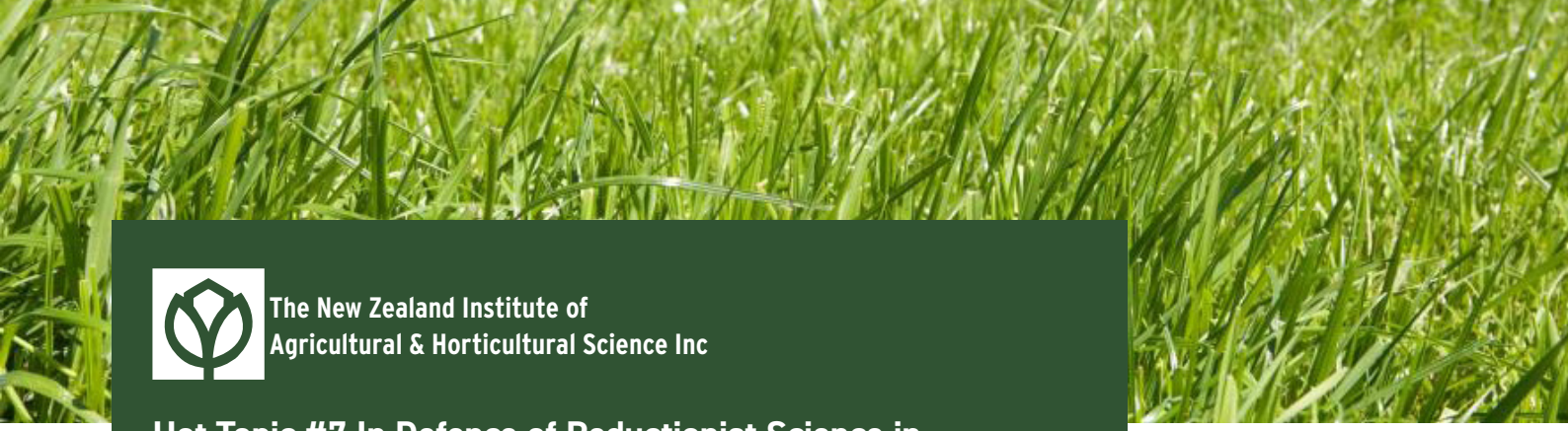

The New Zealand Institute of Agricultural & Horticultural Science Inc

Hot Topic #7 In Defence of Reductionist Science in Agriculture and Horticulture

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'Reductionism is one of those things, like sin, that is only mentioned by people who are against it.'

–Richard Dawkins 1996, The Blind Watchmaker. Why the Evidence of Evolution Reveals a Universe Without Design, New York: Norton & Company.

'The whole is greater than the sum of the parts' (translated from ancient Greek)

–an unfortunately all too often cited misquote of Aristotle (384 B.C.E. —322 B.C.E., Book VIII, 1045a.8–10)

Context

Science is the methodical study of the structure and behaviour of the physical, chemical, and biological world through systematic observation, experimentation, and the testing of theories. Through these activities knowledge is established: thus, science represents both a process for acquiring enduring knowledge and the knowledge itself. It defines a universal language, and one that traverses cultural boundaries. It welcomes and can accommodate aspects of things like Mātauranga Māori (Māori knowledge), whilst also providing a mechanism for that knowledge to be challenged and grown. At its heart, science is driven by curiosity.

Science enables the collection and organisation of knowledge. It provides testable explanations and predictions about the biological, chemical, and physical worlds, while also providing an approach and framework that enables improved or new understanding to develop. It is never static, albeit at times making progress is hard. Regardless of its pace, to make progress science requires the ability to establish new findings and insight, in the context of what is already known.

There are several terms in common usage describing the approaches used in scientific research to achieve improved knowledge and outcomes. At the extremes, the words 'reductionism' and 'holism', are often encountered, suggesting that these are diametrically opposing things. But are they? Within these so-called extremes one also finds scientists using words like 'systems', 'integration', and 'unifying', while perhaps contrastingly referring to the 'weight of evidence', or 'current thinking'. Such expressions suggest science is not a simple dichotomy of reductionism versus holism, but instead that it is more fluid and complex, and that by its nature it accommodates uncertainty and opinion, albeit well-informed opinion.

