Applying Principles of Immunology for Sustainable Dairy Production

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Introduction:

> *"When we have textbooks devoted to the 'production diseases' in farm animals, the time as come for deeper introspection and to reassess how we are caring for our animals today and whether the increased dependency on 'immunological fixes' we are embracing are actually papering over the deficits of husbandry."*

This paper is intended for critical thinking about what we are doing with the immune system of animals in our care and doing it right. It is intended to prompt critical thinking in considering how we use the immune system. Do we protect the immune system, or do we exploit it?

In terms of applied veterinary immunology, animal production has greatly benefited from the scientific advances made in giving us a far greater understanding of how the immune system functions and the interaction between pathogens and immune processes. These new insights have enabled the development of improved immunological tools in terms of new vaccines and better diagnostic capabilities.

Such advances have brought us into a new watershed of livestock production. Better immunological tools have allowed animal agriculture to intensify and create new efficiencies and greater economies of scale than ever before. But behind the economic accomplishment, there is growing concern about how sustainable our animal production systems really are, whether we are too dependent on external inputs, whether we are using up too many resources, and if we are really paying the 'full cost'.

From an applied immunology perspective, we might also be concerned that we are testing the limits of what is physiologically and ethically prudent. When we have textbooks devoted to the 'production diseases' in farm animals, the time has come for deeper introspection and to reassess how we are caring for our animals today and whether the increased dependency on 'immunological fixes' we are embracing are actually papering over the deficits of husbandry.

During the past decade, the dairy industry has been scaling-up following the intensification pathway forged by the poultry and pig industries during the past 40 years made possible by the post-war emergence of new technology and scientific advancements.

Intensification certainly brought improved economics for the chicken and pork industries, but it also came as a double-edged sword with a considerable amount of heavy baggage. We had, and still have, very difficult lessons to learn, as there is always some new disease or production issue to emerge and resolve as we continue 'to push the envelope' towards some kind of economic nirvana that we never seem to quite reach.

There are lessons for the dairy industry to learn.

This paper emphasizes four important principles of veterinary immunology that have a specific application towards sustainable dairy production. In the process, we review the history of intensive animal systems, define sustainability, and discuss some of the ethical

consequences created by intensification. Finally, we reach our objective for creating a framework for ourselves to build a sound, ethical philosophy of husbandry focusing on protecting the immune system as a major step towards establishing sustainable dairy production over the long term.

A Short History and the Hard Lessons of Intensive Animal Production:

From my immunologist's point-of-view and 30 years experience in the veterinary biological field, I watched the intensification of the pig and poultry industry firsthand. It allowed me to ask deeper questions about how far can we can go with relying on immunological tools to keep on pushing the envelope. The continuing parade of emerging pathogens and production diseases raises questions about how sustainable our intensive production systems really are.

And it is not just the concern over controlling diseases. Whether we like it or not, society is already putting the heat on livestock industries on the ethical and welfare implications of intensive animal production. From sow crates, to battery hen cages, colostrum deprivation, to the effect on the environment of large-scale farming from contamination issues to the depletion of aquifers there is a full spectrum of issues being aired.

Bernard Rollin, the noted Colorado State University veterinary ethicist, has pointed out that to ignore society's warnings and concerns about animal ethics and welfare issues is literally tantamount to crossing the road in front of a runaway truck despite your friend telling you to look out and jump back to the curb. These issues are no longer in the sole domain of fringe politics. Indeed, animal and environmental welfare are very old, traditionally conservative values and not something recently dreamed up by political ideologues (Rollin, 1995).

We are, therefore, cautioned about complaining too much about society criticizing us. In reality, society is our friend warning us to get back on the curb. Society is only reminding us that animal production has to be sustainable and carries out an ethical duty to protect animal welfare, health and the environment.

It is important to note the trend of large farming operations beginning to respond to society. Recently, the largest pork producing companies in Canada and the USA are phasing out sow stalls. Burger King and the Wolfgang Puck chain of restaurants have announced they are going to only buy from egg and pork producers who are 'cage' and 'crate' free. Such changes will almost certainly arrive in New Zealand.

Since the 1960's, the intensification of the pig and poultry industries placed us on a very steep learning curve about the brave new world of 'bottom-line farming' that has created an obsession with economic drivers and performance parameters. We realized somewhat late in the day, intensification and our fixation with the bottom-line was surreptitiously shifting our traditional values and becoming the antithesis of optimal animal welfare, husbandry skills, and the innate understanding of stewardship of the land, animals, and the environment.

