DEFINITION IN BEEF CATTLE IMPROVEMENT: SOUTHERN AUSTRALIA

C.A. Morris

Australian Meat & Live-Stock Corporation, c/- Animal Genetics & Breeding Unit,

University of New England, Armidale, N.S.W. 2351.

INTRODUCTION

An effective breeding program for genetic improvement depends on a clear definition of what performance characters are to be changed. This definition is expressed here in economic terms. An attempt is then made to translate it into a framework for use in practice, because building blocks of a breeding program are cows and bulls, not dollars. This paper is in four sections:

* The present situation at national and farm level
* Breeding objectives
* Selection criteria and traits to be monitored
* Problem areas

A fuller discussion of breeding objectives for beef cattle in Australia is given by Morris (1979). This article will concentrate on southern Australia; supplementary information for northern Australia is given in this Conference by Turner (1979).

It is assumed that the reader is familiar with the distinction between breeding objectives and selection criteria. Although not clearcut, a general distinction is that breeding objectives are those characteristics to be improved, and selection criteria are the measurements used as a basis for selection in practice (e.g. reduction in calving difficulty is a breeding objective; birth weight can be used as a selection criterion to reduce calving difficulty).

PRESENT SITUATION AT NATIONAL AND FARM LEVEL

The June 1978 national statistics for the Australian beef industry are given in Table 1. Of the 29.3 million cattle in Australia in 1978, 26.1 million were classified as mainly for meat. There were 12.7 million beef cows and heifers, and 468,000 beef bulls (not shown in Table), equivalent to 14 cows per bull if bulls are kept for an average of two years. There were also 93,000 bull calves for breeding included in Row C in the Table, although it is difficult to believe that the figure is so low.

Only 48,000 live cattle were exported for slaughter, and 15,500 breeding stock exported.

Interpretation of the beef calf data is complicated by the spread of calving dates across the country, and by the AMLC classification of veal meat which tends to include bobby calves but not 10-12 month vealers. State by State dependence on the 'vealer' trade is thus difficult to deduce. Of course slaughterings include those from the dairy herd. The percentage of beef production exported varies widely from State to State, and in some years the variation among States is wider than in 1977/78. However, Queensland exports a higher percentage of total beef production than other States.

TABLE 1: National Beef Statistics[1] (June 1978, except rows B-D which are 31st March 1978)

	NSW	VIC	QLD	SA	WA	TAS	NT	Aust[2]
A. Cattle numbers (millions)	7.5[2]	4.6	11.4	1.3	2.2	0.7	1.6	29.3
B. Beef cow numbers[3] (millions)	3.5	1.4	4.9	0.6	1.0	0.3	(4)	12.7
C. Beef calves (millions)	2.1	0.8	2.3	0.3	0.5	0.2	(4)	6.6
D. Other beef stock[5] (millions)	1.2	0.6	3.5	0.2	0.5	0.1	(4)	6.4
Row C / (Row C + Row D), percent	65	60	40	63	52	64		51
Weight of veal / (beef + veal), percent	3.8	7.0	4.8	4.0	2.4	2.6	0.4	4.7
Percent beef exported[6]	50	48	71	48	50	50	50	55.0
Beef and veal production ('000 tonnes carcass)	651	515	592	124	149	61	26	2124

[1] Source: AMLC (1978) and Australian Bureau of Statistics (1978).

[2] Includes ACT.

[3] Cows and heifers one year and over.

[4] NT value included in national total.

[5] Excludes breeding bulls.

[6] Carcass weight basis.

National objectives for beef production are often stated in terms of

* Increasing Total Beef Production (kg beef).
* Increasing Total Value of Production ($). Calculating value of production from physical production accounts for price and carcass quality.
* Increasing Productivity (kg beef/head - preferably per breeding cow, or kg beef/ha). Although a productivity criterion might be preferred in theory, as much care is needed to interpret this as the other criteria, because the addition of or loss of herds from time to time in areas of different grassland production can cause apparent changes in national average which do not reflect technical improvements.

