among large populations of tetraploid clones produced by crossing superior parental clones. Neat cytogenetic tricks with diploids have yet to have any significant effects though they have been favoured objects of research for nearly 30 years and figure frequently in this volume. True Potato Seed (TPS), a popular topic in the past ten years, is still a popular topic rather than a matter of practical exploitation and I have yet to see a critical review of it. Biotechnology and genetic engineering are still about to revolutionize potato breeding, though seemingly mostly applied to blight and virus resistance, characters for which breeders have long suffered from *un embarras de richesses*; there is no shortage of disease-resistance genes – the difficulty lies in assembling them into excellent varieties.

The experienced reader, then, will read with the appropriate scepticism and, skipping chunks of trendy irrelevance, will learn things of interest. The non-potato person, however, is advised to read with care. There are some nice new tricks around (even 'technological advances') but the solid core of potato improvement, though represented in this book, is not being revolutionized; and it still presents many and difficult problems of efficiency of selection and testing which deserve more attention than they get here.

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Exploiting New Technologies in Animal Breeding: Genetic Developments. Edited by C. SMITH, J. W. B. KING, and J. C. MACKAY. Oxford University Press, 1986. 216 pages. £30. ISBN 0 19 854 209 7.

This rather pricy book is made up of 20 papers, plus discussion summaries, presented at a symposium held in Edinburgh in 1985. Drawn from nine European countries, the participants surveyed the application of new methods of livestock production and speculated on the future. At one end of the spectrum we have advice on how to get more mileage out of the established methods of biometrical genetics, with better indices of selection and better understanding of genetic causes of variation, as a consequence of new ways of manipulating reproduction. At the other end we are propelled into the uncharted realms of bioengineering. It is convenient to consider the contents in that order.

Within the context of animal breeding there has often been a degree of mutual suspicion between the biometrical geneticists and the physiologists. The former deal with the statistical analysis of phenotypic variation and are content to consign antecedent causes to the black box. The other approach, natural to biologists, encourages a search for causes in the hopes of rational intervention. This is very often frustrated by the complexity of living systems. But times are changing, due partly to new methods of handling embryos and partly to the impact of molecular genetics, which drives a new and independent path to what it sees as ultimate causes. This book reflects the transition which is taking place.

One feature of the contemporary scene is the growth of interest in single genes of major effect and several papers are devoted to this theme. Ovulation rate in sheep is influenced by polygenic variation within and between breeds. But there is also a gene in the Booroola Merino which causes a substantial increase in the rate, while in the Cambridge and also Javanese breeds there is segregation of genes with equally noticeable effects. There is the prospect of enhancing the prolificacy and twinning rates of improved breeds by incorporating these genes. In addition, analysis of how they produce their effects should extend our understanding of the control of ovulation.

The Belgian Blue Cattle breed is distinguished by some 25% hypertrophy, especially of superficial muscles, drastic reduction of adipose tissue in males and sundry other effects, associated with homozygosity of a partially recessive gene. Increase in muscle size has been traced to accelerated mitosis during the early stages of primary fibre formation and hence an increase in fibre number. The process of myogenesis, upon which the beef industry is founded, might well be clarified by an understanding of how these primary changes are caused, while molecular characterization of the gene could pave the way for transfer to other breeds.

Another contribution deals with the exceptional prolificacy of several native Chinese breeds of pigs, which manage to surpass European crossbreds by some 30%. In this instance the increase in yield is due to higher embryo survival. The results of crossbreeding trials are presented, as first steps to make use of this unexpected cache of genes, which may also promote a better general undestanding of embryo survival.

Two of the papers consider biological rather than the usual statistical indices of selection. One deals with back-fat thickness in pigs, the other with milk production in cows. In the former the index is based on the sum of the activity of four NADPH-generating enzymes, which are involved in fatty acid synthesis. The index proved effective but was no better than simple selection for back-fat differences. In the other account, the physiological criteria for identifying genetic merit in milk production are considered. But it seems we are still at an early stage of identification although there may be some immediate advantage in identifying in bulls variables, such as perhaps the blood level of growth hormone, which may be genetically correlated with mammary development in cows.