It should be a warning sign that in this era of science and technology in the 21st Century we have had to create 'codes of practice' for animal welfare. Have we lost the skill of animal husbandry so much that we now have to fix the deficit with heavy regulation, audits, and operation manuals rather than carry forward the stewardship skills and love of animals that defined the ingrained ethics of rural life only a generation or so ago?

The irony should not go unnoticed that in more recent years, we have had to re-introduce the concept of 'sustainable production'. Sustainability was once considered already implicit in our traditional understanding of agriculture. The fact that we have to re-invent it should give us pause for contemplation of just where did we lose it in the first place.

During the 1970's, the advent of new vaccines, coccidiostats, and antibiotics allowed today's poultry industry to become a vertically-integrated, intensive industry. The advent of Marek's Disease, Newcastle Disease, and infectious bronchitis vaccines along with improved anti-coccidials gave us the advantage to control serious, ubiquitous diseases that allowed a massive scaling-up to intensive production systems. The pig industry started to slowly scale-up to intensive production in the 1960's with some operations adopting Specific Pathogen Free (SPF) production methods (e.g. USA and Denmark) to control diseases. In the 1970's, SPF operations became too expensive to maintain and the pig industry soon took advantage of new antibiotics and an improved and wider range of vaccines to control emerging disease and allow for extremely large production units. One extremely large piggery in the middle of the Utah desert maintains a herd of 60,000 sows, i.e. one third larger than the entire pork production of New Zealand with our 46,000 sows spread around 250 farms.

The intensification of dairy farming has been following this same trend. Herd sizes have expanded by an order of magnitude. The term 'mega-dairies' is now often heard to describe these very large units. In Kern County, California, there are 290,000 dairy cattle on 55 farms with a dozen projects planned to add another 214,000 cows with one herd planned for 10,000 head. In Tulare County, California, there are 337,000 dairy cows in production with an average farm size of 1200 head. Most of these dairies are on based on intensive 'dry-lots' with no grazing and a reliance of grain-based supplements. However, recent moratoriums on new, intensive dairies in California and Idaho are pushing the dairy industry to seek other locations where the environmental impact meets less opposition, e.g. the New Mexico desert (as per the large piggery in Utah).

In New Zealand, we too have experienced rapid intensification with the scaling-up of dairy herd sizes during the past decade. Where once the Canterbury Plains were devoted to extensive pastoral grazing, it is rapidly being replaced with intensive grazing systems based on high-input, high-output, large-scale production technology. We are already seeing signs of our own dairy industry pushing off overseas, e.g. South America, as continued large-scale expansion is reaching its sustainable limits as experienced in California.

The euphoria of intensive animal production finds its roots in the 1960's when agricultural economists and universities famously touted the adage to farmers to 'get big or get out'. It was the message to small family farms that their future was doomed.

As an animal science major forty-years ago, my university professors preached the new message of how science and technology were going to transform farming. Every performance measure now had a dollar sign. Farmers were told to tear down shelterbelts and plant fencerow-to-fencerow to maximize the hectares for tillable production. Centre-pivot irrigation revolutionized the tedious tasks of setting water race and border dyke systems. What a welcome invention! It enabled farm kids like me to not have to set alarms for 2.00 am to crawl out of bed and stumble around in the dark to re-set the irrigation siphon tubes in the cornfield. Finally, we could sleep through until milking time. We then tapped into the aquifers as if there was no tomorrow.

But with the disappearance of the tedium and cost of labour thanks to new science and technology, our husbandry skills, stewardship, and concern for individual animal welfare

have tended to take on lesser importance. We now talk about 'flock health' or 'herd health' that in a curious way led us to diminish the overall concern for the individual animal.

We have had to learn a great deal about the new disease dynamics of producing animals in increasingly larger intensive operations that created pathological tensions we had never experienced. Minor or unknown pathogens suddenly emerged under the increased pressure of modern animal production with greater animal numbers and more confined spaces. We have gone beyond with just dealing with the endemic pathogens; we now have diseases being created primarily by our production methods.

