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Animal Health: Present and Future

A. C. L. Brown

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Animal health: present and future

By A. C. L. Brown

Chief Veterinary Officer,
Ministry of Agriculture, Fisheries & Food, Tolworth, Surbiton, Surrey

The importance of the health of farm livestock is considered in relation to the need to economically produce enough human food of an acceptable quality. The control and eradication of important diseases is discussed. Success in this work has allowed the development of high performance breeds by genetic selection. It has also encouraged the development of large scale units and intensive husbandry techniques. These new production methods require high standards of management from all concerned, and represent considerable financial investment. Biochemists, geneticists, physiologists, veterinary surgeons, all have a part to play in the modern livestock industry. The work of the State Veterinary Service is seen as catalytic. The possible development of a disease surveillance unit is discussed, also the type of information required by both veterinary surgeons and farmers.

There can have been few papers presented under the aegis of the Royal Society which opened with a prayer. I wish to do so with the Form of Prayer ordered by Her Majesty in Council in September 1865 on the occasion of the outbreak of cattle plague which killed over 400000 cattle in England and Wales.

'O Lord God Almighty, whose are the cattle on a thousand hills and in whose hand is the breath of every living thing, look down we pray Thee in compassion upon us Thy servants whom Thou hast visited with a grievous murrain among our flocks and herds.'

The prayer finishes: 'Defend us also gracious Lord from the pestilence with which many foreign lands have been smitten, keep it we beseech Thee far from our borders.' (Ministry of Agriculture, Fisheries and Food 1965)

In the last hundred years, dedicated men of science have, through their research, identified the cause of contagions, and new sciences have emerged to give us a clearer understanding of the aetiology and epidemiology of animal disease. Without question this knowledge has permitted increases in livestock production, increases on a scale never known before in history. I would suggest, without undue pessimism, that the rate of progress is unlikely to be sustained unless the contributions to livestock production of the individual sciences develop in parallel, and the application at farm level of new knowledge is more even than it is at present.

The success of disease eradication programmes in these islands has influenced world attitudes to disease control and eradication. The retrospective work of Peter Ellis and his colleagues of Reading University (Ellis 1972; Asby, Ellis, Griffin & Kingwill 1975; Hugh-Jones, Ellis & Felton 1975) in showing the cost benefits stemming from these programmes has confirmed that they were completely worthwhile. These studies have now led to the development of techniques which permit future disease control programmes to be set out in module form which will permit a detailed analysis to be made of alternative approaches, taking account of factors such as cost, manpower input, short term disruption of trade and long term benefits.

It is fortunate that the conviction of veterinarians, this century and last, in the right of their programmes was such that these were funded and completed without the need to develop the advanced methodology essential today for planning schemes to control or eradicate those diseases of livestock which lend themselves to resolution on a national basis under the direction of Central Veterinary Authorities.

The virtual eradication of bovine tuberculosis and the complete eradication of swine fever and foot and mouth disease are good examples of national eradication schemes which created the climate among livestock owners enabling them to invest with greater confidence in larger individual livestock units or complexes of individual units.

The time is long past when 40% of the national dairy herd was infected with bovine tuberculosis, and today herds of several hundred cows are becoming commonplace. The absence of swine fever has permitted the emergence of herds of sows numbering into the hundreds and individual units of fattening swine with populations of many thousands of pigs.

Table 1. Increased livestock performance

	milk yield, national average per cow/l
1946	2360
1976	4090
	piglets reared per sow
1946	11
1976	17
	feed conversion
	pigs
1946	5 kg feed–1 kg meat
1976	$3\frac{1}{2}$ kg feed–1 kg meat
	poultry
1946	3 kg feed–1 kg meat†
1976	2 kg feed–1 kg meat

† Estimated.

The economics of production in large units is convincing with a reduction in expensive labour and an increase in mechanization. It is not claimed that the great increases in productivity in the livestock industry result solely from the eradication of endemic diseases. All eradication has done is to provide more stable conditions in which the major developments in animal genetics, animal nutrition and animal husbandry can be more fully exploited. The progress has been substantial and this has given stimulus and released more resources for further research and development work.

Since 1946 the average yield of the dairy cow has doubled, the food conversion rate of broiler chickens and laying pullets has narrowed significantly. Similarly with swine: productivity figures and piglets reared per sow are now at levels considered impossible at one time (see table 1.)

