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Farm Animal Care Trust

Sustainable livestock farming into the 21st century

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2 Developments in livestock transport and slaughter

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INTRODUCTION

This paper has been written with the underlying assumption that the outlook for the agricultural industry over the next forty years is good. The population is unlikely to decline and so demand for food and the amenity facilities provided by the industry will hold, if not rise. More importantly, world mineral oil reserves will decline and they will have to be replaced by energy extracted from plants and animal by-products. New industrial outlets such as this will in turn help to maintain land prices and investment in the farming sector. The aim of this paper is to consider how the hauling and slaughtering trades could change over this period, and to focus particularly on animal welfare. Needless to say improvements and innovations will occur where they are likely to be cost effective. The increasing customer awareness about environmental and welfare issues should provide opportunities for the industry to capitalise on the improvements it creates in both agricultural hygiene and animal welfare. It will however be up to the producers to look for and take up the incentives.

It has been suggested that supermarket companies will be in a powerful position to improve animal welfare. They are major purchasers of meat at the wholesale level and they can press their suppliers to introduce or improve welfare standards where they see fit. Some view this as a marvellous opportunity to exert influence on those who produce animals and meat, whereas others are worried that such power should be concentrated in a small group of people who are experts at marketing food but are not well informed when it comes to animal welfare. The supermarkets however, are only likely to pursue a policy on a particular welfare issue if it is going to improve or protect their trade. The factors which will help determine this are whether the welfare-improved product is:–

(i) recognisable – a marketable product label has to be attached to the item which describes the perceived welfare improvement.

(ii) quality assured – the perceived welfare improvement should not seriously harm the quality of the product, the quality image of the supermarket company, or the quality image of the adjacent alternative products.

(iii) guaranteed – can the supermarket guarantee that the label describes what the product actually is? Is it possible to 'police' the welfare improvement or rely on the supplier to do so?

(iv) profitable – the return from the product has to outweigh the additional effort and cost of marketing it.

The third requirement (policing) can be particularly daunting and could deter supermarkets from promoting animal welfare in the future. This should become evident when one considers the likely move to an enlarged international market for meat. For instance, it is unlikely that British retailers would go to the trouble of inspecting production standards in East European countries, and many of these will probably be supplying a larger proportion of Britain's food in the future. Some of these countries have agricultural systems which operate at a low cost and have a 'green' image (eg Rumania), whilst others have outstandingly high standards in abattoir hygiene (eg Hungary).

In the future, will consumers be more aware of how animals are slaughtered or will they shun the subject? Some people find the subject so distasteful that they prefer to ignore it. Others would tend to share this view but add that they need to be assured that the animals killed on their behalf are despatched in a humane and dignified manner. Whereas others feel that all meat eaters should be educated in the subject because they are in part responsible for the animal's death. These arguments have been well rehearsed and nowadays adolescents think about them at an earlier age than in previous generations. Young people are probably more sensitive than adults to the implications of taking an animal's life, and because of this a relatively high proportion of the population in the future will at some time in their lives probably be vegetarian. The meat producing sector of the agricultural industry will be particularly susceptible to such 'responsible decisions' made by consumers.

Besides the fact that slaughter involves the taking of an animal's life, there are three reasons why slaughter and preslaughter handling receive so much attention amongst all the topical animal welfare issues. Firstly, when animals are transported to a market or slaughterhouse, laired overnight and then killed it is easy to transgress the 'five freedoms' that animals are expected to enjoy (Table 1).

Table 1
The five freedoms animals can expect to enjoy

(i)	freedom from thirst, hunger and malnutrition;
(ii)	provision of appropriate comfort and shelter;
(iii)	prevention, or rapid diagnosis and treatment of injury and disease;
(iv)	freedom to display most normal patterns of behaviour;
(v)	freedom from fear.

Source: Farm Animal Welfare Council. Report on the European Commission Proposals on the Transport of Animals (1991).

In fact there are few other situations in which all 'five freedoms' collectively share such a high level of risk, albeit for a short period of time. Secondly, a large number of animals are put through these procedures every year. In the UK about 580 million farmed animals are slaughtered for meat consumption annually (Table 2). Thirdly, the ugliness of animal transport is displayed in front of the public every day and so susceptible consciences are being regularly pricked.

Table 2
Number of farmed animals slaughtered in the UK every year

	Million
Chickens	450
Trout	45
Turkeys	32
Sheep	19
Pigs	13
Salmon	8
Ducks	8
Rabbits	3
Cattle	3

There is bound to be some disparity between what one would like to see happen in the future and what actually happens. From the welfare point of view it would be good to see on-farm slaughter of a wider variety of species than deer, trout and salmon. However, hygiene standards have to be complied with, and the logistics of slaughtering large numbers of animals in mobile slaughterhouses makes the idea impractical. Nevertheless there could be an opportunity for slaughtering some of the exotic species in this way.

