The remainder, four-fifths, still have the same average genetic value as they did before we started selecting. This does not mean that some of the original animals are not as good as some of the selected young ones. Rather, it means that the *average* of the selected individuals is higher than the *average* of the original herd.

To illustrate this, let's use another numerical example. Let's assume we have a herd of 100 cows with an average genetic value of 800 lb. for heifer yearling weight. If we continually breed these 100 cows year after year with no replacement, they will always have an average genetic value of 800. On the other hand, if we cull 20% of the cows because they failed to wean a live calf and replace them with 20 *selected* heifers, we expect the average to increase. How much? Well, let's assume that h^2 = .50 and that our phenotypic selection differential is 200 lb. This means that the genetic superiority of the replacements is 100 lb. (.50 x 200). With the addition of these heifers into the herd, the new herd is composed of four-fifths old cows with an average of 800 and one-fifth new cows with an average of 900; hence, the new overall average = (4/5) 800 + (1/5) 900 = 820. Our actual genetic progress has been 20 lb. Now, let's see if our fancy equation gives the same answer; with h^2 = .50, SD = 200 and replacement rate = 1/5-fifth, annual genetic change = (.50 x 200) X (1/5) = 20. How about that!

Must Make a Trade-Off

From this discussion we do not want to give the impression that minimizing generation interval will automatically improve rate of progress. We should keep in mind that the selection differential will be reduced if a higher proportion of replacements are kept. As is the case so often, a trade-off must be made.

Although the equation for annual genetic advance is a useful barometer for projecting what might be accomplished in a selection program, these authors have some reservations about prescribing it to be gospel.

First, the equation was derived before the advent of artificial insemination. Therefore, it applies exactly to herds where no A.I. sires are used and selections are made only from within the herds.

When A.I. sires are used, the equation probably applies only to the females. Second, by defining generation interval to be the average age of the parents when the calves are born, it penalizes older cattle without exception. For example, if a 15-year-old cow transmits the very same genes to her calf as a 2-year-old cow, this formula tells us that the genes from the young cows are somehow better. This makes no sense at all.

Another Way to Look at It

We believe it is more appropriate to view the generation interval as we did in our example with the 100 cows. That is, it is the reciprocal of the proportion of the breeding herd that is replaced each year. If 25% is replaced each year, the generation interval = 1/.25 = 4. If 10% is replaced each year the generation interval is 1/.10 = 10, and so on. Mathematically, this makes more sense. Intuitively, it makes more sense also.

Younger cattle certainly don't have better heredity simply because they're younger. Presumably, they have better heredity because they have been selected.

The essence of this is that an older cow should not be able to compete, genetically, with the youngest cows in the herd if genetic advancement is occurring at a rapid pace. Once again, this is true on the *average.* Many of us have 15-year-old cows that still stack up very well against the youngest cows in the herd even if genetic progress has been very rapid. This occurs because each calf gets a sample half of its genes from each parent and it is possible that your 15-year-old cow happened to get an above average complement of desirable genes.

It Really Happens

For example, she may have been born in 1965 when the average genetic value in your herd was 700 lb. Even though the average that year was 700, she may have been "lucky" and received from her parents a genetic value of 850 lb. Now, each year you have improved the average genetic value of the herd but have not yet brought the average up to 850. Therefore, that old

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cow is still above average genetically. This is not an absurd collegiate example, it really happens!

The same is true of bulls but to a much lesser degree. Any particular bull calf may receive an above average complement of desirable genes as in our example with the old cow. However, since a bull must not only be above average but must be the absolute top individual before he is used as a herd sire, he has little chance of staying on top very long. This is particularly true if rapid genetic advancement is taking place in the herd.

The real limits of genetic improvement are most noticeable as they affect the rate of improvement. The closer we get to the ideal, the fewer will be the number of animals that greatly exceed our average.

Hopefully, we have gone through this equation with enough diligence that it has taken on a little more meaning. Even if our explanations were sometimes confusing, that's not all bad. Confusion *can* be thought-provoking.

What Are the Limits?

The final topic regarding genetic progress is one which has probably been in the thoughts of most breeders. Namely, what are the limits? Biologically, this is a question that possibly has no clear answer. Economically, however, most of us have a good idea of what our final point should be.

Earlier we discussed the importance of variation in a trait and this is a good time to reiterate this. As long as variation is still present, genetic change can be made. Now, if all Angus breeders were to select for the same trait for five or six generations, we might notice that the available variation would decrease, but it still wouldn't disappear.

This is not something that should alarm any of us. If we take a case where two breeders are both selecting for 140-day ADG but one is feeding a high concentrate ration and the other is feeding a high roughage ration,

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they may not be selecting for the same trait. That is, ADG on high concentrate rations may be a function of appetite while ADG on high roughage may be more a function of metabolic efficiency. Additionally, a cow with the ideal genotype in Turner's home state, Ohio, may not have the ideal genotype if she is moved to Wilkes' home state, Wyoming. These inequities are known as genetic x environment interactions and they have received only limited investigation by researchers. Consequently, their real importance in beef cattle breeding remains unknown. They may, in fact, be a blessing in disguise since they insure a good deal of genetic variation within the breed.

Rate of Improvement Reflects Limits

The real limits of genetic improvement are most noticeable as they affect the *rate* of improvement. The closer we get to the ideal, the fewer will be the number of animals that greatly exceed our average. For example, if you began using A.I. bulls in 1970 to improve yearling weight in your herd which had an average then of 700 lb. you may have used a bull via A.I. with a yearling weight of 1,400 lb. Consequently, your selection differential was 700 lb. Over the years you may have increased yearling weight to 1,100 lb. Now, in 1981, with your average yearling weight of 1,100 lb., you may not be able to find a bull that will give you a 700 lb. selection differential—it would take an 1,800 lb. yearling to do it! Hence, in 1970 you made an improvement of (if $h^2 = .50$ and G.I. = 5)

$$\frac{.50 \times 700}{5} = \frac{350}{5} = 70 \text{ lb.}$$

but in 1981 your expected improvement, if you find a yearling bull weighing 1,500 lb. is

$$\frac{.50 \times 400}{5} = \frac{200}{5} = 40 \text{ lb.}$$

It's Tougher at the Top

As your herd approaches the top, you will be able to find even fewer bulls which will really move your program forward. This is not a bad place to be. If, for example, you finally reach the point where you can no longer improve yearling weight, you can concentrate on other traits. This, however, is a problem that most breeders will never be faced with. The thought that the genetic variation for a complex trait such as yearling weight would ever shrink to zero is incomprehensible. Hence, genetic *change* will always be possible for such traits. As breeders, we are charged with deciding if the changes we bring about through selection constitute improvement or impairment.

New Advertising Campaign Starts in April

The new national beef advertising campaign will start in April, according to a Beef Industry Council spokesman. Network TV commercials with the theme "Nothing Satisfies like Beef," will be presented in April-May, June-July and September-October periods. There will also be regional spots in 25 major market areas and print ads will appear (also beginning in April) in 10 consumer magazines that have women's or regional interest. Retailers will be encouraged to participate.