A Nuffield Farming Scholarships Trust Report

Award sponsored by

The Royal Welsh Agricultural Society

Alternatives to antibiotics in agriculture

Aled Rhys Davies

September 2016

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NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

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A Nuffield (UK) Farming Scholarships Trust Report

"Leading positive change in agriculture. Inspiring passion and potential in people."

Date of report: September 2016

Title	Alternatives to antibiotics in agriculture
Scholar	Aled Rhys Davies
Sponsor	The Royal Welsh Agricultural Society
Objectives of Study Tour	To gain an understanding as to how to inspire the agricultural industry to lead the global fight against anti-microbial resistance.
Countries visited	Germany, France, Sweden, Norway, United Kingdom, New Zealand, Australia, United States of America and Canada.

Messages

- Agriculture has a great opportunity to lead the process of limiting antimicrobial resistance through developing evidence based strategies to ensure prudent use of antibiotics.
- Farming businesses communicating with consumers the way in which they ensure prudent use of antibiotics in order to limit antimicrobial resistance will prosper.
- Commercial companies offering hygiene and nutritional services with the aim of limiting the introduction of disease and reduce infection pressure on livestock will become the alternatives to antibiotics in agriculture.
- Failure to demonstrate evidence based prudent use of antibiotics in agriculture will restrict new antibiotics from agricultural use.
- The choice as to how to achieve prudent use of antibiotics is for the farmer to decide. Nutritional supplements and immune stimulants can work within the framework of elevated hygiene and husbandry.

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DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body.

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1. Personal information

Raised on a beef and sheep farm in West Wales. I have over twenty years' experience working in **a sales and marketing capacity, predominantly within agriculture. Having gained a degree in food marketing at Harper Adams Agricultural College, I studied to gain a professional qualification in strategic marketing whilst embarking on a career in sales. I have a passion for understanding negotiation, the sales process and the link between price and value of goods within a trade.**

I'm currently forty**six, married to Caryl and we have two Children, Caradog – fourteen, and Gwenno** – eleven. I'm Sales Director at Kilco International.

Figure 1: The author, Aled Davies

2. Background to my study subject

In 1950 Alistair James Hicks, father of five children and the main income provider working in Cross Hands colliery, West Wales, as a fireman, got a cut on his hand infected by a bacteria called Leptospira, from dirty water. He developed Weil's disease and **died of his infection within 48 hours. His family were plunged into relative poverty. Gloria, his youngest daughter, and the only one still living at home, in addition to her education, started work from then on, cleaning, along with her mother, Pisgah School, in Penybanc, Ammanford, where her mother was the caretaker and dinner lady. Whilst the pay was insignificant, it was regular, and contributed towards providing food for the family unit. Penicillin could** have saved Alistair Hicks's life. It **soon became available for administration by doctors.**

Figure 2: Alistair Jams Hicks

I'm allergic to penicillin. Alistair Hicks was my grandfather. In two generations, I've lost the use of this life saving antibiotic. I'm not resistant to penicillin, I'm allergic to it. Nevertheless, I can't use it to help me fight bacterial **infections.**

A return to a pre-antibiotic era, personally scares me, possibly more than others, as the remnants and consequences of that era exist within the living memory of my closest family. Gloria, my mother prevailed, and with John, my father, they educated both of my brothers and me, and we are all grateful to them for doing so.

My intent in conducting this Nuffield Farming Scholarship has been to examine what alternatives to antibiotics exist for use by farmers assuming that the problem which is currently developing with regards to anti-microbial resistance will inevitably restrict the use of antibiotics in food production. By conducting this study, I want to help secure the future viability of agriculture in the area I live.

A matter of weeks into my research I realised how naïve with regard to the subject matter I actually was. As a young man, due to being allergic to penicillin, I avoided as much as possible taking any other type of antibiotic when unwell. I assumed that one day I might need these antibiotics to really work for me, but I was wrong to think that way. I learnt the errors on my way whilst at the world health summit in Uppsala, Sweden, looking at anti-microbial resistance. Having tried in vain for several weeks to secure my right to attend, I got accepted. I think I "winged it" as an Ugandan delegate, who knows? **The quota of delegates from the UK was filled with pre-eminent doctors, vets and academics. My Ugandan counterparts were mainly chemists. They told me that they could sell the latest antibiotic without prescription to any person. They explained the problem further. When ill, a person, if they could afford to do so, would buy a course of antibiotics. As soon as they felt better, they would stop taking the antibiotics themselves, and share the remaining ones out with other family members. By doing so, they are potentially accelerating the speed of anti-microbial resistance to the said drug of choice. I realised that any member of that family carrying resistant bacteria are only one flight away** from Europe. It isn't them that are resistant to antibiotics but the bacteria they carry. I realised that

whether I had taken antibiotics in the past or not, if I was to get infected by resistant bacteria, no antibiotic would help me. I also realised that this issue was greater than agriculture, that there is a socio economic factor to the whole area. Whilst poverty and poor education prevail, in my opinion, we generate breeding grounds for anti-microbial resistance.

For my study, I had decided to look at a multitude of species including ruminants, monogastrics and fish. Whilst at first I thought I had bitten off more than I could chew, I'm glad to have pushed on in a **stubborn manner to look at good practice in each sector. I've gained a real vision as to the issues per species, and have been able to compare and contrast.**

Nuffield 15's Contemporary Scholars' Conference was held in Rei**ms, France. One of the most fascinat**ing aspects of the weeks' activities was the study of the production of champagne. A **masterclass in adding value, I found myself reassessing my ideas on brand management. The train of thought that followed influenced my study and has led me to believe that the global issues of anti-microbial resistance are the biggest opportunity for livestock farmers of all species in my lifetime.**

As farmers we can lead the fight back against infective bacterial resistance to antibiotics. Whilst these life forms are some of the oldest inhabitants of our planet, prudent antibiotic use in agriculture can be achieved to limit Anti-Microbial Resistance from agriculture. Farming can lead consumers and governments to limit anti-microbial resistance. To do so, we need to mobilise a global farming organisation and empower the leaders within that organisation to inspire change within their respective countries. This project could be a real and lasting legacy for the Nuffield Farming family going forward.

3. My study tour – where I went and why I chose those countries:

Germany - October 2014
Whilst I was awaiting confirmation of being awarded my Scholarship, I attended the 4th International Fresenius Feed Conference. A biennial event, it was designed for the "Re**-evaluation** – **Labelling** – **Claims -** Dietetic Feed". I wanted to get a feel for the way legislation and regulation affected the route **to market for feed products that could potentially be alternatives to antibiotics. I got a text, (quite a noisy one), whilst listening to a p**resentation at the conference form my wife confirming I'd received **a letter from the Nuffield Farming Scholarships Trust confirming the award.**

Norway – May 2015
Norway's reputation for low antibiotic **use in agriculture and its large aquaculture sector seemed to be a good place to start analysing. I wanted to know why or how they used less antibiotics than other countries. I wanted to learn if fish farmers could teach pig, poultry, cattle or sheep farmers any lessons about antibiotic use. The Norwegian government protects farm incomes. I wanted to know how that affected management of livestock systems, or regulation of medicines.**

Sweden – June 2015
The world health summit looking at Anti-Microbial Resistance (AMR), was held in Uppsala University, Sweden. It took me weeks and weeks of phone calls, emails, a hand written fountain pen letter, and all my powers of persuasion to gain a delegate space at the event. With human and animal topics on the agenda, I hoped to gain a vision as to the current thinking on antibiotic use.

London – June 2015
The UK Probiotics Conference 2015 – The Royal Holloway University of London – "Bridging the gap between science and industry". **Feedback on pre and probiotics seemed to be mixed. I wanted to get an idea as to the latest thinking. This conference would give me a chance to examine the latest research and practices in a human and agricultural context. I wanted to know if this technology was a realistic alternative to antibiotics.**

France – January 2016
As a country, France has exported their bovine and ovine genetics to many countries in the world. I wanted to get a feel for the work done on health status. Was there any data collection or analysis of genetic potential that illustrated progress in immune function? Also, whilst in the Netherlands on non-Nuffield Farming business, I came across a homeopathic product for dairy cows. I wanted to visit the manufacturer. Was there any merit in this technology as an alternative to antibiotics?

France – February 2016
Paris Agricultural Show. I wanted to study the process of communicating added value of agricultural produce to an urban audience. There are around ten million inhabitants in the city of Paris. This show is the agricultural industry's "shop window". Different to any other agricult**ural show that I know of, the objective is to communicate the merits of French agricultural produce to the urban people of Paris. I wanted clues as to how good practice in terms of agricultural use of antibiotics, could be communicated to urban people.**

New Zealand – May 2016
I wanted to examine the role of diagnostic technology in proving the need for antibiotic treatment of animals. I wanted to examine if low cost dairying and the share farming model results in over-use of antibiotics.

Australia – May 2016
Examining all the species in my study in a different hemisphere to compare and contrast systems of farming, I wanted to know if there were any big differences between Australia and Europe. I also wanted to know if Australian farmers were as clever as the Australian Farming Scholars at the Nuffield Contemporary Scholars Conference said they were.

USA – July 2016
Whilst Norway had a reputation for low antibiotic use in agriculture, the USA did not. However, there seemed to be a growing market there for antibiotic-free meat and milk produce in America. I wanted to know more. I wanted to look at large scale dairying's use of antibiotics, and examine the role of **diagnostic technologies.**

Canada – July 2016
In 1987, I had travelled Ontario on a rugby tour. It struck me then as a country where agriculture was important to the country's economy. I wanted to know how the farmers and allied industries in Canada **are approaching the threat of anti-microbial resistance.**

Glossary of terms

Prophylactic - a medicine or course of action used to prevent disease.

Zoonoses - are infectious diseases of animals (usually vertebrates) that can naturally be transmitted to humans, or vice versa.

4. My study tour - Alternatives to antibiotics in agriculture - what I saw

4a. How I'd planned my study

With such a broad subject topic to address, knowing where to start was quite difficult. I wanted to look at Aquaculture, the Pig, Poultry, Dairy, Beef and Sheep sectors' use of antibiotics. I wanted to see if I could find similar patterns of husbandry or management, and compare and contrast best practice. I wanted to spot products or services that gave farmers realistic alternatives to antibiotics.

A commercial research company, "MarketsandMarkets" had supplied me with some inte**resting desk research. Published in 2014, it highlighted a market for some alternative products, but there was no one type of product taking the lead. Fig.1 demonstrates the dominance of antibiotics/antimicrobials as growth promoters and performance enhancers. It also shows forecasted growth in this sector.**

Did that mean there were inconsistencies in terms of efficacy in these products, that forced farmers to continue using antibiotics/antimicrobials, or was it countries like Russia, China, and the USA where, at that time, no regulation preventing the prophylactic use of antibiotics in agriculture meant that there would be significant growth in use of antibiotics in these countries, or was there another reason?

Product	2011	2012	2013	2018	CAGR% (2013-2018)
Antibiotics/Antimicrobials	4,145.3	4,309.6	4,489.7	5,719.9	5.0
Hormonal Growth Promoters	586.3	604.8	625.2	765.0	4.1
β-agonists	359.4	368.2	377.9	444.9	3.3
Feed Enzymes	367.9	390.7	415.6	584.7	7.1
Probiotics and Prebiotics	276.8	292.3	309.2	423.8	6.5
Organic Acids	247.6	261.3	276.2	376.4	6.4
Phytogenics	139.9	146.9	154.6	206.6	6.0
Others	211.6	217.2	223.3	265.6	3.5
Total	6,334.8	6,590.9	6,871.6	8,787.0	5.0

Source: Annual Reports, Press Releases, World Organization for Animal Health (OIE), World Veterinary Association (WVA), World's Poultry Science Association (WPSA), Animal Health Institute (AHI), Inter-African Bureau of Animal Resources (IBAR), Food and Agriculture Organization (FAO), Asian-Australasian Association of Animal Production Societies, Animal Production and Health Commission (APHCA), Pan-American Health Organization (PAHO), German Feed Additives Association, French Association of Swine Practitioners, Expert Interviews, and MarketsandMarkets Analysis

Figure 3: Global animal growth promoters and performance enhancers market, by product, 2011-2018 (Million $ US)

At the planning stage of my study, almost daily, the media were reporting changes in regulations for the use of antibiotics in agriculture in one country or another. I concluded that keeping up to date

with regulation throughout my study would be a distraction, and at the point of publication, if I documented current legislation, that it would soon become out of date and obsolete. I decided therefore to approach the study, not recording regulatory changes, but assuming that regulation would continue to change, increasing the need for alternatives to antibiotics.

The media also referred to anti-microbial resistance (AMR), not antibiotic resistance. I sought clarity and understood that: Anti-microbial products encompass three types of products:

- **Antiseptic**
  - **For topical treatment of wounds or protection against infection on a person or animal**
- **Antibacterial**
  - **For use on surfaces**
- **Antibiotic**
  - **For internal application in humans and animals**

I decided to concentrate on antibiotics, and investigate the use of alternative products to replace the use of antibiotics in agriculture.

4b. Early realisation – I had to look at this differently

Bergen, on the west coast of Sweden intrigued me. I found it hard to contemplate a region within two hours' flight from home with double the considerable rainfall of my native West Wales.

