NZIC Chemistry IN NEW ZEALAND

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Articles and Features

Other Columns

Comment from the President

As the incoming NZIC President I am actively thinking about what challenges NZIC will face in 2017 and how, with the support of Council, I will address them.

First of all, thanks to Paul Plieger for his contributions as President during 2016. He has begun the process of modernising NZIC and I will pick this up in 2017, supported by Paul as Past-President. We are currently looking at the rules, the website and an overall strategic plan for the Institute. Our membership is dropping at an unsustainable rate and the future of the Institute depends on us addressing our purpose and relevance. How do we best serve our members? What do they need and want from NZIC? Who else could we serve and support and how? These are all big questions which the Council has been addressing and will continue to be asked through 2017. Our most immediate challenge will be finding a new Honorary General Secretary following Richard Rendle's decision to retire from this role at the end of 2017. His are big shoes to fill as committed and able volunteers become harder and harder to find in the increasingly pressured 21st century.

Secondary school chemistry teachers are an important group with whom we engage through special events and resources to support the school chemistry curriculum and learning, and the ChemEd conference. The NZIC Chemical Education Specialist Group facilitates these occasions but there is also an opportunity to engage more teachers directly in the organisation. One way NZIC has been supporting secondary chemistry students is through NCEA practice exams prepared by the Chemical Education Specialist Group. They are well received by schools but their future post-2017 also depends on our new administrative arrangements after Richard Rendle leaves the secretariat.

The NZIC awards and new NZIC Fellows are announced in this issue (later than usual due to the late timing of the second Council meetings this year) – congratulations to the winners. Speaking of awards, the 2016 Nobel Prize in chemistry was announced in October, this year to Fraser Stoddart, Jean-Pierre Sauvage and Ben Feringa "for the design and synthesis of molecular machines". It's always interesting to see what area of chemistry features in the Nobel award – it often heralds a new area of chemistry having reached a recognisable level of maturity. This year's prize is no different – biochemistry is all about molecular machines which run highly complex and efficient production lines driven by complex algorithms and in which all the components are ultimately molecular in origin. The prize heralds the ability of chemists to now begin to develop synthetic molecular machines, as the Nobel winners and their research groups have done, by harnessing many weak forces to act in a coordinated, concerted way. One of the winners, Fraser Stoddart, has defined a new kind of interaction, the "mechanical bond" involving mechanically interlocked components. An example is a [2]catenane which comprises a pair of rings, one threaded through the other – very simple ideas geometrically but very hard to achieve experimentally (for more information see p.46).

Thanks to all our volunteers at Branch level for their contributions to the NZIC – it is a volunteer-led organisation and we depend on the time, energy and goodwill of all our volunteers. Thanks also to those who serve on Council, especially Honorary General Secretary Richard Rendle and Treasurer Colin Freeman. I hope all of you have had a refreshing summer break and are feeling ready for 2017.

Penny Brothers
University of Auckland
NZIC President 2017

New Zealand Institute of Chemistry
supporting chemical sciences
January News

2016 NZIC Prizes

The **Maurice Wilkins Centre Prize for Chemical Science** has been awarded to Prof. *Christian* ***Hartinger*** of the University of Auckland for his work on the synthesis of bioorganometallic compounds and their potential use as targeted anticancer drugs.

The **Shimadzu Prize for Applied and Industrial Chemistry** has been awarded to Dr *Carla* ***Meledandri*** of the University of Otago for her work on the development of functional nanoscale materials for practical applications, particularly in the area of biomedicine.

The **ABA Resources Denis Hogan Prize for Chemical Education** Dr *Jan* ***Wikaira***, University of Canterbury, for her significant contribution to teaching of chemistry in NZ.

FNZIC

The following members have been accepted as Fellows of NZIC:

Dr *Justin* ***Hodgkiss*** (Victoria University of Wellington) and Dr *David* ***McMorran*** (University of Otago).

AUCKLAND

The University of Auckland

Centre for Green Chemical Science Symposium

The Centre for Green Chemical Science held its 2nd annual symposium at the University Conference Centre on 26 October last. Over 100 people from academia, government laboratories and industry attended the event. The day started with a welcome from the Director of the Centre Professor *James* ***Wright*****.** Two key-note addresses were delivered by Professor Colin Raston, of Flinders University, Australia. Other invited speakers included Dr Beri Mbenkum, founder and CEO of NANORAC and Iain Hosie from the nanomaterials company Revolution Fibres. Professor James Wright also gave a sum-

Ivanhoe Leung, Iain Hosie, Beri Mbenkum, Viji Sarojini, Colin Raston, James Wright and Jon Sperry

Juliet Gerrard, Colin Raston and Iain Hosie

Courtney Davy with James Wright

mary on the progress of the Centre, including updates on the new green chemistry courses CHEM260 and CHEM360 (with updates from students themselves), as well as successful grants, research publications and collaborations associated with the Centre. Several members gave short talks highlighting their green chemistry research, on topics ranging from biomaterials derived from protein waste to hydrogen generation and smart catalytic surfaces for water purification. The day also featured poster presentations by students highlighting their green chemistry research. The best poster prize was shared by *Ram* ***Bhusal*** and *Courtney* ***Davy***. The day ended with a networking session that facilitated interaction between academics, industry participants and students. The committee thanks the members of the Centre and all the participants for their valuable contribution to the success of this event. The committee looks forward to building on the momentum created by the symposium to further advance the goals of the centre. Funding from the Vice-Chancellor's Strategic Research Fund for the Centre is also gratefully acknowledged.

Ram Bhual with James Wright

Erin Leito, recipient of the L'Oréal-UNESCO For Women in Science 2016 Fellowship

The winners of the Velocity 100k Challenge 2016

Congratulations

Congratulations to *Erin* ***Leito*** for winning the L'Oréal-UNESCO For Women in Science 2016 Fellowship. Well done Erin! See the following links for more about Erin's award: www.auckland.ac.nz/en/about/news-events-and-notices/news/news-2016/10/young-chemistry-researcher-named-loreal-fellow.html and www.nzherald.co.nz/science/news/article.cfm?c_id=82&objectid =11735472. Erin also won a Marsden Fast Start grant.

Congratulations *Christian* ***Hartinger*** who has been awarded the 2016 NZIC Prize for Chemical Science.

Congratulations Dr *Kaitlin* ***Beare***, who has been awarded a SEED Innovation in Teaching Grant of $5,000 for her project *Developing a science communications learning activity for a large first year course*.

Well done to *Nihan* ***Aydemi***r, *Eddie* ***Chan***, *Jennifer* ***Barnes***, *David* ***Barker***, *David* ***Williams*** and *Jadranka* ***Travas-Sejdic*** for winning the prestigious Velocity 100k Challenge 2016. Their business proposal (SpotCheck) based on Nihan`s and Eddie's PhD theses was distinguished from more than 300 attendees and 17 highly competitive finalists. They proposed a novel platform technology for very rapid identification and diagnostics of infectious and non-communicable diseases, where a characteristic DNA signature is present. They provide a rapid, portable, sensitive and cost effective solution for molecular diagnostics. For more see: www.velocity.auckland.ac.nz/velocitynewsroom/

id/119/velocity-100k-challenge-winners-revealed

Congratulations to PhD student *Emma* ***Davison***, who has been selected by the Royal Society (London) as a New Zealand delegate to attend the Commonwealth Science Conference held in Singapore in July 2017. Seventy PhD students from across the Commonwealth have been selected by the Royal Society to attend. Emma is working with Dr *Jon* ***Sperry*** on novel synthetic methods for heteroaromatic construction.

Also, well done to *Stefanie* ***Maslek*** who successfully defended her PhD thesis entitled *Synthesis and reactivity studies of main group corrole complexes* and was supervised by *Penny* ***Brothers*** and *David* ***Ware***. Stefanie has already started work at her new job at Scion in Rotorua.

Baptiste ***Auguie*** and *Ben* ***Mallett*** in the Photon Factory have won a Rutherford Discovery Fellowship and a Rutherford two-year New Zealand Postdoctoral Fellowship, respectively.

Congratulations to *Dr Duncan* ***McGillivray*** who has won one of the University Teaching Excellence Awards for Sustained Excellence.

Congratulations to *Katie* ***Parish*** who received joint second place for her poster at the 2016 Exposure Postgraduate Research Exposition prize giving on 6 October. Katie's poster was entitled *Reducing the floral aroma of sauvignon blanc wine*. She is supervised by Dr *Bruno* ***Fedrizzi*** and on the Wine Science Programme.

Associate Professor *Yacine* ***Hemar*** has secured three years of funding for a postdoctoral fellow.

Congratulations to Professor *Jadranka* ***Travas-Sejdic*** and her collaborators on being awarded an MBIE Smart Ideas grant for, *Elastomeric, conductive and functionalised electrospun nanofibers for high-performance anti-fouling microfiltration membranes*.

Congratulations to Dr *Bruno* ***Fedrizzi*** and Associate Professor *David* ***Barker*** who secured ~$300,000 from the Ministry for Primary Industries (via NZ Winegrowers) PGP *Lifestyle wines* programme. The 12-month project will focus on developing molecular sponges to remove selected metabolites from grape juice.

Congratulations to the following students for their success in the Postgraduate Students Association (PGSA) poster competition 2016:

- Katie Parish – *Reducing the floral aroma of sauvignon blanc wine*
- Charlotte Vandermeer – *Grape marc extract can handle the heat!*
- Lakshika Perera – *The good without the bad: selective chelators for beryllium encapsulation*
- Timothy Christopher – *The origins of life: peptide formation following amino acid sorption to a metal oxide*
- Chloe Cho – *Is it safe to humans? Is it safe to environments? A novel biodegradable antimicrobial polymer*
- Nina Novikova – *Using light to treat cancer: phototherapy*

Professional Staff Awards

Congratulations to *Katrina* ***Graaf*** and *Anoma* ***Ratnayake*** for winning Faculty of Science Professional Staff Awards. Congratulations to *Stuart* ***Morrow*** and *Sreeni* ***Pathirana*** who have been awarded the Professional Staff Development Award. This particular award offers professional staff the opportunity to further their development to make a significant and excellent contribution to the University in the fields of administration, management and technical or professional services.

Auckland Cancer Society Research Centre (ACSRC)

Two biology members of the ACSRC were elected as Fellows of the Royal Society of New Zealand in late October. They are Professor *Lynnette* ***Ferguson***, a world leader in nutritional genomics with an international reputation in mutagenesis and in the causes and control of chronic disease, and Professor *Peter* ***Shepherd***, who has made important contributions to understanding how defects in a cell signalling pathway contribute to cancer and diabetes. Peter, who has a PhD in chemistry from Massey University, holds a joint appointment between the ACSRC and the Department of Molecular Medicine and Pathology, and is also deputy Director of the Maurice Wilkins Centre for Molecular Biodiscovery.

CANTERBURY

NZIC Conference

The 2016 NZIC conference in Queenstown had a great turnout from Canterbury Chemistry. It was excellent to see so many of our graduate students presenting posters and taking part in the student presentation competition. *Samantha* ***Bodman*** and *Carline* ***Bakker*** got special mentions for the poster prizes, and *Rob* ***Staniland*** came third in the presentation competition. Well done all!

Trivia and Truffles

The annual NZIC (in conjunction with ChemSoc) Trivia and Truffles quiz was held on 5 October last year at the University of Canterbury Club. The previous weekend various members of both committees (and some smaller, louder helpers) invaded *Jan* ***Wikaira*** and *Don* ***McNickle***'s house to make the truffles (and try not to eat them all). A fun time was had by all, although Jan is probably still picking coconut out of her carpet. Fifteen teams entered the quiz, with a wonderful mix of undergraduate students, postgraduate students, academic staff and chemistry professionals. There were lots of rounds, all with chemistry - related answers including a music round and an "Identify the Scientist" for which there were some interesting answers…. To ease the strain on the marking team, at the end of each round peer marking was invoked, leading to some rather interesting "motivational" comments, thanks *Nic* ***Bason*** and *Sam* ***Bodman***... An excellent effort by the NZIC committee saw many fantastic prizes, including vouchers for Lone Star, Joes Garage, Punky Brewster, Wholly Bagels, La Wheat, LB&Co, Café 101/Reboot and UBS bookshop. Woolfram Beta who were *Nathaniel* ***Gunby***, *Andrew* ***Wallace***, *Chris* ***Stinson*** and *Chris* ***Burn*** took the overall honours. The Isodopes (*Andy* ***Pratt***, *Jan* ***Wikaira***, *Don* ***McNickle*** and *Sarah* ***Masters***) were second, WASABI (*Antony* ***Fairbanks***, *Sam* ***Eason***, *Bryce* ***Williamson***, *Wendy* ***Williamson***) were third, with the AJF Group Meeting Survivors

(*Cormac* ***Hayes,*** *Stewart* ***Alexander****, Jude* ***Ayogu*** and *Jesse* ***Laurila***) came in fourth. The Periodic Table Dancers won the best team name, although sadly didn't provide the cabaret we'd hoped for… Many thanks to *Michael* ***Edmonds*** (ARA) for being our tireless quizmaster, *Jimmy* ***Whitmore*** (UC) for checking the marking and adding up the scores, and to Charles and his UCC crew for help setting up the room!

NZIC President's Lecture

The NZIC President's lecture entitled, *The good without the bad: the search for selective chelators for beryllium encapsulation* was given by Professor *Paul* ***Plieger*** on 16 November last. The presentation described the progress made in developing selective ligands for the beryllium cation. This was preceded by a brief account of the NZIC, its current health, and a call for an open discussion on how to strengthen the organisation including proposals for a web-based membership payment system with email reminders.

University of Canterbury

Awards and appointments

Anna ***Farquhar***, a PhD student supervised by *Alison* ***Downard*** and *Paula* ***Brooksby,*** won first prize in the best poster competition at the 3rd International Conference on Nanotechnology, Nanomaterials and Thin Films for Energy Applications at the University of Liverpool, UK. Her poster was entitled, *New reagents for monolayer formation on few-layer graphene and other graphitic carbons*.

Dr *Sarah* ***Kessan*** has made the NASA astronaut pool. Sarah applied to be a NASA astronaut a year ago and was selected into the highly qualified (HQ) pool of applicants for NASA's Astronaut Candidate Class of 2017. This pool represents the top ~3% (~450 of the initial 18,300 applicants this selection period). Sarah made it through the next round of cuts made between July and September, when ~120 of those in the HQ pool were invited to Houston for initial interviews. Details of Sarah's experience and initial interview can be found at: http://www.comsdev.canterbury.ac.nz/rss/news/?articleId=1989. Fifty applicants will be invited for finalist interviews, after which 14 will be chosen as NASA's 22nd Astronaut Candidate Class, reporting for duty in August 2017, conveniently when her current contract with UC expires (http://astronauts.nasa.gov/content/timeline.htm). Sarah is a postdoctoral fellow with *Emily* ***Parker***'s research group in the Chemistry Department.

Congratulations to *Rob* ***Stainthorpe*** who received the VC General Staff Development Award. Rob will use this grant to assist in attending specialised training in Brisbane on the management of metal-free clean room facilities. Congratulations also to *Kalib* ***Bell*** (Downard Group) and *Nathaniel* ***Gunby*** (Masters Group) who both successfully defended their PhD theses. Kalib is working at AuramerBio in Wellington and Nathaniel is undertaking postdoctoral research with Deb ***Crittenden*** and *Ren* ***Dobson***. Deb Crittenden was one of three winners of the Tech Jumpstart competition and receives $20,000 of funding for the development and commercialisation of her research into design, synthesis and fabrication of novel batteries. Congratuations Deb! Professor *Mark* ***Turnbull***, who has visited our department on a number of occasions and who is to be an Erskine visitor in 2017 was recently awarded the prestigious John A. Timm award for excellence in teaching and the promotion of chemistry by the New England Association of Chemistry Teachers.

Professor *Ian* ***Shaw*** was awarded the UC Student Association's Lecturer of the Year (Science) jointly with *Travis* ***Horton*** (Geological Sciences).

The team of Dr. *Alex* ***Yip*** (Chemical and Processing Engineering department), PhD student *Iman* ***Hashemizadeh***, and Dr *Vladimir* ***Golovko*** won the supreme UC sustainability award 2016 for the work by Iman on making novel photocatalysts using bio-templates (see: http://www.sustain.canterbury.ac.nz/awards.shtml). A small amount of funding was also received from the Royal Society of NZ Catalyst Fund to work on this project in collaboration with overseas partners (see: http://www.comsdev.canterbury.ac.nz/rss/news/?articleId=1953).

Congratulations to Dr *Sarah* ***Masters*** (Chemistry) who was awarded $30,250 from the MBIE Catalyst Fund 2016 for a two-year research project, *Direct molecular imaging of gas-phase macromolecular biological systems*. The fund, partly administered by the RSNZ on behalf of MBIE, is aimed at advancing global science partnerships for New Zealand.

Congratulations to the following academics who were successful in the Chemistry Department Contestable Funding recently: *Antony* ***Fairbanks***, *Chris* ***Fitchett****, Sally* ***Gaw*** and *Vladimir* ***Golovko***.

Congratulations to *Antony* ***Fairbanks*** on his success in being awarded a Marsden Grant of $870,000 for his research entitled *A new paradigm for organelle targeting*. A great achievement! Further details are available at: http://www.royalsociety.org.nz/programmes/funds/marsden/awards/2016-awards/.

Jan ***Wikaira*** received the ABA Resources Denis Hogan Chemical Education Award from the NZIC. The following citation given by the Branch is a mere snapshot of the contribution that Jan has made to all levels of tertiary teaching over many years in New Zealand: "Dr Jan Wikaira is possibly a unique tertiary educator in New Zealand as she has taught at all educational levels, from pre-school to PhD students. Jan has made an immeasurable contribution in the area of enabling students to successfully transition from secondary to tertiary education, developing a 100 L mentoring model that is envied across the University of Canterbury (UC). She has also developed a demonstrator training program to ensure that demonstrators are equipped with the appropriate cultural and educational skills and tools to interact successfully with the students. The demonstrator training has also been used as the basis for more generic tutor training at UC. Jan brings an infectious enthusiasm for teaching and learning to the students that she interacts with, and was awarded a UC teaching excellence award in 2005. She was also recently nominated for an Ako Aotearoa Tertiary Teaching Excellence Award, a measure of the esteem in which UC values her teaching

contribution over many years. She has worked tirelessly to ensure that all students have an equal opportunity to maximise their learning. As a mature student who came to chemistry later in life she brings a unique perspective to tertiary education, and is able to relate her struggles and ultimate success to the students to inspire them to greater things." Many congratulations Jan!

Sarah ***Masters*** recently completed a Pre-Hospital Emergency Care Revalidation course with Red Cross New Zealand. The two day revalidation included how to use the PHEC equipment in resuscitation, primary and secondary surveys, burns, fractures, bleeding, how to move someone (drag, lift, stretcher), scene management and various scenario based assessments. Whilst revalidated, she does cordially request that everyone continues to work safely so as not to need her in any way, shape or form!

Ian ***Shaw*** appeared in his regular slot on RNZ National's *This Way Up* on Saturday 5 November pontificating on acrylamide in food…spiffing! Here's the link: http://www.radionz.co.nz/national/programmes/thiswayup/audio/201822511/acrylamide-infood-should-we-be-worried.

Dr *Rebecca* ***Warr*** joined Research & Innovation as a Business Development Manager and will be engaging with the College of Science. She states, "My responsibilities include connecting industry and UC researchers, maximising the value of consultancy and contract research, and identifying IP opportunities arising from the University's expertise. I will be working alongside R&I's other Business Development Managers John Duncan and Dave Humm. I am a graduate of UC's department of chemistry where I completed a BSc (Hons). I then went on to complete a PhD in inorganic chemistry from the Australian National University and a subsequent postdoctoral fellowship at the University of Nottingham. On returning to Christchurch I joined Izon Science, a NZ-founded biotech company who design and manufacture instruments for nano- and microparticle analysis. My role at Izon engaged with many business aspects of developing, releasing and supporting new products to the science market. I look forward to re-connecting with familiar faces and meeting new ones.

Visitors

Associate Professor Peter Teasdale is an Erskine Visitor, hosted by Dr *Sally* ***Gaw***. Peter is from Griffith University, Gold Coast, Australia and teaches at the School of Environment. To see his research expertise and publications, go to https://www.griffith.edu.au/environment-planningarchitecture/griffith-school-environment/staff/peter-teasdale.

MANAWATU

Associate Professor *Vyacheslav* ***Filichev*** gave an invited lecture at the 43rd International Symposium on Nucleic Acids Chemistry 2016, held in Kumamoto, Japan (September 27 – 29). He also presented his recent work in a talk given at the 2nd International Symposium of Chemistry and Biology of RNA Interference organised by Masayuki Fujii and held at Kindai University, Japan (September 30, 2016). On the way back to New Zealand, Vyacheslav visited the School of Chemistry and School of Physical & Mathematical Sciences at Nanyang Technological University in Singapore, and gave a presentation entitled *TINA-DNA assemblies in biomedical and fluorescence applications*.

In September, several members of IFS presented their research at the 5th International Conference on Metal-Organic Frameworks in Long Beach, California. These delegates were Professor *Shane* ***Telfer***, *Heather* ***Jameson***, *David* ***Perl***, and *Adil* ***Alkas***. The next event in the series will be chaired by Shane Telfer; over 500 people with interests in MOFs and related porous materials are expected to descend on Auckland in December 2018.

NZIC Past-President *Paul* ***Plieger*** completed his visits to universities up and down the country giving his presidential talk. He would like to thank the Branches for hosting him.

The Institute of Fundamental Sciences warmly welcomes the newest students and doctors to join our ranks:

- In October, Dr Maksim Kvach and Dr Stefan Harjes joined the group of *Vyacheslav* ***Filichev***, *Elena* ***Harjes***, and *Geoff* ***Jameson***. They will be working on the development of DNA-based inhibitors of the APOBEC3B enzyme, funded by the Worldwide Cancer Research.
- Subo Lee and Joel Cornelio have begun PhDs under the supervision of Professor *Shane* ***Telfer***. Their projects focus on multicomponent metal-organic frameworks.
- Mr Hirofumi Fujii from the group of Professor Masayuki Fujii (Kindai University, Japan), arrived on 12 November and will work in the group of *Vyacheslav* ***Filichev*** for 6 months as a part of his MSc study.
- Mr Tim Engels, from Fontys Univer-

Jan Wikaira receiving her award from NZIC President Paul Plieger on 16 November 2016

sity, Netherlands, is undertaking a six-month internship with Associate Professor *Gareth* ***Rowlands***.

3rd year chemistry student Sidney Woodhouse was awarded an Institute of Fundamental Sciences Summer Scholarship. She has begun her research with Associate Professor *Paul* ***Plieger*** on the design and synthesis of manganese-containing complexes suitable for single-molecule magnet behaviour.

Massey University welcomed several speakers:

- Tony Signal, Professor of Physics at Massey University, gave a seminar on 1 September entitled, *What do we really know about the spin of the proton?*
- *Jonathan* ***Sperry***, RSNZ Rutherford Discovery Fellow and Senior Lecturer in organic and medicinal chemistry, University of Auckland, gave a talk on 19 October on *Design and synthesis of novel biologically active entities based on leads from nature*.
- Tom Bennett, Research Fellow at Trinity Hall at the University of Cambridge, spoke on 15 November on the topic of *Metal-organic framework glasses: a novel family of chemically tunable melt-quenched glasses*.

