Introduction to the Agricultural Engineering and Precision Innovation Centre (Agri-EPI Centre)

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The Agri-EPI Centre is one of a new group of Innovation Centres, being established as part of the Agri-Tech strategy that was launched in 2013. It is a consortium of key organisations in the field of precision agriculture and engineering - bringing together expertise in research and industry, as well as data gathering capacity in all areas of farming, to increase the efficiency and sustainability of the land-based industries. The core partners in the Centre are Scotland's Rural College (SRUC), Harper Adams University, Cranfield University, Harbro Ltd, AgSpace Agriculture Ltd, Kingshay Farming and AGGO Ltd. A further 69 companies are supporting the Centre, including large supermarkets, food producers, farmers, processors and world leading engineering and technology businesses from the fields of Formula 1, aerospace, robotics and machine vision. In addition to the core research institutes, the Centre has links to leading institutes in the fields of sensor development and robotics, social science, agronomy and animal health. By joining organisations in all sections of the supply chain, Agri-EPI will become a world-leading centre for excellence in engineering and precision agriculture for the livestock, arable, aquaculture and horticulture sectors.

The Centre will operate a wide range of industry-led activities in applied research and development, demonstration, training and education. It will explore how to optimise the performance of agricultural production and processing systems. This will include livestock and plant growth rates, nutrient efficiency, product quality, and health. Initial areas of interest will include cutting edge technologies such as automated vehicles, unmanned aerial vehicles (UAVs or "drones"), new instrumentation to monitor both operations and in-field performance of cropping systems, as well as sensing and imaging technologies to monitor livestock production in areas such as product quality and health and welfare.

A central feature of the Agri-EPI Centre will be a series of farms and processing facilities equipped with the latest sensing and imaging equipment. These sites, and associated large-scale production data, will enable the Centre to use detailed analysis of the embedded variance to identify key issues for research and the potential to improve UK production and processing efficiency. The sites will also create a unique resource of locations to develop and demonstrate technologies to UK producers, thereby supporting the rapidly expanding global market for these technologies. Industry-led 'Think Tanks' will use industry data to identify issues and develop projects to address the most important ones. We anticipate a wider role for this process feeding into development of national priorities for basic and strategic research, such as that funded by RCUK. Knowledge exchange will be a significant output of the Centre's work ensuring that the knowledge generated is translated and transferred to relevant audiences.

There is a growing realisation that the industry is at the cusp of an exciting phase of development and the new, disruptive technologies offered from other sectors of science could drive a step-change in our understanding of production, our efficiency of nutrient use, and our control of quality. By optimising the performance of the highly complex production and processing systems in agriculture it will be possible to reduce losses associated with such things as low feed conversion efficiency, production of out-of-specification carcasses, as well as high levels of morbidity and mortality. The UK has globally recognised expertise and facilities, as well as a hugely efficient and powerful supply chain. The agri-food industry is worth £96 billion to the UK economy, with 3.8 million jobs and £18 billion of exports associated but it is clear that the industry operates well below peak efficiency, with huge variation throughout the production and processing chains. Understanding variance is the key to understanding waste, efficiency and opportunity – and the recording systems offered by precision engineering are the key to understanding variance

The Agri-EPI Centre has a truly global reach through the extensive profile of its members and will have technical resource in over 180 countries and the potential to reach a vast network of consumers. Through this network the Centre will offer the opportunity for global collaborative research and put UK science and industry at the forefront of the next agri-food revolution.

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Imaging as a tool to implement precision engineering on-farm

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The pig industry of today faces a challenge: to obtain pork which is satisfactory to consumers in terms of size and fat content. To do this, supermarkets set parameters to abattoirs who in turn produce carcass specifications based on these. Producers must then raise pigs fitting these specifications to maximise returns on carcasses while limiting any penalties arising from condemnations. It is here that the issue manifests. There are many different pig farming systems and contract goals which result in a high variation of carcasses delivered to abattoirs. Any carcass outside of abattoir specifications represents an economic loss to several sectors of the production line: to producers, in the form of penalties/ lower returns and decreased feed efficiency; to abattoirs, by the way of added processing costs; and to consumers, who will pay more at the tills. The solution to this problem lies in more precision measurement of weight on-farm, to adjust feeding to obtain optimum weights and to recognise when pigs are at their ideal slaughter weights to avoid over-feeding. This solution must not be labour intensive, it must be accurate and easy to use, and above all must be above all affordable to the farmer in terms of time and money.

Precision Livestock Farming (PLF) in the form of automated monitoring systems is the way forward. The requirements for PLF are 1) continuous measurements; 2) reliable predictions of changes; 3) target values to aim for; and 4) controllers able to change inputs based on feedback from the integrated system. Conventional weighing falls short on accuracy and frequency requirements, whereas a continuous, non-intrusive weighing system with the ability to detect small but significant changes based on objective rather than subjective observations will revolutionise both industries. Systems do currently exist which address this issue. There are pig finishing set-ups where pigs are run through an automatic weigh scale and sorted into different weight groups, which are then fed according to their needs, however this is not done on a daily basis, and the bulky infrastructure may interfere with normal animal behaviour.

Our solution to this problem is appropriate for the modern pig industry. We use animal handling equipment and auto weighing equipment coupled with 3-D imagery and algorithms to analyse data to provide real time objective feedback on animal condition and market value to the farmer. Our goal is to eliminate the need for this auto weighing equipment and simply be able to install cameras on-farm to provide continuous and accurate growth monitoring. This would remove any interference in normal animal behaviour resulting from incorporation of auto weighing systems, and provide constant, accurate, real-time recording of weights. We have already developed a weighing system based on 2-D images which has been marketed to countries such as China and Denmark. The system successfully highlights this variation in pigs sent to slaughter, and identifies where each individual lies in relation to other animals and the target specifications. The system also accurately predicts the weights of growing animals. In combination with Visual Image Analysis data collected at abattoirs, farmers are already able to receive feedback on their animals' performance as compared with the national herd, and adjust their management practises to improve the health and welfare of their animals while maximising returns.

However, issues have arisen with using 2-D images in terms of difficulties differentiating between animals when close together and issues correctly determining the outline of an animal in poor light. As such, we are working to integrate 3-D capable cameras in the same system, which give a superior result to the 2-D images. Furthermore, these 3-D cameras are able to monitor health and welfare more accurately. Feedback to farmers will be provided via a web based system, using data and charts to present growth patterns and monitor variance in the herd.

The use of such technology will modernise current pig production systems, allowing large-scale farms much more detailed monitoring and control of their animals, improving health and welfare and reducing the variation within animals sent to slaughter. This will in turn have downstream benefits to abattoirs and customers. Imaging animals for weight and health monitoring is a useful and apposite tool for implementing precision engineering on-farm.

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Control of puberty and breeding management of beef heifers for pregnancy success

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Application Heifer conception rates and percentage bred during their first breeding season has been associated with pubertal status before the breeding season. Thus puberty has a critical role in breeding success and longevity.

Background It takes the net revenue from approximately six calves to cover the development and production costs of each replacement heifer, and any cow that misses a single calving is not likely to recover the lost revenue of that missed calf (Mathews and Short, 2001). Therefore, longevity of a beef female is important to the sustainability and profitability of any beef operation. Heifers that calved for the first time during the first 21 days of the calving season had increased longevity compared to heifers that calved during the second 21 day period, or later. In addition, calving period also influenced weaning weight of the first through to the sixth calf born, and consequently overall total lifetime weight of weaned calves produced (Cushman *et al*., 2013). Pregnancy success during the breeding season has been correlated with the percentage of heifers that reached puberty before or early in the breeding season (Short and Bellows, 1971).

It has been reported that pubertal status is one of the main factors impacting on heifer conception rate (Bridges *et al*., 2014). Puberty is a complex series of events that requires maturation of the hypothalamic-pituitary-ovarian axis. The negative feedback of oestradiol on LH release has to be reversed to a stimulatory feedback to induce a LH surge and ovulation. Although ovulation can occur by inducing a surge of LH during the prepubertal stage, animals return to anestrous and normal ovarian cyclicity is not sustained (McLeod *et al*., 1985). While nutrition, age, and genetics are well known regulators of age at puberty, their role in advancement in the age at puberty of heifers is mainly as regulators of the endocrine maturation that must occur for sustained cyclic activity to be initiated. For complete breeding success to occur, several breeding management events need to be considered. These events can be grouped into those that must occur prior to breeding (appropriate age and weight for puberty to occur and health management), at time of breeding (expression and detection of oestrus, timing of insemination, and inseminator efficiency), and following insemination (avoidance of physical and nutritional stress).