About half the papers deal with practical developments made possible by multiple ovulation, transfer of sexed embryos, embryo splitting and long-term storage as well as nuclear transfer or cloning. These

techniques are established or fast becoming so. They open the way to more accurate estimates of components of variance and covariance, of the relative importance of maternal effects and, generally, a more accurate distinction between genetic and non-genetic causes of variation. Provided biopsy of pre-implantation embryos is routinely feasible cytogenetic analysis of appropriately stained chromosomes can pick up abnormalities, which are common in embryos, as well as determine sex and therefore identify which embryos are suitable candidates for transfer. Use of H–Y antigen offers a more convenient alternative for sexing. The immemorial search for separation of *X*- and *Y*-bearing sperm goes on, punctuated by sporadic, tantalizing reports of success, which join a motley company of similar claims.

Cleaving of bovine embryos at the morula or blastocyst stage extends the scope of embryo transfer, especially in the production of monozygotic twins to order. Comparison of the performance of mono- and dizygotic twins has had a long history in cattle breeding. Embryo splitting and transfer replaces the laborious validation of genetic identity. With the additional facility of embryo storage and hence control of timing of transfer, we can anticipate a better understanding of maternal effects, in relation to age, husbandry and genotype.

The methodology can also be manipulated to produce chimeras in which cells of more than one genotype co-exist in the same individual. Cattle chimeras have been produced by combining sections of embryos belonging to different breeds, followed by transfer to a suitable receptor. Although the immediate advantages may seem academic in providing information about the development of genetic defects, chimaeras could play a future role in gene transfer.

To get maximum economic return from the application of these new techniques calls for some revamping of breeding programmes. There is a report of a Danish cattle project designed to exploit multiple ovulation and embryo transfer with the development of nucleus herds, performance testing as well as the use of physiological traits in the prediction of breeding value, a synthetic approach worth watching.

In sheep a convincing case is made for using multiple ovulation and embryo transfer to improve female reproductive rate and improve the effectiveness of selection. A limiting factor is the early age of recruitment to the scheme so it may first be necessary to improve yield and embryo survival in young ewes.

For beef cattle a theoretical exploration of how best to exploit the transfer of sexed embryos suggests that a breeding plan, adapted to exploit fully the new methods, could be competitive when the inherent breeding costs are less than ten times the normal rate.

Transfer of nuclei between early mammalian embryos, followed by implantation, introduces a further dimension of analysis and manipulation. Technically feasible in the mouse, the indications are that, with modifications appropriate to the species, it will be generally applicable to livestock. The nuclear transfer technique is being developed to study interruptions in development initiated by maternal effect mutations and hybrid incompatibility, the failure of parthenogenetic eggs to develop and, most significantly, the practical scope for cloning, using nuclei from later embryos and adults. Recent evidence has highlighted the relationship between nucleus and cytoplasm as well as the remarkable phenomenon of imprinting, in which the effect of particular genes may differ according to the sex of the parent from which they were inherited. Successful cloning requires reprogramming of the transferred nucleus and this may impose limits in the transfer of nuclei from older animals. A note added in proof refers to a 1986 report of successful transfer of nuclei from 8- and 16-celled sheep blastocysts to enucleated halves of unfertilized oocytes, so cloning is already with us.

Multiple ovulation and embryo transfer could also be turned to use in breeding for carcase composition by sacrificing for accurate scoring one member of male identical twin pairs. In practice, attention will more likely be focused on physical aids to the practised eye and the ruler. Ultra-sound and X-ray computerized tomography are being used for live animal evaluation. The X-ray apparatus is borrowed from medical practice and the same is true of nuclear magnetic resonance, which can produce a computerized image of cross-sections of the body of moderately sized species like the pig and sheep. Because of cost and size such instruments are likely to be used chiefly in research while routine application of ultra-sound scanners will make selection for body composition more effective.

A case is made for pressing somatic cell genetics into the service of animal breeding for the purpose of gene mapping, producing monoclonal antibodies and investigating the genetics of disease resistance.

The rest of the contributions deal with different aspects of molecular genetics and possible applications. The sense of unpredictability can hardly fail to evoke a frisson of expectation. As might be expected, considerable effort is going into gene transfer by injecting copies of a cloned gene into freshly fertilized eggs. Following the successful production of transgenic mice we can soon expect reports of gene transfer in many species. Compared with smaller vertebrates, livestock are not ideal material because of their rate of breeding and technical problems associated with opaque egg cells. The search is on for genes which will improve economic traits although just where to search for the candidates is not so obvious. There are many problems to overcome, not only in choice of gene but also in the appropriate location of the insert and the likelihood of expression at the right time in the right place.

