but I hope someone else that is working in this field can.

Dr. Lush, go ahead.

In the plant world, they do know some marvelous series of multiple alleles among the self-sterility genes. Wherever you have self-sterility of such a nature that a pollen grain carrying a given gene cannot grow down the style of a plant that has that same gene in either locus, you must have at least three genes to keep the system going. Natural selection favors the rarest gene of the series. You might call that extreme overdominance, because only the heterozygotes can be formed in the first place. And then each heterozygote can be pollinated only by pollen carrying some allele which is different from the two in the plant itself. I think they know up to forty different alleles in some of those series. Now that is so extreme a case because the homozygotes can't even exist that I wonder whether it can fairly be called overdominance. At any rate, there is that body of knowledge about heterosis and multiple alleles.

Sweet Clover is still another case.

Dr. Lerner, you scare me, I'm afraid we're going to end up by breeding these birds from the test tube. I've been watching all this antigen group deal going along. I'm not a very good laboratory technician.

Neither am I.

Dr. Lush, I want to take this opportunity to thank you. It has been very good. I think we all got a lot out of it. We'll all take a break for 15 minutes at this time. We all heard Dr. Dickerson's introduction this morning so I'm not going to repeat his history. We have assigned to Dr. Dickerson "The Advantages and Disadvantages of Progeny Testing." We thought long and hard to make up that one; I think it is only fair to see how he handles it. Go ahead, Dr. Dickerson.

It seems to me that this meeting today, in itself, is a good example of heterozygote superiority or overdominance or whatever you want to call it, because we college professors are long on pencils and chalk, but short on experimental data. You fellows have lots of chickens. You should have lots of data. Maybe if we get together more often there will be a little hybrid vigor in learning how to breed poultry more effectively. Is it all right to embark that far into your topic, Dr. Lush?

Progeny testing has as its chief advantage increased accuracy in evaluating individuals. We all recognize that, and it has already been mentioned that when you average the performance of a large number of progeny from an individual, the environmental influences which differ between individual progeny tend to be cancelled out. Hence, progeny testing eliminates some of the nongenetic sources of error in evaluating individuals depending upon the adequacy of the test. This has long been recognized, but it is the chief advantage of progeny testing, nevertheless. Also, evaluating an animal on the basis of progeny performance tends to eliminate error from nonadditive gene action, the kind of gene action Dr. Lush was talking about. The effects of dominance and gene interaction may make an individual's performance differ from its average transmitting ability. Another plus factor for progeny testing that might be mentioned before we get into details, is that some of the newer methods of deliberately selecting for maximum cross performance between particular strains require progeny testing as the only tool or basis of selection which will take you where you want to go.

Some of the disadvantages of progeny testing will not be new to you either. The main one is the sharply reduced intensity of selection that is possible on the basis of progeny tests. This comes about first, because we can only progeny test a very limited number of individuals compared to the total number produced. If we are going to save any of those tested for further use on the basis of their superior progeny performance, we must save a fairly large proportion of the whole number tested, because we have a relatively small group of tested birds from which
to select. Mortality among breeding birds further reduces opportunity for selection based on progeny test, depending on how adequately management is able to control mortality among breeders. In addition to the higher mortality among the birds that have been progeny tested, there is the reduced fertility of tested males and the lower level of egg production of tested females which limit reproduction of the progeny tested birds as compared to the cockerel and pullet breeders. All of those things tend to make the amount of selection that can be based on progeny testing small compared to the intensity of selection that can be practiced on the basis of individual or family performance among pullets and cockerel breeders.

That, to me, summarizes the advantages and disadvantages of progeny testing. However, we do need to consider the system of breeding followed. If we're to determine how much emphasis should be given to progeny testing in the breeding program, we can consider by contrast, two different systems of breeding. One is the closed flock system of breeding, in which you have a single homogeneous population, a strain of purebred poultry or a standard-bred strain of poultry. The other system of breeding is one in which the breeder is selecting directly for improved performance of a cross between two different strains. Of course, the role of progeny testing will be quite different in the two cases.

I think it is fair to say that the optimum use of progeny testing for selection within closed flocks depends, in part, on the level of performance of the breeder's flock. In a flock where selection based on individual and family performance with little emphasis on progeny testing has been practiced for many generations, perhaps fifteen or twenty years, and a relatively high level of performance has been achieved, the rate of further improvement from that kind of selection may be slight. Under such conditions, relatively heavy use of progeny tested birds would be indicated. The objective, in the case of overdominance, is to get a closer approach to the optimum equilibrium gene frequency. In the case of intermediate optimum type of inheritance, you're selecting to increase the proportion of the gametes produced by the breeders that are in the intermediate category.

If by contrast, a breeder is in the early stages of a breeding program to establish a new strain, starting with either unimproved stock or with stock that is a mixture of many different strains, then I think the emphasis on progeny testing generally should be kept rather light and the emphasis on individual and family performance relatively heavy. Here we could ignore for some time the effects of dominance and gene interaction that we have been discussing, and the optimum proportion of breeders selected on the basis of a full year's family performance and a part year progeny test would be relatively low. I think perhaps I'll use the blackboard a little bit here to illustrate what I'm after.