Conclusion Proper development of replacement heifers facilitates early onset of puberty, prior to the initiation of their first breeding season, with heifers that reach puberty before their first breeding season more likely to conceive early in the breeding season. This also increases their likelihood of remaining in the herd long enough to recover their development costs. However, successful breeding management also includes other management events including: vaccination, expression and detection of oestrus, timing of insemination, inseminator efficiency, and avoidance of physical and nutritional stress.

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Improving the reproductive efficiency of beef cow herds

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Introduction Globally, beef cows are an important source of cattle for the beef industry and frequently serve a unique role in converting low quality forage to high quality protein for human consumption. Beef cow systems vary enormously across countries in terms of herd size, stocking density and level of output. However, irrespective of the system of production, herd reproductive performance is a key driver of efficiency and profitability. Unlike dairy production systems, where cows frequently have less well-defined calving patterns, the vast majority of beef cowherds tend to be based on seasonal calving with calving occurring at, or around, the time of onset of pasture growth. As the calf is largely the sole output in beef cow enterprises, reproductive efficiency underpins profitability, irrespective of the system of production employed. However, attaining a high level of reproductive efficiency is underpinned by producers being cognisant of and achieving, many key targets throughout the production cycle and requires significant technical competency.

Diskin and Kenny (2014) outlined the following reproductive targets for a beef cow herd: 1) 365 d -calving to calving interval, 2) <5 % cows culled annually as barren, 3) >95% of cows calving to wean a calf, 4) Heifers calving at 24 months of age, 5) Compact calving with 80% of cows calved in 42 days, 6) Replacement rate 16-18%, 7) Sustained genetic improved of the cow herd for economically important traits relating to reproduction, calving ability and calf weaning weight, 8) Close alignment of calving date with onset of pasture availability in the spring.

The lifetime productivity of the beef bred female commences from the onset of puberty and will be dictated by subsequent critical events including age at first calving, duration of the *post partum* interval for each successive calving, conception and pregnancy rate and ultimately manifested as length of inter-calving intervals and number of calves weaned over her lifetime (Diskin and Kenny, 2014). In calved heifers and mature cows, the onset of ovarian activity, *post partum* is a fundamental event dictating the calving interval. Compared with dairy cows, there is typically considerable variability in the duration of the post anoestrous period in suckled beef cows with mean duration often extending to beyond 80 days, particular in cows in poor BCS. Specifically, normal ovarian cycles and oestrus is dependent on the recovery of the hypothalamic-anterior pituitary–ovarian axis, and in particular, attainment of a GnRH/LH pulse frequency of 4-5 pulses per 10 hour period (Crowe *et al*., 2014). Although principally controlled by the strength of the maternal bond between cow and calf, *pre partum* nutrition, manifested through body condition at calving has a major role to play in advancing the resumption of *post partum* ovarian cyclicity. Additionally, there is some evidence of a modest genetic influence on the timing of resumption of *post partum* ovarian cyclicity in beef cows as well as a positive association with age at puberty.

Following the initiation of *post partum* ovarian cyclicity, conception and subsequent pregnancy rate is generally a function of bull fertility in natural service herds and heat detection and timing of insemination in herds bred through AI. Beef cows should be maintained on a steady plane of nutrition during the breeding season, but the contribution of significant excesses or deficiencies of nutrients including protein and trace elements is likely to be minor, where adequate pasture is available. When compared to their dairy contemporaries, genetic improvement of beef cattle has been hampered by lack of use of AI within beef cow herds. The advent of improved oestrous synchronisation programmes to facilitate the use of fixed time AI in beef cows and heifers, provides an effective strategy to increase genetic gain as well as shorten the calving interval and may be best targeted at the breeding of replacement heifers with superior genetic merit for maternal traits. While, increased efforts are being made internationally to genetically identify and select for more reproductively efficient beef cows, this is a long-term strategy and will not obviate the necessity for on-going excellent technical efficiency and management practice at farm level.

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A review of genetic improvement programmes for sheep in the UK and a view of the next 10 years

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Introduction MLC established individual ewe recording services in 1974. Services to measure muscle and fat depth across the loin using ultrasound scanning were launched in 1987 and across flock analyses for Sire Reference Schemes in 1990. Increases in computing power over the last 25 years have led to major advances in the size and speed of genetic evaluations.

Material and methods Data showing **c**hanges arising over the last 25 years were supplied by Signet Breeding Services.

Results AHDB/Signet Breeding Services has recorded 67 different pure breeds since 1990, with 35 actively recorded in 2015. The size of the weight-recorded population and genetic gain achieved in the six largest breeds is shown in Table 1.

Table 1 Genetic gain in the six numerically largest Signet recorded breeds

	Average number of weight records per annum				Average rate of gain (index points)			
Breed	1980-89	1990-99	2000-09	2010-15	1980-90	1990-00	2000-10	2010-15
Charollais	1053	5977	4709	4821	N/A	7.66	6.08	8.82
Dorset	7195	4732	3956	3643	-0.01	4.90	9.68	11.18
Lleyn	5041	6501	8553	16139	1.30	2.06	0.52	8.68
Scottish Blackface	2910	4395	8113	3635	0.64	0.30	8.41	10.27
Suffolk	12867	16880	9704	5509	3.47	7.06	7.76	7.76
Texel	4410	12970	11185	11919	1.36	5.55	4.85	9.69

Discussion Genetic improvement programmes in the UK are challenged by the large number of breeds kept, the small average pedigree flock size and the diverse breeding objectives associated with the stratified UK sheep industry. In 2014 only 10% and 15% of Suffolk and Texel flocks were performance recorded; these flocks contain 25% of the registered sheep.

Emphasis is still placed on appearance and performance at shows. Showing doesn't provide an objective means of comparing genetic merit and group breeding schemes and sire reference schemes have been established in the past to provide this comparison. In the last 25 years there have been up to 14 group breeding schemes and 10 active Sire Reference Schemes (SRS) operating in the UK. None of these schemes are active in 2015, although informal breeding groups still exist. The fall in popularity of co-operative breeding programmes was hastened by the availability of more inclusive across-flock analyses, although high running costs and a lack of group co-ordination have also limited uptake. Genetic linkage also referred to as "flock to flock connectedness" between recording flocks is measured annually. Concerns remain about the strength of this linkage due to the limited use of AI.

High rates of genetic gain have been achieved in terminal sire breeds where traits of interest are easily measured, have a high heritability and genetic change is seen by the user. Performance recording in hill breeds is limited by a lack of commercial demand for recorded rams. Traits routinely evaluated include litter size born, litter size reared, birth weight, lambing ease, 8 week weight, the maternal component of 8 week weight (maternal ability), weight at ultrasound scanning (21 weeks of age), muscle depth, fat depth, faecal egg count (FEC) and traits derived from computed tomography (CT) – lean weight, fat weight, gigot width. Future work will focus on traits derived from existing data (lamb survival, ewe survival), new CT traits – such as spine length and muscle density and new health traits where phenotypes can be derived. Studies in Suffolk and Texel sheep indicate rates of inbreeding over the last 5 years have increased by 0.12% per annum. Increases in inbreeding will have to be addressed within future breeding programmes.

Conclusion Terminal sire recording services will change in 2017, as Signet produces the first combined breed analysis for sheep in the UK. This will provide a more regular service, enable a degree of breed comparison in the future and generate EBVs for crossbred rams. Data from the national progeny test, RamCompare, launched in 2015 will enable commercially-derived phenotypes to be included in analyses, driving commercial and pedigree interest in performance recording.

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Should we feed more metabolisable protein to pregnant and lactating ewes?

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Application Ewes in low BCS or presented with a higher nutritional challenge may respond to additional MP supply.

Introduction Over the last few years terminal sire schemes and genetic selection for higher productivity has increased lamb birth weights and ewe milk production. In addition, there is growing evidence that ewes may require additional metabolisable protein (MP) to maintain immunity to parasitic infection. These issues are compounded by the fact that AFRC (1993) estimates of the net protein requirement for maintenance are lower than those predicted by other nutritional standards, because they do not include an allowance for metabolic faecal protein, which varies directly with level of feeding. As a consequence, there is growing concern that AFRC (1993) may underestimate MP requirements, and that ewes may respond to additional MP supply above recommended requirements.

