The Humboldt Vision:
integrating fundamentals with applied research

Trevor R. Finlayson and Glen E. Wheeler
(Editors)

The cover picture shows the statue of Francis Ormond at the Lonsdale Street entrance to RMIT University. Francis Ormond (1827 – 1889), grazier and philanthropist, is acknowledged as the founder of the Working Men's College (later the Royal Melbourne Institute of Technology and currently RMIT University).

(Photograph by TRF)

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Preface

The Humboldt Vision: integrating fundamentals with applied research is a collection of scholarly works based on presentations at the 20th Biennial Conference of the Australian Association of von Humboldt Fellows (AAvHF) held at RMIT University, Melbourne from Thursday, 13th to Saturday, 15th February, 2025. The AAvHF is the national professional Association of von Humboldt Fellows in Australia. Membership is available to former or current holders of any of the Alexander von Humboldt Foundation Fellowships or Awards as well as current Feodor Lynen Fellows resident in Australia. The Association facilitates professional and social contact amongst Humboldtians, as well as encouraging new and existing links between members and German researchers. Similar links are encouraged with members of the New Zealand Association of von Humboldt Fellows.

Presenting aspects of one's research at a Humboldt Conference is invariably challenging, in the true spirit of Alexander von Humboldt, given that one's audience will be representative of the physical and biological sciences, the humanities, the arts, etc. The full papers in this book have been prepared from manuscripts offered for peer-review by presenters at the Conference and are based on these presentations. But in addition, where presenters have been unable to offer a full manuscript for peer review and subsequent publication, the abstract submitted has been included in the book, in order to preserve a full record of the Conference itself. The order of the presentations during the Conference, has been preserved for both the full manuscripts and abstracts published in this book. All submitted full manuscripts have been reviewed by two professional researchers and modifications/corrections have been carried out by the authors in response to these reviewers' reports.

On the opening afternoon of the conference, all in attendance were welcomed to RMIT University by Deputy Vice-Chancellor Research and Innovation and Vice-President, Distinguished Professor Calum Drummond AO, and we are pleased to include Professor Drummond's most interesting remarks in this publication. The conference was officially opened by Mr Michael Pearce SC, Honorary Consul-General for the Federal Republic of Germany in Victoria. The Editors are pleased to publish the text of Michael Pearce's opening remarks under the heading "Conference Opening". In addition, a message of greeting to the AAvHF was received from Dr Thomas Hesse, Acting Secretary-General of the Alexander von Humboldt Foundation. This message was read out to all present during the Welcoming Ceremony and the Editors are pleased to include the text of Dr Hesse's message as an Introduction to the book.

The work of Professor Gary Bryant, RMIT University and Drs. Sarah Turpin-Nolan and Daniel Priebbenow, Monash Institute of Pharmaceutical Sciences, in organising a most successful 20th Biennial AAvHF Conference is acknowledged. Also the AAvHF is grateful for the hospitality of RMIT University and the provision of associated facilities which enabled the Conference to be run effectively and efficiently. Financial support for the Conference from Research and Innovation, RMIT University and the Monash Institute of Pharmaceutical Sciences is acknowledged.

Trevor R. Finlayson and Glen E. Wheeler
Editors

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Welcome to RMIT University

Good Afternoon, colleagues and distinguished guests. I'd also like to pay my respects to Ancestors and Elders, past, present and emerging.

It is a pleasure to welcome you all to the RMIT University where we are meeting today for the 20th Biennial Conference of the Australian Association of von Humboldt Fellows. Australians have achieved remarkable success in winning Humboldt awards, with 646 awardees to date. RMIT takes great pride in being part of that number. In fact, RMIT has several academics associated with the foundation, including conference session Chairs Gary Bryant and Ravichandar Barbarao.

RMIT has always been a place shaped by visionaries – starting with Francis Ormond who established what was then the Working Men's college in 1887. The belief in education as a force for progress laid the foundation for an institution continually evolving to meet industry and society's demands.

That same spirit of investing in knowledge and research is what brings us together today, as we host the 20th Conference of the Australian Association of von Humboldt Fellows.

Much like RMIT, the Alexander von Humboldt Foundation champions research that transcends disciplines, and generations. Both institutions share a deep commitment to fostering excellence, supporting researchers, and advancing discoveries that shape our world.

It is fitting that this conference takes place here at RMIT – a University that, from its earliest days, has been dedicated to learning with impact. Today, as we gather to discuss and showcase research spanning physics, engineering, humanities, sustainability, and beyond, we honour not just the scholars in the room, but also the enduring values of curiosity, collaboration and innovation.

I look forward to the conversations and connections that will emerge from this conference. Once again, welcome, and may this gathering inspire new ideas and lasting partnerships.

Distinguished Professor Calum J. Drummond AO,
Deputy Vice-Chancellor Research and Innovation and Vice-President,
RMIT University.

Conference Opening

Deputy Vice-Chancellor, Distinguished Guests, Ladies and Gentlemen.

Thank you for the invitation to this Conference and the opportunity to make some opening remarks.

It is fitting that I should do this as Melbourne swelters at the end of another summer heatwave and we wait impatiently for the cool change – forecast to arrive during the welcome reception.

As I am sure you know, Alexander von Humboldt was a pioneer of the science of Meteorology and Climate Change. As you would also know, he was a polymath and a distinguished diplomat. He secured the patronage of the Spanish King for his famous voyage to South America. He later navigated the Courts of Paris and Berlin and was permitted by the Czar to visit the far east of the Russian Empire.

I mention this because it demonstrates the close connection between scientific advancement and political power. The former must be harnessed to the latter to achieve progress.

It is tempting therefore, to speculate about how Alexander von Humboldt would apply his polymathic skills to the present world predicament. On the occasion of his 250th Birthday, Gabrielle McMullen speculated on his prescription for modern Australia, noting his connections with German Scientists who were prominent in the early days of European settlement. These include, of course, the other great German botanist and explorer, Baron Ferdinand von Mueller, one of whose many legacies is the Botanic Gardens of Melbourne. After a promising start, scientific collaboration between Australia and Germany stalled for half a century – for well known political reasons. Also for political reasons, it has been revived. The Alexander von Humboldt Foundation has played a leading role in that revival. The revival has been so successful that it has become difficult to keep tabs on all the scientific collaborations between Australia and Germany today.

They currently include:

- A joint PhD program between Melbourne University and Potsdam University in Climate Science;
- A research collaboration between Bonn University and the Cumming Global Centre for pandemic therapeutics, at Melbourne University;
- The establishment in Melbourne of a permanent office of Bayreuth University; and
- The joint venture between Biotech – the German Pharma Company which invented the Pfizer vaccine for Covid19 – and La Trobe University for a laboratory for MRNA research and development.

Australian research institutes, especially in the biomedical field, are full of German scientists. Even my own discipline of Law has got in on the act with the recent announcement of a joint PhD program between the Melbourne Law School and Bonn University.

This is barely the tip of the iceberg of the widespread and far-reaching scientific collaboration between Australia and Germany today. This Association and its members are, of course, at the forefront of the surge in scientific collaboration between the two countries. I am therefore glad to have the opportunity, on behalf of the German Missions in Australia, to thank you all for your contributions to that collaboration. I also wish you well for the coming conference. I have no doubt you will be guided by the Spirit and Example of Alexander von Humboldt.

I urge you to keep in mind one of his many quotes

"Ideen können nur Nützen, wenn sie in vielen Köpfen lebendig werden."

"Ideas can only be of use if they start living in many minds."

Thank you and all the best.

Michael R. Pearce SC,
Honorary Consul General for Victoria.

Introduction

More than two years have passed since the last Conference of the Australian and New Zealand Associations of von Humboldt Fellows. How time has flown by! I have very fond memories of the meetings in Melbourne and Geelong in November, 2022. I remember especially the welcoming atmosphere and the fantastic team spirit among the Humboldtians I met there. My impression was that you really are a Humboldt family in the best sense. You stick together and yet welcome newcomers with open arms.

So many things have changed in and around the Humboldt Foundation since then. Our new President, Robert Schlögl, took office in early 2023. Last March, our Secretary General, Enno Aufderheide, retired after 14 years at the helm of the Foundation. At present, I am confident that a successor will be in place rather soon.

The Humboldt Foundation has faced – and is still facing – significant challenges. Against the background of multiple international and domestic crises, there is uncertainty around our budget. Last year, we were forced to take difficult decisions regarding our funding for alumni activities – decisions which, to my great regret, also affected plans for a *Kolleg* in New Zealand. We hope that things will become clearer once a new Federal Government has passed a budget for this year, probably around May or June.

Despite these challenges, the Humboldt Foundation has managed to make progress in important areas. Our new strategy for 2024-2028 pursues the vision of a world-spanning network of outstanding researchers who help to develop fact-based solutions for a world in upheaval. Alumni Associations such as yours, which find ways to stay together and to prosper even under difficult circumstances, are essential to the success of this endeavour. The exciting programme of your 20th Biennial Conference is testament to your commitment to "the Humboldtian vision"!

Thanks to Humboldtians like you, I feel confident for the future of the Humboldt network. I am deeply grateful to you for your determination to uphold the values the network embodies, and I wish you all the best for the future.

Dr. Thomas Hesse,
Deputy Secretary General,
Alexander von Humboldt Foundation.

The Colloquia of the Australian Association of von Humboldt Fellows

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This paper provides an overview of the twenty colloquia of the Australian Association of von Humboldt Fellows and related publications. As the major gathering of Humboldtians from across the nation biennially, the colloquia are valued for their camaraderie as Fellows meet as the Humboldt family 'down under'.

1. Introduction

The Australian Association of von Humboldt Fellows (AAvHF) was officially inaugurated at a conference of Fellows held at the University of Melbourne in 1983 and held its first colloquium in 1985. The Association's 2025 gathering has particular significance as its twentieth colloquium.

In relation to these twenty colloquia [1], I note at the outset that there have been two significant partners in such gatherings, namely the Alexander von Humboldt Foundation and the New Zealand Association of von Humboldt Fellows. The Foundation has periodically conducted its Humboldt Global Colloquia in Australia. Each year, the Foundation hosts two such colloquia to which all the alumni from the designated country or region are invited. These events "enable Humboldtians to make contact with one another as well as with German specialist colleagues and also provide an opportunity to draw the attention of junior researchers to the Humboldt Foundation's sponsorship portfolio" [2]. The Global Colloquia in our region have brought together Australian and New Zealand Fellows, developing a collegial relationship between our Associations and enabling some joint colloquia with the New Zealand Association.

This paper provides an overview of the twenty AAvHF colloquia and related publications. It also considers other major AAvHF symposia in collaboration with the Humboldt Foundation and the Royal Society of Victoria. The research that underpins this presentation has, with the kind assistance of the Humboldt Foundation, enabled the Association to enhance its records of earlier colloquia.

2. Australian Gatherings of Humboldt Fellows and the Association's Founding

In 1973, for the first time, representatives of the Foundation visited Australia. Their purpose was stated as follows: "Humboldt was not in Australia, neither was the Humboldt Foundation. We are not coming now to discover but rather to get to know the land better, especially its academic life". As well as visiting several universities, they hosted a gathering in Sydney's Menzies Hotel of some 60 Australian and New Zealand Humboldt alumni or as they called them on the occasion "Humboldt ambassadors" [3]. Significantly, the Foundation's visits to Adelaide, Brisbane, Canberra, Melbourne, Sydney and Perth and the subsequent colloquium provided the first opportunity for Australian Humboldtians to come together and get to know one another and attendees were most appreciative of the Foundation initiative [4].

A report of the colloquium notes that attendees expressed concern at the lack of any Australian reciprocity for the valuable research support afforded by the Foundation to Australian researchers [5]. They "spontaneously decided to establish" a Humboldt Club, with a national identity as well as local branches. The Foundation's report of the meeting recorded that this Club "especially also wants to ensure that in the future the Humboldt Foundation receives qualified applications from young scientists from Australia, and to provide advice to new research fellows before they leave for their stay in West Germany" [4]. The Foundation encourages such national networks and there are currently 111 Humboldt Alumni Associations in 75 countries including Germany [6]. The Foundation conducted its next alumni reunion 'down under' in 1983 at the University of Melbourne. On this occasion several senior German scholars accompanied the Foundation's representatives and spouses were invited to attend the colloquium with their Humboldtian. An article about the colloquium in *Die Woche* highlights its success with two-thirds of the local Humboldtians attending when the norm in other regions was one-third [7].

The gathering explored the possibility of reviving the “now almost non-existent” former Humboldt Club. It was agreed that any club should have well-defined objectives and that a national initiative would foster collaboration better with the Humboldt Foundation and Germany more widely than individual or state-based efforts. The meeting agreed to the establishment of a club titled the Australian Association of von Humboldt Fellows and elected the first office bearers with Professor Peter Schwerdtfeger, foundation Professor of Meteorology at Flinders University, and the first such Chair in Australia, as President and Adelaide representative, Dr Peter Gresshoff as Vice-President and Canberra representative, and representatives also for Brisbane, Hobart, Melbourne (2), Perth and Sydney (2) [8].

3. Australian Association of von Humboldt Fellows Colloquia

The new Australian Association of von Humboldt Fellows organised its first biennial colloquium at the University of Melbourne in 1985. Table 1 below summarises all the Australia-wide gatherings of Humboldtians, including collaborative initiatives. The next AAvHF gatherings were at the University of Adelaide, Flinders University and the University of New South Wales, reflecting in part the home university or city of key members of the Association’s executive. The fifth, sixth and seventh colloquia were held in Victoria, namely in Mannix College at Monash University, at the University of Melbourne and Australian Catholic University’s Ballarat Campus.

In 1996 the Humboldt Foundation conducted one of its Humboldt Global Colloquia in Canberra with the next and eighth biennial AAvHF gathering in 1999 also held at the Australian National University. The Australian Association’s ninth colloquium was at the University of New South Wales. The next AAvHF gathering was during a Humboldt Colloquium held jointly with the New Zealand Association at the University of Auckland. The eleventh and twelfth colloquia were at University of Queensland and Australian Catholic University’s Melbourne campus, respectively, before the Australian Fellows again ‘crossed the ditch’ to meet at the University of Otago. The fourteenth conference was held in Sydney in facilities of Neuroscience Research Australia. Another Humboldt Global Colloquium saw the two Associations gather in Sydney in 2013 where the AAvHF concurrently held its fifteenth symposium.

Table 1: Australian Association of von Humboldt Fellows Colloquia.

Year	Colloquium Title	Venue	Colloquium Organisers
11 – 12 Aug. 1973	Humboldt Colloquium	Hotel Menzies, Sydney	Alexander von Humboldt Foundation
23 – 25 Nov. 1983	Humboldt Colloquium	University of Melbourne	Alexander von Humboldt Foundation and Rolf Beilharz
Jul. 1985	First Biennial Colloquium	University of Melbourne	Peter Schwerdtfeger
4 – 5 Dec. 1987	Second Biennial Colloquium: *The German Experience of Australia 1833 – 1938*	University of Adelaide	Peter Schwerdtfeger and Robert Warner
8 Dec.1989	Third Biennial Colloquium	Flinders University	Peter O’Donoghue, Peter Schwerdtfeger and George Gream
13 Dec. 1991	Fourth Biennial Colloquium: *New Perspectives on the Inter-Dependence of the Economy on Environmental and Social Factors Resulting from Reunification of*	University of New South Wales	Harold Goodwin and David Black

Year	Colloquium Title	Venue	Colloquium Organisers
	East and West Germany in June 1990		
3 – 5 Dec. 1993	Fifth Biennial Colloquium: *The Australian Experience of Germany*	Mannix College, Monash University	Gabrielle McMullen, Trevor Finlayson and Ian Nicholls
1 – 2 Dec. 1995	Sixth Biennial Colloquium	Ormond College, University of Melbourne	Harold Graze, Fred Bull and Helmut Hügel
22 – 24 Nov. 1996	Humboldt Conference: *The Role of Science in Fostering Australian-German Economic Relations*	Australian National University	Alexander von Humboldt Foundation
26 – 28 Sept. 1997	Seventh Biennial Colloquium: *Higher Education in Australia and Germany*	Australian Catholic University – Ballarat	Gabrielle McMullen and Robert Gascoigne
17 – 19 Sept. 1999	Eighth Biennial Colloquium	Australian National University	
7 – 9 Dec. 2001	Ninth Biennial Colloquium	University of New South Wales	Roger Read, David Black and Harold Goodwin
20 – 22 Feb. 2004	Humboldt Colloquium and Tenth Biennial Colloquium: *Research Collaborations with European Partners: Building on Humboldt-Sponsored Links*	University of Auckland	Alexander von Humboldt Foundation and Peter Schwerdtfeger (NZ)
2 – 4 Sept. 2005	Eleventh Biennial Colloquium	University of Queensland	Ralf Dietzgen and Kathy Andrews
7 – 9 Sept. 2007	Twelfth Biennial Colloquium: *In the Spirit of von Humboldt*	Australian Catholic University – Melbourne	Gabrielle McMullen, Trevor Finlayson, Gary Bryant and Ian Nicholls
28 – 30 Jan. 2010	Thirteenth Biennial Colloquium: *In the Spirit of Alexander von Humboldt and Friedrich Willhelm von Humboldt: The Role of Fundamental Research in Our Society*	University of Otago	Peter Schwerdtfeger (NZ), Majella Franzmann and Rob Robson
30 Sept. – 2 Oct. 2011	Fourteenth Biennial Colloquium: *Preserving the Humboldt Tradition of Scholarship in Australasia*	Neuroscience Research Australia	Kay Double, Maria Nowotny and Rob Robson
17 – 19 Oct. 2013	Humboldt Colloquium and Fifteenth Biennial Colloquium: *Looking to the Future: International Research in a Changing World*	University of Sydney/Mercure Hotel	Alexander von Humboldt Foundation
1 – 3 Oct. 2014	*Celebration of German Contributions to Australian Science and Victorian Scientific Institutions: Past and Present*	Royal Society of Victoria	Jillian De Araugo, Matthew Digby, Trevor Finlayson, Rod Home, Doug McCann, Gabrielle

Year	Colloquium Title	Venue	Colloquium Organisers
			McMullen, Jeff Malpas, Paul Mulvaney and Lynne Selwood
20 – 22 Nov. 2015	Sixteenth Biennial Colloquium: *Global Perspectives, Local Knowledge*	University of Tasmania	Peter Jarvis, Simon Ellingsen, Michael Gardiner, Nathan Kilah and Jeff Malpas
17 – 19 Nov. 2017	Seventeenth Biennial Colloquium: *Our Changing World in the South Pacific: Australasian and German Perspectives*	Royal Society of New Zealand	Eamonn O'Brien, Grant Williams, Barry Scott, Andrew Matthews, John Hearnshaw and Trevor Finlayson
22 – 24 Nov. 2019	Eighteenth Biennial Colloquium: *Sharing Knowledge in the Spirit of Humboldt*	Macquarie University	Ingrid Piller, David Black, Roger Read, Michael Gillings, Bronwyn Neal, Lucy Taksa and Eamonn O'Brien
18 – 20 Nov. 2022	Nineteenth Biennial Colloquium: *Humboldtian Research towards a Sustainable World*	Deakin University – Geelong	Jean du Plessis, Rosanne Guijt, Shiri Krebs, Ross Marceau and Jess Holmes
13 – 15 Feb. 2025	Twentieth Biennial Colloquium: *The Humboldtian Vision: Integrating Fundamentals with Applied Research*	RMIT University	Gary Bryant and Sarah Turpin-Nolan

The following year the Association co-hosted a joint symposium with the Royal Society of Victoria entitled 'Celebration of German Contributions to Australian Science and Victorian Scientific Institutions – Past and Present'. This conference, while outside the AAvHF's series of biennial colloquia, was generously supported by a Humboldt *Kolleg* grant and contributed to the Day of German Unity celebrations in Victoria twenty-five years after the Berlin Wall 'came down'.

The Association's colloquium journey then took Fellows to the University of Tasmania, the Royal Society of New Zealand, Macquarie University, Deakin University's Geelong campus and, for the 2025 gathering, RMIT University in Melbourne [9]. The COVID-19 pandemic interrupted the biennial sequence of colloquia and, since Association members did not wish to hold an online symposium, the AAvHF postponed the Deakin gathering for twelve months. Over 42 years, the Association's conferences have progressed from having a prosaic title like twentieth colloquium to themes reflective of the objects of the Foundation and the Australian Association: "international understanding, scientific progress and development" [10].

In each case, the organisation of the colloquium has been undertaken by a team of volunteers, for the most part Fellows from the host institution or other locally-based colleagues. Either through the Association or a Humboldt *Kolleg* grant, some financial support has generally been offered to interstate Fellows to attend the colloquium.

4. The Nature of the Association's Colloquia

Predominantly, the presentations at AAvHF colloquia are by Association members across the range of disciplines. On many occasions, the colloquia have been enriched by keynote speakers from Germany sponsored by the Humboldt Foundation. Eminent Australians and, on many occasions, the Ambassador of the Federal Republic of Germany or one of the Australian Consul Generals have also contributed to the program.

Just as the Humboldt Foundation sponsors high quality "scholars, irrespective of academic discipline" [10], speakers at AAvHF colloquia present across the spectrum of Fellows' disciplines. They have the challenge of delivering their paper to a cross-disciplinary audience and conveying to their listeners the 'excitement' of developments in their discipline. Reflecting on the titles of the twenty colloquia summarised previously, the reader will see that speakers have often been encouraged as well to bring a Humboldtian lens to their presentation – for example, in 2019, 'Sharing Knowledge in the Spirit of Humboldt'. The publications from these cross-disciplinary forums provide exemplars of Humboldtian scholarship to a wider community (see below).

The Association's constitution requires the members to hold a general meeting every two years and these occur during a biennial colloquium. The business covered includes reports from the AAvHF executive and the Awards Sub-Committee, election of office bearers for the next biennium, and consideration of any changes to policy and procedures.

The Association offers three awards in association with its colloquia. Two were introduced at the 2010 colloquium, namely Peter Schwerdtfeger Awards and Distinguished Fellow Awards. These recognise, respectively, the academic or professional achievement of early career members and of long-standing members who have excelled in their professional field and provided sustained service to the Association [11].

The Association's third award was offered for the first time in 2025. In 2022 the Association received a generous donation from Australian Humboldt Fellow Professor David Pollard who, following his Humboldt Fellowship at Bochum University, had a distinguished career at Yale University. The purpose of the donation was to recognise his Humboldt *Gastprofessor* and mentor Peter Gänssler, and to promote the work of the Humboldt Foundation. Following consideration of a proposed new award at the Association's 2022 general meeting, Peter Gänssler Awards have been established to enable potential Humboldt Fellows from Oceania, apart from Australia or New Zealand, to establish contact with an Australian or New Zealand Fellow as a mentor in the preparation of a Humboldt Fellowship application [12].

The Association represents Humboldt alumni – most AAvHF members have been the recipients of Humboldt Fellowships, others of Humboldt Awards, Professorships or of Feodor Lynen Research Fellowships. In this sense, the Association's colloquia are Fellowship gatherings. They are also occasions of fellowship in another sense – as the major gathering of Humboldtians from across the nation biennially, they are valued for their camaraderie as Fellows meet as the Humboldt family 'down under'.

5. Promotion of the Alexander von Humboldt Foundation

The Alexander von Humboldt Foundation summaries its objectives as follows:

- *We sponsor scientists and scholars, irrespective of academic discipline and nationality.*
- *We strengthen Germany as a research location through international research exchanges.*
- *We support our sponsorship recipients during their entire lifetimes and actively promote international understanding, scientific progress and development* [10].

The Association's colloquia offer an occasion to promote the Humboldt Foundation 'down under'. Significantly, many of AAvHF colloquia have been supported by a Humboldt *Kolleg* grant and, on these occasions, the Foundation has generally sent a delegate to participate in, and speak at, the colloquium. Further, the Association has been pleased to welcome to its colloquia representatives from German associations like the Deutscher Akademischer Austauschdienst (DAAD) and, as noted above, from the German Embassy and/or a Consulate. Importantly, the Association encourages the attendance of post-doctoral fellows and postgraduate research students nearing completion, as the Humboldt Fellowship applicants of the future.

7. Colloquia Publications

Following nine of the biennial colloquia and the joint symposium with the Royal Society of Victoria, a publication with some of the papers presented has been issued. The editors, who are listed in Table 2, have made a generous and significant contribution to research and scholarship in the spirit of Humboldt and to promoting the Association. In particular, Associate Professor Trevor Finlayson, the Association's Honorary Secretary, was an editor of four volumes, but also played a leading role in the realisation of the 2017, 2019 and 2022 volumes.

Table 2. Colloquia Publications.

Ian Harmstorf and Peter Schwerdtfeger (eds) 1988 *The German Experience of Australia 1833 – 1938* (Adelaide: AAvHF), 138 pp
Peter O'Donoghue (ed.) 1990 *Proceedings of Third Biennial Conference, Australian Association of von Humboldt Fellows* (Adelaide: AAvHF), 52 pp
Peter O'Donoghue (ed.) 1992 *Proceedings of Fourth Biennial Conference, Australian Association of von Humboldt Fellows* (Adelaide: AAvHF), 45 pp
Trevor R. Finlayson and Gabrielle L. McMullen (eds) 1994 *The Australian Experience of Germany* (Melbourne: AAvHF), 103 pp
Trevor R. Finlayson (ed.) 2012 *Preserving the Humboldt Tradition of Scholarship in Australasia* (Melbourne: AAvHF), 92 pp
William Birch and Mark Williams (eds) 2015 'The Humboldt Symposium Issue', *Proceedings of the Royal Society of Victoria*. **127(1)** 116 pp
M. Davies and T.R. Finlayson (eds) 2016 'Global Perspectives, Local Knowledge', *Papers and Proceedings of the Royal Society of Tasmania* **150(1)** 60 pp
Trevor R. Finlayson (ed.) 2018 *Our Changing World in the South Pacific: Australasian and German Perspectives* (Melbourne: AAvHF), 111 pp
Robert Marks (ed.) 2020 'Sharing Knowledge in the Spirit of Humboldt', *Journal and Proceedings of the Royal Society of New South Wales* **152(3)** Nos 475 & 476 291-345
William Birch (ed.) 2023 'Papers from Humboldt Fellows Symposium, Geelong, Victoria, November 2022', *Proceedings of the Royal Society of Victoria* Special Issue **135(1) & (2)** 6-89

8. Conclusion

Coincidentally, the founding Presidents of both the Australian and New Zealand Associations shared the name Peter Schwerdtfeger, despite having no known relationship to each other. The commitment to the Humboldtian enterprise of these founding Presidents and their respective colloquium committees set the pattern of the biennial scholarly meetings of Fellows. The richness of that legacy is reflected in the record of the colloquia presented in this paper.