We're talking about a closed flock system of breeding, a flock in which some progress is being made from individual and family selection. What is the optimum proportion of tested breeders to use as compared to pullet and cockerel breeders? Pullet breeders would be selected after three or four months production on the basis of part year family and individual performance. In selecting cockerels for egg production you would have to rely on the part year performance of their sisters. The tested birds that I'm talking about in this example would be the yearling hens that have a full-year individual and family egg production and a part-year progeny test. These yearling hens are birds that were used as pullet breeders. On the basis of their full year family and individual performance and their part year progeny test, you're going to pick a portion of those birds that were used as pullet breeders last year to use again as yearling breeders this year.

I have had an admonition from the chairman to keep this simple. Joe said that everything had been fine up to now. Dr. Lush, you can feel very good about that. But Joe is apprehensive about the future. I told him that perhaps I should be, too, but I wasn't going to worry about it.
We will make a rough chart showing along the bottom the proportion of the matings that are with males selected on the basis of progeny test, in this case the percent say of ten tested males. On the side we have expected yearly progress, the measure of your expectation of genetic improvement for each unit of time. I'm not going to put in the numbers here because they are expressed in terms of the standard deviation of genotypes and that would not be good at all, would it? But we will put in some definite proportions of tested males, ranging from 0% to 50%. Suppose we are housing approximately ten pullets from each female breeder used, or full-sib families of ten birds each. The next thing we've got to decide is the number of matings per male. Suppose that the number of dams per male is also ten, and that we house roughly a 1000 pullets each year. Out of a hundred female breeders, mated to ten males, we will house, roughly, ten pullets from each female breeder used. That, by the way, is about the number of pullets you might expect to house per breeder with a normal hatching season, at least with us. Now, suppose we examine progress to be expected from selection. If we use only pullet breeders, we will choose one hundred breeders out of the thousand housed. Using ten females to each male means that we will be picking ten males out of 1000, if we raised all our males. But perhaps ten out of 200 would be more likely if we keep to housing age something like an average of two males from each full-sib family. The first point on the curve of expected annual improvement is for use of all pullets and cockerel breeders. At this next point here, we're using nine young males each year and we're keeping the best one of the nine we tested last year to be used again and expected improvement goes up a little bit. When 20% of the males are yearling tested birds, selection would be two out of eight; 30% would be selecting three out of seven; 40% would be selecting four out of six; 50% would be selecting five out of five. I think you see why the proportion to be mated to tested males can't go too high. You soon get to a point where you can practice no selection whatever on the basis of the progeny test, where you are keeping all the males that were tested to be used the second year. So actual progress expected from use of 50% yearling tested males is that expected from selecting only five males out of 200 or so on the basis of a part year family performance, and using all five of them for two years in a row. Now you could immediately raise the question, why use as many as ten birds for each young male tested? That is a perfectly valid objection because you could test your young males on perhaps three to five birds each. That would give you a larger number of tested males from which to pick those to be used as yearling tested breeders and you could perhaps use your yearling tested breeders on as many as twenty or twenty-five birds. That, of course, would increase the opportunity of selecting on the basis of progeny test. The only drawback is that if instead of using ten birds per young male, you use five, it means that you are going to need twenty instead of ten young males to test. You can't select twenty males that are just as good as the best ten, can you? It means you save twice as many young males. Therefore, this curve will start at a lower point and it only catches up over here some place. By the way, you probably have already been struck with how flat-topped this curve is, how little difference it makes what proportion of tested males we use. This is perfectly true if we consider only the average effects of genes. What happens as you move out this way, as far as males are concerned, is that the more tested males you use, the smaller and more select the group of young males you progeny test, and therefore, the greater the superiority of the young males selected. The larger the proportion of the tested males you have to keep, the less the selection among the tested males and therefore, the smaller the advantage from basing selection on progeny test. In either family performance for young males or progeny test performance for tested males, the larger proportions you have to keep, the smaller the difference is going to be between the average merit of those kept and the whole group that they were chosen from. It is a matter of balancing one against the other in deciding where the optimum
would lie. It looks as though, at least in the early stages of a closed flock breeding program, that one would not be justified in using more than ten to twenty percent of selected tested males. If a larger proportion of tested males is used, you are practicing too little selection among the tested males in picking the ones that you are going to use over again, and you lose the advantage.

Perhaps we should consider further the validity of assuming that breeding males are selected from 200 cockerels each year. Changing this number from 150 to 250 would not affect the intensity of young male selection very much, because 10/150 and 10/250 are both rather intense selections. If selection of young males is to be based on part year family performance, then the culling from 1000 to 200 that you do on the range or even earlier will have to be based upon information that came along after you had already produced these chicks, or on the hatchability or early mortality of the family, before any egg production data is available. This early culling could be still greater. Of course, if you cut down numbers of cockerels too much, then you are limiting the room that you have to select when the part-year egg production comes along. In the many attempts we have made to decide how much relative attention the different traits should have in selection index, egg production really wags the dog. In other words, it is difficult to justify heavy emphasis on hatchability or early mortality and still keep in mind the relative economic importance of the characters.

I am not sure I understand that figure of 200 males when you only have 100 families from which to select?