Henry Wallace in producing his Hyline poultry used the same genetical approach he had used in the development of high yielding hybrid strains of maize (Mann 1959). Today, pure bred poultry are represented only in flocks for the purpose of showing and exhibition, or remain in the diminishing pool of the basic genetic material available for future genetic improvement. In this way the poultry industry has pioneered many significant developments in livestock production by recognizing the contribution available from geneticists and nutritionists. Out of this grew intensive livestock production systems, and today units of 100000 broilers or laying birds are commonplace.

This is not to suggest that the pace of development has been an even one, and that the poultry industry has not had to overcome the many problems which arose from the varying pace of development, intensification and integration. Successful livestock production in large units depends largely, so far as the improved stocks of poultry and pigs are concerned, on the bringing together of technological improvements in ways that reduce the undesirable effects which follow major ecological changes such as an increase in stocking rate and intensive husbandry systems.

The main poultry diseases of the 1930s and 1940s were coccidiosis and salmonellosis due to *S. pullorum* and *S. gallinarum*. With the eradication of pullorum disease from foundation stock and the effective control of coccidiosis by prophylactic treatment, large flocks under systems of greater intensification became possible, giving the geneticists the challenge to breed stock capable of performing well in the new husbandry systems, and the nutritionists the immediate task of providing balanced feed rations for birds well capable of out-producing their parents and grandparents.

Current pathways and pitfalls in livestock production

The problems that arose are worthy of detailed study as undoubtedly there are lessons to be learned which can be applied, if not too late, to the intensified rearing systems and the hybridization programmes for pigs and sheep which are already well advanced.

The poultry industry, legally and illegally, imported genetically improved stock from abroad and with it came a number of important new viral diseases of poultry – epidemic tremor, acute Marek's disease, more lethal strains of infectious bronchitis, infectious synovitis, inclusion body hepatitis, and Gumboro disease. The imported stock seeded bacterial diseases which have caused concern either as primary poultry pathogens or as organisms transmissible and pathogenic to man.

It is possible that under less intensive husbandry systems these diseases would not have caused serious economic loss. However, under intensive conditions, in genetically improved stock already physiologically stressed, new infections took their toll, either as specific viral pathogens or as virus, mycoplasma and bacteria acting together. Vaccines and medicinal products had to be developed to reduce or prevent these losses which were of economic significance.

Today, a not unimportant production cost arises from the need to apply routinely vaccines, antibiotics, coccidiostats and other chemotherapeutic or prophylactic medicinal products. In poultry flocks routine prophylactic programmes involve the use of vaccines to control infectious bronchitis, Newcastle disease, Marek's disease, epidemic tremor, infectious laryngo-tracheitis and Gumboro disease. The development of these reasonably efficacious vaccines is a tribute to the skills of our virologists. The questions to be put are: Is this the right approach to maintaining healthy poultry? Is this approach an escalating and significant production cost as further vaccines are being developed to control the current losses associated with infections such as viral arthritis and *E. coli* septicaemia?

It is only recently that research has been started to develop poultry houses operating under positive pressure and equipped with sophisticated filtration units to prevent the entry of airborne viral infections. There is no doubt the cost of such units will be high. Nevertheless, the alternative vaccination programmes of increasing complexity in the years ahead demand that a fundamental reappraisal be made of existing practices and philosophies.

The position in the pig industry is not too dissimilar and important economic losses stem from endemic diseases like swine dysentery and *E. coli* septicaemia, or disease syndromes such as atrophic rhinitis and enzootic pneumonia. Epizootic diseases, such as transmissible gastroenteritis and others, can periodically occur and add to the hazards of profitable pig keeping.

Undoubtedly the elimination of some of the egg-transmitted diseases from foundation poultry stock is essential to the future of the poultry industry. The formation of specific pathogen free foundation stocks of breeding pigs, or at least the development further of minimal disease breeding herds, is equally essential to the pig industry, and is linked to improved environmental control. These measures alone, and the technology for them already exists, are, however, not enough. The gearing between geneticist and nutritionist needs to be correct if wastage due to white muscle disease, splay leg, muscular dystrophy, and similar conditions is to be contained within acceptable limits. Programmed prophylaxis, possibly involving semi-continuous medication, may well become an essential component of systems for the exploitation of the modern high performance pig. In poultry, kinky back of broilers and aortic aneurism of turkeys now exist and appear to be genetically linked, as is susceptibility to salmonellosis, though this is less clearly identified. Again, overdependence on antimicrobial substances appears, from recent work (not yet published), at the Houghton Poultry Research Station and the Food Research Institute, Norwich, to produce changes in the microflora of the gut in the young chick which increases susceptibility to salmonellosis and extends the period of excretion of the bacteria.