For this reason and because of the relationships between supply and demand on a regional or national basis, national objectives may be inconsistent with farm level objectives (Sharples, 1969). It was shown by Papadopoulos (1973) from ten years' data that a 1% increase in Australian beef supply caused a 0.3% drop in price. Values varied for the five eastern States analysed, from a small 0.05% drop in Queensland (the State with the highest percent beef exported), to a 0.26% drop (S.A.), and 0.39-0.44% (N.S.W., Vic, Tas). Thus not all the potential value of extra national beef production would be received, although individual properties generally would not suffer from this price flexibility. We assume that the following factors determine price/kg: supply, demand, meat quality and the extent of timely information.

According to the Bureau of Agricultural Economics (1975), 47% of cattle are run in the high rainfall zone, 31% in the pastoral zone and the remaining 23% in the wheat-sheep zone. At the time of their survey in 1973-74, there were 27,654 beef *specialist* properties in the high rainfall zone (1504 ha, 352 cattle per herd), 3188 in the pastoral zone (82,336 ha, 2,403 cattle) and 4,038 in the wheat-sheep zone (1,350 ha, 460 cattle). These in total accounted for 30% of properties with beef cattle, sheep and wool.

BREEDING OBJECTIVES

The most common incentive for increased production at the level of the individual grazier is a higher price/kg. Consistent with this we will assume that *"minimizing costs/kg of beef carcass"* is the breeder's objective, although certain conditions need to be specified. These are: 'subject to acceptable carcass quality and satisfactory market outlets'. Minimizing costs will result in a greater margin between costs and prices received by the grazier. Costs do not fluctuate as much as profits, and Dickerson (1976) has argued that to define an increase in profits as the objective is an illusory goal. In the absence of price fluctuation however, increasing gross margins/kg carcass and minimizing costs/kg carcass are equivalent.

Usually the objective of minimizing costs/kg beef is approximately compatible with per hectare or per farm objectives, as long as herd size and farm size remain similar from year to year.

The remainder of this Section describes the major components of the objective: more calves, heavier carcasses and better beef. More fully described, they are:

* higher net reproduction in both sexes, leading to higher turnoff,
* higher carcass weights achieved at normal or lower marketing age, subject to
* optimal carcass quality, at the new age and for the market supplied.

The justifications for these three characters are given below.

1. Net Reproduction

This is defined for females as the number of calves weaned per 100 cows joined to fertile bulls. Male fertility is also important. Increased net reproduction leads to greater turnoff, which is a direct benefit. Less variable and fixed costs/kg are thus incurred. According to the BAE (1975), a 1% rise in beef production on a property should save 1.3-1.5% in per kg costs of production for small increases in reproduction. From this saving must be subtracted the extra direct costs of higher reproduction, e.g. freight costs and perhaps labour for mustering. The extra food costs per kg beef for small increases are expected to be minimal (Fitzhugh, 1978a). In addition, higher net reproduction gives a higher potential intensity for selection, because there are more surplus breeding stock. It also allows for faster herd expansion when necessary.

Higher conception rates achieved by more fertile bulls mean that less bulls are required, or a more concentrated calving can be achieved in a well managed herd with the usual complement of bulls. These two results lead respectively to greater numbers of calves for sale or higher average weaning weights at the usual weaning date.

There is probably an intermediate optimum for reproduction, with the level depending on management practice and food supply (e.g. Carter and Cox, 1973). This suggestion is supported at the breed level by Seebeck's (1973) data on calving percentages of cows previously dry or lactating. Data relating early and later reproduction in females have been reviewed recently by Morris and Blockey (1979).

Although more evidence is needed, it is thought that in most cases increasing reproductive rate is highly important. Although heritabilities are low for female attributes, the net $ returns realized from genetic change in reproduction and weight for age are however similar (see Morris (1979) for calculations).

2. Higher Beef Production Per Animal Per Day

Just as for reproduction, higher beef production per day will reduce fixed costs per kg. Food intake will increase for faster growing animals, but food conversion efficiency will remain about the same or improve, depending on the criterion determining slaughter:age, finish or weight (Barlow, 1978).