We have 100 families and we have assumed more or less arbitrarily that we will keep more than a couple hundred males until the part-year family egg production is obtained.

You are only going on family egg production average and you are selecting ten out of a hundred each time?

But I could save two out of each family. Might even save three.

Well, that would still be out of a hundred. That would be seven out of one hundred, not ten out of two hundred.

Well, two males from each of the five best families is 5/100 families or 10/200 cockerels, the proportions are the same. Before I leave this male picture and before I leave this curve of expected progress, I should say that if by any chance your breeding program is at a point where family selection or part-year family performance is not taking you anywhere, then it may very well be advisable to increase the number of young males tested and reduce the number of matings in which each young male is involved. This is for the purpose of having a bigger selection differential when you come to pick your tested males from among those tested. For example, if I want to test 18 cockerels with 5 females each and keep one to use on the 20% of the breeders the following year, this increases the selection differential because only one out of eighteen tested males is selected instead of one out of nine. The reason that would not be advisable, if you were really making appreciable progress from family selection, is because one can't pick eighteen males that are just as good as the best nine young males. Intensity of selection of young males is reduced by testing too many, if the family selection is doing any good. Are there any questions you want to raise about the general approach?

I don't see that. What if you took two males from one family, what would be the difference? How do you know that one male is better than the other before you test them?

You don't. You are selecting on part-year family performance.

Why shouldn't it happen that one family is better than another? Why not use five males out of one family? Why shouldn't you use that?

The only objection would be the possible effect on inbreeding. Is there still a question on that?

Unless I didn't hear you right, you said it would be harder to select eighteen good
portions of teaches year record. With the pullet case where you're got just a part-year family performance a egg production record tested males.

breeders or progeny test than by selecting on proportion of progeny. You may make little progress for intermediate gametes won't go much further to a much heavier emphasis because the pickings are becoming pretty sigma in the latter case you are in your breeding program, whether you are still on the year Emphasis on progeny tested sires depends a great deal, it seems to me, on how far you are in your breeding program; whether you are still on the up-grade so far as effectiveness of family and individual selection is concerned, or whether you have gotten to a point where the pickings are becoming pretty slim. In the latter case, I think there are good reasons for shifting over to a much heavier emphasis on the use of progeny tested birds. Under the over-dominance picture, you would be pulling closer to the optimum or the equilibrium gene frequency, which is the best that you could achieve in a closed flock system of breeding. Under an intermediate optimum situation, you would be favoring individuals that were homozygous for intermediate gametes. I won't go into this in great detail, but there are reasons in favor of progeny testing. If you are at a point where epistatic variation accounts for a large portion of the genetic variability, you may make little progress. You can, nevertheless, increase the proportion of breeders that produce intermediate gametes to a greater extent by selection on progeny test than by selecting on individual or family performance.

Now, I guess I can leave the same curve up there for the effect of using tested female breeders on expected progress, if we substitute proportion of tested females for proportion of tested males.

By tested female in this case, you simply mean one that has ten pullets with part-year egg production records and one whose family has a full egg production record; as contrasted with the pullet case where you've got just a part-year family performance and the bird's own part-year record. It turns out that progress, when we use all young males but use varied proportions of tested females, coincides almost identically with the curve I've shown already for
males. In other words, there is a slight advantage in using a small proportion of tested females. It isn't great, but there is a little and the optimum, depending on how much attention you pay to the inflection of this curve would vary between 10 and 25% of older yearling birds. Now if you use optimum proportions indicated of both tested males and females, then this curve raises up a little bit up here; one supplements another. So as far as I am able to calculate, and we must recognize that these are calculations based on heritability and how much environmental error is averaged out by having progenies of a given size, etc., the optimum proportion of tested breeders within the definitions I have used here would vary somewhere in this 10 to 25% range. You have to recognize that if your level of performance is high and little progress is being obtained from family selection, then that proportion of tested birds undoubtedly should be higher than 10 to 25%. But again you can't go too far in this direction before you cut off your nose to spite your face. You are using so many tested breeders that you can't practice any selection in choosing them. Now you can bring up variations in which you use some other flock to test large numbers of young cockerels, but that is a little different, because you still have to use those birds to test young males. I think, in the long run, it doesn't come out much differently than if you consider all the birds you are working with as one flock. Any questions?

How do you arrive at the selection of the 200 cockerels that you are going to raise? Are they from all families or are they from the most selected sister families?

Well, in our own closed flock breeding work, we set up a selection index which takes into account hatchability of the family; the early mortality of the family; the egg production of the family; and the adult mortality of the family. We weigh those things according to their relative economic importance as near as we can arrive at it and according to how highly heritable the various traits are to the best information available. Of course, the males are culled from 1000 to 200 before the part-year egg production and adult mortality part of the family index is available.

Then you pick your males from the families that have the best index? In the spring you save these cockerel chicks; is that what you mean? Or do you raise 1000 cockerel chicks, too?