Future considerations in livestock production

In developing improved livestock husbandry systems attention to animal welfare and human health must be given a high priority. The animal protein consuming public, and especially the developing band of animal welfarists, require wholesome products, humanely produced. No absolute criteria exist on welfare standards; these, being largely subjective, may vary over the years. If objective standards are to emerge which satisfy public opinion, objective criteria must be established based on behaviour studies, the application of genetics and the development of husbandry systems which meet the identifiable physiological and psychological needs of livestock.

The sheep industry continues to operate substantially on traditional extensive systems and only now is the contribution of the geneticist making an impact, especially on lowland and park flocks. The paths of development followed by the pig and poultry industries will undoubtedly be adopted for the ruminants, sheep and cattle. Cross breeding has always been a feature of lamb production and the geneticist can now assist in developing more type-specific ewes suited for the many varying climatic and physical conditions present on these islands. Improved fertility and prolificacy are essential in the foundation ewes when linked to milking ability, robustness, early sexual maturity, sound jaws and teeth and ability to reproduce these qualities in their female progeny. Male lines need identifying which can produce the superior cross-bred ewe. In this work, apart from examining new imported genetical material, indigenous breeds should not be ignored (Stone 1976).

In beef cattle successful cross breeding has been practised for many years and the value of the beef bull on dairy stock has contributed significantly to beef production in this country. New breeds have been imported in the last 15 years; I hope the lesson has been learned that because a breed is new it is not necessarily better, and it is evident that the potential of many of our indigenous breeds has not been as thoroughly investigated as that of the imported breeds of cattle and sheep. Nevertheless, the work of the Milk Marketing Board and the Meat and Livestock Commission has been significant in pioneering performance and progeny testing.

The art of the breeder of old in producing improved stock is now largely superseded by the application of scientific knowledge and methodology. This can involve the geneticist, the statistician, the biochemist and the physiologist, working closely together to identify the factors, some genetically linked, which are associated with high production.

Thus the technologies are available today to develop improved stock, to detect oestrus, to synchronize oestrus, to determine early pregnancy, and to identify more precisely the imminence of calving on the farm. The application of these techniques introduces new levels of precision in livestock production which eliminate unprofitable breeding and feeding.

Overall, it is fair to say that the knowledge exists to control most animal diseases and it is the lack of application of this knowledge that impedes improved production. Apathy exists among many livestock owners and their stockmen which the written and spoken word of advice cannot influence. The veterinary profession working directly with stockmen or through the Agricultural Training Board has much to do, as A.D.A.S. has through its officers engaged in advisory, extension and development work.

The eradication, control and prevention of disease – emerging problems

Paterson (1973) most adequately covered animal diseases under three headings – major epidemic diseases, specific diseases, and the diseases of production. It is convenient at this point to examine the current position.

Major epidemic diseases

The country has remained free of foot and mouth disease now for a period of 8 years, the longest period of freedom in recorded veterinary history. The introduction of boneless beef into the international meat trade has been significant in reducing the introduction of the virus from continents where the disease is endemic. The development of vaccines of higher efficacy has been important in controlling epidemics especially in western and southeast Europe. The application of these vaccines in routine programmes of vaccination has reduced the level of infection in western Europe to a point where eradication is almost possible. The improvement in the control of foot and mouth disease in any part of the world reduces the risk to our flocks and herds.

The United Kingdom has pioneered international collaboration in the control of foot and mouth disease, and the report Boldrini (1975) presented at the 20th World Veterinary Congress in Thessaloniki identifies this contribution. In these days of cost benefit assessment it is pertinent to quote from the full text of Boldrini's report:

'The cost of this support, including the development of technical infrastructures, has been very low if compared with the expenses incurred by countries in carrying out regular prophylactic campaigns for their own and common European benefit. Based on the cattle population kept in those countries which contribute to the F.A.O. campaigns, the cost of assistance, including vaccine donations, was 7 U.S. cents per head spread over a 13 year period.'

Swine fever, apart from three related outbreaks in 1971, was eradicated in 1966. The control policy operating for the importation of live pigs and fresh pigmeat from infected countries has been successful. The E.E.C. Commission is currently considering a programme for the eradication of swine fever within the Community. This represents a challenge to western Europe, one which the U.S.A. have accepted with the virtual eradication of the disease from the vast pig population of that country (U.S.D.A. 1964 onward).

