# DEVELOPMENTS IN IMPROVEMENT OF MEAT SHEEP

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## SUMMARY

In most countries efficient production of *lean* meat is likely to remain the most important selection objective for meat sheep, and an important component of a wider objective in multi-purpose breeds. The precise definition of this broad goal varies quite widely between and within countries. However, there is now good experimental evidence that selection on weight and *in vivo* measurements of composition is effective in improving several of these goals. Increasingly this technology is being transferred into industry breeding schemes, and initial results from these are encouraging. Further improvements are expected from developments in the design of breeding schemes, more comprehensive breeding goals and criteria, use of improved methods for *in vivo* assessment and genetic evaluation and the wider use of reproductive (and in the longer term molecular) technologies.

## INTRODUCTION

The aim of this paper is to review some recent developments in the genetic improvement of meat production in sheep. Since the early 1980s the world's sheep population has expanded by about 50 million, with over half of that expansion occurring in the 12 countries of the European Union (EU; Meat and Livestock Commission (MLC), 1991). The global league table of sheepmeat production is headed by China, the 12 EU countries (of which Britain, Spain, France and Greece have the highest output), countries of the former USSR, Australia and New Zealand (1350, 1175, 753, 640 and 488 thousand tonnes respectively; MLC estimates for 1993). Although the remit here is to examine meat production, it is worth noting that in some of the countries referred to, much of the meat production comes as a by-product of wool production (eg. Australia) or milk production (eg. Spain and Greece). Having recognised this situation, I intend to concentrate on within-breed improvement of specialised meat breeds, or meat characteristics of multi-purpose breeds. The paper includes developments in the choice of selection objectives and criteria, including techniques for assessing carcass composition *in vivo*, methods of testing and evaluation, results from experimental and industry selection programmes and, finally, a discussion on possible future opportunities.

## CHOICE OF SELECTION OBJECTIVES AND CRITERIA

**Background**. In many western countries consumers have been expressing a strong preference for leaner meat over the last few decades. This preference has often been reinforced by reports linking high consumption of saturated fats with chronic degenerative diseases (see reviews in Wood and Fisher, 1990). The scientific validity of recommendations to reduce saturated fat intake is still questioned (Blaxter and Webster, 1991), but consumer preferences are unlikely to be reversed in the short to medium term. Hence for these countries, efficient production of *lean* meat is a primary selection objective. It may not be biologically or economically efficient to attempt to match consumer preferences precisely in the live animal. However in 1986 Kempster *et al* reported a fairly major mismatch in Britain, for example, with the average lamb carcass containing 20 percentage units of fat in excess of that desired by consumers. More recent evidence suggests very little improvement in the proportion of carcasses falling in the target range of fatness (MLC, 1993). This must be due partly to payment schemes which do not discriminate strongly enough between lean and fat carcasses, or send contradictory signals to producers. In countries where fatness is not an issue, or where local production systems mitigate the problem, total carcass or saleable meat production may be more relevant measures of output, but much of the discussion on design and operation of breeding schemes and future opportunities still applies.

**Selection objectives and criteria**. Translating the broad selection objective of efficient lean meat production into something usable is more difficult than it seems at first sight. Taylor's (1980) work on genetic size scaling rules provides a conceptual framework which is particularly valuable in designing breed comparisons, in predicting the relative performance of different breeds and in matching breeds to production systems. It can also help in deciding on appropriate selection goals within breeds and in interpreting responses to selection. Taylor's approach is based on the observation that, when breeds are compared at similar degrees of maturity in liveweight, most of the differences in composition disappear (McClelland *et al*, 1976). Differences in mature size may well explain much of the within-breed variation in carcass composition at the same weight. However, it will often be more practical to use immature liveweights and measurements of carcass composition as selection criteria than to prolong selection decisions until mature size can be measured. Also, there is evidence of genetic variation in rates of maturing in fatness and in fatness at maturity in laboratory animals and sheep (Roberts, 1979;

Butterfield *et al*, 1983; Thompson *et al*, 1985, 1987; McEwan *et al*, 1989, 1990) though it is difficult to say how to use this information in an optimal way in breeding programmes. The pragmatic solution has usually been to define the breeding objective in terms of the prevailing markets and production systems. These vary enormously. So, for example, the goal may be to maximise lean meat production in a fixed time (eg. in systems depending on seasonal forage production), or at an optimal level of fatness (eg. if total carcass returns are lower at higher levels of fatness) or to produce a given weight of lean meat in a shorter time (eg. in intensive production systems).