Irrespective of the terms used, we contend that there is an irrefutable requirement for all steps, to be based on reductionist scientific approaches in improving scientific understanding and its effective application. It is only knowledge created from deep and detailed scientific research that leads to the development of new insights. If the simplest relationships cannot be tested and shown to be robust, then any effort to create a broader holistic overview on a subject is likely to be flawed. That said, a

notable feature of fully informed holistic approaches is that they can also offer the potential for the development of new understanding. At times detailed reductionist science of varied origin, needs to be integrated into a 'bigger picture'. In effect, we believe science absolutely needs reductionist approaches, but at times it also requires knowledgeable people to take potentially intersecting strands of reductionist science and propose a new direction or perspective. It needs both approaches to grow and advance.

New Zealand is a global leader in agricultural and horticultural science research and development, and not least because of the critical importance of agriculture and horticulture to the economic well-being of this country. Further, New Zealand's position of leadership in agricultural and horticultural production is the result of discipline experts (who could be called reductionist scientists) providing the wherewithal and ability to integrate their detailed scientific research findings into a holistic viewpoint. This has led to developments such as Integrated Pest Management (IPM) practices in New Zealand's primary industry sectors. IPM can be defined as an approach to pest management that uses comprehensive information on the life cycles of pests and their interaction with the environment, along with a combined range of pest control methods, to manage pest damage by the most economical means and with minimal hazard to people, property, and the environment. It is therefore holistic, but without its underpinning reductionist science, it is lost. For IPM to work, reductionist science must never be dismissed as unnecessary or 'last century'. To do so is absurd.

Despite such identified absurdity, an examination of terminology surrounding different approaches to agriculture shows that that the term 'conventional agriculture' (or horticulture), has become weaponised (or referred to dismissively) by the proponents of 'alternative approaches' (Sumberg & Giller 2022). The same pattern has appeared in science, whereby those who regard themselves as having holistic approaches, can too easily disregard reductionist science as narrow and old-fashioned. The 'reductionist' tag is thus used pejoratively. Indeed, it has been stated that "to call someone 'a reductionist', in high-culture press if not in serious philosophy, goes beyond mere criticism or expression of doctrinal disagreement; it is to put a person down, to heap scorn on him and his work" (Kim 2000).

In his 1986 book The Blind Watchmaker, Richard Dawkins writes 'Reductionism is one of those things, like sin, that is only mentioned by people who are against it'. He goes on to suggest that nobody is really a reductionist: 'The nonexistent reductionist - the sort that everybody is against, but who exists only in their imaginations - tries to explain complicated things directly in terms of the smallest parts, even, in some extreme versions of the myth, as the sum of the parts! The hierarchical reductionist, on the other hand, explains a complex entity at any particular level in the hierarchy of organization, in terms of entities only one level down the hierarchy; entities which, themselves, are likely to be complex enough to need further reducing to their own component parts; and so on.' We will leave it to the reader to investigate how frequently Aristotle is misquoted and his apparent 'sum of the parts' (see https://se-scholar.com/se-blog/2017/6/23/who-said-the-whole-is-greater-than-the-sum-of-the-parts), and to what effect.

As with the tension between holism and reductionism, we strongly believe this rift between conventional and alternative agriculture is unhelpful. We also contend that the belief that there is an acceptable binary or dichotomous approach between holistic and reductionist approaches is impeding scientific progress in New Zealand, and that it will lead to misunderstanding, unnecessary duplication, and distraction. It will accordingly lead to increased research and development costs and waste. Undoubtedly, agricultural and horticultural advancements have involved the findings of reductionist scientists in specific disciplines who often work alongside specialists in other disciplines. Their findings, which sometimes might appear mundane, and possibly irrelevant to the uninformed, are nearly always integrated for the benefit of systems analysts and developers (i.e., informed holistic thinkers), and ultimately for farmers and orchardists; our food producers.