Having attended the 4th International Fresenius Feed Conference in Cologne, Germany, some six months earlier, and in listening to Manfred Coenen, University of Leipzig, Germany, I'd gained an **insight into the role of feed and in particular feed additives in working with an animals' immune system. His work showed that by using proteins and feed additives he could influence micro-bacterial activity in an a**nimal's **gut, with the effect of influencing the environment in the gut inhibiting proliferation of the bacteria Salmonella.**

With this approach in mind. I'd made an appointment in Bergen, Sweden with Ragna Haggegø – **a senior scientist working with functional feed for a company called EWOS. They are a leading manufacturer of fish feed. One in every three salmon farmed in the world are fed by EWOS. She confirmed that salmonid fish account for 60% of the aquaculture production of Canada, Norway, Chile, Scotland and Vietnam.**

Her role, as a pathologist, is to look to *"do something before the fish get a disease"*. **EWOS produce three types of feed:**

- **Support**
  - **Contain immune stimulants**
  - **In feed nucleotides (building blocks of DNA)**
- **Clinical**
  - **For use when viruses affect fish**
- **Synergy**
  - **Medicated feed (zero antibiotic medicine)**

My meeting with Ragna changed my outlook on the whole project. I realised I had to look at this subject differently. Her comment on the role of immunity in prevention of disease - *"The fish with the highest immune response die"* **threw me. Her command of the English language was better than mine,** so it wasn't a linguistic error. **I did however understand her explanation. A strong immune response results in inflammation that can cause vital organ damage. EWOS apply high fat diets that have the effect of diverting the immune system and preventing fish mortality.**

One of the biggest disease management issues for the Norwegian Aquaculture industry centres on sea lice. These parasites attach to the fish and secrete anti-immunity prostaglandins into the fish tissue to prevent the animals' natural defence mechanism from expelling them. With depleted immunity, **bacterial and viral infections take hold.**

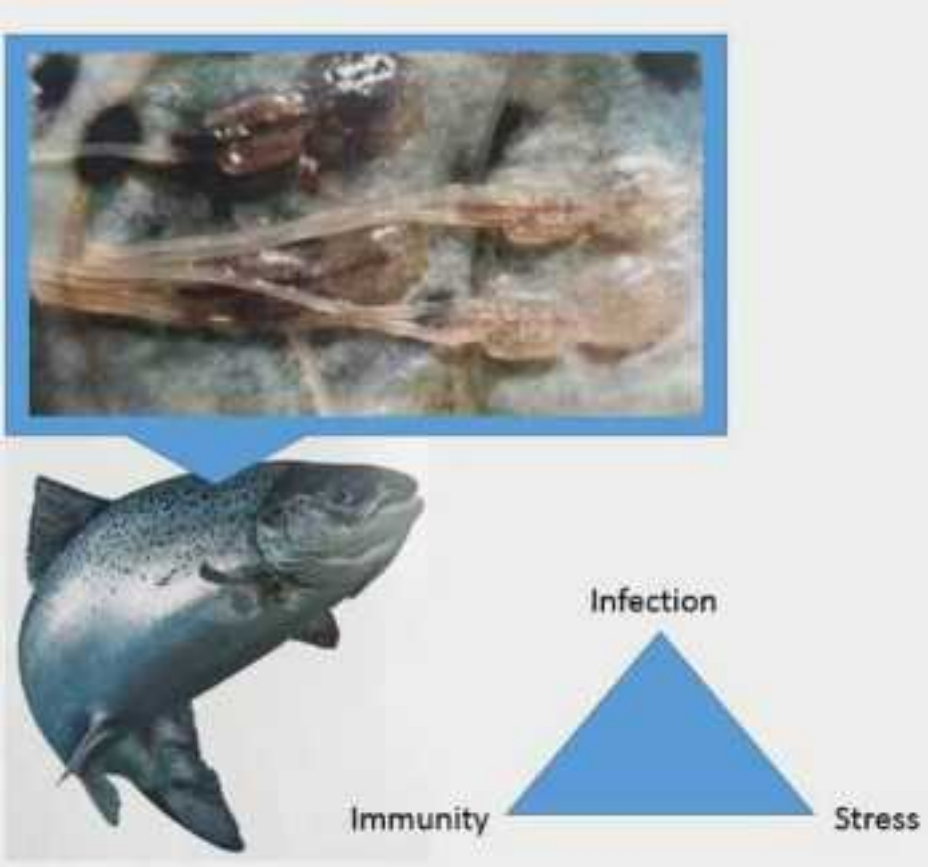

Figure 4: Image showing Sea Lice attached to Salmon tissue, and the relationship between Immunity, Stress and Infection

Ranga stated that in Norway, viruses and inflammation are the biggest problems facing aquaculture as a result of increased stress on fish from sea lice.

Treatment of fish whilst at sea with organa-phosphate chemicals to remove sea lice is controlled and regulated by government, at the chemical cost to the farmer. Large well boats are used to bathe the fish before they are returned to their cages. *See photo on next page*.

Figure 5: A well boat, docked at the World Heritage Site harbour in Bergen, Sweden

Figure 6: Open lid of well boat

Figure 7: Hull of well boat. Fish are transported to and from sea within the hull of the boat. Medicinal treatments are also administered in these boats.

I visited a fish farm along with Pernilla Simolin, a vet for Fishguard AS. Fishguard AS are contracted by the Norwegian government to monitor and control the effect of sea lice on the aquaculture industry. On a routine visit, she undertook a visual examination of live fish for sea lice to determine the need for treatment, as well as post mortem examination of dead fish to measure fish health.

Figure 8: Pernilla Simolin, Fishguard AS

Figure 9: Post mortem on fish

Figure 10: Engesund Fiskeppdrett – Eight cages holding approx. 250,000 fish each

Figure 11: Engesund Fiskeoppdrett A/S – the farm I visited

Pernilla confirmed that antibiotic use in the Norwegian fish industry faded away at the end of the 1990s as bacterial vaccinations were developed for fish. Her recommendations, post our visit to this farm, would determine if medication had to be administered to fish by the owner.

Oslo

ANIMALIA is based in Oslo, Norway and is a private company financed by a farmer levy. Their government contracted remit is to educate farmers on meat quality. Their work is applied to ruminants, poultry and swine. They have no responsibility for fish. A third of their resource is directed to maintaining animal husbandry and welfare at slaughter, a third on classification of meat, and a third on livestock data recording. They work closely with a sister organisation - MARPRAT-NO - which promotes meat to consumers.

Ola Nafstad, the managing director, explained that they work closely with the national Animal Health organisation and universities in an attempt to educate farmers as to ways to limit disease introduction to farms by improved husbandry and hygiene.

Sheep . He informed me of some work they had conducted in 2008. Norway is free from sheep footrot. However, it was found in sheep on the west coast of Norway in 2008. The source was some sheep imported from Denmark in 2004-05. Norway established a National Eradication Programme. They examined every flock in West Norway – 4500 farms, and found 117 sheep with footrot. 47 were culled, and their owners compensated. 69 were treated, of which 16 became re-infected. They were re-treated and the disease eradicated from Norway.

Cattle. In 1990, a National Eradication Programme was embarked upon to eradicate Bovine Viral Diarrhoea (BVD), from the national herd in Norway. In 1993, they tested 400,000 dairy cows and 20,000 beef cows. Of the cows sampled and re-sampled, 25,000 cows were returned as the highest registered presence of the virus. In 2003, the last herd carrying the virus was eradicated. Milk or blood samples were taken from every herd two to three times a year. Cows with new antibodies were slaughtered. Whilst the farmers were not compensated for the loss of their cows, they did not have to pay for the testing. The 13-year eradication programme is estimated to have saved the cattle industry NOK 40m per annum. (Around £4m). Ole commented that the same could be achieved in Great Britain if the political will, and finance, allowed.

Norway eradicated Bovine Tuberculosis in the 1950s in a similar way.

Dairy. Anne Cathrine Whist confirmed that the view of the Norwegian Dairy Health Service is that farmers should use antibiotics at drying off as a means of minimising the total use of antibiotics during lactation.

Swine. **Are farmed very much by family farms. On average 80 to 90 sows per farm. Of the 1000 farms, half of them produce and sell piglets only. The other half keep sows and fatten pigs. Norway slaughters around 1.6m pigs annually and although it is 100% self-sufficient in pig meat, it has to import grain and protein. They do not allow genetically modified (GM) feed ingredients.**

Over the last two years, Norway has been involved in eradicating methicillin-resistant Staphylococcus aureus (MRSA), from its national pig herd. They have found that people working on pig farms introduce the bacteria to the pigs. In 2014, 1000 sow farms were examined, with 1000 pig finishing farms being examined in 2015. All pigs found with MRSA were slaughtered, with all farms having received piglets being audited. Farmers were fully

compensated, but had to wait one year before re-stocking. Every farmer has to implement an eradication hygiene plan that includes the removal of wood from pig housing, and the use of approved disinfectants within hygiene protocols.

Poultry – Norway has around 500 farms that keep 4.6m laying hens. All birds must be kept free range, legislation that was introduced in 2012. There was no great history of prophylactic antibiotic use within this sector prior to regulation preventing such use. Whilst disease was not a big problem with laying hens, cannibalism was when free range systems were first introduced.

There are around 600 broiler farms producing 60m meat birds per annum in Norway. Clostridium and E.coli are problematic disease causing agents. Whilst farmers are allowed to use coccidiostats to control coccidiosis, pressure is building to ban their use.

As a country, they maintain high bio-security standards and have a low tolerance to avoidable disease.

Veterinarians – Ole Nafstad confirmed that vets prescribe antibiotics but are not allowed to sell them. Only chemists are allowed to sell antibiotics to farmers in Norway. Since 2012, new legislation was passed that stated that vets have to report each prescription for antibiotics to the Food Security Department of government. Vets can only earn money by selling their expertise, and not from the sale of medicines. For example, a vet earns money from charging a farmer to apply an antibiotic tube to the cows' teat during the process of drying her off, not from selling the antibiotic to the farmer.

Vaccines – I met Tore Tollersrud of the Norwegian Veterinary Institute, Oslo. He heads up the immunology department at the University of Oslo. I wished to discuss the possibility of developing bacterial vaccines as alternatives to antibiotics. He confirmed the possibility, but cost of development and time frame were both big obstacles.

4c. Explosion of scale of project

Norway highlighted two variables that I hadn't considered whilst planning my study.

- **The effect of parasites on the immune system allowing bacterial and viral infections to take hold.**
- **Zoonoses. But rather than animals transmitting disease to humans, humans transmitting MRSA to animals.**

This meant that I would not be able to concentrate only on products that would be alternatives to antibiotics in the fight against bacterial infections. I had to find solutions to issues that cause on farm disease. I would have to consider all environmental stresses on food producing animals, not just bacteria. I felt that the scale of my study was expanding ten-fold as I learned more.

4d. The veterinary economic model

Uppsala Health Summit, Sweden – "A world without antibiotics"

Having secured my space at the conference, it became obvious quickly why I had found it difficult to gain access. The event was full of academics, veterinarians and doctors who all seemed to be at the top of their game.

In his welcoming address to the conference, Anders Malmberg, Professor, deputy vice chancellor Uppsala University and Chairman of Uppsala Health Summit, stated that there were no alternatives to antibiotics. We had to protect the ones we have and find ways of developing new ones quickly. Nobody in the conference disagreed or questioned him.

The first day of lectures, workshops and reports opened my mind to two issues facing the human population of the world in terms of antibiotic resistance.

- **Access**
  How do we ensure that the populations of poor to middle income countries get access to new antibiotics?

- **Excess**
  How do we prevent resistance developing from excessive use of antibiotics, especially when they are not needed by the patient?

    - **Antibiotics are easier to take than it is to measure AMR (Anti-Microbial Resistance)**
    - **Antibiotics are easier to take than it is to establish if an infection is bacterial or viral.**

Questions were asked as to the need for veterinarians to be given access to the latest antibiotics for use on animals.

Questions were asked as to how regulation should be devised to control the distribution and the accuracy of administration of antibiotics to patients.

From the days' activities, I realised the importance of education in preventing AM**R. From listening to the delegates, who had attended from nearly every continent on earth, there seemed to be a lack of knowledge amongst human consumers of antibiotics as to the risks associated with taking antibiotics. I also understood that agriculture needs to educate consumers, regulators, doctors, governments as to the importance of access to the latest antibiotics for animals.**

I thought of my parents' farming enterprise. As breeders of Texel sheep, they would not want to see a particular blood line disappear with the death of an animal due to a lack of access to the latest antibiotic which could have treated the fatal infection. The same would be true in the poultry industry. Lack of access to the latest antibiotic could be catastrophic to grandparent stock that supply genetic proliferation to the broiler industry. (*See chart on next page***).**

In a workshop entitled, "Antibiotics in animal production", unintentionally, I upset the majority of **veterinarians in attendance by suggesting a change in the veterinary economic model. I stated that, in the UK, generally, vets charge a low call out fee and a high margin on drugs used or sold. I suggested that vets be paid an annual headage fee, according to the number of animals, and supply all medicines needed for the treatment of the animals free of charge. My logic was that the focus would shift from**

cure towards prevention of disease, and hence limit the use of antibiotics. The main objection was to the income potential generation for the vet being adversely affected by farmer inefficiency, and a lack by education as to the importance of hygiene. My proposal didn't make it back to the main conference **as being worthy of further discussion.**

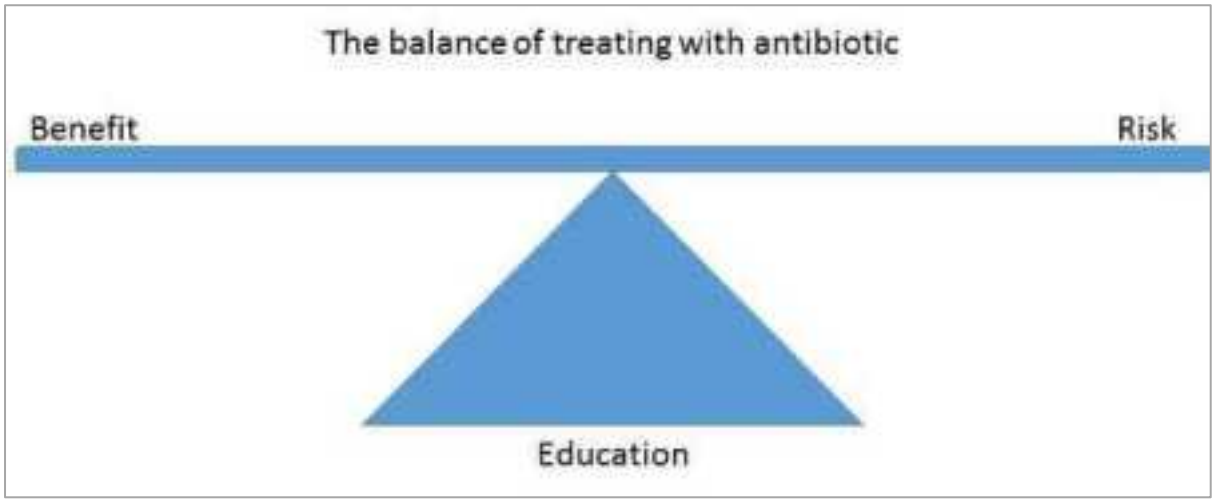

Figure 12: The balance of treating with antibiotic

Summary of facts presented to delegates at the conference

1. **Global livestock populations have increased, and production systems intensified. Livestock populations cluster where there is access to transport and processing systems.**
1. **Livestock food systems have become more complex and global e.g. feed for European poultry grown in South America, the breast meat consumed in Europe, the wings in Africa and the feet in Asia.**

	1995	2010
Global livestock units	2.22 billion	2.48 billion
Global amount of meat/year	35.8 kg/person	41.9 kg/person
Global milk production	540 million tonnes	723 million tonnes

3. **Cattle is the major species in terms of biomass and value**
4. **Poultry and pigs have the most rapid population growth.**
5. **Antimicrobials are used in livestock production:**
   - **to treat sick animals**
   - **to protect sick animals in contact with sick ones**
   - **during periods of stress**
   - **as growth promoters in the absence of clinical disease. (banned in some countries)**

It has been estimated that globally more antimicrobials are used to treat healthy animals than unhealthy humans.