In the dairy industry, we have a similar pattern of emerging disease issues with increases in laminitis, Johne's Disease, Milk Fever, Bovine Immunodeficiency Virus (BIV), and Bovine Leukemia Virus. Ominously, the zoonotic pathogen, *E. coli 0157*, indirectly linked to dairy farm effluent sources created large-scale food poisoning outbreaks in the USA from contaminated vegetables grown in close proximity to dairy farms. In New Zealand, we also have a pre-occupation with production-related ailments such as lameness, liver abscesses, nutritional stresses, and the cascade of illnesses resulting from colostrum-deprived calves. We need to be aware of our own zoonotic pathogens, e.g. *Leptospira* and *Campylobacter jejuni*.

The intensive poultry and pig industries have relied more and more on vaccine development to be able to cope with the emergence of new diseases. The list of poultry and pig vaccines now available looks like a department store catalogue. Preventive medicine in these livestock sectors has increasingly relied on disease control by vaccination and less on good biosecurity and husbandry. We see the same trend in the intensive beef feedlots and dairy 'dry lot' operations in the USA.

I wrote one of my *Intuitive Immunology* columns for *VetScript* and in the Clinical Ethics column of the October, 2006 edition of *Veterinary Forum* (USA) about what biologists call 'The Red Queen Effect', a metaphor used to describe the effect of 'co-evolution' where pathogens and the immune system are in a continuous arm's race against each other in an effort to maintain their respective survival. The term is taken from Lewis Carroll's story, *Alice Through the Looking Glass,* where the Red Queen tells Alice that she has to 'run faster and faster just to stay in the same place'.

It sounds all too familiar. Despite all of the progress we have made in veterinary immunology, the sobering reality is that we are often caught on the Red Queen Effect 'treadmill.' Like Alice, we never seem to quite keep pace with all the challenges we face in preventing animal disease and maintaining public health. We will discuss this in more detail.

In our discussion today, there is one underlying theme that Dr Temple Grandin, the animal welfare and behaviourist, describes as the "Ancient Contract" which simply states, 'if we take care of animals; they will take care of us.' That simple motto rings just as true today as we return to good husbandry and meet the expectations of society on animal welfare and create more sustainable production methods (Grandin, 1995).

So how DO we define 'Sustainable Production'?

In today's cynical world where image and impressions are everything and substance takes a back seat, the terms 'sustainable production' or 'sustainability' are often bandied about as marketing hype. Sadly, the terms are at risk of becoming overused, devalued or even meaningless.

‘Sustainable production’ needs context and clarity in order to give us some kind of tangible meaning.

One of the most succinct definitions of sustainability as applied to agriculture comes from Mark Graham’s excellent book, *Sustainable Agriculture.* He states: *“sustainability is not a specific set of practices, it is a concept with an end goal - the indefinite persistence of conditions necessary to produce food”* (Graham, 2005).

Graham offers a list of ‘bullet points’ that specify what constitutes sustainable agricultural production:

1. A viable farming system that integrates a complex web of reliable external off-farm positive dependencies, relationships, and support;

2. While external threats are difficult to control, ‘sustainability’ requires there is no on-farm deterioration (‘internal threats’) of breakdowns in husbandry or in conditions that create a decline in production;

3. Inputs need to be abundant, easily acquired, renewable, and consistently available for the foreseeable future;

4. There is a self-regulation process of farm ‘homeostasis’ providing predictability and consistency for healthy production;

5. A long-term capacity for consistent performance that adds, and does not subtract, from the environment and community.

It is uncanny how Graham’s terminology and description of what constitutes sustainable agriculture production matches the characteristics and requirements of a healthy, viable immune system. Thus, in so many ways, our animal stewardship is simply an extension of the entire immune process where our husbandry skills are the first barrier to disease and stress.

Applying Principles of Immunology: Seeing the Entire Jigsaw Puzzle

Immunology textbooks have a tendency to cut up the immune system into a jumble of jigsaw puzzle pieces that we eventually have to try and piece together (without having the entire picture of the puzzle to see first!).

We dice up the immune system into a confusing array of separate compartments: innate immunity, adapative and passive immunity, antibody and cell-mediated responses, etc. There are a multitude of immune cell types and organs involved. There is a heavy focus on molecular structures of immunoglobins…and then there is the Major Histocompatibility Complex: the elegant genetic code that decides the repertoire of immune responses. There are cytokines, Complement, immune effector and inflammation mechanisms. I need not go on. We know immunology is an exceedingly complex subject and it is just very difficult to connect all the dots and then put it to day-to-day use.