To date it has not usually been practical to measure any of these objectives directly in candidates for selection (eg. requiring collection and freezing of semen prior to slaughter of candidates) or on large numbers of relatives. (This may change in future if advances in embryo technology allow the production of genetically identical animals at low cost). Hence, most breeding schemes to improve carcass composition have depended on measurements of live weight, either alone or together with *in vivo* estimates of carcass composition. Most of the goal traits or criteria of interest are moderately heritable (see sources cited by Simm, 1992; and Waldron *et al*, 1992). There appear to be only small differences in these genetic parameters between the major meat breeds in Britain (eg. Mercer *et al*, 1944), though larger differences have been reported between other breeds (eg. Brash *et al*, 1992).

In most early experiments, or industry breeding schemes, simple selection criteria such as weight or weight adjusted backfat depth were used. However, classical economic selection indices, as proposed by Hazel (1943), so-called biological indices such as lean tissue growth rate (Fowler *et al*, 1976), or approaches which combine the rigour of an economic index with some prior consideration of the biological outcome of selection (eg. Brascamp, 1984; Rae, 1984; Simm and Dingwall, 1989) have been considered or used more recently. At the last Congress, Bennett (1990) reviewed these options thoroughly. I do not intend to go into detail here. Suffice to say that, despite their intuitive appeal, some of the simpler criteria, such as biological indices do have *implied* economic weights, which may be quite different from the 'true' values. Hence the strict economic approach, or related methods, are likely to give the most predictable responses. The results of the application of some of these indices are discussed later.

__Techniques for in vivo assessment__. The importance of techniques for *in vivo* assessment of carcass composition has already been alluded to, and the methods available have been reviewed recently (eg. Simm, 1992). A wide variety of techniques have been used in research. Of these, ultrasonic measurements of tissue depths or areas are now becoming quite widely used in industry improvement programmes in several countries (eg. New Zealand, Australia, UK, Ireland, France, Norway, Denmark, Canada). (Area, or depth together with width of the *m. longissimus* muscle may be more useful measures of carcass lean content than depth alone (eg. Waldron *et al*, 1992), although area or width are more difficult to measure than muscle depth with most current ultrasonic machines (eg. McEwan *et al*, 1993)). Whilst ultrasonic measurements can be taken on large numbers of geographically dispersed animals at a relatively low cost, there is considerable scope for increasing responses to selection from the use of more precise methods of *in vivo* assessment. For example, expected annual response in carcass lean weight could be increased from +194 g to +262 g, and response in carcass fat weight reduced from +67g to -16g by using an index of live weight and perfect *in vivo* measurements of carcass composition, compared to an index of weight and ultrasonic fat and muscle measurements (Simm and Dingwall, 1989). Advanced imaging techniques developed for use in human medicine, such as X-ray Computed Tomography (CT) or Magnetic Resonance Imaging (MRI), appear to offer the most immediate opportunities in this respect. Although these machines are very costly, their strategic use in sheep breeding programmes, for example, in two-stage selection or in large nucleus flocks, is likely to be cost-effective at a national level. Following early experimental work on CT in Norway, research and industry CT facilities have been established in Australia and New Zealand and are under discussion in Britain. As well as providing more precise *in vivo* prediction of total carcass composition, these techniques potentially allow measurements of muscle and fat distribution, and patterns of change in these over time (see Afonso, 1992 and Simm, 1992). Such measurements could be valuable selection criteria, for example, allowing differential selection for carcass:non-carcass fat, if this proves important, in breeds for harsh environments. The application of more sophisticated methods of image analysis is helping to extract maximum information from both these newer and more traditional *in vivo* methods (eg. Thompson and Kinghorn, 1992; Glasbey and Horgan, 1994; Glasbey *et al*, 1994).

__More comprehensive objectives and criteria__. To date, most selection objectives have been defined in terms of total lean meat produced and have not attempted to classify this according to value or anatomical location. It may well be difficult to alter muscle distribution anyway, and it is certainly difficult to assess on the live animal, except in the more extreme cases, and with skilled operators (eg.