Mature size is positively correlated with faster growth in young animals (e.g. Brinks *et al*, 1964). Calculations done on a herd basis for example by Fitzhugh (1978b) indicate that extra herd food costs will be less than extra beef returns. Morris' (1979) summary of Fitzhugh's and other work was that a 1% *genetic* change in weight at 550 days would result in an 0.76% genetic change in mature weight, and a rise in herd food costs of 0.6%. This means an increase in net returns of 0.4% if the herd food requirements are met by a reduction in herd size, i.e. 1.01 x (100 - 0.6) = 100.4. There would also be the once-and-for-all realization of 0.6% of herd capital costs. In some circumstances an 0.6% increase in herd food supply could be grown or purchased instead.

3. Improved Carcass Attributes

Fat depth or finish can be increased by direct selection, as they are highly heritable (e.g. Swiger *et al*, 1965). This has a direct positive value in terms of price/kg in young slaughtered stock, unless stock are over-finished already (which would be expensive on food resources).

Assuming that intake is not greatly restricted, primary selection for higher weight at a given age will result in slaughter stock which are fatter at the usual slaughter age, or leaner and younger at the usual slaughter weight (see Barlow (1978) for review). These findings are not widely believed in the field, although it is true that results are not documented for severely restricted food conditions. Weight and fat could be selected together in an index, or they could be selected independently, and in sequence.

Dressing percentage, defined as kg dressed carcass/kg live weight at slaughter, is already accounted for in the defined breeding objective - minimal cost/kg *carcass*. The weights chosen in the selection index will determine whether dressing percentage changes with 'kg carcass'. It has a low genetic correlation with final weight (e.g. 0.04, Shelby *et al*, 1963). The consequences of an increase in dressing percentage should be considered seriously because of the possible biological implications: lower hide weight and presumably thickness, more fat, lower gut fill and possibly lower voluntary intake.

Percentage high-priced cuts. Extensive work on carcass composition (e.g. Berg and Butterfield, 1966) has shown that for animals of equal *fatness*, there is little variation in weight *distribution* of muscles and muscle/bone ratio , contrary to popular opinion. If an animal appears to have heavy muscling in the hind-quarters, the apparent excess can be attributed to shape and subcutaneous fat, not muscle weight. An exception is the double-muscling syndrome (e.g. West *et al*, 1973).

The subject of *live animal conformation* has been reviewed by Barton (1967). His conclusions were that it was poorly related to carcass composition and carcass conformation. Any grazier consistently down-graded should consider selling on a carcass weight basis, i.e. change marketing, not breeding. At present only 14% of cattle are sold direct to the meat works (BAE, 1978).

Meat quality shows differences which are inherited, although the genetic variation is small. Large differences can be produced by slaughtering and cooking techniques, and thus change by breeding is best reserved for more important characters. Also there is no evidence that the grazier is being penalized for any differences in meat quality other than bruising.

SELECTION CRITERIA AND TRAITS TO BE MONITORED

Selection criteria are the measurement characters to be used as an indirect assessment of breeding value, for the important items in the breeding objective. First we will discuss the weight criteria.

Carcass weight and live weight at slaughter are closely correlated (see for example, Shelby *et al*, 1963), as also are retail product and carcass (Cundiff *et al*, 1971). All three are reasonably heritable, and slaughter weight is the simplest and cheapest selection criterion of the three. To be more precise in our description, we mean selection of bulls or heifers on weight at the normal slaughter age for steers.

Weaning weight and slaughter weight are also positively correlated (e.g. Brinks *et al*, 1964). Weaning weight selection in addition to or instead of slaughter weight selection will also achieve genetic change. There is a positive genetic correlation of 0.18 between weaning weight and weaning grade (Preston and Willis, 1970; 9 estimates).