OTAGO

This year's High School Chemistry Quiz, held on 22 September, saw 31 teams from schools around Dunedin and from further afield convene on the Otago Museum's Hutton Theatre. After the usual feed of pizza from Poppas, things got down to business with five rounds of questions of both a chemical nature as well as general knowledge. Teams also contributed Chemical Haiku for extra prizes. After a tense tie-breaker question the winning teams were as follows:

1st Place: **The Dandy Lions** (Logan Park High School): Grant McNaughton, Henry Gordon, David Spencer

2nd Place: **HCOONa Matata** (Columba College): Chloe Lai, Jenny Mi, Ophelia Yeung, Annabelle Richie

3rd Place: **Barry B. Benson** (Logan Park High School): Kate Denys, Erica Stedman, Maria Larsen, Katherine Woolrych

Our thanks as always to the generous support of Poppas Pizzas, the Otago University Bookshop, the Otago Branch of the New Zealand Institute of Chemistry, the University of Otago and to quizmaster extraordinaire *Dave* ***McMorran***.

University of Otago, Department of Chemistry

The department was successful in the most recent MBIE and Marsden Fund rounds. *Eng* ***Tan*** was awarded $933,000 over 3 years from the 2016 Endeavour Fund for his Smart Idea project *Intelligently deformable skin penetrating nanoparticles for drug delivery through skin*. *Carla* ***Meledandri***, together with colleagues from the School of Dentistry, was awarded a similar amount for their Smart Idea project *Silverbone - Otago's nanosilver technology plus NZ-manufactured bonegraft produces unique antibacterial biomaterial*. *Keith* ***Gordon*** and *Sara* ***Fraser*** were involved in a successful MBIE research programme with AgResearch for the project: *Capturing the true value of NZ meat: objective measurement of meat quality in beef, lamb and venison*. *Anna* ***Garden*** and *Matthew* ***Clarkson*** were both awarded Marsden Fund Fast Start grants worth $300,000 for their projects, *A green approach to denitrification of water* and *How does the Earth stop global warming? Testing climate stabilisation during 'hyperthermal' events* respectively.

First place winners, the Dandy Lions, from Logan Park High School

Jaydee ***Cabral*** has a Master's student, Claudio Intini, visiting from the Department of Pharmacy, University of Parma, Italy who in collaboration with Michelle McConnell (UoO Microbiology & Immunology) is determining the biocompatibility of 3D printed chitosan scaffolds.

A number of staff and students presented their work at the D4: Diagnostic, Drug, Device, Discovery conference in Dunedin. Special mention goes to *Gemma* ***Cotton*** (PhD student with *Carla* ***Meledandri***) for winning the best student talk prize. Well done, Gemma!

Charlie ***Ruffman*** joined *Anna* ***Garden***'s group as a summer student and *Caitlin* ***Casey-Stevens*** finished her BSc (Hons) degree in the same group. Caitlin was also joint recipient of the P.K. Grant prize for experimental skill and research methodology at 400-level. The prize was shared with *Michael* ***Badart*** (*Bill* ***Hawkins*** group) and *Jordan* ***Smith*** (*Nigel* ***Lucas*** group). Michael and Jordan also shared the Joseph and Emma Mellor Prize for the leading students of 400-level chemistry. Great work, guys!

Dave McMorran holding court at the high school chemistry quiz

In May *Sally* ***Brooker*** was invited by Professor Garry Hanan to the University of Montreal where she conducted a PhD oral and presented a department seminar. Then in June-July, Sally and three of her PhD students, *Ross* ***Hogue***, *Santi* ***Rodriguez-Jimenez***, and *Stuart* ***Malthus***, travelled to Europe. They visited collaborators Professor Martin Albrecht (Bern), Professor Roberta Sessoli (Florence) and Professor Charlotte Williams (Imperial College London) and participated in the 42nd International Conference on Coordination Chemistry (ICCC) in Brest, France (see photos). Stuart and Sally gave invited lectures, and Ross and Santi presented posters – with Santi winning a poster prize. On the way home, Sally, Ross and Stuart were joined by research fellow *Humphrey* ***Feltham*** at the RACI inorganic chemistry division (IC16) meeting in Melbourne. Ross presented a lecture as a finalist for the Stranks award, and Sally and Humphrey also presented invited lectures. More recently, Sally and her PhD students *Hannah* ***Davidson*** and *Ross* ***Hogue*** participated in the winter NZIC conference in Queenstown, with Hannah and Sally presenting invited lectures – Hannah as the Otago representative in the best student lecture competition. Then, in September, Sally visited and presented an invited department seminar at ANU, as the student choice of speaker.

Planning for the second, student-focussed, SANZMAG magnetism workshop, **SANZ-O-MAG2**, which will be held at Otago University, 8-10 February 2017 (prior to AMN8, Queenstown, 12-16 Feb) is coming along really well. Check out the website (http://neon.otago.ac.nz/research/sanzmag2/ – there's a link off Sally's website), to see the exceptional list of tutors and tutorial titles.

Keith ***Gordon*** and his group have had a busy quarter again. Keith gave a talk in South Korea at the 14th International Conference on Frontiers of Polymers and Advanced Materials (ICFPAM) 2016 on *Spectroscopic and computational studies of donor-acceptor compounds: bringing prediction to complex systems*. He gave an invited talk at SciX 2016: The 43rd Annual North American Meeting of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS). *Georgina* ***Shillito*** was a co-author and the talk was titled: *A resonance Raman and computational study of ruthenium(II) complexes with substituted dppz ligands*. Keith gave yet another talk at the Dodd Walls / Agritec joint research meeting. Keith and postdoctoral fellow *Sara* ***Miller*** wrote a book chapter: Gordon, K. C., & Fraser-Miller, S. J. (2016). Raman spectroscopy. In A. Müllertz, Y. Perrie & T. Rades (Eds.), Analytical techniques in the pharmaceutical sciences. (pp. 139-169). New York: Springer. doi: 10.1007/978-1-4939-4029-5_4.

Dan ***Killeen*** (now at Plant & Food Nelson) ex-PhD student of the group (with Nigel Perry) is currently working with Keith Gordon on lipids, see:

Left to right: Ross, Santi, Roberta and Stuart in one of Roberta's labs in Florence

Left to right: Santi, Sally, Ross and Stuart at the ICCC conference dinner

Geoffrey Smith delivering his talk at the Confocal Raman Imaging Symposium in Ulm, Germany

Hall, D. W., Marshall, S. N., Gordon, K. C., & Killeen, D. P. (2016). Rapid quantitative determination of squalene in shark liver oils by Raman and IR spectroscopy. Lipids, 51(1), 139-147. doi: 10.1007/s11745-015-4097-6.

PhD student *Georgina* ***Shillito*** attended a computational chemistry, Gaussian workshop in Japan at the Tokyo Institute of Technology in September. She also recently published a paper entitled, *Effect of bridge alteration on ground- and excited-state properties of ruthenium(II) complexes with electron-donor-substituted dipyrido[3,2-a:2',3'-c] phenazine ligands*. doi: 10.1021/acs.inorgchem.6b01810.

Recent PhD graduate *Geoffrey* ***Smith*** gave a talk in Germany at the 13th WITec Confocal Raman Imaging Symposium about *Easy imaging of processed cheese microstructure*. The content of the talk was also published recently in the journal article: *Raman imaging of processed cheese and its components*" in the Journal of Raman Spectroscopy, doi: 10.1002/jrs.5054. He also recently secured a position as a postdoctoral researcher at the University of Helsinki working with Associate Professor Clare Strachan.

PhD student *Ruth Eloisa* ***Sales*** had a collaborative visit to the Department of Physics, University of Auckland, where she delivered her talk, *Spectroscopy of New Zealand lamb meat: a preliminary analysis*" to the PS1 Sensing Theme seminar for Dodd-Walls Center and to the Bio-Engineering Institute weekly forum. Ruth is currently trying to build broadband coherent anti-Stokes Raman scattering experiment in collaboration with Frederique Vanholsbeeck from the University of Auckland.

PhD student *Jonathan* ***Barnsley*** attended the Gordon Research Conference/Seminar Electron Donor Acceptor and the International Conference on Raman Spectroscopy (ICORS XXV) to present *Donor-acceptor interactions of 2,1,3-benzothiadiazole push-pull dyes* in poster and oral format, respectively. Jonathan was also awarded the Claude McCarthy and Johan Gadolin fellowships for collaborative exchanges with the Wollongong University and Åbo Akademi.

William ***Pellet*** joined the group as a summer student working with Associate Professor *James* ***Crowley***'s team on the *Spectroscopy of decorated iron bipyridyl complexes which show actuation*. *Greg* ***Huff*** submitted his PhD, *Excited states of d^6 and d^8 metal complexes* and had his latest paper accepted in Inorganic Chemistry: *Excited states of triphenylamine-substituted 2-pyridyl-1,2,3-triazole complexes*. *Joshua* ***Sutton*** completed his BSc(Hons) degree in chemistry and is currently studying the resonance Raman of organometallic systems in collaboration with Paul Wagenknech, at Furman University, USA.

WAIKATO

University of Waikato

Nearly 200 students from the greater Waikato region and Bay of Plenty participated in the Annual ChemQuest Competition, held by the Department of Chemistry. This was a fun-filled evening for students studying NCEA level 2 chemistry. It was a very close contest with only two marks separating first and fifth place. Prizes were shared across the Greater Waikato and Bay of Plenty region and were awarded as follows:

1st Place: **Katikati College:** (Fergus Chinnery, Lucy Douglas, Steven Zhang)

2nd Place: **Hillcrest High School:** (Grace Zheng, Kristen Xu, Annabel Zhou)

3rd Place: **Tauranga Boys' College:** (Fraser Blakeway, Adam Hitchner, MD Shadman Jahin)

4th Place: **Waikato Diocesan School for Girls:** (Devon Bree, Katherine Han, Chelsea Lin)

5th Place: **Whakatane High School:** (Thomas Brownless, Ashlee Waikawa, Te Rameka Waldon)

The quiz was generously sponsored by the Waikato Branch of NZIC (major sponsor), Hill Laboratories, James & Wells Intellectual Property, and the Faculty of Science and Engineering, University of Waikato. Question master was *Michèle* ***Prinsep***, ably assisted by numerous other staff and students from the Department.

Michèle ***Prinsep*** attended the Waikato Science Teachers' Association Symposium and gave a keynote talk entitled, *From land to sea & macro to micro: natural products from micro-organisms & marine invertebrates*.

Scion

In September Warren Grigsby (Scion) and his team were awarded the 2016 NZBIO Biotechnology of the Year award for their bio-based adhesive technology. Warren also travelled to Europe on a RSNZ science exchange fellowship, giving a talk on this adhesive system at the Adhesion Society Euradh2016 meeting in Glasgow before spending time at the University of Hamburg and Thunen Institute analysing adhesive interfaces.

WELLINGTON

Two student-focussed Branch events in September and October last year were highly successful. A careers session was held at Victoria University on 14 September and was attended by 40 students who heard from five Victoria chemistry graduates about their jobs in diverse employment sectors, including as a forensic toxicologist, a patent attorney, a policy analyst, a postdoctoral researcher and an application scientist. The panel of speakers gave students advice about securing their first job, what was most useful in their studies for the role they now hold, and encouragement to grasp opportunities. A visit to GlycoSyn by 20 students in October included a pre-tour talk from the General Manager *Paul* ***Benjes*** about pharmaceutical manufacture and projects that GlycoSyn has worked on, followed by the tour to scale-up labs, analytical facilities and the cGMP manufacturing facility, followed by pizza.

In November, we held our AGM and elected the new committee for 2017:

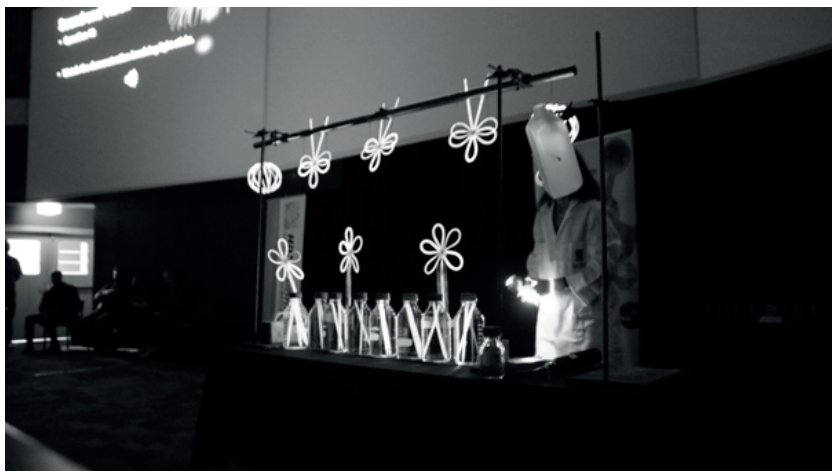
- Chairperson – Robin Fulton
- Secretary – Emma Wrigglesworth
- Treasurer – Ralf Schwoerer
- Committee members – Justin Hodgkiss, Tim Kemmitt, Suzanne Boniface, Ian Brown, Christoph Hasenoehrl
- Branch editor – Joanne Harvey

After the AGM, we were treated to *Paul* ***Plieger***'s Presidential Lecture that covered the state of the NZIC and new initiatives to enhance the institute, as well as a fascinating discussion of beryllium chemistry with a view to encapsulating the highly toxic metal. *Justin* ***Hodgkiss***' Fellowship of the NZIC was awarded at the meeting.

An NZIC Wellington Branch Student Travel Grant was awarded to PhD student *Sophie* ***Geyrhofer*** to attend and present a poster and short talk at the Drug Discovery satellite of Queenstown Research Week, held this year in Nelson. The satellite was organised by Wellington Branch members *Gary* ***Evans*** and *Joanne* ***Harvey*** and was attended by a record 90 delegates, primarily from NZ and Australia.

The NZIC Wellington Branch awarded four prizes at the NIWA Science and Technology Fair in September for projects that had a chemistry focus and/or demonstrated chemical techniques. The winners were a Year 7 student from Hutt Intermediate School, for *Let's 'C' what's in your food* – measurement of Vitamin C in various foods, using starch-iodine titration; a Year 8 student from Wadestown School, for *Shells in acidic seawater* – measurement of shell loss from shells maintained at different pH values; a Year 10 student from Wellington College, for *Electrolysis with a magnetic twist* – measurement of hydrogen gas evolved from the electrolysis of water with and without an applied magnetic field, and a Year 13 student from Queen Margaret College, for *The heat is on* – measurement of oxidation of different quality olive oils using thiosulfate titration.

Prize winners: The winning team from Katikati College, Steven Zhang, Fergus Chinnery and Lucy Douglas, with Martin Brock from Hill Laboratories (far left) and the chairperson of the Waikato branch of the NZIC, Associate Professor Michael Mucalo (far right).



Chemquest in action.

Victoria University (VUW)

Ken ***MacKenzie*** spent three weeks in August as a visiting Professor at the Department of Energy, Environment and Materials, King Mongkut's University of Technology, Bangkok, giving seminars and advising postgraduate students in materials science.

In late August, *Robin* ***Fulton*** attended the International Conference on the Coordination and Organometallic Chemistry of Germanium, Tin and Lead, where she was one of the conference organisers. She presented a talk on *The chalcophilicity of germanium, tin and lead phosphanide complexes*. As it was a very specialised conference, she found it very inspiring to discuss chemistry with like-minded chemists, and was able to develop some international collaborations.

In October, *Peter* ***Tyler*** gave his inaugural Professorial Lecture entitled *Chemistry adventures in drug discovery* to an appreciative audience.

In August, *Joanne* ***Rogers*** completed the requirements for her PhD. Her thesis title was *New luminescent materials based on aluminosilicate and gallium silicate inorganic polymers*,

supervised by Professor *Ken* ***MacKenzie***.

In November, *Christoph* ***Hasenoehrl***, one of this year's student branch committee members, successfully defended his PhD thesis. Christoph was supervised by Richard Tilley, now at UNSW in Australia, and *Martyn* ***Coles***.

Victoria University was successful in the latest round of Marsden grants, with branch members *Justin* ***Hodgkiss*** and *Mattie* ***Timmer*** gaining funding for *The origin of UV photoprotection in the brown skin pigment eumelanin* and *The missing link: a traceless linking strategy for the conjugation of complex carbohydrates to proteins and peptides*, respectively.

In MBIE funding, Victoria University chemists and branch members *Peter* ***Tyler***, *Jim* ***Johnston***, *Justin* ***Hodgkiss*** and *Gavin* ***Painter*** and their colleagues were successful with *New methodology for the synthesis of sulfated oligosaccharides*, *Enhanced geothermal energy recovery through nanotechnology: an innovative enduring solution to the worldwide silica deposition problem*, *Aptamers for customisable analytical devices: application to methamphetamine detection,* and *Manufacture of self-adjuvanting peptide vaccines for cancer and infectious disease*, respectively.

J. Stephen Clark, who is on sabbatical in Sydney, visited Victoria University on 25 November as part of his NZ tour and presented a seminar on the total synthesis of the amphidinolide natural products.

ESR

The international association of forensic toxicologists (TIAFT) held their 54th annual meeting in Brisbane, Australia in August 2016. Dr Helen Poulsen presented *Motorcycle fatalities in New Zealand* and Rosemary Moar presented *A snap 'shot' of fantasy in New Zealand*. Thalita van Aswegen also attended.

The Australia and New Zealand Forensic Science Society (ANZFSS) held their 23rd International Symposium in Auckland in September 2016. Dr Helen Poulsen presented *Motorcycles and tarmac - a slice of heaven* and Andrew Murray presented *A snap 'shot' of fantasy in New Zealand*. Alison Colgate and Thalita van Aswegen also attended.

Samantha Coward presented to the Wellington Branch of New Zealand Forensic Science Society on *Alcohol analysis* in July 2016.

BRANZ

Trish ***Shaw*** delivered the *PF Thompson Memorial Lecture* at the Corrosion & Prevention 2016 conference hosted by the Australasian Corrosion Association in Auckland, 13-16 November. Percival Faraday Thompson (1885-1951) pioneered the science, technology and mitigation of corrosion in Australasia. Trish's presentation focussed on the corrosion of polymeric materials and included a live demonstration of how chemical degradation can be assessed using BRANZ's portable ATR FTIR instrument. By all accounts the lecture was very well received by the audience. At the conference dinner, Trish was presented with the *AC Kennett Award* for the best paper on non-metallic corrosion submitted during the previous 12 months. Our congratulations to Trish for her very successful week!

Trish Shaw delivering her invited lecture (top) and receiving her award (bottom). Photo credit: Australasian Corrosion Association

Biological activated carbon and advanced oxidation processes for the removal of cyanobacterial metabolites in drinking water treatment

Daniel Bernstein,[1*] Graeme Glasgow,[2,3] Merilyn Manley-Harris,[1,3] Mark Lay[2]

[1] School of Science, Faculty of Science and Engineering, University of Waikato, Private Bag 3105, Hamilton 3240

[2] School of Engineering, Faculty of Science and Engineering, University of Waikato, Private Bag 3105, Hamilton 3240

[3] Environmental Research Institute, Faculty of Science and Engineering, University of Waikato, Private Bag 3105, Hamilton 3240 (email: *drbernstein1@gmail.com*)

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Abstract

Biological activated carbon (BAC) and advanced oxidation processes (AOPs) are often used in conjunction during drinking water treatment for the removal of trace organic compounds that are not effectively removed during traditional treatment processes such as coagulation, flocculation and sand filtration. These trace organic compounds include toxic cyanobacterial metabolites such as saxitoxins and taste and odour (T&O) causing compounds like geosmin and 2-methylisoborneol (2-MIB) which are produced by a number of bacterial species including cyanobacteria. At present, the Hamilton Drinking Water Treatment Plant (HDWTP) employs the use of BAC as part of the final stage of drinking water treatment for its municipal water supply. This article provides a general overview of the chemical and physical processes involved and a review of the current state of AOP technology.

Introduction

The use of carbon as a means to purify water dates back to antiquity, with Hindu documents dating from around 450 BC making references to the use of charcoal filters for this purpose. The use of activated carbon for this purpose, however, is a more recent advance and it was first used as a means to dechlorinate chlorinated drinking water in 1910. Since then, it has been applied to a wide range of treatment problems including the removal of taste and odour – (T&O) causing compounds, synthetic organic contaminants (SOCs) and disinfection by-products (DBPs).[1]

Activated carbons (ACs) are porous carbonaceous materials capable of adsorbing a wide range of aqueous phase solutes. Because of their porosity and very high surface area (500-1500 m^2g^{-1}), they have the potential to adsorb very large amounts of material.[1,2]

The nature of the starting material, carbonisation conditions and activation process all contribute to the properties of the AC produced. Such properties include porosity, pore size, pore size distribution, surface functionality, and ash content.[1,2] The surface functionality of ACs plays an important role in the adsorption of organic solutes and is comprised mainly of oxygen based functional groups such as acidic groups including strong and weak carboxylic acids, phenols and carbonyls (α protons). Basic surface groups such as cyclic ethers are also generally present, with higher activation temperatures resulting in a more basic surface. Other components of ACs such as minerals, e.g. calcium, sulphate, and phosphate ions and ash (silica, alumina, iron oxides, and alkaline earth metals) also contribute to the surface activity.[1]

While activated carbon is very good at removing problematic compounds from drinking water sources, due to the physical nature of the process and the finite number of absorption sites, the surface of the AC becomes saturated over time. Once the surface of the AC is saturated, adsorption no longer occurs (or is substantially reduced) and breakthrough of previously adsorbed compounds is observed.[3] To remedy this situation, the AC must either be replaced or regenerated, both of which are costly processes.

A method to overcome this problem that has become increasingly exploited over the years, both in drinking and waste water treatment, is the use of biological activated carbon (BAC). In this mode of operation, microbial communities are allowed to colonise the AC media as the adsorption capacity becomes depleted. Once colonised, compounds that were previously removed by physical adsorption may now be metabolised enzymatically by the microorganisms that inhabit the AC surface.

Granular activated carbon in drinking water treatment

In drinking water treatment, the filter media in fixed bed carbon filters usually consists of granular activated carbon (GAC). Granular activated carbons generally have a particle size ranging from 0.2-5 mm and are designated by mesh sizes such as 8/20, 20/40, or 8/30 for such applications.[1,4]

The use of GAC in drinking water treatment is a very common practice and is implemented with the aim of removing unwanted contaminants from source water intended for use as drinking water that cannot be removed via primary treatment.[1,3,5] As such, the composition of the source water and the specific contaminants it may contain mean that GAC is employed for different reasons

depending on location.[1,5] In Hamilton, GAC filtration was introduced as a precautionary measure for the removal of cyanobacterial metabolites, particularly cyanotoxins like microcystins (Fig. 1) and saxitoxins (Fig. 2), that may pose serious health risks during potential cyanobacterial blooms in the future.[6] Additionally, GAC is extremely effective in the removal of T&O causing compounds[1] such as geosmin and 2-methylisoborneol (GSM and 2-MIB; Fig. 3) which are known to be present in the Waikato River and were another reason for the initial implementation of GAC at the Hamilton plant.[7]

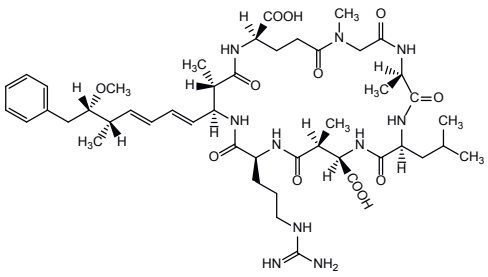
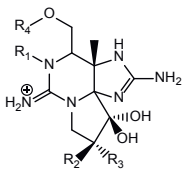


Fig. 1. Molecular structure of microcystin L-R



	Substituent Groups			
Toxin	**R1**	**R2**	**R3**	**R4**
STX	H	H	H	$CONH_2$
GTX2	H	H	OSO_3^-	$CONH_2$
GTX3	H	OSO_3^-	H	$CONH_2$
C1	H	H	OSO_3^-	$CONHSO_3^-$
C2	H	OSO_3^-	H	$CONHSO_3^-$
dcSTX	H	H	H	H
dcGTX2	H	H	OSO_3^-	H

Fig. 2. General structure of saxitoxins and the substituents of some common analogues[8-10]

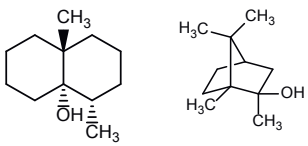


Fig. 3. Molecular structures of geosmin (left) and 2-methylisoborneol (right)

Biological activated carbon

The GAC filters currently in service at the HDWTP have been in use since 2007 following an extensive upgrade of the plant. Due to the length of time the filters have been operating, it is generally thought that adsorption processes have largely ceased and any removal of contaminants is a result of biological activity.[7] Indeed, the long term plan for the use of these filter was for them to operate as BAC filters once adsorption capacity was exhausted and a biofilm was gradually established.[11]

For successful operation of GAC filters operating in the BAC mode, certain operational criteria must be met in order to achieve sufficient removal of the target compounds. These criteria include ensuring the influent target compounds are in a form that is readily biodegradable (biodegradable organic matter; BOM) by the filter microorganisms and allowing sufficient contact time to permit diffusion of target compounds to the surface bound bacterial colony for metabolism to occur.