CAN SCIENCE AND TECHNOLOGY HELP THE LEGISLATORS?

The days when welfare legislation decreed a vague benevolence seem to be coming to an end. Specific requirements are now being put into secondary legislation and Codes of Practice that do not depend solely on reasoned argument and intuition but instead draw on a modest contribution from science and technology. At the moment scientific research is becoming more polarised into its fundamental and applied disciplines. In the UK, applied agricultural research has lost a high proportion of its Government support, and what is left is largely targetted at supporting legislation and Codes of Practice. Those responsible for drafting legislation are sensitive to welfare issues and in a position to contract and direct research according to their specific requirements. Research will probably become even more directed towards serving the Government's legislative and policy aims before we see any departure from this approach.

The draft of the CEC regulations on stunning and slaughter is a good example of how research has been used to formulate the law and I expect we will see more examples of this in the future. The ways in which this has happened can be illustrated by the following examples. In the late 1970s and the 1980s Drs Hoenderken and Lambooy from the Netherlands examined the effect of electrical and concussive stunning methods on the electro-corticogram (ECoG) of the brain in pigs and sheep. In the case of electrical stunning they adopted the assumption that based on analogous experience in man, if the ECoG shows epilepsy after electrical stunning the subject will be unconscious. Using this criterion they determined the minimum currents which will induce epilepsy 98% of the time and these now form the basis for the minimum permitted currents in the proposed regulations (Anon, 1990). Other requirements which have leant heavily on scientific research in this area are the maximum permissible stunning to sticking interval in cattle, the minimum acceptable current for waterbath stunners in poultry, and the blood vessels that must be severed at exsanguination (Anon, 1991).

Many other topics are likely to benefit from scientific research and in the short term these will include stunning and slaughter of farmed fish, avoidance of catching and handling trauma in poultry, and the transportation of livestock. Livestock transport is a more difficult subject to legislate for on the basis of scientific evidence alone because of the greater variation in circumstances and the more nebulous nature of the percieved welfare problems. There are in fact six welfare problems in transporting stock to slaughterhouses – psychological stress, temperature stress, metabolic exhaustion and hunger, dehydration and thirst, trauma and death. Phsyiological investigations based on liver glycogen depletion during fasting have defined the periods over which metabolic exhaustion will set in. For example in pigs the fasting interval over which liver glycogen is depleted to less than 10% of its normal value in the fed state is 21 hours (Warriss & Bevis, 1987), and on this basis it has been recommended that journeys should not exceed this interval without a feeding and resting period. In the

case of sheep and broiler chickens the respective values are approximately 24 and 6 hours (Warris *et al* 1988). In the future similar research should be performed on the time to onset of physiological dehydration, but it is unlikely that physiological indicators will be so useful for assessing psychological stress. Formulating legislation on the basis of metabolic exhaustion and dehydration would be a useful achievement in itself. As our knowledge improves, the legislation will have to be brought up to date. In an ideal world the legislators should take a flexible attitude about previous decisions and be willing to change the law without feeling that they are having to stand down. Future legal systems should encourage a greater flexibility to change the details of the law as our understanding of animal welfare improves.

One of the weaknesses in the structure of the present legal system is that the legislators do not have a hand in enforcement, and so they are not in a good position to know where problems exist and they do not always have a readily available source of information which allows them to gauge the success or failure of the laws they create. In the future their decision making will be strengthened by directives from the CEC, and when contributing to these directives it will be interesting to see whether they stand to support either national commercial interests, the maintenance of domestic legislation, or the interests of animal welfare. One thing one cannot legislate for is the mental attitude of the people who work in slaughterhouses. Much is said about training slaughtermen and lairage personnel, but little is actually achieved. The tasks involved instill the same mental attitudes as most repetitive factory jobs which require some physical effort; there is a preoccupation with ones own comfort and intention, and a desire to minimise exertion. There are many ways in which slaughterhouse staff can cut corners to the detriment of animal welfare. The most imaginative example we have come across recently involved captive bolt shooting of cattle. The slaughterman was provided with a contact firing gun which has to be struck onto the animal's forehead in order to get it to fire. This presented obvious difficulties if an animal refused to raise its head from the bottom of the stunning box, but this problem was dealt with by dropping the gun from a height onto the animal's head. If all went well, and quite often it did, the gun landed on its target, fired and knocked the animal out. I am not sure whether training would help reduce this or many of the other misdemeanours that are committed by slaughterhouse staff. Often as not the staff are well aware that they are abusing a system and the only remedy is adequate supervision or surveillance.