Eye muscle area has a positive genetic correlation with carcass weight, with estimates ranging from 0.15 (Shelby *et al*, 1963) to 0.66 (Cundiff *et al*, 1971). It could be measured ultrasonically, and included in a selection index or used as an independent culling criterion.

Structural soundness. Some would argue that those animals which are structurally unsound tend to "cull themselves" (i.e. be culled automatically) because they or their progeny are less productive. This is a pragmatic approach in that it leads to no prejudice. It may however be risky, e.g. where a bull has suspected low fertility. The other approach is to cull any cattle of which the breeder doubts the soundness (e.g. of feet, legs, jaws, udder, testicles). This tends to be a conservative policy, leaving less scope for selection of replacement stock on other criteria. It is very difficult to put an economic value on these traits. They should certainly rate as "Traits to be Monitored", although it would be difficult or sometimes impossible to distinguish between deterioration due to breeding vs environment.

Items such as heavy muscling in hind quarters have been discussed already; heavy shoulders will be discussed under calving difficulty and calf shape.

Temperament may need to be considered further. Very little is documented about its inheritance, except for one estimate of 0.05 for heritability in dairy cows (New Zealand Dairy Board, 1961). Some beef breeders may express surprise at this low value.

Maternal ability is usually a measurement of milking ability as expressed through calf weaning weight production, and sometimes a record of temperament also. Except for the case of vealer calves, no *direct* returns accrue from better maternal ability. However, Brinks *et al* (1964) and others have shown a large positive phenotypic correlation between calf weaning weight and 12- or 18-month weight, so that heavier weaners achieve higher weights at usual slaughter age.

The situation is complicated by a negative genetic correlation between maternal and calf effects on weaning weight (see Barlow (1978) for review), and a negative environmental correlation between a heifer calf's weaning weight and her subsequent maternal ability (Koch, 1972). These two factors do not render selection for weaning weight impossible, but genetic progress is less than it would have been in their absence. Some selection indices have been developed for weaning weight measured on calf and dam, by Van Vleck *et al* (1977). However, Cunningham and Henderson (1965) have reported different repeatabilities for weaning weights as the time span between records gets larger. Perhaps this should be accounted for also.

Results from a weight selection experiment at two separate feeding levels in Canada by Lawson (1977) suggest that there may be an optimal feeding level for replacement heifers. Alternatively there may be a critical level at young stages, above which the heifer's milk production is reduced later. The level is likely to be higher than applied by graziers in Australia however.

There are many aspects of net reproduction. In the female particularly, accurate selection criteria are difficult to find. The trait, 'calf numbers weaned', is very weakly inherited and also has a low repeatability under many management conditions.

Serving capacity of bulls as measured with restrained heifers in a 40 minute yard test has a high phenotypic correlation with early conception rates achieved at pasture (Blockey, 1978), and has a heritability of 0.59. Genetic correlations are required in order to decide how best to use it as an index. Similarly scrotal circumference, which has a heritability of 0.67 (Coulter *et al*, 1976) and a phenotypic correlation of 0.81 with total sperm output (Hahn *et al*, 1969), could be useful in a selection index or as an independent culling criterion. Genetic correlations are required again here.

Weight at puberty will rise, as it is genetically correlated with weight at other ages (e.g. Smith *et al*, 1976). Selection for lower age at puberty would reduce weight at puberty, and weight selection at weaning would lower age at puberty, (Arije and Wiltbank, 1971; Smith *et al*, 1976). This may seem paradoxical, but is explained because the genetic correlations are intermediate, rather than having higher values of say 0.95-1.00.

Calving difficulty may increase with weight selection, and so may percent cow deaths and percent cows assisted, depending on labour availability at calving time. Barlow (1978) has suggested that there is an intermediate optimal birth weight, although the conclusion may be management dependent. There have been large differences for individual genetic correlation estimates between birth weight and calving difficulty. Birth weight may be used as an approximate indicator, and not as an objective in its own right.