But there are exciting prizes to be won if some of the proposed goals are reached. Thus one project would

clone the △12 desaturase gene in the hope that successful transfer would initiate the conversion of oleic acid to polyunsaturated linoleic acid. Another would go for intervention in milk production with a view to reducing the lactose content, or suppressing β-lactoglobulin in bovine milk, to the advantage of infants, or increasing the casein and organic phosphate content. The lactose idea is appealing. Some 90% of human beings are lactose intolerant, while the high lactose content in milk poses problems for industrial processing. Inhibition of the α-lactalbumin gene by anti-sense RNA or secreting an active β-galactosidase into milk are suggested ways to encompass the objective. Merely to mention them is to point to the stony path that lies ahead.

In a slightly different context we find a report from an Edinburgh group who are investigating the use of transgenic livestock to secrete valuable human proteins in their milk. The preferred animal is the lactating ewe, cast in the improbable role of surrogate bacterium. Since some 20 animals could meet the annual requirement of some of the proteins they have in mind, the advantages of this project will accrue to medicine not agriculture.

Although injecting DNA into single cells occupies the centre of the transgenic stage a more sophisticated medium of delivery may be hatching in the wings. This refers to the use of C-type retroviruses which appear to have several potential advantages in ease of introduction, integration at low copy number as well as ability to enter the germ line and carry foreign DNA. It may be possible to tailor such vectors for better control of insertion. There are many difficulties to be overcome and so much has yet to be learnt about mammalian retroviruses. But it would be in keeping with the development of molecular biology if simple presentation gave way to controlled insertion. It will be interesting to see how well the rival horses run.

In the remaining contributions we are carried back to the problems of polygenic variation. One of them demonstrates a correlation between the presence of transposable P elements in *Drosophila* and response to selection for abdominal bristle number. There is no direct message for animal breeding since transposable elements are apparently absent in mammals. But if the properties of polygenic variation can be clarified by making use of P elements and the mutations they induce, then breeders of livestock should take note, especially since mammalian retroviruses may be relevant in this context.

A theoretical contribution takes up the theme of detecting sufficient restriction fragment length polymorphisms, scattered across the genome, to provide markers for genes which determine quantitative variation and thereby give selection a sharper cutting edge. The limiting factor here is the proportion of quantitative variation associated with variation in the markers. Given the cost and effort required, the counter attractions of transgenic animals, analysing single gene effects and manipulating embryos are likely to take precedence.

Many of the projects discussed in this Symposium are already in train in research centres in Europe and the U.S.A. Scientific animal breeding is breaking away from the douce life-style dominated so long by calculating machine and, more recently, computer and is making for the turbulent, high ground of experimental biology. New kinds of scientist are entering the arena. This is exciting and not without risk. Who can reckon the tally of dashed hopes two decades hence? But that is the price of innovation. The happiest outcome would be one in which the alternative approaches, old and new, would be seen as complementary.

A further reflection might occur to a thoughtful observer. All the new technology of embryo manipulation is likely, sooner or later, to settle down to rather mundane laboratory routine, practised by a large number of expert technicians. But the whole bag of tricks is potentially applicable to our own species. Is it conceivable that widespread familiarity with them could erode the general concern to keep them beyond the pale of humankind? Who can doubt the need for global agreement about where to set the boundary fence?

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Molecular Evolution of Life. Edited by HERRICK BALTSCHEFFSKY, HANS JORNVALL and RUDOLF RIGLER. Cambridge University Press, 1986. 375 pp. £40. ISBN 0 521 33642 2.

The collection of papers in *Molecular Evolution of Life* represent the proceedings of a conference organized by the Swedish Academy of Sciences and held in September 1985. The list of participants is impressive, and the quality of the papers correspondingly high. The contributions are a sample of current research activity in what the editors describe in the preface as 'fundamental molecular aspects of the prebiological and biological evolution of life'.

It is often a problem with meetings of this kind (perhaps especially so in meetings concerned with evolution, where research in all areas of biology have some importance) that contributors largely ignore the theme of the meeting, simply presenting the latest instalment of their research and letting the audience (perhaps with the help of a token sentence or two) make its own connections. This is not the case in the present volume where only a few papers fail to tackle the evolutionary significance of their subject matter. Although most of the contents are written by researchers reporting their own research, there are a number of short reviews also.

Perhaps the major omission among the papers is in population genetics, where a review, if not one or two