ANIMAL TRANSPORT AND HANDLING

In general man has had the good sense to farm those species which are relatively easy to handle and are inclined to live in social groups and so tolerate each other, but within these there are familiar groups which on mixing can lead to torment and outbreaks of fighting. One notable exception

is the mink which is farmed in large numbers even though in the wild it tends to lead a solitary life outside the breeding and rearing seasons. The food market is in a receptive mood for new ideas and new meat products and this is likely to continue into the next century. This has already raised the problem of knowing how to transport and slaughter red deer, and no doubt there will be other cases in the future whether it be with moose, hare, wild boar or whatever.

Denmark and the Netherlands are the principal red meat exporting countries in the EC, and Italy, Britain and Spain are the main red meat importers. This position is unlikely to change when the proposed CEC hygiene regulations come into effect, as the output from EC approved abattoirs in the main exporting countries will be far in excess of the consumption within each country (Table 3).

Table 3
Export potential for red meats from 9 member states of the EC

Throughput of EC approved plants (cattle units) ÷ population of the country (number of humans)

Denmark	1.67
Netherlands	0.78
Eire	0.71
West Germany	0.34
France	0.31
Luxembourg	0.23
Spain	0.22
Britain	0.10
Italy	0.07

Source: Adapted from Palmer (1990).

Nothwithstanding this it is difficult to predict the ways in which live fatstock transport will change in the future. Hopefully transcontinental transport of live animals will decline but whether this happens will rest on political and local marketing forces. To emphasise the importance of local demand we need look no further than the lamb export trade from the UK. One can fit about 400 lambs into a livestock lorry and 1100 lamb carcasses in a refrigerated meat lorry, and so it should be more cost effective to transport lambs dead rather than alive. Nevertheless last year Britain exported over half a million finished live lambs to France, and in spite of the problems created at the ports of landing by French farmers, this number was more than for the previous year. Nearly all the lambs were slaughtered at abattoirs in and around Paris, where the lorries were directed in order to

keep these plants open, and because of the premium that is obtained from locally killed lamb.

In recent months there has been considerable debate over how long animals can be transported without providing a suitable rest period. Such limitation will help to curtail long distance journeys, whether the limit is set at 8, 12, 16 or 24 hours. An important piece of information we need to know is how long the rest period should last. Unloading the animals at a yard, counting up to ten and then loading them back on board would not be in keeping with the spirit of the proposed regulation. Instead, research will have to be done on the recovery of normal physiological and behavioural patterns which indicate what the suitable rest period is likely to be. Any move away from intensive farming methods will probably lead to greater difficulties in gathering animals when they are due to be slaughtered. This is already becoming evident in the case of free range and premium broilers which are grown under daylight conditions and are considerably more agile and adept at avoiding the catchers than standard broilers. They are also prone to piling on top of one another at the end of a shed when they are disturbed. The solution lies with controlling the lighting when they are caught and in the skill of the catching staff; there will be no replacement for careful handling.

Future developments in livestock hauling will be largely influenced by the following factors:–

(i) legal limitations in the time stock can be transported without offering them a refreshment break;
(ii) any decrease in the number of abattoirs and hence increase in the distance some animals will have to be transported;
(iii) any increase in the upper speed limit allowed on motorways;
(iv) the cost advantages of not transporting livestock for long periods.

In general these factors will encourage hauliers to transport stock at faster speeds, and in order to do this they will be looking for more powerful vehicles. This could raise questions about windchill effects in the animals, especially during the colder months, and this in turn will mean that the haulier will need to be more careful in checking on the conditions in the animal compartment behind him. An obvious innovation which should benefit both the animals and the hauliers is the installation of temperature monitoring systems within the livestock compartment. This would include a display of the temperature on the dashboard of the driver's cab and an audio warning system which informs him when the temperature goes outside certain limits. The driver then adjusts ventilation hatches or louvres remotely from the cab to regulate the temperature to the required level. None of this is beyond present technology, and in the case of poultry it could pay for itself through saving on the number of DOA birds. Greater attention will also need to be given to directing cool, fresh air to the hot spots within poultry transporters. Some sacrifice in the density of the animals may be required in order to achieve this.

It is worth considering what we as humans dislike about travelling at high stocking densities. The next time you are in an overcrowded Underground train focus on a person who looks to be irritated and consider the reasons for his or her distress. If nothing else it will help to distract you from your own discomfort, which others might achieve by reading or more rarely by talking to companions. Most people give a large part of their concentration to the journey and coping with the threat of losing their balance, the heat, stale air and odours, close contact with others and noise. In the Underground we are provided with handholds to allow us to keep our balance. Livestock on the other hand have nothing other than another animal or the walls of the container to press against. If an animal goes down, etiquette and good manners do not come into play, but instead it will have to fight for itself to get up. This presents an obvious problem if the animal is weak or injured in the first place. Provision of footholds for poultry is something that is needed, and more is said about floor design of transport crates later. Close contact with other animals and noise are inescapable facets of animal transport, but temperature and ventilation control could be improved. Greater attention should be given to animal transporter design from the hygiene as well as welfare points of view. Is it necessary for faeces and urine to land on animals in lower decks or tiers, and is it necessary for animals to sit in their own excreta?