References

[1] A history of the Australian Association of von Humboldt Fellows prepared by Trevor Finlayson and Roger Read assisted in the preparation of this paper; Finlayson T and Read R 2024 'Australian Association of von Humboldt Fellows – History'; https://humboldtaustralia.org.au/history-of-the-aavhf/. I also express appreciation to Dr Martin Schaffartzik from the Alexander von Humboldt Foundation in Bonn who provided records for the Australasian colloquia organised by the Foundation.

[2] Alexander von Humboldt-Stiftung 2025; https://www.humboldt-foundation.de/en/connect/events-calendar/humboldt-colloquium.

[3] Alexander von Humboldt-Stiftung 1973 Bericht der Australien-Reise (Bonn: Alexander von Humboldt-Stiftung Archives), p 1.

[4] Ibid., p 17.

[5] Schwerdtfeger P 1988 'Preface' *The German Experience of Australia 1833 – 1938* in eds I Harmstorf and P Schwerdtfeger (Adelaide: Australian Association of von Humboldt Fellows).

[6] Alexander von Humboldt-Stiftung 2025 'Alumni and Networking Strategy'; https://www.humboldt-foundation.de/en/explore/about-the-humboldt-foundation/alumni-and-networking-strategy#h6440].

[7] *Die Woche*, 29 November 1983, page number not available.

[8] Alexander von Humboldt-Stiftung 1983 Bericht der Australien-Reise (Bonn: Alexander von Humboldt Foundation-Stiftung Archives), pp 1-4.
[9] Australian Fellows also made a major contribution to the national forum, 'Alexander von Humboldt: The Shakespeare of the Sciences' hosted by the National Library of Australia on 14 September 2019 to mark the 250th anniversary of Humboldt's birth. The author introduced the life and work of von Humboldt, prior to a panel discussion which included Humboldtians Dr Judith Reinhard and Professor Hans Bachor; https://soundcloud.com/nationallibraryaustralia/alexander-von-humboldt-the-shakespeare-of-the-sciences-140919 and https://www.reid.northcanberra.org.au/alexander-von-humboldt-the-shakespeare-of-the-sciences/.
[10] Alexander von Humboldt-Stiftung 2025 'About the Humboldt Foundation'; https://www.humboldt-foundation.de/en/explore/about-the-humboldt-foundation.
[11] Australian Association of von Humboldt Fellows 2025 'AAvHF Award Winners' and 'Distinguished Members'; https://humboldtaustralia.org.au/aavhf-award-winners/ and https://humboldtaustralia.org.au/distinguished-members/, respectively.
[12] Australian Association of von Humboldt Fellows 2025 'Peter Gänßler Award'; https://www.humboldtaustralia.org.au/peter-gansler-award/.

Examples of the Humboldt Vision sampled from an Organic Chemist's Perspective

Roger W. Read

School of Chemistry, University of New South Wales, NSW, Australia. 2052.

This article highlights through a selection of personal experiences how the essential role in which the spirit of discovery and scientific enquiry demonstrated by Alexander von Humboldt and the outstanding support provided by the Humboldt Foundation over an extended period of time can bring fundamental areas of natural product chemistry and modern day synthetic organic chemistry to bear on practical applications, and often be guided by them, with global significance.

1. Introduction

Alexander von Humboldt would not have described himself as a chemist, but he was gifted as, in the words of our Australian Association of von Humbodlt Fellows Honorary Secretary, *a discoverer and cosmopolitan, a universal scholar and fighter for the freedom of research, a humanist and patron of excellent research talents* [1]. His self-driven, extensive travels to various parts of the world allowed him to collect a wealth of carefully acquired data and detailed observations. These activities, and his passion for communicating his findings to specialists and the general public, cemented Humboldt's wider credentials and brought him popularity as a leading geographer and oceanographer. Importantly, the opportunity to evaluate and assimilate results from different fields, and then to consider their applications, and recognise where such applied situations might yield better fundamental understanding, also allowed Humboldt to recognise situations that were of global significance. Examples included his eventual conception of the universe as a system in which every component was interconnected and thereby his establishment of the unknown concept of "ecology". Similarly, Humboldt was the first to highlight the effects of humans on the climate, leading to what is now known as the field of "climatology" [2]. Yet, Humboldt's selfless sponsorship of other young scholars and talents does provide a sound connection to my own field. Humboldt strongly invested in support for one, Justus von Liebig, a principal founder of Organic Chemistry [3], and so serves as a reminder of the powerful ethos of the Alexander von Humboldt Foundation.

In keeping with this 20th Biennial Conference theme, *"The Humboldtian Vision: integrating fundamentals with applied research"*, it is my intention in this paper, not to claim any likeness to Humboldt, but to draw upon four examples from my own career to demonstrate the power, enjoyment and impact of adopting, consciously or otherwise, characteristics of what I perceive as Alexander von Humboldt's life journey: Discovery, Invention, open mindedness and the Scientific Method, with Integration of fundamentals and practical applications, especially when supported by an organisation such as the Humboldt Foundation and its "Humboldtian Vision".

2. Preparation for the Journey

My journey began as a freshly minted Bachelor of Science Honours degree graduate with some basic knowledge of extraction and isolation techniques of natural products from terrestrial plants. I boldly confronted the Head of Organic Chemistry at Sydney University, Professor Ernest Ritchie, with a request to undertake a PhD research project under his direction on natural products chemistry. My request came with stipulations, in that it should yield the isolation and characterisation of a range of novel and interesting natural product types, and involve the opportunity to participate in some level of basic synthetic organic chemistry. Four years later, after co-supervision by Professor W.C. (Wal) Taylor, I was to complete the PhD degree based on a detailed study of constituents from a beautiful ancient flowering shrub, *Eupomatia laurina* R. Br. One of the classes of compounds isolated, the eupodienones, yielded a total of seven examples, all with the same unique, chiral, spirocyclic structural skeleton, which it was discovered underwent an acid catalysed rearrangement process with unexpected selectivity, Fig. 1a [4,5]. Moreover, these rearrangement products were studied and found to be of a type that could undergo a little recognised isomerism process that is now a well-known phenomenon, termed globally as, *atropisomerism*, Fig. 1b [5].

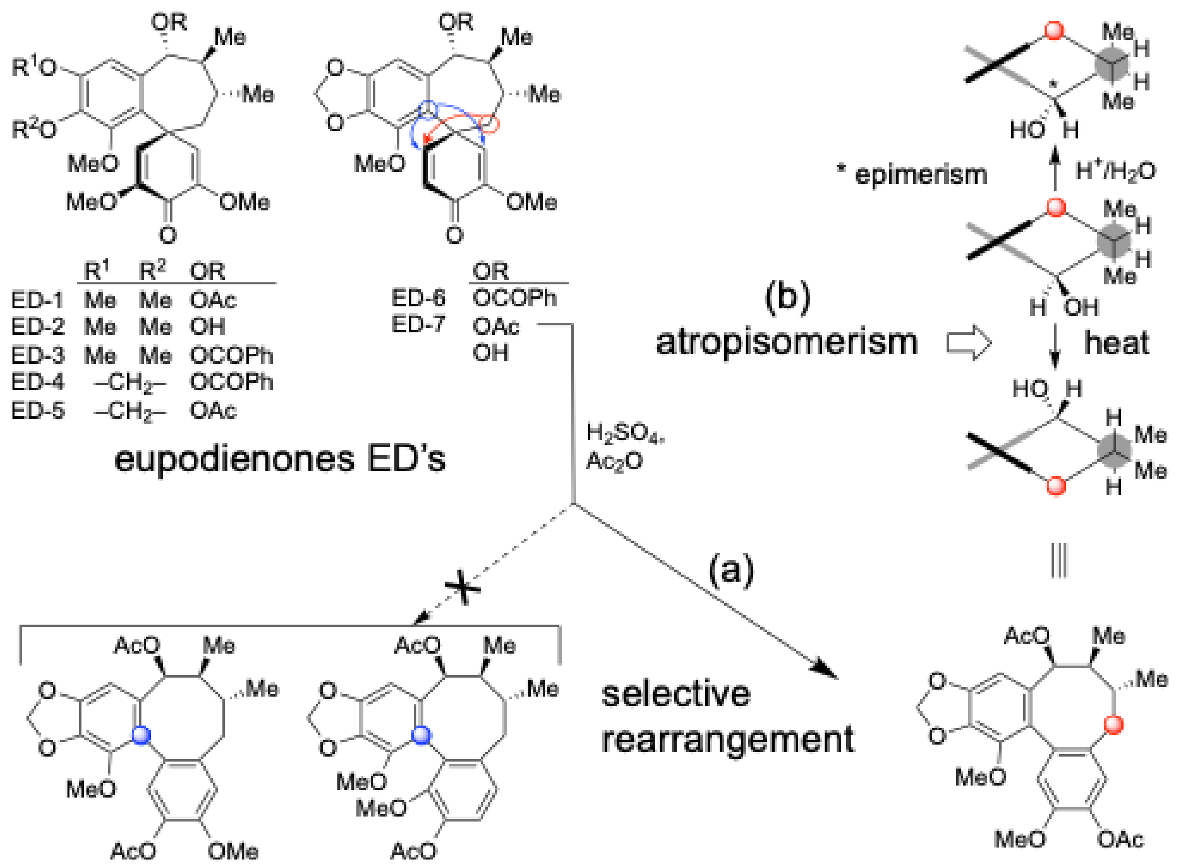

Fig. 1. Eupodienones 1–7 and their novel structures and unexpected chemistry: (a) selective acid catalysed rearrangements and (b) unusual *atropisomerism* of the products.

With newfound confidence, my journey took me for eight years to postdoctoral academic appointments at Imperial College, London, Auckland University, and Melbourne University, and a non-academic position as a research scientist within the Defence Science and Technology Organisation (DSTO), Materials Research Laboratories, Melbourne. Each of these positions provided unique and complementary research experience and exposure in turn to the fields of the invention of new reactions [6,7], the utilisation of natural products [8], organic reaction selectivity [9,10], and the tailoring of physicochemical properties of synthetic materials (energetic substances) [11-15]. The latter research, in particular, was highly collaborative and brought with it daily contact with non-chemistry professionals. This gave a fresh perspective on my chosen field of chemistry and great respect for engagement with other disciplines.

At this point (1985), I and my work had acquired considerable exposure across a wide range of connected fields. In addition, I had established numerous intersecting, local and international, social, scientific and professional networks through inter-institutional visits, cooperation and secondments, conferences, seminars and meetings, and professional association membership and committees. Probably as a result, I was fortunate to secure my long sought after academic career ambition with an on-going teaching and research appointment in Chemistry at the University of New South Wales (UNSW) in Sydney.

3. Selected Career Examples

While undergraduate lecture notes and research grant applications were prepared, research laboratories established, and new students recruited, a number of research projects were reactivated and new ones begun. One organic synthesis project that had received a little preliminary study at Melbourne University (MU), led to my first example of engagement with the Alexander von Humboldt Foundation and serves to demonstrate a number of Humboldtian characteristics from which we, as AvH Fellows have all benefitted and can define within the *Humboldtian Vision*.

3.1 Example 1. Learning resilience and acceptance of disappointments

The project was directed towards a conceptually efficient, alterative synthesis of plumericin iridoids, Fig. 2, natural substances with a range of useful bioactivity and identified as potent insecticidal, moulting hormone disruptors. The planned synthesis would utilise some of the chemical selectivity aspects learned while at MU, however, a preliminary step in the synthesis, Fig. 2 (red [pale] arrows), had been identified at the time as problematic using conventional reagents.

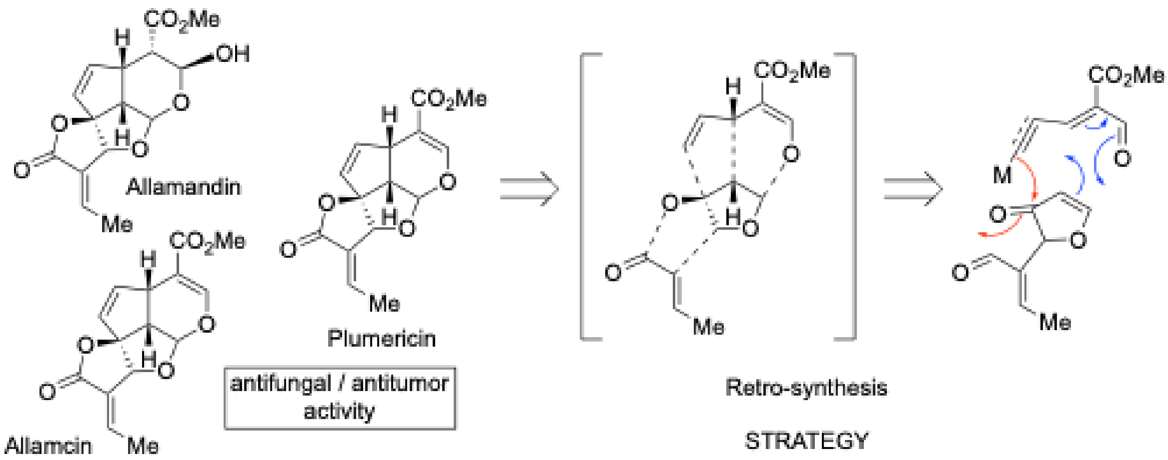

Fig. 2. Strategy for Plumericin iridoid syntheses

In intervening years I had read about ground-breaking work by Professor Dr Manfred Reetz at Marburg in developing organo-titanium reagents that appeared would solve this problem. At the suggestion of a colleague and former Humboldtianer, Professor David StC Black, I applied for and was fortunate to be awarded a one semester long AvH Research Fellowship to visit Marburg in order to gain practical experience making and using these reagents.

Upon my return, a talented Honours student, Ms Jacqueline Matthews, examined their application in model systems, Fig. 3 (red (pale) arrows). While the reagents achieved the desired bond formation, the results overall demonstrated that the intermediates so formed were, in fact, not suitable for completion of the designed synthesis because of unavoidable loss of water. As a result the project was abandoned in favour of others. However, Ms Matthews has since gone on to complete Honours and PhD degrees with distinction and is currently a celebrated full Professor at Sydney University.

While not achieving our immediate goals, this experience reinfored the valuable support that the AvH Foundation has provided to early career researchers when needed. It also demonatated another Humboldtianer characteristic, resilience, knowing that not everything works according to plan, and using disappointments as learning experiences.

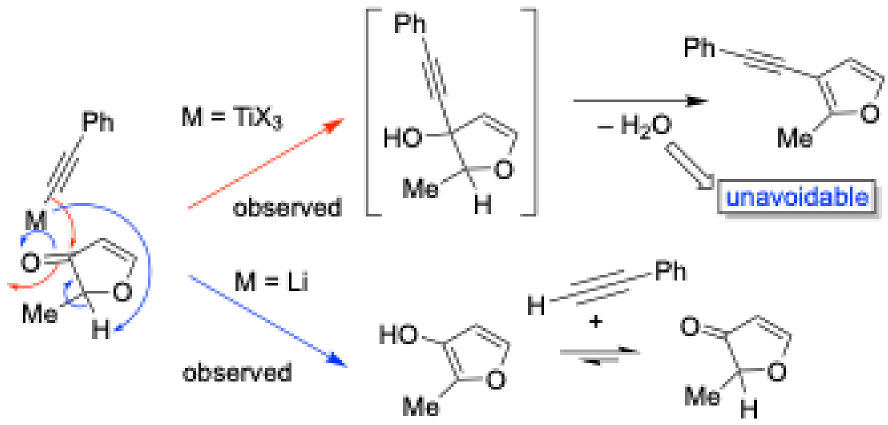

Fig. 3. Comparison of the use of organo-Li (blue arrows) *versus* organo-TiX_3 (red arrows) reagents in

3.2 Example 2. Collaboration and commercialisation

My second example draws on a highly interdisciplinary project across chemical, biological and marine sciences that very clearly involved *integration of fundamental and applied research*, and demonstrates another crucial supportive role played by the AvH Foundation.

This project arose from a chance observation by a marine ecologist, and preliminary investigation by biological chemists led by a microbiologist at UNSW. Together, they identified a series of four related natural products from a locally growing red alga, *Delisea pulchra* (*cf fimbriata*) that appeared to efficiently prevent other organisms from fouling the alga. The structural skeleton of the molecules, termed "fimbrolides", Fig. 4, was new and resembled that of *N*-acylhomoserine lactones, a class of signalling molecules involved in quorum sensing in bacteria, and so of significant interest.

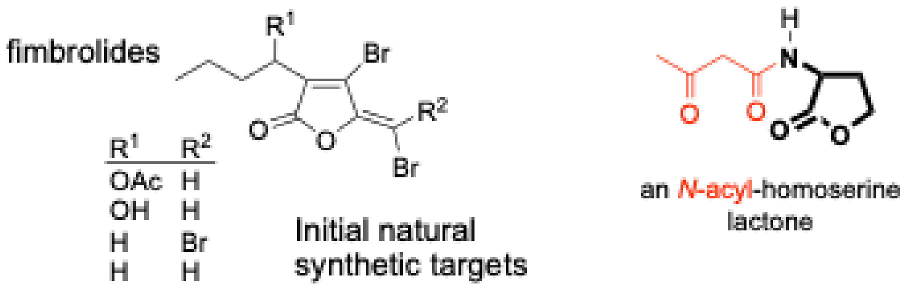

Fig. 4. Structures of naturally occurring, synthetic target 'fimbrolides' and a representative *N*-acylhomoserine lactone.

Severely limited quantities of the pure natural products, and the huge and diverse commercial importance of such a find prompted the initial investigators to seek assistance from more practised chemists to devise a suitable synthesis of the compounds to enable further biological screening of the molecules. Dr Naresh Kumar and I, as experienced synthetic chemists, quickly planned and implemented such a synthesis with the involvement of student assistants, and the early chemical and biological signalling aspects of the mode of action were patented [16] and later published [17]. A full-scale research collaboration was established at this stage and a commercial enterprise, BioSignal Ltd, spun off to further expand testing and improve bioactivity, as well as to understand the mechanism of action better and incorporate specific application adaptations.

Meanwhile, I had become interested in a new synthesis design concept referred to as Combinatorial Chemistry, which opened up the possibility of automation in synthesis, and with it, a field of study referred to as Fluorous Chemistry, which focused on applications of the unique characteristics of highly fluorinated, mostly organic molecules, including polyfluoroalkyl-substituted substances. The latter substances, by definition, mix poorly with water and regular organic solvents like alcohols and xylenes, a property that immediately enhances their separation characteristics, an important consideration in any chemical manufacturing process.

In order to learn more about practical aspects of fluorous chemistry I arranged for another period of personal UNSW Special Studies Program Leave to visit Professor Dennis Curran, a leading proponent of the field, and his research group at the University of Pittsburgh. Here I gave a course of postgraduate lectures on my own field of expertise, heterocyclic chemistry, and learned first hand the essential techniques of incorporating, manipulating and analysing fluorous tagged molecules. During my stay, I was also involved in the invention of a suite of reagents for temporary fluorous protection of amines, including amino acids. These F-Boc-ON reagents, Fig. 5, and their applications were patented [18], and later published [19,20]. Eventually they became part of the repertoire of Fluorous Technologies Incorporated, a US start-up company designed to further develop such technologies at a fundamental level and to service wider industry adoption. Upon my return to UNSW, a fresh PhD student, Chutian Zhang, very capably expanded the temporary fluorous tagging concept by developing our own, Australian, fluorous reagents, this time for the protection of aldehydes and ketones, as well as of alkanediols, as acetal derivatives. These results were also reported [21,22] and disseminated at conferences and research seminars; in so doing, they actually helped pioneer the introduction of fluorous chemistry within Australia.

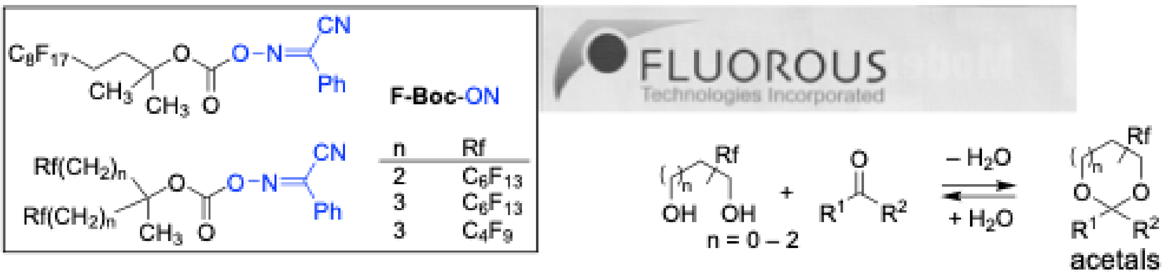

Fig. 5. Structures of fluorous **F-Boc**-ON reagents, developed by Fluorous Technologies Inc for the protection of amines, and fluorous diol reagents developed at UNSW for the protection of carbonyl compounds as acetals.

Relevant to this second illustration of the Humboldtian vision, at this same time I welcomed to our laboratories, Frau Dr Iris Aiglstorfer, an AvH Feodor Lynen Research Fellow from the Universität Regensburg. Dr Aiglstorfer had chosen to investigate alternative synthetic approaches to the preparation of "fimbrolides" and it had been suggested to consider the advantages of fluorous chemistry. Ultimately, a relatively lengthy stepwise synthesis was achieved, but it could proceed through a key polyfluoroalkylsilane intermediate using less corrosive reagents and byproducts than the first, and provided flexibility in the introduction of desirable substituents at two different positions, Fig. 6. The fluorous intermediates also gave an attractive profile in their own right in biological screens and so the chemistry and the compounds themselves were captured within the patent portfolio [23] of the earlier mentioned BioSignal Ltd.

As an aside, after completion of her Feodor Lynen Research Fellowship, Dr Aiglstorfer, returned to Europe and was quickly recruited by a Swiss-based company where she has evolved to become a Senior Commercial Project Manager.

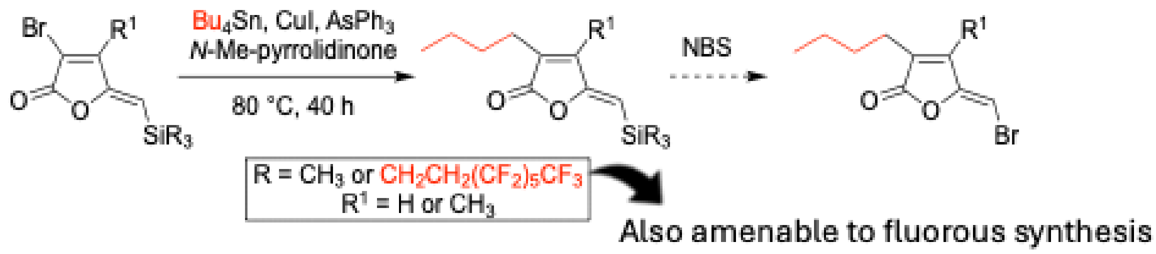

Fig. 6. Alternative, flexible synthesis of fimbrolide analogues with a demonstration of scope for fluorous synthesis adaptations.

3.3 Example 3. Application driven by advances in fundamental knowledge

Following Dr Aiglstorfer's stay with us, contact was established with her former research supervisor, Professor Dr Armin Buschauer, by inviting him to present a seminar at UNSW during an Australian conference visit. Subsequently, I made an informal visit to Pharmacy at the University of Regensburg, and later, 23-27 June 2002, a more formal visit to better introduce myself to staff, and to present a broad lecture on our research, for which I was made the inaugural Vielberth Lecturer. In return, an invitation was also extended to another member of the Regensburg staff, Professor Dr Oliver Reiser, to present a keynote lecture at the Royal Australian Chemical Institute National Convention at the Sydney Convention Centre in July 2005. These interactions strengthened the UNSW Sydney – Regensburg connection and no doubt led to my third example of the *Humboldtian Vision*.

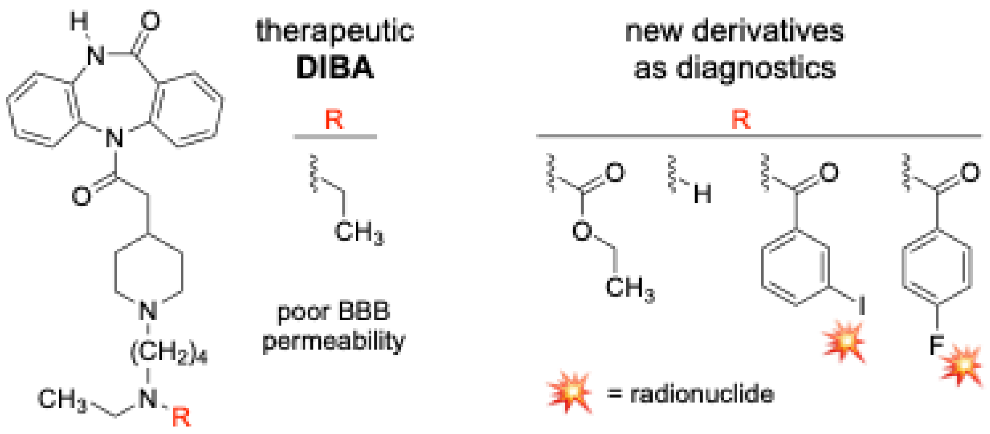

Fig. 7. Halogenated dibenzodiazpinones as diagnostic agents for early-onset dementia.