Review of previous work Experiments where ewes have been fed additional MP above recommended requirements have produced conflicting results. In two dose response experiments Houdijk *et al.* (2003 & 2009) fed five levels of MP ranging from 0.65 to 1.25 x calculated requirements to lactating ewes artificially infected with nematodes. Higher levels of MP increased ewe milk production, and reduced worm burdens. However, in most experiments, no effects of additional MP supply on lamb birth weight and subsequence lamb performance, but variable effects on ewe performance, have been reported (O'Doherty and Crosby 1996; Dawson *et al.*, 1999; Annett. *et al.*, 2008; Amanlou, *et al.*, 2011; Van Emon *et al.*, 2014). For example, during late pregnancy, additional MP was shown by Van Emon *et al*. (2014) to increase ewe LW gain and reduce body condition score (BCS) loss. Similarly, increases in colostrum component yield were reported by O'Doherty and Crosby (1996) and Amanlou *et al.* (2011). Over the last three years a series of experiments have been conducted at Harper Adams University (HAU) and Scotland's Rural College (SRUC) to investigate the effects of additional MP above accepted requirements on ewe and lamb performance (Wilkinson *et al.*, 2015; Houdijk *et al.*, 2015) using different basal forages and different protein sources. In three of these studies ewes were housed throughout pregnancy and lactation, whilst in the fourth they were housed during pregnancy, but grazed during lactation. None of these studies have been able to convincingly demonstrate any effects of additional MP supply on lamb birth weight, lamb performance or subsequent weaning weight. However, additional MP supply increased ewe LW gain, reduced BCS loss and enhanced colostrum component yields. In all of the published studies, and those carried out by ourselves, ewes were in good BCS when the study commenced. In addition, ewes lost LW and BCS even though diets were formulated for no LW change.

Conclusions The results suggest that MP requirements may be higher than predicted. MP is supplied from both the diet, and body reserves. Observed responses to additional MP supply may depend on the balance between nutrient requirements and the capacity of the animal to mobilise nutrients from body tissue. During both pregnancy and lactation, ewes in good BCS may mobilise nutrients from body tissue to ensure that foetal growth and milk component synthesis are not compromised. Consequently, they may only show a marginal response to additional MP supply (Oldham, 1994; Wilkinson *et al.*, 2000). However, energy and protein supply from tissue loss may vary depending on ewe condition, and may only be exploited if tissue loss is not physiologically damaging to the animal. A greater response to additional MP supply may be expected if ewes are in poorer BCS (Dawson *et al.*, 1999), or presented with a greater nutritional challenge. Further work is required to test this hypothesis and to better understand the relationship between BCS loss and nutrient supply.

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The big five iceberg sheep diseases and the actions that are needed

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Application The UK sheep industry is based on a stratified breeding system with most commercial farmers buying cross bred hill ewes to breed with terminal sires. Considerable numbers of sheep move flocks within their lifetime and such sheep movements facilitate the rapid spread of undetected disease through the national flock.

Introduction An 'iceberg disease' is a term used to describe a disease which has a large number of undiagnosed cases so that what is seen clinically is a small representation of the total. In the sheep industry it is a phrase that is generally used to describe diseases that are insidious, production limiting, slow in onset and diagnostically challenging. The following have all been described as 'iceberg diseases' of sheep in UK: Maedi Visna (MV), Ovine Johnes Disease (OJD), Jaagsiekte (OPA), caseous lymphadenitis (CLA), Border Disease (BD), tuberculosis (TB) and scrapie. In a *post mortem* study of ewes at a fallen stock centre in the north of England, 6% were found to have OPA and a further 6% OJD (Lovatt & Strugnell 2013). A sero-prevalence study of 700 GB flocks in 2010 indicated that the average flock level prevalence of MV was 2.8%, though it was as high as 15% in some counties of England (Ritchie 2012). A study undertaken in 2000 indicated that as many as 18% of terminal sire flocks were infected with CLA (Baird *et al* 2004).
This review summarises the situation for MV, OJD, OPA, CLA and BD and suggests possible control measures:

- Healthy stock should be protected from contact with infected stock. This means the flock status must be established. There is a well-established accreditation scheme for MV but no formal schemes for the other diseases.
- Serology is possible for OJD, CLA and BD but the tests are limited, particularly in terms of poor sensitivities for OJD and CLA. *Post mortem* examination of fallen stock and cull ewes is helpful, particularly for OPA and OJD diagnosis though not widely undertaken.
- Removal of infected stock requires rapid accurate identification and depends on an effective test in the live animal.
- Transmission within a flock occurs rapidly and insidiously. It is technically feasible to reduce vertical spread of MV, OPA and OJD by snatching and rearing lambs artificially, though this is not practical commercially. Horizontal spread may be reduced, though not eliminated, by extensive management, low stocking densities and maintaining an age-stratified flock.
- Restocking with clean sheep is difficult to ensure due to poor test sensitivities, low numbers of MV-accredited flocks (except in the terminal sire breeds), low numbers of monitored flocks and low industry awareness and engagement.

Material and methods Within a Sainsbury's Lamb Development Group program aimed at improving sheep flock health, welfare and performance, a sample of 813 commercial sheep farmers were interviewed in 2015. The farms, from all areas of the UK, sell lamb on a deadweight basis and represent lowland, upland and hill flocks with an average flock size of 670 ewes. They were asked if they had experienced MV, OJD, OPA, CLA or BD within their own flock. They were given the option to answer 'no', 'yes and I am concerned', 'yes but I am not concerned' or 'I don't want to answer the question'.

Results Of the interviewed sheep farmers, 99% answered that they had not experienced MV, 97% answered that they had not experienced OJD, OPA or BD and 94% answered that they had not experienced CLA within their own flock.

Conclusion These diseases are difficult to diagnose and difficult to control on a farm level as well as nationally. There is a lack of farmer awareness of the presence and extent of these diseases and hence a high risk of their insidious spread throughout the UK sheep industry. This situation highlights the industry importance of active veterinary engagement with sheep farmers through flock health programs.

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Furry friends and foes: human-animal relationships in the zoo

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People are a significant part of the lives of many animals. In the home, in farms, in laboratories and even in the wild, animals' lives are affected by, and sometimes controlled by people. Inevitably the interactions that take place between animals and people in all of these different contexts lead to the formation of some kind of relationship between them. This relationship will be located somewhere along a continuum from positive (a good relationship) to negative (a poor relationship), depending on the quality of the interactions which have contributed to it. The quality of this relationship affects the animal's welfare, and can have significant effects on other aspects of its life as well. Much of what we know about the Human-Animal Relationship (HAR) comes from research on agricultural animals, but it's important that we apply these concepts and procedures in other human-animal contexts as well, and in this talk I will consider how they have been applied in the context of zoo animals.

Contact between animals and people in the zoo is probably qualitatively different from that in other contexts where the two interact. Animals in zoos are often cared for by the same keeper(s) for extended periods of time, and this offers the possibility of establishing positive long-term HARs between keepers and their animals, hopefully with beneficial consequences for the welfare of the animals. In this respect the zoo context is similar to that for agricultural and companion animals, except that the animals in the zoo have not been domesticated; indeed most zoos go to great lengths to avoid any possibility of their animals becoming domesticated. Very little research has been undertaken on zoo HARs, but now an increasing number of studies are starting to show how important a good animal-keeper relationship can be to the management and welfare of the animals.

But zoos also differ from these other contexts in that the animals are confronted daily with large numbers of visitors. These are people who are individually unfamiliar to the animals, and there is no possibility of establishing individual HARs with them. Interactions between zoo animals and visitors certainly occur, and it is likely that the animals generalise their perceptions of these people into a category of 'visitors'. In this case we can consider that a generalised HAR can also occur between zoo animals and visitors, and this creates a situation which is less likely to occur in agricultural and companion animals. We can also envisage that these generalised HARs with visitors are unlikely to be positive, as there is little scope for positive interactions between zoo animals and visitors.
All of this raises questions of theoretical interest about the way animals perceive us; but also of applied interest in terms of how these relationships affect the lives, and particularly the welfare, of the animals. Research is starting to show how some of these questions may be answered, and this will be reviewed in this talk.

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Human-animal interaction: The benefits of pet ownership

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People have lived closely with animals for thousands of years, but the societal pet keeping as we know it today has arisen mainly over the last century. In the UK over 50% of household own pets and 1 in 4 own dogs. Therefore, surprisingly, it is only in the last few decades that the animals that we share our lives with have received any scientific attention concerning the impact that their presence has on us. It arguably began with the publication of a study by Friedmann *et al* (1980) (Friedmann *et al*., 1980) that claimed that people who owned pets were statistically more likely to survive to one year after discharge from a coronary care unit. Even more interestingly, the findings held even when dog owners were accounted for, so it could not simply be explained through potential increased physical activity. This study received some criticism due to its small sample size and inexplicable findings, however, in 1995 a larger study of specifically acute heart attack patients again found strong evidence for the effect of dog ownership in particular on one year survival, and that any pet effect was independent from reports of having other strong social support (Friedmann and Thomas, 1995). Over the last 30 years the research field of 'anthrozoology' has thus developed, in particular concerning the health benefits of owning pets. However, due to few dedicated resources and many researchers doing the work quite literally as 'pet' projects, the quality of the study designs and analyses presented as evidence has been critically questioned (Herzog, 2011). The literature is predominated by poorly powered cross-sectional studies that cannot distinguish cause and effect, and often do not adjust sufficiently for potential confounding variables.

