

A Submission to the Development of Australia's Agriculture, Land and Emissions Sectoral Plan for Net Zero 2050

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Preface

The Agriculture, Land and Emissions Discussion Paper presented by the Department of Agriculture in October 2023 (this year) aims at submissions that can guide stakeholder discussion. The discussion paper sets out its case in a comprehensive, intelligible and mind-opening form. Its lucidity has inspired rounds of thought, which have converted this submission into a possible first draft of an evolving monograph.

Contemplations have identified two principal concerns. First of these concerns is the pressing need to renew and reinvigorate what could be called Australia's knowledge machine and its component parts, which extend to research, education and training. The second of these two concerns relates to the structures and functions that provide the ways and means for progress. Two existing Commonwealth initiatives are models for the structures, functions and capacities needed in an integrated strategy to meet emissions goals and to pave the way towards a best possible future for Australia and planet Earth. The models in point come from the Australian Biological Resources Study (ABRS, <https://www.dceew.gov.au/science-research/abrs>) and Australia's National Biosecurity Strategy together with the underlying work of the National Biosecurity Committee (<https://www.agriculture.gov.au/biosecurity-trade/policy/partnerships/nbc>).

Structures, functions and capacities for climate action can build from the strengths in these two models and can learn from their possible weakness. A capacity for learning-by doing and using feed-backs and feed-forwards for continual improvement is a necessary. Appropriate criteria for assessment rather than superficial, arbitrary and remotely determined KPIs (key performance indicators) are another necessity.

The broad coverage in this submission requires that its suggestions and their rationale are presented in a concise form that can inform progress. Some suggestions have implications across the whole agriculture, land and emissions discussion paper and indeed across the entirety of Australia's efforts to reach net zero emissions by 2050. Other suggestions may

apply in particular to one or more of the twelve questions in the discussion paper. All suggestions relate to knowledge as the foundation of success in all human enterprises, the root of the understanding and insight that makes for creativity and the unspoken vital force behind strategic planning, building capacity and then implementing action. All suggestions can be dealt with through capacities made possible by an organised structure for Australia's net zero strategy ambitions built on the example of Australia's Biosecurity Strategy and the Australian Biological Resources Study. The capacities in mind within this organised structure can facilitate collaboration on terms of reference for reinvigorating Australia's knowledge machine. Broad discussion on this crucial first step can be initiated by a scoping paper with a format combining that of systematic review and a risk assessment which emphasises hazard characterisation.

A future task is to align the suggestions made in this submission against the questions posed in the agriculture, land and emissions discussion paper. These fourteen suggestions are listed as a box within the executive summary and are accompanied by a set of thumbnail descriptions. More detailed coverage can be found in Section VI within the body of the submission. There is no need for time-constrained readers to go beyond the executive summary and delve at once into the broader substance of the submission.

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Executive Summary

1. List of Suggestions

1. A repository of knowledge relevant to all aspects of action against climate change and which can unleash the insights and foresight required for much needed innovations.
2. A systematic account of all sources of greenhouse gas emissions from land and agriculture and prospects for remediation – see also point 5.
- 3. A back-to-basics revision of the methodology for measuring soil carbon sequestration -URGENT.**

4. A thorough exposition of ways and means for measuring methane, nitrous oxide etc. and possibilities for universal access to simple innovative devices that can be used on site. This is necessary to understand the host, methanogen and environment interactions that lead to excessive methanogenesis and whether there are rogue methanogens.
5. A knowledge resource to elucidate all aspects of methanogenesis in herbivores, especially ruminants. This can lead to high-insight low-input integrated control programs tailored to particular environments.
6. An exploration of the physiological mechanisms underlying possible chemical, immunological and dietary interventions for reducing methanogenesis in livestock. This can provide the insights and foresight needed for innovation.
7. An account of thermophysiology and the impact of heat on life forms that can guide adaptations to climate change and their limits.
8. A comprehensive, evolving and open-access account of the hazards to water quality accompanying climate change.
9. Guidance on ways and means for capturing the benefits of contemporary information technology and online databases for knowledge management and the broader extension, translation and application of that knowledge.
10. An exercise to identify matters additional to those in points (1) to (9).
11. A possible communal and inclusive means for monitoring possible impacts climate change across Australia's diverse ecosystems. The wealth of data possible here could be analysed with contemporary information technology to detect and interpret patterns.
12. Protocols, procedures and codes of conduct for factoring science into Australia's governance.
13. A forum for discussing the path towards a renewed and reinvigorated science enterprise in Australia.
14. A capacity for gathering intelligence on climate action initiatives within international bodies and in other countries.

2. Thumbnail descriptions of suggestions

1. The development of an evolving repository of knowledge relevant to climate action and how it might be realised through the preparation of a scoping paper and a subsequent discussion forum. This can unleash the insights, foresight and innovation required for progression towards increasingly effectual responses to climate change.
2. A comprehensive account of greenhouse gas emissions from farming systems which covers all aspects of methanogenesis in livestock together with possibilities for dampening methane production in livestock, for reducing inputs of synthetic nitrogen and providing opportunities for carbon sequestration. The norms of solid scholarship must apply. Guidance can be had from the ideals of a systematic review, the precedent of risk analyses and the coverage of subject matter in textbooks of comparative medicine. The product must be able to inform the particular actions that fit particular

circumstances (integrated control programs) and must also clarify the inescapable limits to genetic selection.

3. A major revision of the methodology for the measurement of soil carbon sequestration in agricultural systems. Without this there is no sound resource for the development and accreditation of competencies of those involved. Once again, guidance can be had from the norms of scholarship and so on mentioned in (2).
4. A comprehensive account of ways and means for measuring methane and nitrous oxide that begins with an account of past and present methods and their evolution and which provides foresight on future possibilities. The lack of devices similar to the breathalyser used to detect alcohol levels in people or infra-red thermometers to measure body temperatures is a major impediment to progress. Similar devices in the hands of those directly involved in agriculture and land stewardship could be transformational. It would allow for decarbonisation strategies tailored to particular circumstances and give some autonomy to those at the frontline of action.
5. A particular review of methanogenesis in herbivores that emphasises physiology and which can identify the web of causes or the risk factors to be addressed at particular local levels. The paradigm of diagnosis can operate. Diagnosis can be restated as the art or act of determining the nature of disease or phenomena such as methanogenesis. This review can lead to high-insight low-input integrated control programs tailored to particular environments.
6. An exercise to explore the physiological mechanisms that apply to possible interventions to reduce methanogenesis in livestock. Scientific research directed solely immediate practical outcomes forecloses on future possibilities made possible by clearer understandings and insights. An understanding of physiological mechanisms opens possibilities for emerging technologies such as quantum computing. Physiology is emphasised unreservedly.
7. A comprehensive account of thermophysiology and the impact of heat on animals that can inform the realities and limits of possible adaptation and fill an important gap in properly collated knowledge. Guidance can be had from the norms of scholarship and so on mentioned in (2).
8. A comprehensive account of water quality and its shared importance in the health and wellbeing of land and agriculture. The impacts of climate change and the possibilities for adaptation require systematic analysis. Guidance can be had from the norms of scholarship and so on mentioned in (2).
9. A guidance document on ways and means of capturing the benefits of contemporary information technology and online databases in the search for information and knowledge and its subsequent management. Extension of skills and competencies in this area and throughout the community can broaden Australia's knowledge management capacity and the translation of knowledge into action.
10. A process to determine whether there are matters additional to those described in points (1) to (9).

11. The development a communal and inclusive capacity for monitoring possible impacts climate change across Australia's diverse ecosystems. A start could be made by creating a registry of community organisations and other resources that can make direct field observations. Initiatives such as Feral Scan (<https://feralscan.org.au/>) which provides for community input into the management of feral animals suggests a possibility.
12. Refinement to the protocols and procedures for factoring science into Australia's public policy process¹.
13. An open and unfettered forum for discussing a renewed and reinvigorated science enterprise in Australia. This will focus on what happened in the past and how the present and the future can be reshaped according to evolved thinking.
14. The creation of a resource devoted to monitoring, marshalling and communicating intelligence about climate action initiatives within international bodies and in other countries. International bodies include such as UNESCO, WHO, UNEP, FAO, the World Bank, WOAHA and the OECD. It would be remiss not to benefit from the publications of the US National Academies of Science and the US Council for Agricultural Science and Technology (CAST). There are perceptible gaps in this connection.

Abstract

This submission to the discussion paper on the agriculture and land component of Australia's aspirations for reaching net zero greenhouse gas emissions by 2050 has a single theme. It is the distinct absence of suitably packaged knowledge that can guide the development of plans and strategies to address climate change and then put these plans and strategies into effective action. A lesson from history on this point comes from successful action against animal diseases like pleuropneumonia, bovine tuberculosis and bovine brucellosis. These eradication campaigns were driven by well packaged knowledge that was prepared under conditions conducive for solid scholarship. The contention here is that BTEC (bovine tuberculosis and brucellosis eradication campaign) would not have occurred without suitably packaged knowledge that commenced in the early 1950s with a series of official reports, 'Diseases of Domestic Animals in Australia'³.

A dip into history and a perusal of available resources demonstrates that the same well-packaged and accessible knowledge is absent for greenhouse gas emissions from land and agriculture (methane and nitrous oxide). This can be seen as a major impediment to progress. Much excellent work but remains to be amalgamated into a coherent and freely accessible whole. Reasons here are manifold. The discourse around climate has been one of persuasion

¹Bridgman P. & David G. (1998) *Australian Policy Handbook*. Allen and Unwin, Sydney.

²Agriculture, Land and Emissions Discussion Paper. Australian Department of Agriculture, Fisheries and Forestry (<https://haveyoursay.agriculture.gov.au/89774/widgets/420512/documents/272677>: October 2023)

³Series : *Diseases of Domestic Animals in Australia*. (1968) Seddon, H. R. (revised by Albiston, H.E). Commonwealth of Australia, Department of Health. These publications warrant the preparation of scanned copies for open availability in the internet/

and discourse directed at the exposition of knowledge has been overshadowed. The notion of a gradation from familiarity to knowledge and then to understanding and insight provides a way forward here This can come from reviewing, renewing and reinvigorating Australia's platforms for generating, systematising and sharing knowledge.

Directly interested parties may have wide familiarity with the issues and the subject matter outlined in the discussion paper. However, the progression to knowledge, understanding and insight as a basis for sound decision-making cannot be vouched for. Australia's States all have creditable 'lone wolf' plans for climate action in land and agriculture but there is no overall plan from the Australian 'wolf pack'. The biological association termed co-operative mutualism⁴ seems to be absent. The word 'commonwealth' as in the Commonwealth of Australia resonates with co-operative mutualism.

This submission takes a One Health perspective which has value in ordering knowledge and providing for good conduct, including unalloyed respect for the truth. Issues such as disinformation and misinformation, problems with publication in science (parasitic and predatory publishers), quackery and fraud, fallacious thinking, and the processes for science advice into public policy are discussed. Solidarity with the frontline is emphasised and can be realised by empathy for farmers and farming and proper support for scientists (including the possibility of codetermination in the management of the science enterprise). Fourteen suggestions are made for action and a structure for implementing action is suggested. The fourteen suggestions apply across the whole of the discussion paper or to one or more of the twelve questions posed in the discussion paper. The suggestions can be elaborated by capacities within the proposed structure, which has been inspired the Australian Biodiversity Resources Study and Australia's National Biosecurity Strategy plus the underlying work of the National Biosecurity Committee. The process for could begin with a collaborative discussion paper that sets the scene for an inclusive forum and leads to effective and demonstrable action.

I. Introduction

The opportunity to provide feedback on how the agriculture and land sectors can play a part in Australia's economy-wide Net Zero Plan is seized upon. The Agriculture, Land and Emissions Discussion Paper and the five other sectoral plans for decarbonisation⁵ represent a welcome return to the pursuit of the common good by means of constructive, transparent, knowledge-based and trustworthy action to mitigate⁶ greenhouse gas emissions, safeguard Australia's

⁴*Odum EP (1983) Basic Ecology. Saunders College Publishing, Philadelphia.*

⁵The UN defines decarbonisation as reducing the amount of greenhouse gas emissions that a society produces, as well as increasing the amount that is being absorbed.

⁶The UN defines mitigation as human interventions to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere by "sinks".

natural resource base and manage the hazard of stranded assets⁷. A recent newspaper editorial⁸ refers to the forthcoming United Nations annual climate change summit in Dubai (COP28) as an opportunity for Australia to retrieve its earlier global reputation in the area of climate change action. Well conceived, well communicated and well implemented sectoral decarbonisation plans and plans based on the limits for adaptation⁹ can assist in this regard. Well conceived plans build capacity for action in three ways. They provide guides to action and build competencies and systems around knowledge and its deployment (the knowledge machine), which is an absolute necessity for the health and wellbeing of society and its supporting environment. Secondly, soundly formulated sectoral plans can act as worked examples that may be adapted for use elsewhere in the world. Thirdly, they facilitate the intergenerational transmission of knowledge and competencies and their continual refinement.

The Agriculture, Land and Emissions Discussion Paper provides an intelligible and comprehensive scoping of issues and considerations that can be transformed into a coherent strategy and then implemented. These features can be attributed to creativity based on knowledge, understanding and insight and this trio of concepts provide the theme for the present submission. The submission will be distilled into the form of a short briefing note and presented upfront as a preface. The body of the submission can then provide a supporting background of detailed explanations and is designed to enable further contemplation.

The thrust of this submission is the clear need for review, renewal and reinvigoration of Australian systems for the generation, management and sharing of all forms and modes of knowledge. This can be called as Australia's knowledge machine, which extends to education and training¹⁰. Knowledge is the foundation of success in all human enterprises and the discussion paper provides a map indicating where reliable knowledge can have an impact on decarbonisation. The current COP 28 shows that disputatious and divisive dialogue has begun to decline as an impediment to progress and a hazard to reason and reasonableness or rationality¹¹. Solid knowledge about emissions from land and agriculture is essential for a return to constructive dialogue and some explicit suggestions are made for the development of a national open-access compendium of established and emerging knowledge that can support the capacities required for action. Specific competencies involved in the Australian Carbon Credit Units require immediate attention. More general suggestions are made about the cultural and procedural settings required for the generation, management and dissemination of

⁷Mark Carney, the UN Special Envoy for Climate Action and Finance provides an account of stranded assets in his 2021 book, *Value(s): Building a Better World for All*, William Collins, London.