Visscher, 1992). More objective measures of muscularity in the live animal may improve this situation slightly (eg. Ward *et al*, 1992). Carcasses of good conformation produce a higher financial return for producers and meat wholesalers in many countries. However, there are several studies which show that, at least within breeds, conformation is a poor indicator of carcass lean content and proportion of lean in the higher-priced joints, in carcasses of equal weight and subcutaneous fat cover (Kempster *et al*, 1981; Wolf *et al*, 1981; Bruwer *et al*, 1987; Simm and Murphy, 1994). Results may well be specific to the particular methods of assessing conformation used, the level of fatness of the animal's involved and possibly also the breeds concerned, since some other studies show that conformation score, after adjusting for carcass weight and fatness, may be a useful predictor of muscle weight (Bass *et al*, 1984; Schrooten and Visscher, 1987). In a recent study more objective measurements of carcass shape improved the prediction of saleable meat yield modestly, compared to visual scores (Horgan *et al*, 1994).

Strictly speaking, all economically important inputs and outputs ought to be included in a formal definition of the selection goal (James, 1986). In most systems feed is one of the major inputs, but this has not usually been defined explicitly in the selection goal for meat sheep, thought it is sometimes accounted for implicitly (eg. Simm *et al*, 1987). This omission is likely to be more economically important in intensive rearing systems than in extensive systems - at least where utilisation of available forage is relatively low. Grazing trials with high and low genetic merit dairy cows in New Zealand showed that high index cows grazed pastures more severely than their low index contemporaries, with resulting benefits in milk output per area of land, and probably also in pasture quality (Bryant, 1986). It would be useful to know whether a similar situation holds in selected lines of meat sheep. Where the testing and commercial regimes differ widely it would also be useful to know whether intake measurements of a test diet are useful indicators of capacity for lower quality feeds in the commercial environment.

There is evidence of between breed and line and within-breed genetic variation in feed intake or feed conversion efficiency in sheep (Cameron, 1988; Visscher, 1988; Jensen, 1992; Afonso, 1992; Vangen and Thompson, 1992). This is probably largely explained by differences in body weight and composition. However, given the imperfect precision of most current methods of *in vivo* assessment, food intake measurements may well contribute to selection indices where the goal is to alter composition, as well as when the goal includes feed intake itself. Some further work in this area is justified.

Residual feed intake (RFI ) has received considerable attention as a potential breeding goal, particularly in non-ruminants (eg. Luiting, 1991) but also in ruminants (Koch *et al*, 1963; Kennedy *et al*, 1993). However, the latter authors have suggested that the apparent genetic variation in RFI can be illusory, because phenotypic RFI is not genetically independent of the component traits. An experiment involving index selection of sheep for daily gain and residual feed intake has been established at the US Meat Animal Research Center (K A Leymaster, personal communication), and this may shed more light on the problem.

Deciding on selection goals and choosing appropriate criteria is difficult enough for specialised meat breeds, but the problems are greater still when meat production is part of a wider goal. There is often a scarcity of relevant genetic parameters to construct more comprehensive indexes in these cases. However, a number of recent studies have estimated genetic correlations between carcass characteristics and other production traits such as fleece weight (eg. McEwan *et al*, 1993, Olesen, 1993). About 40% of the UK national ewe flock is kept in hill areas. The majority of these animals are of traditional hill breeds and are bred pure. Hence, reproductive and other aspects of maternal performance are important characteristics. There has been little objective performance recording and selection in these breeds, partly because of the difficulty of recording in this harsh environment and partly because of the difficulty of defining appropriate selection objectives. Improvements in productivity and adaptability have probably been achieved through a combination of natural selection and subjective visual selection. There is reasonably good evidence that adaptation to harsh environments varies between species and between breeds, but much less is known about genetic variation in components of adaptation within breeds. A better understanding of within-breed genetic variation in characteristics such as cold resistance, maternal behaviour and disease resistance and, in particular, estimates of their genetic relationships with the major 'production' traits is required in order to design more comprehensive selection programmes (see Bishop *et al*, 1994, and Simm *et al*, 1994 for more details).

An experiment began recently in SAC and the Roslin Institute to address some of these issues. It involves Scottish Blackface rams selected for high or low predicted carcass lean content under an intensive feeding regime (Bishop, 1993) which have been mated to ewes in two different extensive hill environments. The growth, body composition, reproductive performance and maternal behaviour of the progeny of these high and low line sires is being measured, to test for possible genotype x environment interactions, to check on the potential deleterious consequences of selection for reduced fatness in an environment where ewes can lose up to 20 per cent of body weight over winter, and to provide a substantial data set for parameter estimation. Early results indicate (i) an important maternal component to early lamb growth in extensive hill conditions, in line with previous studies, (ii) an important effect of rearing environment on the heritability of growth and carcass traits and (iii) positive genetic correlations of quite variable magnitude between growth and carcass traits measured under different regimes, suggesting that different rearing regimes will be appropriate depending on the combination of traits which are to be selected for (Conington *et al*, 1994).