No. We raise all cockerels to twelve weeks in the closed flocks. By that time, the full year family performance on their parents is available, and you can do some culling on the basis of parent performance and on the basis of viability, hatchability, and growth rate up to twelve weeks of the cockerel's own family. But since egg production swings such a heavy hand in the male selection that you actually want to make, you can't cull too severely at twelve weeks. You can't eliminate males from too many families or you may wish you hadn't. You may find that you don't have any males from families that you would like to have. In practice, we have kept males from about two-thirds of the best families. When we think a family will do exceptionally well, we may keep two or three males at twelve weeks of age from that family. But any selection for egg production at this time must be on the basis of the dam's and sire's families. Egg production records on the parent's families will have been completed by this time.

When do you complete those parent's egg production records?

It all depends upon what you call your full year egg production. We use performance to about 450 days of age, which ends in June and July, in our flocks.

Your year is not a year?

Our year is not a year, no, because we have to be able to empty those houses and have them ready for the new pullets.

Don't you mean to say that information on the hatchability of eggs from the dam is available when the progeny are twelve weeks of age?

You would have to wait awhile after the hatching season in order to summarize the full season's hatchability on the dam. If much culling was done at hatching time, it would have to
be on the basis of the family or individual performance of the parents. Presumably the parents were already selected on this basis. Further culling at hatching would only restrict the opportunity for selection on the basis of information on the new generation.

Did I understand you correctly to say that the time would come when you would eliminate or reduce the amount of selection pressure based on individual performance? Is that right? In any system of breeding, would you eliminate consideration of the individual?

No, not at all but you may reduce it somewhat. If you test a larger number of young males in order to have more choice among tested males, that may reduce progress if you are really making any progress from selection on the basis of part-year family performance, because it means that you are practicing less intense selection in picking the young males to be tested. However, if that early culling on the basis of individual and family performance isn't doing you much good anyway, then it wouldn't hurt you to go ahead and test more young males. It amounts to a little less intensity of culling of young males for the purpose of putting more emphasis on selection based on progeny test.

I am thinking, maybe didn't put my question across. I am thinking of the physical fitness of the bird, over and above theoretical considerations.

Well, I am assuming that you can pick eighteen cockerels that would not be greatly different than nine out of 200 in physical fitness. There is some question as to how much emphasis should be placed on the appearance and growth rate, etc. of the male anyway, provided he is healthy and strong enough to live.

You are speaking of production flocks?

I am talking about phenotype of young males. Is that what you are referring to?

This same selection would apply to meat strains as well as to production strains?

It doesn't matter whether you are talking about a meat strain or an egg strain. If your flock has reached a point where individual and family selection is no longer effective, then progeny test selection is likely to be more important than individual performance selection. As long as you are still getting anywhere from individual performance and family average, progeny testing doesn't deserve a very big place in your breeding program.

Now, let me ask this question. If these conclusions are based on a limited number of matings, then would they apply if the number of individual male matings were greatly increased? Could you go on indefinitely as far as individual family selection is concerned?

As long as you are making good progress.

Well, assuming that?

On that assumption these curves would apply pretty well as far as optimum proportions of tested males and female breeders. What you are really trying to do is to keep to genetic improvement from selection among tested males that takes place in one year's time the same as it is from the selection that you make among young males. Suppose the total length of this arrow represents the difference between the average for all young males, for all hundred families, and the mean performance of those families from which you keep young males to be tested. This is the young males mated in test pens. Since we can pick among our young males only eight or ten out of 200, 5% or less, we can expect quite a large difference in the family performance level for the young males chosen, compared to all young males we might have kept. But since it is based on part-year performance and on family performance of only ten birds, only a portion of that total reach is actually genetic. The rest of it is either environmental error in evaluating the family or it is due to nicking of various types. Now when you come to select among the nine tested males, that were chosen originally from 200 cockerels, you need to save at least one out of the nine. One out of nine is 11% but keeping nine out of 200 is 4 1/2%. Therefore, we get a bigger selection differential or bigger apparent advantage.
in picking our young males, but less of it is genetic. In picking the best tested males among
the nine that were tested, a larger proportion of the apparent superiority is genetic, but since
we have to keep one out of those nine, we cannot have as big a selection differential. In con-
sidering the optimum proportions of young and old males to be used, the real genetic superior-
ity from selection should be the same in the selection among tested males as it was the previous
year in selecting the nine to be tested from the 200 cockerels. In other words, the two have to
be in balance when you are at the optimum proportion of tested and untested males. If you test
only six cockerels, it means that 40% of the females can be mated to tested males and at least
two males out of those six tested will be needed to mate with those 40. Then you have reduced
the amount of culling based on progeny test to keeping only the best third, and if a few males
happen to die, you may end up with only the best half or best two-thirds. Which means that you
are not practicing much selection on the basis of progeny testing and all you are doing apparent-
ly is treading water as far as selection among old males is concerned.

I want to ask you with reference to this curve of expected annual improvement, in terms
of percent, what is the difference between using an optimum number and using no tested males?
Well, compared with using only young males and females, using the optimum proportion
of both males and females, it would be an increase of not more than five or six percent.
It seems to me you are doing awfullot of talking about something that isn't very
significant.

Well, sir, you know they assigned this topic to me and if I don't do anything but show
you that there isn't a whole lot to be gained by progeny testing, where you have individual and
family performance as an alternative, maybe it will be worthwhile.