Prompted by a conversation with former student, Dr Michael Kassiou, who had for a time held a research position at the Australian Nuclear Science and Technology Organisation (ANSTO) in the Radiopharmaceutical Chemistry Division, and had since moved to the University of Sydney, my group began an interest in developing radiolabelled diagnostic agents for the detection of early-onset dementia. A promising target for these agents was M_2 subtype muscarinic receptors in the brain; known to be depleted in Alzheimer diseased patients. While one of the best in class, therapeutic antagonist agents, DIBA (Fig. 7), showed poor blood brain barrier (BBB) permeability, Dr Kassiou had shown that *N*-acyl, R = COR', derivatives showed improved permeability as antagonists.

A series of four halogenated dibenzodiazepine candidates were synthesised in collaboration with a UNSW student, Xue Shi, and evaluated with unexpectedly mixed, subtype selectivity results [24]. Consequently the project was paused until a wider range of analogues could be evaluated.

Coincidentally, the research group in Pharmacy at the University of Regensburg had also become involved in studies of M_2 selective dibenzodiazepinone muscarinic receptor ligands, but more from the perspective of therapeutic agents and developing an understanding of binding for optimisation. As a result, several years later, another graduate from Regensburg, Herrn Dr Max Keller, successfully applied for an AvH Feodor Lynen Research Fellowship in our laboratories at UNSW. Less concerned with agents that would cross the blood brain barrier, his project focussed on analogues of the DIBA type wherein analogues with variations about the pendant tertiary nitrogen group were of interest, especially through its incorporation within a heterocycle and/or within a group that might yield a homo-dimeric final structure, see Fig. 8.

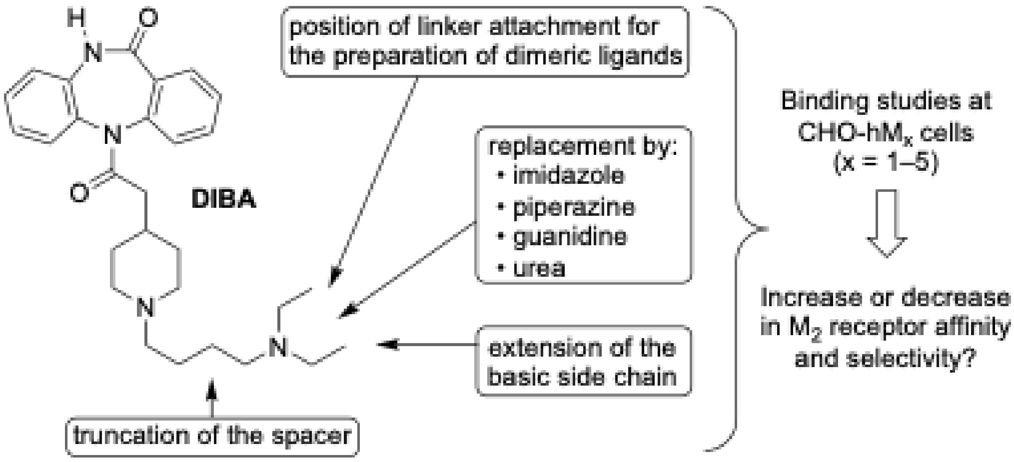

Fig. 8. Aspects of interest in the study of DIBA as an M_2 receptor preferring antagonist in therapeutic ligand design and understanding binding optimisation.

Two primary publications emerged [25,26]. One [25] was reasonably esoteric and focussed on a crystallographic study that revealed fundamental differences in the dimeric association of the dibenodiazopinone head groups of the parent dibenzodiazepinone headgroup itself (a) and one of the fully constructucted, extended molecules (b), Fig. 9.

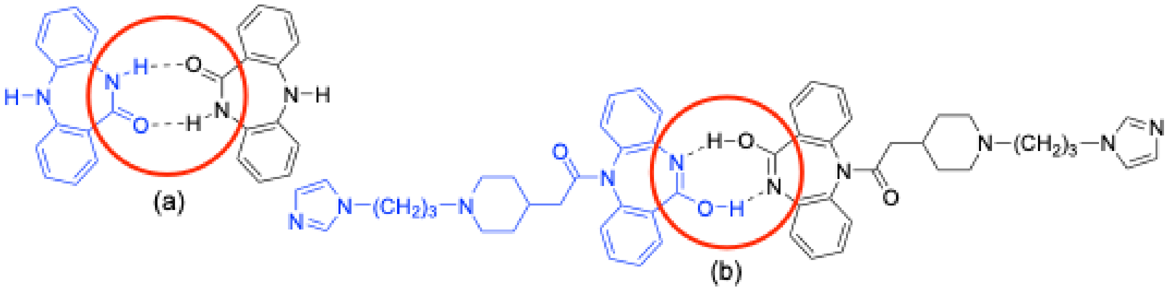

Fig. 9. Different amidic bonding within dibenzodiazepinone dimers (a) and (b).

The other publication [26] described new synthetic analogues prepared through the pendant amino group from which a more practical aspect, the effect of chemical homo-dimerization on orthosteric and potentially allosteric binding could be assessed. Pleasingly, Dr Keller has since returned to the University of Regensburg where he has established his own, independent research group, and is growing in stature as a leader in this field.

3.4 Example 4. Promising ventures now out of favour

An entirely new program in our research group emerged a decade or so ago from our interest in highly fluorinated compounds. It called for the development of functional, discotic fluorous surfactants based on heterocycles. The program was ambitiously aimed at creating entirely artificial vesicles and other multi-layered, supramolecular systems made from assemblies of these molecules [27,28]. The systems would allow the controlled transport of particular small molecules or reagents to pass through the membranes so that the assemblies themselves might serve together, as sustainable micro-transport, micro-storage, or micro-manufacturing centres.

At this fundamental level, the project attracted chemistry researchers from various parts of the globe who generated a large number of new, well characterized substances, and their performance as surfactants and the nature of their aggregation were studied by a diverse range of techniques including nuclear magnetic resonance spectroscopy, X-ray crystallography, optical rotation, surface tension (Fig. 10) [27-31], atomic force microscopy (Fig. 11) [32], and pH titration (Fig. 12) [33].

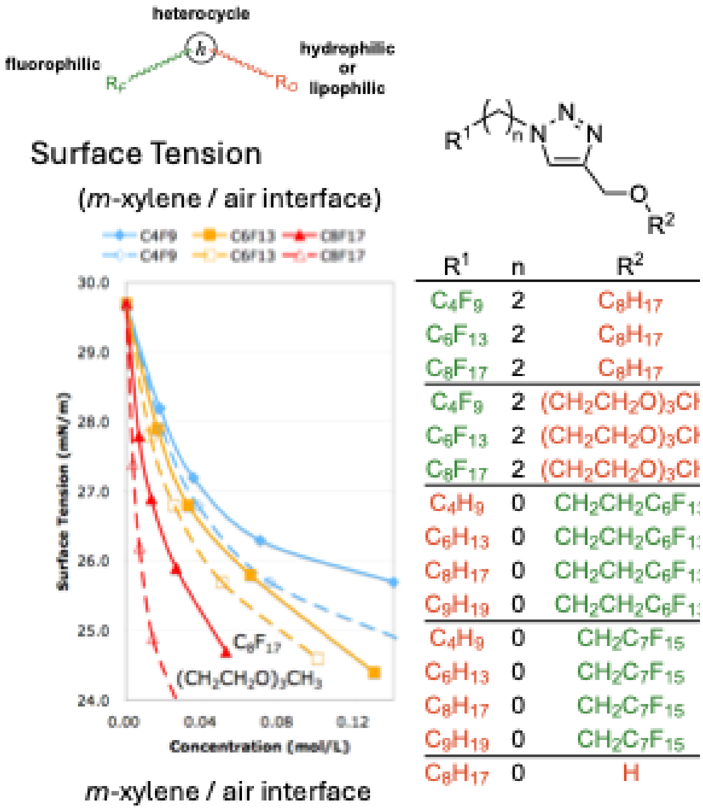

Fig. 10. Representative fluorous mono-triazolyl ethers and their dose dependent effect on surface tension of *m*-xylene at its air interface.

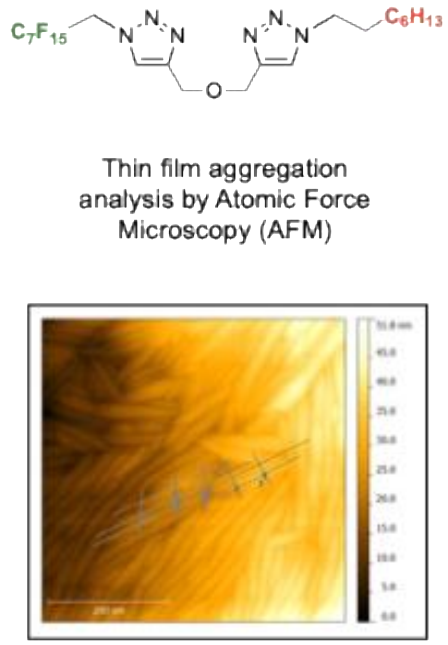

Fig. 11. Analysis of the aggregation characteristics of a surface coating film of a fluorous bis-triazolyl ether by Atomic Force Microscopy (AFM).

Recently, more sophisticated, fluorous triazolyl ethers of protected sugars have been prepared as compounds that might undergo controlled, dipole switching upon deprotection and reprotection of the sugars, Fig.13 [34,35]. At the same time new mono- and bis-triazolyl amine surfactants bearing an additional substituent on the amine nitrogen have been prepared, Fig. 13 [35]. It is hoped that these might serve as models for transport surfactants in which payloads might be transported and deliverd across simpler fluorous membranes.

Throughout this program, much has been learned about the perfluoroalkyl chains themselves, their dominance in terms of molecular assembly, the scope of their potential in supramolecular design and practical functionality.

However, with growing public awareness of the accumulation of highly fluorinated alkyl materials in the biosphere, their seeming inertness to degradation, and the potential of resulting damage to biota, polyfluoroalkyl materials have rapidly fallen from favour in industry and in commercial applications. Most research funding in this field is understandably now directed towards detection methods, understanding their impact on animal health, and efforts to finding alternatives or methods to benignly degrade the materials on a large scale for remediation purposes. We have recognized these concerns and will, at least in the short term, direct our research elsewhere.

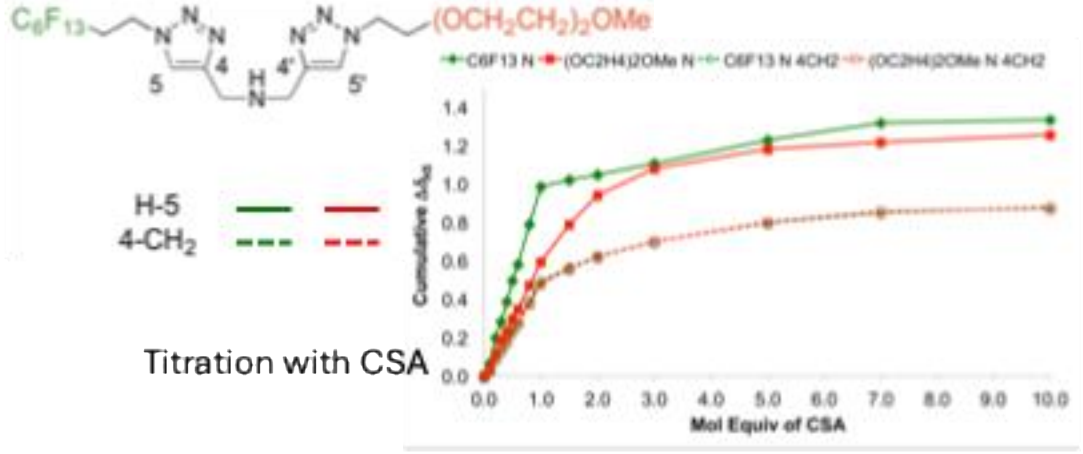

Fig. 12. Evaluation of supramolecular behaviour of a fluorous bis-triazolyl amine in response to camphorsulphonic acid (CSA) titration by [1]H nuclear magnetic resonance spectroscopy.

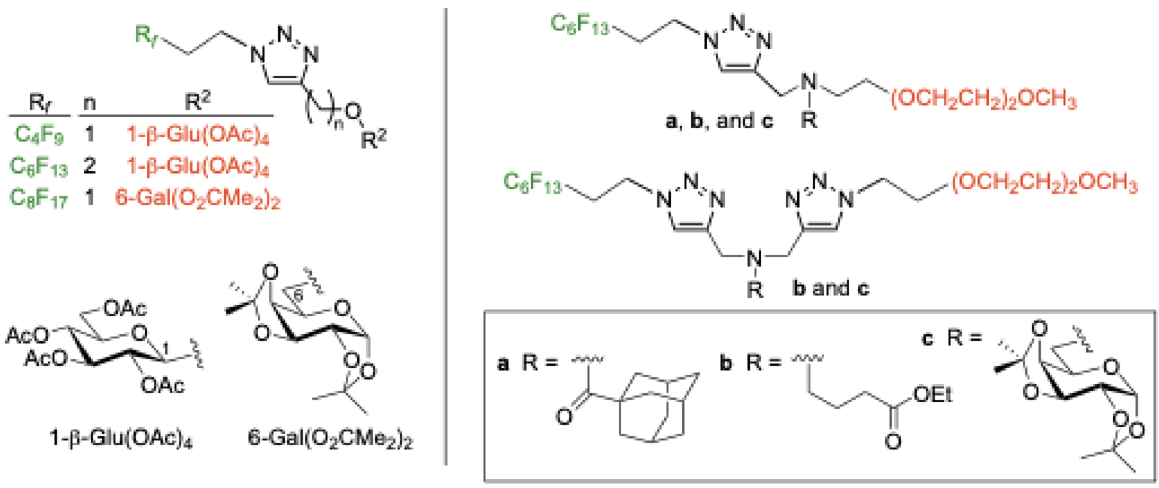

Fig. 13. Examples of designer fluorous surfactant candidates with dipolar switching capability and with transport capability by introduction of a third substituent arm.

Relevant to this last example, there should perhaps be a sobering addendum to the initial list of Humboldtian characteristics I perceived at the start. My career examples make it obvious that the journey has been taken over an extended period of time. Technologies and norms change over time and so there is a definite possibility of contemporaneousness about what we do, and research is not immune. Although not always predictable, and not always applicable, a consciousness that there can be ‘a season for everything’, a ‘contemporaneousness’, as we journey, might also add to our overall fulfilment.

4. Summary Remarks

It is hard to contemplate an end to the journey just described, but at this point there is an opportunity for reflection. In my case I can honestly report that the serendipitous path I have followed has benefitted enormously from the characteristics expressed in my introduction. This applies particularly to the mix of locations and fields in which I have carried out the research, but most importantly the many inspiring people with whom I have travelled. These colleagues and students with whom I have engaged have also been the glue that has ensured the cohesion and the joy in each day.

Acknowledgments

I have mentioned the names and associations of people most involved in the key research areas described in this paper and apologise to the many who contributed and whose names were omitted for the sake of brevity. The support of the Alexander von Humboldt Stiftung in Bonn and the executive of the Australian Association of von Humboldt Fellows over almost 40 years has been outstanding and not only appreciated but been instrumental in whatever success in the outcome the reader attributes to it.

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Navigating Water Security in Australia

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Addressing climate change to ensure water security is a critical challenge, both in Australia and globally. Approximately half of the world's population endures severe water scarcity for at least one month each year. In Australia, this issue is acutely relevant due to the country's unique environmental conditions, such as droughts and bushfires, and the significant impact on Aboriginal communities by water management policies. It is critically urgent to integrate interdisciplinary concepts of bio-physical and socioeconomic origin in water resource management, focusing on aspects such as availability, access, quality, safety, and governance, while harnessing the potential of digital technologies for data-driven, responsive, and efficient water management solutions. This study aims to confront the multifaceted and interconnected challenges associated with water security. This study will include a focus on Australia's unique water systems, like the aboriginal-dominated Kimberly region. Secondly, by understanding these complexities, the project aims to develop innovative methods to study, quantify, and qualify the dynamics of water security. This study will engage a cross-comparison of international water-management cases, integrating sustainable strategies, to draw lessons that are applicable to water management policy and practice in multiple countries, including Australia. This comparative analysis will focus on ensuring equitable water security, particularly for Aboriginal and socially marginal communities in the Kimberly region, emphasizing developing environmentally sustainable and socially equitable digital solutions.

Space, Sound and Architecture – integrating philosophical fundamentals with applied architectural design

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How does architectural design take account of sound? And is sound a more important element in architectural design than is perhaps usually assumed? This brief presentation will set out some of the basic issues at stake here, analysing key aspects of the way sound, space and place inter-relate.

There is a longstanding history of connection between architecture and philosophy – a connection that, as Indra McKewen (1993) argues, goes back to the relation between Socrates and his supposed ancestor Daedalus (the architect of the Minoan labyrinth) (McKewen, 1993).

My own philosophical work connects with architecture on various fronts: through the way hermeneutics has entered into architecture (Vesely, 2004), but also through architecture's concern with space and place (Malpas, 2021). I have held positions as Honorary Professor, RMIT, School of Architecture and Professor of Philosophy in Architecture, University of Tasmania, School of Architecture, as well as collaborating with architects and architectural theorists in Australia, Europe, and North America.

My interest here is specifically in relation to sound – a topic that I have discussed in other works, but which takes on a particular character in relation to architecture. My starting point is the question as to how sound enters into architectural design – what problems does it present, and to what extent are those problems tied to broader issues in contemporary architectural theory and practice?

Acoustic elements are more difficult to manage in design than are, for instance, visual elements. This is a consequence of differences in the physical properties at issue: sound is mechanical, being caused by vibrations in objects that give rise to vibrations in the surrounding medium which move out in waves parallel to their direction of travel (sound waves move longitudinally); light is electromagnetic, therefore requiring no medium, and moving in waves perpendicular to the direction of travel (light waves move transversely).

Acoustic elements are more difficult to include in the representations that dominate design. One reason is the dynamic character of sound which means that it resists static presentation. Representation itself prioritises the visual over the acoustic. This has several consequences including a tendency to emphasize spatial position over topological situation (Malpas, 2021) – a problem for architecture generally but especially significant in relation to sound.

A genuine concern with sound on the part of designers is evident, for the most part, only in a narrow range of cases. It is taken to be an issue in those buildings and interior spaces in which sound, and acoustic experience, is already identified as a key element – in specialised interior spaces such as concert and lecture halls, theatres, assembly and debating rooms, churches, mosques, temples and other places of worship, celebration, and contemplation. This is evident from the way acoustics is treated in standard textbooks on acoustic architecture (e.g., Long, 2005), which focus largely on the problems of managing sound within such specialised spaces. The particularity of this focus, and the tendency for sound to be treated apart from broader design consideration, is also evident in the fact that where sound is taken to be an issue in architecture, it is typically addressed by a specialised acoustician.

The acoustic character of a space is largely a matter of the reverberative properties of a space – of the way sound is transmitted within that space - primarily determined by the conjunction of surface materiality and spatial configuration. Large spaces whose walls, floors and ceiling are made of acoustically reflective and non-penetrative materials, will typically be more sonorous, more acoustically 'alive', than smaller spaces whose interior surfaces are acoustically non-reflective or absorbent, with the latter being acoustically 'dead'. Outside of specialised interior spaces, attention to sound mostly concerns the management of sound *penetration* between spaces. As such, it is typically treated as a secondary element in the overall design.

Where sound is an issue in exterior spaces, it is mostly to do with issues of sound projection in and beyond those spaces. The general issue of sound as it relates to exterior spaces indicates the way that built forms are part of larger landscapes, or, in the specific case of sound, 'soundscapes' (Schafer, 1977), both contributing to those landscapes or soundscapes and being affected by them. This is especially evident in the case of sound because of its more pervasive character: one can isolate interior spaces from their surrounding visual context more easily than one can do so acoustically.

This not only means that buildings need to be considered in terms of the way their external acoustic environments affect their interior spaces, but also the acoustic impact of buildings on their environmental surrounds. Buildings produce acoustic effects, most obviously through air-conditioning and the other infrastructural elements with which buildings are associated, but also through the way built forms affect the way buildings affect the behaviour of sound that may be generated apart from the building through acoustic reflection, concentration, dampening or amplification that arises as a result of built forms and their material constitution. Buildings play an important role, in this respect, in relation to the problem of acoustic pollution (Rosen, 1974).

One of the key differences between sound and vision, in addition to differences in their physical properties, is that sound brings with it a stronger emphasis on topological situatedness over mere spatial positionality (on being *in a place* rather than *at a location*). Such situatedness is important for design in general and is at issue in both sound and vision. But because representation tends towards the visual, and representation also prioritises the positional over the situational, so representational forms tend to favour the visual over the acoustic.

The relative neglect of sound in design is thus tied to a tendency to ignore situatedness in positionality. This is part of a more general problem concerning the emphasis on specific visual spatial forms and representations in design, in particular, as well as a broader tendency within modernity for the dominance of narrowly spatialised forms of understanding that take space as primary. In architecture this not only means that sound is neglected in favour of vision, but also that exteriors tend to be neglected in favour of interiors. Interiority, 'being in', is already presented as a mode of situatedness in a way that exteriority is not (Malpas, 2021). The emphasis on exteriority goes with an emphasis on quantity, surface, static representation, and position over quality, depth, immersive affectedness and situation.

The role of affectivity requires some attention. It is itself tied to the pervasive character of sound which is tied to the physical character of sound at the same time as it also exemplified the connected character of spaces – of the way being situated is a matter of connection within a space and beyond it. Apart from its treatment in specialised spaces, the main focus on sound in design is one directed at its control, meaning, usually, its exclusion from and confinement to specific spaces – i.e., the acoustic separation of spaces, either different interior spaces or interior spaces from exterior. Although often responding to a practical need, this nevertheless serves to reinforce a tendency for design to operate in a way that treats spaces as discrete rather than integrated elements.

What would be needed for sound to be taken more seriously in design? There are several points that are relevant here:

- A greater focus on both exterior and interior acoustic environments;
- A broadening of concern to encompass more than just the management of specialised acoustic performance or the management of sound penetration; and
- Recognition of sound as an integral element in the way spaces are constituted and experienced.

Greater attention to sound in design would mean greater attention given to the connection and separation of spaces, to their overall affectivity, and to the larger environmental context in which built forms are situated. It would mean a shift, overall, away from the tendency to treat buildings in terms of their mere positionality (their mere location at a site) and towards understanding buildings in terms of their broader situational embeddedness – an embeddedness that is multi-sensorial and part of a larger relational structure that encompasses the interiority of buildings as well as their exterior form (Malpas, 2021).

This is a much-condensed version of a paper which appears as ‘Place, Sound, and Architecture’, in Emma-Kate Matthews, Jane Burry, Mark Burry (eds.) *The Routledge Companion to the Sound of Space* (London: Routledge, 2024), chapt. 23.

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Clay Minerals for Environmental and Agricultural Applications: Link to UN SDGs and Net Zero Goals

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Clay minerals are naturally occurring layered aluminosilicates. Their raw and modified forms offer sustainable material solutions for net zero goals. Key applications include wastewater treatment, emissions reduction, soil carbon management, and slow-release fertilisers. All these are linked to sustainable development goals. This article also highlights sustainability considerations in processing and chemical modification of clays, stressing life cycle analysis and regeneration to reduce environmental impact.

1. Clay Minerals and Modified Materials

Clay minerals are abundant in soil, sediment, and rock at the Earth's surface and within the brittle upper crust. These naturally occurring fine-grained hydrous phyllosilicates exhibit plasticity when mixed with water and harden upon drying or firing [1]. Among the commonly occurring clay minerals, kaolinite, halloysite, and smectite (e.g., montmorillonite, saponite) are dominant in commercial applications and research for new uses [2]. Kaolinite is a 1:1 clay mineral, consisting of one aluminium-based octahedral layer and one silicon-based tetrahedral layer (Fig. 1). Halloysite is structurally similar, but often occurs in nanotubular morphology. Smectite, commonly known by its commercial name "bentonite", is a 2:1 clay mineral, meaning one octahedral layer is sandwiched between two tetrahedral layers (Fig. 1). Its interlayer space can accommodate water molecules and exchangeable cations, which help balance the net charge.

These minerals have significant use at present and emerging due to the adsorbent nature of the material, low cost, naturally occurring and good research deposit in the world. However, depending on applications, the physicochemical properties of the raw minerals might not be showing full potential for the desired applications, thus requiring modifications. However, properties such as ion exchange capacity, surface area, and diverse morphologies enable clay minerals to be modified both mechanically and chemically.

2. Area of Applications and Link to UN SDGs and Net Zero Goals

The United Nations (UN) has set 17 goals for a sustainable future. Among these, a significant number are directly linked to the environment and agriculture. Sustainable development goals (SDGs) such as Zero Hunger (2), Good Health and Well-being (3), Clean Water and Sanitation (6), Affordable and Clean Energy (7), Sustainable Cities and Communities (11), Climate Action (13), Life Below Water (14), and Life on Land (15) are particularly relevant. Raw and modified clay minerals can contribute to achieving these goals both directly and indirectly.

We first published a bibliographic article titled "The multidisciplinary science of applied clay research: A 2021–2023 bibliographic analysis" in *Applied Clay Science* [2]. In that study, we systematically analysed data and found that over 52% of clay research was directed towards solving real-world problems. The main applications included clays used as adsorbents, foundry materials, and supporting material for chemicals, agrichemicals, and feed additives. Notably, the adsorptive properties of clays contribute to cleaning contaminated water, enhancing carbon storage in soil, and capturing greenhouse gases in industrial reactor systems.