The basic design of animal transporters has barely changed over the past 50 years; they have merely become larger and in the case of pig transporters they now are made of metal components instead of wood and metal. An interesting exception to this are the poultry transporters used in very cold climates such as in Finland, where the vehicles are insulated and mechanically ventilated, and superficially look like refrigeration lorries. A consequence of changing the structure of livestock transporters from wood and metal to all metal is that they will become noisier when being driven. Containerisation of pigs should be a feasbile proposition and it would eliminate mixing stress and some of the preslaughter handling when it is used in conjunction with gas stunning. In this system the pigs would be loaded into the containers on the farm which would be hoisted onto the lorry and taken off again at the abattoir onto a conveyor which leads to the stunning unit. Gas stunning in this way offers an even greater advantage for poultry because it could be used to eliminate preslaughter shackling. Present poultry transport crates have too many sharp edges and most of them have solid floors which allow the birds to roll in their faeces and urine. At one plant in the UK which uses drawer modules, crushed skulls accounted for 29% of the cases of fatal trauma in the DOAs. This calls for a flexible or curved upper lip in the drawer which avoids damaging any trapped head. Ideally the inner surfaces of the crates would be padded or curved and the crates should be fitted with false floors which allow the birds to tread their faeces through to a collecting floor or shelf as well as giving the birds a foot purchase.

As a rule, forcing or encouraging staff to handle animals at faster speeds without modifying the handling system accordingly is conducive to more

trauma in the animals. This has reached serious proportions in the case of chickens. For example 24% of hens acquire broken bones when they are pulled out of their battery cages at the end of lay (Gregory, *et al* 1990) and 27% of broilers (amounting to about 230 000 per year in the UK) that arrive dead at poultry processing plants have dislocated hips. One plant overcame this problem by changing from a piece work payment system to an hourly payment rate for a fixed number of hours per day. The broiler catching teams had to attend work for 8 hours and so there was no incentive to rush the job in order to leave off work early. This was claimed to have resulted in more careful catching and less trauma. Another way of avoiding handling damage would be to use mechanical catching machines such as the Tamdev. Legislation could also help, by stipulating the catching method. For example, catching chickens by two legs instead of one leg is likely to lead to less damage, particularly in heavy broilers and in hens that get caught in the cage entrance on withdrawal from the battery cage. If two leg catching became a legal requirement for broilers, some processing companies would probably change over to mechanical catching methods in order to maintain a fast catching rate.

Successful driving of animals in a lairage depends on the lairagemen impinging on the animal's flight zone thus causing the stock to take an escape route which is the same as the direction the lairagemen want the animals to move. The system breaks down when the animals cannot identify the escape route (eg because of a sharp bend) or the escape route is blocked (eg by other animals) or there is something intimidating about the escape route (eg a shadow across its entrance). At worst the animals will feel cornered and may turn to face the lairageman adopting a rebuttal instead of flight mode. Besides flight, the other inclinations which are exploited to advantage are the animals' predilection for grouping and for following. Wide races are needed to allow group movement and curved races are one of the better means of encouraging following behaviour. Those abattoirs which are in a position to make large investments in their lairage facilities, could be using flat deck conveyors in the future. These could work along similar lines to the luggage conveyors presently used at airport terminals, and when operated properly, they should help to reduce some of the handling stress.

ABATTOIR DESIGN AND STANDARDS

In some countries hardly a week goes by without some form of industrial action by abattoir slaughterhall staff. Strikes and absenteeism have been the main incentives to developing automated red meat lines. This includes fully automated stunning methods, which have been designed and to some extent developed for cattle in Australia, for sheep in New Zealand and for pigs in Scandinavia. With the exception of CO_2 stunning of pigs all of them are based on electrical stunning. Automatic sticking methods have also been tested successfully for cattle. Slaughterhouse staff in the UK are less

inclined to industrial action than in some other countries, and so the incentive for line automation lies with improved efficiency of production, better carcass, meat or hygienic quality and projecting a modern image to customers. Thus only a select number of companies are likely to follow this route. If you want to envisage what they would look like, make a visit to a modern poultry line and then use some imagination on how it could be translated into a pig or sheep plant. One of the basic differences might be that in the red meat plants four point suspension would be more likely, with evisceration being gravity assisted. Automatic electrical stunning is already used for pigs and sheep and no doubt it will be a common feature in both the automated and semi-automated red meat lines of the future. It would be unwise to make any sweeping generalisations as to whether automatic stunning will be more or less humane than hand stunning. However, there are a few points that are worth keeping in mind. Experience with automatic poultry stunning has shown that there is a danger of ignoring this procedure once the machine has been set up for the day. As with all other automatic procedures surveillance and prompt attention to any shortcomings are essential. Automatic stunning removes human error, and since this is a major component in malpractices such as incorrect positioning of electrodes or guns, one can hope that there will be some improvement in welfare standards. Nevertheless, this advantage may be replaced to some extent by machine-animal misadventures. It is important that automatic electrical stunners allow inspection of the animal as it is being stunned, and during the period between stunning and sticking.