⁸Sydney Morning Herald, Saturday 2nd December, 2023.

⁹The UN defines adaptation as adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. Adaptation refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change (<https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction>).

¹⁰The Encarta Dictionary of World English (1999) has a definition of a machine as a complex system structured to accomplish a specific goal and machinery refers to the parts that make up the machine.

¹¹'Rationality is good reasoning. The traditional concept of rationality in philosophy, which is also singularly appropriate in science, is that reason holds a double office: regulating belief and guiding action. Rational beliefs have appropriate evidence and reasons that support their truth, and rational actions promote what is good. Rational persons seek true beliefs to guide good actions' (Gauch HG Jr (2003) *Scientific Method in Practice*. Cambridge University Press, Cambridge).

knowledge. Inclusivity and universality is emphasised. Explicit processes and protocols for factoring science into the policy process would be beneficial.

II. Background

The input has been strongly influenced from six directions. First is from the Livestock Emissions Reduction Forum (28th December, 2023). Second is from free-ranging discussions with colleagues in a group of former chief veterinary officers and senior veterinary officers who are united by a desire for effective action against climate change and who respect knowledge and scholarship across the board. The input can be regarded as a contribution from a ‘single wolf’ within this ‘wolf pack’¹² and a contribution to further discussion within the ‘wolf pack’. The third influence comes from a recent and fortuitously apt editorial in *Science* magazine, the organ the American Association for the Advancement of Science¹³. The fourth influence is named as serendipity or happy coincidence. It includes experience from a working life in the Australian countryside and the enlightening exposures to the practicalities of animal-based agriculture at CSIRO’s McMaster laboratories, first in Sydney and then in Armidale, NSW, and at the Chiswick Research Station. The fifth direction relates to Australia being part of world and the need for an international outlook. The sixth direction is from history and precedents from the tussle over tobacco use as a causative agent in lung cancer and the lamentable tactics of the tobacco lobby.

1. *Livestock Emissions Reduction Forum*

The third influence came from attending the Livestock Emissions Reduction Forum on Tuesday 28th November this year. There was wide familiarity with the issues and the subject matter from the attendees. However, did this denote actionable knowledge, understanding and insight? The States have their own plans for climate action. How might these be merged into an overall national plan that provides a platform for collaboration and cooperation combined with community engagement and inclusion? The bid for a Cooperative Research Centre (CRC) on net zero emissions in agriculture, mentioned at this forum, has been successful. The challenge now is to position the CRC within an overall national plan such that it creates synergies and catalyses other scientific efforts? Monopolies are a universal hazard to human affairs.

The forum highlighted a major weakness that is linked paradoxically to Australia’s many existing and incipient strengths and competencies for climate action. The utility of a shared repository of established and emerging knowledge was not mentioned. This matter is foundational for all aspects of climate action. The many exemplary reviews of methanogenesis in ruminants that come from Australia and elsewhere have not been united

¹²‘As the creeper that girdles the tree-trunk the Law runneth forward and back. For the strength of the Pack is the Wolf, and the strength of the Wolf is the Pack’, Rudyard Kipling.

¹³Klinsky S and Sajar A (2023) Editorial: Build capacity for climate action. *Science* 389, 979.

and become comprehensive basis for further development and extension (see Appendix 1 which shows some Australian publications found in a 30 minute search on Google Scholar).

2. Ex-CVO climate action group

Discussions within the CVO group highlighted the cardinal importance of knowledge, understanding and insight in Australia's uniquely successful eradication of bovine tuberculosis, bovine brucellosis and bovine pleuropneumonia, in Australia's biosecurity strategies (Ausvetplans¹⁴ and biosecurity import risk analyses¹⁵) and in addressing animal disease emergencies such as avian and equine influenza. Knowledge, understanding and insight are similarly essential for the development and implementation of Australia's Agriculture, Land and Emissions Decarbonisation Strategy. Veterinarians have stewardship and responsibility for the science that drives their professional contribution to society. This stewardship aligns with the ethos of the One Health and depends on respect for all participants in climate, other branches of science and a science culture that encourages reciprocity. A major practical outcome of this inclusive outlook is the identification of a two existing Commonwealth models for a national open-access compendium of established and emerging knowledge that can support the capacities required for climate action.

The first existing model is the current Australian Biological Resources Study which is described comprehensively at <https://www.dceew.gov.au/science-research/abrs>. The second existing model may apply to all aspects of Australia's aspirations for climate action, including knowledge management, planning and implementation. It is Australia's National Biosecurity Strategy and the underlying work of the National Biosecurity Committee (<https://www.agriculture.gov.au/biosecurity-trade/policy/partnerships/nbc>). This was readily identified through discussions within the ex-CVO Climate Action Group^{16 17}. There is an opportunity build upon the strengths of these models and avoid their weaknesses.

A last point is that veterinarians have a brief to care for the health and wellbeing of animals and their living environment. The are indications that livestock in the physiologically stable state known as good health are more productive and this better productivity reduces overall methane production in ruminant-based agriculture¹⁸. Flock and herd health programs can

¹⁴AUSVETPLANS provide a nationally-agreed approach for the response to emergency animal disease (EAD) incidents in Australia. The plan is captured in a series of manuals and supporting documents (<https://animalhealthaustralia.com.au/ausvetplan>).

¹⁵Australia's biosecurity risk analyses are described at <https://www.agriculture.gov.au/biosecurity-trade/policy/risk-analysis>.

¹⁶Helen Scott-Orr was Australian Inspector-General of Biosecurity from 2016 to 2019.

¹⁷Ron Glanville highlighted the importance of biosecurity and a result of involvement in Australia's success in eradicating bovine tuberculosis and brucellosis. Glanville, R.J. (2023) Australia's colourful path to tuberculosis freedom. *Irish Veterinary Journal* 76, (Suppl 1) 15.

¹⁸Huntington, B., T.M. Bernardo, M. Bondad-Reantaso, M. Bruce, B. Devleesschauwer, W. Gilbert, D. Grace, A. Havelaar, M. Herrero, T.L. Marsh, and others. 2021. Global Burden of Animal Diseases: a novel approach to understanding and managing disease in livestock and aquaculture. *REVUE SCIENTIFIQUE ET TECHNIQUE-OFFICE INTERNATIONAL DES EPIZOOTIES*. 40:567-583

assist towards in decarbonisation and can provide a wealth of case-histories with an untapped potential for transforming knowledge in the area.

3. *An editorial from Science magazine (Klinsky and Sagar, 2023)*

The editorial in Science by Klinsky and Sagar (2023) draws attention to capacity building as the essential element in designing and then implementing the ‘course correction’ and ‘systems transformation’ to be discussed at COP28. Capacity is seen as ‘not the ability to implement someone else’s agenda, but the ability to set and pursue your own agenda’. Steps required for effective capacity building are (1) understanding the challenge, (2) weighing options, (3) designing plans, (4) coordinating plans, (5) communicating plans and (6) implementing plans. Multiple sources and modes of knowledge must be integrated with financial and institutional arrangements at each step.

Some impediments to progress with capacity building were identified as a lack of scholarship that provides clarity and guidance and ‘the complexity and contextual nature of capacity for climate action, which complicates scaling and transfer’. One example is the fallacy of composition. One size does not fit all and what applies to the whole does not apply equally to all parts. This and a set of related matters make up the fallacious thinking that can impair the effective application of knowledge. Fallacy refers to erroneous reasoning with the appearance of soundness¹⁹. It is to the fore in the stratagems and statements of climate change denialism and can undermine reasoned civil discussion. There are material fallacies, psychological, and logical fallacies²⁰ or formal and informal fallacies. Material fallacies are elaborated on in section 4 (Issues and considerations affecting climate action). The notion of scholarship is elaborated on in section 2 which delves into the dimensions and indispensability of knowledge as a broad umbrella term. Edward Damer’s twelve principles in a code of intellectual discussion is put forward as a pathway to fallacy-free arguments (See Appendix 2).

4. *Serendipity*

The fourth influence on this submission is serendipity, which includes chance encounters (perhaps from a habit of reading, and listening or from life in general) and experiences and exposures from working life. Serendipity combined with acquaintances from Armidale from 1978 to 1990 chanced upon the potential of the Australian Biological Resources Study to function as a worked example of the curated repository or compendium of the information and knowledge essential for driving the agricultural and land sectoral plan to completion and implementation. Similar knowledge repositories can apply to all sectoral plans. Serendipity arising from discussions within the Ex-CVO climate action group led to a worked example

¹⁹Fallacy. (2010). Encyclopædia Britannica. Encyclopaedia Britannica Ultimate Reference Suite. Chicago: Encyclopædia Britannica.

²⁰Fearnside, W.W. and Holther, W.E. (1959) Fallacy: The Counterfeit of Argument. Prentice-Hall Inc., Englewood Cliffs, NJ.

applying to the machine and the machinery that can catalyse Australia's climate change strategies. This example is biosecurity with its oversight from the Australian Biosecurity Committee (<https://www.agriculture.gov.au/biosecurity-trade/policy/partnerships/nbc>) and its modes of action.

(1) The Australian Biological Resources Study

The breakthrough here came from consulting a 1989 book on the mammals of Australia about sugar gliders. The book is *Fauna of Australia*, Volume 1B Mammalia, by the Australian Biological Resources Study²¹. Thankfully, this Study still exists and has developed into its current form as a broker of information about biodiversity. Two of the section authors in this book on mammals were at the University of New England at Armidale. These are Professors Peter Jarman and Ian Hume. Its form as described on the internet site²² provides a checklist of matters that can guide the formulation and implementation of Australia's strategy for reaching net zero emission target by 2050 and striving for the best possible future for Australia and planet Earth.

(2) Australia's Biosecurity Strategy

In a sense, Australia's Biosecurity Strategy was in plain sight as a fitting model Australia's effort in decarbonisation and preparing for the future. It covers more scope than the Australian Biological Resources studies and the description of its capacities on the internet²³ has an uncanny resemblance to the capacities required for Australia's climate action.

(3) Workplace experiences

Enlightening exposures to the practicalities of animal-based agriculture and their implications for decarbonisation came from experience gained at CSIRO's McMaster laboratories, first in Sydney and then in the Chiswick Research Station at Armidale, NSW. Life in Armidale from 1978 to 1990 allowed close and fruitful contact with researchers at the University of New England.

Some CSIRO colleagues and their insights can be named. Jack Hilder worked on the dynamics of pasture production and the distribution of soil nutrients²⁴. Around 1986 he shared some 'back of the envelope' calculations indicating that an overall increase of one mm in soil organic matter would have a great impact on carbon dioxide drawdown. Keith Hutchinson²⁵ gave some insights that inspired a statement in a report on endemic diseases of farm animals

²¹Walton, D.W. and Richardson, B.J. (eds) (1989). *Fauna of Australia* Mammalia. Canberra: Australian government Publishing Service Vol. 1B.

²²<https://www.dceew.gov.au/science-research/abrs>

²³ <https://www.biosecurity.gov.au/about/national-biosecurity-committee>.

²⁴Hilder, E. J., and P. J. Vickery. "Effect of uneven distribution of superphosphate on pasture production." *Proceedings of the Australian Society of Animal Production*. Vol. 13. 1980.

²⁵ King, K. L. and Hutchinson, K. J. (2007) Pasture and grazing land: assessment of sustainability using invertebrate bioindicators . *Australian Journal of Experimental Agriculture* 47, 392-403

in Australia²⁶. This refers to an ‘over-riding influence of climatic stress – with its wide swings!) and portends the impact of climate change. The statement is reproduced in the box below.

‘Terrestrial ecosystems are not stable and agricultural ecosystems based on the use of grasslands and grazing animals are no exception. During the 1950s and 1960s, much of the land used for grazing sheep and cattle in eastern Australia was primed for increased production by the systematic application of fertiliser (mainly superphosphate) and the introduction of exotic plant species. There is now evidence (Hutchinson, pers. comm.) that pastures prepared in this way are resisting the usual methods used for their maintenance and are degenerating in a disturbing fashion. The underlying problems are not fully understood. Factors involved may include selective grazing and its effect long-term on desirable pasture species, the general mineral economy of the soil/plant/animal complex (together with the decomposer system which makes major plant nutrients available), and the over-riding influence of climatic stress - with its wide swings!. Set-stocking may be an additional problem but a return to the old argument of set-stocking *versus* rotational grazing may not be fruitful. The spelling of pasture to allow recovery according to more appropriate criteria may be the nub of the question.’

Keith Hutchinson also provided ways and means of monitoring good function in pasture systems such as observations of arthropod fauna²⁷.

Justin Lynch studied animal behaviour, including that related to shelter-seeking, grazing and diet selection²⁸. Insights relevant to climate action is that provision of suitable shelter leads to the physiological stability required for production efficiency and this has implications for net methane output. Also, observations of grazing behaviour and diet selection in grazing ruminants could be an important tool for assessing the risk factors associated with a pathological output of methane.

Peter Waller master-minded some flock health plans which could be used to monitor and optimise the health and well-being of ruminants and thus reduce methane outputs. Put simply, if a biomass of ruminant protoplasm produces a fixed amount of methane and a certain production output, a lower biomass producing optimally will produce less methane than the extra biomass required for the same production output. Peter Waller’s work came to fruition in flock health plans used for sheep in Sweden²⁹ and reindeer in Sami regions³⁰. Similar plans could be developed and employed in Australia to optimise ruminant production and assist with decarbonisation.

²⁶Adams, D.B. (1990) An overview of endemic diseases of farm animals in Australia. Bureau of Rural Resources Department of Primary Industries and Energy, Canberra. (Internet access at <https://www.researchgate.net>)

²⁷King, K.L. and Hutchinson, K.J., 2007. Pasture and grazing land: assessment of sustainability using invertebrate bioindicators. *Australian Journal of Experimental Agriculture*, 47(4), pp.392-403.

²⁸Lynch, J.J., Hinch, G.N. and D.B. Adams, D.B. (1992) The behaviour of sheep: biological principles and implications for production. C.A.B. International; East Melbourne : CSIRO.

²⁹Waller, P.J., 1999. International approaches to the concept of integrated control of nematode parasites of livestock. *International journal for parasitology*, 29(1), pp.155-164.

³⁰Waller, P.J., 2005. Domestication of ruminant livestock and the impact of nematode parasites: possible implications for the reindeer industry. *Rangifer*, 25(1), pp.39-50.