## METHODS OF TESTING AND EVALUATION

The majority of improvement programmes in meat sheep are based on on-farm recording of performance. However, central performance tests also operate in France, Canada, the US, Finland, Denmark and in a few other European countries. In France, Norway, Iceland and to a lesser extent in some other European countries progeny testing for carcass composition operates in conjunction with recording performance on-farm or in a central station (see Simm, 1992, for references). Group breeding schemes are important in several countries, and there is good information on their optimal design (eg. Kinghorn and Shepherd, 1990).

Results were most commonly evaluated by contemporary comparisons or indices of various types in the past. However, there is growing interest in applying more sophisticated methods of evaluation. BLUP methods have already been introduced, or are planned, in either national or individual sheep breeding programmes in Canada, the US, Australia, New Zealand, Norway, Finland, Denmark, Sweden, France and the UK. Providing that adequate genetic links exist across flocks and across years, EBVs of animals estimated by BLUP can be compared across flocks and years. This has several important benefits. Firstly, the number of candidate animals for selection which can be directly compared is greatly increased. This has direct benefits on the rate of response which can be achieved. Secondly, if genetic parameters have been estimated in the population under selection (Thompson, 1986) the genetic trend in performance can be charted year-by-year, by comparing the average EBVs in the breed or flock in successive years. This provides a valuable check on genetic progress, both for breeders themselves and for their customers.

Over the past decade, sire referencing schemes have been established in a number of sheep breeds in Australia, New Zealand (eg. Lewer, 1987; Anon, 1989) and, more recently, in the UK (MLC, 1993). These schemes involve the use of 'reference' sires in common across co-operating flocks. This creates ideal linkage between flocks for BLUP evaluations, and for selection across flocks (Kinghorn and Shepherd, 1990). Sire referencing schemes probably have advantages over some other co-operative breeding schemes in that they may require less legal and financial commitment. Also, providing sufficient reference sires are used, they probably have a lower risk of genotype x environment interaction affecting the success of the breeding programme than schemes where sires are evaluated in a single nucleus flock or in a central performance test station (Notter and Hohenboken, 1990).

**Testing regimes and the possibility of G x E interactions**. The issue of testing regimes is an important one, not only for harsh environments as discussed earlier. Some of the early work on the value of ultrasonic measurements in predicting carcass composition *in vivo* showed little improvement in precision over that achieved from live weight alone (eg. see early work cited by Gooden *et al*, 1980). This was thought to be due, in part, to the low variation in subcutaneous fat depths in young extensively reared animals (but results were often confounded by machine type, operator experience, etc). This led to investigations at a later age or following a more intensive rearing regime (eg. see review of Simm, 1987). This approach has been adopted recently in a selection experiment in New Zealand, where an asymmetric response has been observed. Low fat depths in one line, which are thought to be less precisely measured *in vivo*, are thought to be partly responsible (McEwan *et al*, 1990). The evidence on the value of this approach is somewhat conflicting (Simm, 1987; Bennett *et al*, 1988). Animals are often scanned following fairly intensive feeding in experimental and industry schemes in the UK, as this is the most common rearing practice for pedigree rams destined for sale in their first year. Tests on the extensively reared progeny of intensively reared rams with divergent index scores show responses in the expected direction for weight and fatness, and of the expected magnitude for weight (Cameron, 1992a; Lewis *et al*, 1994; Simm and Murphy, 1994). Interpretation of the magnitude of differences in fatness is more complicated, since this was *estimated* in the purebred sires and *measured* in two different ways in the experiments referred to above. However, in at least one of those studies, the differences in fatness were apparently lower than expected (Simm and Murphy, 1994). Further, work is in progress now in the SAC Suffolk flock to measure the responses to selection by dissection, and to investigate methods of enhancing response in extensively reared crossbred lambs, eg. by recalculating index coefficients using correlations between index measurements on intensively reared purebred animals and goal traits measured in extensively reared crossbred lambs.