The appearance in December 1972 of swine vesicular disease in the West Midlands was a considerable setback for the British pig industry. In the intervening years about 384 outbreaks have been confirmed, and with only two new outbreaks in the last 12 months the final eradication of this disease seems not too distant (Richards 1976). Two hundred and four thousand pigs have been slaughtered at a cost of £6 M.

This disease in itself is of no great economic significance to the pig industry. But the inability to distinguish lesions of swine vesicular disease from those of foot and mouth disease make it essential to eradicate the infection if major changes in existing foot and mouth disease policies are to be avoided. The pig industry has accepted certain new restrictions on the movement and marketing of swine which are essential to the eradication programme for swine vesicular disease.

The restrictions basically slow down the movement of pigs between breeder and fattener, and separate slaughter pigs from young store pigs. Field observations suggest that there has been a reduction in other pig diseases as a secondary effect of the movement restrictions. It can be contended that as livestock industries become more complex and sophisticated, traditional marketing systems must also change. The weekly livestock market and the livestock dealer must have a diminishing rôle as sources of replacement of store stock.

The progress in the eradication of brucellosis is in line with the original timetable conceived in 1967. An increasing number of geographical areas are now virtually free of the infection and by the early 1980s all herds in the country will have been included in the eradication programme. The E.E.C. Commission has tabled proposals for the early eradication of brucellosis on a Community basis. No effective vaccine yet exists for transmissible gastroenteritis of pigs. It is fortunate that although the infection still persists in some herds, no major epidemics have occurred for some years.

The position on Newcastle disease remains satisfactory and will remain so provided the immunity of the national flock remains at a high level. The development of Newcastle disease vaccines which cause less stress in birds seems likely. Research on Newcastle disease has contributed much to existing knowledge on the other viral diseases of poultry.

Attention has recently been focused on Aujeszky's disease in swine lest this disease becomes a problem in our larger pig units as it has in eastern and more recently in western Europe. The identification and elimination of infection in breeding herds is the subject of current field studies.

A serological survey was carried out by the State Veterinary Service this year of over 200 élite breeding herds for swine vesicular disease, transmissible gastroenteritis and Aujeszky's disease. The results have confirmed a basic high health status as interpretation of the results now being undertaken suggests that these diseases are absent apart from the single herd with Aujeszky's disease.

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Specific diseases

The general level of specific diseases – viral, bacterial and parasitic – has not significantly altered in recent years and for many of them effective vaccines or medicinal products exist which can control or eliminate loss if correctly applied. It is regrettable that the attitude at farm level to many of these diseases is clouded by complacency or empiricism with the overuse or misuse of the therapeutic products available. The rôle of the stockman is critical. It is anomalous that the stockman in charge of livestock units, representing a capital value of many tens of thousands of pounds, is paid less than the unskilled worker in the manufacturing or distribution industries. The work of the Agricultural Training Board is vital to increased livestock production as is the attitude of the unions responsible for the interests of those who work with livestock.

The importance of the private practising veterinarian to the livestock industry cannot be overlooked. He must develop further an understanding of the economics of livestock production and a greater readiness to work alongside the specialist technical advisers who have contributions to make to the maintenance of health and satisfactory production levels. The comprehensive training of the veterinarian must not in the future be squandered on work that is marginally professional. The recommendations of the Committee of Inquiry into the Veterinary Profession, chaired by Sir Michael Swann (1975), are a possible blueprint for the next decade though it is unlikely that in the short term new resources will be available to implement much of the report. Statements from the Ministers involved are awaited.

It is clear that some redeployment of existing veterinary resources is possible and desirable, with the State Veterinary Service of A.D.A.S. assuming a catalytic rôle between the profession, the M.M.B., the M.L.C., the A.R.C., and the Veterinary Schools. Coordination rather than duplication of effort must be the objective.

The future of the State Veterinary Service

In the last part of my paper I wish to comment further on the rôle of the State Veterinary Service. The Joint Consultative Organisation for Research and Development, set up following the report of the Rothschild Committee, has completed its immediate work (Ministry of Agriculture, Fisheries and Food 1975) and a firm customer-contractor relation has been established. A period of consolidation is now essential to permit the Research Institutes to get on with the primary reason for their existence: well directed research.

Essential to the future is the need to develop an Animal Disease Surveillance and Intelligence Unit which could exploit existing sources of information on disease prevalence and distribution, correlate this and disseminate the data on a routine basis or on request as specific papers to meet specific needs (Ministry of Agriculture, Fisheries and Food 1976). It could operate as a survey planning unit backed by proper statistical and design expertise. The serological survey is essential to this work. Basic parameters could be easily established using serum samples already available from routine sampling as for brucellosis.