Contacts at the University of New England warranting special mention were Professors Ron Leng, John Nolan and Ian Falconer. Ron Leng³¹ and John Nolan³² were animal nutritionists and did foundational research on methane production in ruminants that was driven by the possibility of improving productivity. Metabolism with methane rather than carbon dioxide as its product is energetically inefficient. Their work was based on evolving methods to measure methane and this draws attention to the pressing need for better and more convenient methods that can be applied within day-to-day farming. Ian Falconer³³ studied cyanotoxins as a hazard to water quality and a hazard that will increase with global warming [heating]. Systematised knowledge about water quality is a specific suggestion for action within the land and agricultural sectoral plan. It shows that a separation between land and water for climate action does not make sense.

5. An International Perspective

A particular personal exposure to the issues of land, agriculture and water came from attendance at an international forum sponsored by FAO and had input from other international bodies such as ILRI (International Livestock Research Institute) and CGIAR (<https://www.cgiar.org/>). This was *Livestock in a Changing Landscape (LCL), Integrated Analysis and Global Consultation*, Bangkok Thailand 27 November to 1 December 2006. This experience draws attention to the need for a global outlook rather than an insular and parochial outlook in the design of measures within Australia's land and agriculture sectoral plan. A colleague, the late Mike Nunn³⁴, an executive in the Australian Centre for International Agricultural Research, was instrumental in organising my attendance at this meeting. Mike was a champion of strategic foresight, One Health and climate action. Strategic foresight is another manifestation of knowledge. His influence resonates within this submission.

The output from the LCL meeting (published in 2103³⁵) has been moderated by subsequent publications from the World Bank³⁶ and FAO. The World Bank is sponsoring efforts towards climate-smart agriculture (<https://www.worldbank.org/en/topic/climate-smart-agriculture>). FAO has its LEAP and GLEAM initiatives to reduce methane emissions from agriculture. LEAP is the Livestock Environmental Assessment and Performance (LEAP) partnership: a multi-stakeholder partnership of Governments, Private Sector, NGOs

³¹Leng, R.A., 2014. Interactions between microbial consortia in biofilms: a paradigm shift in rumen microbial ecology and enteric methane mitigation. *Animal Production Science*, 54(5), pp.519-543.

³²Cottle, D.J., Nolan, J.V. and Wiedemann, S.G., 2011. Ruminant enteric methane mitigation: a review. *Animal Production Science*, 51(6), pp.491-514.

³³Falconer, I.R. and Humpage, A.R., 2005. Health risk assessment of cyanobacterial (blue-green algal) toxins in drinking water. *International journal of environmental research and public health*, 2(1), pp.43-50.

³⁴Vale Mike Nunn, 25th May 2023. <https://www.ava.com.au/member-updates/Newsletter/vale-dr-mike-nunn/>

³⁵Steinfeld, H., Mooney, H.A., Schneider, F. and Neville, L.E. eds., 2013. *Livestock in a changing landscape, volume 1: drivers, consequences, and responses*. Island Press.

³⁶Meadowcroft, J. (2009). *Minding the stock: bringing public policy to bear on livestock sector development*. World Bank

and CSOs, and other stakeholders united by a shared commitment to the environmental management and sustainable development of the livestock sector (<https://www.fao.org/partnerships/leap/en/>). FAO's GLEAM has the purpose of quantifying production and use of natural resources in the livestock sector and to thus to identify environmental impacts of livestock. The aim is to contribute to the assessment of adaptation and mitigation scenarios that will assist in the move towards a more sustainable and climate-friendly livestock and sector (<https://www.fao.org/gleam/en/>).

Measures within Australia's land and agriculture sectoral plan can benefit from outputs from US National Academies of Science, the US Council for Agricultural Science and Technology (CAST) and the European Union. The 2004 report from CAST (Climate change and greenhouse gas mitigation : challenges and opportunities for agriculture) is prescient and gives a good short account of the physics of climate change. US National Academies of Science has a wealth of resources on climate action that can be used to inform the renewal and reinvigoration of Australia's knowledge management systems. One example is the 2019 joint publication of NAS and the UK Royal Society (Climate Change and Ecosystems. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25504>).

6. Precedents from history: the tobacco lobby, climate skeptics/denialist and fossil fuel advocates

The climate denial/skeptic movement (the climate inaction lobby) does not openly acknowledge that evidence for the hazard of global warming (perhaps global heating is more explicit) comes from many separate sources and is backed by the coherence, corroboration or consilience³⁷ that makes for reliable conclusions (Whewell, 1840: see Wilson, 1998³⁸ and Gauch, 2003³⁹). They also do not concede that science operates according to evidence and its support through the logic and reasoning offered by laws and theories. The climate inaction lobby has invariably attacked the evidence but not the underlying reasoning. The laws of physics and chemistry guide an understanding of the greenhouse effect and its spillover to global warming. Global heating may be a more apt descriptor.

Oreskes and Conway have written a book, 'Merchants of Doubt'⁴⁰, that analyses the ruses, stratagems, tactics and devices employed by the tobacco lobby and its cadre of public relations operatives to undermine public health imperatives aimed at preventing disease caused by smoking. The book examines the similar ruses, stratagems, tactics and devices used by climate skeptics/denialists in their assault on measures for decarbonisation and climate

³⁷The word 'consilience' is absent from the Encarta Dictionary of World English and from several other popular dictionaries of English. It is a synonym for more commonplace words like 'corroboration' or 'confirmation'.

³⁸Wilson EO (1998) *Consilience: The Unity of Knowledge*. Alfred A. Knopf, Inc. New York.

³⁹Gauch HG Jr (2003) *Scientific Method in Practice*. Cambridge University Press, Cambridge.

⁴⁰Oreskes, N. and Conway, E.M. (2010) *Merchants of Doubt How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* i

change adaptation. The propaganda machine of the two interest groups seems to target doubt and retreat from, ignore or dismiss the established norms of civil and constructive discussion.

Key stratagems, ploys and so on of the tobacco lobby, the network of climate skeptics/denialists, and fossil fuel protagonists include the following:

(i) Doubt

The manufacture and promotion of doubt about defensible and corroborated scientific facts. The two lobby groups feed off the idea of scientific uncertainty and concoct controversy to delay regulatory action and gain public support. The climate skeptic/denial network does not appear to acknowledge that scientists reject the notion of attaining absolute truth and accept some uncertainty as part of nature ⁴¹.

The statement from R.A. Fisher⁴², a statistics expert, about the British doctors study⁴³ that gave statistical backing to the long held suspicion that tobacco smoking profoundly increased the risk lung cancer speaks volumes about the concoction of doubt and controversy. Fisher's statement that 'correlation does not imply causation' contains two glaring conceptual errors. He used 'imply' in the sense of a logical consequence of something and not in the usual sense of suggesting the truth or existence of something. Fisher's view of causation does extend to the notion of component causation⁴⁴ or that multiple factors that act jointly to cause a given effect. Fisher seems also to be unaware of the germ theory of disease and implications of the Henle-Koch postulates⁴⁵ for establishing the microbiological aetiology of infection and disease. The long-standing medical conception of aetiology as the set of causes in the manifestation of disease should have been sufficient to nullify Fisher's statement.

⁴¹AAAS(American Association for the Advancement of Science) (1989). *Science for All American: A Report on Literacy in Science, Mathematics, and Technology*. American Association for the Advancement of Science. Washington, DC.

⁴²According to Wikipedia, Sir Ronald Aylmer Fisher FRS (17 February 1890 – 29 July 1962) was a British polymath who was active as a mathematician, statistician, biologist, geneticist, and academic. He has been described as "a genius who almost single-handedly created the foundations for modern statistical science" and "the single most important figure in 20th century statistics". Richard Dawkins of selfish gene renown applauds Fisher as "the greatest of Darwin's successors" and a founding 'father' (sic) of the school known as Neo-Darwinism. Neo-Darwinism has been rendered obsolete by contemporary understandings of evolution theory. Fisher's 1930 book, *The Genetical Theory of Natural Selection*, is dedicated to Leonard Darwin, one of Fisher's eugenicist colleagues. This book expresses a concern that 'the socially lower occupations [of people] are the more fertile' and that 'we must face the paradox that the biologically successful members of our society are to be found principally among its social failures'. Fisher's depiction of 'social failures' runs against the common morality expressed within the principles of Beauchamp and Childress described in relation to the One Health (section IV). This statement contravenes 'respect for persons'. Fisher's so-called 'social failures' provide strength to, are the backbone of, the Australia team for climate action. Social attitudes where the views of Fisher still resonate are an impediment to progress and the implementation of effective climate action.

⁴³Doll R, Hill AB (1954). "The mortality of doctors in relation to their smoking habits". *BMJ*. **328** (7455): 1529–1533.

⁴⁴Kenneth J. Rothman and Sander Greenland (2005). Causation and Causal Inference in Epidemiology. *American Journal of Public Health* 95, S144_S150,

⁴⁵For example: Tortora, G.J., Funke, B.R. and Case, C.L. (2004) *Microbiology; An Introduction, Eighth Edition*. Pearson, San Francisco.

The Bradford Hill criteria⁴⁶ for causation operate have forestalled repetition of the expression that ‘correlation does not imply causation’. These criteria are set out in Appendix 3 where they accompany the GRADE guidelines which provides guidance for rating the quality of evidence and then grading strength of recommendations in health care. PICO guidelines, the Cochrane collaboration (qv) and the ARRIVE guidelines (qv) used to management the welfare of laboratory animals also assist towards quality in research.

Appendix 3 lists the Bradford Hill criteria for causation and complements other appendices as a set of tools to discipline thinking around climate change. These appendices include Damer’s twelve principles for good intellectual conduct (Appendix 2) , Hohenberg’s ‘What is Science’ (Appendix 5) and the Mertonian norms (Appendix 4).

(ii) Selective use or cherry picking of data

The self-serving selection or ‘cherry-picking’ of data is used by the network of climate skeptics/denialists, and fossil fuel protagonists to support their claims and to dismiss or ignore any evidence that contradicts their claims. This behaviour impedes the possibility of a scientific consensus that advances according to developing knowledge. The constant form of discourse used by this network is one of narrative, argument or persuasion (see Section V). They bypass the expository discourse that operates in science and civil life. They employ *ad hominem* attacks on scientists and experts to discredit the soundness of their findings, by impugning their motives and integrity. The aim is to undermine public trust in the enterprise of science and scientists.

(iii) Creating false equivalences

Creating false equivalences refers to suggestions that a legitimate scientific debate is in operation when this is not so. A false notion of ‘balance’ is fabricated when truth not ‘balance’ is the goal. The aim is to avoid truth-seeking and to obfuscate any existing and powerful consensus on matters such as the harmful effects of smoking tobacco and human-induced climate change.

(iv) Political influencing

This refers to the development of political connections that creates direct access to the legislative arm of government plus lobbying to shape public policy that serves their interests. Depending upon reading habits, elected parliamentary members and their advisers may obtain all their information and knowledge about climate change from discussions with lobbyists. This play highlights how important Australian public service codes of conduct are for Australia’s democratic governance. The values of the Australian Public Service include a statement about impartiality: *The APS is apolitical and provides the Government with advice*

⁴⁶Hill, Austin Bradford (1965). "The Environment and Disease: Association or Causation?". *Proceedings of the Royal Society of Medicine*. 58 (5): 295–300.

that is frank, honest, timely and based on the best available evidence
(<https://www.apsc.gov.au/working-aps/integrity/integrity-resources/code-of-conduct>).

(v) Promoting ideological agendas

The ploy here is to frame issues in terms of ideology in order to appeal to the world views of particular political or social groups. This turns measured scientific discussions into political ‘free-for-all’ debates. The result is the polarisation and hardening of public opinion. Florid taglines such as ‘woke agendas’, ‘virtue signalling’, ‘cancel culture’, ‘inner city elites’ and others are used with abandon. Unhappily, this ploy could nurture an underlying and counter-productive misanthropy.

(vi) Public relations campaigns

The network of climate skeptics/denialists and fossil fuel protagonists invests in extensive public relations effort to channel and manipulate perception. Included here are misleading advertisements and the spreading of misinformation through various media channels. P. T. Barnum, an American showman of the mid-19th century, is said to have used a phrase, ‘there’s a sucker born every minute’, and this may underlie the thrust of public relations campaigns.

(vii) Victimhood

The notion of victimhood is frequently deployed within the repertoire of climate skeptics/denialists and fossil fuel champions. Refutations and rejoinders to the assertions of these groups that follow the discourse of exposition are frequently and falsely misconstrued as *ad hominem* attacks and bullying. These activist groups then claim to be the bullied (victims) and seek public sympathy against the bullies. An appropriate response is to continue with a discourse that delineates and explains (exposition) and to strictly avoid language that ordinary decency would view as personal attacks. The avoidance of candour and openness would be counter-productive. Two virtues from the One Health can apply to climate action. These are empathy, expressed through a good bedside manner, and the equanimity required to deal with adversity⁴⁷.

(viii) Conclusions

The list of ruses and stratagems employed by climate change skeptics/denialists are designed to oppose measures for dealing with climate change. They aim at creating confusion, delaying action, maintaining the status quo and protecting the problematic and perhaps misconceived interests of the fossil fuel industry. The descriptor, problematic, is important because sound financial strategy should consider the concept of stranded assets⁴⁸. Matters regarding the

⁴⁷Olser, W’ (1904) *Aequanimitas, with other addresses to medical students and practitioners of medicine*. Blakiston, Philadelphia, Osler, W. (1892) *The Principles and Practice of Medicine: Designed for the Use of Practitioners and Students of Medicine*. Appleton,

⁴⁸Stranded assets are those that must be unexpectedly or prematurely written down because the economic returns on the asset are no longer present. An asset may also be classified as stranded if the technology becomes unviable, obsolete or superseded

integrity of conduct in science etc. are set out in the appendices. These can form an armoury for counteracting the ruses, ploys and stratagems of climate skeptics/denialist and the fossil fuel lobby. The wordplay used by this group has had an impact on linguistics or communication by language, which is treated in Section V.2. Meanings of words have been blurred and expository discourse has been eclipsed.

III. Structure of this submission

All in all, there is ample justification for deciding that knowledge in the broad must be the prime topic in this submission on the Agriculture, Land and Emissions Discussion Paper. Accordingly, the submission has the following structure:

First is a case for a One Health perspective which (among other things) provides for the norms of conduct within Australia's overall knowledge system or knowledge machine and its extension to education and training that operate for successful planning and execution of Australia's aspirations for Net Zero by 2050.