## RESULTS OF SELECTION IN EXPERIMENTS AND INDUSTRY

During the past decade or so, experimental lines selected for various carcass composition traits have been established in a number of locations, particularly New Zealand and the UK. Simm (1992) summarised the responses achieved in most of these experiments. Other experiments, or more recent results for those reviewed in 1992, include McEwan *et al* (1989), Cameron and Bracken (1992), Bishop (1993) and Solis-Ramirez *et al* (1993). Most of the New Zealand selection lines have been selected for divergent liveweight-adjusted ultrasonic backfat depth. More recently lines have been established where selection is on an economic index. In most cases substantial responses have been achieved. In those reports where conversion of results was possible, approximate annual rates of change in overall index score, or in weight-adjusted backfat depth usually ranged from 2.1 to 2.4% per annum but are as high as 4.4% in one case.

Where carcass composition has been measured directly (eg. Bennett *et al*, 1988; Lord *et al*, 1988; Kadim *et al*, 1989; McEwan *et al*, 1989) selection for reduced ultrasonically measured backfat depth has resulted in reduced carcass subcutaneous fat depth. This has been accompanied usually by reduced proportions or weights of fat in the subcutaneous and other depots, as expected from the fairly strong genetic correlations between fat proportions in different depots (Wolf *et al*, 1981; Bennett, 1990) and by increased proportions or weights of lean tissue. Equivalent results for chemical composition of carcasses from divergently selected Coopworth sheep were reported by McEwan *et al* (1990). Results to date show that fatness of lamb carcasses can be reduced without detriment to eating quality (Wood, 1990; Kadim *et al* 1993). This obviously needs to be kept under review if substantial further reductions in fatness are achieved, as very low levels of intramuscular fat may impair eating quality (Wood, 1990).

Frequently, physiological differences between divergent lines have been investigated, in some cases in an attempt to identify physiological predictors of genetic merit (see Blair *et al*, 1990 for a review; and Cameron and Cienfuegos-Rivas, 1994). For example, Peterson and Purchas (1989) have reported higher liver catalase activity in sheep from a Massey University high backfat selection line than in those from a low backfat line. Higher plasma urea concentrations have also been reported in these high backfat line sheep (Carter *et al*, 1989). Similar results for urea concentrations have been reported for other selected lines by Cameron (1992b). Suttie *et al* (1989, 1991, 1993) have shown that growth hormone (GH) and insulin-like growth factor 1 (IGF1) pulsaltility, and GH response to GH-releasing factor, differ between lean and fat line sheep, and that GH levels were lower in the fatter sheep within each line. Sheep selection lines have recently been established at Massey University for plasma levels of IGF (Blair *et al*, 1990). Other studies have shown a difference between lines in the antibody titre following active immunisation against testosterone, but no difference in growth rate or composition as a result of this treatment (Haines *et al*, 1989). Another study on unselected sheep has shown an association between blood concentration of glutathione and meat yield (Fiebrand *et al*, 1989). Blair *et al* (1990) suggest that although selection solely for a physiological trait has yet to yield startling results, the inclusion of appropriate traits in selection indices may permit faster rates of gain than those currently possible.

The use of ultrasonic machines in on-farm performance testing is a fairly recent development in several countries. For example, in Britain, following pilot trials by the SAC and the MLC in 1986 and 1987 the MLC offered ultrasonic scanning as an option in its Sheepbreeder recording scheme. Measurements of liveweight, fat depth and muscle depth are combined into a lean growth index based on that described by Simm and Dingwall (1989). For the past few years about 400 pedigree flocks have been using this service, with around 15,000 rams scanned and indexed per year (D. Croston, personal communication). There are few reports of progress in industry schemes involving selection for improved carcass composition. Steine (1982) reported annual rates of progress in some Norwegian breeds of about 1.25% of the mean in aggregate breeding value for growth rate, carcass quality and fleece weight, with these traits assessed on progeny. Lower rates of progress (0.4 to 0.5% per annum) have been achieved recently as a result of more emphasis being given to less heritable traits in the index (Olesen and Steine, 1988). Another estimate of genetic trend in industry flocks comes from the British sire referencing schemes mentioned earlier. The first four sire referencing schemes to be established were in the Suffolk, Charollais, Meatlinc and Texel breeds - all specialised meat breeds (other schemes have started or are under discussion in the Scottish Blackface, Welsh Mountain and North Country Cheviot breeds). Members all take part in MLC's Sheepbreeder Scheme, in the meat breeds selecting at least partly on the lean growth index mentioned earlier. These schemes currently involved 30, 15, 3 and 23 members respectively, with a total of up to about 2000 ewes per scheme. Early analysis of genetic trends in these schemes is very encouraging with responses of 0.4 to 0.9 of a s.d. in average index score achieved in 3 years or less (J T Mercer and D R Guy, personal communication).