Policy changes on antimicrobial use in livestock indicate that productivity is not impaired if the change is combined with improved management, reduced stress, use of modified genetics and investment in disease prevention measures.

	Cattle	Poultry	Pigs
Global yearly consumption of antimicrobials	45 mg/kg	148 mg/kg	172 mg/kg

	2010	2030	% increase
Estimated consumption in food producing animal production:	63,151 tonnes	105,596 tonnes	67%
Two thirds of the global increase is due to the growing number of livestock. One third is attributed to a shift in farming practices to more intensive farming systems.			

By 2030, consumption of antimicrobials in Asia is projected to be 82% of the current global consumption.

In 2010, the countries with the largest shares of consumption of antimicrobials in food producing animals were: China 23%, USA 13%, Brazil 9%, India 3%, Germany 3%

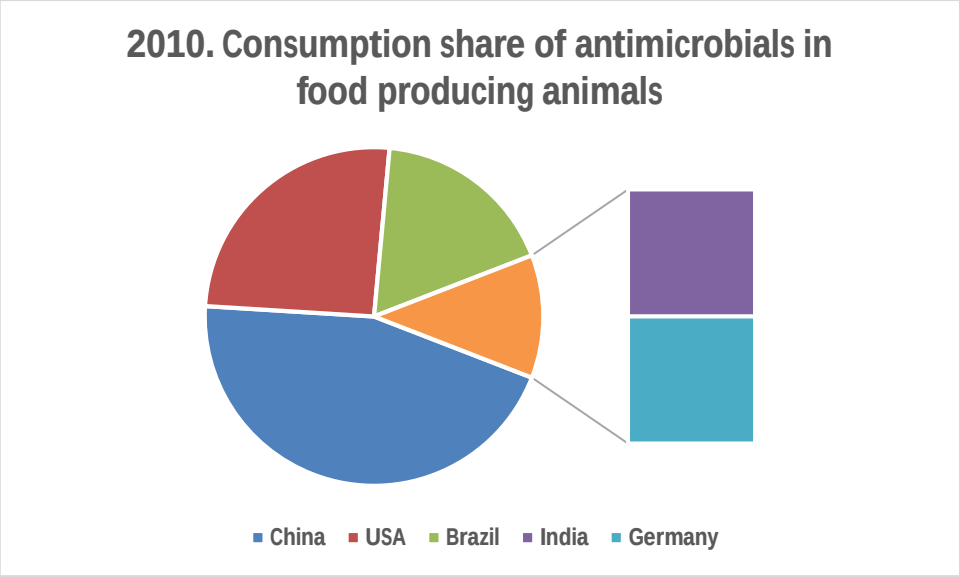

Figure 13: Rushton J, Pino Ferreira J. Stärk KD, 2014. Antimicrobial Resistance: The use of antimicrobials in the livestock sector,OECD Food. Agriculture and Fisheries Papers, No. 68 OECD Publishing.
OECD Working Party on Agricultural policies and Markets:
Global antimicrobial use in the livestock sector.

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Until this conference, my focus had been on the emergence of resistant pathogens from agriculture. During coffee breaks and discussions at workshops another aspect dawned on me. I had not considered the potential for spreading resistant pathogens that could result from agricultural practices. I asked myself the question: *"What effect would we have as farmers on the environmental spread of resistant pathogens by simple spreading of muck?"*

I considered what I had learned in Norway. A staff member with MRSA passes the resistant pathogen on to pigs. The manure of which is spread on fields. What happens to the MRSA bacteria?

I realised that agriculture has to take a lead in the fight against AMR.

4e. Pre and Probiotics

The UK Probiotic Conference was held during a June 2015 London heatwave. The conference was split into five key segments.

- **Gut microbiota and gut microbiome – human health**
- **Gut microbiota and gut microbiome – animal health**
- **Probiotics: human health and diseases/allergies**
- **Veterinary products, aquaculture and companion animals**
- **Product development**

The conference had attracted academic speakers from eminent universities in Europe, North and South America, India, Australia and China. My reflections on attending the conference would marry well with the closing remarks of Professor Simon Cutting of the Royal Holloway University - the conference chairman - who concluded by stating that a great deal more research was needed in the field of probiotics to ensure efficacy and a proper understanding of the mode of action of the technology.

Speaker after speaker presented research showing significant or near significant results, but could not repeat such findings at later trials, or were unable to produce consistent results.

I particularly liked the paper presented by Wolfgang Kunze, Brain-Body Institute, McMaster University, Ontario, Canada. He introduced the concept of the gut being a second brain, and the link between the gut and the brain via the vagus nerve. He presented work where the microbiota and their component molecules changed and improved brain function, especially in the elderly.

Later in the conference, I was alarmed to learn of the problems of diarrhoea caused by a proliferation of gut C-difficile bacteria due to the elimination of other competing gut bacteria by antibiotics. The re-distribution of gut bacteria among these hospital patients can only be achieved by supplementation with other human's faeces. (By enema). No probiotic products can achieve the same results.

A constant theme that emerged from the presentations was the efficacy shown by probiotic products based on bacillus spores.

Whilst probiotics were seen by the presenters as a potential alternative to antibiotics, I felt that there was a realisation amongst those attending the conference that, at best, probiotic products could help as part of a strategy to build alternatives to antibiotics rather than be a straight technology swap.

4f. Returning to the lessons of the Contemporary Scholars' Conference

The Nuffield Contemporary Scholars Conference (CSC)[1] for my year was held in Reims, France. As part of the week's **activities, we visited a farm that produced champagne. The multinational group I was in visited the farm that produces the Vazart Coquart & Fils brand of champagne. Even though I have a professional marketing qualification, until that visit, I genuinely thought that champagne was a brand. What I learned however was that champagne is a quality control system. There are a controlled series of events which growers have to conform to in order to qualify their products to bear the word Champagne on their label. If one or multiple deviations occur in the growing/manufacturing process,** then the optimal quality of the end product can't be guaranteed and the wine can't be marketed as **champagne, nor benefit from the premium that type of wine demands.**

I now realise that the agricultural industry can't say to consumers that as an industry we use antibiotics responsibly if in fact we don't do so. We can't cut corners. We have to use antibiotic**s responsibly.**

4g. Capitalism

In September 2015, I got invited by The Levitt Group to London for an evening entitled "An audience with Philip Kotler". To quote their letter of invitation "Professor Kotler is author of over 100 papers **and 50 books. He is** renowned for 'Marketing Management', which has been the world's most **influential marketing text for almost 50 years. As the S.C. Johnson & Son Distinguished Professor of International Marketing at the Northwestern University Kellogg Graduate School of Management, he** has inspired generations of today's marketing leaders. As a consultant to firms from IBM to General **Electric to Motorola, he has shaped marketing practice in many global companies. Perhaps less well-known is that Professor Kotler, in addition to being the acclaimed marketing guru, is also a classically** trained economist. He received his Master's in Economics at the University of Chicago under famed **Nobel laureate and free-market evangelist Milton Friedman, before pursuing his Ph.D. at MIT under Paul Samuelson and Robert Solow, two Nobel Prize**–winning Keynesian economists."

As a student of marketing, I had read many of his books and gained greatly from the documentation of his thinking. There were around thirty of us present, and even though the discussion with him was via video link, it felt great to be able to ask him a question.

He was promoting a new book entitled "Confronting Capitalism: **real solutions for a troubled economic** system". During his presentation to us, he discussed the scena**rio** of the top 1% of the world's **population being astronomically wealthy, the middle class being squeezed financially, and the poor confined to being financially extremely disadvantaged. He alluded to pressure therefore on food security, shelter, clean water and sanitation. He also discussed the scenario where the top 1% were**

[1] **This annual conference is attended by all the newly awarded Nuffield Farming Scholars, internationally, in the current year**

beginning to worry – *"watch out, the pitch forks are coming"*. He elaborated by explaining that the **very wealthy are looking at means to redistribute wealth.** *"After all,"* **he said,** *"they can only drive one car at a time, wear one pair of pants, eat so much food, or drink so much wine at any one time. If the middle class doesn't have disposable income, then economic growth will stagnate globally."*

I asked him if he thought that the type of leadership demonstrated by Mahatma Gandhi, in communicating a vision to the masses, ensuring they understood what he was attempting to achieve, could be replicated to educate consumers about food safety. His answer was that Gandhi would have benefited greatly from social media because he had got his vision broken down into simple language that his audience could understand and unite behind.

4h. The role of the consumer

Having met Laurent Journaux, of France Génétique Elevage, at the CSC in Reims, I visited his office in Paris to further understand how measuring and developing genetic merit in ruminant animals could limit infection from bacteria in animals and hence limit the need for antibiotic treatments. As general secretary, he coordinates the levy-funded national process of genetic improvements of ruminants. They coordinate performance recording of sheep, cattle and goats, and are instrumental in developing total merit indexes where economic traits are given a weighting according to, and therefore suitable for, the system of farming. High input systems requiring different breed traits than low input systems. Breeding indexes suitable for farmers categorised by system.

I expected to be discussing these traits in detail and then forming a view as to my own weighting of each, but what I got exceeded those expectations. I left with an understanding of how breeding sheep and making good genetic decisions play a key part in the quest for added value for farm produce. I also learnt that genetics alone can't deliv**er such riches for the masses. My education came from an example based on the Brebis Lacaune breed.**

Figure 14: Lacaune sheep

I had heard of Roquefort cheese, I'd sampled it, I'd seen **it in store. I knew it was a blue cheese, and guessed it was either sheep or goat milk cheese. What got my attention was the realisation that only milk from the Lacaune breed could be used for Roquefort, a cheese with European Protected Geographic Identity (PGI), status. Foolishly I thought that like Caerffili cheese, it was simply a type of cheese, but no, to qualify, the milk has to come from Lacaune sheep, the cheese produced has to be stored in a Fleurine cellar, a natural cellar that introduces the blue element of the cheese from the environment. The cheese matures over a four to five month period. Farmers are paid a basic monthly price per kg of milk solids with the premium being paid once the cheese is sold. And what a premium! My contact estimated more than a doubling of farm income per animal.**

Figure 15: Roquefort cheese

We discussed other cheeses where the breed of ewe is linked to the brand of cheese sold. Ossoiraty cheese can be made from the milk of three breeds, Basco Bearnaise, Manech Tete Rousse, and Manech Tete Noire. Marketed in a similar way with controlled processes maintaining quality, the added value returns a living from around 200 ewes. Similarly, the Corse breed of sheep is used uniquely in the manufacture of Corsican cheese. Although it isn't as **widely known as the other two cheeses, it demands a vibrant market in Corsica.**

Figure 16: Manech Tete Rousse sheep

The model of starting the added value pathway with particular breeds of animals is not confined to sheep. Montbeliarde cattle are the only permitted breed for Comte cheese. No silage is to be fed to the cows, hay is permitted due to it having less lactic acid, and hence less danger of carbolic

interference during cheese making. The milk has to be stored at a constant 12 degrees C for eighteen hours post milking, farmers have to ensure no antibiotic residues in the milk. The cooperative employ an Affiner to control the whole manufacturing process. Farmers get on with farming, the company ensure the quality. The added value generated keeps them all in work.

Figure 17: Comte cheese


Figure 18: Montbeliarde cow


Figure 19: Ossau-Raty cheese

Interestingly, farmers of goats produce their added value by making their own cheese and selling it locally to consumers. There doesn't seem to be a structured cooperat**ive infrastructure to the sector. The result is a plethora of cheeses, distinct to a farm, a family of goats.**

The consumer can be confident that when they buy these cheeses, they actually buy a particular set of values. They don't have to worry about con**sistency, they know the product will be the same time after time.**

In terms of limiting AMR, the consumer is key. If that is what they demand, then that is what the market will have to give them if a trade is to be made. There are two obvious

elements that need finalising. That is, the cost of production of using alternatives to antibiotics, and the price the consumer is prepared to pay for food produced with responsible use of antibiotics.

Whilst at the Paris Show, a month later, one of the judges of the Ile de France breed at the show was David Mulligan, a breeder from Co Tyrone, Northern Ireland. David introduced me to Mr Fontaine Emmanuel the president of the Ile de France Society. He told me of a premium he achieves for his lamb by being a part of a group, Bleu, Blanc, Coeur. The group brands food products, communicates with consumers, and promotes the use of linseed in concentrate feed rations as a means of preventing disease by using nutrition.

Figure 20: Fontaine Emmanuel and David Mulligan

The linseed content of the ration alters the fatty acid balance of the resultant meat. So, the Omega 6:Omega 3 ratio of the meat is altered. In other words, the farmer feeds a concentrate ration high in linseed, which alters the fat ratio of the meat. More good fat and less bad fat in the meat, and then the group, by communicating their brand values, generates a premium from consumers.

For Mr Emmanuel, his extra investment in linseed in his ration cost him €0.3 per Kg of meat sold. He gets a premium from Bleu, Blanc, Coeur of €1.20 per Kg of meat sold, so he is better off €0.90 per Kg **of meat sold.**

Amelle Binard a member of staff on the Bleu, Blanc, Coeur stand confirmed that by manipulating the Omega 6:Omega 3 ratio of meat, they have been able to demonstrate improvements in consumer health, and reductions in the use of antibiotics by humans.