Second is a commentary on the nature of knowledge and its components, including science which is composed of lower case 's' science or the 'human activity practised by scientists' (where everybody can be a scientist and scientists are not members of an elite meritocracy – to be explained in section 4) and uppercase 'S' Science or the body of knowledge produced by that activity (Hohenberg 2010)⁴⁹.

Third are some specific suggestions and proposals for renewing and reinvigorating Australia's system for generating, managing, sharing and communicating knowledge; Australia's knowledge machine. These suggestions and proposals are provided in an abridged form within the executive summary and given more detailed treatment in Section VI. They constitute a view on how to build on existing effort and knowledge (see Section 2.5.1 of the discussion paper on agriculture land and emissions). Their aim is (1) to identify present initiatives and innovations and preparing them for action according to time place and population and (2) to outline ways and means for coordinating existing efforts in an overall national plan.

The specific suggestions and proposals include:

1. The development of an evolving repository of knowledge relevant to climate action and how it might be realised through the preparation of a scoping paper and a subsequent discussion forum.

by better technology. Obsolescence will also cause the asset owners to write-down the value of the asset. From *Stranded Assets in Australia with Reference to the Coal Industry*, available at <https://www.un.org › wp-content › uploads › sites>.

⁴⁹Hohenberg PC (2010) *What is Science?* ArXiv. (Internet access at <https://arxiv.org/abs/1704.01614>). See Appendix 2.

2. A comprehensive account of greenhouse gas emissions from farming systems which covers all aspects of methanogenesis in livestock together with possibilities for dampening methane production in livestock, for reducing inputs of synthetic nitrogen and providing opportunities for carbon sequestration. The norms of solid scholarship must apply. Guidance can be had from the ideals of a systematic review, the precedent of risk analyses and the coverage of subject matter in textbooks of comparative medicine. The product must be able to inform the particular actions that fit particular circumstances and also to clarify the limits to genetic selection.
3. A major revision of the methodology for the measurement of soil carbon sequestration in agricultural systems. Without this there is no sound resource for the development and accreditation of competencies of those involved. Once again, guidance can be had from the norms of scholarship and so on mentioned in (2).
4. A comprehensive account of ways and means for measuring methane and nitrous oxide that begins with an account of past and present methods and their evolution and provides foresight on future possibilities. The lack of devices similar to the breathalyser used to detect alcohol levels in people or infra-red thermometers to measure body temperatures is a major impediment to progress. Similar devices in the hands those directly involved in agriculture and land stewardship could be transformational. It would allow for decarbonisation strategies tailored to particular circumstances.
5. A particular review of methanogenesis in herbivores that emphasises physiology and which can identify the web of causes or the risk factors to be addressed at particular local levels. The paradigm of diagnosis can operate. Diagnosis can be restated as the art or act of determining the nature of disease or phenomena such as methanogenesis.
6. An exercise to explore the physiological mechanisms that apply to possible interventions to reduce methanogenesis in livestock. Scientific research directed solely immediate practical outcomes forecloses on future possibilities made possible by clearer understandings and insights. An understanding of physiological mechanisms opens possibilities for emerging technologies such as quantum computing.
7. A comprehensive account of thermophysiology and the impact of heat on animals that can inform the realities and limits of possible adaptation and fill an important gap in properly collated knowledge. Guidance can be had from the norms of scholarship and so on mentioned in (2).
8. A comprehensive account of water quality and its shared importance in the health and wellbeing of land and agriculture. The impacts of climate change and the possibilities for adaptation require systematic analysis. Guidance can be had from the norms of scholarship and so on mentioned in (2).
9. A guidance document on ways and means of capturing the benefits of contemporary information technology and online databases in the search for information and knowledge and its subsequent management. Extension of skills and competencies in this area and throughout the community can broaden Australia's knowledge management capacity and the translation of knowledge into action.

10. A process to determine whether there are matters additional to those described in points (1) to (9).
11. The development a communal and inclusive capacity for monitoring possible impacts climate change across Australia's diverse ecosystems. A start could be made by creating a registry of community organisations and other resources that can make direct field observations. Initiatives such as Feral Scan (<https://feralscan.org.au/>) which provides for community input into the management of feral animals suggests a possibility.
12. Refinement to the protocols and procedures for factoring science into Australia's public policy process⁵⁰.
13. An open and unfettered forum for discussing a renewed and reinvigorated science enterprise in Australia. This will focus on what happened in the past and how the present and the future can be reshaped according to evolved thinking.
14. The creation of a resource devoted to monitoring, marshalling and communicating intelligence about climate action initiatives within international bodies and in other countries. International bodies include such as UNESCO, WHO, UNEP, FAO, the World Bank, WOAHA and the OECD. It would be remiss not to benefit from the publications of the US National Academies of Science and the US Council for Agricultural Science and Technology (CAST). There are perceptible gaps in this connection.

Fourth in the structure of this submission is a set of reflections on issues and considerations relevant to the suggestions and proposals put forward in this submission. This commentary is best described as a work in progress. It will include aspects of history that explain the pressing need for renewal and reinvigoration of Australia's capacities for climate action. The commentaries aim at elaborating on the specific suggestions and proposals in this submission.

IV. A One Health perspective on climate action

This submission commends a One Health perspective because of its power in ordering knowledge and providing for good conduct, including respect for the truth, which is facilitated by reliable knowledge. In fact, a One Health framework can facilitate each step in the formulation, execution and continual improvement of Australian decarbonisation strategies and can guide the essential renewal and reinvigoration of Australia's knowledge management systems, named here as Australia's knowledge machine. A One Health perspective entails norms of good conduct that are indispensable for success in these ambitions. These norms are universal and should be made plain and openly declared. Note here that Mark Carney, the UN Special Envoy for Climate Action and Finance has explored credit, Covid and climate as the three most significant crises of the twenty-first century⁵¹. He states that these three calamities

⁵⁰Bridgman P. & David G. (1998) *Australian Policy Handbook*. Allen and Unwin, Sydney.

⁵¹Mark Carney, the UN Special Envoy for Climate Action and Finance provides an account of stranded assets in his 2021 book, *Value(s): Building a Better World for All*, William Collins, London.

were aggravated and continue to be aggravated by a common crisis of values and then lists the core values that can rebuild the social capital⁵² necessary for climate action and the restoration of trust across society. The list of values comprises solidarity, fairness, responsibility, resilience, sustainability, dynamism and humility.

The One Health High-Level Expert Panel (2022)⁵³ describes the One Health as an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy, and air, taking action on climate change and contributing to sustainable development.

The key underlying principles for the One Health can apply across Australia's ambitions for decarbonisation. These principles comprise (1) equity between sectors and disciplines, (2) sociopolitical and multicultural parity (the doctrine that all people are equal and deserve equal rights and opportunities) and inclusion and engagement of communities and marginalized voices, (3) socioecological equilibrium that seeks a harmonious balance between human–animal–environment interaction and acknowledging the importance of biodiversity, access to sufficient natural space and resources, and the intrinsic value of all living things within the ecosystem, (4) stewardship and the responsibility of humans to change behavior and adopt sustainable solutions that recognize the importance of animal welfare and the integrity of the whole ecosystem, thus securing the well-being of current and future generations, (5) transdisciplinarity and multisectoral collaboration, which includes all relevant disciplines, both modern and traditional forms of knowledge and a broad representative array of perspectives, (6) respect for competencies and scholarship their continual maintenance and (7) the courage and equanimity required to adhere to good conduct in the face of adversity.

Significantly, the norms of conduct within the One Health align with the ethics that apply to health care (Berglund, 2007)⁵⁴. Berglund states that the ethical goals and duties for health care have been simplified into broad, perhaps shorthand, principles and specifies those promulgated by Beauchamp and Childress⁵⁵. These four principles stem from the notion of a common morality and provide a basis for moral reasoning in health care that can be extended to care for the environment and climate action. The first principle is beneficence, which is the

⁵²The Australian Bureau of Statistics describes social capital as the layer of commonly held social values, beliefs and attitudes that lies beneath individual behaviour and encourages transactions that result in greater wellbeing for society (<https://www.abs.gov.au/ausstats/abs@.nsf/latestproducts/D293F36BEA866494CA2571B700160AB0?opendocument>).

⁵³ One Health High-Level Expert Panel (OHHLEP), Adisasmito WB, Almuhairei S, Behraves CB, Bilivogui P, Bukachi SA, Casas N, Becerra NC, Charron DF, Chaudhary A, Janice R, Z Ciacci, Cunningham AA, Dar O, Debnath N, Dungul B, Farag E, Gao GF, Hayman DTS, Khaita M, Koopmans MPG, Machalaba C, Mackenzie JS, Markotter W, Mettenleiter TC, Morand S, Smolenskiy V, Zhou L (2022) One Health: A new definition for a sustainable and healthy future. *PLoS Pathogens* 18, e1010537.

⁵⁴Berglund, C (2007) *Ethics for Health Care, Third Edition*. Oxford University Press, Oxford, UK.

⁵⁵Beauchamp, T.L. and J.F. (2019) *Principles of Biomedical Ethics, Eighth Edition*. Oxford University Press, Oxford, UK.

principle of doing good and providing care for others [plus the environment and its components]. The second principle is non-maleficence, which is the principle of not harming others [plus the environment and its components] and the general minimisation of harms. The third principle is autonomy, which is the principle of allowing and promoting self-rule, of people making rules about their own lives. This principle can lead to broad inclusion in the pursuit of climate action. It can unleash the potential of agency, which refers to the state of being active usually in the service of a goal or having the power and capability to produce an effect or exert influence (VandenBos, 2015)⁵⁶.

The fourth principle of Beauchamp and Childress has particular significance because it draws attention to a particular matter that warrants greater prominence in the dialogue around climate change. The fourth principle is justice and refers to the principle of fair allocation of community resources and burdens. In this regard, Hermansson and Hansson (2007)⁵⁷ have put forward a three-party model tool for ethical risk analysis. The parties are the risk-exposed, the risk beneficiary and the decision-maker and analysis can be made around seven crucial questions. In Australia, the decision makers are governments in Australia's system of responsible government. Responsible here refers explicitly to a political system where the executive government, the Cabinet and Ministry, is drawn from, and accountable to, the legislative branch. However, it is not unreasonable to expect correct, proper or responsible behaviour (the common meaning of responsible) in decision-making according to the three-party model-tool for risk equity.

A last but one word in this section concerns competency and the maintenance and advancement of competencies as part of the ethos of the One Health. The editorial in the journal *Science* by Klinsky and Sagar (2023), mentioned earlier, centred on capacity building as the essential element in designing and then implementing strategies for climate action. Competencies provide substance for these capacities. Klinsky and Sagar (2023) refer to a lack of scholarship as a competency that can provide clarity and guidance to plans and their implementation. The One Health ethos entails the regular refreshing of competencies and the associated knowledge. The same entailment can apply universally to Australia's ambitions for climate action.

The last word is a broad use across the whole of the One Health in the form of methods for guiding the quality of medical research and its application (see appendix 3 which describes the Bradford Hill criteria for causation and some other matters). These methods include those used by the Cochrane collaboration, the evidence hierarchy set out by the NHMRC, the GRADE and PICO guidelines for making the implications of research more intelligible, and the GRADE guidelines used to clearly explain the physiological state of research animals. Nobel Laureate, Howard Florey, insisted that research results were compromised if

⁵⁶VandenBos GR (Editor-in-Chief)(2015) *APA Dictionary of Psychology, Second Edition*. American Psychological Association, Washington, DC.

⁵⁷Hermansson, H, and Hansson, S.O. (2007) A three-party model tool for ethical risk analysis. *Risk Management* 9, 129-144.

circumstances were ‘unphysiological’. An understanding of circumstances applying to studies of methanogenesis in animals over time would assist in evaluating the strength of research findings.

V. Knowledge: Its dimensions and indispensability

1. Preliminary considerations

This section provides explanations and background for the common thread in this submission; namely, that all aspirations outlined in the discussion paper on the sectoral plan for agriculture land and emissions require an unspoken vital force for strategic planning, building capacity and then implementing action. The vital force is creativity and inventiveness, which depends on insights and understanding derived from knowledge. Information and its progression to knowledge and then to understanding and insight is so universally and fundamentally important that it can be lost in plain sight.

The discussion paper mentions building on existing effort and knowledge (Section 2.2), recognition of First Nations knowledge, and asks what skills, knowledge and capabilities do you think producers and land managers need to implement change? In fact, sound knowledge provided by a thriving Australian knowledge machine (including education and training) is at the heart all answers to the twelve questions listed in the introduction and applies to all aspects of the discussion paper.

The notion of intelligence used within the military provides a good parallel for what is required for sound responses to climate change. In military circles, intelligence is (1) the product resulting from the collection, processing, integration, evaluation, analysis, and interpretation of available information concerning foreign nations, hostile or potentially hostile forces or elements, or areas of actual or potential operations, (2) the activities that result in the product, and (3) the organizations engaged in such activities. Strategic intelligence refers to that required for the formation of policy and military plans at national and international levels. Operational intelligence refers to the intelligence required for planning and conducting campaigns and major operations to accomplish strategic objectives within theaters or operational areas. Tactical intelligence refers to intelligence required for the planning and conduct of tactical operations⁵⁸.

A perspective from biology reinforces the absolute and pervasive importance of information. Living entities are ‘chemical, physical and informational machines that construct their own metabolism and use it to maintain themselves, grow and reproduce’ (Nurse, 2020)⁵⁹.

⁵⁸The DOD Dictionary of Military and Associated Terms (2017). US Department of Defense (DOD). <https://apps.dtic.mil/sti/pdfs/AD1029823.pdf>

⁵⁹Nurse, P. (2020) *What is Life: Five Great Ideas in Biology*. Scribe Publications, London.

Information and knowledge are members of associated keyword clusters⁶⁰ that can be named as intelligence, knowledge and rationality. Two matters of linguistics require explanation and perhaps to a degree of pedantry. Linguistics is the scientific study of language and language is the medium for human communication and the sharing of information and knowledge. The two matters are forms of discourse and lucidity within the vocabulary around knowledge.

2. Linguistics

(1) Forms of discourse

Forms of discourse have become an issue affecting accessibility to knowledge. The world's knowledge management machines and that of Australia have been stressed and strained from orchestrated campaigns of misinformation and disinformation during the COVID-19 pandemic. The WHO described this as an infodemic⁶¹. Similar campaigns have been executed by the network of climate change sceptics/deniers/oppositionists and the tobacco lobby. The shared methodologies of these groups are outlined in Section II (Background, precedents from history). At the same time, the COVID-19 pandemic and the matter of climate change have both been accompanied by an enormity of communication from all forms of media. This enormity of communication presents an enormous impediment to the marshalling of actual information that can guide sound action.