Now that we are over on that subject, perhaps I had better bring up what I had on my
mind.

O.K.

I wonder about the practical value of using old progeny tested cocks, anyway? There
are a lot of us who have made up a few pens of old cock birds and find that two or three of
them don't come through with any chickens anyway and that immediately throws out one
breeding pen and you don't get any offspring from them. It certainly doesn't help your business
any. That throws your theoretical proportions all out of kilter. Isn't it just as well to pick your
best young cockerels from your best families?

It all depends where you are on the curve of progress from selection on individual and
family performance. I guess my time is up.

Do you have some more you want to cover?

Well, I'll just make a general statement with regard to this other type of breeding where
you are deliberately selecting for performance of strain crosses. There, of course, you have to
base your selection on progeny testing. You have no alternative. You are selecting one strain
to match another. Somehow or other, these problems of old males dying and not being fertile
keeps right on being a factor, but you need to use the progeny test anyway. Justification for
resorting to selection for maximum performance of strain crosses, of course, rests on the im-
portance of this heterozygote advantage or overdominance we were talking about this morning
and other types of gene interaction in the genetic variability that you have to deal with. That
is why it is so important that we learn more about just what kind of gene action and interaction
we are dealing with. The effects of both inbreeding and crossbreeding indicates that the degree
of heterozygosity does exert a major influence on important performance characters, such as
hatchability, mortality, and egg production. But we certainly need some critical breeding ex-
periments before the relative importance of dominance compared to gene interaction can be
determined. Present evidence, it seems to me, indicates that both are important and that the
rate of improvement from long continued selection within closed flocks may become negligible even though the estimates of heritability continue to be positive. In some work that Mr. Krueger is doing, we have been looking hard to find evidence for negative genetic correlations between the components of egg production and between growth rate and egg production, largely without success. Genetic correlations seem to be more positive than negative so far, but we are still looking for negative relationships that may help explain the sometimes discouraging lack of results from selection. Under these conditions, deliberate selection for maximum cross performance between complimentary strains seems to offer promise of significant further improvement. And, as I believe Dr. Lush mentioned this morning, you need the cumulative effects from recurrent cycles of selection to efficiently obtain crosses that are anywhere near the potential maximum; because the range in performance of crosses within any one generation is very small compared with the potential range. I was going to say just a few words here about different methods of progeny testing for maximum cross performance. I might just run through these and if there are any questions about them, we can drop back. The expected effectiveness of this reciprocal recurrent selection between two non-inbred populations, that Dr. Lush mentioned earlier, can be compared with that from recurrent selection for cross performance with a highly inbred tester line, somewhat as follows: Many of these points Comstock made in his original publication. And others, of course, Fred Hull has made in his various publications. Are we clear on what the two methods are? You have non-inbred A selected to cross well with non-inbred B. You are practicing selection within this "A" strain, both among females and males, on the basis of progeny tests of those birds in matings with individuals of strain B, and the reverse. The other system is one where you use an inbred "A" and select non-inbred population "B" to fit it. Those are the two systems that we are contrasting. Both of them involve progeny-test selection. The first thing that comes to your mind in comparing these two systems, of course, is that if the tester line is highly inbred, you aren't going to be changing it much. If the tester line A were homozygous, you would not be changing it at all, and all of your selection would have to be done over here in non-inbred strain B. So, you would be practicing only half as much selection, with an inbred tester, as you would in fitting two non-inbred strains to each other. In the latter case, you are selecting on both sides. In the first case, you are selecting on the one side only. These two systems are alike in the potential limits of cross performance, so far as dominance is concerned, but the use of a highly inbred tester here would be more likely to limit the ultimate cross performance if partial dominance or gene interaction were important. You could have loci at which partial dominance was the rule in the genetic effect on total performance; and this inbred line A tester could carry some genes that could not be compensated for no matter what you had in strain B. These two systems will be similar in the initial cross performance except that it should be easier to select the B stock from the many stocks that you might be able to start with, to fit a particular inbred line than it would be to select the B stock that would match a non-inbred A stock. In Bell's experiment with Drosophila, fortunately or unfortunately, in comparing these two systems it happened that in selecting the non-inbred stock to fit a particular inbred line, the cross started at a higher level than in the experimental selection between two non-inbred stocks and maintained that advantage throughout the period of selection. Now this may have been purely an accident, presumably it was. In trying to repeat the experiment, he is attempting to start these two systems at the same base, as far as cross performance is concerned. It seems to me it would be easier to pick the strain that would fit the highly inbred tester initially. If heterozygote advantage is highly important and the population is anywhere near this plateau we are talking about in response to ordinary selection, or in other words, if gene frequencies are anywhere near a stable equilibrium, the improvement in cross performance per cycle during the early stages of
recurring selection would be expected to be far greater with a homozygous tester than with two non-inbred strains. The reasons for that are not easy to go into briefly. Simply, when gene frequency in the tester stock "A" is at equilibrium at a given locus, progeny testing birds over here with that strain will give you no discrimination between big "A" and little "a" gene at a given locus in strain B. Hence, progeny test selection won't carry you anywhere if gene frequencies are at an equilibrium level in the tester line. The further away one of your tester strains is from equilibrium gene frequencies, the greater the effectiveness of progeny test selection on the other side. An inbred strain has either a gene frequency of zero, or one, if it is completely homozygous. This means that there will be maximum discrimination between the gametes of males tested in strain B when mated with inbred strain A, and you get much less effective discrimination if your tester is a non-inbred population. In the early stages, selecting a non-inbred stock to fit a highly inbred tester could make more progress per cycle than reciprocal selection between two non-inbred stocks. Progress expected from selection between two non-inbred population increases as the difference in gene frequency between the two strains becomes larger. And it would finally catch up with homozygous tester selection when differences in frequency per locus approached something like 0.5. From what I have said, I think you can see a possible reason, at least, why a partially inbred tester, (which is about all we might be able to actually use at this stage of the game in poultry), would have some advantage over a non-inbred strain of poultry for one side of a reciprocal selection scheme. Now, in any system like this, you have a given number of females in one strain that can be used for testing young males in the other strain. It may be large, or it may be small, depending on the scale of your operation but you'll have a certain number of females raised in each strain each year that can be test-mated with males from the other population. And again in this situation, there is an optimum number of matings to use for each young male tested. Suppose we chart the expected genetic superiority of the tested males that are saved from a given number that are tested. Suppose we have 100 females available for testing males, just as an arbitrary number. It might be half that or twice that, depending upon the scale of your particular operation, but if you have 100 females to be used for testing males, how many males should you test on those, in order to have maximum superiority of the best two tested males for use in reproducing this B line? Each year we are going to test so many males out of which we are going to pick two to use in reproducing that B line, let's say. Well, we could have shown all the possible number of matings per cockerel but we will just take up to ten. If we had as many as ten birds used for each male tested, we could only test ten males out of which we would have to pick two to reproduce the strain the following year. If we used only one female to test each male, we could test 100 males out of which to pick two but if we use only one bird to test each male, we would have a very inaccurate test of the male, wouldn't we? You would only have one mating, with ten pullets housed per mating, from which to evaluate each male. We have used two matings, with twenty test cross pullets housed out of each male tested, so the curve goes something like this with an optimum somewhere between three and five matings per cockerel, for the expected superiority of the two best males picked out of the total number tested. That would mean that if you used three females to test each young male, you would be testing 33 young males and picking two out of those. If you used five pullets for each, that would be testing 20 young males out of which you would pick two to reproduce one. If you go out beyond this, you are not increasing accuracy very much. We could draw similar curves showing that accuracy goes up at an ever decreasing rate, whereas the intensity of the selection, (the proportion saved, in other words), is coming down. What you are after is the point at which the gain from more accurate evaluation of the male by having more matings ceases to cancel the reduction in the amount of culling that can be done on the basis of progeny test among the
Are you assuming ten daughters for a female?