The area of prime investment and thus greatest quality research is arguably concerning the quite plausible suggestion that dog ownership can impact physical activity levels. Numerous studies have now confirmed that dog owners are approximately 50% more likely to achieve minimum recommended activity levels of 150mins per week. However, 50% is not actually that much when you think about it, and a recent review suggests that 40% of dog owners are not walking with their dogs (Christian *et al*., 2013). Studies trying to elucidate why some owners walk their dogs and others not have discovered that the strength of the owner-dog relationship, and how much owners feel their dogs support and motivate them to walk, are key. My further analyses of this topic suggest that underlying this is a drive to experience feelings of happiness together; the joy of seeing your loved pet running around having fun (Westgarth, unpublished). Considering that there is strong evidence that dog owners are more physically active, it has been hypothesised that dog ownership may also protect against the epidemic of obesity. Unfortunately most studies have found no link with weight status (Westgarth *et al*., 2012), likely because obesity is a complex condition influenced by energy intake as well as expenditure.

Fortunately walking with a dog has been shown to have another health benefit – that of increasing our social connections with people (Wood *et al*., 2005). Pets arguably provide social support to us themselves, but they also increase our interaction with others; many people will have experienced that a stranger is more likely to stop and talk to you if you are walking with a dog (McNicholas and Collis, 2000). There are many anecdotal reports along the lines of 'pets make us feel better, however the evidence for clear psychological benefits such as reduction in anxiety, stress and depression, is in general weaker and less consistent than for the physical health effects. However, in one fascinating experimental study, dog owners showed high blood pressure and heart rates in the presence of a spouse or partner whilst undertaking mental tasks, but if their dog was present they experienced even less stress than if on their own (Allen *et al*., 2002).

The combination of physical and mental health benefits of pet ownership has led to economic analysis suggesting that there would be significant increased costs to healthcare budgets if we did not own pets (Headey *et al*., 2002). However such analyses fail to consider the negative wider repercussions for society that pet ownership also brings, including grief when they die, noise pollution, soiled streets and parks, zoonotic disease [e.g. a quarter of healthy pet dogs carry *Campylobacter* sp. (Westgarth *et al*., 2009)], asthma and allergies, the stress of living with a dog with behavioural problems, and most prominently, the treatment of dog bites. Despite numerous epidemiological studies of risk factors for dog bites, there is little robust evidence of risk factors other than inheritance (Westgarth, unpublished). Despite lots of expert opinion as to how bites are best prevented, the complexity of contexts in which dog bites can occur and perceptions of victims about their ability to prevent bites, ensures that it will remain a significant risk of dog ownership (Westgarth and Watkins, 2015).

You would struggle to find a single pet owner who does not describe their pet as a family member; 1 in 7 dogs even sleeps with us in our beds (Westgarth *et al*., 2008). The health benefits and risks from these close interactions are genuine and here to stay, yet this 'closeness' to our everyday lives means that science struggles to objectively study them. We require much more high quality research in order to understand how to maximise the wellbeing of both people and their animals.

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Livestock associated MRSA in the UK

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Introduction *Staphylococcus aureus* causes a wide range of diseases in human beings, from minor skin infections to severe illnesses such as septicaemia, toxic shock, endocarditis, and pneumonia. First described in 1961, the increasing incidence of meticillin-resistant *S aureus* (MRSA), and its spread in hospitals and the community, has posed a major challenge for infectious disease medicine. The evolution of meticillin resistance in *S aureus* is, in part, conferred by the acquisition of one of several staphylococcal cassette chromosome *mec* elements (SCC*mec*), which carry a gene (*mecA*) that encodes a penicillin binding protein (PBP2a) with low affinity for à-lactam antibiotics.

Before 2003, most MRSA identified belonged to multilocus sequence type clonal complexes (CC) associated with human carriage and infection. The emergence of MRSA CC398 (known as livestock- associated MRSA or LA-MRSA) in farm animals and human beings has shown that some *S aureus* lineages might not be strongly host-species restricted. A survey of slaughter pigs in the Netherlands (de Neeling *et al*., 2007) showed that 39% harboured MRSA sequence type (ST)398. MRSA ST398 can cause infection in people, with close animal contact being the main risk factor, (van Cleef *et al*., 2010) suggesting that farm animals could provide a reservoir of MRSA.

Results Work from our group has revealed a divergent *mecA* homologue (*mecC*) located in a novel mobile genetic element (staphylococcal cassette chromosome *mec*), designated type-XI SCC*mec*. The *mecC* was 70% identical to *S aureus mecA* homologues and was initially detected in 15 *S aureus* isolates from dairy cattle in England (García-Álvarez *et al*., 2011). These isolates were from two main lineages (CC130 and ST425). The *mecC* gene was originally identified in 12 human isolates from Scotland, 15 from England, and 24 from Denmark. Subsequent prevalence studies have shown that the new LA-MRSA to be found in approximately 2.5% of dairy farms (Paterson *et al*., Mar 2014) and to be responsible for 0.5% of human MRSA isolations (Paterson *et al*., Apr 2014). Although the UK was believed to be free from ST398 LA-MRSA it is now apparent that this lineage is also present in the UK. Two studies from our group have shown that this lineage is present in the dairy herd (Paterson *et al*., 2012). and can be found in pork retail products of UK origin (Hardjirin *et al*., 2015)

Conclusion There is increasing concern about antimicrobial resistance in the UK. Quite apart from the potential impact on the treatment of animal disease, antimicrobial resistance in farm animals represents a reservoir of resistance genes that has the potential to affect human healthcare. Better surveillance and further research are clearly needed to generate evidence to inform improved antimicrobial stewardship programs and reduce the overall threat of antimicrobial resistance.

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Antimicrobial resistance in companion animals

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Introduction People have frequent and close contact with companion animals; therefore they may be an important link in the development of zoonotic disease, including the transfer of antibacterial resistance. Extended-spectrum β-lactamase (ESBL) producing *E. coli* have emerged in companion animals associated with clinical disease, as well as being commensal.

Results From our studies, a low prevalence of resistance were observed to potentiated amoxicillin, the fluoroquinolones and 3rd and 4th generation cephalosporins in faecal *E. coli* from dogs in the vet visiting population. A much higher prevalence was observed for such multi-drug resistant (MDR) *E. coli* in the faeces of dogs fed raw meat diets and hospitalised dogs, and their environment. However, ESBL genotypes do not always reflect those associated with clinical disease in people, but $bla_{\text{CTX-M-15}}$ and the pandemic *E. coli* clone ST-131 is being increasingly reported in small companion animals. Our work has also examined carriage in in-contact people (dog kennel and veterinary workers) and those working in animal hospitals, finding a relatively high prevalence of antibacterial resistance, but low prevalence of ESBL-producing *E. coli* faecal carriage.

Conclusion Our data highlights the potential for companion animals to act as a reservoir of AMR which could be acquired by pathogenic bacteria. However, the public health risk posed by pets is likely to vary depending upon the levels of contact with different populations of companion animals, such as those which have been hospitalised and with other exposure factors such as being fed a raw meat diet and antibacterial treatment may increase the risk in dogs.

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Steps to Sustainable Livestock – The Global Farm Platform

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Application A global academic network to promote farm research for optimisation of ruminant livestock production and hence contribute to food security, sustainability and poverty alleviation.

Introduction We are at a critical juncture for global livestock production, when competing requirements for maximal production and minimal pollution have led to the concept of *sustainable intensification*. Ruminants make an important contribution to global food security by converting feed that is unsuitable for human consumption to high value protein, demand for which is currently increasing at an unprecedented rate. Sustainable intensification of ruminant livestock may be applied to pastoral grazing, mixed-cropping, feedlot and housed production systems. All these systems have associated environmental risks such as water and air pollution, carbon emissions, soil degradation and erosion, as well as issues affecting production efficiency, product quality and consumer acceptability, such as reduced animal fertility, health and welfare. These contrasting views are the focus of a very lively current debate, reflected in rapid recent development of sustainability policies. Further in many societies livestock represent a resource far greater than just food e.g. fibre, draught, fertiliser, fuel, bank and social.