Preventive medicine must be based on facts so far as these can be established. As I indicated earlier in this paper the days of acts of faith in funding disease programmes are gone nationally; equally at farm level, herd and flock health programmes must have a scientific base and be cost effective if they are to be accepted. Among the many problems that beset the State

Veterinary Service in applying traditional eradication procedures is the growing size of individual livestock units and the complexity of separate farming units organized horizontally or vertically within Farming Companies (see table 2).

In the past a typical outbreak of foot and mouth disease involved herds of limited size. Rarely were more than a few animals infected. The volume of virus excreted was small and on average in the 1950s less than two other outbreaks occurred linked to a primary case. (Northumberland 1969). The analogy is the effect of a small charge of high explosive breaking the windows on a couple of adjoining farms, the cost of the damage being minimal and the repair work easily completed.

TABLE 2. AVERAGE SIZE OF DAIRY HERDS

Average size of dairy herds	
1942	12 cows
1960	21 cows
1976	44 cows

Size of farms in 1976	
over 405 ha	7 %
between 202 and 405 ha	2.6 %
between 61 and 202 ha	19 %
less than 61 ha	71.4 %

Average size of farms in 1976/ha	
Great Britain	41.7
other E.E.C. countries	15.4

Today the size of individual units with high stocking densities under systems of intensive management, present problems of entirely different dimensions in a foot and mouth disease context; dimensions indeed that require complete rethinking of traditional policies. A more apt analogy for the units today is the explosion of a thermo-nuclear device which will not only totally involve all adjoining farms but many others in a 'fallout' area. The volumes of infective virus that could be produced in large units of cattle, pigs or sheep will be considerably greater than in the past. Thus the pattern of outbreaks will require the mobilization of teams of veterinarians, virologists, epidemiologists, and meteorologists, to contain the disease by a stamping out policy.

The campaigns will be proportionally more expensive and the physical problems of killing and the safe disposal of large numbers of stock will have to be undertaken against preconceived plans. I wish only to be totally realistic in looking into the future, yet not pessimistic, given adequate forward planning and degrees of greater cooperation and understanding from livestock owners in following advice given on security and hygiene.

Tables 3–8 illustrate the annual compound change in the size of livestock units forward to 1980. The change is most significant to the future control of animal disease.

The larger livestock units, i.e. those over a certain optimum size, or put another way, those of a critical size and the few that are of a lethal size, will be individually reviewed and advice given on disease security arrangements to be followed while major epidemics are absent from the country and on the more stringent hygiene and security programmes which should operate in the event of epidemic disease breaking our substantial barriers against the introduction of infection from countries exporting to us, at our ports and at the waste food plants such as

Table 3. Distribution of dairy cows by size of herd: United Kingdom

herd size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–19	500	15	288	9	−10.5	148	4
20–49	1321	40	1021	30	−5.0	752	18
50 and over	1454	45	2085	61	+7.5	3221	78
total	**3275**	**100**	**3394**	**100**		**4120**	**100**

Source: agricultural censuses.

† This column shows what the position would be if the proportional rate of change 1969–74 continued to 1980. It is not a forecast.

Table 4. Distribution of breeding pigs by size of herd: United Kingdom

herd size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–19	330	36	177	20	−11.7	84	7
20–49	240	26	181	20	−5.5	129	12
50 and over	343	38	531	60	+9.1	894	81
total	**914**	**100**	**889**	**100**		**1107**	**100**

Source: agricultural censuses.

† This column shows what the position would be if the proportional rate of change 1969–74 continued to 1980. It is not a forecast.

Table 5. Distribution of breeding sheep by size of flock: Great Britain

flock size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–99	2259	18	1719	13	−5.4	1227	9
100–499	6086	50	6267	49	+0.6	6500	46
500 and over	3906	32	4857	38	+4.4	6272	45
total	**12251**	**100**	**12842**	**100**		**13999**	**100**

Source: agricultural censuses.

† This column shows what the position would be if the proportional rate of change 1969–74 continued to 1980. It is not a forecast.

Figures included for Scotland relate to the December censuses.

Table 6. Distribution of broilers by size of flock: Great Britain

flock size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–9999	2947	8	1841	4	−9.0	1044	1
10000–49999	11702	33	11441	22	−0.5	11074	11
50000 and over	21256	59	39824	75	+13.4	84766	88
total	**35905**	**100**	**53108**	**100**		**96884**	**100**

Source: agricultural censuses.