Yes, in this case. Changing that number plus or minus five would not change the conclusion very much. The main point is simply that there is an optimum number of matings per male and it is not terribly high. I think all of you have been very kind. Maybe I had better let you talk for a while.

I am going to take another advantage of my position. I am going to give the poultry breeders the first crack at Dr. Dickerson. I believe that if I get the panel members up here, we are going to run over on time. I think that the breeders have many questions they would like to throw at us. Mr. Hannah, you have the opportunity to ask the first question.

I would like to artificially select and use ten daughters out of a possible thirty. How are you going to evaluate the family from which they came? You are using only one-third, you are throwing away two-thirds, how are you going to know what you have?

There is a misconception here some place. In the progeny testing that I am talking about there will be no culling among the progeny until the end of the laying year. What are you referring to?

To this number of females to be tested from a given hen, you said that you had one hundred tester line females to be used in testing males of this B strain. Where do you get the one-third? You said you would use ten females, but that wouldn't make any difference whether you used five or fifteen. If you do any selection at all out of the females, aren't you influencing to a certain extent the evaluation of the family?

Yes, I think I see what you mean. I assumed when I said five, that you only house five pullets from each dam tested, either the first five pullets from each dam or all pullet progeny in a mating period or hatching period short enough so you would only get five pullets from one mating. I wasn't implying any selection of the progeny of each hen.

Would you do any selection at all, artificially?

No. Selection in this program is entirely based on progeny test. The progeny are cross-bred birds. There is no point in culling them. You aren't going to use them as breeders anyway. What you are going to use as breeders are the best of these hundred pullets that you test-cross, and the best of the males, whatever the number may be, that you test-cross. We are not going to do anything with the test cross progeny except use them for evaluation of their parents.

The number of progeny per mating then would be a minimum of ten.

Well, you would have to decide how many chicks you were going to hatch, how long a hatching season you were going to have in these test-cross matings.

If ten is a minimum, is anything above that more desirable?

Well, the reason I picked ten is because that is about the size of a full-sib family that you get from a single dam in a hatching season of two months. Isn't that somewhere near correct?

Isn't less than ten a good test?