Usually, to increase the BOM fraction of influent dissolved organic matter (DOM), an advanced oxidation process (AOP) such as ozonation is implemented prior to the BAC filter, with the "BAC process" referring to the coupled mode of operation. While this was initially considered during the upgrade of the HDTWP, it was not implemented at the time. However, the design of the upgrade allowed contingency for the addition of such a process in the future if required.[11]

In order to provide sufficient time for the mass transport of these contaminants from the liquid phase into the bacterial cell for metabolism to occur, the contact time of water within the filter must be sufficiently long. In the operation of GAC and BAC filters, this is generally measured using the "effective empty bed contact time" (EBCT), which is a measure of the average time water would take to traverse the filter bed if the filter were empty. For BAC filters, an EBCT of greater than 7.5 minutes is generally thought to be sufficient if it is coupled to an AOP prior to the filter. Without the associated AOP, EBCTs of 10 minutes or more are considered more appropriate and this reflects the current operation of the filters at the HDWTP.

The general mechanism of removal of problematic compounds by bacteria occurs via secondary metabolic pathways acting upon the target compounds as secondary substrates due to their low concentration (ng L^{-1}), with the total organic carbon (TOC) which is present at much higher concentrations (mg L^{-1}) providing the primary substrate for primary metabolism. For example, GSM and 2-MIB are generally present in Hamilton source water at baseline levels of 5 to 50 ng L^{-1} which is noticeable to many people, imparting an earthy or musty character to the water (Table 1). Hence, the degree of removal needs to be very good and provide high percentages of removal even when the influent concentration is very low. The degree of removal is also very important for compounds like cyanotoxins which are covered under the Drinking Water Standards for New Zealand (DWSNZ) where, for example, the maximum acceptable value (MAV) for microcystins is set at 1 µg L^{-1}.[12]

Table 1. Odour concentration threshold values for geosmin and 2-MIB[13]

Compound	Odour concentration threshold (ng L^{-1})
Geosmin	6-10
2-MIB	2-20

While the desired outcome of metabolic transformation of target compounds is, at a minimum, the loss of chemical functionality that imparts undesired properties to finished drinking water (taste and odour, colour, toxicity, etc.), this may not always be the case. For example, there is some evidence to suggest that during the degradation

of saxitoxins in biological filters, those with lower relative toxicity like C1, C2, GTX2 and GTX3 (Fig. 2) are converted to the more toxic STX, potentially leading to an increase in toxicity following biological filtration and in other environmental contexts.[14-16] In situations where the influent water is known to contain high levels of saxitoxins, for example during a cyanobacterial bloom, it may be necessary to implement an AOP temporarily so as not to potentially exacerbate the problem.

Advanced oxidation processes

Advanced oxidation processes (AOPs) are often employed in drinking water treatment as a method of removing unwanted organic impurities and trace organic pollutants via chemical oxidation, with the ultimate aim of complete mineralization to C-O_2.[17] In particular, AOPs are a useful method for increasing the BOM fraction of the TOC prior to BAC or another type of bio-filtration system as a means of allowing compounds resistant to biodegradation to be metabolised more effectively by the biofilm. Of course, as a living biomass is involved, sufficient time must be allowed for the oxidant residual to decrease to a level that will not affect the health of the biological media following the AOP treatment.[18] Additionally, the AOP used must not contribute an increase in the trihalomethane (THM), haloacetic acid (HAA) or other disinfection by-product (DBP) formation potential, as these are tightly controlled under the DWSNZ.[12]

Although a range of AOPs are currently employed in various drinking and waste water treatment scenarios, almost all are based on the production of highly reactive radical intermediates, specifically the hydroxyl radical ($^{\bullet}OH$, Table 2).[19] Under most conditions, $^{\bullet}OH$ will react via addition to unsaturated carbon-carbon bonds, aromatic substitution, hydrogen abstraction, or mono-electronic oxidation.[20]

Table 2. Standard half-cell potentials for some oxidants commonly used in water treatment[5,21,22]

Oxidant	Reduction half-reaction	E°_{red}(V)
Titanium dioxide "hole"*	$TiO_2\ (h^+) + e^- \rightarrow TiO_2$	3.20
Hydroxyl radical	$^{\bullet}OH + H^+ + e^- \rightarrow H_2O$	2.85
Ozone	$^1/_3O_3 + H^+ + e^- \rightarrow {}^1/_2H_2 + {}^1/_2O_2$	2.08
Hydrogen peroxide	$^1/_2H_2O_2 + H^+ + e^- \rightarrow H_2O$	1.78

* h^+ = valence band hole produced by incident photons of sufficient energy

A range of AOPs are available and currently used in full-scale drinking water treatment plants worldwide. The use of AOPs as a mechanism for the removal of pollutants is applicable only in situations where the source water has a relatively low organic load (chemical oxygen demand; COD ≤ 5g L^{-1}). Hence, AOPs are ideally suited for the treatment of water intended for human consumption that has undergone primary treatment (coagulation, flocculation and filtration).[17] Current AOPs can be characterised as catalytic processes, ozone-based processes or UV-based processes.

Catalytic AOPs

Catalytic AOPs utilize H_2O_2, UV or a combination thereof in conjunction with a solid semi-conductor or transition metal catalyst to produce $^{\bullet}OH$. Catalytic AOPs such as the Fenton (Eq. 1) and Fenton-like processes (Eqs. 2-4) are often confined to waste water treatment, as the catalytic activity of Fe^{2+}/Fe^{3+} that is a feature of these processes requires strict pH control at fairly strong acidity (pH = 2.7-2.8) that is unlikely to be feasible for drinking water treatment applications.[17,22,23] The rate of degradation of organic pollutants by a Fenton-like mechanism can be increased by the use of UV light, giving the so-called photo-assisted Fenton processes. However, the pH requirements are the same as for more traditional Fenton-like processes.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + {}^{\bullet}OH \qquad \text{(Eq. 1)}$$

$$Fe^{3+} + H_2O_2 \leftrightarrows H^+ + [Fe - OOH]^{2+} \qquad \text{(Eq. 2)}$$

$$[Fe - OOH]^{2+} \rightarrow HO_2^{\bullet} + Fe^{2+} \qquad \text{(Eq. 3)}$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + {}^{\bullet}OH \qquad \text{(Eq. 4)}$$

Photocatalysis: TiO_2/UV

More recently, photocatalytic AOPs based on TiO_2 (anatase) have been developed. The initial step in the TiO_2/UV type system involves the irradiation of TiO_2 followed by the formation of electron-hole pairs. This is achieved by employing incident photons of sufficient energy to produce conduction band electrons and valence band holes (Eq. 5).

$$TiO_2 + h\nu \rightarrow TiO_2^{h+} + e^- \qquad \text{(Eq. 5)}$$

The extremely high oxidation potential of holes (denoted h^+; Table 2) means that nearly all chemicals should be able to be oxidized, including the oxidation of adsorbed H_2O or OH^- to give $^{\bullet}OH$ (Eqs. 6 & 7).

$$TiO_2^{h+} + H_2O \rightarrow TiO_2 + {}^{\bullet}OH + H^+ \qquad \text{(Eq. 6)}$$

$$TiO_2^{h+} + OH^- \rightarrow TiO_2 + {}^{\bullet}OH \qquad \text{(Eq. 7)}$$

Similarly, direct oxidation of pollutants may also occur, via adsorption and subsequent oxidation at the TiO_2 surface, although this process is thought to play a very minor role in the oxidation of organic components, with respect to $^{\bullet}OH$ (Eq. 8).[22]

$$TiO_2^{h+} + RX \rightarrow TiO_2 + RX^{+\bullet} \qquad \text{(Eq. 8)}$$

Additionally, the electrons produced in the initial step are able to reduce some metals and dissolved O_2 to give the superoxide radical, $^{\bullet}O_2^-$.

This method has the advantage of potentially using solar radiation as a source of UV, thereby not requiring the implementation of UV lamps as part of the reactor. However, as this relies on consistently fine weather, this leads to inconsistent system performance. Additionally, standard TiO_2 only absorbs a narrow bandwidth of the total solar spectrum, meaning the overall quantum yield is low. To overcome this, the development of doped TiO_2 that is able to more effectively utilise wavelengths of the

solar spectrum available at ground level have been investigated as a means of reducing the need for specialised UV reactors.[17,24] TiO_2-based AOPs have been investigated by a number of researchers as a means to remove cyanotoxins from drinking water including microcystins (Fig. 1), cylindrospermopsins and nodularins (Fig. 4) with good results.[25-28]

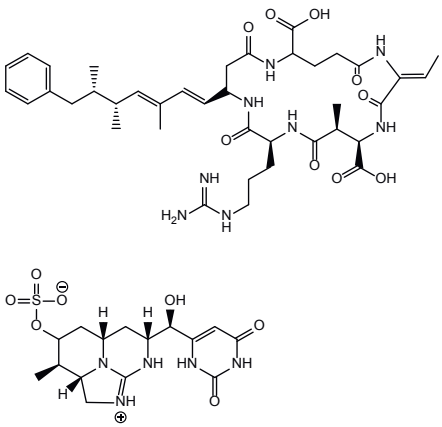


Fig. 4. Molecular structures of nodularin-R (top) and cylindrospermopsin (bottom)

Ozone- and UV-based AOPs

Ozone-based processes rely on the decomposition of ozone (O_3) to produce $^{\bullet}OH$. The yield of $^{\bullet}OH$ can be increased by the use of H_2O_2 or UV in the system. The production of $^{\bullet}OH$ in aqueous systems can also be achieved without the use of O_3 as is the case with UV-based processes like H_2O_2/UV and Cl_2/UV-based AOPs.

Ozone-based processes

The use of O_3 as an oxidant requires the implementation of an on-site O_3 generator. Ozone is usually generated by an electrical discharge (8-20 kV) applied to molecular oxygen, air or oxygen enriched air as per Eqs. 9 & 10.[5]

$$O_2 + \text{energy} \rightarrow O + O \qquad \text{(Eq.9)}$$

$$O + O_2 \rightarrow O_3 \qquad \text{(Eq.10)}$$

The O_3 that is generated can then be introduced into solution via a suitable gas transfer device such an in-line gas injection system or a multistage bubble contactor.[5]

O_3 is highly reactive towards many compounds found in drinking water that contain specific functional groups including alkenes, activated aromatics, amines, sulfides and other organic compounds containing electron rich moieties.[29,30] While this means direct use of ozone is likely to be minimally effective for the removal of many T&O causing compounds (Fig. 3), cyanotoxins are likely to be effectively oxidised due to their wide range of susceptible functionalities (Figs. 1,2,5).

Under the right conditions, O_3 will also spontaneously decompose via a chain reaction mechanism, which includes the production of $^{\bullet}OH$ and $^{\bullet}OOH$ (hydroperoxyl) radicals that are much less selective oxidants according to Eqs. 11-17.

$$HO^- + O_3 \rightarrow O_2 + HO_2^- \qquad \text{(Eq.11)}$$

$$HO_2^- + O_3 \rightarrow HO_2^{\bullet} + O_3^{\bullet -} \qquad \text{(Eq.12)}$$

$$HO_2^{\bullet} \rightarrow H^+ + O_2^{\bullet -} \qquad \text{(Eq.13)}$$

$$O_2^{\bullet -} + O_3 \rightarrow O_2 + O_3^{\bullet -} \qquad \text{(Eq.14)}$$

$$O_3^{\bullet -} + H^+ \rightarrow HO_3^{\bullet} \qquad \text{(Eq.15)}$$

$$HO_3^{\bullet} \rightarrow HO^{\bullet} + O_2 \qquad \text{(Eq.16)}$$

$$HO^{\bullet} + O_3 \rightarrow HO_2^{\bullet} + O_2 \qquad \text{(Eq.17)}$$

The chain reaction can be initiated in various ways including the presence of natural organic matter (NOM), Fe^{2+}, H_2O_2, UV radiation and OH^- (Eq. 11; pH ≥ 8.5).[5,17,23,30]

For example, the production of HO_2^- from H_2O_2 in aqueous solution (Eq. 18) illustrates how the initiation of the chain decomposition to produce $^{\bullet}OH$ may be enhanced, by increasing the quantity of HO_2^- available to react with O_3 (Eq. 12).[17,22,30]

$$H_2O_2 \leftrightarrows HO_2^- + H^+ \qquad \text{(Eq.18)}$$

Hence, oxidation by O_3 can be enhanced by the addition of H_2O_2 into the system. This can be achieved by directly introducing H_2O_2 into the system (O_3/H_2O_2), or by producing H_2O_2 *in situ* from O_3 using UV radiation (O_3/UV system).[22,30] This is achieved via the UV irradiation of ozone, which produces molecular oxygen and excited singlet state oxygen ($O(^1D)$). The singlet oxygen rapidly combines with water to produce hydrogen peroxide (Eq. 19).

$$O_3 \xrightarrow{UV} O_2 + O(^1D) \xrightarrow{H_2O} H_2O_2 \qquad \text{(Eq.19)}$$

The H_2O_2 that is produced can then dissociate (Eq. 18) and initiate the chain reaction decomposition of O_3 (Eqs. 12-17).

The use of additives such as H_2O_2 or UV overcomes the need to maintain the O_3 system at low pH while still producing an adequate concentration of $^{\bullet}OH$ to effect a reasonable rate of oxidation for a wide range of target contaminants. Reaction rates of oxidation by $^{\bullet}OH$ of some T&O causing compounds are generally much higher than O_3 (Table 3), with the faster reaction rates of oxidation with O_3 limited to alkenes and activated aromatic compounds.[29]

UV-based processes

UV-based processes forego the use of ozone as an oxidant and instead aim to form $^{\bullet}OH$ or other radical species from other oxidising agents or from water directly. These include UV/H_2O_2, UV/Cl_2 and vacuum UV (VUV).

UV/H_2O_2

This process aims to produce $^{\bullet}OH$ from H_2O_2 by exploiting the absorption of UVC radiation by H_2O_2 between 100 and 280 nm.[20] As Hg lamps produce an emission line at 253.6 nm, these are most commonly used for this purpose.[20,22] Initiation of the chain propagation reaction begins with homolytic photolysis of H_2O_2, yielding two $^{\bullet}OH$ (Eq. 20), which then undergo a radical chain reaction via the Haber-Weiss mechanism (Eqs. 21 & 22).[22,31]

Table 3. Reaction rate constants of taste and odour compounds via oxidation with O_3 or $^{\bullet}OH$[29]

Compound	Reaction rate constant (k) O_3	$^{\bullet}OH$
β-cyclocitral	3890 $M^{-1} s^{-1}$	7.42 x 10^9 $M^{-1} s^{-1}$
geosmin	0.10 $M^{-1} s^{-1}$	7.80 x 10^9 $M^{-1} s^{-1}$
3-hexen-1-ol	5.4 x 10^5 $M^{-1} s^{-1}$	7.45 x 10^9 $M^{-1} s^{-1}$
β-ionone	1.6 x 10^5 $M^{-1} s^{-1}$	7.79 x 10^9 $M^{-1} s^{-1}$
2-isopropyl-3-methoxypyrazine	50.2 $M^{-1} s^{-1}$	4.91 x 10^9 $M^{-1} s^{-1}$
2-methylisoborneol	0.35 $M^{-1} s^{-1}$	5.09 x 10^9 $M^{-1} s^{-1}$
2,6-nonadienal	8.7 x 10^5 $M^{-1} s^{-1}$	10.49 x 10^9 $M^{-1} s^{-1}$
1-penten-3-one	5.9 x 10^4 $M^{-1} s^{-1}$	4.71 x 10^9 $M^{-1} s^{-1}$
2,6-di-*tert*-butyl-4-methylphenol	7.4 x 10^4 $M^{-1} s^{-1}$	3.20 x 10^9 $M^{-1} s^{-1}$
2,4,6-tribromoanisole	0.020 $M^{-1} s^{-1}$	3.74 x 10^9 $M^{-1} s^{-1}$
2,4,6-trichloroanisole	0.057 $M^{-1} s^{-1}$	5.10 x 10^9 $M^{-1} s^{-1}$

$$H_2O_2 + h\nu \rightarrow 2HO^{\bullet} \quad \text{(Eq.20)}$$

$$H_2O_2 + HO^{\bullet} \rightarrow HO_2^{\bullet} + H_2O \quad \text{(Eq.21)}$$

$$HO_2^{\bullet} + H_2O_2 \rightarrow H_2O + O_2 + HO^{\bullet} \quad \text{(Eq.22)}$$

Stoichiometrically, it would seem that the photolysis of 1 mol of H_2O_2 would yield 2 mol of $^{\bullet}OH$, and experiments in the gas phase do agree with this where the quantum yield of $^{\bullet}OH$ ($\Phi^{\bullet}_{OH}$) has been shown to be 2.09 ± 0.36. However, in the liquid phase this is not true, where $\Phi^{\bullet}_{OH} \approx 1$ and this indicates that only approximately 50% of H_2O_2 is converted to free $^{\bullet}OH$. This is often explained by the solvent "cage" effect, whereby newly created radicals in the liquid phase are surrounded by a solvent cage which promotes recombination of the radical species (Eq. 23).[20,22,31]

$$H_2O_2 + h\nu \leftrightarrows (HO^{\bullet} + HO^{\bullet})_{aq} \rightarrow HO^{\bullet} \quad \text{(Eq.23)}$$

The UV/H_2O_2 system is quite commonly used, and has the advantage of requiring fewer oxidants and dosage systems compared with O_3/H_2O_2 systems, while still providing high enough concentrations of $^{\bullet}OH$ to achieve reasonable degrees of removal of pollutants at the commonly used dosages in water treatment of 2 – 10 mg L^{-1}.[22]

UV/Cl_2

The UV/Cl_2 process is based on UV-induced photo-dissociation of species present in aqueous solutions of chlorine which is produced by introducing chlorine gas to water (Eqs. 24 – 28).[32,33]

$$Cl_2 + H_2O \rightarrow HOCl + HCl \quad \text{(Eq.24)}$$

$$HOCl \xrightarrow{UV} HO^{\bullet} + Cl^{\bullet} \quad \text{(Eq.25)}$$

$$HOCl \leftrightarrows H^+ + OCl^- \quad \text{(Eq.26)}$$

$$OCl^- \xrightarrow{UV} O^{\bullet} + Cl^{\bullet} \quad \text{(Eq.27)}$$

$$O^{\bullet} + H_2O \rightarrow HO^{\bullet} + HO^- \quad \text{(Eq.28)}$$

While the yield of $^{\bullet}OH$ is theoretically higher than the UV/H_2O_2 process, the UV/Cl_2 process is pH dependent, with optimum yield being realised at pH < 6.[32] As the pH of the influent water used at the HDWTP is approximately 7,[34] pH adjustment would be required to achieve optimum $^{\bullet}OH$ yield. However, at neutral pH, the process is kinetically comparable to the UV/H_2O_2 in the oxidation of trace organic contaminants.[32] Additionally, as many water treatment plants, including Hamilton, already employ Cl_2 as a disinfectant, this method may provide a cost effective alternative AOP to O_3 and H_2O_2 based processes which require the installation of new infrastructure. Although this may be a good option in some cases, and has been shown to degrade GSM and 2-MIB quite effectively,[32] it may be more prone to radical scavengers and quenching than the UV/H_2O_2 process, depending on the composition of the influent water.[35]

Vacuum UV

Vacuum UV (VUV) is an "oxidant free" AOP that degrades organic pollutants by the formation of reactive species like $^{\bullet}OH$, $^{\bullet}H$, $e^-_{(aq)}$, $^{\bullet}HO_2$ and $^{\bullet}O_2$ via the direct photolysis of water by irradiation with short wavelength (< 200 nm) UV radiation.[22]

Two main reactions initiate a series of chain reactions (Eqs. 29 & 30).

$$H_2O + h\nu_{<200nm} \rightarrow HO^{\bullet} + H^{\bullet} \quad \text{(Eq.29)}$$

$$H_2O + h\nu_{<200nm} \rightarrow HO^{\bullet} + H^+ + e^-_{aq} \quad \text{(Eq.30)}$$

Photons with wavelengths in the VUV region can be produced in a number of ways, most commonly via the use of excimer (excited dimer) lamps and low-pressure Hg lamps (VUV-Hg). Excimer lamps, which contain inert gases like xenon, argon and krypton, emit VUV radiation at various wavelengths, depending on the gas used. For example, Xe_2-excimer lamps emit at 172 nm with around 5 to 40% efficiency. One problem with the use of these lamps is the fact that water has a very high absorptivity (550 cm^{-1}) at this wavelength. While VUV-Hg lamps provide radiation at 185 nm where the absorptivity of water is lower (1.80 cm^{-1}), this still means that most of the emitted photons are absorbed within 0.3 cm of the water surface. Possible ways to circumvent this problem may be to increase the level of turbulence in the VUV reactor or bubbling oxygen or air through the system via some form of diffuser or aerator.[22,36,37]

More than 30 reactions are known to occur during VUV photolysis of water, and while the direct photolysis of dissolved organic compounds is possible, it is unlikely to be significant compared to the oxidation of these compounds by the radicals produced from water during the VUV process, which is present at a concentrations many orders of magnitude higher.[22]

At present, VUV technology is still at the laboratory stage and in pilot plant development for application to large scale water treatment, although it looks to be a promising technology for future applications in this area.

Summary

AOPs provide a means of mineralising problematic organic contaminants commonly associated with cyanobacteria. When complete mineralisation is not achieved, AOPs may also pre-treat influent water for a downstream bio-filtration system such as BAC by oxidising these problematic compounds and presenting them in a more biodegradable form. While some of these AOPs are well established and used routinely in full scale treatment facilities, some promising new technologies are emerging that minimise the use of chemical oxidants or employ photocatalytic reagents providing greener, more sustainable options.