Material and methods These challenges necessitate multidisciplinary solutions that can only be properly researched, implemented and tested in real-world production systems (Eisler *et al.*, 2014). Moreover, Dumont *et al.* (2014) recently highlighted a major need to 'redesign' livestock systems including integration of crops and livestock. To this end, we have developed a network of 'farm platforms' across different climatic and eco-regions as a global resource for optimising and exemplifying research on the contribution of sustainable ruminant livestock production to global food security (www.globalfarmplatform.org). The farm platforms focus on: optimising production systems, animal genetics and nutrition; improving soil, plant, animal and human health; and minimising impacts of livestock production on welfare, ecosystem services or biodiversity. Some examples of farm platforms in the network are given below but the full list is available on the website.

Example Farms

Palo a Pique, Uruguay - Four different no-till soil use intensities: long rotation (4 years of cultivated pasture; 2 years of annual forage crop); short rotation (2 years cultivated pasture and 2 years annual forage crop); permanent over sown sward; continuous annual forage crop. The winter annual crop is a mixed pasture of oats and ryegrass, the summer annual crop is grain sorghum.

UWA Future Farm 2050, Australia - The foundation is agriculture for food production based on a profitable mixed-enterprise farm, at the cutting edge of practical technology. There are four major activities: Livestock, Conservation cropping, Management of ecosystem and biodiversity, People: happy farmers and vibrant rural communities.

Wisconsin Integrated Cropping Systems Trial (WICST), USA - Established in 1989 to compare six alternative farming systems with respect to productivity, profitability, and environmental impact.

Thiruvazhamkunnu, India - The research farm includes a dairy, fodder and agroforestry plots, cashew, coconut and other agricultural crops. This model integrated farm grants utmost importance to sustainability, ecosystem services and biodiversity in the face of climatic change.

North Wyke Farm Platform, UK – Temperate grassland research facility which allow whole scale system research of grazing practices. Current comparisons include the use of novel grasses, mixed clover systems and permanent pasture. These systems are used to develop a comprehensive set of sustainability metrics based on trade-offs between social, environmental and economic needs.

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Sustainable animal protein (non-ruminant): a commercial perspective

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Commercial companies must satisfy customer needs whilst returning value to their shareholders and meeting all legislative requirements. There is also growing demand for businesses to demonstrate publicly that their activities are not damaging the environment or destroying livelihoods, and to manage a much greater range of risks than ever before. This is shown by the pull from investors and push from governments for more disclosure and visibility of large company performance across a range of indicators not just profitability. Today, meeting customer expectations requires businesses to be involved in issues across the whole food supply chain to ensure the production of affordable, safe and responsibly produced food of good quality. Whilst price will always remain a dominating factor the subject of, "what does sustainably produced animal protein for humans look like", is gaining increasing importance with consumers who are being provided with differing viewpoints from a range of interested parties. This brings real challenges but also major opportunities for the science community to make a real difference to how our food will be produced in the future by supplying knowledge, informing the consumer and providing metrics to monitor progress.

The production of affordable products requires increased attention to be paid to the efficiency of conversion of feed stuffs to protein. To do this requires a complete understanding of the response of the animal to nutrients, how the efficiency of metabolism can be improved, including the effect of nutrients on the expression of genes which may control the metabolic process, and the move to a system where the variation in response of the individual animal can be accounted for. This approach should go hand in hand with genetic improvement and changes to production systems to enable effective decision making that improves the efficiency of use of valuable feedstuffs, reduces impact on the environmental and optimises animal performance.

The safety of food from a human health point of view is of paramount importance in maintaining consumer confidence and demand for animal protein. The main risks are associated with contaminants, for example dioxins, or infectious agents such as bacteria. Contamination of meat and eggs through diet is significantly reduced by embracing the industry's feed assurance schemes and the use of traceability with HACCP to identify and manage risk. The impact of infectious agents was clearly highlighted with the occurrence of BSE and salmonella in eggs which had a significant impact on world trade. Today there is the issue of MRSA with the result of increasing control of the use of antibiotics in animal production around the world. Now is the time to develop alternative methods of disease prevention and control perhaps through nutritional support of the immune system or the development of a healthy microflora.

Responsible production of animal protein increasingly requires management of the environmental impact and the maintenance and enhancement of animal welfare. Diet formulations are being created applying ethical criteria to the raw materials being used and the impact of excess nutrients, such as protein and phosphorus, on the environment. The efficiency of use of waste materials will be improved if used as a feed stuff for animals after re-categorisation through the circular economy or through the generation of energy by use as an alternative energy source. It is vital that the knowledge of nutritional requirements keeps pace with rapid genetic development to ensure that the high welfare status of the animal is maintained. This is relevant in the case of the breeding sow where the number of piglets produced per litter is increasing and consequently requires advances in nutritional knowledge to maintain sow productivity and improve piglet viability. In addition more robust solutions for the detection of the onset and treatment of welfare issues would be desirable.

Good quality animal products are required to maintain levels of consumption and create a memorable eating experience. Many factors affect eating quality of meat including genotype, environment, feeding level and diet composition as well as meat processing. All disciplines working together to further improve eating quality and building on the blue print created by the MLC many years ago may help take this area forward.

For the future the drive to create affordable animal protein will require continued investment in fundamental research essential to provide the knowledge required for breakthrough developments with the subsequent creation of platform and derivative products thus enhancing the efficiency of the industry. Safety of animal products is vital and, as with all these areas, progress must be made through good science, with transfer of knowledge to the public, thus avoiding pressure to act from ill-informed perceptions. Similarly, information used to create environmental protection and welfare controls must be evidence based to ensure the most effective solutions. Finally good quality products with high eating quality must be the goal to ensure continued product demand by the consumers. Ultimately, innovative solutions are required to continue to improve efficiency whilst encompassing animal welfare, environmental protection, consumer safety and product quality through a holistic approach involving long term collaboration across disciplines whilst maintaining profitability.

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Innovations in educational programming: leveraging online learning to deliver graduate instruction in quantitative genetics and genomics

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Application Sharing resources and expertise across academic institutions in the design and delivery of an online graduate curriculum is key to preparing the next generation of professionals in animal genetics and genomics in the US.

Introduction The biological revolution has redefined modern genetics. Society benefits from an ever-increasing understanding of the behaviour of genes and their networks. However, use of such vast information depends on its integration into a quantitative genetics framework, particularly for its routine incorporation in animal breeding programs. Yet, within the US land-grant system, the focus on molecular genetics led to substantial reductions in graduate training in quantitative genetics (Misztal, 2007; Lewis *et al.*, 2008). Sensing a crisis in the making, early in 2005 a faculty group formed to develop strategies to redress this problem. An aim was to leverage expertise across universities to implement a graduate-level online curriculum in quantitative genetics and genomics on a national scale. Our objective here is to describe the development and implementation of that program, and efforts to ensure its sustainability.

Material and methods As a precursory step, in 2006 a survey was conducted to garner feedback on the need and acceptability of an online curriculum for graduate training in animal genetics. In total, 125 faculty members from 73 US universities were contacted with nearly half responding. An overwhelming proportion (0.90) endorsed asynchronous distance-delivery as a method to redress shortfalls in their curriculum. Building on that momentum, and with USDA funding, in 2007 a partnership of land-grant institutions formed to develop and teach online courses. Ten institutions contributed. With the aim to supplement rather than replace face-to-face instruction, course offerings focused on foundational knowledge in quantitative genetics, and its interface with genomics. Target audiences were Master's degree students and industry professionals. Ten core and 6 elective credits were developed, and taught as 1-credit, 5-week courses over 4 academic terms. Experiential and hybrid learning – the former by a web-based genetic simulation game and the latter by face-to-face recitation sessions augmenting online instruction – were integrated. A systematic process of instructional design was adopted to encourage continuity in curriculum delivery. The ADDIE model – analyse, design, develop, implement and evaluate – guided each stage of development (Gustafson and Branch, 2002). With the end of USDA funding, ensuring the sustainability and national access of the program became the priority. In 2015, the curriculum was integrated into AG*IDEA, a consortium of 19 US universities offering courses in agriculture disciplines online. That infrastructure allowed student admissions through their home institution and a common fee structure.