Using the same search criteria, I extended the analysis to include publications from 2024 through to 20 March 2025, to assess their links to the SDGs. In this case, I used Web of Science (Clarivate) analytics to examine these connections. Among the articles considered, over 22% aligned with the SDGs on "Clean Water and Sanitation" (over 857 research papers), followed by"Good Health and Well-being" (8.8%), "Climate Action" (6.4%), and others (Fig. 2). It is worth noting that

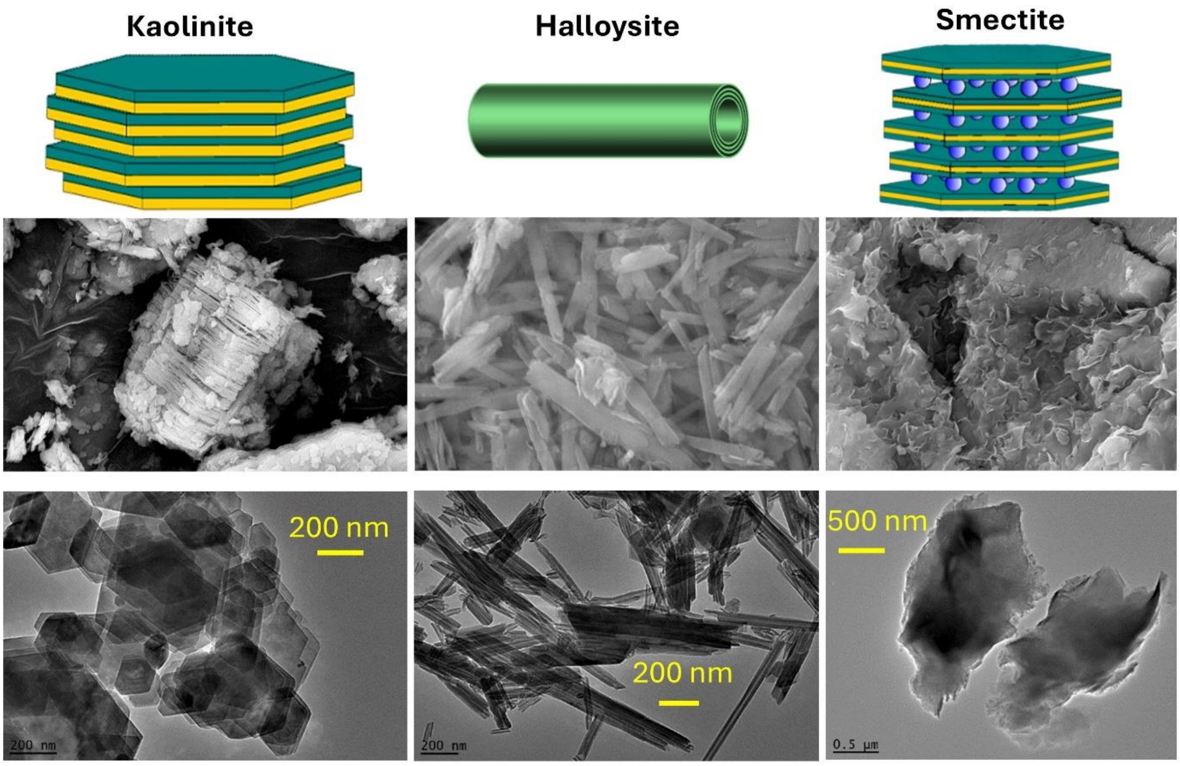

Fig. 1. Commonly occurring clay minerals are shown. The top row presents schematic drawings of their generic structures, with green representing silicon tetrahedral layers and yellow indicating aluminium-based octahedral layers. The middle row shows scanning electron microscopy (SEM) images: kaolinite appears as stacked layers (book-like), halloysite as nanotubes, and smectite as thin, soft, flocky layers. The bottom row features transmission electron microscopy (TEM) images of kaolinite, halloysite nanotubes, and smectite, highlighting their well-defined layered structures, consistent with the SEM images. Images are from the author's collection; drawings are adapted from Tournassat et al., 2015 [3], and Goswami et al., 2019 [4].

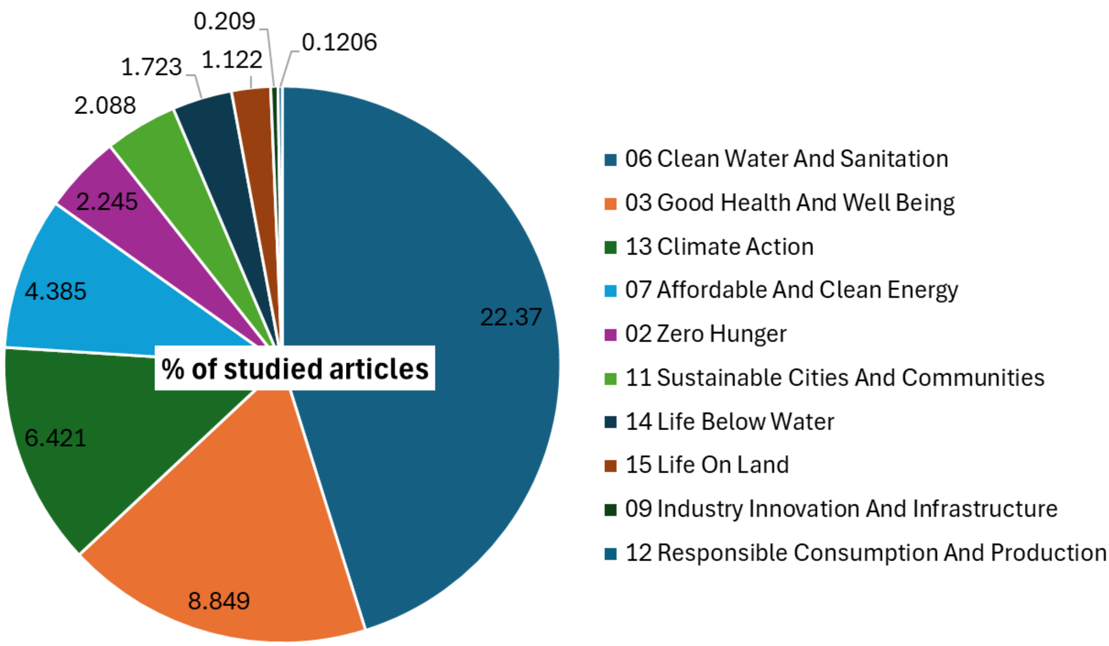

Fig. 2. The percentage of publications that are potentially linked to the UN sustainable development goals (SDGs).

SDG allocations in Web of Science are based on the relevance of each article's citations. In this dataset, nearly 46% of the 3,831 articles published had no SDG-related implications. Nonetheless, the overall potential linkages to the SDGs highlight that clay and modified clays are predominantly used as adsorbents, soil amendments, and foundry materials, among other diverse applications.

When we consider the research streams aligned with Australia's net zero targets, we can identify several areas where clay minerals may play a significant role. For instance, in the fertiliser and soil amendment sector, clay-based slow-release fertilisers and clay or related minerals (e.g., zeolite) have shown reduced emissions compared to untreated soils. Another key area is the waste management, both from domestic landfill sites and animal waste streams. In both cases, clays can reduce greenhouse gas emissions. An emerging line of research also points to the use of clay as a feed additive in cattle diets, aiming to lower enteric methane emissions [5].

3. Sustainability Considerations during Material Processing

For a true contribution of clay and clay minerals to the SDGs and net zero emission applications, a life cycle analysis of their environmental footprint and processing costs is essential. The extraction of clay minerals from deposits may pose relatively low environmental risk due to the absence of fossil-associated compounds in their cores. However, to produce effective adsorbents and other functional materials, clay minerals often require modification. This can involve intensive physicochemical processing, including high water use. Mechanochemical activation, such as planetary milling powered by renewable energy, may help reduce the environmental footprint. Some modified clays, such as surfactant- and polymer-treated clays, have diverse applications, and their production can also be done by dry or wet grinding process where wastage of chemicals and water might be minimal. Some modified clays, such as organoclays produced through surfactant treatment, may pose environmental toxicity if used directly in uncontrolled environmental sites or upon disposal [6]. In such cases, regeneration and reusability of these materials can reduce waste and enhance the sustainability of both raw and modified clays.

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Sustainability Reporting: The New Era for Australia and Comparative Perspectives with the European Union

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The legislation making climate-related financial disclosure mandatory for certain large Australian corporations, was passed by the Senate on 9 September 2024 and received royal assent on 17 September 2024. This new regime will come into effect from 1 January 2025 and will significantly impact many large Australian corporations. In addition, small and medium-sized enterprises (SMEs) will be affected by the legislation within a few years. The legislation introduces a new era regarding climate-related financial disclosure or sustainability reporting for Australia. In this paper the background to the current legislation and what the legislation requires will be analysed and discussed critically. Already in 2014, the European Union (EU) introduced a Directive on disclosure of non-financial matters, including climate-related financial disclosure. The topic has been discussed intensely in the EU since 2014 and in November 2022, the Corporate Sustainability Reporting Directive (CSRD) was adopted by the European Parliament and came into effect on January 2023, which meant that some large public-interest corporations of EU member states were compelled to start to report on various sustainability standards. These developments were necessitated by the European Green Deal. In addition, on 24 April 2024, the EU Council approved the Corporate Sustainability Due Diligence Directive (CSDDD), also affecting a large number of EU corporations and their supply chains. It came into force in July 2024. These developments will also be analysed and discussed critically in this paper. The ultimate aim with the paper is to compare developments and legislation in Australia and the EU. This comparison should reveal whether there are shortcomings in the Australian regime and whether Australia can learn lessons from the EU experience, where legislation regarding sustainability climate-related financial disclosure has been a hot topic of discussion much longer than in Australia.

CERAMIDES: The Bittersweet Lipids Regulating our Health

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Ceramides are lipid metabolites that are made within cells in our bodies. These important lipids are made to keep cells healthy and in check. However, when there is an imbalance of ceramide production, our bodies don't function as they should, leading to disease. Over the past 20 years, I have studied how too many ceramides are bad for the body, and that they are highly specific in causing disease. We now know that there are different types of ceramides, and they accumulate in different tissues to individually influence tissue function. Furthermore, we also know where these ceramides are located within the cell in specific organelles is also extremely important and can cause that cell to behave in different ways. But are ceramides always bad for our health? After immersing myself in the pharmaceutical scientific landscape, I am now exploring how increasing specific ceramides can help benefit human health. This new research is being focussed on providing a therapeutic, rather than answering research questions. This is a new way of conducting applied medical research, which we hope will help expediate new medicines from the bench to the bedside.

A Model of Translation from Rufinus of Aquileia to AI

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In the late fourth century and early fifth century the Christian monk and intellectual Rufinus of Aquileia translated from Greek into Latin many of the works of Origen of Alexandria, a divisive mid third century Christian philosopher. On the back of Rufinus' efforts Origen's work began to be read in earnest in the Latin West. This led to the Origenist controversy, an intense ecclesiastical dispute between Origen's critics, like Jerome of Stridon, and his supporters, led predominantly by Rufinus. The nature of translation – what a translator should and can do – was a major source of conflict. Rufinus claimed that a translator should look to reproduce the sense of the original, not a verbatim or literal rendering, and allowed for a translator to redact and even add to the work where they deemed it appropriate. Jerome – himself a famous translator, best known for his new Latin edition of the bible, known as the Vulgate – argued that a translator should not redact or emend the work, and should instead be literal. In recent years the capacity for AI to translate modern languages had improved dramatically, including tools like ChatGTP, Deep-L and various new iterations of Google translate. These tools have largely struggled to translate ancient languages well for various reasons including the limited amount of text that exist in their canons and their heavily inflected nature and their complex grammatical use of word terminations. In this paper I consider how the ancient debate between Rufinus and Jerome on the nature of translation and the role of translation should affect our understanding and use of AI translation tools. I detail a robust model of translation, and argue that this model is critical for the effective and accurate use of AI translation tools. Lastly I consider how the application of ancient examples to a modern context may steer our use of AI translation.

Different Thoughts on Particles and Cosmology

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Based on a particle-centric viewpoint we introduce a 3d crystal in three (charged) colours Y(-1), B(0), R(1) that holds particles, nuclides and atoms. When the charges disappear, they are called y, b, r. Then, we have precise formulae for atoms, nuclides, and important particles such as protons, neutrons, neutrinos, photons and energy. This may provide a way forward for quantum mechanics and cosmology.

1. The Way of Mathematics

Consider an octahedron, one of the five Platonic solids that is dual to the cube. It has six vertices, 12 edges and eight triangular faces. Truncate each vertex, replacing it with a small square, each vertex of the square on one of the four edges through that vertex. This produces the truncated octahedron, one of 13 Archimedean solids, that has 24 vertices, 36 edges, six square and eight hexagonal faces. The squares partition the 24 vertices into six subsets of size 4. Each vertex is joined by an edge to three others, making a cubic graph. This graph is bipartite: all the cycles in it have even length. It is well-known that the group of rotations of the cube (and therefore also of its dual, the octahedron) is isomorphic to the symmetric group S_4 on four letters. Thus, this group is also the rotational symmetry group of the truncated octahedron. This allows us to represent its vertices by the 24 permutations of the set {a,b,c,d}. We can use the Cayley (or Bruhat) graph to describe the edges. Let A = (1,2) be the transposition taking position 1 to position 2 back and forth, fixing positions 3 and 4. Similarly, let M = (2,3) and Ω = (3,4). (They are the Greek letters, Alpha, Mu and Omega denoting beginning, middle and end.) Let the vertices be all 24 possible four-tuples (a,b,c,d), (a,b,d,c) ... (d,c,b,a). Let two vertices be joined by an edge when the four-tuples differ by one of the "adjacent" transpositions, A, M or Ω. e.g. (a,b,c,d) joins to (a,b,c,d)Ω = (a,b,d,c). This cubic graph is bipartite, with one subset of bipartition being the subgroup of 12 even permutations (the alternating subgroup A_4 of S_4) and the other subset (coset of A_4) containing the 12 odd permutations. This Cayley graph (S_4; {A, M, Ω}) is isomorphic to the truncated octahedron (TO) graph. The spin (a fundamental quantum number) of a permutation is 1/2 if the permutation is even, and -1/2 if it is odd. This transfers to the crystal, so that if two elements (vertices of the graph, or eventually positions in the crystal) are adjacent, then they have opposite spins. The spin of a collection of vertices is then the sum of the spins of the individual vertices.

Consider a product of 24 elements in S_4:

$$((MA)^2(M\Omega)^2)^3 = MAMAM\Omega M\Omega MAMAM\Omega M\Omega MAMAM\Omega M\Omega.$$

This describes a path in the graph (starting at any vertex) that goes through each vertex once and finishes at the beginning. It is a Hamilton cycle, which was named after the Irish mathematician William Hamilton, when he did a similar thing for the dodecahedron. Let's rotate the 24-cycle right by one, and break it into two pieces:

ΩMAMAMΩMΩMAM AMΩMΩMAMAMΩM.

Then it is curious that this is a second Hamilton cycle when we use the transposition (A, Ω) on the final 12 elements of the first cycle: ΩMAMAMΩMΩMAM ΩMAMAMΩMΩMAM.

Suppose we start with any arbitrary four-tuple (b,a,c,d). We obtain the following 2 tables by using the 24 permutations in the above two cycles. We split each into eight rows of length 3.

	Y	B	R	Y	B	R	spins
p_0:	(b,a,c,d) Ω	(b,a,d,c) M	(b,d,a,c) A	(b,a,c,d) Ω	(b,a,d,c) M	(b,d,a,c) A	1/2
n_1:	(d,b,a,c) M	(d,a,b,c) A	(a,d,b,c) M	(d,b,a,c) M	(d,a,b,c) A	(a,d,b,c) M	-1/2
n_0:	(a,b,d,c) Ω	(a,b,c,d) M	(a,c,b,d) Ω	(a,b,d,c) Ω	(a,b,c,d) M	(a,c,b,d) Ω	1/2
p_1:	(a,c,d,b) M	(a,d,c,b) A	(d,a,c,b) M	(a,c,d,b) M	(a,d,c,b) A	(d,a,c,b) M	-1/2

p_2:	(d,c,a,b) A (c,d,a,b) M (c,a,d,b) Ω (d,c,a,b) Ω (d,c,b,a) M (d,b,c,a) A	1/2
n_3:	(c,a,b,d) M (c,b,a,d) Ω (c,b,d,a) M(b,d,c,a) M (b,c,d,a) A (c,b,d,a) M	-1/2
n_2:	(c,d,b,a) A (d,c,b,a) M (d,b,c,a) A (c,d,b,a) Ω (c,d,a,b) M (c,a,d,b) Ω	1/2
p_3:	(b,d,c,a) M (b,c,d,a) Ω (b,c,a,d) M(c,a,b,d) M (c,b,a,d) A (b,c,a,d) M	-1/2

Table 1: Baryons YBR of shells 1 and 2 in two possible arrangements (right ones seem better). Symbols Y, B, R represent particles of charges -1, 0, 1 respectively.

In Table 1 the p_0 (proton) and n_0 (neutron) are the two baryons YBR forming deuteron d_0, which has spin 1 = 1/2 + 1/2. Each baryon consists of three consecutive Y, B, R which have alternating spins. Notice that the connections between p_0 and n_0 are stronger than between p_0 and n_1: (b,a,c,d)A = (a,b,c,d), (b,a,d,c)A = (a,b,d,c). This means that having equal spins in the same shell determines the strongest binding and the pairing of protons and neutrons into deuterons. (The standard physics model reasoning for this is not so obvious!)

It turns out that the three-colouring of the 24 vertices into three colours (arbitrarily labelled Yellow, Black, Red) is unique. No adjacent vertices have the same colour. The connection with physics is that Table 1 exhibits two alternate models for Beryllium-8. This has eight baryons, the four protons p_i and the four neutrons n_j. In all the experiments Be-8 doesn't endure: it splits almost immediately into two heliums: these are the first four rows and the second four rows respectively. We consider these to be the first shell and the second shell (layers). It is not a worry that there are two models. The second four rows of the two models only differ by a reflection in the space of the crystal. Our formulas at present use the second (preferred) representation. For building wooden models the second makes it easier. Then the protons and neutrons have the same shape under rotations: not differing by a reflection. For the first type of representation the protons and neutrons of the even shells 2, 4, ... would be reflections of the protons and neutrons of the odd shells 1, 3, ... We are making it easier, so we assume the second kind of representation, even though the basic Hamilton cycle formula is less obvious.

Now we give some insight into why we are representing protons and neutrons in the same way (as a formula YBR in a connected sequence). In physics, these are called baryons and they are in many ways the same particle (except for their charges). The standard model uses quarks to explain this. However, here we do not use quarks at all, but the three basic elements Y, B, R which are specific points of a 3-d crystal. The charges are explained by giving Y one-unit negative charge –1, B a zero charge 0, and R a positive unit charge +1. Thus, the charge of the neutron is zero. But we have been telling a lie for the formula of a proton: the Y should be the smaller y, which means that it is in the same yellow position of the crystal, but it is weaker, with zero charge and smaller (or no) mass. Another reason for the formula is the binding energy, or strength of forces between the various Y, B, R. In the crystal theory this comes from actual connections. Now we assume from physics experiments that the binding energy within the atoms (in baryons) is large, and that of the electromagnetic force is much weaker. (Not to be confused with the "weak force" which is different.) Thus, we have a hierarchy of binding strengths: YB = RB > YR. It is more likely that B's dominate in gluing the particles together. If we have a sequence like YBRYBR, we see that it splits easily into two sub-particles YBR. The same happens between atomic shells: there are only YR connections between them. A particle such as BRY is not stable because the RY disassociates, while RBB is only possible if the B's are not adjacent (as in graph-colouring, the same colours are never adjacent), and both B's must be next to the R. In Section 3 we define this as the anti-tau particle RB^2.

Another reason is the mass (related eventually to gravity) of a particle. We make the fundamental assumption that the hierarchy of masses is: B > Y = R > y = b = r = 0. Of course, we are not completely sure of the actual values and how to calculate them right now, but this is an approximation. For example, our neutron formula is YBR and a proton is yBR, so the neutron is slightly heavier than a proton. What about particles with zero mass? A photon can have the formula yrb^2 (two b's joined to r). This has zero mass and spin 1. A neutrino has a formula yb^2 of spin 1/2.

Also, zero mass. Then, a muon neutrino has the formula yB^b (one b is replaced by a heavy B), so has some mass. (The SM still hasn't worked this out precisely.)

Consider the rows of the tables above. The first row will be a proton. The second row is a neutron, but together rows 1 and 3 make a deuteron (or deuterium atom). Note that the y's in the protons are basically place-holders for the proper electron Y which to some extent roams around, but "home-base" is that y. We shall see using the notation (R^r, B^b, Y^y etc.) in Section 3, that Y is not our formula for an electron: it is Yb^2 (a heavy Y with two zero mass b's). This is theoretical evidence for the three particle generations, with the muons YB^b and tauons YB^2.

Another nuance concerns the positioning of the crystal and how the Be-8 TO extends to the whole space crystal. We can centre the TO around an integer lattice point (0,0,0) so that three axes correspond to the various Y, B, R directions. Then we do the same at every integer lattice point with an even sum of coordinates. The whole 3-d space is filled completely. In the next section we explain it better using the alternate representation with a surface.

It turns out that there are two kinds of YB and RB connections. Those inside the deuterons are like planes on the outside of a square tube, so that the angle between them is inside. Other YB, RB connections (in pions connecting baryons) are like planes intersecting on the inside. This is clearer with the surface representation. Indeed, our best models of the deuterons have their central elements being outside the tube.

2. The Way of a Topological Surface

So far, we have a description of a crystal with points (or vertices) coloured in Y, B, R in a unique regular way. We first constructed a truncated octahedron (TO) with 24 vertices and then put it into an integer 3-d lattice at every even position (with a sum of integer coordinates that was even.) Then, we can work out that two of these crystals with 24 vertices are adjacent whenever the difference of their central points is one of the 12 vectors (0,±1,±1), (±1,0,±1), (±1,±1,0). Then, we put two extra edges between each pair of adjacent TO's. Notice that there is a partition of the 24 vertices of a TO into 12 edges (called a perfect matching), and each of these edges is paired with an edge in the adjacent TO forming a four-circuit in the whole crystal filling 3d space (called the "space crystal" or just "crystal"). When we have constructed the crystal, we see that around each odd lattice point there is another TO. Given a TO there are 6 others surrounding it with difference of lattice points being (±1,0,0), (0,±1,0), (0,0,±1). The intersection between these TO's is a four-circuit of each graph. There is a partition of a TO into six four-circuits and each of these can be extended uniquely into the next TO along the corresponding lattice axis. Now, we can construct the same crystal by looking at rectangles.

Around each integer lattice point we put a small cube, oriented so that its faces are orthogonal to the three lattice axis directions. Each cube has 12 edges. When two cubes are adjacent in one of the three lattice axis directions there is a natural way to form four planar rectangles connecting one cube to the other so that each plane contains one edge from each cube. This makes a square tube connecting the two cubes. But then there are two adjacent cubes for each edge of a cube. Hence, we have two (orthogonal) rectangles for each edge of the cube, making 12 times 2 = 24 rectangles. In fact, each vertex of the graph of a TO corresponds uniquely to one of these rectangles. We could put a vertex into the centre of each rectangle and join the vertices up to create the graph. Two vertices will be adjacent whenever their corresponding rectangles intersect (orthogonally) in an edge of one of the cubes that we started with, or when they intersect on the outside of one of the tubes between the cubes. Thus, we obtain another description of the crystal, via the collection of rectangles in 3-d space. Each rectangle will also have a unique colouring via the colouring of the crystal into Y, B, R.

There is a big advantage with using rectangles rather than point-vertices over the TO graph. We have an orientable surface! When we join up all these rectangles a two-sided surface is formed. One side of the surface will be covered by rectangles of the three colours, grouped together to form particles such as the yBR proton. If we look at the positioning of the yBR on our crystal TO we see that it is always paired with a unique neutron YBR with maximal binding (spin 1). But there is a four-circuit in the subgraph formed by that deuteron with formula either Y^2B^2 or R^2B^2 and this is on one of the six tubes coming from the central cube. We call this a "solid" tube because we could make it from a solid piece of wood. The deuterons in the crystal model will all have these "solid" centres. However, there is another type of four-cycle in the crystal. This comes from considering the "other" side of the surface. Each rectangle will be on the outside of a "solid" tube but also on the inside of another type of "hollow" tube. When a small cube of side length a is put at each integer lattice point L another "hollow" cube of side length b = 1–a can be inferred at each lattice point L + (1/2,1/2,1/2). Then the solid tubes will have dimensions (a,a,b), and the hollow tubes will have dimensions (b,b,a), but the dimensions of all the rectangles will be (a,b) with area ab.

This gives a natural way to see that there is an anti-universe hiding on the "other side". It is possible that these two universes only interact globally, via the whole surface that may change shape or deform. With time going oppositely, if one universe expands then the other contracts. Left-handedness becomes right-handed in the anti-universe, so that there is a possibility to see why all our usual particles are left-handed. The reason may just be how crystals work: once one orientation is chosen the rest form because they pack in better. Having a right-handed form in amongst a lot of left-handed ones is an unstable situation. Of course, this kind of argument works best if they are packed in tightly, as is the case in our crystal. It can explain the charge, parity and time (CPT) symmetries by rotations, reflections and flipping of the Y and R colour charges. Time is related to the B direction, orthogonal to the B planes.

3. Summarising the Ways

3.1 Cosmology

A surface arises and expands, inducing uni-directional time. The (a,b) parameters of §2 start with (a,b) = (0,1), go through (1/2,1/2), and end with (a,b) = (1,0). Rectangular sheets join to form particles which stick to form atoms. All particles have indivisible charges and integer or half-integer spins. Shells form as layers and subshells within them. Dark matter is involved in transformative processes such light emission and absorption, particle decay, and even movement. Binding forces are determined by content and positioning. The surface eventually contracts, turns inside-out and disappears taking its particles with it.

3.2 Assumptions

From the particle-centric point of view the world is this 3-d space with three fixed directions Y, B, R (the three colours yellow, black and red). Equally spaced planes orthogonal to Y are coloured yellow, planes orthogonal to B are black and planes orthogonal to R red. Then, there are rectangles forming a patchwork in each of these planes so that the union of all the rectangles in the three directions is the whole orientable crystal surface. Particles, atoms, nuclides, sub-particles, energy are all contiguous parts of this surface. Often, a coloured rectangle, say Y, has no negative charge, and this is denoted by y, similarly b and r. Spins are related to joins in the crystal: rectangles that meet (always orthogonally), have opposite spins.