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Of tutu and bugs

Anatoly Chernyshev

Analytica Laboratories Ltd, Ruakura Research Centre, Private Bag 3123, Hamilton 3240
(email: *anatoly.chernyshev@analytica.co.nz*)

Keywords: *picrotoxane terpenoids, tutin, New Zealand honey*

Anatoly Chernyshev obtained an MSc in organic chemistry in 1994 followed by a PhD in physical chemistry in 1999, both from Saratov State University in Russia. In 2001 he moved to the USA to continue as a post-doctoral scholar in the field of molecular biophysics (mechanistic enzymology and protein ion channels). He then worked for six years in Oman, as an assistant professor of chemistry, and then as a science consultant at the Research Council of Oman. For the last two years he has worked as a scientist at Analytica Laboratories in Hamilton, carrying out research on Manuka honey.

From the bonny bells of heather
They brewed a drink long-syne,
Was sweeter far than honey,
Was stronger far than wine.
They brewed it and they drank it,
And lay in a blessed swound
For days and days together
In their dwellings underground.

— R. L. Stevenson*, Heather Ale*

Historical introduction

Not quite along the lines of the epigraph, but New Zealand has its very own convoluted history of poisonous honeys. In the early days of European settlement there was a plant, looking like an ornamental one, with irresistibly appealing juicy sprouts. This plant has claimed the lives of up to 75% of the first introduced cow herds and sheep flocks, and even one circus elephant, according to some accounts.[1] Some other animals (horses, birds) appeared less susceptible to the plant's poisoning; notably, goats were allegedly used to clear it from the pastures.

The plant's name is tutu (genus *Coriaria*), with *Coriaria arborea* being the most widespread and most studied species. Certain discrepancies exist in the early records of tutu usage. Despite its proven toxicity to humans, there are mentions of dishes and drinks made of tutu juice, together with pith of the black tree fern (*Cyathea medullaris*), and some seaweeds. Moreover, those dishes were described by the witness not less than 'very palatable'.[2] The brew made with tutu fruit petals (the only non-toxic part of the plant) was described by the same witness as liking to a red Bordeaux wine. On the other hand, tutu berries, and a brew and pies made from them, have an established record of serious poisoning in people.

These are very early accounts of New Zealanders' experience with tutu. It took two more events before the poisonous honey story began to unfold. The first event had been the introduction of the European honey bee (*Apis mellifera*) *c*. 1840. It is not unusual for the bees to collect nectar from the flowers of poisonous plants. Fortunately, the honey produced in most cases is harmless, at least if consumed moderately. The notable exceptions are 'mad honey', and honey from *Serjania letalis* of Brazil. The information on the latter is scarce. Allegedly, it is so toxic that was used as an arrow poison to kill fish.[3] The 'mad honey' has been known from as early as the fifth century BC in the Mediterranean region. Bees make it from the nectar of rhododendrons, and other plants of the *Ericaceae* family containing grayanotoxin alkaloids. Its consumption induces symptoms similar to incapacitating alcohol intoxication.[4]

Typically, one would expect a straightforward transformation of a bee-collected nectar into honey. The nectar is incubated in a hive at 35±0.5°C, where it undergoes water evaporation and chemical transformations. Plant secondary metabolites (alkaloids, terpenoids, glycosides), which happen to be in the nectar, are sturdy molecules, and often remain unchanged in honey. However, the case of honey poisoning by tutu is not so straightforward.

Records of human intoxication by honey in New Zealand trace back to the end of the 19th century. The signs of poisoning were epilepsy-like seizures, hallucinations, delirium and even memory loss in severe instances. Although similar to tutu poisoning, those cases were not connected to the plant until the 1940s. A scientifically dramatic history of this discovery is thoroughly laid out in two somewhat contradictory accounts.[5] It is left to the curious reader to go through those and form his/her own picture of the events involved.

What appears to be crucially important is the field observation made by an apiary instructor, Roy Paterson. He noted that the passion vine hopper insect infests *Coriaria* plants and produces honeydew which is then collected by bees, instead of a *bona fide* nectar being produced. The passion vine hopper (*Scolypopa australis*) is a moth-shaped insect of *Hemiptera* order introduced from Australia around 1880. The investigation following this discovery revealed two major toxic components of the tutu honey dew and the honey: tutin and hyenanchin (hydroxytutin). These are sesquiterpenoids of the picrotoxane family (Fig. 1). Hyenanchin content is small in *Coriaria* parts, but it significantly increases upon the transformation of the plant juice into honeydew by the vine hopper. In the honey its concentration is higher than that of tutin but its toxicity is approximately ten times lower.[6,7] Therefore, the overall toxicity of honey stems from tutin,

and the current standards set the allowed limit for this compound at 0.7 mg of tutin per kilogram of honey. According to records in our laboratory, in some extremely bad (but rare) cases, the concentration of tutin in honey can be as high as 20–30 mg/kg.

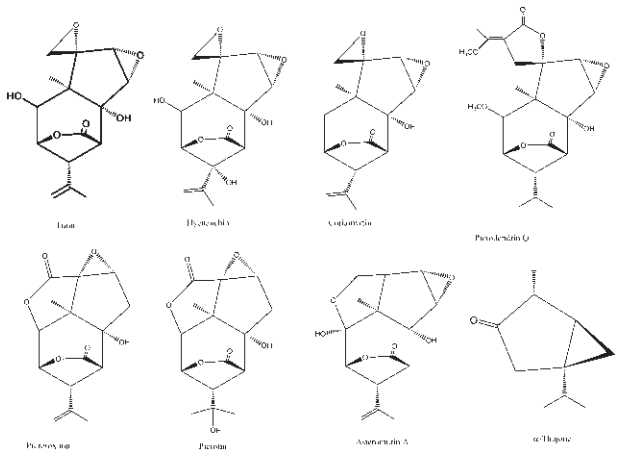

Fig. 1. Representative picrotoxane terpenoids and α-thujone. A common chemical scaffold is highlighted in bold in the tutin structure.

Upon passage through the vine hopper's digestive system, tutin is detoxified by forming mono- and diglycosides with glucose (Fig. 2), which are present in honey in concentrations of up to 200 mg/kg. Apparently they are not toxic per se, but might be hydrolysed when ingested, yielding the free terpene. A recent study[8] on the pharmacokinetics of tutin-contaminated honey in human subjects showed two distinct maxima of the poison concentration in blood; the first is reached one hour after honey ingestion whereas the second is higher and takes about 15 hours to develop. This second maximum is explained by a slow formation of tutin from glycosides undergoing chemical cleavage in the body.

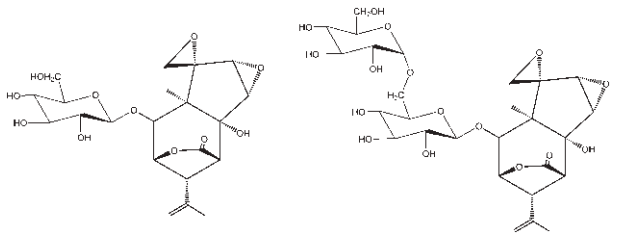

Fig. 2. The glycosides of tutin isolated from New Zealand honeys[6]

Since the 1940s, when detailed investigations of the linkage between tutu trees, the passion vine hopper and cases of honey poisoning were completed, tutin has not been viewed in a good light in New Zealand. This does not seem to be a fair treatment of the compound. Beyond an intricate chemical structure, picrotoxane sesquiterpenes possess some promising biological activity which has been the subject of a number of recent successful research projects in medicinal chemistry. This article is an attempt to draw attention to tutin, not as a nuisance food poison, but as a valuable substance which could prove to be useful to humans and pets.

The effects of picrotoxanes as a component of vernacular medicines have been known worldwide. Picrotoxin, the most studied member of the family, is actually a mixture of the two compounds picrotoxinin and picrotin (Fig. 1). It was isolated from the fruits of the Indian vine *Anamirta cocculus* in 1812, and has had quite a history since then. Its name is a derivative of the Greek words *pikros* (bitter) and the self-explanatory *toxikos* (toxic).

The first half of the name came in handy in the late 19th century, when the beer brewing industry was addicted to adulteration. Picrotoxin was used then in many countries including the USA, Europe, Russia and Australia to infuse the brew with a pleasant bitter taste. Yet, one could think of it as an innocent additive compared to the alkaloid strychnine used for the same purposes.[9] Picrotoxin is still used nowadays as an illegal doping substance in horse racing, with uncovered scandals being regularly reported in the media.

The fruits of *Anamirta* have received their own historic pharmaceutical name, *Cocculus indicus*, and were used as insecticides and fish poison. However, these fruits also contain a number of alkaloids, so their toxicity might be not due to picrotoxine alone. On the other side of the world, in the Caribbean, there is a tree, *Picrodendron baccatum*, which contains a whole distinct sub-family of picrotoxane terpenes called picrodendrins.[10] The most biologically active, picrodendrin Q, is shown in Fig. 1. The locals also used this plant to exterminate lice and bedbugs.

The toxicity of tutin and its relatives for invertebrates has been acknowledged in modern times, when their synthetic derivatives were being investigated as promising crop protection agents.[11] Despite the strong insecticidal activity of the picrotoxanes, it just so happens that the passion vine hopper is resistant to it, to the great displeasure of beekeepers.

The accumulation of picrotoxanes by an insect is not unique for the *Coryaria*/*Scolypopa* pair. Asteromurin A (Fig. 1) has been isolated from a sap sucking scale insect *Asterococcus muratae*;[12] however, no information on the host plant is provided in the few publications on this terpene. In China, tutin together with another picrotoxane was isolated from nests of the common paper wasp (*Polistes* sp.). These nests are known as *Nidus vespae*, and are a distinct component of traditional Chinese medicine. They are applied primarily as external treatments for a wide range of conditions including pain and toothache, skin rash, itching, chronic sores, tinea, swelling and even cancers.[13] While the role of picrotoxanes is unclear, these age-old observations certainly deserve academic attention. How the picrotoxanes get in the nests is also currently unclear. Their source could be parts of the Chinese *Coriaria* species (*C. sinica*), or *Loranthus parasiticus*, a mistletoe-like parasitic plant, which lives on *Coriaria*. The possibility of wasps collecting honey dew yielded by some other insects cannot be ruled out.

Neurotoxicology of picrotoxanes for dummies

The states of the neural system, in health or in pathology, are regulated by electrical currents. These currents

are due to the movement of ions, positive (Na^+, K^+, Ca^{2+}) and negative (Cl^-). So, whoever has declared that table salt is bad for your health was deadly wrong. The ions do not move arbitrarily but do so under the action of electrical potential of the cell membrane, and they can go only through special protein pores in the membrane. For a pharmacologist these structures are known as 'receptors'; for a biophysicist they are known as 'ion channels'; for an average chemist they are not known at all, hence a short overview here.

These ion channels are specific for each kind of ion, and the subject of strict control by means of small organic molecules, so-called neurotransmitters or agonists. Often, each ion channel has several agonists, which non-covalently bind to it at specific sites and initiate certain actions. Typically, this action will be channel opening to allow the ions to pass through.

Competitive antagonists are compounds which bind to the channel at the same site as agonists, but cause no physiological effect. Doing so, they effectively block the receptor from the action of neurotransmitters. Non-competitive antagonists bind at different sites, and induce an action opposite to that of the agonist.

For each type of ion, there are many families of ion channels, each with different structures, localisation and mechanism of regulation. The primary targets of picrotoxane terpenoids are two families of ligand-gated chloride channels. As the name suggests, these channels are opened upon binding of a small molecule (ligand). The first large family is γ-aminobutyric acid (GABA) receptors; the second one is the glycine (Gly) receptors. Proteins of both families have similar structures, and their major difference is in the chemical structure of agonists causing them to open.

Both GABA and Gly-gated ion channels are composed of five protein subunits. The amino acid sequence of the subunits is variable, and currently classified into six isoform types (α, β, γ, δ, ε, ρ). Their tertiary structure, however, is very similar, which allows them to assemble into heterologous protein complexes made of two or more isoforms. To complicate the picture even more, affinity to agonists or antagonists can vary between isoforms, yet the expression level of different isoforms may change at different stages of the organism's development. This might result, for example, in different susceptibilities of children and adults to the same drugs. The same variability in the ligand affinity could be responsible for the resistance of the passion vine hopper and bees to tutin.

In the Protein Data Bank (PDB) there is only one crystal structure of a chloride channel bound to a picrotoxane molecule (Figs. 3 and 4).[14] This is the glutamate-gated channel of *Caenorhabditis elegans,* a roundworm employed for several decades as a model organism to study the nervous system of animals.

The interpretation of this structure, supported by a number of electrophysiology studies,[15] is straightforward. A picrotoxane molecule is a non-competitive chloride channel blocker. It fits just right in the bottom part of the

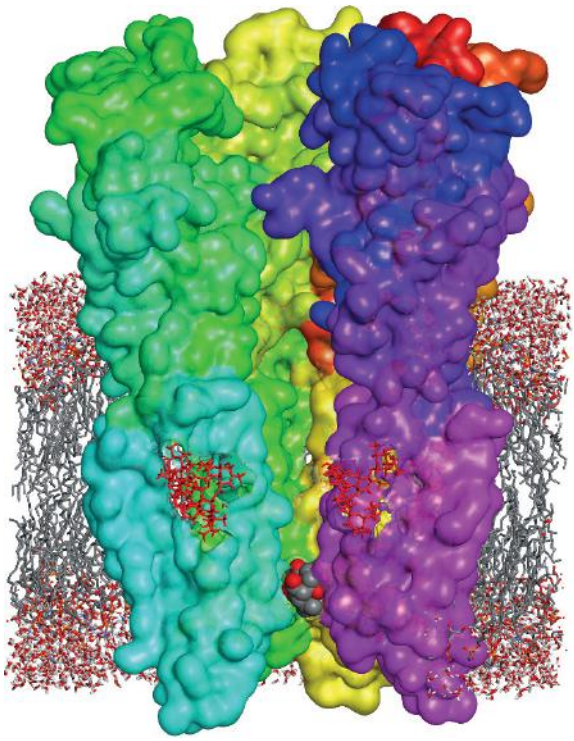

Fig. 3. Side view of *C. elegans* glutamate-gated chloride channel in the lipid bilayer[14] (PDB ID 3RI5; the front subunit is removed for clarity). The picrotoxin molecule blocking the pore is at the bottom; ivermectin molecules are shown in red.

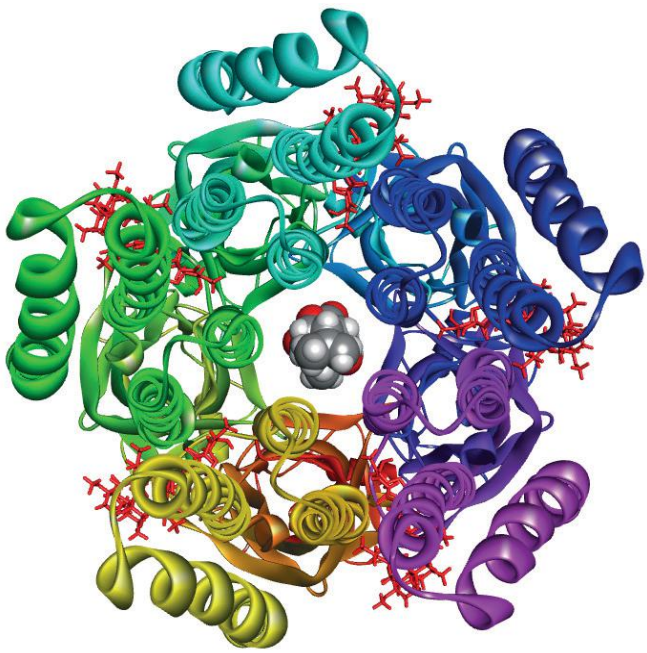

Fig. 4. Axial view of the chloride channel blocked by picrotoxin[14]

channel due to the specifics of its geometry and electrostatics, effectively stopping the ion current. The molecular electrostatic field here is of utmost importance. For instance, introduction of an extra hydroxy group does not change the overall compact shape of the molecule, but leads to a sharp decrease in the toxicity. This effect has been observed in the tutin/hyenanchin pair (~10-fold decrease in toxicity) and in the picrotoxinin/picrotin pair (~45-fold decrease).[7,16] Another substance bound to the same protein (shown in red in Figs. 3 and 4) is ivermectin, a well known agonist of invertebrate Glu-gated chlo-

ride channels. This property makes ivermectins powerful anti-parasitic agents for treatment of lice and a range of tropical diseases.

Human startle disease (hyperexplexia) is a neurological condition resulting in overreaction to external loud noises or sudden touches, sometimes with uncontrolled falling, followed by a period of stiffness. It originates in a single mutation in the α-subunit of a human Gly-gated chloride channel (the Arg-271 residue is replaced by either Leu or Gln). This mutation results in a decreased maximal ionic current through the channel, and a lowered susceptibility to its glycine agonist. However, the same mutation apparently changes the mode of action of picrotoxanes. Instead of being sheer blockers, they become allosteric activators of the compromised channels. Therefore, their action compensates for the lowered sensitivity of the ionic channel to glycine, which could be used in the drug development for this particular disease.[17]

The situation shown in Figs. 3 and 4 is quite interesting, with the channel activator and blocker bound simultaneously. The question is: what would be the net ion flow through the pore in this case? Or, rephrasing, what would be the overall feeling of a human being subjected to such two drugs? Although the exact answer can be found by experiment only, a generally accepted answer is that the agonist and antagonists somehow compensate each other (at least in the case of chloride channels). To oversimplify (the following statements should not be shown to a neurologist!), the blockade of chloride channels leads to seizures and convulsions, whereas setting these channels open leads to relaxation in the form of a general slowdown of body functions - ultimately to heart and respiratory failure. Barbiturates are a well-known example, being strong GABA receptor agonists.

Too much of a good thing could kill a cat — this is especially true for the drugs targeting ion channels. Poisoning by barbiturates is common due to voluntary or occasional overdose in humans. Legitimate applications of picrotoxin include attempts to use it as an antidote for severe cases of such a poisoning, especially in the case of respiratory failure. This practice ceased in the 1960s due to the narrow safety margins of the substance. However, picrotoxin is still recommended as an antidote against accidental poisoning by ivermectin in domestic animals.[18] The reverse is true as well: poisoning by picrotoxanes could be relieved by sedating agents such as ethanol, benzodiazepines and barbiturates.[19]

Another example of the mutual action of agonists and blockers on GABA receptors is famous for its cultural and historical heritage. Absinthe was the alcoholic drink of choice for artists and other Bohemians in the late 19th and early 20th century. It contains a volatile oil of the wormwood plant (*Artemisia sp*.), the most notable component of which is the monoterpene thujone (Fig. 1). When over-imbibed, absinthe can cause agitation, hallucinations, distorted colour perception, convulsions and seizures. Some art historians attribute the particular palettes of Van Gogh paintings to the action of absinthe.

Thujone was found to act in the same way as picrotoxanes, namely by non-competitive blockade of the GABA-gated chloride channels.[20] Its action could be alleviated to a large extent by high concentrations (up to 75% v/v) of ethanol in absinthe. Ethanol is a known agonist of GABA receptors. Its binding increases channel opening, reducing the effect of channel blockers.[21] A remarkable study[21] was carried out on the ethanol effect in rats injected with a lethal dose of picrotoxin (10 mg/kg). This dose initiated convulsions in 330 seconds after the injection, quickly leading to 100% mortality in the experimental animals. Another group of rats received the same dose of the toxin, together with 2 g/kg of ethanol. The onset of seizures in this case was delayed to 650 seconds, and, miraculously, all were alive at the end of the trial. Despite such a clear demonstration, one shall refrain at this point from any human-related speculation or recommendations.

LD_{50} of thujone in mice is roughly 15 times higher than that of picrotoxinin and tutin (45 mg/kg *vs*. 3 mg/kg); this might explain why the alcoholic drink containing it might be highly regarded. The fine balance between thujone and ethanol action on GABA receptors could produce some interesting sensations, while keeping the subject within safety margins.

The author did not find any references to alcoholic drinks made in New Zealand with tutu parts, except for beer and wine. Apparently, the alcohol concentration in these drinks is not enough to counteract tutin poisoning. Should the early settlers have opted for stronger liquors, who knows, maybe New Zealand would have become the fatherland of a new absinthe-like craze. However, the curious reader is advised not to try experimenting with this at home: tutin in honey still remains a deadly mixture.

A model of epilepsy

Progress in drug development is due in large measure to the existence of specific lines of animals which carry particular symptoms of diseases. These creatures are bred with high genetic homogeneity, so that the effects of experimental drugs are observed with much better reproducibility. These lines are known as animal models for specific health disorders. Often these models are created using genetic engineering methods. However, there are instances when certain human conditions can be inflicted by simple delivery of a low-molecular compound. The combinations of the organism and the chemical delivery protocol are known as 'chemical models' and have the advantage of lower cost and better accessibility for researchers. Additionally, some chemical models do not have acceptable analogues in genetically-modified animals.

Epilepsy is a multi-faceted neurological condition of humans and some other mammals (specifically dogs and cats) which generally manifests itself as seizures. It is relatively easy to induce seizures in living beings, so that epilepsy researchers currently utilise more than one hundred diverse animal models. A range of anticonvulsant medicines is available for epilepsy management. However, some cases are not responsive to treatment

by anticonvulsants. Such a condition is known as pharmacoresistant (refractory) epilepsy, and represents a particular challenge for pharmacology. Research on the treatment of pharmacoresistant epilepsy is also hindered by a shortage of suitable animal models.

Loranthus parasiticus known from Chinese medicine is a remarkable example of a modern day application of tutin. Its extract (known in pharmacology as Coriaria lactone) contains a mixture of tutin and coriamyrtin (Fig. 1) in roughly equal amounts. The plant as a whole has been reported to have anti-cancer, diuretic, tranquilising and hypotensive activity. Coriaria lactone was used for some time in China's ethnic and official medicine as a shock therapy for schizophrenia.[22]

A controlled intramuscular injection of this extract in a specific line of rats induces very stable and reproducible seizures. This application of Coriaria lactone is known as a 'kindling' animal model. The term 'kindling' here means that the strength and duration of the seizures increase after repeated application of the chemical stimulus. This is similar to the experience of eating too much garlic: each additional portion causes stronger irritation of the tongue until the pain becomes intolerable (if curious, the garlic sting relates to the activation of certain Ca^{2+} channels in tissues, but this is a different story).

Of more importance is that the induced seizures are, at the same time, resistant to treatment by common anticonvulsant drugs.[23] The key factor in drug resistance in epilepsy is the expression of a protein product of the multiple drug resistance gene (MDR1). This product is a membrane glycoprotein, a member of a family of ATP-binding cassette (ABC) transporters. It uses the energy of adenosine triphosphate (ATP) to expel quite a non-discriminatory range of non-polar molecules from the cell. This results in decreased efficacy of medical treatment in a number of serious illnesses (cancer, HIV, heart disorders). Apparently, the components of Coriaria lactone are capable of inducing the expression of MDR1. Rats with the developed condition are in great demand by pharmacologists working on a treatment of drug-resistant epilepsies.

Finally, only the very well experimentally supported facts about picrotoxane terpenes have been presented in this article. Many interesting observations were omitted due to lack of information. For example, there have been reports that picrotoxine facilitates maze learning in rats[24] and that ethnopharmacologies in China and some other countries list a multitude of medical applications of picrotoxane-containing plants.[16] There is no doubt, however, that given enough attention, some promising drugs could be derived from the picrotoxane scaffold. Dare it even be said that tutin-containing honey might be in high demand by patients with yet-to-be-identified neurological conditions.