See photos on next page

Figure 22: The Bleu Blanc Coeur logo

Figure 23:Amelie Binard of Bleu Blanc Coeur and Fontaine Emmanuel – farmer producer

Figure 24: A selection of food bearing the Bleu Blanc Coeur logo

Figure 25: Freshly cooked lamb

This was a model of leadership where the aim of healthier consumers was communicated. The farmer knew what rules he had to comply with in the production of his livestock in order to achieve a premium. The consumer valued the brand and was prepared to pay a premium based on the health benefits the brand carried.

4i. Alternative alternatives

Whilst in the Netherlands on non-Nuffield Farming duties, I'd come across a**n alternative to an intramammary antibiotic treatment for cows. It was a homeopathic remedy, also given to cows intramammarily.**

I tracked the manufacturer down to Reims in France. Bonapp manufacture homeotherapy remedies for pets, equine and farm animals. Their main customers for the intramammary product are Dutch dairy farmers in the Netherlands. Whilst my French language skills were lacking, I was able to get an understanding of the restraints of regulations in different European Union member states that limited the market for the product. I was amazed by the physical and tangible volume of product I witnessed being packed for dispatch to the Dutch: not boxes but pallets of product. Over the last three years, the volume of product sold to the Dutch had increased three fold. Whilst I didn't understand the **technology, I knew that repeat sales volume of product could only be the result of an effective product.**

Whilst I'm a commercial man, I've always approached the scie**nce behind a product with vigour. I enrolled onto a course at the Welsh School of Homeopathy in Carmarthen to find out more about the science behind the remedies.**

On this one-day introductory course, I gained an understanding of the philosophy of homeopathy. I was surprised to learn that water has a memory. I didn't know that each **snowflake has a unique design, and if melted and re-frozen, it goes back to that same design.**

After my introduction day, I still wanted to see evidence of efficacy in terms of homeopathic remedies in farmed animals, for my own curiosity.

My proof came in Victoria, Australia on a dairy farm. Terry, Pauline and Brendan Hehir used to farm conventionally, but having been visited by Nuffield Farming Scholar Jo Scammel, they converted to producing milk organically in 2000, and now consider themselves to be "biological farmers". **They keep 650 dairy cows on a home platform of 230ha, with another 110ha nearby. They use another 277ha for dry cows, to rear replacements and for cropping. Terry commented that since converting to biological farming, his veterinary bill has virtually disappeared.**

Figure 26:Terry, Pauline and Brendan Hehir's milking herd

The philosophy of their farming methods is based on the concept that healthy soils give you healthy animals. They use homeopathic remedies, hydrogen peroxide as a water sanitiser, cider vinegar in water, and kelp amongst other inputs to help them achieve low somatic cell count (SCC) milk.

They utilise the Albrecht system of soil nutrient management. The alternative products they use fit their system for their farm and their successful way of farming.

Figure 27: Terry, Pauline and Brendan Hehir

Figure 28: Terry, Pauline and Brendan Hehir's irrigated pasture

I realised that in the process of leading farmers to use antibiotics responsibly, it wasn't up to me or **anyone else to tell farmers how to do so. It was up to me as a leader of this change to get their buy in to the concept.**

4j. Focus on ruminants

By this stage in my study, I felt that I had examined the issues of alternatives to antibiotics at a macro level. It was time to concentrate at a micro level. In an attempt to get at more detail, I decided to choose the dairy cow as the type of ruminant to focus in on.

Arwel Chesby and I were in school together. He along with his family sharemilk near Rotorua in New Zealand.

Figure 29: Welshman Arwel Chesby, share farming in New Zealand

In 2011, Arwel ranked 154th out of all the suppliers of milk to Frontera, in New Zealand, in terms of low SCC. That put him in the top 2% of New Zealand dairy farms. He put his continued success in terms of maintaining a low SCC down to attention to detail and working closely with his vet.

I visited Karl Weaver, his vet at his office in Rotorua to get an idea of the mastitis strategy they adopt as a practice.

See Arwel Chesby's Certificate of Achievement on next page

Figure 30: Aled Davies outside Karl Weaver, vet's office

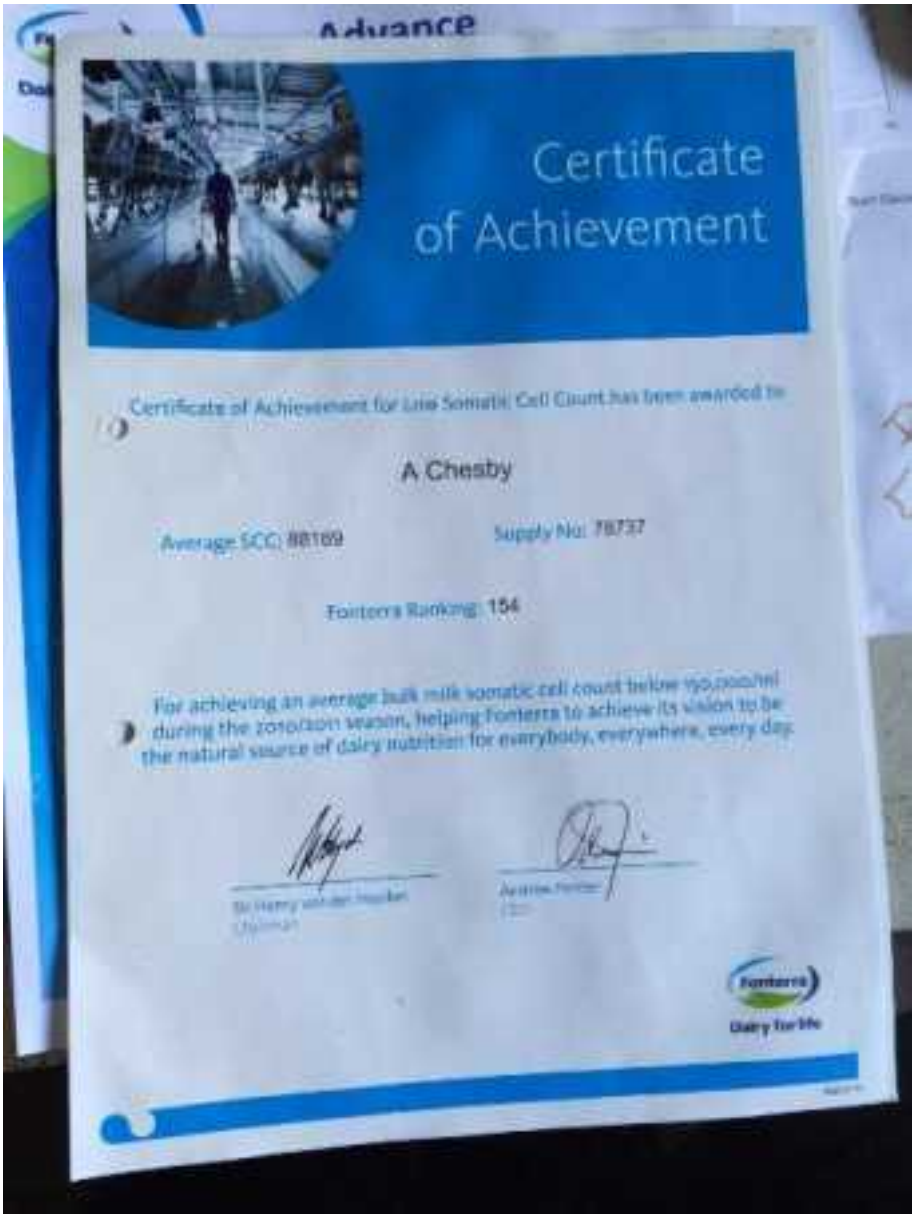

Figure 31: Arwel Chesby's Certificate of Achievement for low somatic cell count

Karl demonstrated the dry cow strategy he uses on Arwel Chesby's farm by means of a drawing. He **informed me that at four weeks post drying off, 25% of** cows' teats have still not sealed natur**ally. Therefore, the teat canal is still susceptible to infection from bacteria. So, his recommendation, that Arwel follows, is to blanket treat all cows at drying off with a 10 week, broad spectrum antibiotic.**

He continued to explain that his practice offers a service whereby a team will travel to farm to administer teat sealant to the udders of in-calf heifers around a week to ten days pre calving. This practice has proven to almost eliminate cases of mastitis in the first two weeks of their first lactation.

I questioned Karl as to the reasons why they did this. Was it due to the conditions the heifers were kept prior to calving? He thought that the economic and climatic conditions in New Zealand resulted in high cow numbers and low staff numbers, that could cause husbandry and hygiene issues when the

weather creates damp muddy conditions. His strategy enabled farmers to overcome these issues, and was proven to limit mastitis in early lactation for first calving heifers.

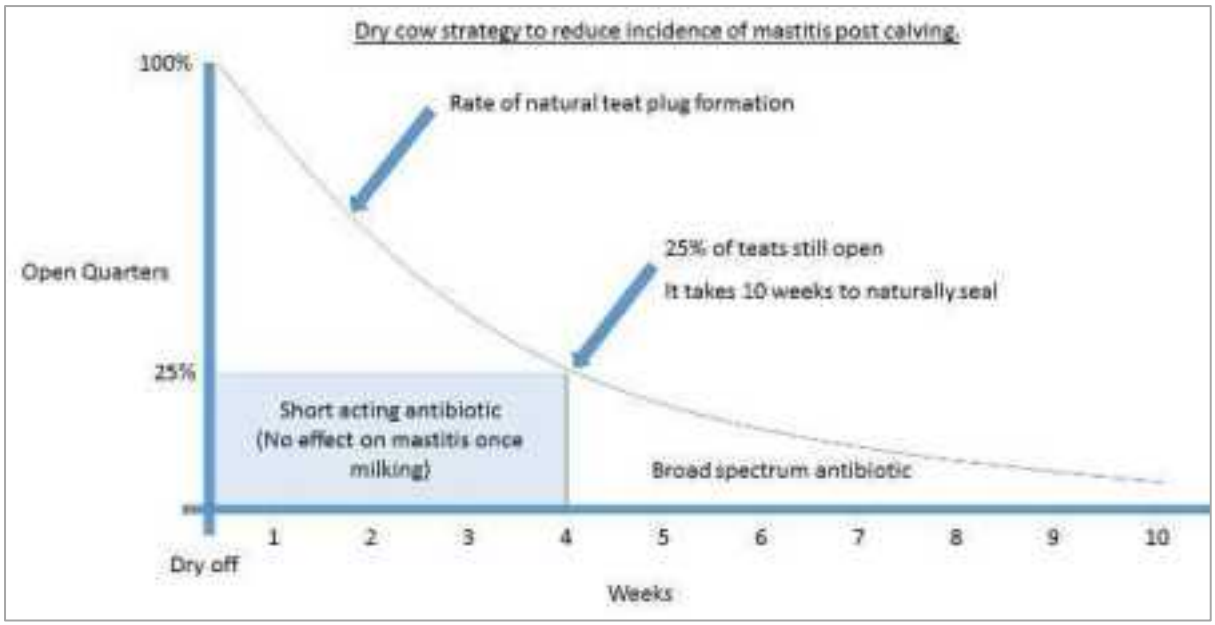

Figure 32: Karl Weaver's dry cow strategy to reduce incidence of mastitis post calving

Whilst I couldn't argue with Arwel's SCC results, I was very concerned that within this strategy there **was no consideration for the developme**nt of resistant bacteria. Karl's **response was that the incidence of mastitis was limited by this strategy. There was an obvious thought process behind the treatment, and consideration for the withdrawal period of the product, but no consideration for the risk of resistance development.**

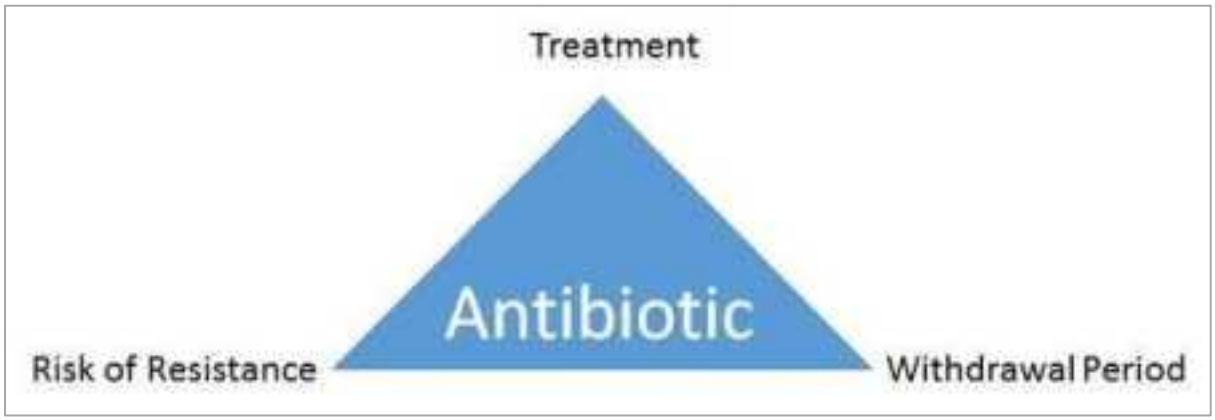

Figure 33: The antibiotic use variable triangle

Figure 34: Dutch vet Arjan de Wilde of Landmark vets

Less than an hour away in Matamata, I met a Dutch vet - Arjan de Wilde of Landmark vets.

His approach to dry cow treatment was different. He commented that 80% of dairy farmers in New Zealand blanket treat all cows at drying off, and that this process was the single biggest usage of antibiotics there. He is working with his clients to reduce the use of antibiotics in cows that don't need **treatment at drying off.**

He recommends that his clients use a Rapid Milk Test (RMT), otherwise known as the Californian milk test on each quarter during the last milking before drying off as a means of identifying a high SCC. The quarters with a high SCC are treated with an intramammary antibiotic, whilst those without a high SCC are given a teat sealant, again by intramammary tube.

Figure 35: Landmark Vets Ltd office

During lactation, if a farmer identifies a quarter with suspected mastitis, he recommends that they take a sample of the milk and freeze it. Treat the cow with antibiotics. If the symptoms improve, dispose of the frozen sample. If not, he would test the sample to attempt to grow the bacteria to identify it. Then test an alternative antibiotic to recommend the cow be treated with.