Ménissier (1976) reported a genetic correlation of 0.21 between 18 month weight and calving difficulty. For bull breeders a partial solution is to use extensivley only bulls known to be 'easy calvers', or at least not 'difficult calvers'. This is in addition to choosing these bulls on an index for superior growth potential.

The genetic correlation between calving difficulty of bulls' daughters and birth weight of bulls' sons may be different. It may represent a different biological situation. Philipsson's (1976) estimate was 0.60, and more estimates are required.

Calf shape. It is thought by many breeders that 'heavy shoulders' in calves are associated with more difficult births. However, Laster (1974) could show *no* effect of calf shoulder width, hip width or chest depth on birth difficulty, other than due to higher birth weight itself, i.e. a greater quantity of *all* calf tissues.

Selection criteria applicable to northern Australia are described in greater detail at this Conference by Turner (1979), but they could include cattle tick scores and fecal egg counts (Seifert, 1971), eyelid pigmentation (Vogt *et al*, 1963), coat type (Turner and Schleger, 1960), and simple heat tolerance tests (da Silva, 1973).

PROBLEM AREAS

1. The Reproductive Complex

One important area requiring further study is the interplay between mature weight, condition, female reproduction and milk production. This question would require very large experimental resources for research. It has been investigated theoretically by Sanders *et al* (1974) and in subsequent papers. Recently his model has been tested and validated with data from a wide range of management systems and feeding levels. If it could be validated against Australian data it would be a valuable tool for answering further questions. For example, it would be possible to decide on optimal management systems for different breeds, or the implications of suboptimal feeding.

To what extent do genetically heavier cows differ in the efficiency with which they use the annual food supply? The model could be used to test the hypothesis of Seifert and Rudder (1976) that higher mature weights may not be achieved phenotypically in suboptimal environments.

2. Genotype x Environment Interaction

Frisch and Vercoe (1978) have reported positive *between breed* correlations among maintenance requirements, appetite and growth rate. It is already known that appetite and growth rate have a positive genetic correlation (e.g. Swiger *et al*, 1965); what are the other *within-breed* correlations? A current selection experiment for growth rate may show the answer (CSIRO, 1978). A positive genetic correlation would mean that genotype x feeding interactions are likely for growth. Other features of adaptation also deserve further study in addition to those related to food intake, i.e. cattle tick effects independent of appetite (Seebeck *et al*, 1971), and non-additive effects of different stresses (see Turner (1975), p 11).

It has been noted already that more information is required on the various inheritance pathways for maternal ability. The importance of negative environmental effects should also be considered further by experiment or by modelling. The development of indices to combine maternal weaning weight and calf weaning weight is required.

3. Postbranding Gains

It has been recommended for weight selection that adjusted final weight should be used in preference to a postweaning gain (Anon., 1974; Seifert, 1975). It is thought that postweaning gains under pasture conditions have lower heritability (Carter, 1971). Many analyses have shown that adjustment of weights for calf and dam ages will reduce the variance of the weight measurement. One suggested alternative is postbranding gain, which could avoid the problem of calf and dam age adjustment, but still requires calf identification. Presumably the longer the gain period, the more this measure will approximate to final weight. Some genetic parameters have been estimated by Barlow and O'Neill (1979); more are required.

The genetics of other growth measures should also be looked at, along with the implications of using them as selection criteria (Fitzhugh, 1976). One of these is preweaning *relative* growth rate which has a negative genetic correlation with birth weight and mature weight (Smith *et al*, 1976).

4. Bull Buyer vs Breeder

The most important method of continuing genetic improvement for bull breeders is *selection* of superior stock as parents of the next generation. Occasional transfer of superior bulls or cows from other herds may also contribute to this improvement. The difficulty remains of ensuring that purchased bulls are really superior. The structure of the breeding scheme, methods of selection, and recording procedures will also influence the rate of genetic improvement. The endpoint and justification for all these selection tools is the improvement of traits in the breeding objective.