Coincidentally, there has been a general imperative for drawing attention to the hazard of climate change and global warming/heating has meant a concentration on persuasive discourse rather than the expository discourse that applies more generally to scholarship. A persuasive discourse was a clear necessity in the situation reports required to initiate action. Examples of such reports are shown as a footnote⁶². An understanding of different forms of discourse provides a way of systematising information and transforming it into knowledge that can lead to understanding and insight.

Encyclopaedia Britannica (2010) covers four forms of discourse in its entry on nonfictional prose. The basic purpose of communication is to convey thought and feeling to a particular audience (Vivian and Jackson, 1961)⁶³. Thought and feeling includes factual information, opinions, attitudes, points of view, aspects of persons and places, and accounts of events true and fictitious. Systematic communication in words can be classified into four sorts of discourse named exposition, argument (or persuasion), description, and narrative.

⁶⁰The Macquarie Thesaurus. Macquarie Library Pty. Ltd, Sydney.

⁶¹An infodemic is too much information including false or misleading information in digital and physical environments during a disease outbreak. It causes confusion and risk-taking behaviours that can harm health (https://www.who.int/health-topics/infodemic#tab=tab_1).

⁶²Pittock, B. editor (2003) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office. Canberra. Steffen, W. and Hughes, L. (2013) *The Critical Decade 2013: Climate Change Science, Risks and Responses*. Commonwealth of Australia (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education), Canberra.

⁶³Vivian, C.H. and Jackson, B.M. (1961) *English Composition, College Outline Series*. Barnes and Noble, New York

Exposition has the central purpose of setting forth or explaining something. In exposition, the material communicated is primarily that of information. Argument (persuasion or argumentation) has a central purpose in convincing or persuading an audience to adopt a certain doctrine of attitude or, perhaps take a certain course of action. Argument includes propaganda. The central purpose of description is to evoke impressions produced by aspects of persons, places, scenes and so on. Description is always coloured by the author's interpretation and is thus subjective. Narrative or narration has the central purpose of recounting happenings, events or series of events such that meaning emerges from them,

(2) The meaning of words

The content of this section is incomplete and is foreshadowed for its possible importance for innovation and for its potential for converting what has been called the 'climate war' into the climate peace (Thorp, 2022).

Clarity around the meaning of words (semantics) and the meanings of words in particular context (pragmatics) can address ambiguities that may impede constructive discussion around climate change. At the same time, peace-making can be based on truth and reconciliation, and truth aligns depends on sound knowledge. A common understanding of words like truth and knowledge can pave the way to peace and facilitate a move from polemics. 'To win the climate war, we must win the climate peace' (Thorp, 2022).

Clarity around the meaning of words may also open the way to innovations in information technology that have the potential to revolutionise action against climate change. Advances in machine learning and the imminent arrival of quantum computing are in mind. Understanding the relationships among words and their associated concepts in keyword clusters⁶⁴ containing information and knowledge can set the scene for constructing ontologies that underpin the expert 'knowledge engineering'

To be continued

VI. Suggestions and proposals for supporting and enabling change

All suggestions can be dealt with through capacities made possible by an overall form of Australia's net zero strategy built on the example of Australia's Biosecurity Strategy and the Australian Biological Resources Study. These capacities allow for collaboration on terms of reference that can commence with a scoping paper.

⁶⁴*The Macquarie Thesaurus*. Macquarie Library Pty. Ltd., Sydney.

1. A repository of knowledge relevant to all aspects of action against climate change.

The repository in mind simple does not exist anywhere in the world and the task of distilling knowledge about the many aspects of climate change has become onerous and inefficient. It has a parallel in the enormous effort required to separate sound information from the clamour that accompanied the COVID-19 pandemic. There are official statements on climate change from national and international bodies and from non-governmental organisation, articles in the scientific literature, single author and multi-author books of varying utility, attempts at encyclopaedias, outputs designed for education and training, and a media output that can be of good quality but amount to an overall cacophony. The repository should follow the example of living systems and build upwards in levels of organisation upwards from accounts of physics and chemistry to hazards and possible remedies applying to living organisms, ecosystems, planetary systems, and then to human society. Information framed around a discourse of exposition should be made prominent. Capacities facilitated by elements within the model presented by Australia's Biosecurity Strategy and the Australian Biodiversity Resources study provide a platform for collaborative consideration of the terms of reference for the repository in mind. A scoping paper could set the scene. The repository must be comprehensive, evolving, properly maintained and easily accessible. It can be the starting point for renewal and reinvigoration of Australia's knowledge machine.

2. A systematic account of all sources of greenhouse gas emissions from land and agriculture and prospects for remediation

An editorial from the journal *Science* of December 8, 2023, sets the scene⁶⁵. It states that satellite observations (perhaps widely uncertain) suggest that China emits roughly 19 Mt from the energy sector each year plus 18 Mt from livestock, 16 Mt from waste and other sources, and 12 Mt from rice agriculture. It goes on to say that whereas reducing coal emissions is not easy, China may achieve up to 8 Mt in cuts by 2030 and that this may be accompanied by another 8 Mt in cuts from waste and other sources and a further 4 Mt in emissions from livestock (including manure) and rice production. The point is that although attention to livestock emissions is essential, a comprehensive campaign to address greenhouse gas emissions from must address all sources of methane and must include nitrous oxide. Ruminant-based farming systems can reduce inputs of synthetic nitrogen fertilisers and reduce nitrous oxide emissions. Regardless of scaling effects from atmospheric concentrations,

⁶⁵Nisbet, E.G. (2023) Editorial: New hope for methane reduction. *Science* 382, 1093.

nitrogen oxide is a clear-cut greenhouse hazard that has come under some scrutiny^{66 67 68}. Nitrous oxide has 265 times the atmospheric heat-trapping ability of carbon dioxide on a per-molecule basis and considered over a 100-year period. This compares with methane which has an impact of 85 times the atmospheric heat-trapping ability of carbon dioxide measured the same way⁶⁹.

A package of relevant knowledge equivalent to the strategic intelligence, operational intelligence and tactical intelligence used within the military is required to guide proper and all-inclusive action. Once again capacities facilitated by the innovative management model suggested earlier the model elements within the model presented earlier can provide a platform for collaborative consideration of the terms of reference for the package of intelligence required. A scoping paper could initiate the effort.

3. A back-to-basics revision of the methodology for measuring soil carbon sequestration

Carbon Credit Units (ACCUs)⁷⁰ were introduced as part of a market-based approach towards decarbonisation and abatement⁷¹. Their purpose is to quantify the value of offsets⁷². ACCUs were administered through the ERF or Emissions Reduction Fund⁷³ with oversight from the ERAC or the Emissions Reduction Assurance Committee. This is an independent expert committee set up to assess whether methods meet the requirements of the ERF.

⁶⁶Tian, H., R. Xu, J. G. Canadell, R. L. Thompson, W. Winiwarter, P. Suntharalingam, E. A. Davidson, P. Ciais, R. B. Jackson, G. Janssens-Maenhout, M. J. Prather, P. Regnier, N. Pan, S. Pan, G. P. Peters, H. Shi, F. N. Tubiello, S. Zaehle, F. Zhou, A. Arneeth, G. Battaglia, S. Berthet, L. Bopp, A. F. Bouwman, E. T. Buitenhuis, J. Chang, M. P. Chipperfield, S. R. S. Dangal, E. Dlugokencky, J. W. Elkins, B. D. Eyre, B. Fu, B. Hall, A. Ito, F. Joos, P. B. Krummel, A. Landolfi, G. G. Laruelle, R. Lauerwald, W. Li, S. Lienert, T. Maavara, M. MacLeod, D. B. Millet, S. Olin, P. K. Patra, R. G. Prinn, P. A. Raymond, D. J. Ruiz, G. R. van der Werf, N. Vuichard, J. Wang, R. F. Weiss, K. C. Wells, C. Wilson, J. Yang, and Y. Yao (2020) A comprehensive quantification of global nitrous oxide sources and sinks. *Nature* 586, 248-256.

⁶⁷Hristov, S., A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J. and Oosting. A review of technical options for non-CO2 emissions FAO Animal Production and Health Paper No. 177. FAO, Rome, Italy.

⁶⁸Nisbet, E. G., E. J. Dlugokencky, R. E. Fisher, J. L. France, D. Lowry, M. R. Manning, S. E. Michel, and N. J. Warwick (2021) Atmospheric methane and nitrous oxide: challenges along the path to Net Zero. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 379:20200457.

⁶⁹Myhre, G.; Shindell, D.; Bréon, F.-M.; Collins, W.; et al. (2013). "Chapter 8: Anthropogenic and Natural Radiative Forcing" (PDF). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. pp. 659–740.

⁷⁰Australian carbon credit units (ACCUs) represent the quantity of greenhouse gas sequestration or emission avoidance that has occurred by businesses registered under the ERF. One ACCU is the representative of one tonne of carbon dioxide.

⁷¹Abatement refers to both the removal of greenhouse gases already in the atmosphere or the avoidance of greenhouse gas emissions.

⁷²Carbon offsets reduce or remove greenhouse gases (GHGs) in one place to compensate for emissions elsewhere.

⁷³The Emissions Reduction Fund is the scheme run by the Australian Government that awards Australian carbon credit units to businesses for abating carbon dioxide equivalents.

A 2022 independent review of the ACCUs⁷⁴ stated a need for a new body with a major responsibility for ensuring method integrity. This need is whole-heartedly endorsed. A **back-to-basics, transparent and accessible revision of the rationale underlying the measurement of soil carbon sequestration in agricultural systems is urgent and can be triaged to the top of the actions list.**

Aggregators at the online forum were concerned about the accreditation of competencies via the ACCUs and the maintenance of trust with their clients. These competencies are impossible to vouch for without a clearly articulated and properly accredited account of methods to measure carbon sequestration.

Attempts to make sense of (1) the Carbon Credits (Carbon Farming Initiative—Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination 2018 and (2) the were onerous and unproductive. The documents were virtually impenetrable and for many reasons. They have a fatal flaw that goes beyond the legalistic and obfuscating layout and lack of references. Their mathematisation is problematical. Mathematics is about the quantification of things and mathematical modelling is unreliable in the absence of clarity about the precise nature of things⁷⁵.

4. A thorough exposition of ways and means for measuring methane and nitrous oxide and possibilities for innovation

There are accredited methods for measuring methane and nitrous on a macro-scale and in the controlled environment of a laboratory or research farm. However, there is a glaring absence of accredited and simple methods and devices for measuring methane in individual animals and specific sites such as manure heaps on farms or other premises. Note that animals refers to ruminant livestock in particular but not to ruminant livestock alone. Police have access to convenient breathalysers for measuring ethanol concentrations in people. Sniffer dogs can detect an amazing range of gaseous but perhaps not methane. Plumbers have access to convenient gas leak detectors

Sites specific methods for managing methanogenesis can be guided by a simple hand held device, perhaps as an attachment to a smartphone. The absence of these devices creates a situation akin to attempts at health care without a stethoscope or thermometer. A scoping paper on the possibilities for hand-held devices for measuring methane and nitrous oxide could unleash the talents of budding inventor

⁷⁴ Chubb, I., Bennett, A., Gorrington, A., Hatfield-Dodds, S., 2022, Independent Review of ACCUs, Department of Climate Change, Energy, the Environment and Water, Canberra, December.

⁷⁵ Hogben L (1968) *Mathematics for the Million, Fourth Edition*. WW Norton and Company Inc, New York. Mathematics deals with spatial and numerical relationships whereas ordinary languages ‘describe the sorts of things in the world’.

5. A knowledge resource to elucidate all aspects of methanogenesis in herbivores, especially ruminants

The specific suggestion here is for comprehensive account or compendium of greenhouse gas emissions from farming systems which covers all aspects of methanogenesis in livestock. This should extend to possibilities for dampening methane production in livestock, for reducing inputs of synthetic nitrogen and providing opportunities for carbon sequestration. The norms of solid scholarship must apply and evidence for this capacity in Australia is demonstrated by the list of scientific review articles from Australian scientists show in Appendix 1 of this submission. Guidance on the conduct of this project and the form of its product can be had from the ideals of a systematic review, the precedent of risk analyses⁷⁶ and the manner for arranging the subject matter in textbooks of comparative medicine. The product must be able to inform the particular actions that fit particular circumstances and also to clarify the limits to genetic selection. High-insight low-input integrated control programs tailored to particular environments are the goal.

It would be gratifying to see the term holobiont mentioned or highlighted in the desired compendium. This term came to the fore in 1991⁷⁷. A holobiont is an assemblage of a host and the many other species living in or around it, which together form a discrete ecological unit through symbiosis, though there is controversy over this discreteness. The components of a holobiont are individual species or bionts, while the combined genome of all bionts is the hologenome. The population of micro-organisms in the host is termed the microbiome.

Systematic and comprehensive coverage of the ruminant microbiome and its complement of methanogenic cyanobacteria would represent a major step forward. Answers to some fundamental questions could yield major insights. Is the association between ruminants and all members of their microbiome always one of cooperative mutualism? Are there circumstances where some parties benefit and the impact on other parties is neutral? Are there circumstances where some parties benefit but other parties are harmed? Could some methanogenic cyanobacteria be rogues and act like pathogens? What checks and balances determine the composition of the ruminant microbiome?

Where the compendium of greenhouse gas emissions from farming systems might cover methanogenesis in herbivores, it should emphasise physiology. Knowledge of physiology can be used to identify the web of causes or the risk factors to be addressed at particular local levels. The paradigm of diagnosis can operate for methane abatement in the field. That way, remediation measures can be tailored to particular circumstance. Diagnosis is broader than the art or act of determining the nature of disease or phenomena such as methanogenesis.

⁷⁶The example of risk analysis of the Codex Alimentarius Commission is a classic: Codex Alimentarius (2007). Working principles for risk analysis for food safety for application by governments, First Edition. Codex Alimentarius Commission, Joint FAO/WHO Food Standards Programme, Rome. <http://www.fao.org/docrep/010/a1550t/a1550t00.HTM>.

⁷⁷Margulis L. Symbiosis as a source of evolutionary innovation: speciation and morphogenesis. In: Cambridge MA MLFR, editor. Symbiogenesis and Symbioticism: MIT Press; 1991.