He confirmed that the standard practice in New Zealand during lactation if mastitis is suspected in a cow's quarter is to treat with a standard antibiotic **to target Streptococcus Uberis**. If that doesn't work, use a broad spectrum antibiotic. If that doesn't work, cull the cow.

Again this caused me concern as to the lack of consideration for the risk of bacterial resistance.

A meeting with Natasha Maguire of Farm Medix in Auckland, New Zealand opened my mind as to a way forward.

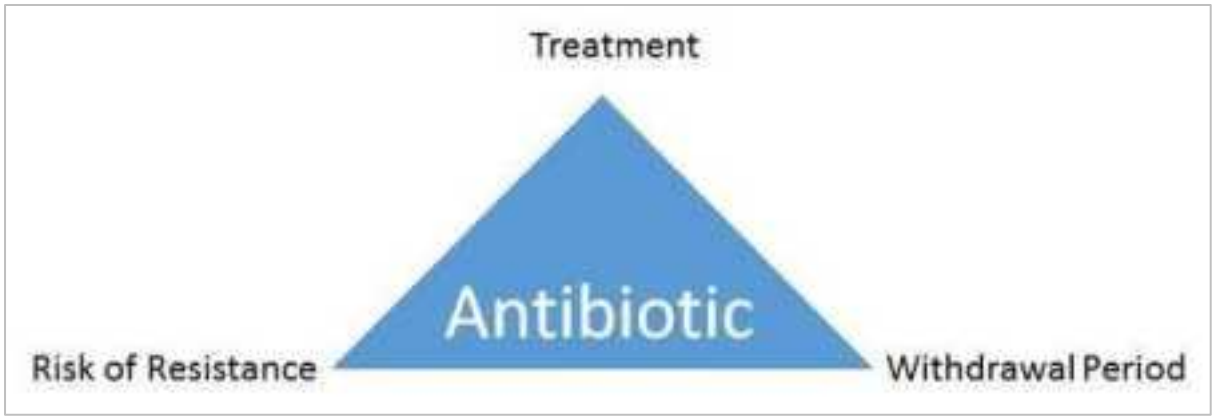

Figure 36: The antibiotic use decision variable triangle

I liked the work Arjan was conducting in the process of developing a treatment by identifying a strain of bacteria before treating with an antibiotic. I couldn't see how the length of time needed to get the **identification, and the cost of getting the vet to do so, was going to grow the demand for this service.**

Farm Medix have developed an on-farm testing kit that identifies the strain of bacteria present in milk, or from swabbing surfaces by the next day. What impressed me about the system was that it gives farmers the information they need in order to make management decisions. Somatic cells are a mixture of milk-secreting cells that have been shed from the lining of the milk secreting gland and white blood cells which have entered the mammary gland in response to injury or infection. A high SCC in a cow's **quarter might therefore be an indication that an infect**ion had occurred, but the cow's **immune system had reacted and defended itself. There might not be a need for the costly application of antibiotics at this point.**

Figure 37: Photographs of check-up plates showing 24-hour bacterial growth

We looked at photos of bacteria that had grown in a 24 hour period from cows that were suspected of having mastitis. All of these, apart from the one showing no growth, were from cows with high SCC.

Then we re-arranged them as shown below.

Figure 38: Photographs of check-up plates showing 24 hour bacterial growth categorised for treatment, cull and don't treat

Analysis of the above:

Can't treat/ Cull

The most likely course of action for the cows infected by Staphylococcus Aureus, Kleibsiella or Pseudomonas would be to cull, saving feed, vet bills, staff time and reducing the risk of cross infection to other cows.

Treat

Whereas all of these bacteria would increase a SCC, there were only two types of bacteria where treatment with an antibiotic would actually work: streptococcus uberis, and streptococcus dysgalactiae.

Don't treat

There would be no point spending money, time and effort treating E.coli, yeast, either of the Coagulase-Negative Staphylococci (CNS) bacteria, nor no growth with an antibiotic. Depending on the type of E.coli, generally the cow's **immune system could cope with these infections.**

This system was a low cost, easy to use, well thought out protocol that allowed farmers to make informed herd health decisions within 24 hours of suspecting a mastitis issue based on evidence gathered from their cows on their farm.

At a meeting with Nita Harding, Jane Lacy-Hulbert and John Williamson who all work for Dairy NZ, I got a real feel for the importance of dairy farming to the economy of New Zealand. A levy board, *"Dairy NZ invests dairy farmers' money into a wide range of programmes, guided by the dairy industry strategy."* **I was able to drill down into the issues of communicating good practice within dairying to**

their farmers. I learnt that through research, Dairy NZ develop technical notes. These are their "blueprint" documents. They recommend best practice for dairy farmers in New Zealand.

I discussed the use of monensin in the New Zealand dairy industry. They confirmed it was an antibiotic that was used prophylactically by New Zealand dairy farmers to manage/alter gut bacteria as a means of preventing bloat. I discussed a bolus marketed in the UK as a means to treat ketosis, that contained monensin. Farmers that had used it were quoting a 10% yield increase by doing so. Jane commented that monensin was used in New Zealand to alleviate some of the pressures of the grazing system and not as a driver of milk production. I further questioned them as to the potential detrimental effect on consumer confidence if the latter realised an antibiotic was used prophylactically in the production of New Zealand milk. They didn't see it causing a problem as monensin wasn't critical to human health. **They** also didn't think t**he principle of prophylactic feeding of monensin would cause any issues with consumer confidence in the future.**

John Williamson gave me a tour of his laboratory and the facilities at Lye farm.

Figure 39: Apparatus to measure methane from cows

Figure 40: Entrance to Lye Farm

Figure 41: John Williamson of Dairy NZ holding a Farm Medix check-up plate

Figure 42:Rotary milking parlour

Figure 43: Feed trial cubicles

Of greatest interest to me was the work he had done to validate the Farm Medix testing kit on behalf of Dairy NZ. For me this confirmed that the kit offered value to farmers in terms of efficacy.

The culture of the New Zealand dairy farmer that I experienced was to attempt to treat the herd as opposed to the individual cow in an attempt to maximise the number of cows per labour unit.

In South Dakota, USA, I witnessed a similar objective for dairying large numbers of cows with low numbers of staff.

Figure 44: Dakota Plains dairy farm

Dakota Plains Dairy was a 160 acre concrete pad where 4,200 cows were milked on a zero grazing system. All feed including forage was purchased, the cow barns were ventilated on a horizontal fan basis, temperature being controlled.

Figure 45: Feeding 4,200 housed cows at Dakota Plains dairy farm

Figure 46: Silage clamps in background at Dakota Plains dairy farm

Figure 47: Feed store at Dakota Plains dairy farm

Figure 48: Rotary parlour with robotic teat sprayer at Dakota Plains dairy

Figure 49: Left to right: Aled Davies and Nial O'Boyle, vet and farm manager, Dakota Plains dairy

The farm has a rolling SCC of around 240,000 cells per ml of milk, which Nial admitted was high. He thought it was high as a result of the bedding sand, which they recycle, being too moist. His big objective is to prevent a bulk milk tank antibiotic failure.

They operate a simple mastitis control programme. They blanket treat all cows at drying off with a broad spectrum antibiotic. During lactation, if a cow is suspected of having mastitis, she is transferred

to the hospital group, the high SCC quarter is identified by Californian Milk Test. On further visual examination, a decision is made if she should be culled, if the infected quarter should be dried off, or if she should return to the herd intact. The farm cull in excess of 40% of their cows per annum. The risk of polluting the bulk tank is too great. Nial commented that whilst he doesn't want to flood the **herd with new heifers, this strategy is economically viable as long as the beef price achieved for a cull cow is close to the heifer replacement cost. He also commented that there is an ample supply of dairy heifers in America.**

The farm owners had recently secured planning permission for another 6,000 cow unit some 20 miles away, operating on the same principles. I discussed consumer perception of high culling rates with Nial. He commented that it was likely to be an issue in the future.

4k. Full Integration – the effect on the veterinary economic model

In a meeting with Kenton Shaw, General Manager of Rivalea Australia, I got an understanding as to the benefits of an integrated company in terms of controlling the limitation of disease from farm to plate. I also understood that by being integrated, and controlling/owning the breeding/farming/processing/distribution and marketing of end products, consumer perception was of major importance to this farming company. (https://www.rivalea.com.au)

Figure 50: Image from Rivalea Australia's website

Figure 51: Sign at entrance to Rivalea's pig farm

For their 40,000 sows, they employed one full time vet and two consultant vets. I questioned Kenton as to the process of prescribing antibiotics. He confirmed that there was no economic benefit to their company vets from supplying antibiotics. He continued by stating that their mission is to find the causes of disease, and eliminate them by improving husbandry or hygiene. In the last few years, they have been able to move away from antibiotic use to the use of more bacterial vaccines as and when they have become available.

Kenton stressed the point that preventing disease at an early age was paramount. The earlier a pig became infected, the more problematic the whole growing process would be. He confirmed that limiting environmental stresses and building robust hygiene systems especially when piglets are young were key profit drivers for their business.

I got the same message when I visited Robert Peffer, a fellow 2015 Nuffield Farming Scholar on his family run New South Wales egg laying poultry farm. A reduction in disease infection at hatchery improved production in laying hens.

Figure 52: Chicks in a hatchery

continued on next page

Figure 53: Sign to indicate biosecurity level

The message was further driven home when I visited Huan Aquaculture in Tasmania. Steve Percival, company vet, confirmed that the success of biosecurity measures in preventing disease at the hatchery was a major variable in the performance of fish when they went to sea cages.

Figure 54: Fish being transported for weighing and grading

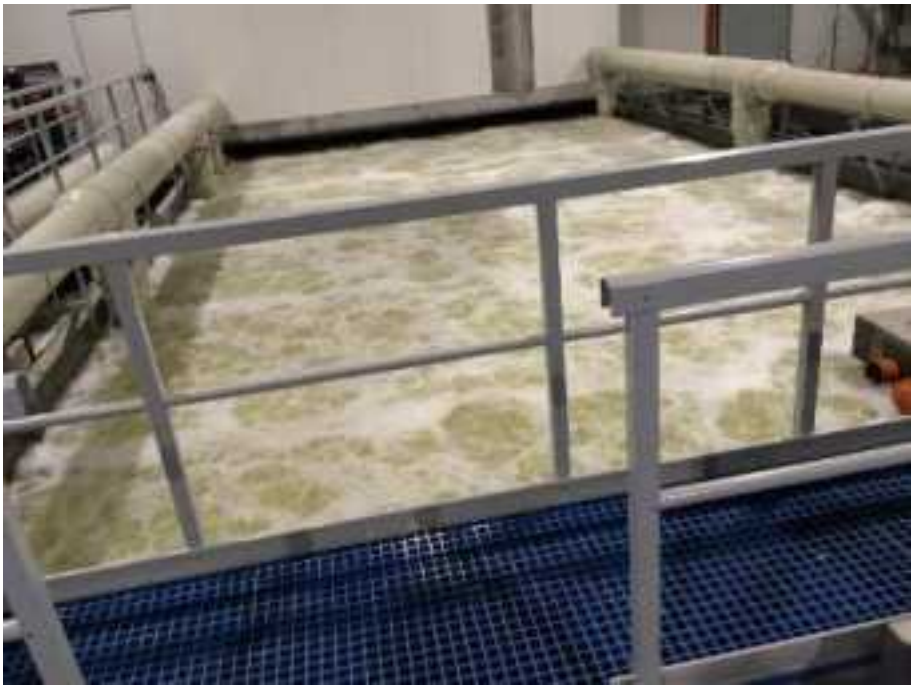

Figure 55: Water purification

Figure 56: Fish faeces extraction from water

4l. The role of the stockman

Whilst in Hamilton, New Zealand, I visited LIC automation. They have developed in line Rapid Milk Test technology. Within a parlour, their system, named CellSense -one per four jars/cows, in the parlour, will highlight cows with high SCC.

In Denver, Colorado, USA, I visited Scott Cockroft of BallaAg. Scott, along with his brother, farms 2000 acres in Kersey. On the farm there are 900 dairy cows, and they grow forage, with the majority of crops being under irrigation.

Figure 57: Scott Cockroft's farm yard

Scott had read an article in Hoards Dairyman magazine on the 10-day temperature check protocol for cows. He found that by performing rectal temperature checks on his cows for the first 10 days post calving he could help maintain healthy cows, and improve fertility. He identified infections in his cows quickly, and found that by ensuring the cows were properly hydrated, he could limit the use of antibiotics in his herd. He was using equipment manufacturer by EllaAg

BellaAg was formed with the aim of developing a technology to measure cows' temperature easily. **Scott claims that their bolus technology helped him reduce the use of antibiotics in the herd by 90%. He supplemented cows that showed temperature hikes with electrolytes, trace elements and** vitamins. "*The system told me that an infection was going to happen in three days' time*"**, he stated.**

Each cow is given a bolus with a five year life. See photo below.

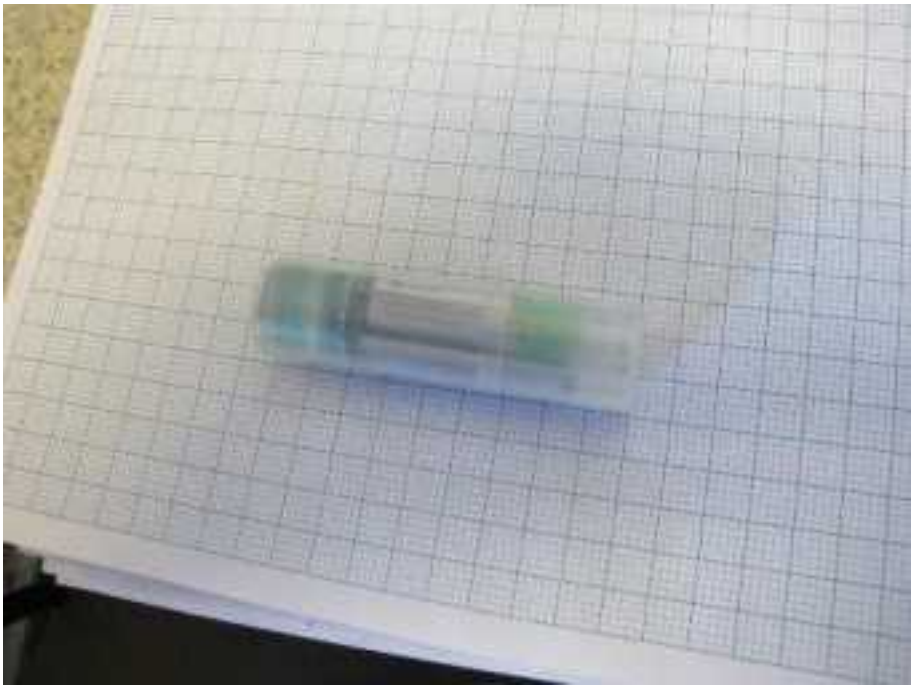

Figure 58: Each cow is given a bolus with a five year life

Figure 59: A BellaAg data receiver in the collecting yard

A radio receiver assembled in the collecting yard collects data from the boluses as cows wait to be milked.