The rate of progress in bull buying herds will depend entirely on the source of bulls. The *rate* will copy that of the breeder's herd from which purchases are made, but the *actual level* of improvement will lag behind. The buyer can lengthen or shorten his lag by buying a poorer bull or a better one (or by selecting amongst his own cows). He can do little to alter the fact that the two herds are changing at about the same *rate*, unless he then purchases from another herd which has different objectives, or which is genetically above or below the original source herd.

Because of possible interactions between sire and location, or sire and feeding level, bull buyers should be encouraged to buy from local breeders with similar breeding objectives. Under these conditions, the relative economic values for breeder and buyer should be similar. However, this may not apply if the bull buyer sells all weaners, in contrast to the breeder's practice of retaining stock to later ages.

Finally, a grazier who fattens stock but does not breed them may have different objectives to the weaner producer who sells to him. There is little the grazier can do about this except through the price of his purchased stock. Although vertical integration is possible in theory, it is unlikely to be successful in practice unless valid and timely market information is available on the calves.

SUMMARY OF PROBLEM AREAS FOR DISCUSSION AT THE CONFERENCE

1. Reproduction: females. Is there an optimal reproductive rate? How does the nutritional level influence how much we try and improve reproduction by breeding? What is the interplay between mature weight, condition, reproduction and milk production?

2. Reproduction: males. What is the best way of introducing the relatively new measurements on males into the breeding program? What emphasis should be applied to them?

3. Relationships between early heifer growth and subsequent cow production and reproduction.

4. Relationships between maternal ability and daughter's maternal ability.

5. How important to the outcome of weight selection is the choice of feeding level? (Is there an important *within-breed* interaction between genotype and environment?)

6. What features of adaptation need to be considered further?

7. How useful are postbranding gains as criteria for weight selection?

8. What about relative growth rate as a selection criterion?

9. What can the bull buyer do to help identify genetically superior bulls?

REFERENCES

ANONYMOUS (1974) Report of a Workshop on genetic improvement of beef cattle for southern Australia. Animal Production Committee Conference. Glen Ormiston, Vic.

ARIJE, G.F. and WILTBANK, J.N. (1971) Age and weight at puberty in Hereford heifers. *J. Anim. Sci.* 33: 401-406.

AUSTRALIAN BUREAU OF STATISTICS (1978) Principal Agricultural Estimates, Australia: Second estimates 1977/78. Australian Bureau of Statistics. Canberra, 11 July 1978. 4 pp.

AUSTRALIAN MEAT AND LIVE-STOCK CORPORATION. (1978) Statistical Review of Live-Stock and Meat Industries, for year ended 30 June 1978. AMLC Sydney. 63 pp.

BARLOW, R. (1978) Biological ramifications of selection for preweaning growth in cattle. A review. *Anim. Breed. Abstr.* 46: 469-491.

BARLOW, R. and O'NEILL, G.H. (1979) Performance of Hereford and crossbred Hereford cattle in the subtropics of New South Wales: genetic analyses of preweaning performance of first-cross calves. (in preparation)

BARTON, R.A. (1967) The relation between live animal conformation and the carcass of cattle. *Anim. Breed. Abstr.* 35: 1-22.

BERG, R.T. and BUTTERFIELD, R.M. (1966) Muscle:bone ratio and fat percentages as measures of beef carcass composition. *Anim. Prod.* 8: 1-11.

BLOCKEY, M.A.deB. (1978) The influence of serving capacity of bulls on herd fertility. *J. Anim. Sci.* 46: 589-595.

BRINKS, J.S., CLARK, R.T., KIEFFER, N.M. and URICK, J.J. (1964) Estimates of genetic, environmental and phenotypic parameters in range Hereford females. *J. Anim. Sci.* 23: 711-716.

BUREAU OF AGRICULTURAL ECONOMICS (1975) The Australian beef cattle industry: submissions to the Industries Assistance Commission inquiry. Industry Economics Monograph No. 13. Bureau of Agricultural Economics, Canberra. 105 pp.

BUREAU OF AGRICULTURAL ECONOMICS (1978) Issues in the evaluation of the proposed carcass classification schemes. Occasional paper No. 45. Bureau of Agricultural Economics, Canberra. 47 pp.