Innovations which save labour within the lairage will also be attractive to abattoir proprietors. Mechanical 'walking dog' gates are already becoming popular in pig lairages in some countries. Remote opening of gates should also be feasible, and coupled with 'walking dog' gates this would help reduce man's direct interference with animals and promote voluntary movement. We are already seeing a change in markets and lairages towards 'through-flow' systems where animals enter a holding pen at one end, and leave it from the other. When operated properly this also has the advantage of reducing the amount of chasing required in emptying a pen.

The design of crowding pens and race systems that are suitable for high throughput cattle, pig and sheep plants have been well documented (Grandin, 1989). The systems that are recommended when building a new plant are diagonal 'through-flow' lairage pens with a crowding pen and curved race system for cattle, a rail conveyor for sheep and a stepped crowding pen with tandem race for pigs. It is up to the abattoir companies to take up these ideas and exploit them when they replace their old facilities. The crowding or holding pen before the race leading to the stunner is often the point at which difficulties develop and it requires a high standard of stockmanship to ensure that the flow of animals runs smoothly. Tandem races could be the answer in some slaughterhouses. By having a choice of two races from which a lairageman can draw a pig for loading into a restraining

conveyor or restrainer, there is double the opportunity of having a pig available when it is needed. This should help to reduce the amount of goading required to get a pig up to the restrainer. Small abattoirs cannot always justify a high capital expenditure on animal handling facilities and it is difficult to make generalisations on the optimum layout and design.

Some of the biggest changes that are likely to be seen in British abattoirs over the next thirty years will originate from a stronger emphasis on hygiene. In certain instances this will have a bearing on animal welfare. For example the requirement to separate dirty animals from clean carcases could be upheld to the extent that stunning, bleeding and flaying will be performed in an isolated area. This will provide a useful opportunity to stun livestock in an area which is not subject to the noisy machinery of the dressinghall. It will also become increasingly important for the abattoir to process carcasses which have no obvious soiling on the skin. To achieve this abattoirs will buy more of their stock from dealers and farmers that can be relied on to supply clean animals. In line with this there will be a temptation to fast animals for as long as possible prior to transport; animals will need to be laired on clean bedding; and penalties will be imposed for sending in animals which have been scouring or have gastroenteritis.

The present design of cattle stunning pens leaves a lot to be desired. They are noisy and in general they are too wide and the walls are too high. According to British regulations, head restraint will be required for cattle in the future. This is one approach to solving the problem of animals not presenting their heads for shooting, but it is open to abuse and distress if the animal is left in the head yoke for unnecessarily long periods. A less aggressive alternative would be to use low sided stunning pens, with bars fitted over the top to prevent the animal jumping up. Such a system is used at the abattoir in Linkoping in Sweden, and the low sides encourage the animal to look up rather than hide its head near the bottom of the exit door.

Besides slaughtering animals, abattoirs offend sensitive feelings in a number of other ways. They can be smelly places; they produce large amounts of foul water; the noise associated with handling pigs can be distressing; and the sight of animals being trucked into a compound lined with chainlink fencing topped with barbed wire also adds to the macabre image of the industry. In the reign of Henry VII the problems created by liquid effluent were dealt with by a statute which made it illegal for any city to have a slaughterhouse. Perhaps we should reconsider the wisdom of this regulation in a broader sense, and also put some thought into screening the premises with trees or earthbanks. In the late 19th century abattoirs used to be clustered around the ports and railway lines of Britain, but in the future we could see more of them alongside animal rearing units. They would be similar to the American and Australian feedlots, but in the case of Europe the feedlots would be indoor and they would hold pigs instead of cattle.

METHODS OF STUNNING AND SLAUGHTER

There are three ways in which stunning and slaughter can go wrong. Firstly, the animal may not be stunned immediately. Secondly, the application of the stunning device or system may be unduly distressing. Thirdly, the animal may be stunned straight away but it regains consciousness either before or shortly after sticking.

Table 4
Duration of insensibility in seconds (SD) according to current level and duration following electrical stunning in sheep

Current level amp	Current duration, sec (SD) <1	3	6
<0.3	33 (9)	52 (13)	49 (20)
0.3 to 0.66	34 (12)	62 (14)	71 (18)
>0.66	39 (6)	63 (16)	87 (25)

Source: Daly (unpublished data).

The first problem can occur when low stunning currents are used. This can be tested experimentally by applying the current for a short period (eg less than a second) and determining the proportion of animals that are not immediately stunned. The problem can escape notice if the same average current is applied for a longer period (say 7 seconds) and all the animals appear to be stunned at the end of that period.