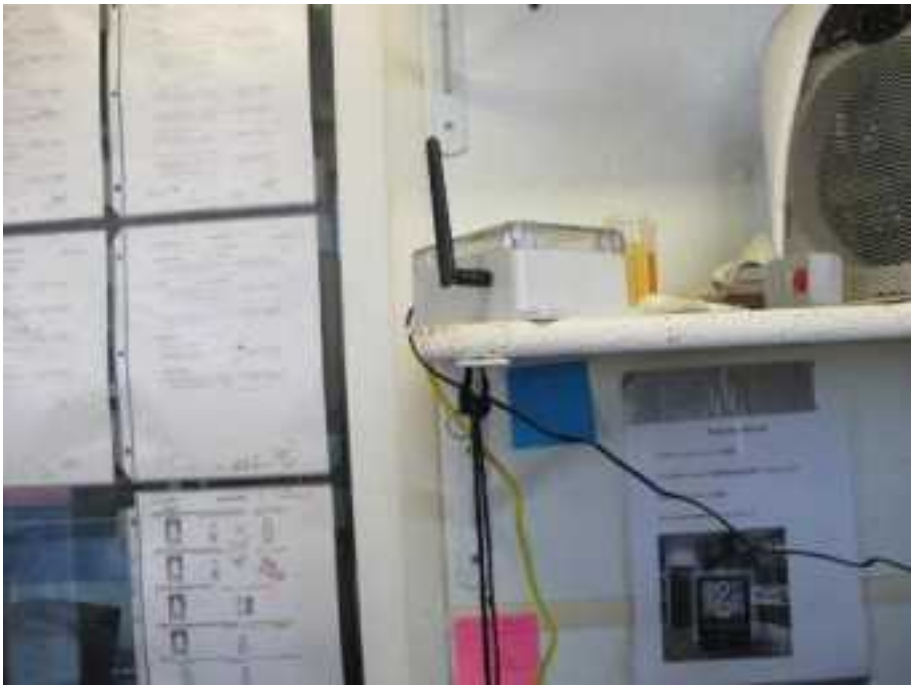

Figure 60: A photo of BellaAg data receiver in farm office

The data is sent via radio wave to a receiver in the farm office.

Post milking, cows are identified as: Normal, Spiking in temperature (Purple), and Confirmed three days temperature spikes (Red).

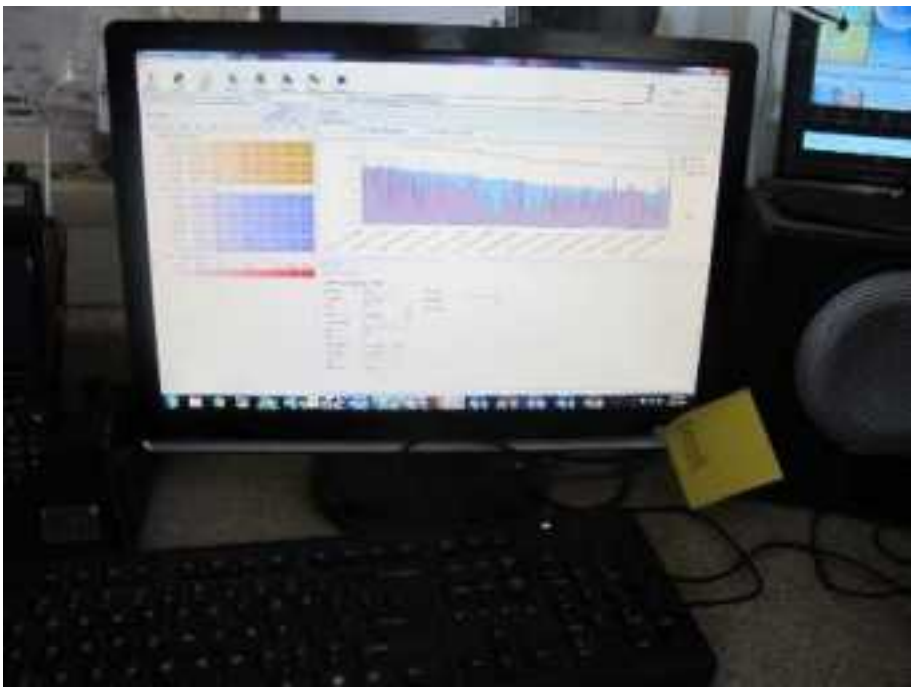

Figure 61: A photo of BellAg data on computer screen

This system, as well as the LIC Automation system are both a fantastic aid to management. Knowing that an infection is beginning to develop is very powerful in fighting an infection early, and limiting the need for veterinary intervention, or administration of antibiotics.

Identifying SCC mechanically does highlight that an infection has taken place in the udder. It could be argued that the infection has already taken hold.

Highlighting a temperature spike tells a farmer that a cow needs examination.

Scott told me of early issues with the system. The boluses would highlight cows that were temperature spiking. The farm staff/farmers wouldn't accept that there was anything wrong with the cows. They **knew their cows, and they were fine. However, three days later, those cows became sick.**

Technology on large farms with low staff numbers will become more important if culling rates decrease. In the fight against infection, an early warning system could be vital.

Figure 62: Left to right: Stephen Weilnau, Technical Manager BellaAg, Scott Cockroft, farmer and shareholder BellaAg, Aled Davies, Caradog ab Aled

4m. The danger of complacency

Whilst at a meeting with Andrew Litchfield and Andrew Denman, both mixed practice vets at Orange Vet Hospital, New South Wales, Australia, I was given a real life example of how complacency might cause AMR. A hobby beef farmer had called at the practice with a pet goat that needed treatment with antibiotics. Having diagnosed the animal, and treated with an antibiotic, the remaining antibiotic in the bottle was sold to the farmer so that he could administer follow-on doses. If that farmer became complacent and administered the antibiotic to a different animal, then resistance could potentially develop.

4n. Regulation and control

Driving from Melbourne, through Victoria and New South Wales to Sydney, I got a perspective as to the remoteness and sheer distance that exists between farms and veterinary practices. Andrew

Litchfield of Orange Vet Hospital, New South Wales, Australia explained how the veterinary profession managed the issue of distance in terms of prevention of AMR.

As vets in New South Wales, it is a regulatory requirement - they have to visit each farm client once a year to formulate a standard operating procedure policy. A health plan, it allows farmers to hold a stock of antibiotics, which under certain circumstances, they can administer to their livestock without the vet seeing the animal; for welfare reasons, and to save time and cost for the vet.

4o. Hoof pressure and immunity

Figure 63: A cow walking through a footbath

As sales director for Kilco, I get involved in new product development. A new footbath product really got my attention.

The photo on the next page shows digital dermatitis infection on a cows' hoof after three walk**-through footbaths on consecutive days. Whilst the cow** wasn't badly lame, the infection was significant. I **always knew that this disease troubled cows, but seeing the extent of the infection made me think of** the effect of this on the cows' immune system. I asked myself, if a cow is fighting this intensity of **infection can the immune system cope with other potential infections or stresses?**

Figure 64: Close up photo of a cow's foot showing digital dermatitis infection after three walk-through footbaths on consecutive days

4p. Focus on monogastric

Dr David Shapiro is Director of Veterinary Services for Perdue Foods. They are the 3rd largest broiler farming company, and are the largest producer of organic and antibiotic-free broilers in the USA. They process 12m birds per week from 2500 contract grower farms. And 10m Turkeys per annum. They are fully integrated, have parent stock, hatchery, growers, processing and post processing facilities.

They market their meat as being: No antibiotics ever.

Figure 65:Image of Perdue Foods website, confirming objective to use no antibiotics ever

In my discussion with him, he confirmed that *"All our chicks are placed without the use of any antibiotic in the hatchery, ever. We use no antibiotics whatsoever in the feed. That includes not using any ionophore coccidiostats. So, although the intention is to deliver all the chickens to the plant as 'No Antibiotics Ever', when flocks get sick and the veterinarians determine that they need antibiotic treatment, they are treated with antibiotics."* **The ones given antibiotics are diverted to a different market, via a different route, vigorously audited by the US Department of Agriculture.**

The process of going from: "*Continuous antibiotic use, to no antibiotics ever, has taken 10 hard years***."**

On a high disease occurrence year, 5% of their birds are treated with antibiotics and diverted to a less premium market. On a healthy year, only 1% are treated and diverted.

His definition of husbandry included nutrition, water sanitation, improved staff and environmental sanitation, improved cleanliness, efficient use of vaccinations, and water treatments with natural remedies. He also emphasised the role of reducing conditions on farm conducive to bird stress. Natural remedies include pre and probiotics, yeasts, vitamins and minerals and essential oils. These natural remedies are used in both water and feed at various times. Whilst he sees these as a very small addition to the birds' diets, they are a major part of the live production department's t**oolbox to maintain healthy birds, and are a focus for the marketing depa**rtment's **toolbox in generating a premium for their end product.**

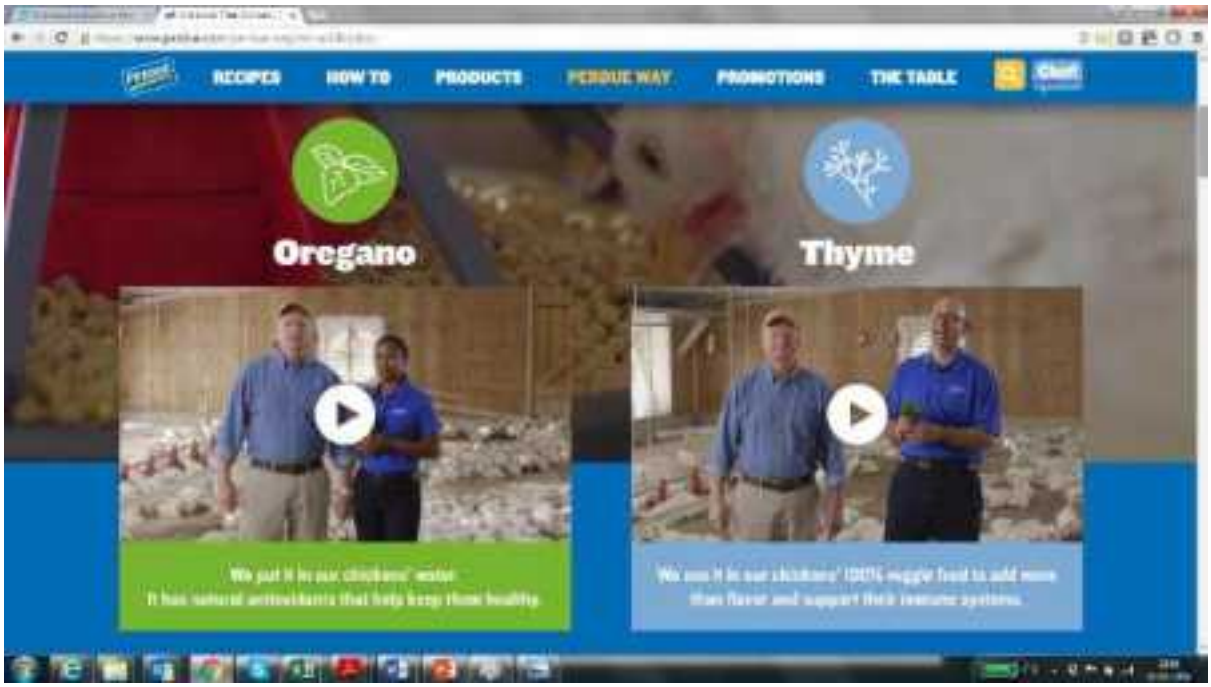

Figure 66: Image of Perdue Food's website, confirming use of essential oils

On further questioning, he confirmed their strategy for reducing to a target of zero their use of antibiotics:

1- Absolute best practice in husbandry
2- Early detection, diagnoses and treatment of disease.

As a business, they have invested in both their own laboratory facilities as well as spending at outside laboratories to improve their diagnostic capabilities. The natural remedies play their part when bacterial infection is at an early stage. Hours can make big differences.

With their investment in laboratories and diagnostics, they have no issue with detecting coccidiosis, nor clostridial infections. They have been able to learn about infection sources and manipulate their hygiene protocols to suit.

4q. Stress and infection

Alex Zieleman, Almarz Dairy, Ontario, Canada

Along with his family Aklex farms 200 cows. When we were discussing his calves, he made a comment that immediately caught my attention.

The previous year, he had had trouble with calf scour. The calves struggled with heat stress. This year, they were preparing an extension on their cow barn and were able to assemble their calf hutches indoors. He commented that the calves had no scour problems this year due to no heat stress.

Figure 67: Left to right: Alex Zieleman's daughter, Alex Zieleman, Caradog ab Aled, Aled Davies, Alex Zieleman's son

Figure 68: Calf hutches indoors at Alex Zieleman's Almarz Dairy

Figure 69: Calf in hutch at Alex Zieleman's Almarz Dairy

4r. More than genotype

During my time in Canada, I visited the offices of both EastGen and WestGen. They are two of the farmer-owned companies that own Semex, the exporter of Canadian Dairy genetics.