Well, practically, I expect you had better stick pretty close to ten. If you reduce that number, it means that you must use some more females of the tester line for testing males, if you have fewer pullets produced by each female of the tester line. I would say that you would probably want to keep the number of females of the tester line that you needed to use in matings down within reason. Of course there is nothing holy about this number of 100. In actual practice you might much rather try selecting between three or four different pairs of lines with smaller number involved in each case than putting all of your hopes on this one particular combination of B strain with C.
What is a partially inbred line? What is an inbred?
A partially inbred line is the kind that you have and everybody else has. You don't want to run inbreeding up so high that you have a strain that is impossible to work with and, on the other hand, you ought to have enough inbreeding to give you a little hand-hold for effectiveness of progeny-test selection. That isn't a very good answer, is it? What do you want me to say, 25%? O.K., 25%.

Why can't you sib-test in reciprocal recurrent selection? You said you must progeny test. Well, you could select brothers of males that had a favorable progeny test. Is that what you mean? That again is a matter of degrees. Here you are selecting A and B, over here two different breeds.

I am selecting males adaptable in their ability to cross but I am doing it on sib testing basis because I am doing it entirely on January hatched stock, and my test is from June until November.

I am not clear on what sort of sib testing you have in mind. Well, egg production and mortality. You are basing your selection on birds that are A x B?
Yes. You want to know if strain A crosses well with B and you are making some test matings between the two?
Yes.

What can that do except to evaluate the parents of the cross? Well, I make my selection on a sib test, all January hatched, egg production June to November and I believe from the brothers of the best sisters sib tested. I mate up ten brothers with their sisters.

In other words, you have a full-sib family in the A line here. You use a portion of those birds in test cross matings and if they do well, you can go back and breed from their full sisters in the A line.

No, I switch my cockerels. I have four hatches of A with B matings and then I switch my cockerels and have four hatches pure A, from the same cockerels.

Oh, all right. In other words, in the same season you are test crossing males and reproduce from them.

I take four hatches in January, I take four hatches in late February or March of pure A. Then you have to practice your selection among the progeny of these within strain matings after you find out how the test crosses behave, for the individual and other members of the same family. That is all right, provided you feel that you can afford to reproduce from birds and then cull maybe two-thirds of the progeny after you find out which parents you should have used.

That's the niece test, rather than a sib-test, isn't it?

I think the plan has merit. In fact this past year, we did that same thing. We reproduced from young males at the same time that we were test crossing them. If the young male's test-cross progeny turn out well, we will keep his within-line progeny. If they don't, we'll discard them. However, it does mean that you will have to raise more within-line progeny in order to be able to cull.

You talk about a short term test. Which months do you mean? Do you mean Dr. Lerner's September to June period?

Oh, in our particular case, we house pullets at twenty-two weeks and take production to approximately 300 days of age, which would be about one hundred forty-six days, a little less than five months from housing at a standard age. That might differ with somebody else, but it
constitutes part-year egg production of test-cross progeny, for use in selecting the better males and females tested.

I believe that by putting your hatching date forward to early January on the short term testing that you do your test from June to November, which I believe makes your sib testing four times more severe, from June to November with no lighting and contains 70% production in October and November, than if you are doing Dr. Lerner’s way of sib testing from September through January. I mean by bringing your hatching date forward two months, you can make your test four times as severe for your short term testing. It is four times more severe a test because you have that resistance to molt of pullets that come in to lay in May and June and lay 70% in October and November without lights.

Well, with pullets you would not be bothered much with that molt.

Before we go on with that, I would like to have the breeders and geneticists have another opportunity to ask some more questions of Dr. Dickerson.

What experience has he had in holding these tested males over for breeding ability during the year?

Rather sad! I think we had some management problems to consider. When these young males were put in the breeding house, it had some older birds in it. In our particular case, we were reproducing from young males and older females in some cases. We found that those young males seemed to die off quite readily. We think, or we hope, that a different management procedure where we used only young cockerels and pullets in one breeding house and older males and older birds in another may help, but it was serious. If it kept on being as serious as it has been with us, we would have to go entirely to the method that this gentleman brought up of reproducing from the same young males while we have them alive, and at the same time we are test-crossing them. We would have some test-cross matings and some within-line matings within the same pen, or at least in the same hatching season. Then we would do our culling among their progeny rather than using the best better-tested males over again the next year. We hope we can lick this tested-male mortality to a greater extent than at present so that we will have some opportunity to select between tested males themselves. When most of them die, you reproduce from what you have left, and the amount of selection based on progeny performance may be slight.

With regard to progeny testing, I know from my former visits to breeders, every breeder I know is so discouraged that he uses very few males over the next year.

It is very serious.

You will be surprised how young cockerels will stand up for their own rights if you put them in a week sooner than your old birds.

Putting the two together, put the cockerels in a week sooner and let them become accustomed and let them become "boss" and then add your old males.

Our trouble is not from old males and young males fighting together. We use single-male mating pens.

But I say, put the young males in the room first and let them become accustomed to it and then the old ones are newcomers. It will make quite a little difference on the scraping.

You are talking fighting between males, that is not our problem.

If it is holding them over, we used to put them out in alfalfa fields and timber, etc., and the smaller room you put males to hold them, either young or old, the less males are going to lose. This is our experience.

You mean that if you keep them in small individual wire cages, for example, you feel like there will be less loss.