The second problem occurs when, for example, there is an interrupted application of the current because the slaughterman loses his grip on the animal as he tries to apply the tongs. In this situation the animal can get an electric shock instead.

Recovery of consciousness following application of the stunning current is a more complex problem, and I will describe how it can happen by using sheep as the example species. When head only electrical stunning is used the length of overt behavioural unconsciousness varies to some extent with the duration of the current application (Table 4). If 0.5 amp is delivered for 3 seconds then on average the duration of insensibility (as assessed from the time to recovery of head righting behaviour and at least partial control of balance) will be 62 seconds. So, we can take this as the given duration of anaesthesia when electrical stunning is applied correctly. The next question is how long is the required duration of anaesthesia for sheep in UK abattoirs. This will be equal to the sum of the time between stunning and sticking plus the time between sticking and permanent loss of brain function. In the UK the average time between electrical stunning and sticking is 23 seconds,

and at worst (ie in the slowest 1% of sheep) it is 70 seconds (Gregory & Wotton, 1984a). The time between sticking and loss of visual evoked cortical responses in the brain (which is taken as an index of a profound form of brain failure) is on average 14 seconds when sticking is performed correctly (Gregory and Wotton, 1984b). So, on average, the required duration of anaesthesia is 37 seconds. This estimate, however, applies to the average sheep in the average British abattoir, and we all know that in reality there is no such thing. Stunning methods should cater for every sheep in every abattoir, and in this respect it has been estimated that the anaesthesia should last for at least 96 seconds if it is going to satisfy 99% of the sheep population.

Clearly there are instances where the given duration of anaesthesia (62 seconds) falls short of the required duration (96 seconds). As this will occur in only a small proportion of sheep it is important to inspect a large number of animals when trying to establish whether a particular abattoir falls short of the requirement. The above estimates are based on the assumption that sticking is performed correctly. If in some sheep only one carotid artery is severed the time to loss of cortical responsiveness increases five fold to 70 seconds, and the proportion of sheep that could or do regain consciousness will increase.

All this begs the question how can we ensure in the future that no sheep regain consciousness following stunning. Firstly, limitations could be put on the period between stunning and sticking. In the abattoir survey in the UK this interval was as long as 84 seconds (on average) in one of the plants using the captive bolt. The proposed CEC regulations will limit this period to 20 seconds. Secondly, greater effort could be put into ensuring that both carotid arteries are severed at sticking. Using a double-edged knife helps in this respect. Where single-edged knives are used it is advisable to turn the knife when it has been inserted between the trachea and backbone and press the blade against the vertebral column as it is being withdrawn. It is important that supervisors check that both carotids are always cut. The third approach, which pre-empts all problems to do with recurrence of consciousness, is to use a stunning method which simultaneously induces a cardiac arrest. Although the time to loss of evoked responses with an electrically induced cardiac arrest is 14 seconds longer than for severing both carotid arteries, in the slaughterhouse situation the time to brain failure is on average 9 seconds quicker than the average conventional stunning and slaughtering procedure which does not induce a cardiac arrest (Gregory & Wotton 1984b). In the worst case it is 51 seconds quicker than the conventional method. Besides being quicker, it pre-empts any problem associated with poor sticking, as it is immaterial from the welfare point of view which blood vessels are severed. It is unlikely that future legislation will insist upon the cardiac arrest stunning method being used, but those abattoirs that have adopted it tend to prefer it largely because it guarantees a more humane slaughter and because it is associated with less convulsions

in the carcass. Hopefully we will see this method used a lot more in years to come.

The situation with pigs is similar except that they are more prone to carcass damage when cardiac arrest stunning methods such as the head to back system are used. It should be possible to inspect and monitor the current used when stunning pigs and have the profile of the current flow displayed on a desk top VDU, along with the number of interrupted applications of current and the average duration of current flow per pig.

In the case of poultry, things are more complex and deserve special comment. The problem here is that most poultry are bled by severing some of the smaller blood vessels in the neck instead of the main carotid arteries (Gregory & Wotton, (1986). There have been some pitiful instances where a sizeable proportion of birds have regained consciousness because of inadequate neck cutting, especially when the 'beak cut' was being used (the beak cut severs the anastomosis between the left and right jugular veins at the base of the cranium).

With automatic neck cutting the blade cuts into the back of the neck, whereas the carotids are situated at the front. If the spinal cord is severed death may occur from asphyxiation rather than exsanguination, and, as with punctilla it is difficult to tell whether consciousness is present or absent. The reason why poultry processing plants use this approach is because there is trepidation about severing the trachea and cutting too deeply into the neck. The former results in a stub of trachea being left attached to the neck flap which has to be removed manually further down the evisceration line, and the latter may result in the carcass losing its head in the pluckers which in turn causes complications in automated trachea and oesophagus removal. Hopefully, in the future, automated machinery will be developed (possibly along the lines of present crop cleaners) which will overcome these problems and allow a deep ventral neck cut which severs the main blood vessels in the neck. The alternative to this is to induce a cardiac arrest at stunning. This can be achieved quite simply by increasing the current applied in waterbath stunners. For instance, the values shown in Table 5 will ensure that 90% of the birds of the respective species will experience a ventricular fibrillation, and these have been included in the draft Code of Conduct on Stunning and Slaughter prepared by the Council of Europe.