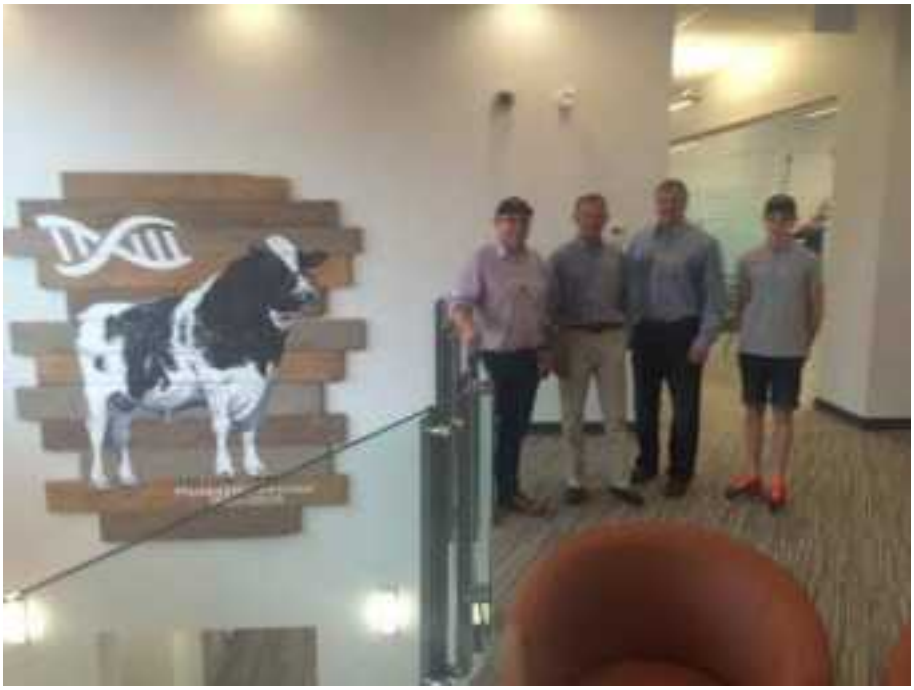

Figure 70: Left to right: Aled Davies, Paul Mayer, Chris Parry, both of WestGen and Caradog ab Aled

Here I really got an understanding of:

- **The role of genetics in the fight against AMR**
- **The role of environmental factors in preventing infection**

To understand the role of genetics in the fight against AMR, Paul Mayer gave me a comprehensive presentation on immunity.

I lerned that there are three types of immunity

- **Passive**
  - **Initial and temporary**
  - **Passed through colostrum**
  - **Contains protective features from dam**
  - **Fades as own immune system matures**
- **Innate**
  - **First lie of defence against harmful microbes**
  - **Non-specific responses**
  - **No memory of past exposureto pathogens**
  - **Not long lasting**
  - **Initiation of Immune response**

- **Adaptive**
  - **Primed by inate immunity**
  - **Recognises a broad range of micro-organisma and remembers them on subsequent exposure**
  - **Specific and long lasting**

The following two slides helped me futher understand how adaptive immunity is split in two.:Type 1 fighting viral infections and Type 2 fighting bacterial infections.

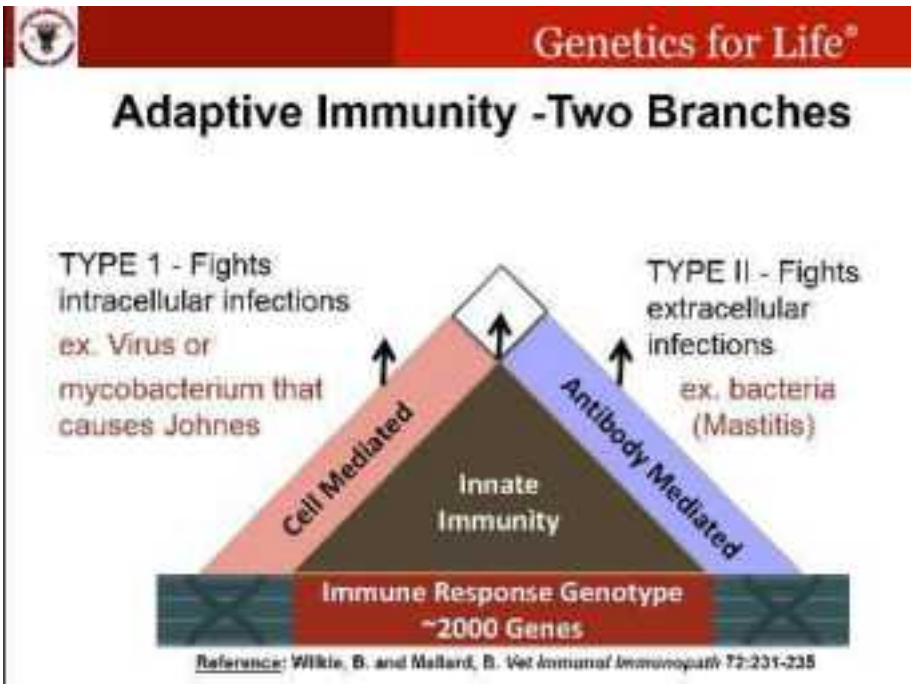

Figure 71: Image showing the two branches of adaptive immunity

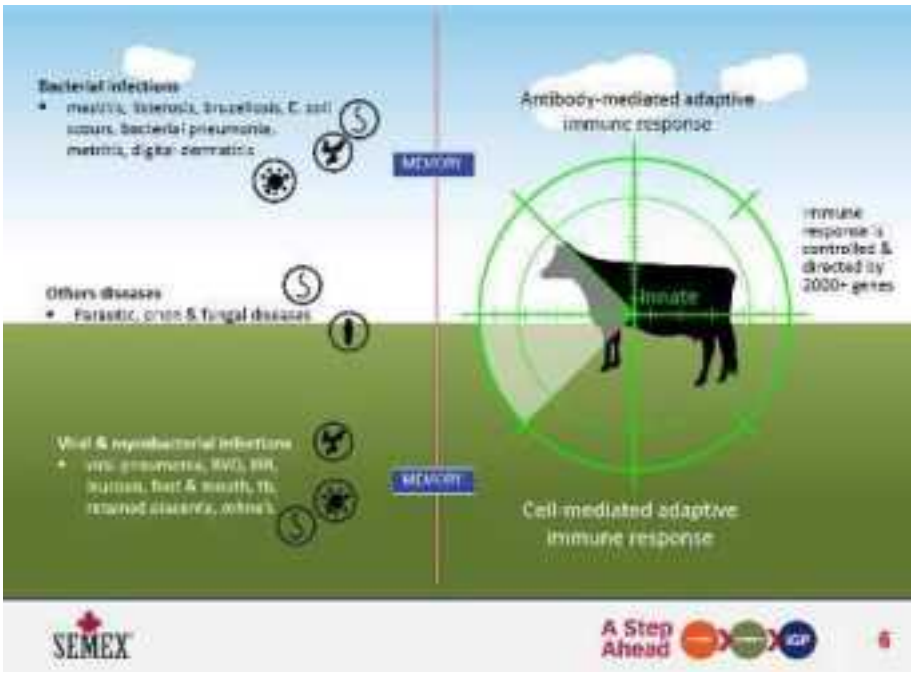

Figure 72: Image showing different types of infections and the immune response used to defend against them

Our discussions were varied in terms of species. When I discussed stress affecting immunity, Paul gave me the following equation:

Phenotype (What you see) = Genotype (Genetic potential) + Environment

This made perfect sense to me. Stresses from the environment allowed bacterial and viral infections to take hold. Alternatives to antibiotics could therefore be a means of preventing environmental stress on the animal's immune system.

4s. A new veterinary economic model in practice

East of Calgary, in Alberta, Canada. I visited Namaka Farms Inc. Contracted to McDonalds, the feedlot finished around 32,000 head of cattle from its 5,500 acre farm. 25,000 cattle were fed the day I visited. They grow silage on their 5,500 acres with 1,500 acres being under irrigation.

The owner, Stuart Thiessen, was the first farmer I'd spoken to **who questioned the threat of AMR. He could not see where the problem was. He had been using broad spectrum antibiotics for years with no proven resistance on his farm.**

On questioning further, he explained that some 25 years ago, his father had done a deal with their vet whereby the vet got a headage payment and supplied all treatment medicines free of charge. I nearly fell off my chair. I wish Stuart would have been with me in Uppsala all those months before.

Figure 73: The Namaka Farms Inc. sign

Figure 74: Grain store at Namaka Farms Inc

Figure 75: Feedlot cattle at Namaka Farms Inc

Figure 76: Left to right: Caradog ab Aled, Aled Davies and Stuart Thiessen

Figure 77: Feedlot cattle at Namaka Farms Inc

Figure 78: Feedlot cattle at Namaka Farms Inc

As a result of his deal with the vet, Stuart commented that there is a team ethic to prevent disease from happening.

He commented that young cattle, especially ones that have been stressed by transport or other factors prior to arrival at the feedlot, are very prone to disease. They concentrate on getting young cattle healthy as soon as they can.

4t. Nailing the vocabulary

At Ontario Vet College, Guelph, Canada I met David Kelton, DVM, PhD, DFO Research Chair in Dairy Cattle Health, Professor of Epidemiology, Department of Population Medicine University of Guelph: and his wife, Dr. Ann Godkin, Veterinary Science and Policy Unit, Ontario Ministry of Agriculture and Food and Ministry of Rural Affairs.

We discussed my findings on my travels from start to finish. Of all the subjects we discussed, the one that stuck with me, and annoyed me, and nagged me the most was our discussion about culling policy on dairy farms. The question posed to me by David was: *"If farmers were culling high SCC cows, were they culling the cows with the best immunity?"*

The answer of course was yes. A high SCC illustrates a strong immune response, but I was uncomfortable in delivering my answer.

Our discussion on leadership caused more dilemma. Where would the veterinary industry source income in future if the traditional model of low call out fee and high drug margin was to change?

Dr. Ann was confident that even though there was change ahead, probably as a result of regulation, the veterinary industry had a bright future if the vets can learn to adapt.

Where we all struggled was in answering the question: *What does good/responsible antibiotic use on farm look like, and how can we control it so that we limit AMR?*

The discussion finalised some vocabulary in my mind. Dr. Ann suggested we use the term "Prudent use of antibiotics" as an aim.

4u. The danger of assumptions

Leon Spurrell Director of Farm Medix, the company from New Zealand that manufacture diagnostic kits, and I visited Glen & Tony DeGroot in Chilliwack, British Columbia, Canada. They farm 120 high yielding Holstein cows using Tonesa as a Prefix.

Figure 79: Left to right: Caradog ab Aled, Aled Davies, Tony and Glen De Groot

The big area of discussion was centred on cattle bedding and cattle lameness. Tony, the father, commented that if digital dermatitis was originally found in Italy in 1971, how did it get to his farm in British Columbia? There was a debate about farmers that bed cubicles with sand having more heifers to sell due to lower culling rates, but big costs to replace the machinery the sand destroys. The discussion moved on to assumptions about hygiene and SCC. Leon Spurrell confirmed that Farm Medix have found staph aureus in cows whose SCC was as low as 50,000 cells per ml of milk. That cow didn't **have a strong immune response, and was a carrier that could infect other cows. As a result of that conversation, Leon Spurrell was asked to take swab samples from the farm's teat dip cup and from inside a teat liner twenty minutes after washing through, to find out if any bacteria had survived the farms current hygiene regime.**

The milking parlour looked spotless. I assumed it was very clean.

Figure 80: Clean milking parlour

Figure 81: Leon Spurrell taking samples

Figure 82: Farm Medix incubator

Tony sent us a photo of the plates the following morning: not a full 24 hours' growth. The results for both show the existence of bacillus Spp. Bacillus cases can cause acute mastitis. Infections can be difficult to treat. Sources of bacillus spp include soil, water, dust, faeces, vegetation, wounds and abscesses. The father and son whilst I was with them deliberated about moving from sawdust bedding to sand. They assumed that they were having problems with E.coli mastitis. Whilst sand would carry less threat of bacteria, the sawdust does not damage their machinery. They decided to stick to sawdust. They have implemented a whole new hygiene regime on their farm to limit the risk of infection which includes a strategy for cubicles. I experienced with my own eyes on this farm, the importance of knowing what bacterial challenges exist on farm if we are to truly develop alternatives to antibiotics. Due to accurate information, these farmers learnt how to better manage the risk of bacterial infection on their farm. They could make evidence based decisions to protect their business.

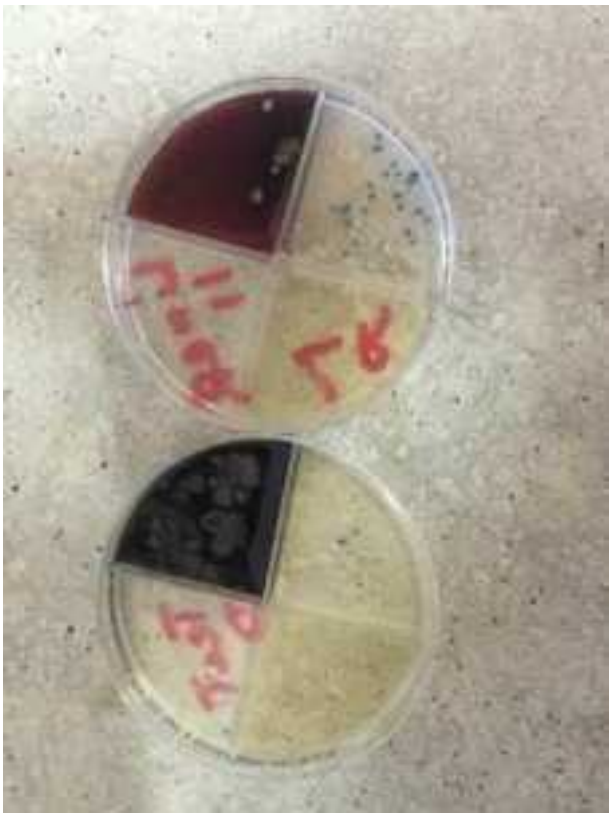

Figure 83: Farm Medix plates showing growth of Bacillus Spp

4v. Realising the obvious

All throughout my Nuffield Farming study I hadn't been able to visualise the control process for **prudent use of antibiotics. In Cilliwack, British Columbia, Canada, that evening, I visualised the way forward.**

> **Hygiene companies delivering evidence-based solutions to on-farm threats, limiting the introduction of disease and helping reduce infection pressure could be the alternative that allows farmers in all sectors to use antibiotics prudently.**

5. Discussion

From 1928, when Sir Alexander Fleming, a Scottish biologist, discovered the antimicrobial properties of a mould called penicillin, through to the time of the Normandy landings during World War II in 1945 where it was assumed that enough penicillin had been produced to treat the bacterial wounds of the Allied soldiers, antibiotics have been the main weapon used to help the immune systems battle against bacterial infections, especially in developed countries.