## FUTURE OPPORTUNITIES

Primarily for animal and human health reasons, there are moves within the EU towards compulsory unique identification of animals. This, coupled with improved methods of data capture and transfer, could have important implications for the genetic improvement of meat animals. For example, the accuracy of estimated breeding values for pure bred animals could be greatly enhanced by the collection of direct information on carcass weights and grades of their crossbred relatives.

The impact of artificial insemination (AI) in cattle breeding is well documented. Similar benefits are expected in the improvement of sheep, but the technique is far less widely applied. This is partly due to the reduced conception rates which follow transcervical insemination with previously frozen semen. Whilst laparascopic techniques are more successful the increased cost, and in some countries requirements for veterinary input, limit the scale on which the technique can be used. Developments in AI techniques for frozen semen would therefore be of tremendous benefit. Olesen (1994) has recently reported promising results in Norway which may be a consequence either of using AI at natural rather than synchronised oestrus, or of the method of freezing semen.

Recently there has been much interest in the parallel female reproductive technology, multiple ovulation and embryo transfer (MOET) for accelerating genetic response. Smith (1986) reported expected rates of genetic change about double those possible in a conventional breeding scheme following MOET in sheep selected for growth or carcass traits measured prior to reproductive age. Relatively high yields of embryos at a young age were assumed. As a result of this, and a number of other assumptions, such as infinite or large population sizes and failure to account for the effects of inbreeding and selection on genetic variation, early studies are now believed to have overestimated responses to selection and underestimated rates of inbreeding (see Villanueva and Simm, 1994). However, appropriately designed MOET schemes are still expected to result in accelerated responses to selection. Also, results reported recently by Dingwall *et al* (1993) show that considerable progress has been made in improving both the response to superovulation and the survival of embryos in specialised meat breeds. The development and application of newer reproductive technologies based on ET, such as *in vitro* embryo production, sexing and cloning, could all have a large impact on rates of genetic improvement (in appropriately designed schemes) or on rates of dissemination of genetic improvement. However, it is unclear whether the unit costs of such techniques will be justified in sheep, with smaller absolute profit margins per head than cattle.

The prospects of gene transfer to accelerate genetic improvement are discussed thoroughly elsewhere at this Congress. A more immediate application of molecular biology will probably be in assisting with the identification of animals of favourable genotype. Genes having large effects on important traits, quantitative trait loci (QTL), are likely to become more readily detectable as ovine gene mapping programmes advance. It will be possible to select indirectly for these QTL by selecting on genetic markers found to be closely linked on the same chromosome, (marker assisted selection (MAS)). MAS will be applicable in both crossbreeding and within-breed selection. In crossbreeding, MAS may be useful for introgressing a favourable QTL into an otherwise superior breed. For within-breed selection, including markers linked to QTL in the selection index may increase genetic progress by an additional 15 to 30 per cent (Lande and Thompson, 1990; Kashi *et al*, 1990).

Researchers at the US Meat Animal Research Center have recently set up a resource population for detecting markers cosegregating with loci affecting growth, composition and meat quality (K A Leymaster, personal communication). A gene with major effects on muscle development has apparently surfaced in the US Dorset breed and they have incorporated this gene in their study (Cockett *et al*, 1993). (Evidence of a major gene affecting carcass composition also emerged recently in Iceland (Thorgeirsson and Thorsteinsson, 1989)). The plan is to genetically and phenotypically evaluate the $F_2$ generation originating from Dorsets and Romanovs. The $F_2$ lambs born in 1994 will be serially slaughtered and a comprehensive set of carcass and compositional traits recorded. They plan to genotype sheep of 3 generations for 150-200 markers distributed over the entire genome. The genotypic data will be combined with the phenotypic data collected on the $F_2$ lambs to test for markers cosegregating with QTL.

## CONCLUSIONS

There is now good experimental evidence that selection on weight and *in vivo* measurements of composition is effective in improving lean meat production in sheep. Increasingly this technology is being transferred into industry breeding schemes, and initial results from these are encouraging. Further improvements are expected from developments in the design of breeding schemes, use of more comprehensive breeding goals and criteria (including new *in vivo* assessment methods) use of improved methods of genetic evaluation and the wider use of reproductive (and in the longer term molecular) technologies.


## ACKNOWLEGEMENTS

I am grateful to Harry McClelland, Bill Dingwall, Ron Lewis, Jo Conington, Peter Amer and Stephen Bishop for their comments on the manuscript, and to other colleagues for access to results in press.


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