Results Since fall 2007, 277 students have completed 1064 credit hours in the program. Enrolments included students from 34 US universities, several international educational institutions and industry. Course enrolments ranged from 4 to 37, with 1 to 9 students from an institution completing a course. Those class sizes were substantially larger than the norm at individual universities. Many participants mentioned such coursework would otherwise be unavailable to them without this curriculum. Anonymous student feedback on the content and structure of the courses was overwhelmingly positive. As illustrations, students completing the curriculum stated: "As a distance learner, I got practice on not only lecture contents, but also communication skills"; "My overall experience was very positive. The curriculum helped me quickly learn concepts and skills that would have been difficult to learn on my own"; "I think the instructors did a good job and the courses were a success." Areas for improvement included consistency of instructional approaches across courses, timely instructor responsiveness and detailed feedback. Operational benefits to the multi-state collaboration include faculty members instructing in their own areas of expertise, with more diverse and larger course enrolments.

Conclusion Innovations in educational programming have afforded strategies for universities to address the national knowledge gap in quantitative genetics. Institutions have demonstrated the benefit of sharing information, expertise and resources in creative and collaborative ways. The outcome is more students pursuing and completing graduate degrees in quantitative aspects of genetics, with advanced skills and knowledge directly applicable to the agricultural workplace.

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From transfer to brokering: fostering multiple links and types of exchanges to enhance impact of animal science

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The process of knowledge transfer or knowledge translation (KT) in the agricultural sector, has been studied since the 1950s. While initially focussed research push models, KT gradually moved towards research pull and collaborative research models.

However, current systems perspectives on innovation go beyond seeing research as the main input to change and innovation, and recognise that innovation emerges from the complex interactions among multiple actors and is about fostering combined technical, social and institutional change.

As a result of adopting this systems perspective, KT is refocusing to go beyond enhancing research uptake, and more broadly focused on brokering relationships between all relevant stakeholders in production systems and value chains (e.g. farmers, policy makers, researchers, service providers, input suppliers, traders, retailers, NGOs) and about creating an enabling context for learning, development and innovation, and effective policy formulation and implementation. This has been called Knowledge Brokering (KB) and Innovation Brokering (IB).

The presentation will focus on several examples of KT, KB and IB, in relation to innovations in animal production, ranging from tackling herd health issues such as mastitis, to creating novel animal production system concepts. The presentation will conclude with reflections on the implications of a shift from predominantly applying KT to also enacting KB and IB for research and advisory systems connected to animal production.

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Farm business performance and the emotional & social competence of managers

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Application Improving management capability

Introduction Successful farming has traditionally been associated with technical skills and business acumen – but what role do the 'softer' skills play? This study with 65 UK dairy farmers looking at the drivers behind farm performance suggests profitability is also linked to good emotional and social intelligence.

In other industries leadership ability has been positively correlated with components of emotional and social competence (ESC) but surprisingly little research has been conducted in agriculture around this topic. To address this deficiency the purpose of this study has been to test the hypothesis that farm performance is associated with the level of social and emotional competence of the farm business manager.

Material and methods Emotional and social competence assessments were carried out on 65 dairy farmers based in England and Wales. The reports of these assessments were compared to assessments of international business managers. In addition the ESC scores of farmers taking part were compared to farm financial business performance using Promar Farm Business Accounts. To explore the interactions and relationships the farmers have in managing their businesses twenty three of the farmers were also interviewed by a qualified executive leadership coach within a semi-structured interview format.

Results In comparison to international business managers the farmers in the study were significantly lower for the competences conscientiousness's, service orientation, building bonds, understanding others, emotional awareness, accurate self-assessment and communication. For the remaining competencies differences with the international business manager population were not significant apart from the self-control competence where farmer scores were on average significantly higher.

Two groups split by profit per cow were analysed. The High Profit (HP) group made £739 per cow and consisted of the top 20 farmers in the sample. The Low Profit (LP) group consisted of the bottom performing 20 and made £117 per cow average for the whole sample was £366. The groups also analysed on a pence per litres basis – HP group made 10.2 pence profit per litre compared to the LP group which generated a profit of 1.2 pence per litre. The average profit for all farms in the study was 4.89 pence per litre.

By comparison the competencies teamwork and collaboration, conscientiousness, developing others, leadership and persistence are significantly higher in the high performing group than the low performing group of farm. There is a lack of correlation between the remaining ESC competencies and farm performance.

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Conclusion Lack of interpersonal sensitivity, personal flexibility and emotional resilience have tremendous capacity today to arrest the career prospects of intelligent, qualified and technically proficient professional farmers. Being able to carry out farm work and farm management tasks, being able to get the hub of the issue in a logical and insightful manner, demonstrating excellent project management skills and being task driven count for little if the individual is a source of friction in the team, has difficulty dealing with ambiguity and uncertainty and is emotionally ill-equipped to handle stress and criticism.

Extending the value of the literature; holo analysis of agricultural data

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Individual scientific papers address specific topics and deliver information relevant to the hypothesis being tested. The scope of most papers is necessarily narrow as the goal is to control all sources of variation so that the variation attributed to the variables/treatments of interest can be isolated and detected. Ideally each new paper yields information which is incremental to the current knowledge base with some papers, the exceptions, providing quantum leaps. In many cases the response to a set of treatments within any given trial is subject to influence from a multitude of conditions, some of which are known and some unknown. Those conditions that are known to influence the response should be controlled or at least measured, and those that are unknown simply contribute to the variation in the data in the literature. Many of the "unknown" conditions may have actually been measured in many individual experiments and simply not been recognised as having a role to play in the responses observed. In this regard a data driven review of all the information in the literature may enable such conditions to be teased out. The problem is that the scientific literature is vast, refereed articles which are tagged as addressing poultry nutrition exceeding 500,000. Even when specific topics are considered such as broiler methionine requirement, the number of papers can be so large (>5000) that it is not possible to have a working knowledge of all data. As a result no one individual scientist will be able to give a completely objective interpretation of the literature surrounding a specific topic. Indeed most reviews are the author(s) subjective interpretations of the subset of papers selected. Objective reviews of the literature should be based on a numerical rather than subjective analysis of the data available. Such reviews are now becoming more and more evident in animal nutrition due to the value they bring but they have been a common feature of the medical literature for many years. As indicated above, such data driven reviews may well find effects or factors which influence the response in a given field which were never recognised in any of the individual trials conducted. An example from Rosen suggested that the response to an NSP'ase enzyme was severely reduced if that enzyme was not fed from day of age. Data has emerged which subsequently has suggested that such an effect is real. It should be noted that in such comprehensive analysis, all available data is considered for use, hence the term 'holo-analysis. These methodologies are equally applicable to data collected in commercial situations. Many large commercial animal and poultry production companies collect data at breeder farm, broiler and layer farms, mill and feed formulation levels. Often these data are captured in separate data sets. If these data can be captured and aligned so that the performance of the animals at the farm can be related to, for example, breeder stock, mill and feed formulation, then the processes described above can be applied to the dataset generated. Two distinct advantages accrue from such an activity. The first is that the data collected relate to the commercial companies own situation and as a result any models generated apply to that company and probably with some degree of a bespoke nature. It is unlikely, for example, that any other company would have the same set of raw materials, formulations, feed milling processes, husbandry conditions and costs. Thus profit optimisation or cost minimisation would likely settle on a set of circumstances which suit the company concerned and probably no other. In short, profit maximisation would far more likely be achieved using data from the company concerned rather than literature or generic performance data. The second is that, should the data be collected on a real time basis, the robustness of any models generated could be tested on a relatively frequent basis and newer, better estimates generated as more data is added with time. Given the volume of data produced by medium to large sized companies it would not take long to have at hand a dataset that has greater width and depth than is available from all of the literature. For example, commercial feed mills have the capacity to record feed formulation, throughput, energy consumed per tonne, conditioning time and temperature, pellet press temperature and temperature rise and cooling conditions amongst many other variables, very few of which are ever recorded in scientific papers. If any of these conditions affect final profitability either through influencing the nutritional value of the diet or the cost of diet manufacture then such a relationship should be quickly established and the conditions of feed manufacture set to optimise overall profitability. Furthermore, the more complete and organised the data, the more streamlined the above processes become, making such analysis relatively straightforward for even the largest of outfits and may easily become regular practise, allowing almost minute by minute optimisation. Optimisation of animal production over such a broad set of inputs, ie from ingredient selection, through feed manufacture to husbandry, is possible today using commercial data but has yet to be considered in academic research projects as it is simply too large a question to consider. There is an argument, therefore, that the application of holoanalysis may move away from the academic literature and more towards large scale datasets generated by commercial companies. Perhaps it will be from this forum that topics for research will be generated as a result of interesting associations discovered from empirical data generated in the field. Regardless of where holoanalysis is implemented, it will be far more successful if adherence to the tenet, "The quality of the data determines the quality of the output" is upheld.