Diagnosis is a universal skill. Motor mechanics diagnose problems in motor vehicles. Swimming coaches diagnose flaws in backstroke etc.

6. An exploration of the physiological mechanisms underlying possible chemical, immunological and dietary interventions for reducing methanogenesis in livestock.

The suggestion here is made according to solidarity with the scientists looking at possible chemical, immunological and dietary interventions for reducing methane emissions from livestock and is designed to increase the impact of their efforts. The scientists in question are beset by an atmosphere of hyperbole and a management culture intent on immediate application. There is not evidence from publications so far that an understanding of underlying issues is a consideration in their efforts. It seems that if the product fails to be marketable, their research has failed. Implications for a continuing career? This is far from true if their research has shed light on the physiology of methanogenesis that opens up new possibilities. The issue of management culture in science is taken up in suggestion 13.

The suggestion is that mechanisms for action should be recognised as a necessary component of research into interventions against methane emissions. Immunological methods are a special case given that the histology of the rumen compared to the rest of the gut provides no *prima facie* case that immunological mechanisms based on the lymphoreticular system have a potential to control methanogenesis. Furthermore, the antigen ('non-self') targets within methanogens seem to be far from clear. Is the rumen microbiome regulated by other means, perhaps through chemoresponsive cell like tuft cells? Research into basic issues around immunity and the rumen could be expedited

7. An account of thermophysiology and the impact of heat on life forms that can guide adaptations to climate change and their limits

A recent foray into the physics of heat, thermophysiology and the impact of heat on life forms identified a gap across the globe. There is no resource that brings these matters together as single cohesive and readily accessible whole that can inform how living systems might be protected from global heating and what the limits to possible adaptations are. There are many excellent textbooks, but alone they fall short of what is required. The suggestion here is for a stand-alone knowledge base on heat, its impacts and possible interventions.

8. A comprehensive, evolving and open-access account of the hazards to water quality accompanying climate change

Agriculture is a form of land use and a sectoral plan directed at both land and agriculture makes plain common sense. Water resources and their quality are necessary for both.

Water resources will be affected by climate change and one predictable consequence is upsurges in the hazard of toxic cyanobacteria. This hazard is already on the increase and has dogged water supplies in many places. Cyanobacterial toxins are now known to be a component cause of neurodegenerative disease in humans and a common cause of mortalities in livestock and fish.

The suggestion is for the sectoral plan to include a comprehensive account of water quality and its shared importance in the health and wellbeing of land and agriculture. Possible hazards should be identified and characterised. The impacts of climate change and the possibilities for adaptation should be scoped.

9. Guidance on ways and means for capturing the benefits of contemporary information technology and online databases for knowledge management

Until the advent of the internet and the flowering of its potential, the scientific literature was scoured for information in libraries and through resources like Index Medicus, Index Veterinarius, the Veterinary Bulletin and the abstracting services of the Commonwealth Agricultural Bureau International. Morrison (1978)⁷⁸ prepared a guidance document on access to the veterinary literature that was invaluable for its time and place.

The suggestion here is the preparation of similar guidance document directed on ways and means of capturing the benefits of contemporary information technology. There should be a comprehensive listing of online databases and what they do, a list of available reference management software and a list of online open libraries might be useful. in the search for information and knowledge and its subsequent management. Online databases include Entrez PubMed, Google Scholar, Semantic Scholar and Open Alex Reference management software includes Jabref, Bibdesk, Mendely, Zotero and Bookends. Trove from the Australian National Library is a boon. Online libraries include Project Gutenberg, the Heritage Library and the Open Library located in Archive.org. Skills and competencies for accessing and managing information are definitely not the province of a select few and are within the grasp of all. Extension of these skills and competencies throughout community, particularly in light of the broadband network, can broaden Australia's knowledge management capacity and spillover to the capacity for climate action.

10. An exercise to identify matters additional to those in points (1) to (9)

This suggestion speaks for itself as a necessary and usual cross-check for omissions. Horizon scanning on such matters should be standard practice.

⁷⁸Morrison, N.H. (1978) *Access to the Veterinary Scientific Literature: An Australian Guide*. Australian Government Publishing service, Canberra.

11. A possible communal and inclusive means for monitoring possible impacts climate change across Australia's diverse ecosystems

A communal and inclusive capacity for monitoring possible impacts climate change across Australia's diverse ecosystems is desirable. A start here could be made by creating a registry of community organisations and other resources that can make direct field observations. Initiatives such as Feral Scan (<https://feralscan.org.au/>) which provides for community input into the management of feral animals suggests a possibility. This initiative could be a means for capturing indigenous knowledge, which is a prime example of tacit or implicit knowledge gained by particular acuity in observation. Such knowledge qualifies as 'know how' that can prime the 'know why' of science and produce a virtuous cycle of progress. Avid recreational fishers have an eye to environmental changes as do park-care volunteers and birdwatchers.

12. Protocols, procedures and codes of conduct for factoring science into Australia's governance

Inspiration here comes an editorial in the journal *Science* and by the previous UK Government Chief Science Adviser (Vallance, 2023)⁷⁹. It starts by stating that governments need to understand science and that science has something to offer to policies across the board. It finishes as follows:

'Policies must balance conflicting interests while addressing specific problems. Science advice cannot be followed slavishly, but if decision-makers ignore such advice, or treat it as a box-ticking exercise, then the systems that uphold societal well-being will be at risk. The most stark example of this is climate change—and we are witnessing the results of that crisis.'

Vallance proposes that science advice is unlikely to be effective if governments lack scientists. An absence of scientists can mean the absence of effective means for evaluating recommendations and assessing their implications for policies. He goes on to say attracting more scientists into government will require new means for recruitment and training. Scientists in government in the mode described by Vallance will bolster Australia's capacity for climate action.

Another editorial in the journal *Science* comes from the Chief Science Adviser to the Prime Minister of New Zealand and Chair of the International Network for Government Science Advice (Gluckman, 2016)⁸⁰. This editorial alludes to ways and means, competencies and norms of conduct for those packaging science for public policy. Gluckman has many publications in this area that add to many other instructive articles. Renewal and reinvigoration of Australia's knowledge machine as the driving force behind climate action requires renewal and reinvigoration of protocols for factoring science into policy according to

⁷⁹Vallance, P. (2023) Modern government and science advice. *Science* 382,13.

⁸⁰Gluckman, P. (2016) The science-policy interface. *Science* 353, 969.

Australia's public policy process⁸¹. A start could be made through the preparation of a discussion paper.

13. A forum for discussing the path towards a renewed and reinvigorated science enterprise in Australia

Contemporary and enlightening accounts of the nature and methods of science were not available during most of the twentieth century and could not inform the governance of science in Australia. Examples here are Sagan (1997)⁸², Jarrard (2001)⁸³, Gauch (2003)⁸⁴, Laake et al. (2007)⁸⁵, Hohenberg (2010), Mäiväli (2015)⁸⁶, Ruxton and Colgrave (2016), Oreskes (2019)⁸⁷. Furthermore, The works of Popper and the importance of falsifiability had limited penetration⁸⁸. They were overshadowed works by R.A. Fisher with their emphasis on statistical methods^{89 90}, which has now found its appropriate but not superordinate role. This emphasis may have disrupted the practice of science by downplaying the role of observation as the first in the triad that makes up science. Feynman (2011)⁹¹ states that observation, reason, and experiment make up what we call the scientific method. Experiment refers broadly to tests, trials, procedures and so on undertaken to discover some unknown principle or effect, to test an hypothesis, or to illustrate a known principle or fact⁹².

The so-called Green Revolution illustrates impotencies in the paradigm for managing science in the twentieth century. What counted were results that had practical application and anything more than this was superfluous. The Green Revolution led to great increases in the production of feed grains such as rice and wheat brought about by the introduction of new varieties. These new varieties, however, required large amounts of chemical fertilisers and pesticides. Poor farmers who used these new varieties and could not afford fertilisers and pesticides had poorer results. Older varieties were better adapted to local conditions, and had some resistance to pests and diseases. The Evergreen Revolution has replaced the Green Revolution. It

⁸¹Bridgman P. & David G. (1998) *Australian Policy Handbook*. Allen and Unwin, Sydney.

⁸²Sagan, C (1997) *The Demon-Haunted World, Science as a Candle in the Dark*. .

⁸³Jarrard, R.D. (2001) *Scientific Methods: An Online Book*.
http://www.researchgate.net/publication/41432580_Scientific_methods_an_online_book.

⁸⁴Gauch HG Jr (2003) *Scientific Method in Practice*. Cambridge University Press, Cambridge.

⁸⁵Laake, P., Benestad, H.B and Olsen, B.R. (Editors)(2007). *Research Methodology in the Medical and Biomedical Sciences*. Elsevier, Amsterdam.

⁸⁶Mäiväli, U. (2015) *Interpreting Biomedical Science: Experiment, Evidence and Belief*, Academic

⁸⁷Oreskes N. (2019) *Why Trust Science?*. Princeton University Press. Princeton, NJ.

⁸⁸Popper, Karl (1962). *Conjectures and Refutations: The Growth of Scientific Knowledge*. London and New York: Basic Books.

• ⁸⁹Fisher, Ronald A. (1971) [1935]. *The Design of Experiments (9th ed.)*. Macmillan, London

⁹⁰Fisher, R.A. (1925). *Statistical methods for research workers* (11th ed. rev.). Oliver and Boyd: Edinburgh

⁹¹Feynman, R.P. (2011) *Six easy pieces : essentials of physics, explained by its most brilliant teacher / ; originally prepared for publication by Robert B. Leighton and Matthew Sands; new introduction by Paul Davies*. Kindle Edition.

⁹²Hoerr NL and Osol A (1956) *Blakiston's New Gould Medical Dictionary, Second Edition*. The Blakiston Division, McGraw-Hill Book Company, Inc., New York.

considers farming ecosystems as interconnected units, does not make a distinction between agriculture and land and is not constrained from investigating mechanisms.

The governance of public science in Australia could be renewed and reinvigorated such that it generates imaginative insights and creativity that can feed into developments such as quantum computing. Quantum computing came about by means of a free rein given to working scientists and the same free rein and associated benefits can be applied more widely. Science can take its place as the generator of justified true belief in a manner that accepts uncertainty and the advancement of knowledge through corrective feedbacks.

Renewal and regeneration could be catalysed in Australia's science enterprise through an open and unfettered forum that could consider what happened in the past and how the present and the future might be reshaped according to evolved thinking. The possibility for working scientists to have representation on boards of management should be on the agenda. This refers to the practice of codetermination that operates productively in many Western European countries.

14. A resource for gathering intelligence on climate action initiatives within international bodies and in other countries

A resource devoted to monitoring, marshalling and communicating intelligence about climate action initiatives within international bodies and in other countries is a felt need. International bodies include such as UNESCO, WHO, UNEP, FAO, the World Bank, WOAH (World Organisation for Animal Health) and the OECD. Benefits can be reaped from the outputs from these bodies and from the publications of the US National Academies of Science and the US Council for Agricultural Science and Technology (CAST). There are perceptible gaps in this connection.

VII. Reflections on issues and considerations affecting climate action

The hazard of fallacious thinking

Various fallacies, whether they are material, psychological, logical, formal, or informal, can undermine the application of knowledge, understanding, insight, and common sense required for effective methods against climate change. Every one of these fallacies has operated in the parlance of climate change denialists/sceptics. Here's how different types of fallacies could have an impact on efforts to address climate change:

1. Material Fallacies:

- **Cherry-Picking Data:** Selectively using data that supports a particular viewpoint while ignoring data that contradicts it can lead to misguided climate

change strategies. This fallacy can result in incomplete or biased information, hindering the development of effective solutions.

2. Psychological Fallacies:

- **Denialism:** Psychological mechanisms such as denial can prevent individuals or societies from acknowledging the reality of climate change. This can hinder the adoption of proactive measures and impede collective efforts to address the issue.

3. Logical Fallacies:

- **False Cause:** Assuming a cause-and-effect relationship without sufficient evidence can lead to incorrect conclusions. For example, attributing a temporary change in climate to unrelated factors may result in misguided policies or inadequate responses.

4. Formal and Informal Fallacies:

- **Ad Hominem Attacks:** Dismissing arguments or individuals based on personal characteristics rather than addressing the substance of the argument can divert attention from valid concerns related to climate change. This can hinder constructive discourse and collaboration.
- **Appeal to Tradition or Novelty:** Assuming that traditional practices are inherently better or that new technologies are always superior without considering their environmental impact can lead to ineffective or counterproductive strategies.
- **False Dichotomy:** Presenting a situation as if there are only two possible solutions when, in reality, there may be multiple viable approaches. This oversimplified thinking can limit the range of strategies considered for addressing climate change.
- **Appeal to Emotion:** Relying solely on emotional appeals without solid scientific evidence can lead to misguided policies driven by sentiment rather than rational analysis. While emotional engagement is essential, decisions must be grounded in factual information.
- **Bandwagon Fallacy:** Assuming that a belief or course of action is valid or desirable simply because a majority of people endorse it can lead to conformity rather than critical evaluation of climate change strategies.

Addressing climate change requires a comprehensive and evidence-based approach. Fallacious reasoning can introduce biases, distort information, and hinder the development and implementation of effective solutions. It is crucial for policymakers, scientists, and the public to be aware of these fallacies and engage in rational, fact-based discussions to ensure that efforts against climate change are well-informed and impactful

Misinformation and disinformation campaigns

West JD and Bergstrom CT (2021) Misinformation in and about science. Proceedings of the National Academy of Sciences USA 118, e191244

McNutt Crow Enhancing trust in science and technology 2023

To be continued

Predatory and parasitic publishers – and other hindrances to science publishing

To be continued

Indigenous knowledge base

To be continued

The upsides and downsides of ‘Meritocracy’

To be continued

Religion and climate action

Leaders of the world’s major religions are unanimous in accepting that climate change is a real and present hazard that requires concerted action. Documentary evidence is listed.

- Buddhism: The Time to Act is Now A Buddhist Declaration on Climate Change May 14, 2015 https://fore.yale.edu/files/buddhist_climate_change_statement_5-14-15.pdf
- Islam: Islamic Declaration on Global Climate Change
<https://www.ifees.org.uk/about/islamicdeclaration/>
- Christianity: Laudate Si of Pope Francis
https://www.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html
- The Interfaith Center for Sustainable Development
<https://interfaithsustain.com/religion-and-ecology-articles/> documents evidence on climate change acceptance for Bahai, Buddhism, Christianity, Confucianism, Daoism, Druze, Hinduism, Jainism, Islam, Sikh, Shinto, Sufism, Zoroastrianism.