As with putting together any jigsaw puzzle, it certainly helps to have a complete picture of the immune system so we can visualise what it is and what it does. I find there are four helpful principles of immunology that can be applied for to understanding the protective immune

response and the role of vaccination, and a final principle that is very specific to dairy production:

- Having a new, broader perspective of immunity;
- Using the immune system comes at a physiological cost;
- Intensive production and the Red Queen Effect
- Passive Immunity and colostrum: where good husbandry begins.

First Principle: Broadening our definition of immunity:

We no longer simply take the old view that the immune response is confined to its old definition of recognizing foreign antigens and triggering host immune defenses. That is only part of a much larger picture puzzle.

A contemporary perspective of immunity is far more encompassing. We see the wider effects of the immune system on metabolism and incorporate how the host's physiological system responds not only to infectious agents and traumatic injuries (which we call '*tissue events*') but also to psychological stressors (called '*life events*') that trigger immune responses (Colditz, 2002).

The immune system is viewed as detecting an entire range of immunological stress factors that signal 'danger' and accordingly activate the immune response to regulate many physiological systems.

This broader view has deeper implications in veterinary immunology and dairy production.

It carries an inherent responsibility that we need to focus much more on minimising tissue and life events that induce 'immunological stress' and temper our over-reliance on exploiting the immune system to bail us out of trouble.

We are not only concerned with eliminating the ***tissue events*** of infectious disease or traumatic injury, but also with reducing the incidence of ***life events*** that affect the animal's comfort, behaviour and condition: unhygienic surroundings, overcrowding, poor stockmanship, inadequate nutrition, or sudden environmental changes that excessively stimulate the immune system and reduce disease resistance.

The traditional view of the immune system was simplistically based on the recognition of foreign antigens, the immune defence mechanisms, and a simplified view of the memory response. Our contemporary view encompasses all of the potential immunological stress factors that can upset homeostasis and trigger immune responses that carry a physiological cost.

With such a definition of the immune systems functions and what constitutes 'immunological stress', *it is obvious that we can no longer evade re-integrating strong principles of animal husbandry into veterinary immunology*.

Second Principle: Using the immune system comes with a physiological cost

Every time we trigger the immune system and turn it on, we have a price to pay. Immunity is not 'free'. It has a sticker price in the form a **physiological cost**. Allowing tissue or life events to occur in animal production systems throws the immunity switch to 'on' creating inflammatory responses. The physiological cost comes from diverting protein away from

growth and maintenance requirements and shunts the protein towards feeding the complex of immune processes.

Immunological *stressors* can excessively activate the immune response, trigger abrupt changes in the pro-inflammatory immune response, cause a loss of appetite, and re-partition nutrients away from homeostasis and production (such as muscle formation) in order to support the immune response. In excessive immune activation, muscle tissue may be degraded to supply sufficient quantities of amino acids for the production of **acute-phase proteins (APR)** and **cytokines** for the pro-inflammatory response. APR synthesis can increase several 100-fold. In an inflammatory response, APR would increase as much as 850 mg per kilogram of body weight (Reeds *et al,* 1994, cited in Johnson, 2002; Black *et al,* 2002).

The cost of immunological stress is further heightened by the loss through excretion of the amino acids that are surplus to the acute phase protein synthesis demand. An example from pig production illustrates the point. The cost of chronic immune stimulation in grower pigs between 6 to 112 kg was a 5% reduction in daily feed intake, 12% lower feed efficiency rate, and 10% reduction in lean meat content. Alterations in efficiency of gain in pigs associated with immunological stress increased maintenance requirements because of increased metabolic demand, resulting in poor pig performance with a significant economic impact (Williams *et al*, 1997; Almond *et al,* 1996).

Laboratory trials to mimic chronic immunological stress in chickens over a 10-day period resulted in significant reduction in growth and feed consumption, enlargement of liver and spleen, and increased activation of certain inflammatory responses (Takahashi *et al,* 2000).

Armed with this insight into the physiological cost to the host of the immune response, the intuitive view of immunology starts with a heightened awareness of the unacceptability of immunological stressors in livestock production systems. If we are to improve the health, welfare, and performance of animals, we need first to eliminate the physical, psychological, and nutritional stresses that combine to excessively activate the immune system and challenge homeostasis.