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Article

Meat science in New Zealand

Carrick Devine

Plant and Food Research Ltd., Hamilton (email: *quackerbottom@xtra.co.nz)*

Keywords: *meat, tenderness, electrical stimulation, stress, welfare*

Carrick Devine commenced his career with the New Zealand Oceanographic Institute measuring ocean currents and salinity patterns in Antarctica. This was followed by an MSc at Canterbury University on the ecology of a shrimp in a sandy beach, a PhD at the University of Otago on the ultrastructure, physiology and pharmacology of smooth muscle and its innervation and a postdoctoral fellowship at the Presbyterian University of Pennsylvania Medical Center on smooth muscle. After joining the Meat Industry Research Institute of New Zealand (MIRINZ) in 1973, he worked on optimising electrical stimulation to make meat tender - a process now applied in all New Zealand lamb, beef and venison processing plants. Subsequent research showed further tenderisation, not only required the best electrical stimulation parameters, but also holding at optimum temperatures throughout critical parts of processing. He was involved with procedures ameliorating animal pre-slaughter stress that toughens meat, by conditioning animals to various stressors. His research, monitoring brain function and following neurotransmitter changes, showed pre-slaughter head only electrical stunning to be humane and thus enabled the harmonisation of halal and western slaughter procedures. He later joined Plant and Food Research and with AgResearch, successfully developed near infrared spectroscopy techniques (NIR) to measure meat tenderness on-line. Dr Devine DSc, FRSNZ, FNZIC, ONZM received the 2016 KUDOS University of Waikato Lifetime Achievement award. He is an editor of the Encyclopedia of Meat Sciences.

Abstract

If there is a country that has benefitted from the beginnings of industrial refrigeration it is New Zealand. While refrigeration did allow us to export high quality meat overseas, the interaction of the improved chilling and freezing processes caused shortening and toughening problems that were incrementally overcome over 40 years. Resolving these issues enabled New Zealand to reliably export high quality chilled and frozen beef, lamb and venison using electrical stimulation but further improvements required an understanding of the biochemistry and physiology of muscle, the effect of elevated temperatures and pre-slaughter stress on inhibition of tenderisation and the assurance of the humaneness of the slaughter processes. There are minimal putative health issues associated with excessive consumption of meat but overeating is not peculiar to meat and meat alone cannot be blamed. – Rather, it would appear more likely that the absence of vegetables would give rise to health issues. Methane from ruminants is recycled to carbon dioxide used by plants.

Introduction

Artificial refrigeration's first successful development by Carl von Linde in 1873 (first developed for lager production and later to liquefy air), enabled William Soltau Davison to fit a refrigeration unit to a ship in 1882 leading to a meat and dairy boom in Australasia and South America. This momentous event included organisation, trust, building a unit, placing on a ship and sailing to the destination in nine years in the absence of emails and telephone calls. Refrigeration has had a huge impact on global well-being, on industry, lifestyle, agricultural food distribution and thriving settlement patterns in inhospitable areas. One wonders if a similar event could occur so fast today with added bureaucracy.

The early sheep meat exports were of a high quality, but after World War II major changes in efficiency in farming through to refrigeration and shipping occurred so that lambs were processed rapidly and efficiently using methods that involved blast freezing. By the late 1960s the resultant severe toughening in frozen lamb exported to the United Kingdom was recognised and controlled chilling was needed. In the early 1970s extensive research, much by the Meat Industry Research Institute of New Zealand (MIRINZ – now part of AgResearch Ltd.), developed electrical stimulation described in this journal in 1980.[1] Eventually there was a processing specification for frozen export lamb to meet a minimum tenderness standard in 1989 – a world first. Once tenderness is right, other quality attributes generally follow. More than this, however, has been achieved by scientists and engineers at MIRINZ, with the resultant export of tender high quality lamb, beef, and venison. Without such progress New Zealand would now be a minor player.

Chemistry underpinned the key developments that were important for understanding pre-slaughter stress effects on tenderness, humaneness of slaughter, effects of elevated temperatures inhibiting enzymes responsible for tenderisation, near infrared (NIR) spectroscopy to measure tenderness and meat quality on line, and the mechanisms underpinning tenderising meat by electrical stimulation.

Meat processing - old and new

A comparison of traditional meat production and modern processing is shown in Fig. 1.

What is meat?

Meat comes from the skeletal muscles of animals following slaughter and processing and commercially comes from relatively few animals such as sheep and goats, cat-

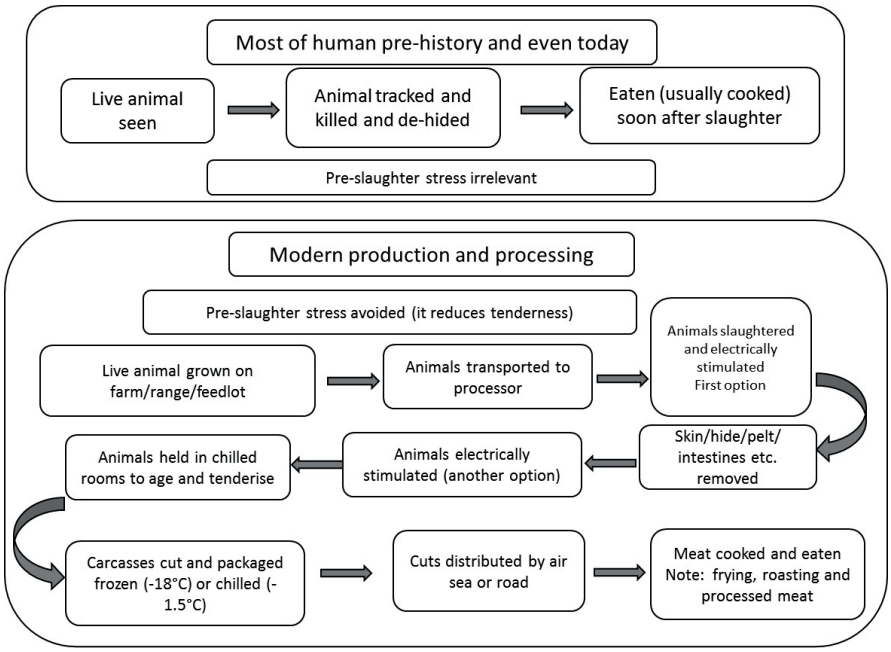

Fig. 1. Traditional and modern meat production and processing

tle, pigs, venison and poultry with associated by-products such as leather and pharmaceuticals. Worldwide there are approximately one billion pigs, 20 billion poultry, 1.4 billion cattle, one billion sheep and 800 million goats. In New Zealand there are nearly 10 million cattle, 30 million sheep and one million deer - we are a small player but produce high quality meat.

Timeline: a history of events

Exports have been a large part of New Zealand's history as shown in the following timeline:

- ***1882***: Meat was great – our first shipment of frozen meat was a success.
- ***Post WWII***: Greater production meant blast freezing lamb caused meat to become tough (beef wasn't so bad).
- ***1963***: The effect of muscle shortening and toughening was discovered by Locker from MIRINZ.
- ***Late 1960s***: This led to temperature control in chillers for special markets before freezing.
- ***Late 1970s***: High voltage electrical stimulation was introduced for lamb before chilling. Beef followed with successful low voltage stimulation just after slaughter.
- ***1980s onwards***: Hot boning of beef used for manufacturing (slash and pack) – now we can electrically stimulate and wrap (preventing shortening) with tender meat.
- ***Mid 1980s***: Special packaging/temperature control for lamb and beef (vacuum / controlled atmosphere packaging) for exported chilled cuts.
- ***1986:*** Muslim World League accepted prior head-only electrical stunning for halal slaughter.
- ***1989***: Processes involving stimulation and ageing for lamb, termed AC & A, introduced as a specification – meat was genuinely sold on known quality.
- ***Mid 1990s***: Stress reduction shown to improve tenderness – animals could be conditioned to stressors.
- ***Late 1990s***; High pre-*rigor* temperatures were shown to inhibit tenderisation.
- ***Early 2000s***: Tenderness development shown to be accompanied by drip. Drip appearing in meat early is not a consequence of high temperatures but because it tenderises faster.
- ***Mid 2000s***: Electrical stimulation prevented this inhibition.
- ***2007-2011***: Electrical stimulation shown to prevent toughness in tropical breeds.
- ***2008-present***: Successful development of NIR to measure meat tenderness on-line.
- ***Recently***: Health issues only relate to large excesses of meat.

Muscle to meat - general considerations and a glimpse of problems

Muscles in a live animal connect bones and consists of bundles of fibres surrounded by connective tissue, that in turn consists of smaller units, with the fine details of individual muscle cells only being seen with light and electron microscopy. Individual cells contain fibrillar contractile proteins, actin and myosin, and cytoskeletal structural proteins, titin, nebulin and desmin. Initiated by nerve activity, calcium released from the sarcoplasmic reticulum network binds to troponin/tropomyosin on the actin filament resulting in the actin and myosin filaments sliding in relation to each other. During relaxation, there is reuptake of calcium sequestered by the sarcoplasmic reticulum.

A connective tissue net (Fig. 2) consisting of collagen surrounding muscle fibre bundles is present in small amounts (1-4%) and has an overriding influence on toughness - the smallest amounts are present in frying cuts and the larg-

est in cuts used for manufacturing (a term used for meat that undergoes some further processing into sausages, salamis and smoked products) and roasting.

In a living animal, aerobic muscle function requires an energy source such as ATP from fatty acids or glycogen when oxygen is supplied. Without oxygen (following slaughter), ATP comes from anaerobic glycolysis, producing lactic acid and a drop in pH. Consequently, the muscles become stiff and enter *rigor mortis* – this succession of changes results in meat. The procedures include electrical stimulation, controlled pre-*rigor* holding temperatures, and ageing for defined times and temperatures to ensure fully tenderised meat.

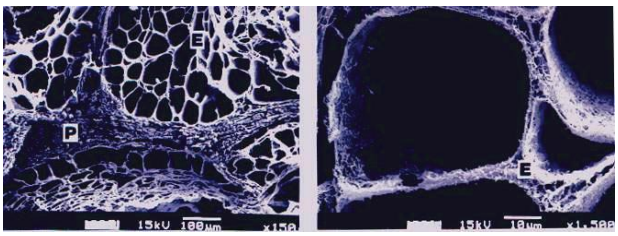

Fig. 2. Scanning electron micrographs of beef longissimus muscle where contractile and cytoskeletal proteins have been dissolved.[2] The remaining collagen network surrounds bundles of muscle fibres with a single muscle cell on the right.

Holding carcasses for a period increases the tenderisation – a term called ageing - involving the degradation of cytoskeletal proteins. This makes it seem like producing meat is a simple operation and perhaps it was in the past (Fig. 1.) when meat was valued merely for its protein content and eaten quickly, with quality relatively unimportant. Not all of the carcass is used for whole tissue meat to fry or roast as some is used for further processing such as cured/smoked products, sausages, hamburgers and frankfurters. For these, issues of tenderness do not arise. Today, high levels of animal welfare, low pre-slaughter stress and humane slaughter are required, with the result we now produce reliably tender meat with exceptional hygiene and food safety with specialised packaging and temperature control during shipping. All are critical in the highly competitive world of international trading.

Cooking and tenderness measurement

Tenderness (with the inverse being toughness) is a consumer subjective perception requiring panellists. For an objective assessment, the force required to shear a standard size piece of meat (1 cm x 1 cm) cooked to a standard temperature of 75°C was developed. If the temperature is below 67°C the meat is "rare", the collagen does not shrink and the meat is tender. As the temperature rises, the collagen shrinks and meat becomes tougher (medium rare through to well done) and with further temperature rises, e.g., roasting/stewing, solubilisation of collagen occurs with meat becoming tender. Low connective tissue cuts such as fillet, cube roll (rib eye), striploin (porterhouse) and rump can be fried quickly and those with higher connective tissue, roasted or stewed for long periods. The cook is often blamed for the toughness of meat but this criticism is misplaced – it is control of the entire process that dictates tenderness before cooking.

ATP, *rigor mortis*, shortening, temperature and electrical stimulation

Following slaughter of animals, the blood supply ceases and oxygen is unavailable so anaerobic glycolysis provides ATP to keep muscles alive. As glycogen is used up, lactic acid is produced and the pH falls to around 5.5 at *rigor mortis* (Fig. 3). It is during this fall in pH that events have a bearing on meat quality.

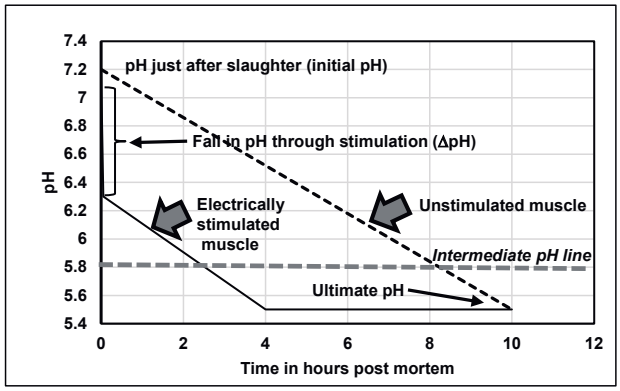

Fig. 3. The post mortem pH falls of beef sternomandibularis muscle held at a steady 35°C, with and without electrical stimulation (in conventional chilling the meat temperature falls). During stimulation there is a fall in pH (ΔpH) and the rate of subsequent pH fall is increased over unstimulated muscle. If the ultimate pH does not fall below the dashed line (through pre-slaughter stress) the meat does not tenderise as expected.

Rigor mortis and *rigor* contracture occurs when all muscle fibres are depleted of ATP and the pH falls so the muscle becomes stiff. This state of *rigor mortis* is well known and the fall in pH following normal first order kinetics is temperature dependant (if one were a forensic human pathologist, knowing the weight, temperature, pH and levels of stress after death one could calculate back and work out the time of death). Not all muscle fibres have the same levels of glycogen/ATP so individual muscle fibres enter *rigor* sequentially depending on the initial glycogen levels, at which point each individual fibre produces a burst of tension – a *rigor* contracture. Summated, these contractures produce tension and shortening. *Rigor* shortening does not toughen meat (although it is often associated with temperature inhibition of tenderisation described below), whereas shortening by a different mechanism called cold shortening does toughen meat.

Cold shortening occurs when muscle is exposed to low temperatures before *rigor mortis* – the shortened muscle is tough when cooked as was first shown in 1963 by Ron Locker of MIRINZ[3] and occurs independently of a *rigor* contracture. Cold shortening occurs through calcium slowly leaking from the sarcoplasmic reticulum causing a contracture – in other words calcium re-uptake relaxing living muscle just cannot keep up in the cold. The colder the temperature, the faster the shortening with greater toughness. Once muscles enter *rigor mortis* cold shortening stops.

Cold shortening occurs in lamb when the muscle temperature falls below ~10°C during blast freezing, e.g. New Zealand lamb sent to the United Kingdom prior to 1970. It is less likely in beef with a much larger carcass to

cool. Pork has a lower critical temperature and shortening occurs in poultry below ~2°C. Recognising that cold shortening does occur meant that meat needed to be held above 10°C for 24 h until *rigor mortis*. Until recent times, chilling was slow and shortening wasn't an issue and if there were no commercial imperatives, and no microbiological constraints, slow chilling would be normal and one would have tender meat most of the time. The solution required a holding period in chillers at defined temperatures.

Once each muscle fibre enters *rigor* it is protected from temperature and pH influences and starts to tenderise - those fibres that enter *rigor* first are protected and tenderise first. At elevated temperatures, enzyme inhibition is additionally responsible for reduced tenderisation affecting fibres that entered *rigor* slowly - so the faster to *rigor* the greater tenderness potential. Fortunately electrical stimulation achieves this.

Electrical stimulation, investigated by Bruce Marsh and developed by MIRINZ in the 1970s and onwards, accelerated the *rigor* process. Work performed by the muscle during the stimulation-induced contraction progressively used up glycogen, the pH fell and *rigor mortis* occurred rapidly. It was reasoned muscles would enter *rigor mortis* so fast they would not be affected by chilling, would not shorten and meat would be tender. This indeed occurred, so research on obtaining the best electrical parameters (Fig. 4) took place. The effect was so dramatic, that times to *rigor mortis* were now 3-4 hours compared to 24 or more hours normally.

Early studies on electrical stimulation indicated that the optimum frequency was 14.28 pulses per second using voltages as high as 1130 volts applied for 90 seconds (Fig. 5), 30 min after slaughter for both sheep and cattle, but other parameters can be used. Voltages as low as 80 volts applied soon after slaughter need only 30 seconds.[4]

Experiments undertaken in Sweden in 1995 showed after exposure to high temperatures (>30°C) non-stimulated meat prevented from shortening by tight wrapping did not tenderise, suggesting an inhibition of tenderising enzymes rather than shortening effects.[5] Invariably, extrapolations suggested rapid *rigor mortis* following electrical stimulation would mean muscles could not cool and tenderising enzymes would be inhibited - especially in cattle - so tenderisation would be reduced. However, fortunately this did not occur – most muscle fibres entered *rigor* so fast immediately after stimulation that they were protected from shortening and enzyme inhibition. In 2007 that electrical stimulation was shown to do more than prevent cold shortening, it even enhanced tenderisation.[6] This was confirmed by studies in Australia where following electrical stimulation, tropical cattle breeds (not normally as tender as British and continental breeds) were all more tender than non-stimulated animals of either breed.[7] It would be fair to say that most of the meat produced in the world without electrical stimulation would not fully tenderise.

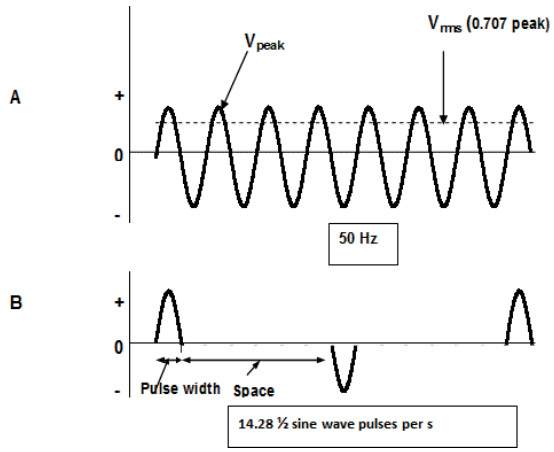

Fig. 4. Pulse frequencies used for electrical stimulation. The waveform (14.38 pulses per second - high voltage 1130 V peak - low voltage 80 V peak) is derived from the 50 Hz mains frequency where some cycles have been removed electronically.

Fig. 5. High voltage electrical stimulation system using 1130 V peak, 2 A peak, applied for 90 s at 30 min post mortem.

Tenderisation - the role of calpains

Reaching *rigor mortis* and merely preventing shortening results in the meat being very chewy and unacceptable with a shear force approximately 100-150 N - it has to age and fall below 50-60 N to be ideal.

The rates of tenderisation are exponential with the greatest rate immediately following *rigor mortis* and increasing with rising meat temperatures shown by Lester Davey of MIRINZ.[8] Meat tenderises by calpains, the enzymes responsible for muscle remodelling in life (normally inhibited by calpastatins). Calpains are proteins belonging to the family of ubiquitous calcium-dependent cysteine proteases. They occur in most tissues including brain, where with oxygen deprivation following stunning and slaughter, calcium influx into nerves activates calpains destroying brain tissue within minutes, ensuring humaneness of slaughter (cryopreservation of brains at this point would be pointless). Calpains are activated in each muscle fibre after *rigor* and ageing commences in that fibre - once in *rigor* factors inhibiting tenderisa-

tion do not occur (the term *rigor mortis* is applied to the whole muscle after summation of *rigor* of the individual muscle fibres). Because some fibres enter *rigor* early they tenderise early, so electrical stimulation by accelerating *rigor mortis* enhances tenderness.

Meat contain ~ 74% water. As meat tenderises, calpains act on a set of muscle proteins termed cytoskeletal proteins, titin, nebulin and desmin, bound with water in their tertiary structure. When these proteins denature, free water is released as drip with a close relationship of the muscle dry matter to the shear force (Fig. 6). Drip appearing in meat trays is by-product of tenderisation and not a defect, although much effort is made to reduce its appearance using absorbent pads. The main cytoskeletal protein is titin (largest molecule in the animal kingdom, 3,000,000+ daltons) comprising 10% of the muscle proteins. Originally titin (responsible for energy recovery in life), first seen by Ron Locker of MIRINZ using electron microscopy, was called connectin.

On farm, transport, pre-slaughter stress and effects on meat quality

New Zealand has predominantly range/pasture oriented production systems. Animals moving from the farm in difficult terrain and transported to slaughter use muscle glycogen. If the glycogen depletion is sufficiently severe, there is an elevation of the ultimate pH and the meat is less tender. The pH effect is unusual in that both high ultimate pH meat (unacceptably dark) and low ultimate pH meat is tender, but meat of an intermediate pH is tough as the enzymes available to tenderise the meat are reduced.[9,10]

Stress arises from high muscular effort, such as bulls riding each other, mixing and interaction of naïve animals, or moving mobs long distances on a farm before slaughter. Some psychological factors exacerbate the situation but are not a cause. Levels of stress cannot be determined pre-slaughter and can only be evaluated from the ultimate pH in a chiller at, say, 0°C - a mind numbing exercise. In New Zealand, one survey showed over 90% of steers but only 40% of bulls were satisfactory. Meat from rapidly growing bulls was therefore preferentially exported for manufacturing, e.g. as ground beef and frankfurters. Low pH lean bull meat is normally tender and bulls are farmed in many European countries - any toughness is due to raised ultimate pH. Sheep have the similar pH problems with exercise during rounding up on farms. Low intensity effort, such as travelling in a truck are not issues - other than the effort required during loading and unloading. Elevated pH reduces the shelf life of chilled meat so there are economic reasons to reduce pre-slaughter stress – this can be done by conditioning animals to common stressors and resting before transport to slaughter.[11] It takes several days for ruminants to replenish glycogen stores on standard feeds, so resting animals with food before slaughter is beneficial.