The New Zealand challenge

In this context, 'reductionist' pest management research in pastures has led to the now obvious recognition that although of similar appearance, pasture ecology here in New Zealand is different to the 'evolved' and well-established native grasslands found globally, and that this likely explains the occurrence of exotic pest outbreaks (Goldson et al. 2020). In a similar vein, expertise in soil science and agronomy resulted in a re-examination of the nitrogen needs of small seed crops in New Zealand (Rowarth & Archie 1994), and the resulting 'targeted approach' of nitrogen has since become part of best practice crop management. In another iteration, molecular biology, which led to the genetic engineering revolution of the past 25 years, has

been argued to epitomise the reductionist approach to science (Fang & Casadevall 2011). Combined with this, breeding expertise has provided a basis for evaluating and interrogating the intended and unintended consequences of this biology in the development of new crop cultivars, while also indicating the possibility for more robust yet flexible methods of regulating and monitoring GM crops (Caradus 2022a, b).

In these three areas the underlying and original science has by necessity been reductionist. However, such work can be dismissed by adherents to holism, as at best ever-increasing research into scientific minutiae of no consequence or value. At worst, in New Zealand some claim the science creates consequences that are hostile to the well-being of humanity. In all these cases though, the results of the apparently reductionist science have been examined in a broader context to understand interactions, the balance between risk and benefit, and the potential for unintended consequences.

We therefore contend that in agricultural and horticultural science in New Zealand, reductionist research has been vital to better understanding the complexity of differences observed here, when compared with what is observed elsewhere in the world. Whether imported beneficial insects, imported concepts about nutrient needs, or imported plants for breeding, and remembering that nearly all our agricultural and horticultural production systems are imported; the knowledge of discipline minutiae and context have ultimately enabled New Zealand farmers and growers to consistently improve practice and sustainably increase their productivity.

How reductionist science has informed holistic practices in New Zealand

New Zealand successfully uses pasture-based production systems to its immense benefit in generating export earnings. However, the pasture species are in no way endemic to New Zealand. Instead, we have adapted and optimised pasture systems based entirely on exotic plants and animals to create resilient production. This has been achieved through reductionist science.

For example, there is an ongoing challenge from pest species that enter New Zealand as a consequence of biosecurity breaches and that can severely limit pasture plant production and persistence. Such risk threatens our economic well-being, as the lack of pasture plant and natural enemy diversity results in there being little biotic resistance to invasive species. Consequently, these pests can build up to levels way above those found in their native ranges. In contrast, there is indeed an evolved New Zealand-native natural enemy fauna, which has evolved over tens of millions of years embedded in our native ecosystem, with nil interaction with our introduced species. In effect this ecology has been disrupted, and apart from ceasing all pastoral production practices, we face ongoing challenges that need to be addressed. Science-based limitation of the effect of biosecurity breaches from pasture pests is an immense task. However, for the same ecological reasons associated with our isolated island nation status, biological control agents introduced to combat the pests can work extremely well, as they too are not impacted by their own suite of enemies.

Thus, the circumstances of New Zealand's pastures are quite different from what is found in many locations elsewhere where pests and their natural enemies have co-evolved in complex species-interaction networks. An immediate conclusion from the reductionist science points to the possibility of increasing the plant diversity in our pastures to lure native natural enemies to control the pests. However, detailed reductionist studies have shown that this does not lead to the hoped-for pest suppression. This is because New Zealand's natural enemy fauna has been found to remain firmly in their indigenous ecosystems and rarely venture beyond their native plant communities (e.g., Tomasetto et al. 2017; Goldson et al. 2020).

As an aside, good reductionist practice where precision and accuracy are held in high regard, can also lead to new and serendipitous discoveries. In investigating the activity of the Argentine stem weevil, which poses a multi-million-dollar problem for New Zealand pastoral agriculture, it was discovered by chance that insect population measurement techniques such as the use of vacuum-based sampling methods can lead to significantly biased population estimates and over-estimation of pest parasitism rates (Goldson et al. 2020). Good science begets further good science.

Recently Stewart et al. (2022) have provided another example of reductionist research. These workers were able to conduct multidisciplinary analyses of historical (sealed) seed samples collected in 1917. Through seed curation they provided a picture of the quality of seed lots at that time. Perhaps unsurprisingly, the 'old' seed was quite different to that of the modern ryegrass seed industry, which is based largely on crops grown on arable land in Canterbury. The

modern seeds have been bred and better adapted to be highly productive in New Zealand conditions.