In this regard, we humans as the stewards of the animals in our care, become the first line of defense in building a '**sustainable immunity**', i.e. *the sum of protected reserve capabilities of a healthy and primed immune system able to rapidly and proficiently respond to immunological stress without causing a major depletion or chronic drain on an animal's physiological processes.*

As we develop further insights into the immune system, our understanding and application of vaccination strategies will evolve so that we establish husbandry systems that rely on the immune system only when other management strategies fail.

Third Principle: Intensive Production and The Red Queen Effect

"You have to run faster and faster just to stay in the same place!"

- The Red Queen to Alice, from Lewis Carroll's book, *Alice Through the Looking Glass.*

As we introduced earlier, 'The Red Queen Effect' is a metaphor used by biologists to describe the effect of 'co-evolution' where pathogens and the immune system are in a continuous arm's race against each other in an effort to maintain their respective survival.

Despite all of the progress we have made in veterinary immunology, the sobering reality is that we are often caught on the Red Queen Effect 'treadmill.' Like Alice, we never seem to quite keep pace with all the challenges we face in preventing animal disease and maintaining public health.

We attempt to apply new technologies in this war to stay ahead of the constantly changing landscape of emerging disease, biosecurity threats, and the 'microbial tension' created by modern animal production. Pathogens can change rapidly or suddenly emerge (e.g. SARS, BSE or H5N1 strain of avian influenza). Biosecurity can be thwarted (e.g.West Nile Virus), or we simply push our animal production systems too far and create ripe conditions for new diseases.

What is ominous is the increasing emergence of pathogens that act as 'Trojan horses' that have the ability to dodge detection by the immune system and then attack it creating immunosuppression and an opportunity for other secondary infections to emerge and become established. Infectious bursal disease in chickens, porcine circovirus associated-disease (PCVAD) in pigs, and bovine immunodeficiency-like virus (BIV) are just some of the immunosuppressive pathogens that have emerged with production intensification.

A recently published book on the war in Iraq (*Fiasco: The American Military Adventure in Iraq)* by the Pentagon correspondent of the *Washington Post,* Thomas Ricks, offered a quotation about military strategies that had eerie similarities with The Red Queen Effect:

> *"Every military strength contains the seeds of its own weakness. Make a weapons system too strong and it will be too slow or will consume so much energy in moving it requires a burdensome supply chain to keep it fueled. Make it too light and it will dangerously vulnerable when it breaks down, which is inevitable. Make it too successful and commanders will stick with it too long, until its weaknesses are revealed by the enemy."* (Ricks, 2006)

It's a quote that could easily be applied to intensive animal production and the war with pathogens. Playing their role in the 'Red Queen Effect,' pathogenic organisms work much harder to find the weaknesses in our systems as they try to find new ways to infect and survive. We continually strive to catch-up and put up new defenses until those too are defeated. *Unfortunately, pathogens have the distinct advantage on working from the 'inside of the host' while we have the disadvantage of trying to figure it all out from the 'outside'!*

Relating this to veterinary immunology, we are in a constant battle 'to fix things up' by creating new or better vaccines in a struggle to keep pace with the rate that 'things are breaking down'.

It begs an obvious question: *Are the immunological solutions sometimes part of the problem?*

This is a significant ethical question that is the 'large elephant in the room' that we are ignoring in our performance-based animal production systems.

For example, when a new vaccine comes along that gives us a new 'health dividend' in animal performance, do we use that dividend to finally get off the treadmill or simply ramp up

our production intensity, increase the pathogen tension once again, and face the specter of another pathogen emerging?

Inevitably, beating the 'Red Queen effect' prompts us to take a good look at where we are heading in terms of veterinary immunology and how we manage animal health. In short, we need to find some brakes to slow the Red Queen effect and get off the treadmill.

At a certain moment, we arrive at a point where technology and science are not going to save us from the Red Queen.

Veterinary immunology has advanced to provide solutions, however the lesson of the 'Red Queen' is that successful disease control may be fleeting if we only create a temporary hiatus from disease in order to use the gains to increase pressure on animal production and thus renewing the microbiological tension. The final solution is an ethical choice: a combined approach where we opt for better husbandry skills, reduction of immunological stress, and relying on vaccines prudently when husbandry is not enough.