Acceptance by leaders does not mean that all followers hold the same view. For example, the late Cardinal George Pell is quoted as follows in ‘Heaven and Earth, Global Warming: The

Missing Science’ by Ian Plimer⁹³: “In the past, pagans sacrificed animals and even humans in vain attempts to placate capricious and cruel gods. Today, they demand a reduction in carbon dioxide emissions.”

The sales pitch for Plimer’s book included the statement that ‘climate change politics is religious fundamentalism masquerading as science’. The substance of the book does not reflect several of the principles for good intellectual conducted described by Edward T. Damer (see Appendix 2). These are principles of truth-seeking, clarity, structure, acceptability and sufficiency and are particularly apparent in Plimer’s account of Svante Arrhenius’ journal article of 1896, *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground*. This article foreshadowed climate change⁹⁴. Plimer appears to be unaware of an earlier article with the same thrust that was written by Eunice Foote in 1856⁹⁵.

Tony Abbott, Australia’s Prime Minister from 2013 to 2015, accepted and acted upon Plimer’s assertions about climate change being a new ignorance that fills the ‘yawning spiritual gap in Western society’ and Plimer’s superficial and *ad hominen* contention: ‘To argue that modern climate is driven by slight changes in a trace gas in the atmosphere requires many non-scientific leaps of faith’. Tony Abbott refers to these assertions in his book, ‘Battlelines’⁹⁶, and presents no evidence of having researched other sources of information like reports of the IPCC or delved into commonplace physics. The impact on Australia’s actions to combat climate change has been severe. Tony Abbott, an avowed Roman Catholic, has not explicitly acknowledged or heeded the common sense in Pope Francis’ *Laudate Si*.

VIII. Appendices

Appendix 1: A sample of Australian publications on methanogenesis in ruminants found in a 30 minute search on Google Scholar.

The publications shown below are evidence of the resources possessed by Australia within its science community and which can inform cogent climate action.

Badgery W, Li G, Simmons A, Wood J, Smith R, Peck D, Ingram L, Durmic Z, Cowie A, Humphries A & others (2023). Reducing enteric methane of ruminants in Australian

⁹³Plimer, I. (2010) *Heaven and Earth, Global Warming: The Missing Science*. Connor Court Publishing, Brisbane.

⁹⁴Arrhenius, S. (1896) *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground*. Philosophical Magazine and Journal of Science Series 5, Volume 41, April 1896, pages 237-276 (https://www.rsc.org/images/Arrhenius1896_tcm18-173546.pdf).

⁹⁵The paper, titled “Circumstances Affecting the Heat of the Sun’s Rays,” was presented by Eunice Foote at a meeting of the American Association for the Advancement of Science (AAAS) on Aug. 23, 1856.

⁹⁶Abbott, T. (2009) *Battlelines*. Melbourne University Press, Melbourne.

- grazing systems--a review of the role for temperate legumes and herbs. *Crop and Pasture Science*
- Baker SK (1999). Rumen methanogens, and inhibition of methanogenesis. *Australian Journal of Agricultural Research* **50**, 1293–1298.
- Black JL, Davison TM & Box I (2021). Methane emissions from ruminants in Australia: mitigation potential and applicability of mitigation strategies. *Animals* **11**, 951.
- Cottle DJ, Nolan JV & Wiedemann SG (2011). Ruminant enteric methane mitigation: a review. *Animal Production Science* **51**, 491–514.
- Durmic Z, Black JL, Martin GB & Vercoe PE (2021). Harnessing plant bioactivity for enteric methane mitigation in Australia. *Animal Production Science*
- Hegarty RS (1999). Reducing rumen methane emissions through elimination of rumen protozoa. *Australian Journal of Agricultural Research* **50**, 1321–1328.
- Hegarty RS (2013). Applicability of short-term emission measurements for on-farm quantification of enteric methane. *Animal* **7**, 401–408.
- Leng RA (2014). Interactions between microbial consortia in biofilms: a paradigm shift in rumen microbial ecology and enteric methane mitigation. *Animal Production Science* **54**, 519–543.
- Moate PJ, Deighton MH, Williams SRO, Pryce JE, Hayes BJ, Jacobs JL, Eckard RJ, Hannah MC & Wales WJ (2015). Reducing the carbon footprint of Australian milk production by mitigation of enteric methane emissions. *Animal Production Science* **56**, 1017–1034.
- Moate PJ, Richard S, Williams O, Deighton MH, Pryce JE, Hayes BJ, Jacobs JL, Eckard RJ, Hannah MC, Wales WJ & others (2014). Mitigation of enteric methane emissions from the Australian dairy industry Proceedings of the 5th Australasian dairy science symposium. **121**, 140.
- Ouwerkerk D, Turner AF & Klieve AV (2008). Diversity of methanogens in ruminants in Queensland. *Australian Journal of Experimental Agriculture* **48**, 722–725.
- Pickering NK, Oddy VH, Basarab J, Cammack K, Hayes B, Hegarty RS, Lassen J, McEwan JC, Miller S, Pinares-Patino CS & others (2015). Animal board invited review: genetic possibilities to reduce enteric methane emissions from ruminants. *Animal* **9**, 1431–1440.
- Suybeng B, Charmley E, Gardiner CP, Malau-Aduli BS & Malau-Aduli AEO (2019). Methane emissions and the use of desmanthus in beef cattle production in Northern Australia. *Animals* **9**, 542.

Appendix 2: Damer's twelve principles for good intellectual conduct

Twelve principles that comprise a code of intellectual conduct for effective discussion: Edward T. Damer (2008) *Attacking Faulty Reasoning: A Practical Guide to Fallacy-Free Arguments* (Sixth Edition). Wadsworth Cengage Learning, Boston. These principles were highlighted in Section 2 on the dimensions and indispensability of knowledge.

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|--|
| 1. The Fallibility Principle: Each participant in a discussion of a disputed issue should be willing |
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to accept the fact that he or she is fallible, which means that one must acknowledge that one's own initial view may not be the most defensible position on the question.

2. The Truth-Seeking Principle: Each participant should be committed to the task of earnestly searching for the truth or at least the most defensible position on the issue at stake. Therefore, one should be willing to examine alternative positions seriously, look for insights in the positions of others, and allow other participants to present arguments for or raise objections to any position held on an issue.

3. The Clarity Principle: The formulations of all positions, defenses, and attacks should be free of any kind of linguistic confusion and clearly separated from other positions and issues.

4. The Burden-of-Proof Principle: The burden of proof for any position usually rests on the participant who sets forth the position. If and when an opponent asks, the proponent should provide an argument for that position.

5. The Principle of Charity: If a participant's argument is reformulated by an opponent, it should be carefully expressed in its strongest possible version that is consistent with what is believed to be the original intention of the arguer. If there is any question about that intention or about any implicit part of the argument, the arguer should be given the benefit of any doubt in the reformulation and/or, when possible, given the opportunity to amend it.

6. The Structural Principle: One who argues for or against a position should use an argument that meets the fundamental structural requirements of a well-formed argument. Such an argument does not use reasons that contradict each other, that contradict the conclusion, or that explicitly or implicitly assume the truth of the conclusion. Neither does it draw any invalid deductive inferences.

7. The Relevance Principle: One who presents an argument for or against a position should set forth only reasons whose truth provides some evidence for the truth of the conclusion.

8. The Acceptability Principle: One who presents an argument for or against a position should provide reasons that are likely to be accepted by a mature, rational person and that meet standard criteria of acceptability.

9. The Sufficiency Principle: One who presents an argument for or against a position should attempt to provide relevant and acceptable reasons of the right kind, that together are sufficient in number and weight to justify the acceptance of the conclusion.

10. The Rebuttal Principle: One who presents an argument for or against a position should include in the argument an effective rebuttal to all anticipated serious criticisms of the argument that may be brought against it or against the position it supports.

11. The Suspension-of-Judgment Principle: If no position is defended by a good argument, or if two or more positions seem to be defended with equal strength, one should, in most cases, suspend judgment about the issue. If practical considerations seem to require a more immediate decision, one should weigh the relative benefits or harm connected with the consequences of suspending judgment and decide the issue on those grounds.

12. The Resolution Principle: An issue should be considered resolved if the argument for one of the alternative positions is a structurally sound one that uses relevant and acceptable reasons that together provide sufficient grounds to justify the conclusion and that also includes an effective rebuttal to all serious criticisms of the argument and/or the position it supports. Unless one can demonstrate that the argument has not met these conditions more successfully than any argument presented for alternative positions, one is obligated to accept its conclusion and consider the issue to be settled. If the argument is subsequently found by any participant to be flawed in a way that raises new doubts about the warrant of the position it supports, one is obligated to reopen the issue for further consideration and resolution.

Appendix 3: Bradford Hill criteria for causation, levels of evidence, GRADE and PICO

In 1965, Austin Bradford Hill proposed a set of nine criteria to provide evidence from epidemiological studies for causal relationships between presumed causes and an observed effects. This builds from the connection between cigarette smoking and lung cancer.

[Hill, A.B. (1965) *The environment and disease: association or causation?* *Proceedings of the Royal Society of Medicine* 58, 295-300.

Hill, A.B. (1977) *A Short Textbook of Medical Statistics*. Hodder and Stoughton, London]

The nine criteria are:

1. **Strength** (effect size): A small association does not mean that there is not a causal effect, though the larger the association, the more likely that it is causal.
2. **Consistency** (reproducibility): Consistent findings observed by different persons in different places with different samples strengthens the likelihood of an effect.
3. **Specificity**: Causation is likely if there is a very specific population at a specific site and disease with no other likely explanation. The more specific an association between a factor and an effect is, the bigger the probability of a causal relationship.[1]
4. **Temporality**: The effect has to occur after the cause (and if there is an expected delay between the cause and expected effect, then the effect must occur after that delay).
5. **Biological gradient** (dose–response relationship): Greater exposure should generally lead to greater incidence of the effect. However, in some cases, the mere presence of the factor can trigger the effect. In other cases, an inverse proportion is observed: greater exposure leads to lower incidence.[1]
6. **Plausibility**: A plausible mechanism between cause and effect is helpful (but Hill noted that knowledge of the mechanism is limited by current knowledge).
7. **Coherence**: Coherence between epidemiological and laboratory findings increases the likelihood of an effect. However, Hill noted that "lack of such [laboratory] evidence cannot nullify the epidemiological effect on associations".
8. **Experiment**: "Occasionally it is possible to appeal to experimental evidence".
9. **Analogy**: The use of analogies or similarities between the observed association and any other associations.

A possible tenth criterion is that of reversibility; that is, if the cause is deleted then the effect should disappear as well.

In practice, the Bradford Hill criteria for causation can be complemented with:

- Considerations of a 'hierarchy of evidence'⁹⁷.

⁹⁷National Health and Medical Research Council. (2009). *[Hierarchy of Evidence]*. Retrieved 2 July, 2014 from: <https://www.nhmrc.gov.au/>

- The PICO framework for framing questions about evidence⁹⁸.
- The GRADE approach for interpreting evidence that can guide healthcare⁹⁹.

Appendix 4: Mertonian norms for the conduct of science and ‘On Being a Scientist’ from the US National Academy of Sciences.

Disinterestedness along with communalism, universalism and organised scepticism make up the four sets of institutional imperatives that can guide the ethos of science (Merton, 1942)¹⁰⁰.

Merton (1942) proposed that four principles under the acronym of CUDOS principles can guide the ethos and good conduct of science. These principles are restated as follows: 1. **Communalism** [stated as Communism by Merton] where scientists have equal access to scientific goods (intellectual property), and sense of common ownership promotes cooperation with no secrecy (c.v. solidarity, global common goods and the One Health).; 2. **Universalism** all scientists can contribute to science regardless of race, nationality, culture, or gender (c.v. solidarity, justice, equity and the One Health). 3. **Disinterestedness** where scientists act for the benefit of a common scientific enterprise, not for personal gain (c.v. solidarity, common good, professionalism and the One Health). 4. **Organized Skepticism** where scientific claims are open to critical scrutiny and science’s practice of refutation and falsification (Popper, 1963)¹⁰¹.

An extract from a report titled, *On Being A Scientist* (National Academy of Sciences, 2009)¹⁰² is shown below. It captures the essence of disinterestedness or impartiality within the practice of science and show how climate denialism can be understood in terms of values that compromise objectivity.

‘Strongly held values or beliefs can compromise a person’s science in some instances. The history of science offers a number of episodes in which social or personal beliefs distorted the work of researchers. For example, the ideological rejection of Mendelian genetics in the Soviet Union beginning in the 1930s crippled Soviet biology for decades. The field of eugenics used the techniques of science to try to demonstrate the inferiority of particular human groups, according to nonscientific prejudices.

⁹⁸Schardt, C., Adams, M. B., Owens, T., Keitz, S., & Fontelo, P. (2007). Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Medical Informatics and Decision Making*, 7, 16. doi: <http://dx.doi.org/10.1186/1472-6947-7-1>

⁹⁹Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, Norris S, Falck-Ytter Y, Glasziou P, DeBeer H, Jaeschke R, Rind D, Meerpohl J, Dahm P, Schünemann HJ. GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol*. 2011 Apr;64(4):383-94. doi: 10.1016/j.jclinepi.2010.04.026. Epub 2010 Dec 31. PMID: 21195583.

¹⁰⁰Merton RK (1942) The normative structure of science. In: *The Sociology of Science: Theoretical and Empirical Investigations* (Edited by Merton RK). University of Chicago Press, Chicago.

¹⁰¹Popper KR (1963) *Conjectures and Refutations, The Growth of Scientific Knowledge*. Routledge and Kegan Paul, London.

¹⁰²National Academy of Sciences (2009) *On Being a Scientist: A Guide to Responsible Conduct in Research, Third Edition*. Committee on Science, Engineering, and Public Policy, National Academy of Science, National Academy of Engineering, and Institute of Medicine of the National Academies, Washington, DC.

Despite such cautionary episodes, it is clear that all values cannot—and should not—be separated from science. The desire to do good work is a human value. So is the conviction that standards of honesty and objectivity must be maintained. However, values that compromise objectivity and introduce bias into research must be recognized and minimized’.