Table 5
Currents required to ensure that 90% of the birds experience a ventricular fibrillation during electrical stunning

Species	Current mAmp/bird
Broilers	120
Layers	120
Turkeys	150
Ducks and geese	130

Source: Adapted from Schutt Abraham *et al.*

Another example of how animals can fail to be stunned in the first instance arises when geese are put through a waterbath stunner. The necks of these birds are very agile and they can hold the head out of the water and thus only the crop region makes contact with the water. Perhaps this is a case where only handheld electric stunners should be allowed. Gas stunning would be inappropriate for geese and ducks because they can withstand relatively long periods of hypoxia.

The captive bolt is one of the few stunning methods that can instantaneously induce a loss of evoked potentials in the cortex of the brain (Daly *et al* 1986). It causes a failure in neurotransmission in or near to the cortex rather than the optic chiasma and so it is associated with concussion of the brain rather than concussion of the optic nerve. The principle behind captive bolt shooting is to impart kinetic energy to the head of the animal, and this in turn depends on the velocity of the bolt when it strikes the head and the diameter of the bolt. In the future, gun designers should take note of the following research findings. The certainty of an effective stun in cattle is high if the peak bolt velocity is 55 metres/second or more. Before the gun is fired the tip of the bolt should be recessed within the muzzle of the gun to allow it a short distance in which to accelerate to its peak velocity before it strikes the animal's head. This contrasts with some guns where the tip of the bolt protrudes from the gun when it is set to fire. The diameter of the bolt in future guns could be larger than current models as this would encourage the transference of energy to the cranium.

It is possible that decapitation without prior stunning will not be allowed as a routine slaughtering method in the future. It has been found that evoked responses in the brain continue in a normal manner following decapitation or neck dislocation in chickens and in this respect neither system exerts a concussive effect (Gregory & Wotton, 1986; 1990). Because of this there are doubts about whether they induce an instantaneous stun. Nevertheless, in some situations manual neck dislocation is the only feasible euthanasia method for poultry, and I doubt whether it will be replaced by anything that is

as convenient. Punctilla (severence of the spinal cord without prior stunning) is one stage worse than either of these methods and unfortunately it is still used in some contries even though there were calls for its abolition over 180 years ago (Plymley, 1803). In this method the spinal cord is severed but the carotid arteries are left intact and so the animal collapses immediately and presumably loses consciousness and dies in response to respiratory arrest.

One of the likely consequences of the new stunning and slaughter regulations proposed by the CEC is that pig processors in the UK will become disenchanted with high voltage electrical stunning using a 50 Hz frequency. The UK pig market is more sensitive than the European market as a whole to broken bones and blood splash because a higher proportion of its meat is sold fresh. High voltage 50 Hz stunning has a reputation for inducing blood splash and broken bones in pigs and so processors will either turn to high frequency stunning or gas stunning. High voltage high frequency stunning employing novel waveforms could be an exciting development in the future, as it should allow the use of head to back stunning and the induction of a ventricular fibrillation without the carcass quality problems associated with high voltage 50 Hz stunning. The welfare aspects of the second alternative, gas stunning, are controversial. At high concentrations carbon dioxide is a pungent gas and it induces breathlessness before the loss of consciousness. If it is agreed that the inhalation of carbon dioxide is unacceptably distressing then the method will have to be abandoned. So far there is some evidence which supports this view (Cantieni, 1977; Gregory *et al*, 1990), but because it is so widely used it is unlikely that the method will be dropped altogether. Instead, we should be working towards alternative gas methods which are less stressful. In this regard Dr Mohan Raj at the University of Bristol is using relatively low concentrations of carbon dioxide (thus aiming at minimising the discomfort this gas causes) in combination with argon which is used to displace oxygen. The carbon dioxide is present to act as an anticonvulsant during the throes of death, and time will tell whether this will be a viable option for pigs. This approach has been tested in chickens and turkeys and it has been found to work (Mohan Raj & Gregory, 1991). Another system which has been developed is based on argon alone. Anoxia or hypoxia produced by this gas induces severe convulsions once the bird is unconscious but prior to this there are no or limited symptoms of breathlessness. Reports in man suggest that the inhalation of inert gases can be a stress-free even euphoric way of losing consciousness (Ernsting, 1965). The incidence of the main symptoms associated with hypoxia are given in Table 6, the degree of hypoxia determines the major sysmptoms that are perceived. For example the incidence of dyspnoea (breathlessness) is greater with mild hypoxia than with severe oxygen deprivation. This is because loss of consciousness is likely to occur before gross respiratory changes are produced when severe hypoxia is applied. In general, hypoxia is a much less potent stimulus of a sense of breathlessness than inhaling carbon dioxide or asphyxiation (obstruction to breathing).