Interestingly with the old seeds, close inspection detected the presence of insect fragments suggesting the presence of Argentine stem weevils. This extended the 1927 first record (Marshall 1937) of the weevil in New Zealand by at least ten years, and indeed based on its distribution, the pest may well have been established at the turn of the twentieth century. Reductionist science can therefore reveal hitherto unknown historic detail. Perhaps unexpectedly, the 1917 perennial ryegrass seeds also showed levels of the common toxic Epichloë endophyte (and associated alkaloids) comparable to those rates found in the 1980s and 1990s in samples from old pastures across New Zealand. The authors therefore speculated that this again could indicate that the weevil had been in New Zealand for some time prior to 1917, and that this had then exerted selection pressure for endophytic ryegrass (e.g., Easton 1999).

At a broader level, through soil, pasture, and animal management, in combination with selection of plants and animals, New Zealand has created highly greenhouse gas (GHG)- efficient pastoral production systems for milk (Mazzetto et al. 2022) and meat (Mazzetto et al. 2023). When we set out to become pastoralists, we didn't intend to improve GHG footprint, but by focusing on production efficiency and ensuring the resilience of our systems, we have achieved low GHG emissions per kg of product. The gain in efficiency has come about in most part through typically reductionist and certainly concerted scientific approaches to improve pasture plant and ruminant animal health and resilience. This extends to genetics and breeding, fertility, and longevity. Unless any newly proposed holistic systems can match this improved conventional agricultural performance, then the GHG footprint of pastoral production systems is likely to increase. (There is already evidence to suggest that this is the case for meat production https://ourlandandwater.nz/outputs/regenerative-agriculture-value-proposition-final-report/). Despite such evidence, some environmentalists and others are active in claiming a 'better' way to approach food production, namely one that 'works with nature'. The implication here being that science-based agriculture somehow works against it, and the assumption being that nature per se, in some way cares. Reductionist science does however enable us to garner a better understanding of how nature may be affecting the efficiency.

Contrary opinions to this are epitomised in the current promotion of regenerative agriculture in New Zealand. For example: "One of RA's distinguishing features is the holistic pursuit of continuous improvement, not only on environmental but also on social, economic, and cultural outcomes, both within and beyond the farm gate". Also "While RA is informed by the many predecessors of alternative agricultures, unlike them it does not preclude any particular practice if it is needed to facilitate the transition of the agroecosystem to a state of increased health" (Grelet et al. 2021). Here it needs to be asked if these statements are based on hard-won fact, or a moving feast of hope and aspiration? This is important because one of the immense benefits of reductionist science is the accumulation of accepted (i.e., peer-reviewed) knowledge in searchable and publicly available repositories. Do holistic approaches equally enshrine the simple act of record keeping? We can find detailed and well-documented science from centuries ago (think Newton or Lavoisier), but in comparison, readily available detail of holistic approaches appears to be rather more lacking in our history. It is notable that in a letter to Robert Hooke (in 1675), Isaac Newton made the statement: 'If I have seen further it is by standing on the shoulders of Giants'. This statement is now often used to symbolise scientific progress and achievement.

The tension between reductionist science and holism is similarly found in medicine. The practitioners of complementary and alternative medicines (CAM), indulge in various practices including 'natural medicine', herbal remedies, non-conventional medicine, and holistic medicine (https://www.healthnavigator.org.nz/medicines/c/complementary-and-alternative-medicine/). In an article published in the International Journal of Health Science (Tabish 2008) the editor wrote: "The list of CAM practices changes continually as CAM practices and therapies that are proven safe and effective become accepted as 'mainstream' healthcare practices (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068720/). Proving that which is 'safe and effective' unequivocally requires a scientific approach, but holistic insight can lead to the establishment of new approaches to health and well-being. However, it is also notable within the CAM 'industry' that fashion can prevail, and the mighty dollar can rule supreme. That which might have been 'fashionable' historically, such as blood-letting to remove impure fluids, doesn't pass as acceptable today, and in this context, will currently popular holistic approaches in agriculture and food production, one day look archaic, if not entirely inappropriate?

The problem with approaching anything in holistic fashion is that it is difficult to identify the components of the drivers of change. Complicating matters is the placebo effect which is undoubtedly real in health (Benedetti 2022). Placebo-like factors also apply to non-medical areas. The positive effect of the encouragement provided by coaches in regenerative agriculture has been documented in Australia (Ogilvy et al. 2018): regenerative graziers self-reported higher wellbeing than conventional graziers, despite being under greater financial stress (Francis 2020). And after all everyone likes to feel good most of the time, because life without hope and optimism is wretched.