In their natural surroundings, and under normal stress conditions, bacteria don't seem to develop a **resistance to antibiotics. But, when fatal antibiotic stresses are introduced to bacterial colonies, the populations of bacteria with the greatest tolerance to the antibiotic survive the longest and become the dominant genetic population for further growth once the antibiotic stresses diminish and stop. Under-dosing of antibiotics will therefore result in antimicrobial resistance as the most tolerant bacteria survive longer than the dose of antibiotics. The duration of time of supplementation is critical in ensuring a total kill of the target bacterial population. Additionally, if antibiotics are given to animals** or people that don't have an infection, then some **form of bacteria present in the body, not causing a disease, might develop a resistance to the antibiotic given and become problematic to the patient.**

Bacteria can also transfer their drug-resistant properties to other forms of bacteria, similar to a trade. So, every time an antibiotic is administered to an animal or human, there is a real risk that bacteria within the animal could become resistant to that antibiotic, rendering it obsolete as a means to help fight that bacterial infection.

The same types of antibiotics are used by doctors, dentists and vets to treat bacterial infections. So, both humans and animals can be media to develop resistant bacteria if the antibiotics are not used prudently. Both humans and animals have the ability to render antibiotics obsolete as effective medicines.

In generating a strategy to limit the threat of anti-microbial resistance, we as humans have a great deal to learn from bacteria. They change according to stress, and adapt to the environments they inhabit. They cooperate for the greater good, with the aim of the survival of their genetic pool.

Resistant bacterial infections can't be treated by antibiotics. **Even simple surgical wounds that become infected by antibiotic-resistant bacteria could prove fatal for patients, as did normal bacterial infections pre the discovery of antibiotics.**

To avoid agriculture becoming a "scapegoat" for this global issue, agriculture must take the lead in the **fight against AMR. To do so, farmers must develop and implement evidence-based treatment strategies to ensure prudent use of antibiotics and be able to demonstrate to consumers that they are able to achieve prudent use of antibiotics. Evidence based analysis of bacterial loading on farm will need to be used to i) create new and adaptive hygiene systems that limit the introduction of disease to farm animals - systems that can modulate according to the extent of the challenge, ii) highlight the need and appropriate timing of administration of nutritional supplementation with immune-stimulating or -suppressing feed inputs, in order to reduce the pressure of infection on the immune system.**

Blatant non prudent use of antibiotics in agriculture could easily be blamed for the development of antibiotic resistant bacteria and the return to a pre-antibiotic era of elevated disease, fatality of human populations, and increasing food costs. The threat of such a scenario might fuel the rise of cellular agriculture as a morally acceptable source of food: meat products and milk grown from stem cells.

Non prudent use of antibiotics in humans could develop resistant strains of antibiotics that could infect animals and drastically affect efficiencies of food production, elevating the cost of meat and milk protein. There is a growing academic and moral dilemma developing. Governments have to toy with the concept of limiting access of developing countries to the latest antibiotics. Agriculture needs to take the lead in the fight against AMR or we might find that the latest antibiotics are restricted from use in our industry.

The triangle of farming vocabulary in terms of antibiotic use has long been missing one element.

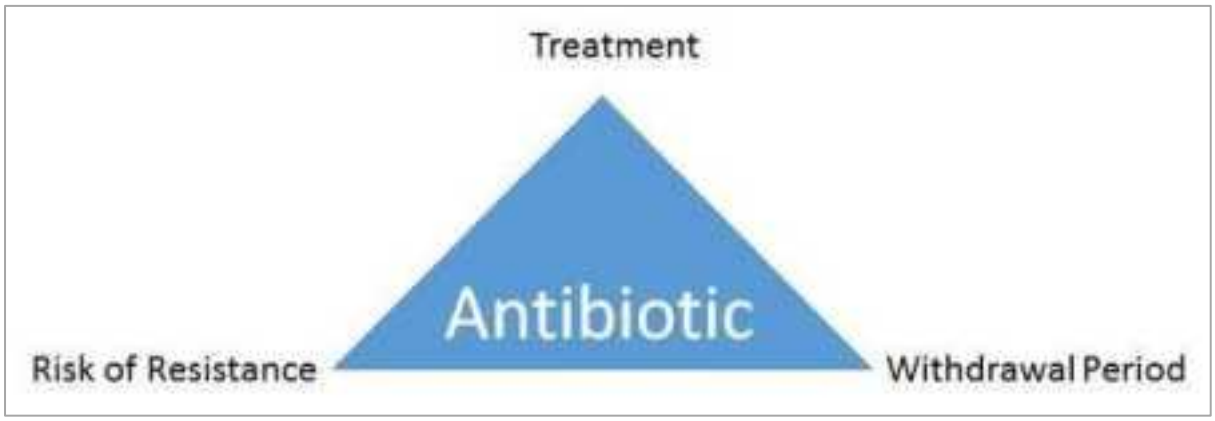

Figure 84: The antibiotic use decision variable triangle

As farmers we have used the words treatment, antibiotic and withdrawal period, when discussing an infection with a vet or representative from a drug company. We have not, in my opinion - based on my discussions with farmers during my travels - held a discussion with regards to the risk of developing a bacterial resistance to the antibiotic we intend using.

The use of antibiotics in agriculture has allowed farmers to optimise the welfare of their animals. Sick and infected animals have been diagnosed and treated. However, animals that did not require antibiotics have also been treated with antibiotics. The focus has thus been taken away from understanding the root cause of infection. The understanding of how environmental stresses from dirt, heat, cold, lameness, overstocking, limited access to clean water, poor ventilation have all served to overwhelm and limit the immune system's capability to fight infection. This is even more important when considering the health and wellbeing of young animals. A common theme through my comparisons of species during my study was the increased susceptibility of young animals to disease. Once I understood the equation: phenotype = genotype + environment: I understood why. Young animals have an additional stress factor i.e. growth in their environment.

Prudent use of antibiotics requires evidence based, accurate and rapid identification of the type of agent causing an infection. Identification of the cause of infection allows the following choice of actions to be decided on:

- **Treat or not with antibiotic**
- **Treat with hydration and immune stimulating products**
- **Adjust husbandry and/or improve the hygiene protocols to reduce the chance of further infection.**

Each country I visited applied regulations on the use of antibiotics within agriculture in a different way, but all with the aim of achieving prudent antibiotic use. Some regulations have changed during my study period, and will likely change again going forward.

The solution to limiting AMR, in my opinion, does not lie entirely within the realms of legislation and regulation. The solution lies within the capitalist model of competitive advantage. AMR, in my opinion, is the greatest opportunity for agriculture in my lifetime. Agriculture can lead the global fight against AMR and prosper by doing so. I experienced in America a growing market for antibiotic-free food. Whilst I would prefer to see a sick animal treated with an antibiotic if the bacteria are known to be susceptible, and its food product enter the food chain once the withdrawal period has elapsed, I can understand why consumers would generate demand for food produced with no antibiotic use.

The more the farming business I visited was integrated, the more important consumer perception was to the people I was talking to. The better farmers get at communicating brand values to consumers, the more likely the consumers are to back them financially. *"A brand is no longer what we tell the consumer it is – it's what consumers tell each other it is."* **Scott Cook, Co-founder Intuit (financial business software)**

Developing evidence based strategies to ensure prudent use of antibiotics is only half the job. We also need to ensure that those values are transparent to the consumer. We need to let them see that we are good at dealing with disease and that our health and hygiene programmes will limit the risk of AMR, so that they can tell each other that we are good at what we do and that we won't be causing **AMR**

I translated three signs as I travelled:

Please see photos on next 2 pages:

Figure 85: Use antibiotics on your animals as you would on your children.

Figure 86: Poor hygiene isn't always visible.

Figure 87: Infection risks change over time, especially when stress increases.

6. Conclusions

- **Agriculture has a great opportunity to lead the process of limiting antimicrobial resistance through individual farming businesses developing evidence based strategies to ensure prudent use of antibiotics.**

- **Farming businesses, large and small, communicating with consumers the way in which they ensure prudent use of antibiotics in order to limit antimicrobial resistance will prosper.**

- **Commercial companies offering hygiene and nutritional services with the aim of limiting the introduction of disease and reducing infection pressure on livestock will become the alternatives to antibiotics in agriculture, by enabling farming businesses to develop and demonstrate prudent use of antibiotics.**

- **Failure to demonstrate evidence based prudent use of antibiotics by the agricultural sector will result in new antibiotics being reserved for human use and restricted from agricultural use.**

- **The choice as to how to achieve prudent use of antibiotics is for the farmer to decide. Nutritional supplements and immune stimulants can work within the framework of elevated hygiene and husbandry.**

7. Recommendations

Farmers, regardless of species of animal farmed, should develop evidence based strategies on their farms to enable them to demonstrate to consumers their prudent use of antibiotics.

Farmers should focus on limiting the introduction of infection and reduce infection pressure by:

- **Identifying quickly what is causing an infection**
- **Treat the ones that have a bacterial infection and that can be treated effectively with antibiotics, quickly, ensuring correct dosage.**
- **Cull and dispose efficiently the animals that have resistant bacterial infections**
- **Ease the pain of the ones that have bacterial infections and can't have an antibiotic with anti-inflammatories, and hydration.**
- **Supplement the non-cull, infected animals with stimulants to help their immune function**
- **Hydrate the animals that have viruses**
- **Ensure the water they allow their livestock to drink is at least as clean as the water they drink themselves**
- **Analyse their data to determine the cause of infection**
- **Develop strategies to prevent similar infections going forward**
- **Record the estimated microbial loading of their livestock**
- **Record the estimated intensity of attack on the immune system**
- **Use their data to build hygiene and husbandry protocols to prevent disease on their farms**
- **Tell consumers how they are achieving their improvements/maintaining good practice**
- **Allow consumers to reward them with custom**

8. After my study tour

My study has taught me the importance of "knowing your enemy": **confirmation that an infection is bacterial, and the type of bacteria are starting points in building strategies to limit the introduction of disease and reduce infection pressures on farm.**

I've learned that when setting objectives, clarity a**nd thought are needed to ensure that the simplest route is taken to achieve the goal set. When communicating an objective with others, that there needs to be a confirmation that all understand the objective and the constraints that need to be adhered to. I**'ve also learned that once the goal and constraints are set, and that everyone involved understands **them, that to get people to buy into the project, they need to be empowered to suggest how the goal should be achieved.**

In order to help farmers use and demonstrate prudent use of antibiotics, I have resigned my position as Sales Director of Kilco and am setting up my own company: PRUeX Ltd. (PRUdent not EXcessive antibiotic use)

By working with farms to identify their current and changing potential disease problems, we can help them work out how to combat them by providing hygiene, nutritional and pest control solutions to prevent those problems from escalating, and build robust protocols to prevent future problems. To aid farmers in this role, I have secured distribution rights for Pruex of the Farm Medix product range in Great Britain.

Once a farm has developed strategies to ensure prudent use of antibiotics, they need, for the sake of securing new antibiotics for agricultural use in the future, to be able to communicate their good work with consumers. I hope to share what I've learnt about branding throughout my career, this study**, and from t**he Chartered Institute of Marketing's continual professional **development programme, with farming groups, individual** farmers, the Young Farmers' Cl**ubs and the wider industry.**

9. Executive Summary

Stresses form the environment that surround animals put pressure on their immune system which if excessive for the animal, allows infections to take hold. Since the 1950s, farmers have used antibiotics to treat infections that have taken hold due to the environment animals have been kept in. The discussion on use of antibiotics has centred on withdrawal periods with little or no consideration for the risk of generating resistant bacteria from under-dosing with antibiotics or treating with antibiotics when there was no reason to do so.

Bacterial vaccines are the only medicinal alternatives to antibiotics accepted by academia and science. Products and services that limit stresses from the animals' environment are therefore the only non**-medicinal alternatives to antibiotics available to agriculture.**

Across all sectors studied: fish, monogastric, ruminant – young animals are most at risk of infection as their immune systems develop. Prevention of disease at this stage of production determines later life production output and affects farm profitability.

Farmers have to start using antibiotics prudently, then demonstrate their ability to do so to consumers, legislators, government and lobby groups in order to secure future access to new antibiotics and to secure viable income going forward.

The farming companies studied that were fully integrated, from animal to plate, understood the need for communication with consumers and for demonstrating their brand values. They communicated their efforts to limit the use of antibiotics in their production systems. They benefited financially from doing so. They dedicated time and effort into the process of identifying the cause of infection, viral or bacterial, then the type of bacteria causing infection. They then went further and fine-tuned their hygiene and husbandry practices to eliminate the stress in the animals' environment that enabled the **disease agents to take a hold.**

Hygiene companies can help farmers identify the cause of infection on farm, and work with them to limit the introduction of disease and reduce infection pressure.

The problem of antimicrobial resistance and the threat of a return to a pre-antibiotic era can be the biggest opportunity in my lifetime for agriculture. Farmers need to take the lead, develop evidence based strategies to enable prudent use of antibiotics and then communicate their ability to do so to consumers. By communicating these brand values, they can gain consumer buy-in.

10. Acknowledgments and Thanks

I'd like to thank the Nuffield farming Scholarship Trust and the Royal Welsh Agricultural Society for investing in my participation in this Scholarship scheme. I have learned the difference between leadership and management and am grateful for the insight and support.

The never ending support of my wife Caryl, and our children Caradog and Gwenno has been invaluable over the last eighteen months since being awarded the Scholarship in 2014, and to our extended families for providing the support network to enable travelling.

To Gerry and Margaret McGladery and the staff at Kilco International for supporting me through my Scholarship and allowing me time to be spent outside the business.

To all the people across the countries I visited who helped play a part in some way to make this all possible.