3.3 The Way of Chemical-like Formulae

Notation for formulae: S = {y,Y,b,B,r,R} (coloured rectangles in the crystal). Capital letters V are charged (with mass), small v aren't. A particle is a word in S. If U, V in S, UV means U, V are adjacent and have opposite spins. $UV^2 = VUV$, $UV^v = VUv$, $Uv^2 = vUv$.

Baryons: proton yBR, anti-proton rBY, neutron YBR, anti-neutron RBY (mirror image), delta particles of spins 3/2 (around 10 possibilities with 2 Y or y's, 2 R or r's adjacent B): y^2Br^2, y^2BR^r, y^2BR^2, Y^yBr^2, Y^yBR^r, Y^yBR^2, Y^2Br^2, Y^2BR^r, Y^2BR^2.

Leptons: electron Yb^2, electron neutrino yb^2, positron Rb^2, anti-electron neutrino rb^2, muon YB^b, muon neutrino yB^b, anti-muon RB^b, anti-muon neutrino rB^b, tauon YB^2, tau neutrino yB^2, anti-tauon RB^2, anti-tauon neutrino rB^2.

Pions: negatively charged B^bYrB^b, neutral B^byrB^b, positively charged B^byRB^b. Photons: spin 1 b^2ry, b^2yr each with two orthogonal versions, electric (between shells) or magnetic (inside shells), or (higher energy) b^2YR, spin 0 (magnetic, inside shells) RbYb.

Energy: b^2ryb^2 or ry (zero energy), b^2RYb^2 or RY (higher energy), b^2yrB^b (larger energy). These packets can join to form chains of zero spin and charge. Magnetic energy is inside a shell, and electric energy connects adjacent shells. Nuclear energy is intra-shell with B's.

3.4. Balanced Equations, with Spins, as Alternatives to Feynman Diagrams

Fission (Fermi beta decay): $RBY + b^2ryb^2 = RBy + Yb^2 + rb^2$; $½ + 0 = ½ \pm (½ - ½)$;
(Neutron + no energy = proton + electron + anti-electron neutrino)
Fusion (allowed transition): $Rby + b^2RYb^2 = RBY + Rb^2 + yb^2$; $½ + 0 = ½ \pm (½ - ½)$;
(Proton + more energy = neutron plus positron + electron neutrino)
Electron absorption: $RBy + Yb^2 = RBY + yb^2$; $½ - ½ = ½ - ½$;
(Proton + electron = neutron + electron neutrino)
Muon (Michel) decay: $YB^b + b^2ryb^2 = Yb^2 + yB^b + rb^2$; $½ + 0 = ½ \pm (½ - ½)$;
(Muon + no energy particle = electron + muon neutrino + anti-electron neutrino)
Charged pion decay: $B^bYrB^b = B^bY + rB^b$; $0 = \pm(½ - ½)$;
(negatively charged pion = muon + anti-muon neutrino)
Neutral pion decay: $B^byrB^b + ry = B^byr + ryB^b$; $0 + 0 = \pm(1 - 1)$;
(Neutral pion + no energy = 2 energised photons)
Neutrino oscillation: $yb^2 + B^bryB^b = yB^b + b^2ryB^b = yB^2 + b^2ryb^2$; all $½ + 0$;
(electron neutrino + energy = muon neutrino + less energy = tau neutrino + no energy)
Lyman-Alpha photon production: $b^2Y + RYb^2 = b^2YR + Yb^2$; $½ + 1 = 1 + ½$;
(Electron in second shell + magnetic photon = electric photon + electron in first shell)
Hydrogen 21 cm line photon production: $b^2Y + RbYb = b^2YR + bYb$; $½ + 0 = 1 - ½$;
(electron + spin 0 photon = photon + electron in next subshell)

Mechanisms within the crystal that implement equations are still being worked on. The rule should be that particles can only move together by symmetries in the crystal that preserve the protons and neutrons. These are various translations combined with various rotations by 180º. We suggest that the particles interact via joining in the crystal and by overlapping. When they overlap or join, they can divide into new contiguous particles. Here is *electron absorption*: RBy and Yb^2 overlap at the B and y positions to form the composite particle R(Bb)(Yy)b. Then the particles change with the (Yy) transposing and the RBY (neutron) and byb (neutrino) form. For the *fission* equation or *neutron decay*, it is similar: the YBR and b^2ryb^2 overlap at the (Yy)(Bb) and when (yY) transposes, the yBR, Yb^2 and rb^2 subsequently disconnect.

We can see using crystal coordinates (3.8) that the proton points up or down to the next shell layer, and the neutron points sideways into the shell. There is a rotation by 180º about either the Y or R direction, of the resulting baryon to complete the beta or muon decay processes. This could be an aspect of *weak force parity violation* detected in the 1956 Wu experiment. The parity changes because the proton and neutron, (and muon and electron), point in opposite directions indicated by a rotation about a certain axis.

3.5. Atoms and Atomic Shells

See [2,3] for more details about how atoms can be built within the crystal. That work was done before the realisation that the R, B, Y could be chargeless with the r, b, y. The idea was to construct the atoms, nuclides and electronic shells all together. It turned out that the pairing of the deuterons in the shells (with parities accounted for) and then the addition of further neutrons between gaps on the outside of the shells, produced the stable nuclides, and it was done for many atoms up to the largest, bismuth-209, for many spins and parities. We used tetrahedra instead of rectangles. But inside each tetrahedron there is a rectangle joining the centres of the shorter sides and all these rectangles generate the crystal surface.

3.6. Geometry and Topology of Surfaces

See [1,5] for various mathematical theorems showing how coverings by graphs and maps on orientable surfaces can be used to find important geometrical properties such as Desargues and Pappus configurations. Since the crystal we have described is a covering of an orientable surface by rectangles having infinite genus (the number of holes) we expect that a (projective) geometry can arise from the surface, related to the various spaces that we find in physics.

3.7. Recent Results

Many recent results imply that the current physics and cosmology models have major inconsistencies or at least doubts [4,7]. Astronomers [6] found that the universe is not expanding as fast as was thought and might in fact be slowing down. This would be in line with the surface of the crystal starting out from rectangles with sides (a,b) = (0,1), reaching a maximum when the rectangles (a,b) = (1/2,1/2) are square (area 1/4), and then contracting towards rectangles (a,b) = (1,0) of area zero.

Instead of the S_4 representation of the TO in Section 1, one may use Cartesian coordinates in 3-d Euclidean space. The points of the TO (Be-8) are the 24 columns of the following matrix. These are the centres of the rectangles (assuming they are squares) covering the topological surface of Section 2.

$$\left(\begin{array}{|ccc|ccc|ccc|ccc||ccc|ccc|ccc|ccc|} 1 & 0 & 0 & -1 & -2 & -2 & -1 & 0 & 0 & -1 & -2 & -2 & -1 & 0 & 0 & 1 & 2 & 2 & 1 & 0 & 0 & 1 & 2 & 2 \\ 0 & -1 & -2 & -2 & -1 & 0 & 0 & 1 & 2 & 2 & 1 & 0 & 0 & -1 & -2 & -2 & -1 & 0 & 0 & 1 & 2 & 2 & 1 & 0 \\ -2 & -2 & -1 & 0 & 0 & -1 & -2 & -2 & -1 & 0 & 0 & 1 & 2 & 2 & 1 & 0 & 0 & 1 & 2 & 2 & 1 & 0 & 0 & -1 \end{array}\right)$$

The colour (charge) of a point $(u,v,w)^t$ is Y, B or R if u, v, w is respectively ±1. A 3 by 3 submatrix is a proton or neutron if the central B coordinates going right are resp. decreasing or increasing. Hence, going from Y to R, protons and neutrons point oppositely in the B direction. The spin of a baryon is 1/2, -1/2 if the determinant is -3, 3 respectively. Upon dividing by 3 one sees coordinates that are reminiscent of the quark and gluon charges, but we haven't seen how to construct those standard model particles from the crystal. The same goes for weak force particles W and Z. They are not needed to describe interactions and binding in this theory. Two column vectors are adjacent in the crystal TO when separated by distance $\sqrt{2}$. The eight submatrices are in order the baryons p_0, n_1, n_0, p_1, p_2, n_3, n_2, p_3.

Each baryon, P or N = YBR, in the crystal is paired with its anti-baryon and their centres form a plane hexagon, a cycle YBRYBR. Thus, the Y (electron) of the proton is adjacent (paired with) a positron R of the antiproton, and similarly for the neutron. However, the proton/anti-proton pair YR are in neighbouring shells, while the neutron/anti-neutron YR are in the same shell. So, we expect that the annihilation of proton with an anti-proton and a neutron with an anti-neutron will behave differently. The handedness of a baryon is left and that of its anti-baryon is right. This is displayed in the crystal, by going around the hexagon. There is a space reflection which divides the hexagon that flips the baryon and the antibaryon.

3.8 Some Predictions

The anti-universe, as envisaged in this present theory, is on the other side of the orientable surface of Section 2. Thus, time there can be said to go backwards but marching along with ours. Left- and right-handedness (chirality) and perhaps parity are interchanged (parity is often a relative thing, not an absolute). But at this stage we have found no direct way to go between the two universes. The anti-particles that we find in experiments are in our universe, even though they may be superficially right-handed. We can say certain things: the two higher generation neutrinos are massive, but the electron neutrino not. Dark matter is everywhere, even holding together protons and neutrons, and in light, also energy. The amount of dark matter, and its forms, is much more that ordinary (baryonic) matter. There are certain kinds of dark matter that enable things like the "weak force", or change of particles into others. We do not at this stage have a formula for the weak interaction particles (W and Z) and consider them to be unlikely for a consistent theory. Quarks may have a place in the crystal theory, if the 1/3 and 2/3 coordinates of our Cartesian system may be transformed by some unlikely method into charges. Time travel seems to us to be unlikely, if time is determined by a global change (expansion and then contraction) of the entire surface on which the universe resides. We are working on fitting the important equations of physics, such as Dirac's equation for the particles of spin 1/2 and the theory of relativistic space-time into this, all necessary to allow for measurements of forces, masses, binding energies, and so on, but at this stage we are trying to understand the more static side of the theory and how particles are formed and interact. The symmetries of this theory and that of the Lorentz group are somewhat similar. For example, the rotation group of a (Bloch) sphere of a qubit certainly contains the group S_4, upon which the crystal can be envisaged. These are different thoughts that may lead to new horizons.

So far, this short article has only glimpsed the theory beyond the first two shells. A general atom is made from shells going up in levels 1, 2, 3, ... The odd shells are vertical translations of shell 1, and the even shells are rotated images of this. Each shell is made from subshells going out in the crystal in circular fashion, with the quantum parities flipping whenever a new subshell is encountered. This corresponds to a rotation of a baryon by a 1/2 turn. However, this rotation does not change the directions of the protons and neutrons in the B direction. Although the crystal colouring with Y, B, R is unique, the possible positionings of the neutrons and protons are not. However, we have a "best" method to assign these, which was explained in [2,3], using "atomic graph paper" made on a spreadsheet, one page for each layer or shell of the atoms or nuclides. It is basically a different "shell model" for the nucleus. Let's extend the coordinate system of Section 3.7 to the whole 3-d space. Each crystal deuteron D = PN has a centre point, 1/2 way between the centres of the two B's in D. The coordinates of these centres form a rectangular 3-d point lattice (u,v,w) = (0,0,-2) + r(2,0,-2) + s(0,4,0) + t(2,0,2) = (2r + 2t, 4s, -2 -2r+2t), where r, s, t are integers. We call u, v and w the Y, B, R directions resp. The shell (of deuterons) is a plane u+w+6 = 4i, where i is the shell number. Thus, 4 + 4t = 4i implies i = t+1. For a usual atom we assume that the bottom layer is shell 1, so that $t \geq 0$. An atom has (magnetic) subshells, which in the crystal match with arrangements of deuterons, one deuteron D = PN for each electron with home position in P. We can match this with the usual standard model (SM) notation so that the subshells going outwards within given shell are labelled s, p, d, f, g, h matching the numbers in the crystal 1, 2, 3, 4, 5, 6. Subshell s has the two D's with centres (0,0,-2), (-2,0,0). The next subshell p has six D's with centres (0,-4,-2), (2,0,-4), (0,4,-2), (-2,4,0), (-4,0,2), (-2,4,0). The sums of the absolute values of the three components in each vector in subshell j add to 4j-2 and there are 4j-2 D's or electrons in subshell j. This is the same as the SM for electron subshells. The sum over all subshells up to i is $2i^2$ giving the sequence 2, 8, 18, ... A general D = (u,v,w) of the crystal is in subshell j of shell i when 4j-2 = |w-u| + |v| or j = (|w-u| + |v|+2)/4, and i = (u+w+6)/4. Experimentally, the parity of an electron starts at 1 (or +) for the s subshell, and is -1 (just -) for p, 1 (+) for d, alternating in signs going outwards. So, we have that the parity of a proton P in deuteron D = PN with centre (u,v,w) is $(-1)^{j-1} = (-1)^{(|w-u| + |v|-2)/4}$. Experimentally, Par(D) = 1 (or +). Therefore, N in D = NP satisfies Par(N) = Par(P), as parity is multiplicative.

Define the basic Y, B, R points (u,v,w), (union of three integer lattices):

Y when u odd, v and w even, v+w+2 divisible by 4,

B when v odd, u and w even, u+w+2 divisible by 4,

R when w odd, u and v even, u+v+2 divisible by 4.

The spin of (u,v,w) depends on the colour and we have $Sp(Y) = (-1)^{v/2} = (-1)^{w/2+1}$, $Sp(B) = (-1)^{w/2} = (-1)^{u/2+1}$, $Sp(R) = (-1)^{u/2} = (-1)^{v/2+1}$. The parities of a neutron or electron in a deuteron D are the same as the P in D parity above and so can be calculated using coordinates.

The parity has a rotational meaning: the transformation (u,v,w) goes to (u,v+4,w) moves the D to another D of containing baryons of same spin but opposite parity in the same shell, but in adjoining subshells, and they are rotated. However, if one moves a D straight upwards to another shell by a (2,0,2) jump then the parity and subshell number are not changed, there is a spin change, and there is a different rotation.

Atoms can be described approximately in the crystal as the inside of a cone, with onion-ring-shaped subshells getting larger as we go up into higher shells. However, atoms are finite and the number of deuterons in each shell goes up (usually starting with two) to a maximum and then can decline down to a small number in the (valence) shell. The larger atoms tend to assume a spherical shape in the crystal, to maximise the binding: more connections between the D's, P's and N's. As the atomic number increases up to shell numbers around six, stability tells nuclides to increase the ratio of neutrons to protons from around 1 and up to around 3/2. The crystal explains this ratio N/P as the need to increase the connections. If the number of protons (atomic number) is fixed, neutrons are added in the spaces between the subshells. To build atoms we fill all the lower subshells with D's first until the shells are filled, just as the electrons fill the shells and subshells. But the outer subshells in each shell will have gaps. The number of contiguous components of subshells j starting from j = 1, 2, 3, ... is: 1, 1, 4, 8, 12, ... Thus, more N's are needed to fill these. Then, at the end of each "spin tube" (defined later) we can put another neutron or two (in a joined pair N-N). This can be made into a standard construction that shows how larger, more stable atoms may be formed.

3.9 The Crystal Bonding

The main bonding is inside a shell, for the connections between the shells are electronic (no B's are involved, only YR bonds) and much weaker than the connections (forces) inside each shell. The structure of a shell is much like a chemistry molecule with "elements" P and N in a single layer (similar to graphene). We make some notation that helps with this intuition. The valency of both P and N is 6. That is, the number of "bonds" emanating from each P or N in the shell is six. Two P's are either joined by a single bond P-P, the same as two planes having a common edge in the topological representation (see Section 2) or are not joined. Then P and N can have a single P-N or double P=N connection. Similarly, we can have N-N but never N=N. There is a strong pairing of the neutrons, for every N in a unique paired N-N in the given shell. This property of neutron pairing has been verified experimentally but does the SM say it is unique? Surrounding each N-N there are four P's, each P forming an N-P=N with the N-N. Then, each N has a double bond with two of these P's and a single bond with one of the other P's. The protons P on the other hand form chains of P's of lengths 1, 2 or 4. A lone P = yBR (as in the helium atom) is bordered on each of the two sides by an N-N. This like a bowtie with the P in the middle and the N's on the outside, with two P=N bonds and two P-N's. Similarly, any chain P-P is surrounded by four N's with double bonds and two N's with single (at the two ends of the chain). A chain P-P-P-P is surrounded by eight N's with double bonds and two N's with single bonds at the ends. Remember that the valencies of the P's is six if you want to draw this.

An important property is that a shell is made from an infinite collection of chains ...D=D=D=D... which we may zoom down into ...P=N=P=N=P=N=P=N... and even further into $Y^2BR^2BY^2BR^2BY^2$... (neglecting that each proton is actually yBR). We call these "spin tubes", because they go in a straight direction (the v or B) direction and every P or N in it has the same spin, either +1/2 or -1/2. The tubes form parallel lines covering the plane shell, and the adjacent ones have opposite spin. Every P or N of the crystal is in a unique spin tube. If two D's are adjacent in the same tube (D=D), they have parity 1 (+), but the P's and N's in the first D have opposite parity to the those in the second D, because they are in adjacent subshells. Some atoms (or nuclides) have large spins. The way that this happens is that long spin tubes form. The spin of a finite spin tube T with chain D=D...D=D made from k D's is ±k. If k is even then its parity Par(T) is 1 (or +). If k is odd then Par(T) can be either 1 or -1. Constructing formulas for nuclides with certain spins and parities boils down to finding ways of putting these spin tubes together so that the number of protons (electrons) in the atomic shells is respected and the spins add up and there is the correct parities. Then connections have to be maximized.

Consider the short half-life (unstable) atom He-5, which is important in atomic fusion (D + Tritium = He + N [8]). The nuclide has two protons and three neutrons. The parity-spin has been measured as -3/2. Some SM shell models of the nuclide have the 3/2 coming from the binding of a spin zero He-4 with a spin 3/2 neutron. The decay is almost always into these two components, but the spin of a lone neutron is (±)1/2, so something might not add up. The crystal model has a different idea. The spin of each baryon P or N is ±1/2, so the only way to obtain 3/2 is for four of them to have spin 1/2 and one to have spin -1/2. This means we have a spin tube of length 4 bordered by a P or N. But a spin tube has alternating P's and N's so that this tube has two P's and two N's. The bordering baryon is an N. Also, the length of the spin tube is even so that it has parity +1. The N must have parity -1 and it is in an even p, f or h subshell. Further, the longer spin tube is unstable unless it is bordered by something that holds it together. Thus, we have a formula for He-5. This is D=D or N=P=N=P with another N joined with two single bonds to the central P and N of the spin tube of length 4. This gives uniquely the required -3/2 spin-parity of He-5. A factor in favour of the (relative) stability of this nuclide is that the N-N connection is a neutron pair which is favoured in nuclide construction. As with any observed nuclide, the other alternatives, with other spins or parities should be less favourable (have less binding energy). Our postulated SM shell idea, with a neutron having spin 3/2 is impossible in the crystal, but what if a helium were joined to a neutron? The helium and the neutron are very stable in themselves (helium extremely so, and the neutron has a long half-life). This means that it is not likely that such a combination would bind for much time at all, and it would have spin 1/2 anyway.

There are many other generally accepted properties in the structure of the SM models for the nucleus, such as the "magic numbers" of protons and neutrons for the more stable nuclides. The investigation of these further properties in the crystal model is only just starting.

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Beyond Ice and Water: solids that are heavier than their liquid

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Most commonly encountered substances have melting and freezing boundary curves over a small range of densities at which both solid and liquid phases coexist [1]. Whether or not the melting and freezing curves eventually coincide at extreme values of both temperature and pressure remains unresolved because measurements at pressures of many giga Pascals are very challenging. We discuss [2] molecular simulations [3] of solid-liquid equilibria using a relatively soft-repulsion, short attractive-ranged pair potential that demonstrate the closure of the freezing and melting lines at high pressures and temperature. The point of closure is accompanied a density inversion of the solid and liquid phases that is usually only observed for water [4]. This may indicate that is a more general behaviour at extreme conditions.

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Silicon Chip Optomechanics, Quantum Enabled Sensors for (almost) any Application

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Optomechanical resonators have been used to investigate the physical world from the observation of gravity originating from black-holes down to the vibrations of individual molecules. Integrated optomechanical cavities microfabricated on silicon chips offer great potential for use as lightweight, compact, and low powered precision sensors for multitudes of applications ranging from navigation to medical imaging and biosensing. These devices are and allow for precise probing of physical stimuli with light. Such sensors leverage the interaction between light and mechanical motion, offering the potential for dual-resonant enhancement from coupled optical and mechanical resonators providing state-of-the-art sensitivity at room temperature, and can achieve quantum-limited performance with just microwatts of optical power. Further, the geometry of the sensors can be tailored to application with device sizes ranging from several mms to sub-micrometre. There is growing interest in using this technology to further understanding of physical processes underpinning phenomena in the fields of biology and physiology. These include the demonstration of single-protein sensors and of integrated magnetic-field sensors which have sparked interest in the potential for the use in investigating biomagnetism.

Particularly SUPER Symmetries

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Fascination with repetitive patterns and symmetries in the natural and human worlds has been a source of scientific and artistic inspiration down the ages. We will take an anecdotal view of a few well-known and not so well-known examples, but honing in on the fundamental elementary particles, beloved of physics. The aim is to make a case that, amongst the systematics of the relativistic particle fields of the so-called Standard Model, there lurks a hitherto unrecognized symmetry pattern, that has been overlooked for more than 40 years.

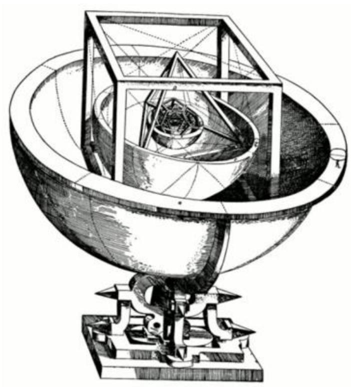
1. Introduction

In 1987 I was a Humboldt Fellow at the Physikalisches Institut, Universität Bonn. At the annual Tagung reception that year (at the presidential *Schloß Bellevue*), my name badge stated that my subject was "Elementarteilchenphysik". This faithfully reflected my background in Mathematical Physics at the University of Adelaide, and PhD in theoretical physics at Imperial College, University of London, and postdoctoral experience at the University of Southampton. Having returned to Australia, though, and after more than ten years' lecturing in Mathematics and Physics at the University of Tasmania, my research and teaching had become a little more heterogeneous.

The topic of this presentation is to visit "symmetries down the ages" from the lens of a very small selection of paradigmatic exponents. A Greek dictionary will list one meaning of anecdotal, *ανέκδωτως*, as "unpublished", which confers a licence not to attempt intensive citation. Leaving aside the (ancient) Greeks, the heroes of symmetry that we will meet – whose preoccupations all bear on the particles theme – are Johannes Kepler (a *cosmic* symmetrizer), Murray Gell-Mann (the true *particle* symmetrizer) and Yuval Ne'eman (a *hypo* symmetrizer). Last but not least, we introduce a heroine from Tasmania, Joan Taylor (a *para* symmetrizer).

2. Johannes Kepler (1571–1630)

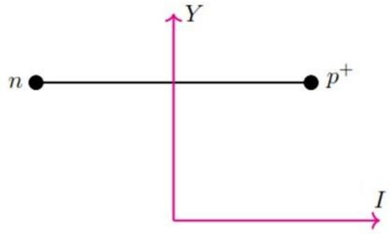
Bronze of Tycho Brahe and Johannes Kepler in Prague [1]

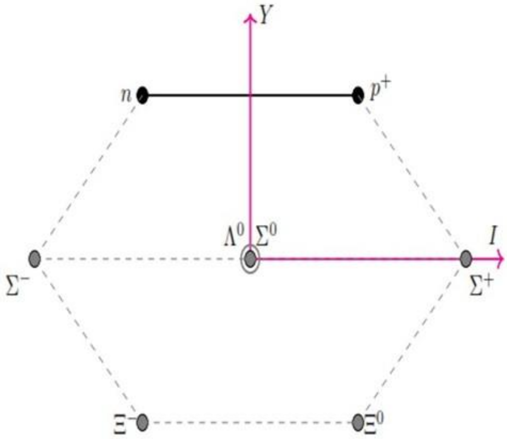


Kepler's orrery [2]

Kepler is justly renowned as the scientist who completed the Copernican revolution with his unrelenting analysis of Tycho Brahe's exquisite observational data on the planets, and at the close of the sixteenth century, furnished to the world his famous laws of planetary motion. But he was much more than an astronomer– with interests and writings reflecting his profound conviction of a universe ordered by numbers and harmonies, mathematical, musical as well as cosmological (*Mysterium Cosmographicum* (1596), *Harmonice Mundi* (1619)), and perhaps even astrological. In Regensburg there is a beautiful little *Kepler Gedächtnishaus* – in the very house where Kepler used to visit and stay while on courtly business, and where he died, after succumbing to an illness at the end of a journey there in 1630. Locally staffed, the museum has copious handout notes on all aspects of Kepler's activities including religious and political convictions [3]. He is sometimes also said to be the first writer of science fiction. His "*Traum vom Mond*" (1610) was apparently only published posthumously by his son in 1634 [4]. Kepler's most enduring fascination, or perhaps obsession, is his *matryoschka* concept that the orbits of the six then known planets could be arranged on six concentric spheres, each touching one of the five perfect regular solids. This “theory of everything” is memorably displayed as a sort of 3D model orrery.