Appendix 5: Hohenberg’s ‘What is Science’

Hohenberg’s essay is quoted in full to inform ways and means for managing the misinformation, disinformation and the assault on reason and reasonableness associated with climate change denialism.

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What is Science?

Pierre C Hohenberg,
New York University
December 2010 - Self-published.
(born October 3, 1934 – died December 15, 2017)

Abstract

This paper proposes a new definition of science based on the distinction between the activity of scientists and the product of that activity: the former is denoted (lower-case) science and the latter (upper-case) Science. These definitions are intended to clarify the nature of scientific knowledge, its authority as well as its limitations, and how scientific knowledge differs from other forms of human knowledge. The body of knowledge we call Science is exemplified by elementary arithmetic: it has the following properties: (i) Science is collective, public knowledge; (ii) Science is universal and free of contradiction; (iii) Science emerges from science; (iv) Science is nevertheless bathed in ignorance and subject to change. These properties imply that many questions that are of great interest to humanity are out of reach to Science, since they necessarily involve individual and group commitments and beliefs. Examples are questions of ethics, religion, politics, art and even technology, for which diversity is a fundamental virtue.

Scientists need philosophers and historians of science like birds need ornithologists. (Attributed to Richard Feynman)

I. Introduction

If you type the question in the above title into Google you will get an abundance of answers, many of them sensible and unsurprising. I will single out four of them for illustration:

(i) The National Academy of Sciences (2008) *“The use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process.”*

(ii) Stephen Jay Gould (1997) *The net of science covers the empirical universe: what is it made of (fact) and why does it work this way (theory).*

(iii) The US Supreme Court (1993) in *Daubert v. Merrell*

“Science is not an encyclopedic body of knowledge about the universe. Instead, it represents a process for proposing and refining

theoretical explanations about the world that are subject to further testing and refinement. But, in order to qualify as ‘scientific knowledge,’ an inference or assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation—i.e., ‘good grounds,’ based on what is known. In short, the requirement that an expert’s testimony pertain to ‘scientific knowledge’ establishes a standard of evidentiary reliability.”

(iv) Richard Feynman (1968) *Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceding generation . . . As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.*

The purpose of the present paper is first to refine the discussion by establishing a clear distinction between the human activity of scientists (hereafter “science” or “lower-case science”) and the body of knowledge produced by that activity (which we will refer to as “Science” or “upper-case science”). We will attempt to describe and characterize the latter concept and to demonstrate why the distinction between science and Science leads to greater clarity. A second aim of this essay is to clarify the distinction between Science/science on the one hand and everything else, which we shall refer to as “non Science”.

What we call “science” is the human activity practiced by “scientists”, who are often assembled in scientific communities, and whose results and pronouncements often conflict. The history of science is full of ups and downs, which have famously been likened to political revolutions. There are stated and unstated principles and rules by which scientists operate, primarily encoded in the “scientific method”, which is in principle based on empirical observation, logic, verification and falsification, but in practice affected by many other contingencies.

Out of this scientific activity there emerges a body of knowledge we will call “Science”, which has special properties that are quite different from those of “science” (the human activity) or of any other human activity. This body of knowledge, of which the clearest example is *arithmetic*, is a unique creation of the human community. It must be stressed, however, that the features of Science that lend it authority are also the source of *limitations* of Science, limitations that need to be identified and understood.

II. The characteristics of Science

We will define what we mean by Science with reference to an idealized body of knowledge (e.g. arithmetic), to which all of science aspires, but which only reaches the status of Science by a mysterious process of *emergence*, over which no individual or group of individuals has direct control.

2.1 Science is collective, public knowledge

This knowledge belongs to no one and to everyone (to all mankind); it is anonymous. This is what we mean when we say that Science represents *objective* knowledge. We are not claiming that Science is not a product of human activity, but rather that it is one that has been liberated from its creator(s). Newton's Second Law ($F = ma$) is no more Newton's than $2+2=4$ belongs to the person or persons who first conceived of arithmetic.

2.2 Science is universal

Scientific truths are intended to apply everywhere and are not tied to individuals or groups of individuals. There is no "German Science", "Jewish Science", "African Science". It follows that a new result will frequently *supersede* and invalidate an existing result, but this can only happen if it is *consistent* with previously established elements of Science. Any inconsistencies must be considered the unfinished business of Science, part of the sea of ignorance in which Science is bathed (see below).

The anonymity, universality and consistency of Science contrast sharply with other products of human endeavor, such as art, laws, religion and even technology. Beethoven's symphonies did not supersede Mozart's and they shall forever be associated with ("owned by") Beethoven. It is common for different nations to have different laws or customs and these differences are considered part of human diversity, not inconsistencies that must be eliminated. In contrast, well posed scientific questions have a unique answer.

2.3 How Science emerges from science

The mechanism by which this emergence occurs is shrouded in mystery and must be considered an empirical fact, rather than a fully understood process, but one thing is certain: it is not subject to individual control. What scientists do (even great ones like Newton and Einstein) is science, not Science. A piece of work is created by a scientist, who sends it out into the (scientific) world, where it becomes fair game for modification, criticism, verification and falsification. Most scientific work cause barely a ripple in the grand scheme of things, but in fortunate cases some works stimulate further activity or even become adopted as important, and eventually emerge (normally with modifications) into Science. Notable cases adorn the textbooks, often with more or less fanciful historical reconstructions. The important point is that once a result has emerged to the level of Science it is no longer "owned" by its originator.

2.4 Science is bathed in ignorance and subject to change

Scientific knowledge (Science), even though we characterize it as universal and objective, is nevertheless only partial and subject to change. It is much more stable than the knowledge produced directly by scientists (science) and is subject to a different dynamic, which causes it to change more slowly and smoothly than science. Apart from this lack of permanence, the knowledge inherent in Science is also *partial* in that it leaves many questions unanswered. The Nobel laureate David Gross has said (private communication) that "the most important product of science is ignorance", by which he is referring to new questions that are raised by important scientific results. Another expression of the same idea is the statement from H. Bondi (quoted in Morris, 2008, p. 7): "The power of science is the ability to say something without having to say everything".

The historian and philosopher of science Thomas Kuhn (1962) has famously used political revolutions and national conflicts as a metaphor for the development of science, but it is our view that a more apt metaphor, at least for Science, is provided by plate tectonics. Scientific knowledge is represented by land masses that emerge from an underwater world of scientific activity of individuals and scientific communities (science). All of this land is bathed by the sea and enveloped in a fog of humidity that constitute *ignorance*, i.e. a wealth of unanswered and perhaps unanswerable questions. As time progresses the land masses might rise, merge and evolve and the sea might well recede in places though there is no absolute guarantee that the sea level will always fall. The only mechanism for accretion of land mass is the activity of the (underwater) scientists who feed the continents (science), thus causing continual shifts in the shoreline between sea and land.

Another metaphor for Science, which emphasizes the requirement of consistency is the image of a *multiply connected web* (Anderson, 2001). Progress usually occurs on the periphery and it is difficult, though not impossible, to introduce new elements in the interior since so many links would have to be broken. This is the source of the (relative) stability as well as the authority of Science.

IV. The paradigm of Science

It can be said that Science does not require belief: $2+2=4$ whether you believe it or not.

Nevertheless, the process of emergence of knowledge from science to Science is built on a generally accepted set of basic assumptions, a *paradigm* that seems to be implicit in the history of science (and of Science), at least over the past 400 years. This is not a credo that every scientist must adhere to, but rather a minimal set of implicit assumptions that the collective human phenomenon we are calling Science in practice rests on:

- The world of observable phenomena is real and intelligible in a collective manner.
- This public knowledge is subject to the requirements of logic and consistency.
- In addition to logic the knowledge must be based on observation and experimentation.
- Science is based on *naturalism*, by which we mean methodological naturalism. In particular *supernatural* explanations are rejected.

I am aware of the many philosophical issues surrounding naturalism, reductionism, materialism and the so-called mind-body problem, and my aim is certainly not to provide a solution of these problems, or even to add a substantive contribution to the philosophical debate. My aim, rather, is to identify the *minimal* assumptions that appear to be inherent in the pursuit and construction of Science. The term "methodological naturalism", seems to me to best summarize these minimal assumptions.

Supernaturalism, on the other hand, allows for the intervention of causes affecting natural phenomena that are themselves not part of nature and might thus well contradict the laws of nature. This rejection of supernaturalism is an aspect of the requirement of consistency and not a detailed statement about the ontology of the world. In particular, I do not believe that physicalist reductionism, either of ontological or methodological variety, is a necessary presupposition of Science, though admittedly some prominent scientists would disagree with this view. Further discussion of these issues may be found in Hohenberg (2010).

IV. What is non-Science?

Apart from science, which we have already distinguished from Science, all other human activities belong to what we call "non-Science". This is the domain of art, literature, philosophy, politics, business, technology, medicine and of course, religion. The common characteristic of these diverse domains is the link to individuals or

communities that must “own”, “commit to” or “believe” the knowledge contained in the activity. Another characteristic is the celebration of diversity in these areas. What would be considered an inconsistency in Science is an expression of individual or collective freedom in art, politics or religion.

The strength of Science comes from the (intended) universality of its answers, but this is also a source of significant *limitations*, since many (some would say most) questions that interest people deeply are not subject to universal answers. Examples are:

- How do I find meaning in my life?
- Is this good or bad?
- How do I deal with the loss of a loved one?
- How do I face the prospect of my own death?
- Whom should I vote for?
- Does God exist?

It should be noted that many elements of non-Science involve large doses of Science or (science), for example medicine, technology, or even politics. Nevertheless, Science is properly used as a *tool* in these areas, to find appropriate answers in which, however, many other considerations, e.g. ethical or cultural values, must be brought to bear. These considerations necessarily engage the will or commitment of individuals or communities.

V. What are alternatives to Science?

For questions that have or might have a universal answer the alternative to Science is not the various forms of non-Science, but rather *ignorance*, which in some measure is a component of each and every part of Science (see 2.4 above). For questions that have little or no expectation of possessing a universal answer the alternative, as we have said, is to be found in non-Science, for which Science is at most a useful tool but not an absolute source of authority. Such questions require belief, engagement, commitment, either individually or collectively. This distinction is inherent in our understanding of Science and it leads to crucial limitations of Scientific knowledge, which are often insufficiently stressed by enthusiasts of Science.

VI. What are appropriate attitudes toward Science?

Since Science does not require belief and its tenets are not owned by any individual or group, it should be viewed as a *natural phenomenon*, akin to Niagara Falls, say, just not a material object. One does not argue with or contest Niagara Falls, one observes, admires or fears it and one might attempt to harness it for human benefit. In our view there are thus only three rational attitudes toward Science:

- You can ignore or distort Science (this is the option chosen by most people).
- You can try to learn Science.
- You can try to contribute to Science, but that activity will be what we call science.

Whether it then emerges as Science is not under your control nor that of any individual, and if it eventually does emerge, it will no longer be associated with you as its originator.

In some real sense, Science is immune to criticism (like Niagara Falls). The main potential source of controversy in any scientific dispute is to decide if a statement or theory is indeed part of Science, as opposed to still being science, and if yes what the proper mix of knowledge and ignorance attaches to that statement. In terms of the geological analogy introduced in 2.4 above, the question is how far out of the water does this piece of land emerge and how much of the sea and fog of ignorance still envelops this land. In that sense, the distinctions and definitions we have introduced have not in themselves resolved any controversies. What we hope to have accomplished is to sharpen the questions in order to make correct answers more likely.

Note that our point of view is *not* that Science represents fact and non-Science represents value and thus Science is objective (see e.g. Harris, 2005). On the contrary, the values that Science is based on are what we have called the ‘paradigm of Science’ (Sec. IV) and these are a necessary component, along with the facts of Science. The difference is that both value and fact are *collective*, i.e. they must pass through the strong filter of universal or near-universal acceptance, which makes them both robust and restrictive, in that they exclude many questions and answers that cannot be (or have not been) collectivized. The operation of this filter is the process of emergence, which although always approximate in some sense, is unmistakable for true Science.

VII. Science and religion

Elsewhere (Hohenberg, 2010) we have elaborated on the relationship between Science and religion, particularly as it affects the teaching of evolution, so we will only summarize that discussion here. As noted earlier, religion is the quintessential component of non-Science, addressing questions that have not led, and most likely never will lead, to universal answers. The age of universal religion essentially disappeared at the end of the Middle Ages, when it was replaced by the universal knowledge of Science, at least as an aspiration. Today, people who advocate universal religion are to be pitied or locked up, or both. The proper religious attitude toward Science is in my view either to ignore it as irrelevant to the aspirations of believers (appropriate in many cases), or to concentrate on those aspects which Science cannot confront (see IV above), taking care to remain consistent with Scientific knowledge. This is essentially the tactic used by Pope John Paul (1996) in his statement entitled “Truth Cannot Contradict Truth” concerning the theory of evolution. Religious attempts to confront Science on its own turf result at best in “junk science”, which is the most one can say about Intelligent Design. Science and religion do indeed represent “Nonoverlapping Magisteria” (NOMA) as stated by Gould (1997). What we have attempted to do is to explain more clearly why the magisteria do not overlap.

VIII. Conclusion

Science is a body of knowledge that belongs to humanity as a whole. Its emergence and success over the past 400 years is a *miracle*. Science aims at, and thus attains at least approximately, objective and universal knowledge and it is thereby limited to those questions that can have universal answers. This contrasts with many other human endeavors (art, politics, religion) whose product is tied to individuals or communities and often requires an act of (implicit or explicit) volition, commitment or faith on the part of its adherents.

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Appendix 6: Lack of science knowledge among political leaders as an impediment to progress.

An extract from the Australian Guardian newspaper of 20 November, 2023 that points to one stumbling block for science into policy. It comes from an account of the UK review of its COVID response and from the evidence given by Sir Patrick Vallance, the UK's Chief Science Adviser:

Boris Johnson last studied science at the age of 15 and "would be the first to admit it wasn't his forte", and he had the habit of pretending to misunderstand things to test out whether an alternative could be true, Vallance said.

Extracts from Vallance's contemporaneous diary showed Johnson found it "a real struggle" to understand some graphs. One entry said the prime minister was "bamboozled" by modelling, while another said Johnson would fail to understand ideas he had had put to him six hours earlier.

This was not an issue just for the UK. Vallance recalled being on a group call with scientific advisers from various countries, when one said their leader could not understand exponential curves, "and the entire phone call burst into laughter because it was true in every country".