Fourth Principle: Colostrum is where immunity and good husbandry begin

Ethical dairy husbandry revolves around the healthy birth and care of a calf. Everything we ever learned about veterinary immunology can be defined by how well we apply our knowledge of the passive immunization process and the transfer of antibodies from mother to calf. Everything else in immunological terms starts with the colostrum. If we get this one wrong, we get everything else wrong!

How well we protect the process of early and efficient colostrum transfer is probably a good indicator of how good our stewardship role is for maintaining proper animal welfare and husbandry.

Two particular issues involving passive immunity are important to highlight:

- Insufficient exposure of the dam to antigens that are important to passive maternal antibody protection of their young raised in high risk conditions;
- Deprivation of colostrum that leads to the increased susceptibility of young animals to disease.

It is important to review how we protect the passive immunity mechanisms and allow them to function properly for the sake of the health of newborn animals.

Unlike humans where passive immunization of maternal antibodies (as IgG) is transferred *in utero* from mother to fetus, mammalian livestock and companion animal species transfer maternal antibodies (primarily IgG but includes IgM and IgA) through colostrum intake by the newborn.

A key point to remember about the colostrum transfer of maternal antibodies is the very limited time for the newborn animal to absorb the immunoglobin proteins through the lining of the intestinal tract. This process amounts to a massive transfusion of maternal antibodies into the bloodstream where timing is everything. For mammalian species, there is a 12-36 hour 'window' for the IgG transfer to be made before *closure* of the gut takes place. Prior to gut closure, trypsin inhibitors in the colostrum along with the neutral pH of the digestive tract prevent proteolytic digestion of the IgG proteins. In the newborn animal, the intestinal wall is lined with immature epithelial cells that are capable of absorbing IgG antibodies. The

'window' closes as mature gut epithelial cells rapidly replace immature cells and IgG can no longer be absorbed. Additionally, the increasingly acidic pH of the digestive system breaks down the unprotected IgG immunoglobin protein.

In the race against time before gut closure, IgG concentration in the first fraction of colostrum is at its highest. We refer to this first fraction as 'true colostrum'. The next phase of colostrum production is called 'transition milk' that is characterized by the decrease of IgG and the increase in secretory IgA antibodies. Secretory IgA has a molecular component that makes it resistant to the increasingly acidic environment. IgA's primary responsibility is to keep the intestinal tract bathed in pathogen-neutralising antibodies by binding to potential pathogens and excluding them from infecting through the intestinal mucosa tissue.

Another point to remember is that the gut 'window' is also open to pathogens. They can be easily absorbed through the immature gut epithelial cells. If the early fractions of colostrum are not consumed, then it's easy to understand how early disease pathogens can get through and create problems. This forms the basis for one of the welfare issues associated with colostrum deprivation that we wish to avoid.

These factors involved with early colostrum intake are critical to the future well being of the newborn:

1. True colostrum has the highest antibody levels;
2. Immunoglobin absorption is highest nearest birth;
3. Sufficient intake at the earliest opportunity in the race against gut closure;
4. The risk of pathogens entering the immature gut.

The above should underpin the advice given to clients rearing young animals. Besides, the high immunoglobin content of colostrum, it is loaded with other essential nutrients and bioactive components to start the young animal off on the right foot.

A conclusion for contemplation:

Other livestock sectors have boldly gone before the dairy industry in the scaling-up and intensification of production. The experience of the chicken and pork industries in their respective intensification and managing disease is instructive. The most striking aspect of intensification of animal production has been the dilution of husbandry skills and a compensatory over-reliance on immunological fixes to batten down the hatches against emerging diseases. The overuse of vaccines may become an unhealthy dependency that Dr Rollin calls a 'technological sander' that becomes necessary for reshaping the 'round peg' of animals so they will fit into the 'square holes' of intensive animal production systems.

We have reached an opportune moment in the expansion of our own dairy industry to seriously review that what we do is retaining all the characteristics of sustainable dairy production in the long term. How well we apply the principles of immunology will determine whether or not we are protecting or exploiting the immune system of the dairy animal.

We will need to be cognizant of society's reminders for us to preserve the health and welfare of animals. Society is keen for agriculture to be sustainable and balanced. Exploitation of animals and resources is seen as a 'one-off' experiment that has no winners. At some stage, sustainable production requires that we use good husbandry to create a large 'health and welfare dividend' and use it to take off the pressure of endemic and emerging pathogens that our responsible for keeping the Red Queen Effect in business.

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