Humaneness of slaughter

Animals must be humanely slaughtered and the slaughter process needs to conform to various religious and

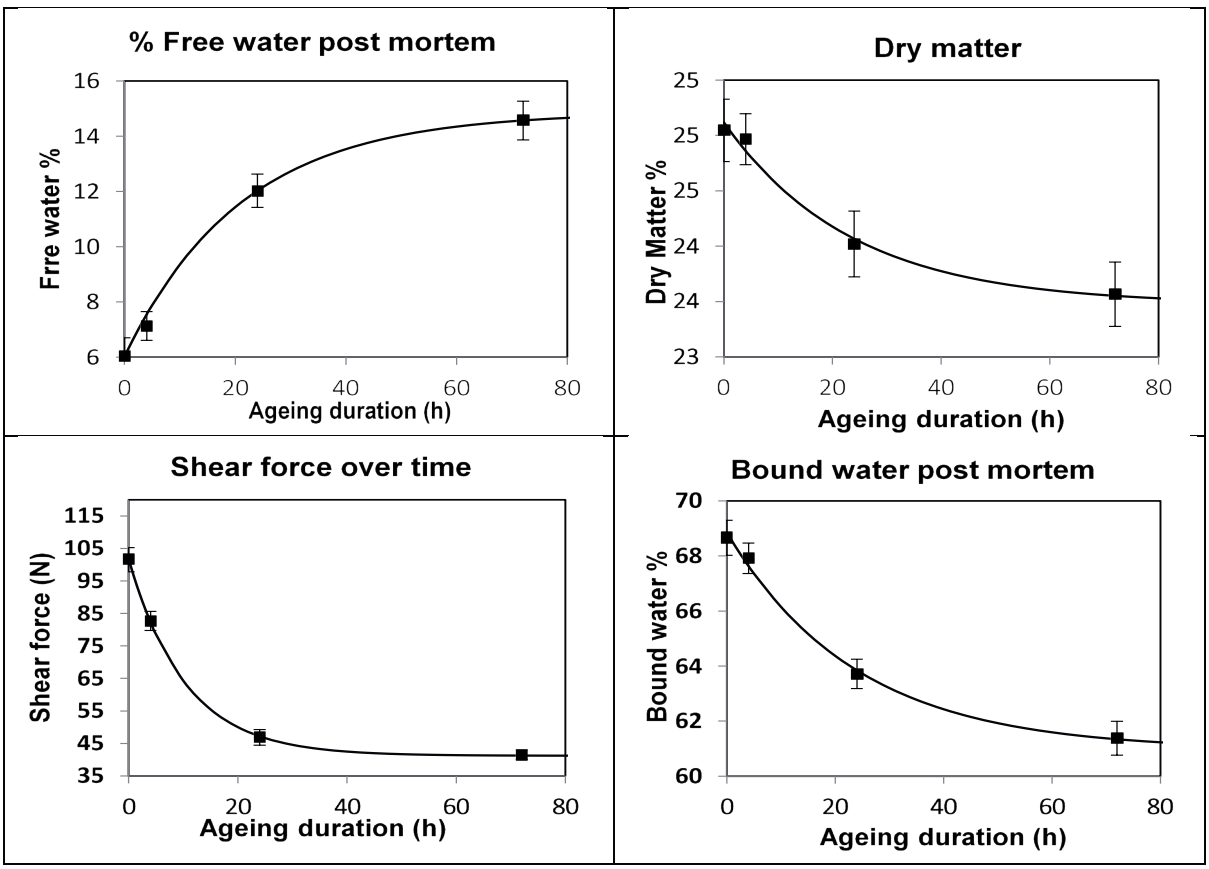

Fig 6. The exponential relationship of free water (drip) and bound water (water bound to cytoskeletal proteins), and decrease in dry matter (all water dried off) correlated with reduction in shear force. This study used meat held at 15˚C (much higher than the usual 1-4˚C to complete the experiments rapidly). Meat with an initial shear force post mortem is only barely edible.

market requirements. In traditional slaughter, the throat was cut without prior stunning. Animals may now be stunned electrically or by a captive bolt that sends a shockwave into the brain, destroying it. A captive bolt is not acceptable for some types of religious slaughter as it, rather than the slaughterman, kills the animal.

Electrical stunning was developed for sheep and cattle in New Zealand and takes place by applying 300-400 V across the head for both sheep and cattle. There is an instantaneous change in neurotransmitters in the brain causing immediate unconsciousness that lasts for over a minute and there is an absence of pain for up to 15 minutes. A head-only stun is suitable for halal slaughter as the slaughterman actually takes the life of the animal since it could have recovered (without pain). If other electrode positions are used involving the middle of the back or body, cardiac inhibition occurs, post-stun movements are reduced and the animal will not recover - this is not halal.

Studies on the humaneness of slaughter focussed on changes in brain function monitored by electroencephalography, where the seizure from the stun (huge swings in the amplitude) indicated immediate unconsciousness and the following sequence of brain patterns indicated continued unconsciousness. Perfusate, from microdialysis probes (Fig. 7) inserted into the brain showed parallel neurotransmitter (glutamate, aspartate) changes during the seizure and neurotransmitter (gamma amino butyric acid) changes following the seizure.[12] Procedures used in New Zealand for stunning and slaughter were confirmed humane and enabled export to both halal and western markets. Electrical stunning was accepted for halal slaughter at a Muslim World League meeting in Berlin in 1986.

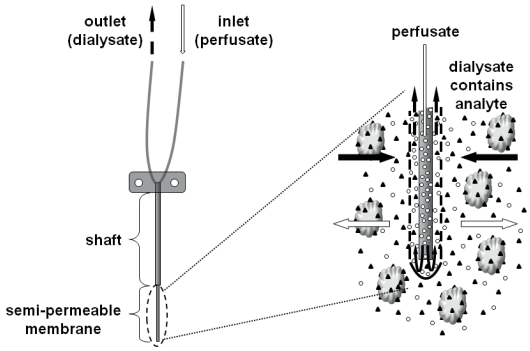

Fig. 7. Diagram of a microdialysis probe[13] that can be inserted into the brain of an animal. Brain neurotransmitters that moved into the perfusate can be collected and measured during stunning/slaughter.

Online measurement of tenderness

Evaluation of meat tenderness is made on cooked meat by measuring its shear force. The chemical changes underpinning tenderisation are biochemical leading to the degradation of the cytoskeletal proteins, an increase in free water, reduced bound water and a decrease in dry matter. These result in spectral changes that can be measured by near infrared spectroscopy (NIR)[14,15] (Fig. 8) and can be correlated with shear force, colour, pH and many other meat quality attributes. The changes could be measured at standard times to monitor various processing procedures.

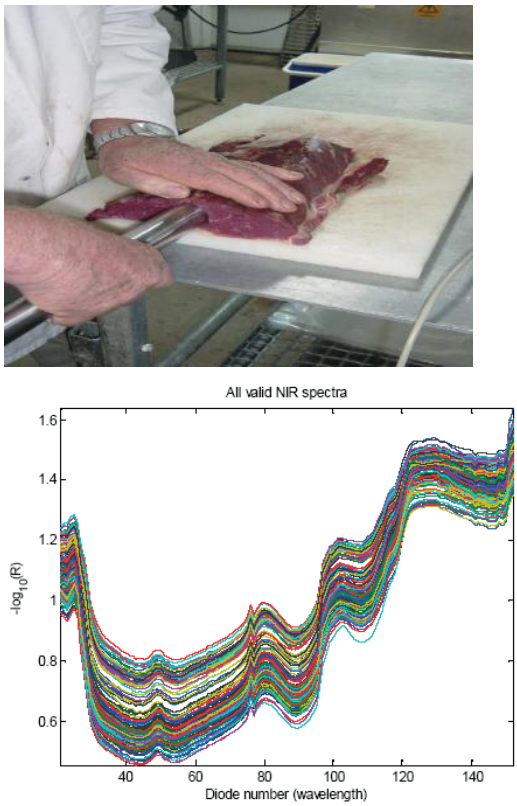

Fig. 8. A fibre optic probe placed on the meat with illumination from a quartz-halogen light source. The resulting NIR spectra collected contain information about shear force, pH, drip and colour and are analysed using multivariate analysis.

Importance of meat in the diet

Meat is a food that readily provides amino acids, essential fatty acids (such as omega 3 fatty acids), essential vitamins and minerals such as iron and zinc that are difficult to get in other ways. In a study by MIRINZ in 1989[16] on the composition of cooked sheep meat, beef, venison and poultry, some techniques for obtaining nutrition information had to be modified as they were designed for foods other than meat. Moreover, the values obtained, especially for the composition of New Zealand meat from pasture/range fed animals in terms of fat, in many instances differed from the values found in the literature for feedlot animals elsewhere.

The pasture effect and putative health aspects of meat in a diet need to be considered carefully. High levels of meat intake appear to be associated with increased risk of colorectal cancer in some situations, albeit at a relatively low level.[17,18] For example, while colorectal cancer has the 3rd highest cancer prevalence, it is low (6%) compared with lung (16%), breast (13%) and prostate (13%) cancers, with 30% of colorectal cancer deaths occurring in those over 80. It "may" be reduced by only 1% if one did not eat large amounts of meat, but is also reduced if one eats vegetables[19]. Levels of obesity also appear to be important.[20]

As an example, a beefburger might in fact be healthier than expected because of the lettuce, tomatoes and vegetables – provided it is not eaten with fries and sugary drinks. A Big Mac has roughly 540 calories (adding fries and a drink makes 1100 calories in total), a cheeseburger

300 calories, an avocado 240 calories, fries 230-330 calories, a chocolate shake 540 calories, a soda drink 310 calories and a McFlurry 650 calories. Paracelsus in the 15th century said, "The dose makes the poison".

Any relationships, based on epidemiological studies are complex and unlikely to have a single cause. The colorectal cancer risk is much lower than effects from smoking, atmospheric pollution, excessive alcohol, communicable diseases and the diseases of poverty. It would be fair to say that one could die of the diseases of poverty early in life or live longer and die of the diseases of affluence.

Environmental considerations

In the New Zealand context, meat production using sheep, beef and venison is mainly on land that cannot easily be used for arable farming activities that are potentially more efficient in terms of protein production. The situation is similar to extensive farming worldwide that generally occurs on land unsuitable for growing crops. The waste products from a meat processing plant, however, are as environmentally damaging as those from a large town and MIRINZ has played a large part in developing adequate effluent treatment in New Zealand.

Methane (25 times as potent as carbon dioxide) from ruminants is often seen as a significant greenhouse gas contributor and New Zealand produces a disproportionate amount per head of population. The situation is, however, less clear than generally stated because of the dynamics of methane production and recycling. The contribution to greenhouse gases would be true if methane was continually released as a slug of gas (similar to that from industrial sources). However, the breakdown of methane to carbon dioxide (over 12 years) and re-utilisation of carbon dioxide by plants via photosynthesis, ensures methane does not accumulate in the atmosphere. The process takes 60 years resulting in a steady state, so it could be argued methane does not continually contribute further to future global warming once an equilibrium is set up. Atmospheric modelling also does not support the view that methane produced by ruminants is as bad a greenhouse gas as the Global Warming Potential would indicate.[21]

Microbiology and packaging

Meat is inherently sterile with spoilage bacteria on the surface coming from the environment, so hygienic processing and chilling/freezing is important to limit growth of microorganisms. Frozen lamb was exported in stockingnette bags stacked in holds of ships until the 1970s. Today meat is wrapped in a plastic film and shipped in temperature controlled containers. Frozen meat should be tender before freezing (will tenderise if thawed before cooking). For fresh meat, the most common plastic film for supermarket displays is overwrap, but oxygen ingress limits shelf and display life. Meat chilled and placed in an oxygen impermeable barrier bag (vacuum package or Vac) held at -1.5°C does not freeze and tenderises over 6-10 weeks, e.g. during shipping. The environment in the bag promotes the production of lactic acid bacteria preventing growth of pathogens. Another type of packaging developed in New Zealand by Colin Gill[22] is a master pack containing carbon dioxide with packaged meat inside, called controlled atmosphere packaging (CAPtech) increasing the shelf life even further. The bag has to be virtually impervious to oxygen, e.g. aluminised film as small amounts of oxygen allow formation of brown metmyoglobin. For retail display, high concentrations of oxygen in a modified oxygen package (MAP) also limit bacterial growth also allowing the oxymyoglobin in meat to bloom bright red.

Acknowledgments

I wish to acknowledge the efforts of my colleagues in the MIRINZ for the work covered here as well as colleagues in Australia, Japan and Sweden. Many MIRINZ scientists and engineers worked closely with industry bodies and personnel in introducing the outcomes to the whole industry. Because the research challenged long lasting entrenched beliefs and conventional wisdom in New Zealand and overseas and included legislative changes, it is remarkable that so much was achieved in such a short time.

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The modern apothecary: reviving the romance of chemistry

Peter Hodder

HodderBalog Social and Scientific Research, Wellington, New Zealand *and* Victoria Business School, Victoria University of Wellington, New Zealand (email: *peterh@hodderbalog.co.nz*)

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A little more than a decade ago, an award-winning science journalist described the origins of chemistry thus:

"Modern chemistry has a panoply of origins: in the arts of metallurgy and brewing; in the ancient philosophers' puzzles over the nature of brute matter and the distinction between substance and form; in the mystical obsession of alchemists. To explain the basics of matter, the latter groped for underlying principles such as the four Aristotelian elements (earth, air, fire and water), the seven metals, the universal spirit and the philosopher's stone. They understood the natures of substances through their links with the planets, with mythological characters, with theology. They represented them using symbols, colours, pictures, secret names and codes. The achievement of chemistry over the last two hundred years has been to remove these romantic underpinnings."[1]

Do any 'romantic underpinnings'[2] of chemistry survive? Perhaps they do in places such as in an undistinguished early twentieth century building in Wellington's Cuba Mall which hosts a small self-styled apothecary – "a herbal dispensary, natural therapy clinic, botanical factory and alchemists delight", the staff of which are 'dispensers of herbal remedies'.[3] However, what catches the eye of the passer-by in the shop's window is an 'essential oil burner',[4] a small candle gently heating a flask of yellow oil (Fig. 1) maintained in its position by a clamp and stand which are clearly based on traditional chemistry equipment.

Fig. 1. The 'Essential Oil Burner'"...draws reference to a classic yet refined science theme. The dark heaviness of the metal components and clamp create a beautiful contrast with the Tasmanian Oak hardwood base. The height of the clamp is adjustable so the *scientist* [italics added] can personalize to suit the size and strength of the candle and liquid" (ref. 4).

A glimpse through the open door of the shop shows orderly shelves containing remedies for purchase at the rear of the shop and hints that there might be other equipment and activities undertaken here (Fig. 2A). There is a sense of theatre[5] and a quasi-scientific ambience to the place: a laboratory of sorts, but without the white coats (Fig. 2B).[6]

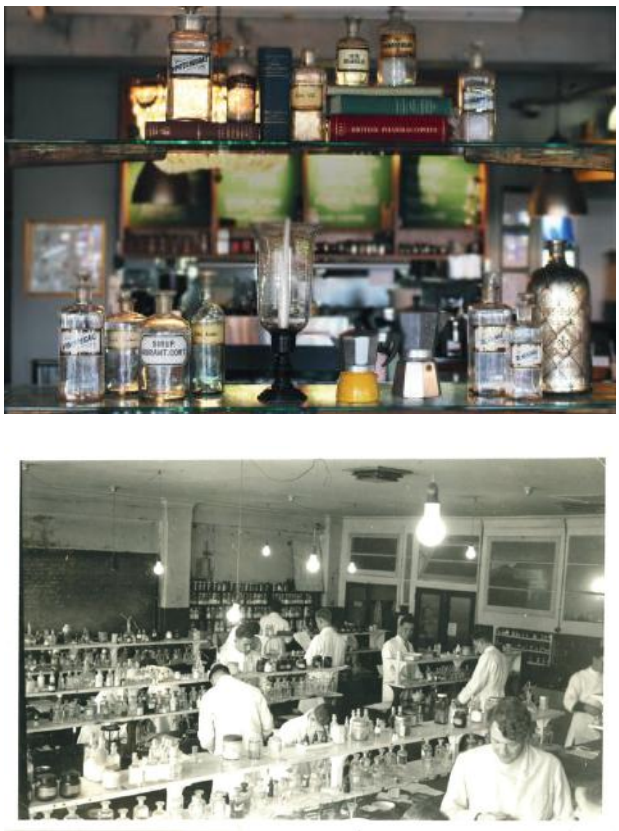

Fig.2. Chemistry as theatre. ***A (Upper):*** The ambience of an apothecary transposed to an Auckland bar: "Welcome to the Apothecary. A unique slice of French history, nestled in Auckland. Lovingly restored, this original 1950s Apothecary interior from Northern France has transformed itself into a lovable and exciting space for foodies." (http://www.theapothecary.co.nz/, accessed 14 June 2016). ***B (Lower):*** Pharmacy laboratory, University of Otago, 1950s-1970s. (http://www.otago.ac.nz/library/exhibitions/phamacy/, accessed 17 June 2016).

Of course, apothecaries are hardly new entities:[7] the *New Zealand Tablet* of 17 June 1892 commented of Wellington that

"the apothecaries are here in their numbers, you can scarcely see a shop at one side of the street but an opponent is sure to be found on the opposite corner. Judging by the numerous disciples that Aesculapius [the Greek god of medicine and healing] has here, a visitor would not be led to form a very high opinion of this city as a health resort".[8]

Richard Ayres was such a 'dispenser of herbal remedies', ultimately having three shops: in Petone, Newtown, and Cuba Street – this last at no. 90 (Fig. 3A),[9] close to the current Wellington Apothecary at no. 100A. Although he had no pharmaceutical or medical training, "his [Ayres'] mother had treated her neighbours with herbs, giving her son a belief in the power of folk medicine".[10] Ayres' Cuba Street shop was also equipped with apparatus for mixing, rolling, piping and coating pills and capsules. His concoctions – said to number more than 100 – included those of his own manufacture, e.g., Ayres' Asthma Powder, Ayres' Composition Powder, Ayres' Herb Extract, as well as those of others, e.g., Dr Lane's Catarrh Cure, Ogilvie's Morak – being a chemical preparation which increased the contrast in photographic negatives[11].[10] However effective a herbalist Ayres may have been, he was less of a success in business and was declared bankrupt in 1908.[12]

Better trained was William Crothers Fitzgerald, a "consulting chemist", the advertising on whose shop on the corner of Wellington's Lambton Quay and Willis Street drew attention to his skills as a surgeon-dentist, a public vaccinator, a ship surgeon, and to his providing "advice and medicine" (Fig. 3B).[9] His training was as a pharmaceutical chemist, but "he had worked in London as a dispenser for a medical practice. On three occasions he acted as medical officer, or surgeon, on passenger ships sailing to New Zealand", attending to 'minor ailments', and, once established in Wellington, multi-tasked "as surgeon-dentist, adopts a painless system of extracting teeth, and is exceptionally skillful in ear-syringing". [13]

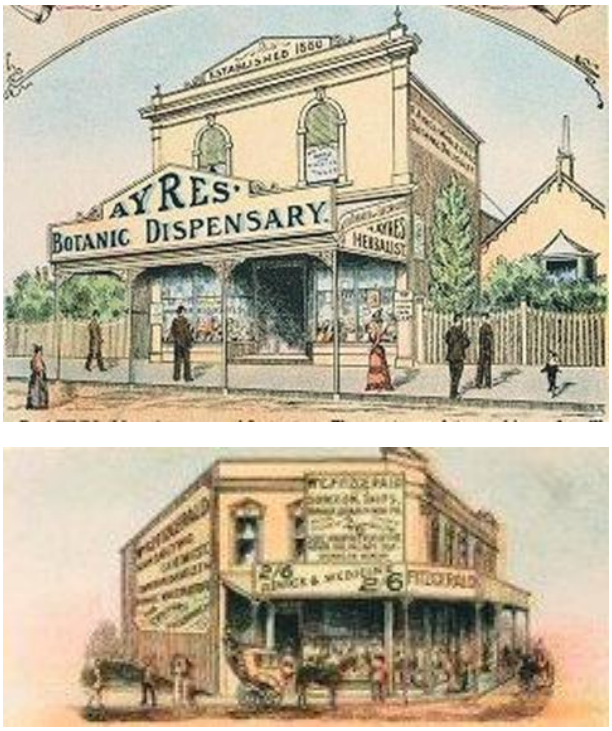

Fig. 3. Examples of Wellington's colonial apothecaries. ***A*** *(upper):* Ayres' Botanic Dispensary (Alexander Turnbull Library, Ref.: D-002-008-006). ***B*** *(lower):* W.C. Fitzgerald's Central Pharmacy (Alexander Turnbull Library, Ref.: D-002-007-003).

Consultation charges, such as Fitzgerald's – two shillings and sixpence – let alone the cost of the herbal remedy, may have prompted the publication in several newspapers of a piece entitled 'An Apothecary's shop in the garden', in which readers were reminded:

"The money a man – especially a family man – spends on bottles of medicine in a lifetime would take him on a holiday trip around the world or start one of his children in life. And all the time he has Nature's own simple remedies, better than any chemist's concoction outside his door."[14]

The reality of early colonial gardening was often unlikely to provide a setting for such a garden (Fig. 4A),[15] but something approaching such an ideal could be realised later – in suburbia (Fig. 4B).[16]

Fig. 4. Reality and an attempt at a romantic garden. ***A*** *(upper):* "The stark reality of a small habitation set amongst burnt-off bush slopes. There are no picturesque herb or cottage gardens in this backyard. Angela Jacobs at Apiti, near Fielding, 1890s" (reference 14). ***B*** *(lower):* "The owners of a Hawke's Bay bungalow photographed in the early 1920s, with their quite remarkable garden" (ref. 15).

By comparison with Ayres' and Fitzgerald's premises, the 'Apothecaries' Hall', the somewhat pretentiously named drug and herbal remedy dispensing business in Auckland owned by W. Sharland appears to have separated the drug dispensing part of the business from other activities,[17] consistent with the registration of pharmacists from 1880.[18] Perhaps surprisingly, the publishers of a history of pharmacy in New Zealand[19] chose an image for the cover of the book which is much more reminiscent of an apothecary than of a pharmacy at the time the history was compiled (Fig. 5).

The Wellington Apothecary also offers workshops offering guidance in simple techniques: steeping the plants in

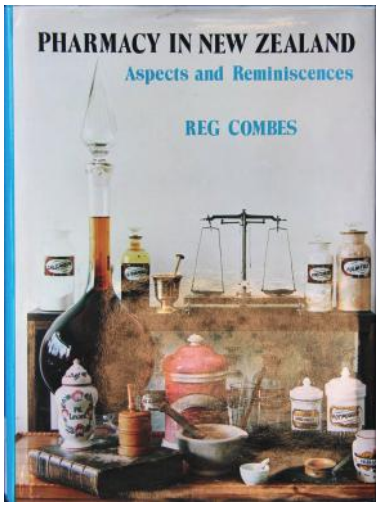

Fig. 5. *Top*: The cover of *Pharmacy in New Zealand - Aspects and Reminiscences*, reference 19 (http://ourheritage.ac.nz/items/show/7728). *Bottom:* Chemist in pharmacy 1972. (Alexander Turnbull Library, Ref.: 1/2-224520-F)

a cold liquid, e.g., oil, vinegar, alcohol, glycerine, honey, or by heating them in a warm liquid, e.g., water or a mixture of sugar and water, and then making infusions, decoctions, tinctures, syrups, oxymels and elixirs for internal use; and herbal baths, ointments and creams, compresses, poultices and oils for external use (Fig. 6). Of course, such activities can be carried out in the home kitchen, [20,21] but such a setting is unlikely to have the theatricality of The Wellington Apothecary.

The two sections at the left-hand side of Table 1 show the distribution of chemical elements and vitamins in selected herbs, while the right-hand section shows the systems of the human body in which those herbs are inferred to be effective for particular ailments. Comparison between the first and third sections of Table 1 enables a compilation of the number of herbs that are effective for the human body's systems by chemical elements (Table 2), while comparison between the second and third sections of Table 1 enables a compilation of number of herbs that are effective for the human body's systems by vitamin (Table 3). From Tables 2 and 3, herbs could be inferred to be generally more helpful to ailments of the digestive system than other body systems, and that calcium and vitamins A and C are the most effective constituents. Such a simplistic interpretation takes no account of the actual concentrations of these constituents.

Fig. 6. Workshops at the Wellington Apothecary, where participants "Learn to make your own natural and organic skincare range with therapeutic botanical extracts and nourishing plants oils. In our workshops you will learn about the therapeutic uses of a range of botanical extracts and how to blend them for your skin type. Make a lip/face/body balm and create a nourishing hand and body cream using our herbal and aromatherapy extracts. All equipment is provided and take home everything you make. You will learn to make creams, balms and oil blends; the therapeutic properties of herbal extracts; suitable plant oils for different skin types and ailments; [and] how to blend hydrosols, floral waters and essential oils for skincare."

The concentrations of such elements and vitamins are low in the plants themselves (shown for dandelion, as an example, in Table 4[1]).