What is “symmetric” about the Platonc solids? Thinking of them as solid objects in 3D, we can find transformations – like rotations, reflections, inversions – which can be applied (or imagined, if they require temporarily destroying the object), whose final result is identical to the starting object. Such a “symmetry group” also exists for a simpler object, like a dumbbell, where one has 180 degree rotations, reflections, and maybe axial rotations. But if we draw the dumbbell as a line on paper, a richer situation obtains: we can think of all points on the line as belonging to the “same” entity, where the transformations now effect convex combinations of the endpoints. More mathematically, the endpoints are just characteristic vectors of the system, and not only convex combinations, but also general complex combinations, can be thought of as “belonging” to it. Going a step further, we can draw lines representing coordinate axes, and give the endpoints specific labels – for example, vertical height 1 and horizontal shifts ±½ .



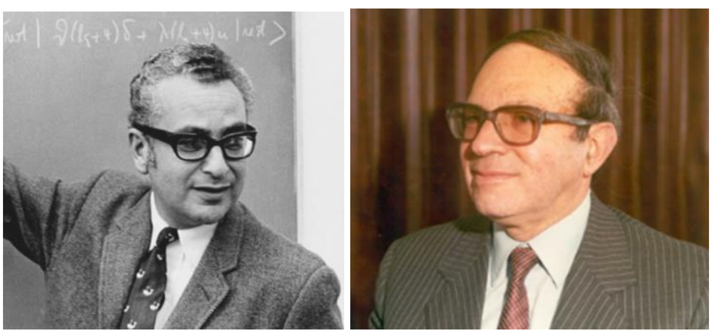


Here is our first example of particle “classification" – it was realized in the 1930’s that a useful approximation to some aspects of nuclear structure was to regard the neutron and proton as two such coordinates of the nucleon “doublet” – thought of as “up" and “down” by analogy with electron spin. They have almost identical masses, and while as characteristic vectors of the system they are the only points having definite electric charge ($Q = I + \frac{1}{2}Y$ with the axes chosen), nonetheless we can build models where the physics is independent of which combination we select.

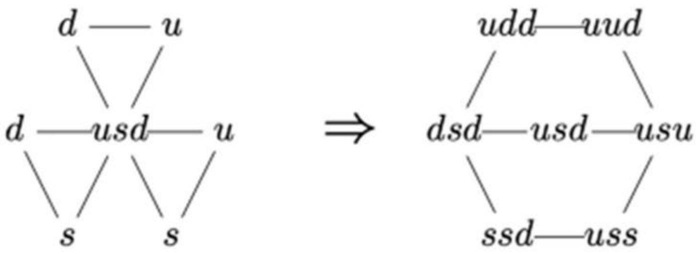
The coordinate axes have been chosen in such an awkward way with the nucleon doublet off centre, in anticipation of the next, huge, step. It turns out that the nucleons are only part of a larger “octet” family, filling out a beautiful hexagonal shape, with the sibling nodes labelled with strange and unfamiliar names. For the discoverer of this pattern, and its explanation and its further ramifications, we have to skip over three centuries and meet our next symmetrizers.

3. Murray Gell-Mann (1929 – 2019) and Yuval Ne’eman (1925 – 2006)

Murray Gell-Mann (Nobel Prize 1969) is famous as a polymath, polyglot, ornithologist and eminent particle theorist. In the early sixties, in what could be called the diluvial age of particles, accelerating machines were of sufficient energy to produce showers of unexpected and puzzling “resonances", or unstable particle states. It was Gell-Mann’s brilliant vision to see how to organize things into what he memorably called the “eightfold way” in a reference to the Noble Eightfold Path of Buddhism. The trick was to use a basic set of three objects called



(Left): Murray Gell-Mann [5] (Right):Yuval Ne’eman [6] "quarks", which name he took from a line from James Joyce's "Finnegan's Wake", where a publican shouted "three quarks for Muster Mark" – possibly echoing Joyce's pun on the German "*Quark*" (cottage cheese) being a thing of little value. Building octets using quarks *u,d,s* almost became child's play, and the octets were used, not only for the nucleon family, but for classifying some of their higher spin counterparts and mesonic cousins.

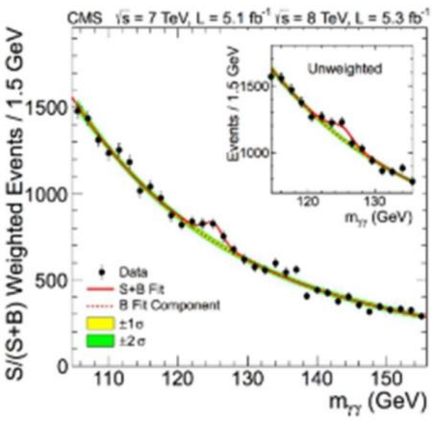


Why all the fuss about the particle zoo, if they are all only ephemeral unstable states: the Ω-minus (or *sss*, belonging to a decuplet, which Gell-Mann predicted), one of longest lived (lifetime 10^{-10} seconds), can barely leave a visible track in an emulsion. But were it not for the weak and electromagnetic interactions, the lighter baryons and mesons would be stable, three quark or quark-antiquark composite bound states. Thus even the neutron, due to its tiny mass excess over the proton, is also unstable, but only just (lifetime 15 minutes). (If the mass difference were reversed, protons would decay into neutrons, and hydrogen atoms and everything else would collapse).

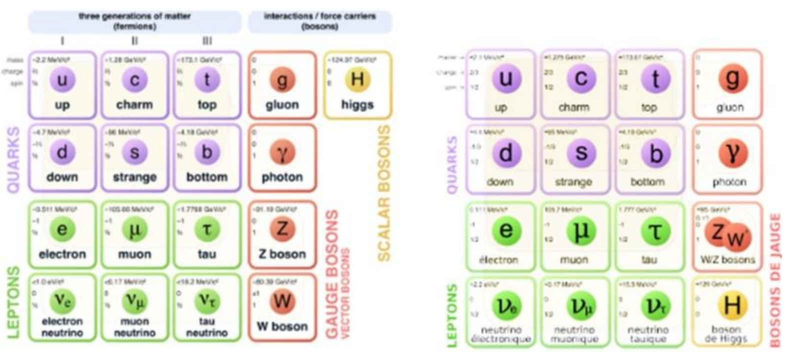
A final Gell-Mann story. In the charge formula $Q = I + \frac{1}{2}Y$, the symbol I ("isospin") was in use from nuclear physics, by analogy with spin. For Y, Gell-Mann does not draw on literary allusions as he had with "quarks". On a hot Cal Tech summer afternoon, Gell-Mann and his visitor Yuval Ne'eman, deep in discussion about physics, are visiting a local Baskin and Robbins icecream shop. Suddenly Murray notices their famous advertising slogan "*I scream, You scream, We all scream for ice cream !* ". W already being taken, thus enters Y, "hypercharge", into the particle lexicon!

Fast forward another 50 seminal years. After mammoth experimental effort, theoretical understanding - and more symmetries - have emerged, but space does not permit an exposition of the particulars. The accelerator machines are now behemoths compared with their "high energy" forerunners, with about one thousandfold the available energy. Quarks – literally the "dreams that stuff is made of" when Gell-Mann first hypothesized them – are now accepted as fundamental spin-½ subconstituents of subatomic matter. They come in families, which all readily bind with each other, the previous patterns of *u,d* and *s* (the first member of the second family) via Gell-Mann's eightfold way *SU(3)* group, having been an artefact of the limited energy regime. The binding, or confinement, is attributed to massless exchange particles, the gluons, and their and the quarks' strong attraction via their colour charge. The photon is accompanied by its weak interaction cousins, massive spin-one particles W^+, W^- and Z^0 . To the spin-½ electron and its neutrino (the first family quarks' second cousins) are added their second and third family counterparts.

The crowning achievement is the identification of the missing link, the so-called Higgs boson (a scalar particle with spin 0). Despite its first showing up as a rather inauspicious resonance in a very specific channel, the evidence is overwhelming, and it is soon seen in much noisier interactions. On the CERN web page there are about 50 versions (in different



Evidence for Higgs boson [7]



CERN version of the Periodic Table [8]

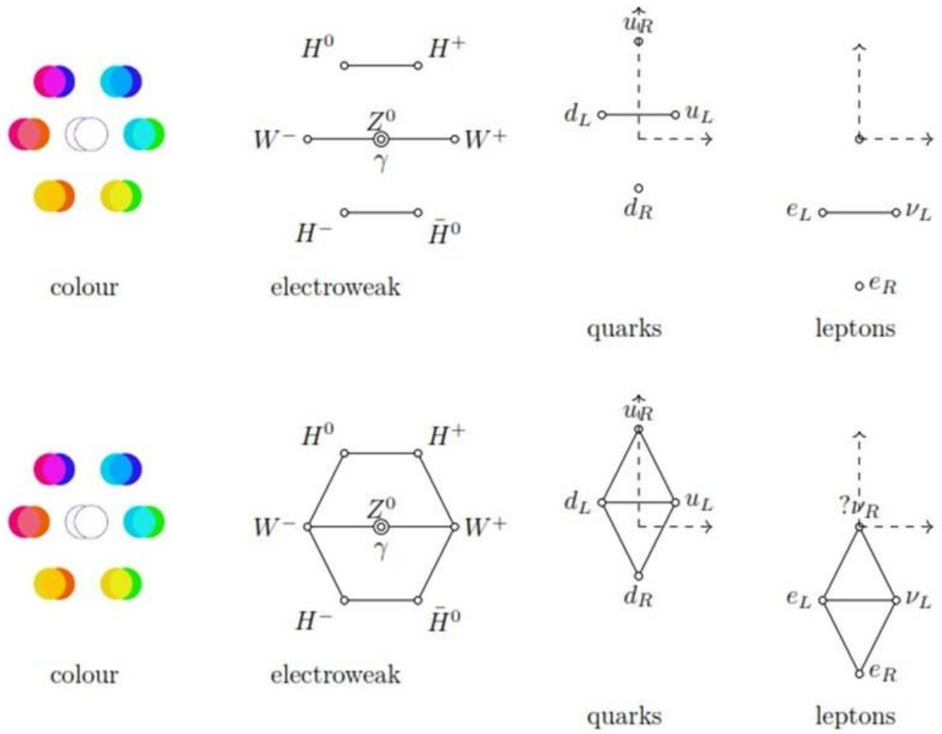
languages and fonts) of the periodic table-like diagram of the “particles of the Standard Model". All of them (since 2012!) also show the Higgs in a separate box on the side, as if the artist was uncertain of its status, or reluctant to redesign the table. Surely, a more aesthetic arrangement would be to include the Higgs in the last column, saving space by grouping the weak vector boson triplet $W^{\pm}$ and Z^0 together in one box?

Yuval Ne’eman was a colonel in the Israeli army corps when, in the ’fifties, he asked his boss, Moshe Dayan, if he could undertake further study in physics. The deal that they came up with was for him to take up a posting as science attaché in the Israeli embassy in London, to enable him to enrol around the corner at Imperial College, for a PhD in theoretical physics under the supervision of Abdus Salam. In those years Ne’eman (reading US Naval Academy translations of Russian maths textbooks available at the embassy) was independently studying candidate particle symmetry group schemes, and published on *SU(3)* . He went on to combine his formidable physics output with senior management positions in academia, and also cabinet positions (including minister of science) in subsequent Israeli governments.

For all his political engagement, Yuval Ne’eman remained true to the ideals of science and scientific understanding. His much quoted assertion, “Even after more than eighty years, the number of people who understand [relativity] is far less than the number of people who read horoscopes” expresses this lifelong commitment.

In 1978 Ne’eman made a profound observation about the particle structure of the Standard Model, which arguably represents a lacuna in understanding that has eluded our grasp for more than 40 years.

If we re-plot all of the Standard Model relativistic field ingredients on weight diagrams, we recognize again a complete *SU(3)* octet, (this time of the coloured gluons, with colour *I* and *Y* axis labels), and next to it, for the weak *I* and *Y* sector, what looks like another octet, but only partially drawn in. The job of the Higgs mechanism recipe is, after some field redefinitions, to bring the four off-centre Higgs fields into service as the extra degrees of freedom needed for the three weak interaction vector bosons to become massive spin 1 (with the massive neutral scalar Higgs left over). The spin -½ quark fields (in coloured triplets), and accompanying lepton fields, are plotted (the second and third families just repeat the pattern), but now disaggregated into their separate right and left spin polarizations, appearing as incomplete quartets, to be brought together as bona-fide massive particles via the Yukawa interaction. Ne’eman’s idea – on paper – was “simply” to imagine lines connecting the



Upper figure: Weight diagram of the relativistic field ingredients of the standard model. (Left hand side): gluon octet; middle: electroweak spin-1 vectors and Higgs spin-0 scalars; (Right hand side): quarks (coloured triplets) and leptons are represented as quartets, with weak hypercharges shifted (first generation shown).
Lower figure: As above, but with connecting lines between the different spin components, to suggest an underlying symmetry [9].

disconnected parts of these incomplete-octet and incomplete-quartet diagrams, implying the existence, at the core of the observed particle spectrum, of some sort of underlying “hypo”-symmetry (no new particles!) as opposed to a “hyper"-symmetry (many new particles!). Unfortunately, despite earnest attempts, no-one has yet succeeded in realizing this vision in a way that is properly consistent with the principles of local relativistic quantum field theory.

4. Joan Taylor

Joan Taylor is a creative artist, fabric designer and weaver from Burnie, Tasmania. Tertiary trained, but largely self-taught in mathematics. In 2009 she made a significant discovery in the theory of aperiodic order. For tessellations of the plane by decorated regular hexagons, Taylor gave a set of matching conditions (rules determining which edge decorations can be paired across neighbours and next-to-nearest neighbours) which, she proved, cannot be realized by any repetitive periodic pattern. In 2010 Joan shared her findings with a US collaborator, and the results developed as a publication, known in the literature as the Socolar-Taylor tiling - one of the first such *einstein* arrangements.

With Joan Taylor’s monotiles we complete our lightning overview of “symmetries down the ages". Aperiodic order is one more step in this long journey. About four centuries ago, none other than our Johannes Kepler also studied a related topic: the problem of closest sphere packing. Just as he may have had commercial or mercantile interests in mind, so too do the exotic “quasicrystal” substances, which break all the established rules of crystalline order, hold out the promise of new material science applications.

Disclaimer and Acknowledgements

Any account of scientific developments focussing attention on individuals inevitably neglects the independent contributions of many others. This applies especially in the modern era, from quasars to quarks (which George Zweig called “aces”). In particular, the SM has simply been presented above as a *fait accompli* (thanks to a reviewer for a technical correction). Joan Taylor: thanks to Uwe Grimm and Michael Baake for hosting details on the University of Biefefeld online encyclopaedia of aperiodic tilings. See http://www.math.uni-bielefeld.de/sfb701/preprints/view/420.

Sources of Images

[1] https://upload.wikimedia.org/wikipedia/commons /6/6c/Brahe-Kepler.jpg (with acknowledgement to Ken Barnes)

[2] https://upload.wikimedia.org/ wikipedia/commons /1/19/Kepler-solar-system-1.png

[3] Life and work: hand-out notes, Kepler Museum, Regensburg

[4] Traum vom Mond: “50,000 Deutsche Meilen weit im Äther liegt die Insel Levania”

[5] Gell-Mann portrait: American Institute of Physics Science Photo Library; (images.fineartamerica .com); Life and work: see his semi-autobiographical “The Quark and the Jaguar” (The SFI Press, 1994), including an account of his role in the interdisciplinary Santa Fe Institute ; Ice-cream: Jean Thierry-Mieg, private communication.

[6] Ne’eman portrait: https://vilaglex.hu /Lexikon/Html/Neeman-.htm; Life and work: Jean Thierry-Mieg, private communication.

[7] Higgs in $\gamma\gamma$:http://www.atlas.ch/news/ images/stories/1-plot.jpg

[8] CERN SM “periodic table”; streamlined version: https://cds.cern.ch/record/2315477/files/ 2000px_Standard_Model_ of_Elementary _Particles.png

[9] ©Seth van Heijster. (See also Yuval Ne’eman. Irreducible gauge theory of a consolidated Salam-Weinberg model. *Physics Letters B*, 81(2):190-194, (1979) ; Thierry-Mieg, J., & Jarvis, P. D. *SU(2/1)* superchiral self-duality: a new quantum, algebraic and geometric paradigm to describe the electroweak interactions. *J High Energy Physics*, 2021(4), 1-25 (2021); Jarvis, P. D., & Thierry-Mieg, J. Indecomposable doubling for representations of the type I Lie superalgebras *sl(n/1)* and *osp(2/2n)*. *J Phys A* 55(47), 475206 (2022)).

Development of Next-Generation Polymer-Based Drug Delivery Platforms

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In this presentation our recent efforts in the design of new polymer-based drug delivery platforms will be highlighted. The potential to modulate and control the interaction of polymeric nanoparticles with biological entities through variation of size, shape and surface modifications will be discussed. Examples of targeted delivery to specific sites of action through exploitation of tissue/cellular microenvironment conditions will be presented.

Science Communication with Programs, Books and Screens

Frances A. Rosamond

Lebanese American University Beirut, Distinguished International Research Professor.
University of Bergen, Norway, Professor (Emeritus).
Western Sydney University, Australia, Professor (Adjunct).

While writing a series of youth-oriented science books imaginatively based on the adventures of a band of compost pile denizens with the principal character being an earthworm, we encountered an obstacle. There is a serious decline in the number of young people who read books. We describe the books and their aim, and give some perspective on the decline in youth literacy.

1. Introduction

Alexander von Humboldt would have appreciated as an astute method of science communication, Australia's Acknowledgement of Country, which is given as a preamble to most meetings, events, and even Parliament. The message reaches a great number of people from all walks of life across Australia. Its emphasis on nature is a reminder that the land and waters of Australia have always had caring custodians. One might hope that every country had a dedicated preamble to keep the populace aware of everyone's ongoing responsibility for our planet.

The Acknowledgement of Country given by Professor Gary Bryant (13 February 2025, Australian Association of von Humboldt Fellows (AAvHF) Biennial Conference, *The Humboldtian Vision: Integrating Fundamentals with Applied Research*, RMIT University Melbourne) laced AAvHF's long tradition of encouraging the pollination of ideas across broad fields of inquiry--geopolitical and mathematical sciences, materials, physics and space science, chemistry, architecture and sound, biological sciences, environmental science, philosophy—with their well-developed antecedents by First Nations People.

In her 2020 AAvHF paper, "Visionary scientist and research communicator *par excellence*", Gabrielle McMullen [1] describes Humboldt as a nineteenth-century superstar. "His publications were to become legacy — significantly, he wrote for both scientific and wider audiences, the latter transporting readers into Humboldt's adventures."

Ingrid Piller's, "Editorial: Sharing knowledge in the spirit of Humboldt" [2], gives a vivid picture of Humboldt as an extraordinary science communicator. His book *Views of Nature* (1808), was an international bestseller. He was a hugely popular and passionate speaker, giving numerous talks to both scientists and the general public. Humboldt maintained a global correspondence in addition to his academic publications, writing around 4,000 letters in one year alone (1856). Not many of us do that today, even with email.

Science communication has undergone many changes since von Humboldt, and huge changes as a result of Covid in the last few years. The isolation required by Covid forced new means of communicating. Many public places were closed, including libraries. Magazines were removed from doctors' offices waiting rooms. Quickly, we learned to use zoom, facebook and other means of communication rather than face-to-face at work, home, schools and universities. Partly as a result of the increased screen time that people have learned to use, modern science communication is one of today's hot topics.

Young people must be encouraged to pursue the professions mentioned by Professor Bryant in his 2025 Acknowledgement of Country, and others encouraged by AAvHF. The big challenge is finding ways in which scientists can reach out and connect with young folks and share with them the excitement, curiosity, community and soul-satisfaction of science and its amazing mission.

There is a wide variety of STEM Programs. To name a few, the Sonia Kovalevsky Mathematics Days for Girls [3], the various Australian Science and Engineering Challenges [4], Computer Science Unplugged! [5], Creative Mathematical Sciences Communication [6], Cadet Programs, Volunteer

Firefighters and Ocean Rescue, Citizen Science, and others. These activities are largely initiated by thoughtful, caring adults or teachers or schools, and yet attendance is sometimes resisted by the children. In contrast, young people can self-initiate reading a book. They can choose what to read.

This paper describes what my sister and I learned about science communication while collaborating on three books (non-textbooks) about sustainable ecology [7]. Sequestered due to Covid, Barbara (living in Washington DC) and I (living in Australia) made the topic of our books close to home—the compost pile, and nothing is as interesting as one's own backyard![1] We wrote about the thriving, bustling underground metropolis that is home to billions of nematodes and bacteria, so tiny they can barely be seen with a microscope, alongside roly-polies, millipedes, snails, slugs, ants, beetles, flies of medium size, and the wiggly worms—the giants of any compost pile. Time and again in his writings and in his lectures, Humboldt emphasized the interconnectedness of all living creatures on this planet, and this was an aim of our books.

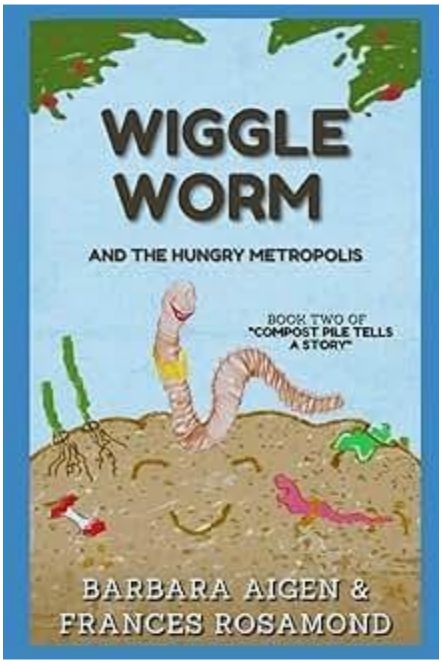

Fig. 1. The Compost Pile

This paper also examines the reported decline in literacy among youth and adults worldwide, focusing on the decreasing prevalence of book-reading among younger generations, usually attributed to increased screen time which diverts available time and attention away from reading. Conversely, proponents of digital learning argue that new modes of literacy and engagement with information should be embraced as part of the evolving educational landscape. This paper explores these perspectives, and asks the challenging question of researchers of whether they are willing to use more digital media to reach the up-coming youth in their respective fields or do they find it best to stic form for transmitting science enthusiasm.

2. Description of the Books

At a recent lecture, Professor Toby Walsh, Chief Scientist at UNSW, a member of the Australian Academy of Science, and the author of a dozen books on artificial intelligence (AI), was asked why he has written so many books on the subject (19 February 2025, University of Sydney). Toby laughed and said that he had not meant to, but there were so many new questions after writing the first book that he wrote a second. And, the same after the second, and so on.

Our experience was similar. We did not intend to write three books, but now find ourselves writing the fourth, tentatively titled "Earthworm Apocalypse", in which earthworms are blamed for emitting methane in the Arctic and catastrophically warming the planet. Actually, earthworms do not emit methane (they are not sheep) and they are not native to the Arctic. If it wasn't warm, they wouldn't survive. They were brought to the Arctic by fishermen for bait and by gardeners because they do what gardeners want them to do, which is to aerate the soil and break down organic material, making nutrients more accessible to plants and other microbes. The primary danger is the melting of the permafrost, a cap over vast amounts of carbon dioxide and methane from decomposed plants (during the Pleistocene Epoch about 2.6 million to 11,700 years ago). The melting will release enormous amounts of CO_2 and CH_4.

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[1] Readers of the UK Guardian crowned the earthworm as 2024 Invertebrate of the Year. Competitors included the Swallowtail Butterfly, Minotaur Beetle, and Barrel Jellyfish. At least 95% of life on Earth is made up of wondrously diverse invertebrates, and is not like us at all.

The books are illustrated, but they are not picture books. Our aim was to write books that had the flavour of *Wind in the Willows* by Kenneth Grahame or *George and the Big Bang* by Lucy and Stephen Hawking, books that would appeal to adults as well as children.

We did our best to keep the story as factual and close to nature as possible. There are no illustrations of worms with eyes (they have none). Worms have both male and female reproductive parts. They are hermaphrodites. Thus, we have not given any of the worms a gender. There is no “he said” or “she said” attributed to any worm.

The first book, Wiggle Worm and the Quest, answers the question: “How do the worms find the compost pile?” Our goal was to inspire children to dig in—literally—to create a compost pile in their backyard and to become active participants in caring for the earth. In doing so, we incorporate language that appeals to both adults and children, introducing terms such as pheromones, the chemical signals used by humans and nearly all flora and fauna to guide, warn of danger, or communicate in other ways.

We also weave in fascinating facts, like how earthworms have four hair-thin, stiff, retractable grippers called setae on each segment, which they use for movement. They move like inchworms, not slithering sideways like snakes, and they can move backward just as quickly as forward. The setae help them anchor themselves in their burrows, making it harder for birds to pull them out.

We aim to foster awareness of the environment and scientific advancements, spark curiosity about interspecies communication, and encourage attentiveness to current events, such as the recent discovery of a new species of giant pill bug off the coast of Vietnam [8].

The second book, Wiggle Worm and the Hungry Metropolis, addresses the question: “What exactly is a compost pile, and why is it more than just a pile of dead leaves or a heap of garbage?”

Book three, *Wiggle Worm Canterbury Tales: from London to Charles Darwin* talks about how scientists can change the attitude of the populace, specifically by Darwin’s research and his book about earthworms.

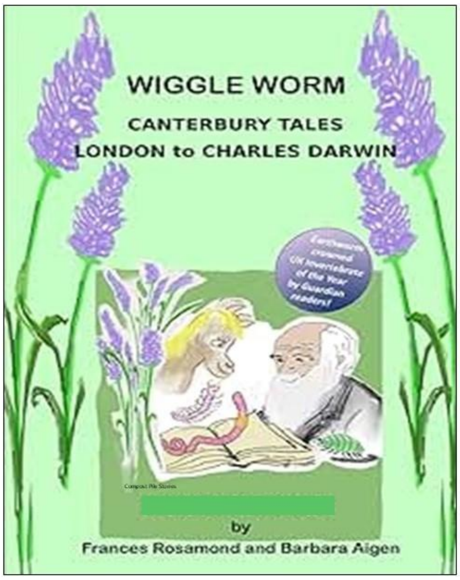

Fig. 2. Darwin’s Book

Charles Darwin’s best-selling book in his lifetime was not *On the Origin of Species* (1859). It was about earthworms – the lowly worm. The book was a best seller. Bookstores could not keep it in stock. Even Darwin was surprised at its popularity. In its day, it sparked public interest in worms and soil science.