CARTER, A.H. (1971) Effectiveness of growth performance selection in cattle. *Proc. N.Z. Soc. Anim. Prod.* 31: 151-163.

CARTER, A.H. and COX, E.H. (1973) Observations on yearling mating of beef cattle. *Proc. N.Z. Soc. Anim. Prod.* 33: 94-113.

COULTER, G.H., ROUNSAVILLE, T.R. and FOOTE, R.H. (1976) Heritability of testicular size and consistency in Holstein bulls. *J. Anim. Sci.* 43: 9-12.

CSIRO. (1978) Effects of selection (mainly for growth) in unadapted cattle. *Division of Animal Production Research Report 1976/77*: 51. Commonwealth Scientific and Industrial Research Organization, Blacktown, NSW.

CUNDIFF, L.V., GREGORY, K.E., KOCH, R.M. and DICKERSON, G.E. (1971) Genetic relationships among growth and carcass traits of beef cattle. *J. Anim. Sci.* 33: 550-555.

CUNNINGHAM, E.P. and HENDERSON, C.R. (1965) Repeatability of weaning traits in beef cattle. *J. Anim. Sci.* 24: 188-191.

DICKERSON, G.E. (1976) The choice of selection objectives in meat producing animals. In: *Meat Animals: Growth and Productivity*. Lister, D., Rhodes, D.N., Fowler, V.R., and Fuller, M.F. (Eds). pp 449-462. Plenum, New York.

FITZHUGH, H.A., Jr (1976) Analysis of growth curves and strategies for altering their shape. *J. Anim. Sci.* 42: 1036-1051.

FITZHUGH, H.A., Jr (1978a) Bioeconomic analysis of ruminant production systems. *J. Anim. Sci.* 46: 797-806.

FITZHUGH, H.A., Jr (1978b) Animal size and efficiency, with special reference to the breeding female. *Anim. Prod.* 27: 393-401.

FRISCH, J.E. and VERCOE, J.E. (1978) Utilizing breed differences in growth of cattle in the tropics. *Wld. Anim. Rev.* 25: 8-12.

HAHN, J., FOOTE, R.H. and SEIDEL, G.E. Jr (1969) Testicular growth and related sperm output in dairy bulls. *J. Anim. Sci.* 29: 41-47.

KOCH, R.M. (1972) The role of maternal effects in animal breeding. VI. Maternal effects in beef cattle. *J. Anim. Sci.* 35: 1316-1323.

LASTER, D.B. (1974) Factors affecting pelvic size and dystocia in beef cattle. *J. Anim. Sci.* 38: 496-503.

LAWSON, J.E. (1977) Beef selection for gain on two rations. *Canada Agriculture Publication, Winter 1977.*

MÉNISSIER, F. (1976) Comments on optimisation of cattle breeding schemes: beef breeds for suckling herds. A review. *Ann. Génét. Sél. Anim.* 8: 71-87.

MORRIS, C.A. (1979) Goals for improving net income from beef cattle by selection within breeds or breed crosses. *Aust. Meat Res. Comm. (AMRC) Review.* No.38.

MORRIS, C.A. and BLOCKEY, M.A.de B. (1979) Relationships between aspects of reproduction in beef heifers and their lifetime production: A review. *Anim. Breed. Abstr.* (In preparation).

NEW ZEALAND DAIRY BOARD (1961) Traits other than production - heritabilities. Unpublished data, N.Z. Dairy Board, P.O. Box 417, Wellington, N.Z.

PAPADOPOULOS, C. (1973) Factors determining Australian saleyard prices for beef cattle. *Quarterly Rev. Agric. Econ.* 26(3): 159-170.

PHILIPSSON, J. (1976) Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. III. Genetic parameters. *Acta Agric. Scand.* 26: 211-220..

PRESTON, T.R. and WILLIS, M.B. (1970) *Intensive Beef Production.* Pergamon Press, Oxford. 544 pp.