Care is needed in the interpretation of such chemical analysis of herbs. As an example:

"Dandelion leaf is a good source of potassium; 1 analysis found that 100 g (just over 3 oz) of leaf contained 297 mg potassium [cf. 397 mg in Table 4], putting it in a league with other high potassium-source foods. This means

that, by dry weight, up to 4% of dandelion leaf is potassium. However, it should be pointed out that food-level doses (not the smaller medicinal doses) of leaf must be ingested to obtain potassium. A 5 mL (1 tsp) dose of leaf tincture with a 1:2 (weight:volume) ratio containing 4% potassium would provide just 100 mg of potassium, approximately one-fifteenth the dose necessary to be clinically relevant."[2]

The Wellington Apothecary stresses the holistic effects of the oils and extracts in the products they and their workshop participants make, rather than attributing benefit obtained from the presence of specific chemical elements or vitamins. Although the concentrations of elements and vitamins are likely to be enhanced in the extracts, the dispensers and therapists have neither the equipment nor the analytical techniques at their disposal to determine the actual concentrations in the products.

This recognition that the efficacy of the apothecary's products is based on the herbal dispenser's knowledge and experience of the herbs' clinical effectiveness (rather than in the details of their chemical composition) and in the setting of their use (Fig. 7A) is reminiscent of the recognition that the therapeutic value of geothermal waters was more related to their warmth than their specific chemical composition (Fig. 7B).[3]

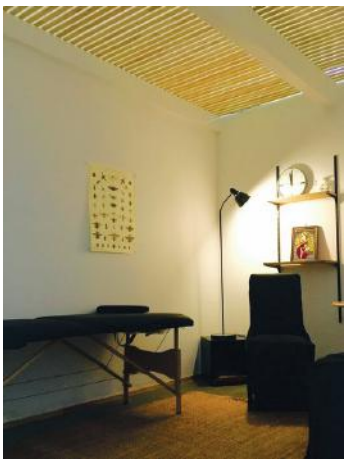

Fig. 7. The physicality of therapy. ***A (Left):*** Clinic at Wellington Apothecary, 2016: soft lighting, muted colours, and simple understated décor. ***B (Right):*** Inside the Duchess Baths, Rotorua, *ca*. 1908: the plain tongue-and-grooved wood-lined bathroom contrasts with the elegance of the rest of the water therapy suite. (Alexander Turnbull Library, Ref.: PA-o-503-05).

Unlike geothermal waters, in which the chemical elements of Table 1 are generally found as simple ions in solution, the elements found in herbs are in the form of compounds (including vitamins), the characteristics of some of which are expected to be responsible for the herbs' efficacy. The identification of these compounds and their isolation and/or synthesis is a province of modern organic chemistry, while the dosage of these specific compounds to achieve the desired medicinal function is the province of pharmacology.

Using dandelion as the example again, an old herbal notes that "the chief constituents of Dandelion root are Taraxacin, a crystalline bitter substance, of which the yield varies in roots collected at different seasons, and Taraxacerin, an acid resin, with Inulin (a sort of sugar which replaces starch in many of the Dandelion family, *Compositae*), gluten, gum and potash."[4]

Taraxacin was reported as first isolated in 2000,[5] and was more recently described as a number of compounds which "belong to a group of novel eudesmanolides with tetrahydroridentin B and taraxacolide-β-D-glucopyranoside and germacranolides such as 14-*O*-β-D-glucosyl-taraxinic acid, its 11β,13-dihydro derivative (with anti-leukatriene B4 activity) and the isomeric ainslioside…; [and] guaianolides such as 11β,13-dihydolactucine and ixarine D".[6] As a crude drug, taraxacin has been said to "lack any real therapeutic value", but that "taraxacin in the plant resin [inferred to be taraxacerin] may stimulate gastric secretions".[7] However, eudesmanolides are recently reported as having "anticancer, anti-migraine, analgesic, sedative, antimalarial, antibacterial and antifungal properties".[8] Moreover, a recent review identifies chemical constituents in dandelion that make it a "good antidiabetic drug", likely to help in regulating blood sugar and cholesterol.[9]

There may be no particular romance[2] about dandelion, but there certainly is about chamomile, as the example from a comparatively recent novel suggests.

"She dreamed of the summer days when Polly, Walter, Calypso and Oliver had lolled on the camomile [sic] lawn, laughing and joking…. Every night before she slept she wished herself back in her bedroom; from there she would climb out along the branch of the Ilex above the camomile lawn and sniff its scent, mixed with the salt smell of the sea."[10]

Polly, Walter, Calypso and Oliver were following in the footsteps of those who used chamomile as "one of the aromatic strewing herbs in the Middle Ages, and used often to be purposely planted in green walks in gardens. Indeed, walking over this plant seems specially beneficial to it".[11] In its use as a drug (it is said to be included in the pharmacopoeia of 28 countries), sesquiterpenes, flavonoids, coumarins, and polyacetylenes are considered the most important constituents; in addition "more than 120 chemical constituents have been identified in chamomile flower as secondary metabolites, including 28 terpenoids, 36 flavonoids, and 52 additional compounds with potential pharmacological activity. Components, such as α-bisabolol and cyclic ethers are antimicrobial, umbelliferone is fungistatic, whereas chamazulene and

Table 1. Presence of selected chemical elements and vitamins in "favourite herbs", and the human body's systems in which those herbs are inferred to be efficacious

Favorite herbs	Chemical elements*											Vitamins*									Human body's systems‡								
	Ca	Co	Fe	Mg	Mn	K	Zn	Cr	*Cu*	*Se*		*A*	*B*	*B3*†	*C*	*D*	*E*	*K*	*P*		*EX*	*CS*	*RS*	*NS*	*DS*	*ES*	*RP*	*IS*	
Aloe vera	•					•					2										Δ				Δ				3
Basil				•	•						2				Δ			Δ		3	Δ			Δ	Δ				3
Caraway	•		•	•	•		•	•			5				Δ					1			Δ		Δ			Δ	3
Cayenne	•	•				•					3	Δ							Δ	2	Δ				Δ		Δ		3
Chamomile	•						•				2										Δ			Δ	Δ				3
Coriander	•		•	•	•		•		•	•	7	Δ	Δ		Δ					4	Δ		Δ	Δ	Δ		Δ		5
Dandelion¶	•	•	•		•	•	•				7	Δ	Δ		Δ	Δ	Δ	Δ		6	Δ				Δ	Δ			3
Dill	•		•	•	•	•			•		6	Δ			Δ					2	Δ				Δ		Δ		4
Echinacea		•									1				Δ					1	Δ								1
Fennel	•					•					2										Δ		Δ		Δ		Δ		4
Fenugreek													Δ	Δ	Δ					4									
Feverview														Δ						1			Δ	Δ					2
Garlic			•		•		•		•	•	6		Δ		Δ					2		Δ	Δ		Δ				3
Gotu loka				•							1	Δ						Δ		2									
Marshmallow	•						•				2										Δ		Δ		Δ			Δ	4
Nettles			•					•			2										Δ		Δ		Δ	Δ			4
Oregano	•		•	•	•	•					5				Δ					1									
Parsley	•	•	•	•		•					5	Δ	Δ	Δ	Δ		Δ			6				Δ	Δ		Δ		3
Peppermint	•		•	•	•	•	•		•		7	Δ	Δ	Δ	Δ					4	Δ				Δ				2
Plantain												Δ								1	Δ		Δ						3
Rocket															Δ					2			Δ		Δ				2
Rosehips						•					1				Δ	Δ				2	Δ			Δ					2
Rosemary	•		•	•	•	•	•		•		7	Δ			Δ					2	Δ				Δ			Δ	4
Sage	•		•	•	•		•		•		6	Δ	Δ		Δ		Δ	Δ		5	Δ		Δ		Δ		Δ		4
Skullcap			•				•		•		3						Δ			1				Δ					1
Sorrel															Δ					1									
Wood betony				•							1										Δ	Δ	Δ	Δ	Δ				5
Wild celery						•					1										Δ			Δ	Δ				3

*from McIntyre, reference 20, p. 15; by 'minerals' he means 'chemical elements'

† Vitamin B3 is often known as niacin

‡The human body systems that benefit from the herbs are inferred from commentary in McIntyre's 'Herb and plant Directory', pp. 120-139; the body systems are: ***EX***, Bones, joints, muscles, skin; ***CS***, Circulatory system; ***RS***, Respiratory system; ***NS***, nervous system; ***DS***, Digestive system (including metabolism); ***ES***, Endocrine system (includes thyroid and pancreas); ***RP***, Reproductive system; ***IS,*** Immune system

¶ *Taraxicum officinale*

α-bisabolol are antiseptic".[12] So extensive is chamomile's therapeutic value, that it is now commercially grown and the growing conditions of its botanical varieties tailored to optimise the yield of particular natural products.

These two examples serve to demonstrate the progression of chemical knowledge and skills from usage of herbs in their natural state, to simple extraction of essential oils, to identification of the active compounds and their use in drugs, to the synthesis of related compounds, which after appropriate clinical trials, become new drugs. This progression is shown schematically in Fig. 8.

Table 2. Number of herbs that are effective for the body systems by chemical elements

		Human body systems							
		EX	***CS***	***RS***	***NS***	***DS***	***ES***	***RP***	***IS***
		No. of herbs							
Selected chemical elements	Ca	11	1	8	2	13	1	5	4
	Co	3	0	0	1	3	1	2	0
	Fe	7	1	7	3	10	2	4	2
	Mg	8	1	6	4	10	1	4	2
	Mn	6	2	5	2	9	1	3	2
	K	9	0	3	3	9	1	4	2
	Zn	7	1	6	3	9	1	2	3
	Cr	1	0	1	0	1	1	0	0
	Cu	5	1	5	2	6	0	3	1
	Se	1	1	2	1	2	0	1	0

Table 3. Number of herbs that are effective for the body systems by vitamins

		Human body systems							
		EX	***CS***	***RS***	***NS***	***DS***	***ES***	***RP***	***IS***
		No. of herbs							
Selected vitamins	A	9	0	6	3	11	1	4	0
	B	4	1	3	2	6	1	3	0
	B3	1	0	1	2	2	0	1	0
	C	9	1	7	4	11	1	4	1
	D	2	0	0	1	1	1	0	0
	E	2	0	1	2	3	1	2	0
	K	4	0	2	3	5	1	3	0
	P*	1	0	0	0	1	0	1	0
*Vitamin P is a collective term for flavanioids, apparently in popular use from the mid-1930s to the early 1950s									

Table 4. Chemical composition of dandelion*

'Minerals'	Concentration (mg/100g)†	Vitamin	Concentration (mg/100g of fresh leaves)	Other nutrients	Concentration (mg/100g)†
Ca	187	A	14,000	Calories	45
P	66	Thiamine (B1)	0.19	Protein	2.7
Fe	3.1	Riboflavin (B2)	0.26	Fat	0.7
Na	76	Niacin (B3)	0	Carbohydrate	9.2
K	397	C	35		

*This herb was selected because it has the largest number of both chemical elements and vitamins in Table 1

† The part of the plant analysed is not specified, but it is probably the root

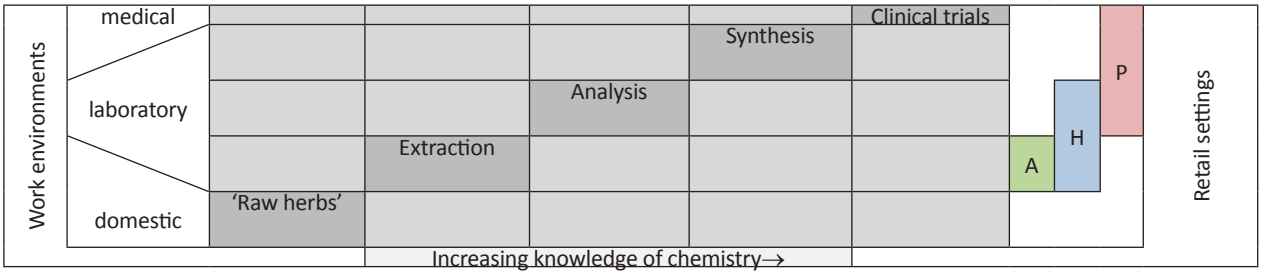

Fig. 8. Schematic representation of development of drugs from herbs, and associated work environments and retail settings in which the drugs are sold (viz., A, Apothecary; H, Herbal remedy shop; P, Pharmacy).

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Feature Series

Some Unremembered Chemists

A series of articles that explores the lives and work of selected chemists who have made a significant contribution to the advancement of the discipline, the profession and well-being of mankind, yet who are little remembered.

Rosalind Elsie Franklin (1920-1958)

Brian Halton

School of Chemical & Physical Sciences, Victoria University, PO Box 600, Wellington 6140
(email: brian.halton@vuw.ac.nz)

Much has been written about Rosalind Franklin in books, biographies and web-based items. The Royal Society (London) inaugurated its Franklin award, The Rosalind Franklin University of Medicine and Science in North Chicago, named after her, and college buildings, laboratories and graduate residences are now named in her honour. Despite these, many chemists remain unaware not so much of her crystallographic studies as the environment and attitudes prevalent throughout her short career. It is for this reason that she is the subject of this issue's *Unremembered Chemist*. However, to provide balance and perspective, the King's College DNA studies are briefly summarised.

Rosalind Elsie Franklin (image by Elliott & Fry, 11 June 1946, © National Portrait Gallery, London)

Rosalind Franklin was born in London on July 25, 1920, the first daughter and second child of Ellis Arthur and Muriel Frances (née Waley) Franklin. Two sons and a second daughter were born after her and David, her elder brother was born in 1919. The family home was in Notting Hill, now an affluent district in North West London but not quite so in the 1920s. Both her parents' families were involved with and prominent in the London Jewish community. Her great-grandfather Jacob Waley had been a respected barrister and the first Jewish professor in an English University (Political Economics, UC-London) while her uncle Herbert Samuel had been the Home Secretary and became Leader of the Liberal party for four years from 1931. The family was politically involved dominantly in striving for the working classes. Her father was a merchant banker with liberal politics who voluntarily taught at the London Working Men's (LWM) College (one of the earliest adult education institutions in the UK) throughout his adulthood, on electricity, magnetism and the History of the Great War. He had intended studying physics at Oxford, but was called up to join the army at the outbreak of the First World War instead. His involvement at the LWM had him rise to become Vice-Principal and have the physics laboratory named after him. In the period before WWII Rosalind's parents helped settle Jewish refugees from Europe and particularly those from the Kindertransport, taking two Jewish children into their own home.

The Franklin family were financially comfortable in their home at 5 Pembridge Place, Notting Hill, reputed to be a lively and happy place with the children an integral part of it. Ellis and Muriel were particularly supportive of their offspring, ensuring that they developed their individuality in comfortable surroundings, treating both sons and daughters with surprising equality given the era in which they lived.[1] Rosalind grew up surrounded by brothers, the older David and younger Colin and Roland until the birth of her sister Jenifer nine years later. From them she learned about competition, sports, and other things more typically of interest to boys and is reputed to have often taken to them more than her brothers.[2] They were a close family, partaking in lively discussion and vigorous debate at which, according to sister Jenifer, the highly intelligent, logical, determined and articulate Rosalind excelled. Rosalind had such a strong independent streak that she would even argue with her assertive father. She was also unusual in that she ignored dolls, greatly preferring to craft items, draw, photograph, or read, talents she used later in life to sketch, and then build her own molecular models and equipment.[2]

From early childhood Rosalind Franklin showed exceptional scholarly ability. At the age of six she joined David at the nearby Norland Place (Holland Park) private school where she was reputed[3] to 'do her sums for pleasure'. At age nine, she entered Lindores School for Young Ladies, a boarding school in the seaside town of Bexhill in Sussex; her parents thought it appropriate for her delicate health.[3] After two years there and at age eleven she transferred to St. Paul's Girls' School in Brook Green, Hammersmith, West London, about 3.5 km from home. It is, and was, a school known for its high standards and success rate, and was one of the few girls' schools to teach chemistry and physics when Miss Franklin entered. As the Franklin women were expected to focus their education, talents and skills on political, educational, and charitable forms of community service, it was perhaps surprising that Rosalind expressed an early fascination with physics and chemistry classes. At St. Paul's she excelled in science, Latin and sports, also becoming fluent in French and taking German. She topped her classes,

winning annual awards; her sole weakness was in music. This to the extent that her music teacher, the noted Gustav Holst, enquired of her mother if the girl had had tonsillitis or suffered from a hearing problem. When she was 15, she decided to become a scientist despite her father being decidedly against ladies using education to gain a career.[2,3] His ideal was for Rosalind to gain a diploma and spend her life like her mother. And this was much because career prospects for women in science, and particularly academia, were decidedly poor – no woman held a major post in a British university.[1] With six distinctions, a 1938 matriculation, a School Leaving Exhibition scholarship of £30 a year for three years, a scholarship for university, and £5 from her grandfather, Rosalind entered Newnham College at Cambridge a year earlier than many students and against the advice of the Head of the College. Her father asked that she donate the £30 scholarship to a deserving refugee student and told her he wanted to be kept informed of her progress at least weekly.[4]

On entry to Cambridge University and Newnham College, which with Girton was the only woman's one, she studied chemistry within the Natural Sciences Tripos graduating in 1941. She was one of the 500 women admitted, a limit set so that the women would not exceed 10% of the total male numbers. These women were not undergraduates but designated students of Girton and Newnham. Oxford University granted women degrees from 1921 but Cambridge steadfastly refused and did not award them a BA Cantab or any other degree deferring, instead, to a 'degrees titular'. Despite this, the facilities of the university, male supervisors and male research partners were the norm. Marriage was no deterrent to teaching, although such women were not allowed to participate in the affairs of the institution nor allowed to sit with their male colleagues at university ceremonies; instead they were included with the academic wives and without academic regalia. Rosalind's preliminary (end of first year) examination result in May of 1939 was a first class, a result far above the third class she expected; her self-doubt was strong. The result allowed her to continue to the first part of the Tripos the next year.

Her undergraduate teachers included spectroscopist W.C. Price, with whom she worked while a laboratory demonstrator, and F.S. Dainton, an early pioneer who had recently joined Cambridge to work with Norrish in photochemistry. She attended as many lectures as she could taking in such noted academics as Lawrence Bragg, J.J Thompson and J.B.S. Haldane. Then, in 1940, Adrienne Weill, a French refugee and former student of Marie Curie, arrived at Newnham and became Franklin's mentor and friend. She had a huge influence on Franklin's life and career. She also helped Rosalind to improve her spoken French. When war broke out in 1939 Rosalind was starting her second year and her father tried, unsuccessfully, to persuade her to abandon her studies for war work – Rosalind took the view that she would be of more use to the war effort if she completed her chemistry degree.[2] However, at that time she, and all the other students were expected to continue their study with less supervision because the science staff were occupied elsewhere in the war effort. This suited Rosalind but her independent enthusiasm led her close to the point of exhaustion. Yet she remained sufficiently dutiful to her family that during the university vacations, following the family tradition, she worked with the German-Jewish Refugee Committee in London. With the impact of war very evident by May 1940, Franklin found herself doubting her ability to the extent that she cut labs so as to revise for the first part of the Tripos. Again she expected failure and not the first-class pass she obtained. This gave her a £15 college exhibition scholarship and allowed her to proceed to the final year.

This last year saw her specialising in physical chemistry and attracted to crystallography. She had a supervisor in Newnham College, Delia Simpson, but felt it more appropriate to be under physical chemist and Yorkshire man F.S. (Fred) Dainton. Despite his full schedule, Dainton was sufficiently impressed by Rosalind's directness, and the assistance she offered other students that he took her on. He is reputed to have told Newnham College that he did not expect Rosalind to gain a first-class degree, not because of inability but because she would spend far too long on one topic rather than moving on to the next and attending to the entire examination paper; apparently she answered two rather than the three questions required on two of her papers.[4] She was just as pessimistic in approaching her final exams as those of the first two years. When Franklin graduated from Cambridge in 1941 she (and all women graduands) was not awarded her degree until 1947, when the university changed its regulations. As Dainton had predicted, it was not first class but an upper second, a result that bitterly disappointed her but fitted to his comments, her over-enthusiasm, and her exhaustion. Despite the result, she was offered a scholarship for fourth-year research with Professor Ronald Norrish (the British photochemist and 1967 Chemistry Nobel Prize winner). At that time Norrish's family had moved away from Cambridge to Devon to escape the possibility of bombing and he had succumbed to heavy drinking. This led to a lower than expected security rating and his inability to partake in significant war work. One outcome of this was that he treated his juniors badly and Rosalind Franklin was no exception.[4] Her research project was to study further the polymerisation of acetaldehyde and formic acid that had been the subject of a 1935 paper by Norrish and Carruthers.[5] Rosalind's research and study led her to the conclusion that the result anticipated by Norrish was untenable and Dainton agreed with her. This led to a major confrontation between student and professor and eventually a new project. By the summer of 1942 Rosalind Franklin had to decide whether to apply to stay at Cambridge for a PhD under Norrish or leave.[4] The decision was in large measure forced upon her by the Ministry of Labour decree that all female research students were to be de-registered and become eligible for military service. Surprisingly perhaps, Norrish encouraged her to apply to retain her reserved status and then painted an unimpressive picture of research in industry. It seems that he had recognised her ability and potential.

When the opportunity of research at the British Coal

Utilisation Research Association (BCURA; pronounced B cura) availed itself that 1942 summer Franklin resigned her scholarship, left the Norrish laboratory and began work with the new organisation. The BCURA laboratories were located near Kingston upon Thames and other sites around London, all under the direction of D.H. Bangham.[6] He employed young scientists trained in the latest research techniques in his new organisation and, because of the various locations, they had comparative freedom in their work. For the next four years, Rosalind Franklin worked there studying the micro-structures of various coals and carbons. Her research explained why some coals were more permeable to water, gases, and solvents and how heating and carbonisation affected permeability. She found that the pores in coal have fine constrictions at the molecular level and that they increase on heating, depending on the carbon content. They are molecular sieves that successively block the penetration of substances according to molecular size. Franklin was the first to identify and measure the effects of heat on the microstructure of coal which included the changes that occurred during the conversion of some coals to graphite. The work led to a classification of coals and an accurate prediction of their performance, an area in which her expertise clearly was recognised. The results of her study were written-up and submitted for her Cambridge PhD with a thesis, completed back at Newnham College and entitled: *The physical chemistry of solid organic colloids with special reference to coal*. It was submitted in May 1945 and deposited in the university library the following year.

During her professional role as assistant research officer and graduate student at BCURA, Rosalind shared an uncle's house on Putney Common with a cousin and her friend, and where her lifestyle became markedly more relaxed. Her work hours were restricted and she took delight in becoming more domesticated, cleaning, cooking and shopping. The four years at BCURA generated five papers, one jointly with Bangham,[7] and as sole author of three. Her Cambridge friend and mentor Adrienne Weill had spent the war years working with Lawrence Bragg in Cambridge but returned to Paris as a metallurgist in the French government laboratory for naval research after the 1944 Liberation. Rosalind stayed with BCURA for a year after her PhD and became recognised for her forceful and direct approach to matters in which she knew she was correct, and this irrespective of the place or her position.[4] In looking for a post-war position she wrote to Adrienne Weill: *If you ever hear of anybody anxious for the services of a physical chemist who knows very little about physical chemistry but a lot about holes in coal, please let me know*. As a result, Marcel Mathieu (William Bragg-trained crystallographer working in the French Department of Materials in the Ministry of Defence) made contact when he attended the autumn 1946 carbon research conference in London with crystallographer Jaques Méring.[1,4] Within weeks Franklin had the offer of a *chercheur* (postdoctoral) position in Laboratoire Centrale des Services Chemiques de l'Etat (LCSCE) (the 'labo') in Paris, downstream from Notre Dame. She accepted.