Darwin’s descriptions of worm intelligence, sensory abilities, and industriousness (e.g., pulling leaves to protect their burrows) and their sense of community, helped people view worms as fascinating and purposeful, beneficial creatures.

Prior to Darwin, worms were seen as insignificant pests or symbols of decay. After Darwin's book, *The Formation of Vegetable Mould through the Action of Worms* (1881), public and scientific perceptions of worms shifted dramatically. Now worms were viewed as “soil engineers”, or sometimes as “intestines of the earth”, a phrase attributed to Aristotle [9].

3. Dramatic Decline in Reading

One wonders how public and scientific perceptions can be shifted as dramatically today. In 2002, the National Endowment for the Arts in the United States surveyed literary reading in America. They found that literary reading was in dramatic decline with fewer than half of American adults reading literature, and that all age groups showed declines in literary reading between 1982 and 2002, with the largest rate of decline among the young.

This downward trend has continued. In 2023, America's National Assessment of Educational Progress reported a long-term decline in the number of 13-year-olds reading for pleasure. In 2012, 27% reported doing so almost every day, but this has declined to only 14% in 2023.

The situation is similar in Australia. According to the 2024 Grattan Institute Reading Guarantee Report, a third of Australian children can't read properly. This means that, "In a typical Australian school classroom of 24 students, eight can't read well," says Grattan Institute Education Program Director Jordana Hunter [10].

NAPLAN data from the report reveals that students from well-off families struggle, too, although students from poor families, regional and rural areas, and Indigenous students face bigger barriers to reading success.

The research presented is consistent with data reflecting the wider population, with 44% of Australians having low or very low literacy. Over a quarter of Australians did not read or listen to a book last year, and a significant 7% drop in young readers since 2018 according to the Australian Bureau of Statistics (https://www.abs.gov.au/census).

The answer to the question of how the decline in book reading affects young people is mixed. According to the Educator Australia, ninety percent of the teachers interviewed in the Reluctant Readers study, which involved teachers across Australia, the Middle East, Europe, and Africa, believe social media has a negative impact on children's reading habits. Three quarters believe students who cannot read at an expected level will be ill-equipped to access the curriculum (https://www.theeducatoronline.com/k12/news/social-media-to-blame-for-kids-reading-reluctance-global-study-finds/282629).

The decline in book reading is attributed to TikTok, Instagram, Facebook, YouTube and other social media. Studies have demonstrated the negative effects of screen media use on cognitive areas such as executive functioning, sensorimotor development, sense of well-being, and academic outcomes. Media multitasking has been found to have a negative impact on teenagers, notably on working memory, inhibition, and the capacity to switch between tasks [11].

On the other hand, Professor Daniel Immerwahr, American historian and author, in his "Check This Out" article (The New Yorker, January 27, 2025) makes a case that reading on TikTok or other social media can still be considered as reading, and that it is also participatory, with more than half of TikTok's adult users posting elaborately constructed posts. Immerwahr also makes a case for the large amount of concentration required by social media.

4. Conclusion

Charles Darwin's "Worm Book" changed the perception of earthworms forever. How today, can we continue to change perceptions? For example, mathematics repeatedly and constantly has a poor reputation. Merely mention the word, and the response is (usually), "I'm scared of math!! I don't like math!!" This reaction is similar to the way that people used to scream when they saw a worm: "EEEEEEE!! I'm scared of worms!! I don't like worms!!" All of the sciences—chemistry, biology, physics, etc.—contain at least a tidbit of mathematics. We have written our books in the old-fashioned way—accessible by going to the library. However, research shows that young people are not reading as much as they did in the past.

How do we move forward to share our scientific quests with children? Do we continue with adult initiated STEM activities and books, or do we bring the young into our fields using what appears to be their preferable way, which is social media? For example, recall the enormous resistance of calculator usage in schools. They were forbidden in schools long after standard usage by business or parents. Calculators in schools are now acceptable and generally required.

There is a plethora of YouTube science videos. The "Official TikTok Science" has over five million followers and eighty-five million Likes (@officialtiktokscience) and this is only one of dozens of science TikToks. Look on Google for the best science sites for children and find websites and videos from "Bill Nye the Science Guy" to "NASA Kids Club", Ducksters (https://www.ducksters.com), National Geographics "Science for Kids" (https://www.natgeokids.com/au/category/discover/science/), and more.

Schools are increasingly requiring screen usage by students, and even Bill Gates believes there may be merit in AI individualized mentoring of students. (Both Bill Gates and Steve Jobs limited the amount of time their children were allowed to use the very products they helped create.)

In summary, the educational landscape is evolving to incorporate AI and digital resources, with teachers encouraging students to utilize these tools. This shift results in increased screen time, prompting parents and educators to seek balanced approaches that maximize learning benefits while mitigating negative effects. At the same time, students (and all of us) must find ways to sort out the misinformation that is often incorporated into the deluge. For examples, see [12]. Co-author Barbara and I are exploring using new AI tools to turn our worm adventure stories into animations.

It's a jungle out there.

Fig. 3. Another perspective

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Conflict of interest

The author declares no conflict of interest.

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Digital Twins for Discovering Complex Biological Rules: A Case for Achieving Precision and Personalization in Healthcare

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The pursuit of precision and personalization in healthcare has led to investigating computational means to model sophisticated patient-related aspects. Extending this line of enquiry, this study investigates the application of Digital Twins (DTs) to model patients—i.e., to create virtual representations of patients that integrate multi-omic and clinical data—to uncover complex biological rules that can inform treatment planning. As a clinical case study, we focus on Triple-Negative Breast Cancer (TNBC). We examine how DTs can be used to enhance the planning of PD-1/PD-L1 inhibitor therapies for TNBS. PD-1/PD-L1 is a class of immune checkpoint inhibitors with variable patient responses for TNBC. Our approach aims to computationally identify patterns of statistical congruence in cellular information that may predict therapeutic outcomes, thereby enabling clinicians to determine in advance which patients are most likely to benefit from specific immunotherapies. By leveraging DTs, we propose a novel pathway for integrating cellular and other potential complex biological insights into clinical decision-making. The central research question guiding this work is: How might the concept of Digital Twins be used to discover complex biological rules to enhance precision and personalization in treatment? Through this inquiry, we aim to contribute to the evolving knowledge of personalized medicine by demonstrating the potential of DTs to bridge the gap between biological complexity and individualized or personalized care.

1. Introduction

1.1 Precision and Personalization in Healthcare

Precise and personalized medicine is a novel concept in healthcare that innovatively attempts to tailor interventions to the individual characteristics and needs of each patient [1,2]. Different factors such as genetics, comorbidities, lifestyle, diet, environment, and so on, are considered to attain this precision and personalization in different health contexts. This approach contrasts with the "one-size-fits-all" model that is predominantly used in modern healthcare. The aim of precision and personalization is to provide the right treatment to the right patient at the right time. Ultimately the goal is to enhance the efficacy of interventions while minimizing adverse effects.

Attaining this precision and personalization in healthcare is typically done computationally [3]. It is as such, a data and computationally intensive process. In this era where advances in Artificial Intelligence (AI) are made in conjunction with super and quantum computing, the means are becoming available to advance healthcare to the next generation backed by AI and computational insights. This is where concepts like Digital Twins (DTs) in healthcare come to play. As a building block paving way to this next generation of healthcare, through this paper we attempt to explore how DTs can be used to computationally discover complex biological rules hidden in our cells, to help attain more precision and personalization in healthcare. This exploration is attempted through a case study, targeting the enhancement of precision and personalization of immunotherapy treatment planning for Triple-Negative Breast Cancer (TNBC).

1.2 Immunotherapy for Triple-Negative Breast Cancer (TNBC)

TNBC is an aggressive form of breast cancer that is linked with the lack of three receptors: namely, estrogen receptors, progesterone receptors, and human epidermal growth factor receptor 2

(HER2). TNBC is therefore typically more aggressive and grows faster with higher risk of metastasis. Moreover, it has limited treatment options and poor prognosis.

To tackle this challenge, certain immunotherapies have been identified as potential treatment options for TNBC. These include immune checkpoint inhibitors. These inhibitors typically make cancer cells more vulnerable to our body's own immune system. Our immune system is thus made to work against cancer. However, such treatments often carry side effects. When delivered, such treatments affect the whole body. Healthy cells too often become more vulnerable to the immune system. This leads to complications and side effects. That trade-off persists with these treatments.

However, immune checkpoint inhibitors such as PD-1/PD-L1 inhibitors have been approved in certain countries. This includes Australia. There have been variable outcomes and side effects because of this. This challenge is a motivator to predict likely prognosis prior to immunotherapy treatment for TNBC. We explore through this case study as to how DTs might be used to enhance precision and personalization of planning PD-1/PD-L1 inhibitor treatments for TNBC. We attempt to find beforehand which patients might benefit from PD-1/PD-L1 inhibitor treatments based on some criteria of statistical congruence.

1.3 Digital Twins (DTs) in Healthcare

DTs are digital (or virtual) replicas of physical entities [4]—meaning, the entities could be objects, systems, processes, beings, or even parts of beings. DTs are mainly used to simulate, predict, and optimize different aspects of their physical counterparts. DTs allow for dynamic and accurate representations of their physical entities through communication and linking with data, often in real-time, or at least as fast as it can be. The concept of DTs has evolved significantly over the years. DTs have had applications in various industries. These include sectors like manufacturing and automation, construction and planning, supply chain and logistics, and more. DTs in healthcare is rather a novel concept and an emerging idea with great potential.

Enhancing precision and personalization of healthcare is one of the main purposes of using DTs in healthcare [3]. DTs can serve as comprehensive and dynamic models of patients and other healthcare-related processes through integrating data from various sources. These data sources may include genetic information, comorbidities, lifestyle factors, medical records, real-time sensor data, environmental factors, and more. These models can be used to simulate different scenarios. Such simulations can be used to predict various factors such as disease progression, and tailor interventions to the specific needs and characteristics of patients.

For instance, DTs can be used to design precise and personalized treatment plans for chronic conditions such as cancer [5]. Considering the present state of a patient, likely future outcomes for different treatment options can be simulated. Through such simulations, healthcare providers can select the most effective interventions. This in turn would minimize adverse effects as well. Ultimately, the trial-and-error process often associated with medical interventions is minimized. It would be complemented or perhaps replaced through more data intensive and evidence-based approaches enabled through DTs, leading to superior outcomes and improved patient satisfaction.

1.4 Research Question

As outlined in the preceding subsections, this study explores the potential of DTs as a tool for achieving precision and personalization in healthcare. Specifically, we investigate how DTs can be applied to enhance the planning and administration of PD-1/PD-L1 inhibitor treatments for patients with TNBC.

The core premise of this work is that complex biological rules, often embedded within our cells, can be computationally discovered and leveraged to tailor treatments to individual patients. By capturing patient-specific biological rules through DTs, we aim to identify patterns of statistical congruence in certain cellular information that may predict responsiveness to specific immunotherapies.

Thus, the overarching research question guiding this study is: How might the concept of Digital Twins be used to discover complex biological rules to enhance precision and personalization in treatment?

This question encapsulates our goal of integrating computational modeling, cellular information, and clinical decision-making to move toward a more individualized, or personalized approach to cancer therapy. Through this lens, we seek to contribute to the broader discourse on how DTs can redefine the future of personalized medicine.

2. Complex Biological Rules

Biological rules governing treatment responses are often complex, multifactorial, and context-dependent. In the case of TNBC, our discussions with cancer biologists and immunologists have highlighted the importance of various immune-related cell types within the tumor microenvironment (TME) as potential indicators of immunotherapy response and prognosis. The specific cell types identified as relevant to this study are listed in Table 1. We mainly look at the number of cancer cells present in some unit area, then the CD3, ICOS and CD8 cells. In summary, CD3+ marks all T cells. ICOS+ marks a subset of those CD3+ T cells that are activated. CD8+ marks a subset of T cells that have cytotoxic activity.

In collaboration with a leading Australian cancer research institute, we utilize spatial transcriptomics to quantify the presence of these immune cells within the TME. As an initial step, we focus on measuring the density of selected cell types per unit area, as shown in Table 1. In future stages of this research, we plan to incorporate spatial relationships—that is, the physical proximity and arrangement of different cell types relative to one another—which may further refine our understanding of treatment outcomes.

Table 1: Description of relevant notations.

Symbol	Description
C	Number of Cancer Cells within a unit surface area.
CD3	Number of CD3+ T cells present within the same unit area.
ICOS	Number of activated T cells present within the same unit are (as indicated by ICOS+ expression).
CD8	Number of CD8+ cytotoxic T cells present within the same unit area.
C\CD3	Percentage (%) of CD3+ T cells with respect to the number of cancer cells.
C\ICOS	Percentage (%) of ICOS+ T cells with respect to the number of cancer cells.
C\CD8	Peercentage (%) of CD8+ T cells with respect to the number of cancer cells

To illustrate the concept of biological rules, we present synthetically generated data in Table 2. This table outlines hypothetical rules based on varying cell densities and their corresponding outcomes under different PD-1/PD-L1 inhibitor treatments. The data represents three distinct patients (i.e., Patient 1, 2, and 3) in three color codes, each characterized by unique cellular compositions within their TME. Based on these implicit biological conditions, each patient is presumed to respond optimally to a different immunotherapy regimen.

However, such granular biological insights are typically unknown at the outset of treatment. Consequently, patients are often assigned therapies without full knowledge of their likely efficacy. In our proposed approach, each patient's treatment journey—including administered therapies and observed outcomes—is recorded and modeled as a DT. Over time, as more patient data accumulates, statistical patterns may emerge, revealing the underlying biological rules that affect treatment responses.

This approach enables retrospective analysis to inform prospective decision-making. By identifying statistically congruent patterns between past and new patients, clinicians can more accurately match therapies to individuals, thereby enhancing precision and personalization in treatment planning. Ultimately, this approach aims to improve clinical outcomes—such as overall survival, as illustrated in Table 2—by leveraging DTs to uncover and make use of complex biological rules in real-world settings.

3. Proposed Solution

The proposed solution includes a web-based Digital Twin (DT) frontend. It is illustrated in Figure 1. It serves as a clinical decision support interface. It is designed to be used by clinicians—potentially in collaboration with patients—to facilitate shared decision-making in treatment planning.

At the top-right corner of the interface is a 'Load Patient' button, which initiates the process. When a patient is present, the clinician can begin by selecting this option, which prompts the scanning of a unique patient identifier, such as a QR code. Upon scanning, the patient's biomarkers and other relevant clinical data are securely retrieved from a dedicated server and displayed on the DT interface.

To ensure data accuracy and patient privacy, a confirmation popup appears first, showing limited personal identifiers (e.g., name and date of birth) for verification. These identifiers are visible only within the popup and not on the main DT screen, preserving confidentiality. Once verified by both clinician and patient, the popup is closed, and the patient's data is rendered on the DT dashboard.

As shown in Figure 1, patient data is organized into two primary categories: demographic information and disease-specific details. Demographic attributes include age (with a ±5-year range for cohort matching), sex (Male/Female), and ethnicity (e.g., African, East Asian, South Asian, Southeast Asian, MENA, European, Hispanic or Latino, Indigenous Peoples, Pacific Islander, etc). These factors are used to identify a statistically congruent cohort of past patients, forming the basis for personalized treatment recommendations.

The disease-specific section is tailored for TNBC. Key clinical variables include cancer stage (e.g., Stage IA, IB, IIA, etc.) and biomarkers (listed in Table 1) relevant to PD-1/PD-L1 inhibitor therapies. These are treated as quantitative variables, and for cohort matching, a ±10% margin is applied to identify patients with similar biomarker profiles.

Clinicians can then select from available immunotherapy options, including PD-1 inhibitors and PD-L1 inhibitors. By clicking the 'Match Cohort' button, the system retrieves outcome data from the matched cohort and displays it in the 'Outcome Measures' panel.

This panel presents key metrics such as: Objective Response Rate (ORR), Progression-Free Survival (PFS) range (in months), Overall Survival (OS) range (in months), likely side effects, including fatigue, nausea, and immune-related adverse events (AEs).

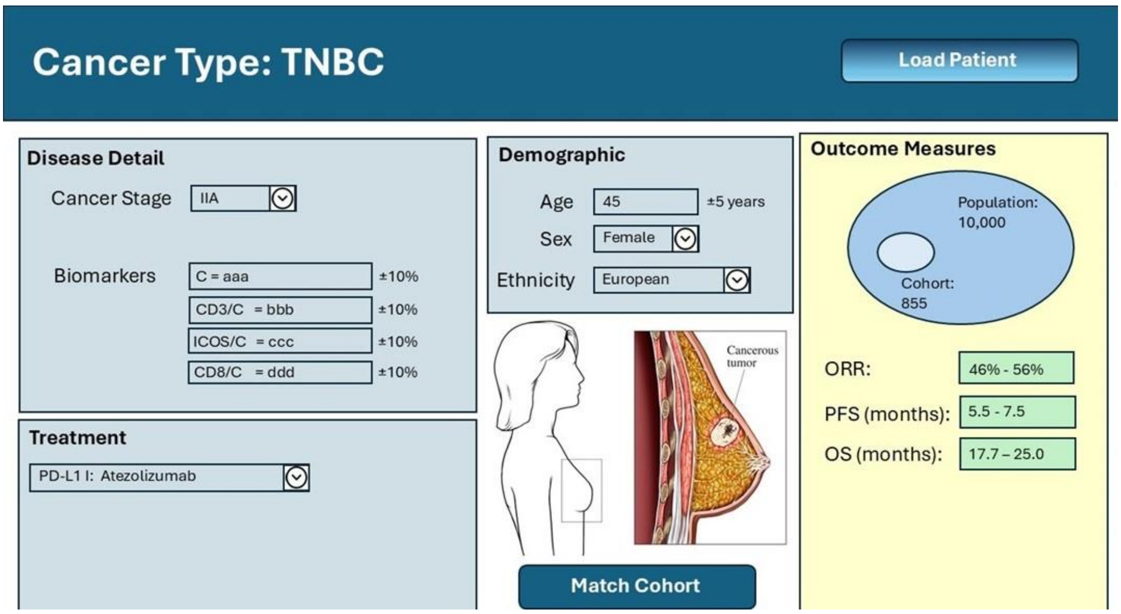

Fig. 1. Proposed web-based DT dashboard for precise and personalized immunotherapy treatment planning.

These insights enable clinicians to make evidence-informed decisions tailored to the individual patient, thereby enhancing precision and personalization. The process also supports patient empowerment by facilitating transparent, collaborative decision-making.

Importantly, the DT interface functions as an intelligent digital model of the patient, continuously updated with treatment and outcome data. Over time, this enables the discovery of statistically significant patterns that inform future treatment strategies. As illustrated in Figure 2, we also plan to incorporate more advanced visualizations that show the distribution of past patients and the most statistically congruent cohort for the current patient—further reinforcing the degree of personalization achieved.

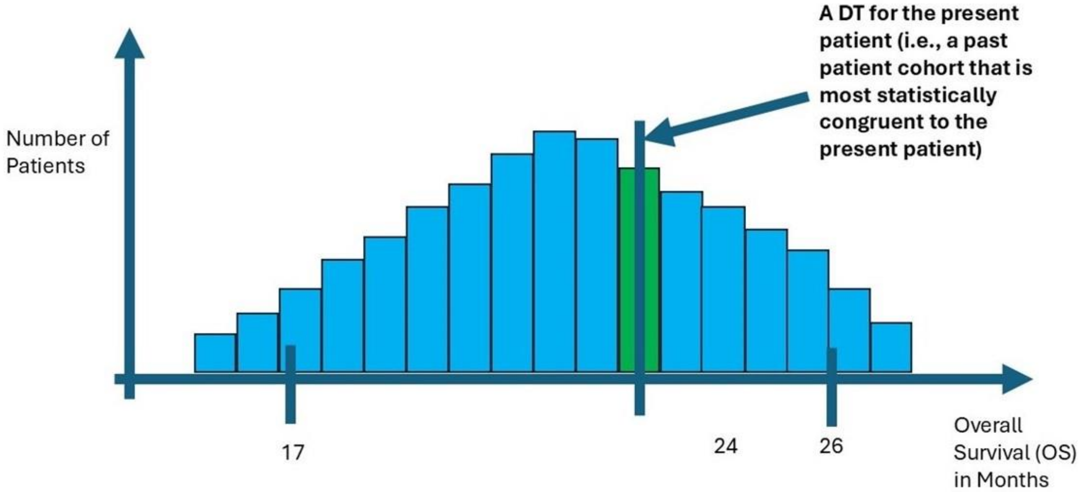

Fig.2. Population of past patients alongside a discovered DT (i.e., the most statistically congruent cohort to present patient) depicting personalization of outcomes measures.

4. Conclusions

This study presents a novel approach to achieving precision and personalization in cancer treatment using DTs. Focusing on Triple-Negative Breast Cancer (TNBC) and the administration of PD-1/PD-L1 inhibitor therapies, we explored how DTs can be used to uncover complex biological rules embedded within the cancer tumor microenvironment. By leveraging spatial transcriptomics and computational modeling, we demonstrated how immune cell densities—particularly CD3+, ICOS+, and CD8+ T cells—can serve as predictive indicators of treatment response.

Our proposed solution integrates these insights into a web-based DT interface designed for clinical decision support. This solution enables clinicians to match new patients with statistically congruent cohorts from historical data, thereby informing treatment choices based on prior outcomes. The interface supports shared decision-making, enhances transparency, and empowers patients by providing personalized treatment insights grounded in real-world evidence.

Over time, as more real-world patient data is collected and modeled, the DT solution is expected to evolve into a powerful tool for discovering and validating biological rules that govern therapeutic efficacy. This iterative learning process not only improves the accuracy of treatment recommendations but also contributes to the broader vision of data-driven, individualized medicine.

In conclusion, this work highlights the potential of DTs to bridge the gap between complex biological data and actionable clinical insights. By enabling the discovery of hidden patterns in patient-specific data, DTs offer a promising pathway toward more effective, personalized, and equitable care.

Table 2: Indicative implicit rules (synthetically generated) pertaining to efficacy of immunotherapy (Legend: Patient 1; Patient 2; Patient 3).

Implicit rule on Cancer Cell Count	Implicit rule on CD3+ T Cell Count	Implicit rule on ICOS+ T Cell Count	Implicit rule on CD8+ T Cell Count	Immunotherapy A (Overall Survival (OS)/months)	Immunotherapy B (Overall Survival (OS)/months)	Immunotherapy C (Overall Survival (OS)/months)
C < 1,000	C\CD3 ≤ 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	17 (± 5)	21 (± 5)	13 (± 5)
			C\CD8 > 1%	16 (± 5)	5 (± 5)	8 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	23 (± 5)	11 (± 5)	7 (± 5)
			C\CD8 > 1%	20 (± 5)	24 (± 5)	14 (± 5)
	C\CD3 > 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	7 (± 5)	5 (± 5)	22 (± 5)
			C\CD8 > 1%	22 (± 5)	13 (± 5)	6 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	8 (± 5)	31 (± 5)	7 (± 5)
			C\CD8 > 1%	20 (± 5)	11 (± 5)	17 (± 5)
1,000 < C ≤ 10,000	C\CD3 ≤ 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	23 (± 5)	28 (± 5)	19 (± 5)
			C\CD8 > 1%	16 (± 5)	30 (± 5)	7 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	6 (± 5)	7 (± 5)	10 (± 5)
			C\CD8 > 1%	14(± 5)	27 (± 5)	11 (± 5)
	C\CD3 > 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	12 (± 5)	7 (± 5)	12 (± 5)
			C\CD8 > 1%	21 (± 5)	23 (± 5)	5 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	8 (± 5)	20 (± 5)	5 (± 5)
			C\CD8 > 1%	23 (± 5)	31 (± 5)	16 (± 5)
10,000 > C	C\CD3 ≤ 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	10 (± 5)	19 (± 5)	24 (± 5)
			C\CD8 > 1%	14 (± 5)	36 (± 5)	11 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	14 (± 5)	18 (± 5)	10 (± 5)
			C\CD8 > 1%	10 (± 5)	8 (± 5)	18 (± 5)
	C\CD3 > 10%	C\ICOS ≤ 5%	C\CD8 ≤ 1%	5 (± 5)	35 (± 5)	15 (± 5)
			C\CD8 > 1%	5 (± 5)	17 (± 5)	9 (± 5)
		C\ICOS > 5%	C\CD8 ≤ 1%	17 (± 5)	36 (± 5)	5 (± 5)
			C\CD8 > 1%	14(± 5)	6 (± 5)	24 ± 5)

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Sustainable Chemical Synthesis: Making Molecules Using White-Light Irradiation

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Innovations in chemical synthesis play a critical role in the discovery of new life-saving medicines, agrochemicals and functional materials. Significant advances in chemical synthesis have been made in recent decades, however many of these approaches require the use of precious metal catalysis (e.g., rhodium, gold, platinum and palladium). The low natural abundance, toxicity and high cost of these precious metals limits the widespread application of many useful chemical reactions across medicinal chemistry and pharmaceutical programs. Visible light irradiation is considered a 'benign' and renewable chemical reagent that can be used to drive chemical reactions not achievable by other means (i.e., thermal activation). In recent years, our group has explored the reactivity and properties of unique photoactivatable functional groups, discovering new highly efficient synthetic methods to access molecular building blocks using only visible light irradiation. These new photochemical methods are expected to enable chemists to design more sustainable strategies for the synthesis and manufacture of molecular frameworks of immense value in pharmaceutical chemistry (e.g., scaffolds for structurally novel therapeutic candidates or tool; compounds for deciphering biological mechanisms) whilst minimising the use of expensive precious metal catalysis.