† This column shows what the position would be if the proportional rate of change 1969–74 continued to 1980. It is not a forecast.

Figures included for Scotland relate to the December censuses.

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exist today. The rationalizing of the processing of waste food has been the most important single factor in recent years in the prevention of exotic disease.

In looking to the future of livestock production, let no one ignore the growing challenge to the stock farmer from soya based protein or the proteins now becoming available from the petro-chemical industry. The lesson is clearly there when the place of margarine today in the diet of man is considered.

I conclude with an epilogue: 'Be thou diligent to know the state of thy flocks and look well to thy herds.' (Proverbs 27: 23)

Table 7. Distribution of beef cows by size of herd: United Kingdom

herd size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–19	448	37	496	26	+2.1	563	16
20–49	403	33	625	33	+9.2	1060	30
50 and over	364	30	767	41	+16.1	1879	54
total	**1214**	**100**	**1887**	**100**		**3502**	**100**

Source: agricultural censuses.

† This column shows what the position would be if the proportional rate of change 1969–74 continued to 1980. It is not a forecast.

Table 8. Distribution of laying fowls by size of flock: United Kingdom

flock size group	1969 $10^{-3}\times$ number	1969 % of total	1974 $10^{-3}\times$ number	1974 % of total	annual compound percentage change	1980† $10^{-3}\times$ number	1980† % of total
1–999	11397	22	4683	9	−16.3	1610	3
10000–4999	14173	27	7997	16	−10.8	4032	9
5000 and over	27320	52	37244	75		41190	88
total	**52891**	**100**	**49924**	**100**	**−1.1**	**46832**	**100**

Source: agricultural censuses.

† Because of the exceptionally rapid changes in structure between 1969–74, we have not felt able to assume that these changes continue till 1980. Consequently, we have projected total livestock number and calculated the number in the largest size group by difference. The figures in this column are not forecasts.

References (Brown)

Asby, C. B., Ellis, P. R., Griffin, T. K. & Kingwill, R. G. 1975 *The benefits and costs of a system of mastitis control in individual herds*. Reading: Department of Agriculture and Horticulture, Study no. 17.

Boldrini, G. M. 1975 Thirteen year campaign against exotic foot-and-mouth disease in south eastern Europe and Anatolia. *Proc. 20th Wld vet. Congr.*, Thessaloniki 1975, **3**, 2485–2504.

Ellis, P. R. 1972 *An economic evaluation of the swine fever eradication programme in Great Britain, using cost-benefit analysis techniques*. Reading: Department of Agriculture and Horticulture, Study no. 11.

Hugh-Jones, M. E., Ellis, P. R. & Felton, M. R. 1975 *An assessment of the eradication of bovine brucellosis in England and Wales*. Reading: Department of Agriculture and Horticulture, Study no. 19.

Mann, E. E. 1959 *Hybrid chickens*. Ministry of Agriculture, Fisheries and Food, Bulletin 180. London: H.M.S.O.

Ministry of Agriculture, Fisheries & Food 1965 *Animal health; a centenary* 1865–1965. London: H.M.S.O.

Ministry of Agriculture, Fisheries and Food 1975 Second reports of the Boards of the Joint Consultative Organisation for Research and Development in Agriculture and Food. London: H.M.S.O.

Ministry of Agriculture, Fisheries and Food 1976 *Animal disease surveillance in Great Britain; the report of a M.A.F.F. working party* (chairman: G. Davies). Weybridge: M.A.F.F., Central Veterinary Laboratory.

Northumberland, Duke of 1969 *Report of the Committee of Inquiry on foot-and-mouth disease. Part One*. Cmnd 3999. London: H.M.S.O.
Paterson, A. B. 1973 Animal health. *Phil. Trans. R. Soc. Lond.* B **267**, 113–130.
Richards, R. A. 1976 *Bull. Off. int. Epizooties*. (In the press.)
Rothschild, Lord 1971 *The organisation and management of Government R. & D.* In *A framework for government research and development*. Cmnd 4814. London: H.M.S.O.
Stone, P. 1976 Breeding better sheep. *M.A.F.F. A.D.A.S. Cornwall Mentor*, no. **6**, 20–22.
Swann, M. 1975 *The Committee of Inquiry into the veterinary profession*; *report*, Cmnd 6143. London: H.M.S.O.
U.S.D.A. Animal and Plant Health Inspection Service 1964 onward. Cooperative State–Federal hog cholera eradication program. Progress reports. Washington.

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