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Data driven smart farm management with Farm Intelligence solutions

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How commercial farm managers can capture data from their birds using data recording and management systems and subsequently make use of the information to both trouble shoot and maximise efficiency.

We live in the era of Big Data, Cloud computing and the Internet of Things. However, the poultry sector has only started adopting these technologies. There is no doubt that using these technologies will contribute to improve efficiency and support sustainable intensification of modern poultry production. Yet, adoption is slow and does not only require technological changes at farm level, but also a shift of a management approach focused on collaboration and transparency.

This contribution will focus on the opportunities of using modern ICT & Big data analytics technologies in poultry production, with the poultry farm as the central starting point. Key is the capability of a poultry farm manager to translate all the information he can collect in business relevant information. Livestock production processes are complex, they are typically highly variable and insufficiently predictable. However, novel Farm Intelligence solutions will help him with this by cloud based data management and first-line data-analytics. Such solutions are already proving their value in practice.

But a critical success factor is whether the farm manager succeeds in using these data to feed the “Living Expert System” at his farm. By engaging feed companies, veterinarians, genetic companies, food processors and other stakeholders, he will access the critical expertise to make his poultry business more profitable.

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The importance of gut health – The veterinary clinician's perspective

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This paper will consider the effects of gut health on the overall production of weaned and growing pigs. It is becoming increasingly clear that the integrity and structure of the intestine is linked with the development of the microbiota in the pig through the growing phase with pathogens both disturbing this development themselves whilst also potentially taking advantage of such disturbances. Furthermore, actions that veterinarians and stockmen take to control disease can have serious consequences for normal gut development. Concerns over antibiotic use and transferable resistance have stimulated veterinarians to review practices with, in some cases, marked effects.

Disturbance to gut function in the immediate post weaning period has been recognised for decades with *E coli* and Salmonella the most frequently identified pathogens. The almost universal adoption of *ad libitum* feeding has removed the technique of severe feed restriction or little and often feeding historically used to control disease. Over time and with better diagnostic techniques, it is now clear that whilst these agents remain highly significant, earlier gut damage during the suckling phase is also key. This can be illustrated by a number of case investigations.

Coccidiosis. The protozoan parasite Isospora suis, with its complex life cycle produces diarrhoea as a result of major damage to the SI in pigs from 7 to 10 days of age up to weaning. Immunity following infection only results if the late stage meronts or merozoites are destroyed. Control is readily achieved by administering toltrazuril at the appropriate time – typically 96 hours after first challenge which usually occurs at birth. Cutting corners and treating all litters on one day a week (i.e. between 0 and 7 days) whilst potentially controlling active diarrhoea can leave some pigs subclinically infected and non-immune, leading to maldigestion and fading in the post weaning period.

Rotavirus. Piglets can be infected from birth and suffer small intestinal villous atrophy. The later infection occurs in the suckling period, the more chance gut integrity and with it the ability to digest complex nutrients post weaning can be compromised. Vaccines are not available in the UK and disease control relies on the combined effect of raising maternal immunity - primarily to boost milk antibody levels (not easily achieved given restrictions on 'feedback' techniques) and maximising hygiene for the piglet.

Antibiotic treatments. Routinely treating piglets at birth with antibiotics to control neonatal diarrhoea or joint infection has historically been widely applied with ever more sophisticated and broad spectrum antibiotics being used. Withdrawal of routine treatments (which were thus proven to have been unnecessary) has led to an improvement in pigs post weaning on some farms to the tune of 10% increase in growth rate from 4 to 8 weeks and a reduction in overall mortality from 5% to 1.2% as wasting and diarrhoea disappeared.

From the clinician's perspective, more active techniques to improve or promote gut development and digestibility can assist but often prove unpredictable or unreliable – organic acids via feed or water, probiotics (especially in the young piglet, including "bio" yoghurts), fermented liquid feeding (now fallen from favour due to concerns over inebriated pigs!) are variably claimed to improve colonisation with particularly Bacteroidetes (including Bacteroides sp) and Furmicites (including Lactobacilli) bacteria thus assisting the competitive exclusion of pathogens. However, we lack understanding of the positive mechanisms involved with such products and the pig industry is vulnerable to the strong marketing messages that accompany them. Moreover, but most importantly in practice, veterinary surgeons may not have fully appreciated the risk of damaging the development of the microbiome by the liberal use broad spectrum antibiotics, particularly aminoglycoides and potentiated sulphanomides as well as heavy metal ions such as zinc and copper, and the harm that these may do to gut health and performance in the longer term.

As the growing pig develops a change occurs in the pathogenic challenges with hind gut disease starting to predominate (Brachyspira and Lawsonia) and these diseases may be more responsive to dietary manipulation including prebiotic use. However, the common problems of gastric hyperplasia, erosion and ulceration start to come into play. Possible interaction between nutrition, management, co-existing disease and genetics need to be addressed on a case by case basis. Gastric erosion and ulceration are not routinely monitored at slaughter and unless severe haemorrhagic ulcers occur on farm the significance is often overlooked. Some of the clinical effects, complications and remedial actions are also worthy of discussion.

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Strategies to improve intake and gain in the weaned pig through gut health

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Weaning is a critical time-point in a young pig's life. The separation from the sow, new environment, and establishment of a new social hierarchy coupled with the change from liquid to dry feed creates stress that can have consequences on growth, physiology, and disease status. These abrupt changes at weaning can cause transient anorexia which leads to decreases in intestinal barrier function and absorptive capacity (Spreeuwenberg *et al*., 2001; Pluske *et al*., 1996; Wijtten *et al*. 2011). This lack of intake and concurrent gut health challenge can have consequences on long term growth performance.

A major factor influencing the degree of gut health challenge encountered around weaning and post-weaning performance is weaning weight or weaning age. While weaning age has been remaining steady or increasing in recent years, sows are producing larger litters and more pigs per sow per year, which can cause weaning weights to decrease and increase the risk for digestive health challenges. One potential strategy to increase weaning weight in piglets and lessen the digestive health impact at weaning has been to provide supplemental nutrition during farrowing. This includes dry, liquid, or gel feeds. Potential benefits of supplemental nutrition during lactation include an easier transition to solid feed at weaning, reduction of fall-back pigs, encourage foraging and exploration, and to increase weaning weight. With larger litter size, the benefits of providing supplemental nutrition during lactation can become much more apparent. A study in the Netherlands (unpublished, 2014) determined that supplemental liquid nutrition can improve weaning weights and reduce the amount of small pigs at weaning. This translates to less risk of gut health challenges, and better growth post-weaning.

Even with increased weaning age or weight, there are still many gut health risks associated with weaning that can negatively impact performance. Besides the use of antibiotics, zinc oxide, and spray-dried animal plasma, there are several strategies that can improve gut health at weaning. One of these strategies is the control of un-digested nutrients. Consumption of poorly digestible protein can lead to an increase in protein substrate available for fermentation within the intestine. This can promote the growth of potential pathogenic bacteria and cause an increase in toxin production, branched chain amino acids, ammonia, and diarrhoea. Data from Heo *et al*. (2014) determined that dietary reduction of un-digested protein reduces intestinal ammonia concentrations and improves faecal consistency. Additionally, the reduction of un-digested protein can reduce the concentration of branched-chain fatty acids and inflammation in the colon (Pieper *et al*., 2012). Understanding nutrient needs, the use of high quality raw materials, and limiting the quantity of un-digested protein in the diet is an effective strategy to reduce diarrhoea and improve gut health.

The use of additives is another strategy used to improve gut health and post-weaning performance in weaned pigs. There are currently a number of different types of gut health additives used within the animal feed industry including probiotics, yeast derivatives, medium chain fatty acids, essential oils, nucleotides, prebiotics, acidifiers, etc. A number of different modes of action have been attributed to these additives as well, including improvements in digestion, immunity, anti-oxidant activity, and anti-microbial activity. For example, during an *E. coli* challenge, the use of live yeast can reduce inflammation in the ileum (Daudelin *et al*. 2011) and improve growth performance (Trckova *et al*. 2014). Understanding the mode of action and benefit of gut health additives can improve application and consistency of response.

Our current understanding on the impact of gut health additives on microflora modulation for the most part has been limited to specific bacteria or genus of bacteria. As our knowledge and tools continue to grow, we will be able to further define the impact of gut health additives on microflora. This will allow us to better define beneficial populations not only specific bacteria, but specific functions of groups of bacteria. The next frontier of animal feed may not be limited to feeding the pig, but could encompass feeding for an optimal microflora, which could further improve animal health and growth.