Hype and Trust in Quantum Technology

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We can trust science in the way that it evolves and is constantly tested and verified. We need trust in scientists to address many of the challenges we deal with as individuals and globally. To progress we need reliable predictions but also bold, visionary proposals and imagination. To get attention we all use some hype, but too much can clearly be obstructive. Let me discuss the balance between trust and hype in the area of quantum science and technology, a field that is rapidly emerging from the labs and minds of experts and might influence our way of creating and dealing with data and information.

FeNi254 – A Potent Bifunctional Efficient Catalyst for the Overall Electrochemical Water Splitting in Alkaline Electrolyte

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For a carbon-neutral society, the production of hydrogen as a clean fuel through water electrolysis is currently of great interest. Since water electrolysis is a laborious energetic reaction, it requires high energy to maintain efficient and sustainable production of hydrogen. Catalytic electrodes can reduce the required energy and minimize production costs. In this context, herein, a bifunctional electrocatalyst made from iron nickel sulfide (FeNi254 [FNS]) for the overall electrochemical water splitting is introduced. Compared to Fe_2NiO_4 (FNO), FNS shows significantly improved performance toward both OER and HER in alkaline electrolytes. At the same time, the FNS electrode exhibits high activity toward the overall electrochemical water splitting, achieving a current density of 10 mA cm^{-2} at 1.63 V, which is favourable compared to previously published nonprecious electrocatalysts for overall water splitting. The long-term chronopotentiometry test reveals an activation followed by a subsequent stable overall cell potential at around 2.12 V for 20 h at 100 mA cm^{-2}.

Revisiting Bismuth: New Horizons in Medical Applications

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Bismuth, a non-toxic element with unexplored potential in biomedical research, offers unique possibilities when combined with key biomolecules like peptides and proteins. Our work harnesses bismuth to modify and enhance these molecules, increasing their potential as drug candidates. Additionally, radioactive bismuth may act as a “trojan horse” within peptides and proteins targeting cells, with promising implications for future anticancer therapies.

Reflections on Humboldt Stiftung Branding

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The Alexander von Humboldt Foundation, as we know it today, was reformed following the Second World War in 1953. The branding introduced for the advertising of its various research support schemes featured a traditional logo which became most familiar to both Fellows themselves and even the general public. It is worth noting, however, that the very first research funding under the name of Alexander von Humboldt occurred as early as 1860 when branding for advertising and promotional purposes was perhaps not as important as it is today. This initial scheme was suspended in 1923 on account of the depression. In 1925 the Alexander von Humboldt Foundation was formed by the German Foreign Ministry but the fall of Germany in 1945 led to the closure of the Foundation. 2023 marked the 70th anniversary of the post-war Humboldt Stiftung and with this anniversary came a new branding. In this presentation I shall outline the background for this new branding and suggest why the change was necessary.

1. Introduction

The original Foundation which was known as the "Alexander von Humboldt Foundation for Nature Research and Travel" was established on 19th December, 1860, just a short time after Humboldt's death on 6th May, 1859 [1]. It continued throughout World War I but was discontinued in 1922 on account of the loss of capital due to the post-war inflation.

On the 2nd April, 1925, a new "Alexander von Humboldt Foundation" was established specifically for the "sponsorship of foreign students at German Universities and other German educational establishments" [2]. The Foundation ceased in 1945 and it would appear that many records were lost on account of the extensive bombing during World War II [3]. While a PhD thesis completed at Bonn University in 2013 reports on activities of the Foundation from 1925 to 1945 [4], it is true to state, from communications with Dr Martin Schaffartzik, the current Foundation's Program Director – North America, Australia, New Zealand and Oceania, that there are no records from the activities of the Foundation prior to World War II, in the current archives in Bonn [5].

2. Early Australian Records

But here in Australia, following the establishment of the Australian Association of von Humboldt Fellows, we were privileged to have an Association Member, Mrs Mary Angela Miller who had studied at Munich University during the early 1930s, with support from an Alexander von Humboldt Foundation Scholarship. Angela used to be brought to our Association Meetings by the late Dr Harold Graze and his wife, Marion. Although to me Angela seemed to be a quite elderly lady, she regularly contributed to the discussion in our Humboldt Meetings, as one would have expected from an Humboldt Fellow. Angela is the first-named Distinguished Fellow of our Australian Association [6]. I have enquired of Dr Michael Wishaw who provided some of the information which is on our Association website about her, in the hope that there may be something in the family records pertaining to the pre-WWII Humboldt Foundation, but without success. It is also interesting to note that, consistent with the loss of Foundation records during the bombing in WWII, our contact at the Foundation in Bonn has reported that there is no record of Mary Angela Miller in the current Foundation files [5].

3. The "New" Alexander von Humboldt Foundation

What I have called the "New" Alexander von Humboldt Foundation was established on 10th December, 1953 by the German Foreign Minister, Konrad Adenauer, with the eminent physicist, Werner Heisenberg as the Foundation's first President [7]. Branding was created from a medal which had been designed by Christoph Karl Pfeuffer in 1829 [8], which had been created specifically to give to students who, at that time, were attending Humboldt's lectures at the University of Berlin (Fig. 1). Although not totally clear in this image, around the edge of the medal was the Latin inscription of Alexander von Humboldt's birthdate: "ALEXANDER AB HUMBOLDT NAT. XIV SEPT. MDCCLXIX". The imprint of this medal together with its Latin inscription appears on Alexander von Humboldt Foundation Annual Reports from the late 1950s until 1997 [9].

Fig.1. Image of Alexander von Humboldt on the medal designed by Christoph Karl Pfeuffer in 1829, which was given to students attending Humboldt's lectures at the University of Berlin [8].

However, on the 1998 report, the Latin inscription was removed from around the head image of Humboldt and the words "Alexander von Humboldt Stiftung/Foundation" were added, to create a corporate logo (Fig. 2) which thereafter appeared on all Foundation advertising material. This corporate logo was designed by a Stuttgart company named Jung: Kommunikation [10].

Fig. 2. Corporate logo of the Alexander von Humboldt Foundation prior to 2023.

In addition, Humboldt memorabilia had been created (Fig. 3). These included a lapel badge, a tie given to male Fellows and a scarf given to female Fellows. The tie and scarf were in recognisable "Humboldt Colours" of green and black. In addition, the "Humboldt Pocket Diary" sent to all Fellows from Bonn, was first created prior to 1985, and it was quite common at an International Conference to recognise an Humboldt Fellow from his or her tie, scarf or pocket diary. There will be more discussion of the Pocket Diary later in this paper.

A few years later the Humboldt tie was changed, to become more fashionable. (See Fig. 3.)

Fig 3. Humboldt memorabilia, (left) the lapel badge, the scale being mm, (centre) the initial Humboldt tie and (right) the later Humboldt tie.

4. The "New" Humboldt Stiftung Branding

2023 marked the 70th anniversary of what we now know as the Alexander von Humboldt Foundation. For whatever reason, a group of staff at the Foundation was assigned the task to search for a new corporate image. The consensus of opinion was that a stylized painting of Alexander von Humboldt created in 1843 by the famous nineteenth century portrait painter, Joseph Karl Stieler, was a more popular image of Humboldt than the previous image taken from the Christoph Pfeuffer medal. So, clearly it was time for change.

It is worth noting some of the work of Joseph Stieler and some of his famous paintings have been presented in Fig. 4 [11]: a self portrait, completed in 1806; his painting of Ludwig van Beethoven (1820) is recognised as Stieler's most reproduced work; King Ludwig I (1826) was painted in his Coronation robes; Johann Wolfgang von Goethe (1828) with whom we know Humboldt had a very close friendship; and the painting of Humboldt (1843), chosen by the Foundation corporate group, from which it was decided to take the new branding.

The head of Alexander von Humboldt from the Joseph Stieler painting, to compare directly with the "artistic image" created as part of the new corporate logo for the Foundation, is shown in Fig. 5. The design and implementation of this new branding was carried out by a Bonn agency called Kreativkonzept [12]. While one would have to admit that the geometry of Humboldt's head, including the hair is accurate, the colouring, particularly the black hair for grey, is done with a certain "artistic l;icence". But no doubt in "corporate advertising" such modifications are acceptable.

Fig. 4. Some examples of the paintings of Joseph Karl Stieler [10]: (L→R): Self Portrait (1806); Ludwig van Beethoven (1820); King Ludwig I (1826); Johann Wolfgang von Goethe (1828); Aleander von Humboldt (1843).

The press release which accompanied this new branding, read as follows [13]:

"In a time of upheaval and change, rather than look back and take stock, we want to look ahead. So in the Foundation's jubilee year, we are asking 'What next – in visual terms too.'"

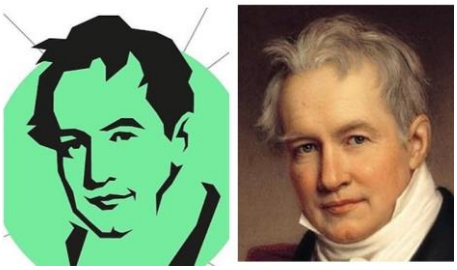

Fig. 5. Comparison of the head of Alexander von Humboldt taken from the Joseph Stieler painting (Fig. 4) with the image used in the new Humboldt corporate logo.

The new Humboldt Stiftung logo is worth considering as is the new lapel badge (Fig. 6). To me the disappointment is that the words identifying the Foundation have been removed from the new lapel badge. Also, for any other "branding" such as a new scarf or a new tie, it is unclear as yet if they will be continued in the new design because there have been complaints to the Foundation from Humboldtians that the tie and the scarf imply a strictly binary interpretation of "gender". [14].

Fig 6. (Left): New Humboldt Stiftung logo introduced in 2023. (Right): the new lapel badge.

But clearly, as the press release continued [13]:

"The Humboldt Foundation is embarking on its anniversary year with a new look, setting the tone for future highlights."

5. The Humboldt Pocket Diary

As a constant user of an Humboldt Pocket Diary, and given that I have often been identified as an Humboldt Fellow on account of having the diary in my pocket, I thought it appropriate to review this aspect of "Humboldt branding" via Fig. 7.

Fig. 7. Humboldt pocket diaries, (L→R): 1985, 2000, 2007, 2024, 2025

The first Humboldt diary was sent to us as Humboldt Fellows, prior to 1985. The cover imprint on this diary was copied from another medal which was given to students attending Humboldt's lectures in Berlin, and which had been created by Henri Francois Brandt [15]. Fig. 8 shows a comparison of the image of this medal with the cover imprint on this 1985 diary. The diary also contained the lettering "ALEXANDER VON HUMBOLDT STIFTUNG BONN BAD GODESBERG". This cover branding continued until 1999. From 2000 to 2006 the cover branding took the form of the medal designed by Christoph Karl Pfeuffer, pictured for comparison here (Fig. 9). This design changed again in 2007 when the format for the diary cover became consistent with the corporate logo adopted by the Foundation for its advertising.

Fig. 8. (Left): Image of the medal created by Henri Francois Brandt. (Right): Cover imprint on the Humboldt diaries, 1985 to 1999.

Fig. 9. (Left): Image of the medal created by Christof Karl Pfeuffer. (Right): Cover imprint on Humboldt diaries, 2000 to 2022

For 2023, there was no Humboldt Diary sent to us and I was reliably informed [16] that the reason for this had been a shortage of materials. But then for 2024, we were sent a new diary with a cover design consistent with the new Humboldt branding based on the Stieler portrait which had been used for the new corporate logo.

We have seen a further design change for the 2025 diary which includes a change of colour from "Humboldt Green" to Grey.

6. Australian Humboldt Association Branding

Fig. 10. Logo of the Australian Association of von Humboldt Fellows, designed by Ms Heidi Cartwright [18].

Finally, I should like to add a few words about our own Association branding via our logo (Fig. 10). In an attempt to find the origin of this logo, I wrote to a number of "senior" Australian Humboldt Fellows. One in particular, Emeritus Professor Elspeth McLachlan, replied to my email to suggest that she believed the design had been done by Professor Kay Double [17]. My correspondence with Kay [18] resulted in an immediate reply to inform me that our Australian Association logo had been the work of a cartographer at Neuroscience Research Australia (NeuRA), Heidi Cartwright. In subsequent correspondence with Heidi who is now at Sydney University, I learned that our logo had been based on an image of Alexander von Humboldt taken from a picture of Humboldt she had been given by Kay Double [19].

With a little more "detective work" I was able to prove that Kay had given Heidi a picture of the famous marble statue of Alexander von Humboldt in front of the Humboldt University in Berlin, (Fig. 11) [20]. From a comparison of the head image copied from this picture and the head of Humboldt cropped from our Association logo, (Fig. 12), one can see that from a picture of the statue taken at a certain angle, the head of the statue would appear to be identical to that in our logo.

Fig. 11. Marble statue of Alexander von Humboldt in front of the Humboldt University in Berlin [20].

Concluding Remarks

I'd like to end by suggesting a consistency between this presentation and the theme of this conference. In these times of highly competitive research funding, it is essential for the Alexander von Humboldt Foundation to market itself successfully via its branding, in order to continue its support of both fundamental and applied research across all scholarly disciplines.

I should like to acknowledge Dr Martin Schaffartzik for his most willing assistance during my preparation of this paper and Professor Kay Double and Ms Heidi Cartwright, University of Sydney, regarding our AAvHF logo.

Fig. 12. Comparison of the head of Humboldt taken from the image of the marble statue in Figure 11, with that from the Australian Association logo.

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How to Train a GAN: Monotone Operator Splitting without Cocoercivity

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Generative adversarial networks (GANs) are an approach to fitting generative models over complex structured spaces. Within this framework, the fitting problem is posed as a game between two competing neural networks which are trained simultaneously. Mathematically, this problem takes the form of a min-max problem; a well-known example of the type of problem where the usual gradient descent-type approaches used for training neural networks fail. In this paper, we discuss an alternative gradient-based approach for training GANs which overcomes this difficulty. The proposed approach is based on the theory of *monotone operator splitting a*nd gives rise to an algorithm whose per iteration computational cost is the same as existing methods.

1. Introduction

Generative adversarial networks (GANs) are a popular approach to fitting generative models over the space images or, more generally, any space with complex structure [1]. Within this framework, the fitting problem is posed as a mathematical game between two competing neural networks which are termed the *Generator* and the *Discriminator.* The Generator network takes random noise as input and attempts to generate realistic "fake" images from target space. Once trained, the Generator network produces different image for each random input. The Discriminator network takes an image as input and must decide whether the image is real or fake. The Generator's goal is to fool the Discriminator. A schematic of a GAN is shown in Figure 1.

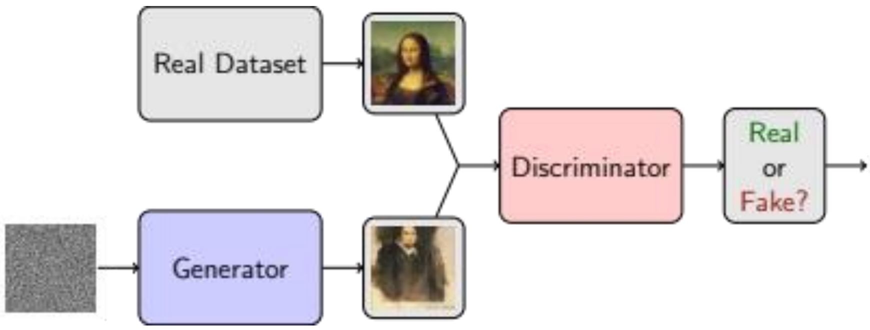

Fig. 1. Schematic of a GAN.

As a coupled system of two neural networks, training a GAN is significantly more difficult than training a single neutral network. Training of the Generator and Discriminator must be done simultaneously to ensure they both "learn" at the same rate to avoid phenomena such as *mode collapse,* whereby the Generator only procedures a single image or small family of similar images [2]. Mathematically, the training problem takes the form of the *min-max problem* given by

$$min_x max_y \phi(x,y) ,$$

where x denotes the Generator network's hyper-parameters, y denotes the Discriminator network's hyper-parameters, and $\phi(x,y)$ represents the Discriminator's prediction accuracy for a given choice of x and y. Note that in the context of GANs, the gradient of ϕ can be efficiently computed using *backpropagation.*

A common approach to solving the above min-max problem in the context of GANs involves using the *saddle-gradient method*.[2] Given an initial point (x_0,y_0) and stepsize $\lambda>0$, this method generates a sequence (x_k,y_k) according to the update

$$x_{k+1}=x_k-\lambda\nabla_x\phi(x_k,y_k)$$
$$y_{k+1}=y_k+\lambda\nabla_y\phi(x_k,y_k),$$

with the hope that a solution to the problem is attained in the limit. However, as the following example shows, the saddle-gradient method can fail to converge quite spectacularly even on the simplest min-max problems.

Example 1 (Failure of the saddle-gradient method). *Let $n=m=1$ and $\phi(x,y)=xy$. Then the unique solution of the above min-max problem is given by $(x,y)=(0,0)$, however the saddle-gradient method diverges for any stepsize $\lambda>0$. Indeed, for this problem, one has*

$$x_{k+1}=x_k-\lambda\nabla_x\phi(x_k,y_k)=x_k-\lambda y_k$$
$$y_{k+1}=y_k+\lambda\nabla_y\phi(x_k,y_k)=y_k+\lambda x_k,$$

which can be expressed in matrix form as

$$\begin{bmatrix}x_{k+1}\\y_{k+1}\end{bmatrix}=M\begin{bmatrix}x_k\\y_k\end{bmatrix}=M^{k+1}\begin{bmatrix}x_0\\y_0\end{bmatrix}\quad \textit{where}\quad M=\begin{bmatrix}1&-\lambda\\\lambda&1\end{bmatrix}\in\mathbb{R}^{2\times 2}.$$

The spectral radius of M is greater than 1 for any $\lambda>0$. Hence $\|M^k\|\to\infty$ and so the sequence (x_k,y_k) diverges.

To understand the aforementioned issue with the saddle-gradient method, the next section will explore the mathematical properties of min-max problems using a framework known as *monotone operator theory*.

2. Monotone Operator Theory

Monotone operator theory is an overarching and unifying framework for understanding and analysing first-order algorithms in mathematical optimisation. Within this framework, optimisation problems are formulated as *operator inclusions* via their optimality conditions, and then algorithms are designed to exploit the mathematical properties of these operators rather than the original problem directly.

For example, consider the *minimisation problem given by*

$$min_x g(x)+f(x),$$

where f represents a differentiable function with L-Lipschitz continuous gradient and g represents a potentially non-differentiable function. In monotone operator theory, this problem is formulated as the following operator inclusion

$$0\in A(x)+B(x),$$

where the operators are A and B are taken to be *subdifferential* of g and the gradient of f, respectively. That is,

$$A(x)=\partial g(x)\ \text{and}\ B(x)=\nabla f(x).$$

To solve this inclusion, the *forward-backward method* can be used. The update for this method takes the form

$$x_{k+1}=J_{\lambda A}(x_k-\lambda B(x_k)),$$

where $J_{\lambda A}:=(I+\lambda A)^{-1}$ denotes the *resolvent operator* of A. This algorithm can be shown to converge to a solution whenever the stepsize satisfies $\lambda< 2/L$.

Returning to a setting inspired by GAN training, consider the *min-max problem*

[2]In practice, stochastic versions of the saddle-gradient are used. However, for simplicity of exposition, we discuss only the deterministic version of algorithms in this paper.

$$min_x max_y g(x) + \phi(x,y) - h(y),$$

where ϕ is a differentiable function with L-Lipschitz continuous gradient, and g and h are regularisers (potentially non-differentiable) used to influence the properties of x and y respectively. This problem can be formulated in the same form of the previous operator inclusion but with the operators A and B given by

$$A\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \partial g(x) \\ \partial h(y) \end{pmatrix} \quad \text{and} \quad B\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \nabla_x \phi(x,y) \\ -\nabla_y \phi(x,y) \end{pmatrix}.$$

It is tempting to apply the forward-backward algorithm with this choice of operators in an attempt to solve the min-max problem. However, in general, this approach fails due to a counter-example similar to the one presented in Example 2. At first this might appear surprising as, in both minimisation and min-max context, the operator B has the same assumption; it is L-Lipschitz continuous. However, it turns out that the reason for the success of the forward-backward method for minimisation (as compared its failure for min-max) is because when a Lipschitz continuous operator is also the gradient of a function, it automatically satisfies a strong property known as *cocoercivity.* This holds in context of minimisation but not in minx-max. This is summarised in the following celebrated theorem.

Theorem 1 (Baillon-Haddad [3]). *Let f be a differentiable convex function and let $L>0$. Then ∇f is L-Lipschitz continuous if and only if ∇f is $(1/L)$-cocoercive, that is,*

$$\langle x - x', \nabla f(x) - \nabla f(x') \rangle \geq \frac{1}{L} \| \nabla f(x) - \nabla f(x') \|^2 \qquad \forall x, x'.$$

By using the Cauchy-Schwarz inequality, it is easily seen that, for *any* operator, cocoercivity always implies Lipschitz continuity. However, the Theorem 3 shows that the converse need only hold when the operator is the gradient of a convex function. As the operator B in min-max is not a gradient (due to the negative in "y-coordinate"), it need not be cocoercive. This gives some reason to expect the failure of the saddle-gradient method for training GANs.

3. Monotone Operator Splitting without Cocoercivity

Finally, we explain how to derive a modification of the saddle-gradient method for solving min-max problems whose convergence does not rely on cocoercivity, and thereby resolving the "cocoercivity issue" outlined in the previous section. The explanation presented here is simplification of the one in [4], to which the interested reader is refered to for further details.

To this end, first consider, the following impractical modification of the forward-backward method which involves replacing $B(z_k)$ with $B(z_{k+1})$ in its update. In other words, consider the iteration

$$z_{k+1} = J_{\lambda A}\left(z_k - \lambda B(z_{k+1})\right).$$

This modification can be shown to converge to a solution without needing cocoercivity, however it is no longer computationally efficient because of the implicit nature of the update (ie z_{k+1} appears on both sides of the update). To overcome this, we make the approximation

$$B(z_{k+1}) \approx B(z_k) + \left(B(z_k) - B(z_{k-1})\right).$$

Substituting this back into the original update gives

$$z_{k+1} = J_{\lambda A}\left(z_k - 2\lambda B(z_k) + \lambda B(z_{k-1})\right).$$

We refer to this update as the *forward-reflected-backward algorithm (FoRB).* Its convergence for abstract operators A and B is guaranteed due to the following theorem.

Theorem 2 (Malitsky-Tam [5]). *Suppose A is maximally monotone, and B is monotone and L-Lipschitz continuous. Let $\lambda < 1/(2L)$. Then, for any initialisation z_0, the sequence (z_k) generated by FoRB converges to a point z such that $0 \in A(z)+B(z)$.*

As a consequence of Theorem 4 specialised to the setting of min-max problems with $z=(x,y)$, FoRB yields the following gradient-based algorithm which is suitable for training GANs:

$$x_{k+1}=prox_{\lambda g}\left(x_k-2\lambda\nabla_x\phi(x_k,y_k)+\lambda\nabla_x\phi(x_{k-1},y_{k-1})\right)$$
$$y_{k+1}=prox_{\lambda h}\left(y_k+2\lambda\nabla_y\phi(x_k,y_k)-\lambda\nabla_y\phi(x_{k-1},y_{k-1})\right).$$

Here $prox_{\lambda g}$ and $prox_{\lambda h}$ denote the proximity operators of g and h, respectively. As the past gradients can stored in memory and reused in the subsequent, implementing this update only requires one evaluation of $\nabla\phi=(\nabla_x\phi, \nabla_y\phi)$ per iteration. In other words, it has the same per-iteration computational cost as the saddle-gradient/forward-backward methods, but with the advantage of converging without relying on cocoercivity.

Acknowledgments

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3D Printing of Functionally Integrated Devices

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The integration of chemical functionalities in microfluidic devices can be accomplished by the combination of different materials. 3D printing has readily been proposed as an alternative for manufacturing of fluidic devices, in particular, for small scale production. Resin-based printers are most suitable for printing small features, however, the combination of different materials remains a challenge. This presentation focuses on the development of resins for digital light projection 3D printing of porous materials, and their integration into fluidic devices by resin exchange and using greyscale masks. Applications of the devices include phase separation, chemotaxis, extraction of DNA and the detection of iron from soil.

Systematic Quantification of Hydrogen in X65 Pipeline Steel by Atom Probe Tomography after Ambient Charging and Transfer

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Storage and transportation will be key factors for the forthcoming hydrogen economy, and utilising established gas pipeline networks are a potential way both to store and to transport large-scale quantities of hydrogen-containing fuels. However, hydrogen embrittlement (HE) poses a significant threat to high-strength gas pipelines in the presence of pressurised H-carrying gases. To mitigate this risk, a thorough understanding of HE behaviour is essential, where accurate quantification of the spatial location of hydrogen (H) in the microstructure, is required at the atomic scale. Atom probe tomography (APT) has gained recognition for this purpose, especially with cryo-vacuum preparation and transfer systems. In this work we characterise X65 pipeline steel, commonly used in the gas industry, by utilising APT after ambient charging and transfer, and different hydrogen and deuterium (D) charging conditions. The aim is to investigate the trapped H/D without possible influence from cryo-fixation of un-trapped (diffusible) H/D, which is perhaps more representative of in-service conditions. The effect of passive (oxide) layers is another critical aspect that is investigated, due to their influence on the penetration of H/D into the metal surface. This aspect is particularly pertinent for industrial applications, offering insights into hydrogen ingress in high-strength pipeline steel for future fuel mixtures of hydrogen and natural gas.

A Simple and Effective Mathematical Model for Bushfires

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In this talk I describe a new mathematical model that we have developed for predicting motion of fire fronts, with specific application in mind to bushfire dynamics in the Australian climate. I will discuss some aspects of fires, the formation of the model, its alignment to real (controlled) fire experiments, numerical simulation, and a bit of mathematical analysis. This is a joint project with Valentina-Mira Wheeler, Serena Dipierro and Enrico Valdinoci.