SANDERS, J.O., JOANDET, G.E. and CARTWRIGHT, T.C. (1974) Simulation of female bovine fertility. *J. Anim. Sci.* 39: 149 (Abstr.).

SEEBECK, R.M. (1973) Sources of variation in the fertility of Zebu, British, and Zebu x British cattle in northern Australia. *J. Agric. Sci., Camb.* 81: 253-262.

SEEBECK, R.M., SPRINGELL, P.H. and O'KELLY, J.C. (1971) Alterations in host metabolism by the specific and anorectic effects of the cattle tick (*B. microplus*). 1. Food intake and body growth. *Aust. J. Biol. Sci.* 24: 373-380.

SEIFERT, G.W. (1971) Ecto and endoparasitic effects on the growth rates of Zebu crossbred and British cattle in the field. *Aust. J. Agric. Res.* 22: 839-850.

SEIFERT, G.W. (1975) Effectiveness of selection for growth rate in Zebu x British crossbred cattle. II. Post-weaning growth and genetic estimates. *Aust. J. Agric. Res.* 26: 1093-1108.

SEIFERT, G.W. and RUDDER, T.H. (1976) The genetic implications of selecting cattle for large size. In: *Principles of Cattle Production.* Swan, H. and Broster, W.H. (Eds). Butterworth, London. pp 373-386. Proc. 23rd Easter Sch. Agric. Sci., Univ. Nottingham.

SHARPLES, J.A. (1969) The supply function in agriculture revisited. The representative farm approach to estimation of supply response. *Amer. Econ. Review.* 59: 168-174.

SHELBY, C.E., HARVEY, W.R., CLARK, R.T., QUESENBERRY, J.R. and WOODWARD, R.R. (1963) Estimates of phenotypic and genetic parameters in 10 years of Miles City ROP steer data. *J. Anim. Sci.* 22: 346-353.

DA SILVA, R.G. (1973) Improving tropical beef cattle by simultaneous selection for weight and heat tolerance. Heritabilities and correlations of the traits. *J. Anim. Sci.* 37: 637-642.

SMITH, G.M., FITZHUGH, H.A.,Jr, CUNDIFF, L.V., CARTWRIGHT, T.C. and GREGORY, K.E. (1976) A genetic analysis of maturing patterns in straightbred and crossbred Hereford, Angus and Shorthorn cattle. *J. Anim. Sci.* 43: 389-395.

SWIGER, L.A., GREGORY, K.E., SUMPTION, L.J., BREIDENSTEIN, B.C. and ARTHAUD, V.H. (1965) Selection indexes for efficiency of beef production. *J. Anim. Sci.* 24: 418-424.

TURNER, H.G. (1975) Breeding of beef cattle for tropical Australia. *Aust. Meat Res. Comm. AMRC. Review.* 24: 1-30.

TURNER, H.G. (1979) Definition in beef cattle. Supplementary notes - northern Australia. *Proc. Inaug. Conf. Aust. Assoc. Anim. Breed. Genet.* Armidale, N.S.W.

TURNER, H.G. and SCHLEGER, A.V. (1960) The significance of coat type in cattle. *Aust. J. Agric. Res.* 11: 645-663.

VAN VLECK, L.D., ST. LOUIS, D. and MILLER, J.I. (1977) Expected phenotypic response in weaning weight of beef calves from selection for direct and maternal genetic effects. *J. Anim. Sci.* 44: 360-367.

VOGT, D.W., ANDERSON, D.E. and EASLEY, G.T. (1963) Studies on bovine ocular squamous carcinoma ('Cancer eye'). XIV. Heritabilities, phenotypic correlations, and genetic correlations involving corneoscleral and lid pigmentation. *J. Anim. Sci.* 22: 762-766.

WEST, R.L., CARPENTER, Z.L., DUTSON, T.R., HOSTETLER, R.L., SMITH, G.C. and KIEFFER, N.M. (1973) Double muscling: carcass and palatability traits. *J. Anim. Sci.* 37: 273 (Abstr.).

* * *