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Equine welfare indicators and impact of management practices

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Introduction With their ambiguous status of farm, leisure, sport and « pet » animals, horses are often exposed to different types of constraints that can alter their welfare, such as social or sensory deprivation (Cooper *et al*., 2000; Heleski *et al*., 2002) and feeding and spatial restrictions (Nicol *et al*., 2000). Moreover, horses have repeated and varied interactions with humans that lead to the establishment of a relationship which valence will depend on how these interactions were perceived by both interlocutors and may influence their welfare state (Fureix *et al.*, 2009; Hausberger *et al*., 2008 pour revue).

Review Different studies have been devoted to the evaluation of horse welfare since the 90's mostly with an emphasis on stereotypies and other abnormal behaviours, which prevalence in a facility may indicate inappropriate life conditions (e.g. Mason 1991; Mc Greevy 1995). They reveal feeding (Nicol *et al.*, 2000), spatial (Cooper *et al.*, 2000), social (Heleski *et al.*, 2002) restrictions or even inappropriate working conditions (Hausberger *et al.*, 2009).
Other sanitary indicators are also obvious such as wounds (Cook 2002, 2003; Popescu & Diugan 2013) or limping (Burn *et al.*, 2010) whereas major problems such as back disorders remain underestimated because of their lack of clear visibility (Jeffcott *et al*., 1999). The need of developing further reliable indicators of horse welfare has led different research groups to investigate this issue. Thus, Burn *et al.* (2010) and Popescu & Diugan (2013) have attempted to build welfare scales. Their observations reveal potential « candidates » such as the quality of the human-horse relationship or the attentional state. More recently, studies by Fureix *et al*. (2012, 2015), Lesimple *et al.* (2012, 2013, 2014), Rochais *et al*. (2016a,b) have led to the emergence of visible (behavioural and physiological) indicators that converge with evaluations of physiological and sanitary measures. Because the perception of situations is subjective, using such indicators, allow an animal-centered approach that can help identify the factors of influence and their relative weight in determining horse welfare, (Lesimple *et al* in revision). In addition to usual management aspects, work, and in particular riding techniques, appear as quite influential on the horse's quality of life (Hausberger *et al*., 2009; von Borstel *et al.*, 2009)..
Altered welfare may be underestimated by the familiar caretakers or owners either because the signs are not identified or because of a surexposition to these signs (Lesimple *et al*., 2013, 2014). Here we will review the existing proposed indicators and their interest in identifying good/altered welfare.
Horse welfare is important not only for ethical reasons but also because it alters cognition and fertility (Hausberger *et al.*, 2007; Benhajali *et al.*, 2013, 2014).

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Enabling Equine Technologies

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The past 30 years has seen unprecedented changes in technology. Developments in electronics and computing have lead to the availability of affordable consumer technology and the explosion of the internet, impacting on almost every aspect of our lives. Even in the horse world, historically a very traditional industry, the impact of science and technology is clear. Many riders now own GPS systems that calculate speed and track their training, hacks or competitions. Systems that also record heart rate, stride length and stride frequency are also now widely available. 2015 also saw the launch of a low cost thermal camera attachment for IPhone and Android phones to allow owners to scan their own horses. For comparison, 30 years ago there were a few equine heart rate monitors around but these were basic, and not many riders owned them. Thermal imaging cameras were very big, had low resolution and cost £50,000. As the technology available to the horse owner has increased, the technology used by academics has also increased in sophistication. For example, scintigraphy, CT, MRI, standing MRI, kinematics, gene sequencing, pressure mapping, computer modelling.

A growing proportion of horse owners are now accessing scientific information via the internet and becoming more informed and discerning, to the extent that many companies providing products and services to the horse owner, rider and or trainer will promote the use of science in development. Today, technology is no longer solely the preserve of academics and large companies. Many companies have begun to bring their research and development activities "in house" whilst at the same time using the external services of Universities and other commercial service providers. One of the main differences between academics and commercial organisations which both need to appreciate when it comes to R&D is time. Academics are usually highly focussed on getting things right, while commercial organisations who have contracted research may feel more pressured by time, competitor activity and an imminent product launch. For the relationship to work well it is essential that both sides have an appreciation of the others "culture", and that requirements and deadlines are clearly identified from the outset.

The use of technology in the development of products and services for the equestrian market has a cost implication. It is essential when embarking on a research and development pathway that those doing so are clear on the size of the market, the likely chances of the project producing a successful product, and the number of units that need to be sold in order to recoup investment in a reasonable time frame. On the plus side, a technologically driven R&D programme should allow products to be developed which can be shown to address a specific need or needs, remove a large amount of guesswork, improve product safety and contribute significantly to marketing. Furthermore, investing in structured R&D also opens up the possibility of obtaining funding through various schemes such as Life Sciences Research Network Bridging Fund through the Welsh Assembly Government in Wales, Innovate UK (formerly the Technology Strategy Board) and Scottish Enterprise. Where a project may have a significant impact on health and welfare, especially of the racehorse, applications for funding can also be submitted to the Horserace Betting Levy Board (UK). For commercial organisations the likelihood of success will be increased by working with one or more UK based academic partners.

Specific R&D also has tax advantages for limited companies under the HMRC Research & Development tax relief/credit scheme. This scheme is available to companies carrying out clearly defined R&D activity and can reduce the company's overall tax liability or provide cash in the case of small or medium SME) companies (1). Another related tax relief scheme that may be applicable for companies involved in R&D is the Patent Box which allows companies to incur a reduced tax rate (10%) on profits from newly developed, patented technologies (2).

From the customer's perspective, the use of science in product and service development can be a double edged sword. On the one hand, appropriate R&D activity combined with properly designed and controlled trials can lead to better products. On the other hand some companies see science purely as a marketing tool and may use it in their marketing campaigns in ways that appeal to consumers, but which are at the same time misleading. The issue of how well the general public actually understands science was first addressed seriously in the 1980's with the publication of a report on the topic by the Royal Society. In 1989 a paper entitled "The Public Understanding of Science" was published in Nature, which included the results of a survey of the general public on science. The results were considered at the time to be disappointing. In 1989 63% of people questioned in the UK correctly identified that the Earth goes around the Sun. In 2014, 66% of Europeans answered the same question correctly. Could it really be that we have only improved our science knowledge (at least based on one question!) by only 3% in that last ~25 years? Or are the Europeans dragging us down?

Whether the scientific understanding of the "average" lay person has or has not increased doesn't mean that use of science in marketing is without influence or relevance. The past 25 years has also seen the unprecedented expansion of accessible information. Good and clear scientifically valid information on equestrian subjects does exist on the web. Unfortunately a large proportion is misleading or wrong, and popular bloggers or those with large budgets can rank highly. Many people are able to evaluate the quality of information. However, there is also the influence of social media where unrestricted advice is offered both by experts and those with no credentials. Thus, whilst 25 years ago the poor understanding of science by the public could potentially be explained by lack of access to scientific material, today the lack of any significant

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progress may potentially be due to extremely large amounts of available information and an inability to distinguish good from bad.

Should those who ride for pleasure, compete or those who make a living from the horse industry take an interest in science, or does science simply spoil a nice traditional pastime? Riding and being around horses is not without risk. In the 1980's horse riding was cited as being more dangerous than riding a motorbike. More recent figures suggest that riding a motorbike (x45 increased risk) or a bicycle (x13 increased risk) are much more likely to get you killed but riding does carry a high risk of head and spinal injuries. In 2012 a judge ruled that horse riding is dangerous and riders cannot sue when they fall off and that riders must accept the "inherent risks" of their sport. Thus, both with respect to trying to reduce the risk of death or serious injury, riders would probably be well advised to have an appreciation of science and technology behind products that may protect them such as hats and body protectors. An interest and basic level of scientific understanding may also help owners choose appropriate protective products for their horses and to ask challenging questions of manufacturers rather than simply accepting bold marketing statements such as "scientifically designed and tested" or "the safest on the market".

The key to using technology effectively is to clearly identify the problem or need, choose the right technology to further understand the problem or need being addressed and if necessary, pick the right partner to work with. Finally, when it comes to choosing the technology to use, the simplest approach that delivers the required results is often best; it would be unwise to employ a whole University department to develop a sophisticated software controlled electro-mechanical device to crack a single egg when a teaspoon would do. On the other hand, if you need to crack and separate a 1000 eggs per hour then that's a different matter!

Links

HMRC CIRD80150 - R&D tax relief: introduction: overview http://www.hmrc.gov.uk/manuals/cirdmanual/cird80150.htm
Patent Box: https://www.gov.uk/guidance/corporation-tax-the-patent-box
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