No, in a room, in confinement. There are a much larger percentage of them get by than
where they are turned out on range.

On this problem of keeping over old males, we had that unfortunate experience of carrying through a male in the summer and ready to use them in a special mating the next breeding season, and you find that he is sterile. We learned that if we keep our males with hens on a year round basis, they have no sterility at all. We were able to use them continuously and we are using males four or five or six years old.

Our difficulty on mortality comes during the same season these young males were used for mating. When we pull them out of the mating pens in order to use the second series on those same pens, the ones that are pulled out we have been putting in laying pens and they have already been in contact with some older breeders. They not only die out themselves but they spread respiratory infections, etc., to the laying houses. I am taking down my hair unnecessarily, I think. You people don't have those kind of problems.

Now, I believe we have one more question.

If you were interested in making the greatest possible gain each generation and considering the fact that you have considerable losses from males, infertile, etc., what would you say is the optimum number of females per pen per male?

I am not sure I get the gist of the question. You say, if you were bothered by heavy mortality among tested males?

Considering that?

Considering that, what is the optimum number of matings per male? You are thinking that in order to have any room for selection left, if you are going to lose a lot of the tested males, that you should test a larger number with any given limitation, as far as total number of females is concerned? Yes, that is right. You tend to move back on this diagram that I have here, as far as proportions, instead of staying up around five, you might move back towards three or four matings per male.

Well, let's assume that all the males live. How many females per male would you say was optimum?

That is where the three to five came in.

You say three to five?

That's right. It is a fairly flat top curve in that range from three to five. In other words, what you gain in accuracy by going from three to five, you just about lose in the room for selection among the males left.

You are assuming, though, that you only have one hundred females. Say if you could use as many females as you wanted to, is there some advantage then in putting more than five females to the male? That is the case of most commercial breeders. Well, we are not limited to one hundred females, normally it is closer to four or five hundred.

In a reciprocal selection program?

Yes, you are talking about reciprocal selection.

If you have four or five hundred females in these strains that are being selected to fit the test, remember you have to select replacements for those next year so that just because you have a bigger population of females with which to test males, it doesn't mean you can change this optimum too much. You have to save more males to reproduce the strain with next year.

Let's switch then to the other type and when you are not just standard progeny testing, you are not worrying about that. Wouldn't it be some advantage then to putting more females per male?

If you do that, you are going to test fewer males.

Well, I know, in our set-up, we have fifty pedigreed pens we are going to fill up with females, why not put twenty in instead of five? That's my point. That way we could use
selection on the female side with respect to egg quality, egg weight and hatchability, along that line.

Well, if you are going to put twenty in instead of five, it means that you are going to use four times as many female breeders.

We've got them, that's a fact.

You might better increase the number of pens and test more males, as far as the genetics of the situation is concerned. When you put twenty or twenty-five birds in to test single males, it means that you are definitely restricting the total number of males that you can test with a given number of females. The more you restrict the number of males tested, the less choice you have in picking the best tested male out of those, so there is an optimum, there.

If, in closed flock selection, you are going over then to almost entirely selection of young males on the basis of family performance, then you have an incentive to use as few young males as you can in order to have the maximum selection pressure between these families and it would be wise to go toward higher numbers of matings per male.

You mean the main difference would be to limit the number of females we should use in our breeding pens? If we are trapping a thousand birds, we want to use four hundred of them to fill up our breeding pens or only two hundred?

No. You are saying that you wouldn't use any tested males, or hardly any?

Hardly any.

In that case, as far as the males are concerned, your whole objective is to use as choice a bunch of young males as you can. Therefore, you want to use as few young males as you can and still not run your inbreeding up too fast.

We use about twenty and cut them down pretty heavily as we go along.

How about using full-brothers of the best tested males? Is that fairly accurate?

Well, there is a correlation of 0.50 between full brothers, you are just losing half of your opportunity to select.

It would be some help in the flock mating, wouldn't it?

This concludes Dr. Dickerson's portion of the program and I'm sure we all enjoyed it very much. We will have a two hour break until this evening's meeting.

Even though it is Sunday morning, it is still an informal meeting. You can take off your coats, if you want to. You can put your feet on the seat in front of you if the occupant doesn't object.

We have had Dr. Lerner's pedigree and performance record. I won't repeat that again this morning. We certainly are familiar with his work because we discussed it quite a bit yesterday. His subject, here again an assignment "Circumstances that Increase and Decrease the Effectiveness of Selection." I will now turn the meeting over to Dr. Lerner.

Mr. Chairman, I am very glad to hear that you have already had your $50 worth so you won't expect any more from me. I hope that holds true for the rest of you. When this topic was first assigned to me, I thought it sounded very attractive but the more I looked at the title, the less I knew what I was expected to talk about. My predecessors on the program actually dealt with two somewhat specific aspects, and apparently I was expected to cover something much more general, since both of the topics dealt with yesterday are in a way circumstances or conditions that affect efficiency of selection. So, I think the best way to introduce the subject is perhaps to go over in a very general way some of the points that have occurred to me in connection with the general title leaving the details and some of the numerous other circumstances that may arise that have not occurred in my tabulation to the discussion by the panel and by the floor.