A path forward – don't indulge a needless dichotomy

In science, reductionism and holism do not necessarily have to be at the opposite ends of the spectrum, as both approaches have limitations (Fang & Casadevall 2011). Singular reductionism can result in key relationships and linkages being missed, whereas holism appears to ignore the need to identify how confounding factors can affect the outcomes derived from complex systems. These can include factors that are different, yet result in the same response, or when the same factor can elicit different responses in a different system. Essential indicators can be glossed over, and the power of scientific inference and relationships lost. Such an outcome has been described negatively: "When fecklessly performed, systems biology may merely describe phenomena without providing explanation or mechanistic insight or create virtual models that lack biological relevance" (Casadevall & Fang 2008). Fortunately, these weaknesses are usually 'cured' with the passage of time.

Here we emphatically support hypothesis-driven science over qualitative description, albeit the latter has a place provided it is repeatable and durable. The former provides insights into causation, and for science, this is critical for progress. Further, agricultural scientists often work in multi-disciplinary teams to ensure that different and at times reductionist perspectives and expertise are brought into play (e.g., Caradus et al. 2021).

For example, the company IDEO (https://cantwait.ideo.com/) has developed into a world-leading design firm, based on intense cross-disciplinary project work to enable discovery and innovation. The company focuses on the art of collaboration and the development of a certain kind of talent known as 'T-shaped'. IDEO's CEO, Tim Brown, has explained that T-shaped people have two kinds of characteristics (Hansen 2010). The vertical stroke of the "T" is a depth of skill that allows them to contribute to the creative process. The horizontal stroke of the "T" is the disposition for collaboration across disciplines, which requires empathy (which allows people to imagine the problem from another perspective) and enthusiasm for disciplines other than their own. T-shaped people have both depth and breadth in their skills. In contrast, I-shaped people are considered to have very deep experience and expertise but might not be good collaborators. These might be close to the ideal of pure reductionist scientists, if such a scientist exists, but that would seem to suggest that scientist works in a vacuum devoid of any interaction with colleagues, if not reality. Given the need to publish in science and the moderating force of peer evaluation and review, that would seem unlikely.

There is also a need to collaborate in modern reductionist science. Most peer-reviewed scientific papers now comprise groups of specialists. While this isn't necessarily a new approach, in agriculture the development and use of sustainable land management systems requires that we work closely with practitioners of other disciplines. However, it is vital that in working with others, the standards of scientific research in the individual disciplines are not compromised via short-cuts towards holism (Bridges & Catizzone 1996). Increasingly scientists must also take broader legal, economic, and social conditions into account. Harsh economic reality often drives what scientists do. If science isn't funded, then the practitioners tend to make little progress. He or she who pays the piper, tends to call the tune, whether it be holistic or reductionist.

In the last decade, ways have been identified (e.g., Brown et al. 2015, Palmer et al. 2016) that encourage inter-disciplinary and transdisciplinary science, including the development of 'T-shaped scientists'. It suggests that funders, publishers, and institutions have a major role to play in the way they invest in and reward outcomes. Similar comments have been made in New Zealand (Duncan et al. 2020), but evidence suggests that in agricultural science collaboration is the norm and inter-disciplinary science (when people with expertise work together), is recognised as the way to advance understanding and opportunity.

Conclusion

What is discussed here coincides with the appearance of widely enunciated and aspirational intentions for improving agricultural practices in New Zealand. In

effect, many feel the need or desire to move beyond the 'conventional', if such a thing exists. As an aspiration, this is of course a good thing, but with this comes the danger that such intentions may engender the pursuit of ill-advised short-cuts that ignore the robust analysis provided by reductionist science. Accordingly, the pursuit of 'working with nature' may be based more on 'feel-good' factors and not systematic, tested, peer-reviewed and documented science as a reliable measure of progress. Reductionism must not ignore serendipity, but neither can holism. With reductionist science, libraries contain a precise record that allow us to stand 'on the shoulders of giants'. Can holism deliver this benefit, or just a bit of 'feel good'? There is a place for both ends of the spectrum as described by Tim Brown's T-shaped people, but it is a question of proper balance, and each has its place. The view that reductionist scientific research is somehow indulgent or 'last century' is absolutely unacceptable.

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