Table 6
Incidence of symptoms associated with altitude-induced hypoxia

Symptom	Incidence %
Visual disturbance	64
Dizziness	57
Light headedness	49
Inability to think clearly	42
Tingling	37
Muscular inco-ordination	37
Numbness	21
Unsteadiness	20
Apprehension	19
Euphoria	19
Fatigue	15
Sweating	15
Dyspnoea	14
Sleepiness	13

Source: Adapted from Ensting (1965).

Cine camera recordings of subjects undergoing rapid hypoxia, induced by explosive decompression from 750 to 70 mm Hg, have shown that unconsciousness can be induced within 20 seconds of which 6 seconds was the time taken for the circulation to carry the effect from the lungs to the brain (Miles and Mackay, 1987). A freezing of expression and posture preceded the collapse which was either complete or coincided with a few quick convulsions. An important outcome of this study was that unconsciousness can be the first indication of hypoxia. At the other extreme, where oxygen tension was declining slowly, it was reported that there was 'an abnormal sense of well-being and over confidence. Even if a task is being done and increasing numbers of mistakes are made this is not recognised. In a recent series of experiments experienced divers breathed in and out of a large spirometer through a carbon dioxide absorbing canister so exhausting the oxygen supply. They were instructed to let go the mouth-piece and breathe the ambient air if they felt they were not getting enough oxygen. Not one in fact did so – they either quietly became unconscious or were told to let go by an observer. The percentage oxygen being breathed to produce unconsciousness was between 6% and 10%.'

Loss of consciousness induced with hypoxia is often associated with retrograde amnesia, and so it is difficult to place complete confidence in recollections after the event. This, however, would not necessarily apply when the exposure is gradual and fails to induce unconsciousness. In this respect, the sequence of sensations and behaviour that were experienced

during gradual hypoxaemia induced during a simulated dive were as follows (Miles and Mackay, 1976):–

(i) light headed, increasing self-confidence, loss of fine discrimination, some euphoria;
(ii) joviality, garrulousness, perhaps some dizziness;
(iii) laughter (sometimes uncontrolled and approaching hysteria), power of concentration lessened, mistakes made in simple practical and mental tasks, tingling sensations sometimes present, delayed response to signals and stimuli;
(iv) depression, loss of clear thinking, impaired co-ordination;
(v) unconsciousness.

The symptoms experienced during the inhalation of an inert gas are not reported in such detail but are probably similar to the above; the predominant feelings that have been described are ones of 'happiness' and 'activity' (Biersner *et al*, 1978).

A final oxygen concentration of approximately 2% is required in order to ensure that an inert gas (eg argon) will kill broilers within a 2 minute period (Mohan Raj *et al*, 1990). It is important to kill them with the gas, as distinct from stunning without killing, because they can regain consciousness very quickly when returned to air. A commercial advantage from using argon is that the convulsions have a similar effect as electrical stimulation on the carcass. When argon stunned carcasses are rapidly chilled they can be deboned shortly after slaughter without inducing toughness in the meat (Mohan Raj *et al*, 1991), and this raises the prospect of processing plants receiving chickens and despatching them as chilled portions within 5 hours without any chilled storage or toughening of the meat. Such an innovation would have a major impact on the poultry processing industry.

In the case of religious slaughter it is possible that Halal slaughter of cattle in the UK will follow the example set by New Zealand and start using electrical stunning. The system used at the moment in New Zealand is based on 2 amp applied between the nose and neck (through a yoke) followed by the Halal cut and then electroimmobilisation of the carcass to prevent convulsions. This method has been accepted by some religious authorities and hopefully it will be considered by the appropriate authorities in the UK.

FINAL THOUGHT

In line with most of the above comments I think that in the future there will be increases in the scale upon which animals are transported and slaughtered. This in itself will encourage increased automation, which in turn will call for a different type of person working in abattoirs. Where a greater sense of responsibility exists within abattoirs, greater care about animal welfare should also prevail. As a final comment it is worth pointing out that there is a danger of the UK becoming over occupied with its own welfare problems. Consider for a moment the journeys taken from the

ranches in Northern Territory Australia down to the abattoirs near Perth in daytime temperatures which often exceed 40°C and with cattle which are virtually wild. Consider also the transport of weaned calves from suckler herds in Canada to feedlots up to 2000 miles away, and the subsequent losses from shipping fever through stress-induced immunesuppression. Although the British public's concern over the welfare problems in its country is commendable it should keep them in perspective with those occurring in other parts of the world.

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