Rosalind learnt X-ray crystallographic methods and techniques from Méring and immersed herself in her work and French lifestyle. Méring's expertise was with disordered crystals using low angle monochromatic, highly focussed X-rays, then a technique and speciality of French crystallographers. He was studying graphite. Franklin soon became proficient in X-ray techniques and studied the structure of coal and related carbons. With her skill in preparation she was soon detecting and clarifying the fundamental differences between those carbons that transformed into graphite on heating and those that did not. Her four years at the LCSCE were productive and gave rise to a series of twelve papers from 1950 (*Influence in the bonding electrons in the scattering of x-rays by carbon*) to 1957 (*Changes in the structure of carbon during oxidation*) of which only two were co-authored. Soon after her arrival, Vittoria Luzzati (an Italian Jew married to a French medic who had spent the war years in Argentina) joined the 'labo' and moved into the room next door; they became strong friends. She worked hard and played hard. Throughout her short life, Rosalind Franklin undertook strenuous hiking, climbing and mountaineering holidays. Initiated when a child by her father in the mountains of Norway, her aptitude for and enjoyment of such vacations was one of the ways she spent time away from the laboratory. Her friendship with Luzzati was cemented by their vigorous debates on science and politics. The photograph below by Luzzati shows her in a cabin in the French Alps.

Rosalind Franklin in Cabane des Evettes, French Alps (image by Vittoria Luzzati, © National Portrait Gallery, London)

In France, Rosalind immersed herself in art and culture and made friends with her 'labo' colleagues. Despite the short distance from London, travel was not easy (the cross channel ferries had no stabilizers) and her parents expected her to return to London fairly soon. In fact, she applied for a position to work with J.D. Bernal at Birkbeck College (University of London) in the autumn of 1949 and, like Francis Crick (who was leaving the Admiralty in London), she was unsuccessful. She decided to stay in Paris until more of her work was published. Strenuous vacations became the norm with planning as detailed as for a laboratory experiment. Companions, usually female scientists, usually accompanied her.

From early in 1950 Rosalind Franklin began the search for

a London position. Her upbringing would not have her take anything in the provinces and so she approached senior academics with whom she had had contact. In particular, she asked Charles Coulson, Head of Theoretical Physics at King's College London and known from her BUCRA time, about ICI research fellowships and the application process. His reply said that were she interested she could apply for one at King's in the biological application of X-ray techniques. Knowing little biology she responded in the affirmative saying she would learn. Then, in March, she visited Coulson who introduced her to Professor J.T. Randall, the King's College head of physics and biophysics, the only department in Britain studying biophysics; she applied for a Turner and Newall fellowship in his sphere. Her publications from the Paris studies advanced with the most significant paper appearing in *Acta Crystallographica* that June.

She holidayed in Italy with Luzzati and his wife, and was then called to London for interview by the Turner and Newall Board early in June. She won a three-year Fellowship to work at King's under J.T. Randall from the autumn. The departmental secretary advised her that she would be using her X-ray expertise to study proteins in solution and the structural changes involved in them. The salary was set at £800 p.a., almost double that of a Junior Lectureship. As she was reluctant to leave Paris so soon, she applied for deferral until the beginning of 1951 and, with that approved, she went off to Normandy with the Luzzatis.

As time passed, Rosalind became less and less satisfied with her decision to return to London, again doubting herself and feeling that a life in France or Italy would be preferable. Yet change she could not and so she applied her energies to settling the scientific matters concerning her start at King's College. She suggested improvements for the equipment King's was to obtain for her and especially in the design of the X-ray camera. All of these went in a late November letter to Randall but his response came as a bombshell. Her entire project was to change. The study of proteins in solution was to become one of certain biological fibres using high and low angle diffraction, an area that now interested him. She was told that the X-ray work would be done by her with PhD student Ray Gosling and Mrs Heller a temporary assistant from Syracuse, New York. The fibres in question were of DNA provided by Professor Signer of Bern to Maurice Wilkins after a Faraday Society lecture in London the previous June and from which Gosling already had good fibre diagrams.[1] Whether this change caused Franklin concern or not is not clear but she left the Seine for the Strand at Christmas 1950 more concerned with her relocation home than the work itself.

Following the pre-WWII work of Astbury and Bernal in the UK, the experiments of Avery in New York in the 1940s and the theorising of Erwin Schrödinger in Dublin on life, the scene was set for physicists to advance biology. As Schrödinger put it to explain why genes do not disintegrate as expected from entropy: *Life is doing something*. Then, in 1949, Chargaff at Columbia College of Physicians and Surgeons found that the number of thymine and cytosine molecules always equalled those of adenine and guanine in DNA, but he could not explain why. And that is where matters stood in January 1951 when Rosalind Franklin entered King's College London.

Colleagues and friends of Rosalind Franklin considered her to be a brilliant scientist and a kindhearted woman with a personality marred by short temper and stubbornness when she knew she was right. This provided a challenge to those working with her and eventually these included Maurice Wilkins, her colleague at King's College. The contrast of male dominated and bombed London to the intact and liberal Paris were hard for Rosalind to readjust to. King's was no Cambridge in either its speech or attitudes despite it predating Oxbridge with serious study in laboratory science. Shortly after arrival Rosalind was told that women were not allowed in the King's senior common room where staff could take lunch, nor was she or any of the MRC women admitted to the upstairs smoking room for coffee afterwards.[8] There was, however, a second dining room available to both men and women and some of the male staff preferred to eat there than in the senior common room. This was encouraged by Randall who had many female staff members and liked everyone to get together for morning coffee and afternoon tea and eat lunch as a group there with him. However, the environment was alien to everything Rosalind had become.

On Monday January 8, J.T. Randall held a meeting in his office to introduce Rosalind to her group – Gosling and Heller, and Alec Stokes a physicist and mathematician who was to study theoretical problems. He advised Rosalind that Gosling was now to work with her and not Wilkins.[9] Maurice Wilkins, the deputy director who had been working almost exclusively on DNA at King's for several years and had with Gosling recorded X-ray images, was on holiday. As an aside, Stokes had suggested to Wilkins that what Gosling had shown could result from a helical structure. Now Randall was not simply Wheatstone Professor of Physics at King's but also head of department and honorary director of the Medical Research Council biophysics unit. He was recognised for appointing highly competent staff and giving prominence to women scientists. He was less successful at settling their responsibilities once he had them. It needs be remembered that by 1951 the Royal Society had elected just seven women Fellows and their number remained below 4% until the end of the 20th century; physics was the most male dominated discipline.

Maurice Wilkins returned from his break some days later unaware that Franklin had been given responsibility for the DNA X-ray work or that Ray Gosling had been transferred to her. She, in turn, did not realise he assumed her to be a member of his team. Nevertheless, the first months proved to be amicable enough with both working separately but cordially on DNA; this to the extent that discussions led to Rosalind being acknowledged in one of his papers,[10] then not common from a senior scientist to a female colleague. The pair occasionally lunched together on a Saturday at the Strand Palace Hotel (a good and inexpensive buffet even for academics) and conversation was not difficult as Rosalind had interests in painting,

theatre, poetry and existentialism. She was a very different person socially than when at work. Their disagreement stemmed from their conflicting characters – Franklin was forceful especially when she knew her topic and it related to research, whereas Wilkins was shy and retiring and disliked argument. The situation Rosalind found herself in was not improved by her junior status and that, except for Coulson and Randall, her colleagues were unaware of the reputation she had built for herself in the coal area. The situation deteriorated and Gosling found himself very much in the middle and trying to play the peacemaker.[9] Eventually, the dispute reached the stage where Professor Randall suggested that Franklin could be better off leaving King's even though the DNA work was not yet complete. This she did, but not until March 1953 when she joined the Bernal group at Birkbeck on Malet Street.

Rosalind Franklin spent 27 months at King's College. There Sven Furberg, a Norwegian researcher, had shown from a model he made that the DNA sugars were orthogonal and not parallel to the bases, and stacked like pennies contradictory to Astbury's prediction. She began her studies using a new fine-focus X-ray tube and micro-camera ordered by Wilkins, but which she refined, adjusted and focused carefully. Working with Gosling, she began to apply her expertise to the structure of DNA. Drawing on her background, she skillfully manipulated the critical hydration of her specimens. Eight months into her new job, in September 1951, she made a pivotal breakthrough by discovering a previously unsuspected second type of DNA that comes from exposure to high levels of moisture. She termed this B DNA. The previously known drier form became A DNA. Furthermore, Rosalind realised that the earlier X-ray studies were less helpful than they might have been because the DNA had contained a mixture of both forms, causing blurring of the photos. She presented this information in a small seminar in King's in autumn 1951, when Jim Watson was in the audience; he took no notes and was subsequently unable to recall all the information

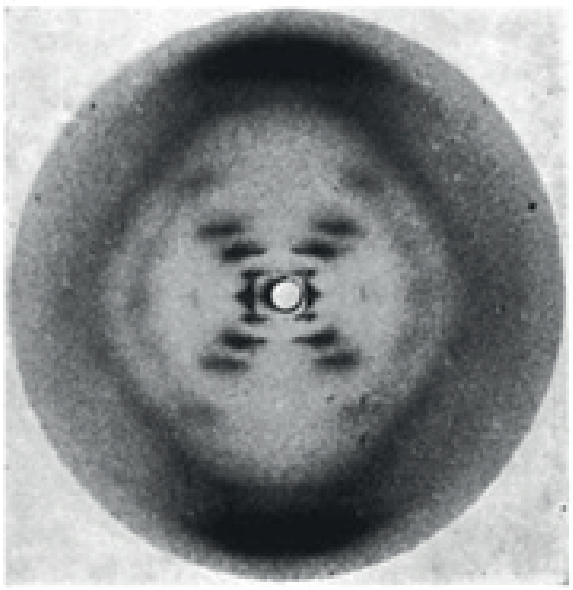


Photo 51 X-ray diffraction image

On May 2, 1952, Ray Gosling took an X-ray diffraction photo of B DNA that would become both famous and notorious, now termed Photo 51. Rosalind had been able to draw out exceptionally fine DNA fibers and, when appropriately hydrated, were examined using the new equipment that she had designed and ordered. She was then able to quickly establish the crucial differences between the A- and B-forms of DNA. Vittorio Luzzati had suggested that Rosalind incorporate the labour intensive (no computers) Patterson function [Patterson was the British physicist born in Nelson, New Zealand, on July 23, 1902] into her study of DNA while she was on holiday over the 1951 Christmas break. This she did to the X-ray pictures of the A-form and correctly located and measured the positions of the backbone phosphate groups (outside) and the nitrogenous bases (inside) which she hypothesised as being a double stranded helical molecule. She measured the unit cell dimensions, classified the space group as C2, but did not realize that the two sides of the sugar-phosphate backbone ran in opposite directions (anti-parallel). Nonetheless, Photo 51 was clear enough to allow her to determine precisely the 34 Å helical repeat and the 20 Å helical diameter.[2] We now know that B-DNA is the usual arrangement within living cells, where the environment is very moist. By January 1953, Franklin had reconciled her conflicting data, concluding that both DNA forms had two helices, and had started to write a series of three draft manuscripts, two of which included a double helical DNA backbone. Her two manuscripts on A-DNA reached *Acta Crystallographica* on March 6, 1953, one day before Watson and Crick had completed their famous model of B-DNA and before Rosalind knew of their work. On July 8, 1953 she modified one of these, by then *in proof* items, in light of the King's and Cambridge work. On learning of Watson and Crick's model, Rosalind rewrote her own draft manuscript on the B molecule as a supportive paper that was published[11] in the same April 1953 *Nature* issue as Watson and Crick[12] and that of Wilkins, Stokes and Wilson.[13] Franklin had initially found it difficult to interpret her results but had come to the conclusion that DNA had a double helix structure, with component nucleotides or bases on each strand that were complementary, enabling the molecule to replicate. Above all, Franklin noted that an infinite variety of nucleotide sequences would be possible to explain the biological specificity of DNA,[2] thereby showing that she had glimpsed the most decisive secret of DNA: the sequence of bases contains the genetic code.

It seems that Rosalind Franklin never knew that her data had been given to Watson and Crick and contributed critically to their proposal. With hindsight, several of Franklin's new precise findings could have been inferred from formerly published poorer data, but those older data did not sufficiently stimulate Watson and Crick to build a correct model, whereas Franklin's results did. Furthermore, Franklin distinguished between the A versus B forms of DNA, measured the unit cell dimensions, and identified the space group, which indicated the anti-parallel nature of the backbone. These were new essential pieces of information. What Rosalind Franklin had not known was that on a visit to King's College on January 30, 1953, Jim Watson was shown (but not given) Photo 51 by Wilkins,

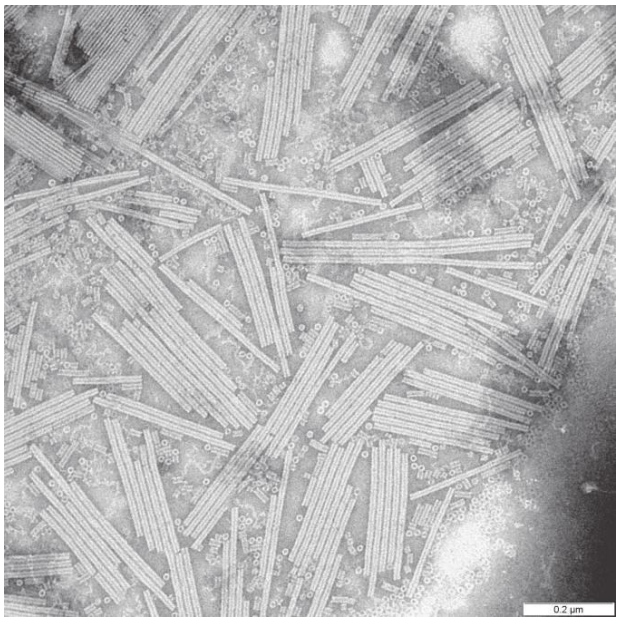
and Wilkins a preprint of a Pauling-Corey manuscript[14] that included a DNA structure remarkably like their first incorrect model. From the Franklin-Gosling photograph it became obvious to Watson and Crick that that they needed far more than a helix; they needed precise observations from X-ray crystallography and those numbers were unwittingly provided by Franklin herself as they formed part of a brief informal report given to Max Perutz of Cambridge University. In February 1953, Perutz passed the report to Bragg, and he to Watson and Crick.

With those data, Crick had what he needed to perform his calculations. The numbers were decisive in showing the molecule to be in two matching parts running in opposite directions. Franklin's report was not confidential, and there is no question that the Cambridge duo acquired the data dishonestly. However, they did not tell anyone at King's what they were doing, and they did not ask Franklin for permission to interpret her data. Whilst undoubtedly cavalier, the behaviour of Perutz, Bragg, Watson and Crick would likely have been just the same had the data come from Maurice Wilkins, and with whom Ray Gosling completed his PhD.

In mid-April 1953, Franklin wrote to Crick from Birkbeck College asking if she could see their model. This she did but still remained sceptical of model building. As an experimental scientist, she was always cautious and wanted significant evidence before publishing anything as proven. This fitted with much of the scientific community hesitating for some years before accepting the double helix proposal.

Rosalind Franklin had decided to leave King's early in 1952 as the feud with Wilkins had deteriorated to the extent that they were not speaking, and she had taken all the X-ray equipment as was her right according to her appointment letter. She sought a position with Bernal at Birkbeck College, received support and an agreement that she could transfer her Turner and Newell fellowship there. However, Bernal did not have this happen until the following January and, in fact, she did not move until March 1953 so as to complete the DNA work first. Her impending departure signalled to Randall that she might take his school's work on B-DNA with her and so he got an undertaking from Rosalind that it would remain King's. This did not mean that she would move to other areas of crystallography rather than stay with biomolecules; she moved her attention from DNA to RNA and the tobacco mosaic virus (TMV). In addition she helped Ray Gosling with his thesis and published the results on the helical nature of A-DNA.[15]

TMV is a positive-sense single stranded RNA virus that infects a wide range of plants, especially tobacco and other members of the family Solanaceae. It manifests itself as mosaic-like mottling and discoloration on the leaves and was the first virus to be discovered. At Birkbeck with Bernal as Head, Rosalind blossomed, working as a Senior Scientific Officer and team leader with her own research group funded by the Agricultural Research Council. Her work there was as successful as that at King's and took her through the rest of her short career. She generated a



Electron micrograph of tobacco mosaic virus (T. Moravec, Wikimedia)

first-rate research team that included subsequent Nobel Laureate Arron Klug, and it provided some sixteen seminal papers on a range of viruses. Klug, a theoretical physicist, chemist and crystallographer, moved to Birkbeck as a Nuffield Fellow in late 1953 on gaining his Cambridge PhD. His office was on the same floor as Rosalind's and after seeing some of her X-ray images early in 1954 became committed to work with her. The first major work on TMV appeared in 1955 in *Nature*[16] where all the TMV particles were shown to be the same length (3000 Å) in contradiction to the eminent virologist Norman Pirie's view; he would not accept the result even though subsequently she was proved correct. The disagreement with him meant that from then on she had to grow her own viruses rather than have him provide them. The complete structure of TMV was handled by PhD student Kenneth Holmes and gave a total of eight publications together and with Klug and his student. As a team, the publications on TMV, the cucumber virus and the turnip yellow mosaic virus from 1956 were seminal. By then Rosalind was using the Perutz heavy atom substitution technique of adding electron-dense atoms to the protein without disturbing its structure. Team members continued working on other RNA viruses that affected plants, including the potato, tomato and pea; American postdoctoral Donald Caspar worked on the precise location of RNA molecules in TMV. Complementary papers in the March 10 issue of *Nature* showed that the RNA in TMV is wound along the inner surface of the hollow virus.[17]

The ARC research grant was due to expire in 1957 but was extended until March 1958. In applying for the extension, Rosalind sought promotion to Principal Senior Scientific Officer but it was declined. It illustrates the disparity at that time between full-time academic researchers and those who also taught, and between men and women (something the universities began to address in 1955). Rosalind had little choice but to apply for a new grant and got one from the US National Institutes of Health.

At £10,000 for three years to work on the polio virus, it was the largest ever received at Birkbeck.[4] Then the first major international post-WWII world fair was the held in Brussels in 1958 and Franklin was invited to provide a 1500 mm high model of TMV. She started the build in 1957 using table tennis balls and plastic bicycle handlebar grips and it was displayed in the International Science Pavilion from April 17, one day after she died.

After leaving King's College and working on TMV, Rosalind became friendly with both Watson and Crick, though more so with Crick and his wife. She spent time at their home[4] and toured Spain with them in the spring of 1956. Francis Crick noticed changes in Rosalind's health but with her high reserve he did not pursue the topic with her. A little later that year, while on one of a few work-related trips to the US, she began to suspect a health problem and when back in London she sought medical advice. The outcome was an operation on September 4 that revealed two tumours in her abdomen. Following the surgery and other periods of hospitalisation, Rosalind spent time convalescing with various friends and family members that included the Cricks. She continued working throughout the following two years, despite having three operations and experimental chemotherapy. She experienced a 10-month remission and worked up until several weeks before her death. Even while undergoing cancer treatment, Rosalind continued to work, and her group produced seven more papers in 1956 and six in 1957. At the end of 1957, she again fell ill and was admitted to the Royal Marsden Hospital. She made her will at the beginning of December naming Aron Klug principal beneficiary, then returned to the lab in January 1958. She was promoted to Research Associate in Biophysics on February 25 but fell ill again on March 30, and died on April 16, 1958, in Chelsea, London, of bronchopneumonia, secondary carcinomatosis (widespread dissemination of carcinoma), and ovarian cancer.

Exposure to X-ray radiation could be a factor in her illness as safety precautions were not as stringent in her time as they are now, and it was known that she had exceeded the limit of her dosimeter in France. However, her own DNA may have predisposed her to ovarian cancer as it is known that Ashkenazi Jews, who settled and established communities throughout Central and Eastern Europe, have a predisposition to it. Moreover, other members of her family had died of gynaecological cancer. Undoubtedly, Rosalind Franklin was brave through the final stages of her cancer. Unable to walk, she crawled up stairways between laboratories at Birkbeck insisting that she continue to work. Her Birkbeck research team comprising Klug, Finch and Holmes moved to the Laboratory of Molecular Biology in Cambridge in 1962.

Her death of ovarian cancer on April 16, 1958 was four years before the Nobel Prize was awarded to Watson, Crick and Wilkins for their DNA work. She never learned the full extent to which Watson and Crick had relied on her data to make their model; if she suspected, she did not express any bitterness or frustration. She could not have received a share in the award unless she had been nominated before or in the year of her death. She is buried in the Franklin family plot at the United Jewish Cemetery in Willesden, London.[18] The British Heritage foundation attached a plaque to the outside of her apartment at Donovan Court, 107 Drayton Gardens, Chelsea, in 1992.

The Rosalind Franklin tombstone in the United Jewish Cemetery, Willesden, London (with permission Julia Keld and modified from ref. 18)

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18. Rosalind Franklin at Find a Grave (findagrave.com). The photograph was placed there by Julia Keld (46812479); see: http://www.findagrave.com/cgi-bin/fg.cgi?page=gr&GRid=5858699 (accessed 16/09/2016).

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Brian Harford Robinson, MSc(NZ), PhD(Cant), FNZIC, FRSNZ

Brian Robinson passed away on 30 August 2016 aged 76 years. Brian was educated at Christchurch Boys High school and completed his BSc (1960), MSc(Hons) (1962) and PhD (1965) at the University of Canterbury studying with Dr Jack Fergusson. He undertook postdoctoral research with Professor Norman Greenwood at Newcastle upon Tyne and in 1966 received an 1851 Exhibition scholarship to undertake postdoctoral research with Professor Jack Lewis (later Lord Lewis) at Manchester. He was appointed as a lecturer at the University of Otago in 1967, to a personal chair in 1985 and was Mellor Professor from 1996-2006 and Head of Department from 1987-1998. He supervised over 30 postgraduate students, many of whom went on to successful academic positions.

Brian had an illustrious chemistry career and his research activities were wide ranging and prolific. He co-authored well over 180 quality research publications and gained several large external research grants. In 1999 he was elected to a Fellowship of the Royal Society of New Zealand. In addition, Brian was awarded Fellowships of the New Zealand Institute of Chemistry, the Society of Perfumers and Flavourists (Geneva) and he was a Bye Fellow of the University of Cambridge. He received the Marsden Medal in 2010 recognising his lifetime of service to science. His research activities were marked by an ability to assemble teams of highly skilled co-workers and to forge productive research relationships. In this regard, his long term association with Professor Jim Simpson was particularly productive and successful. Brian's areas of research varied quite widely from a core base of organometallic chemistry containing synthetic, mechanistic and structural elements. His research productivity continued at a high rate even in periods when he was fully engaged in administration such as the decade spent as Head of the Department of Chemistry. He also had a strong interest in the commercialisation of research and was ahead of his time in that regard. In the 1980s he developed a company based in Dunedin providing raw materials for the perfume industry and more recently went on to assist in the commercialisation of a wound healing medical gel and the establishment of a company, Chitogel, to manufacture the components.

Finally, Brian had a very strong service ethic. His senior roles within Otago were extensive and he sat on many of the important committees of the day. He had a significant role with the NZ Universities Academic Audit Unit and audited a number of NZ and overseas universities. For a large part of his career he was heavily involved in the management of hazardous substances. He assisted government, through the office of the PM, and the university to develop systems and policy around chemical and biological hazards and associated risk assessment. In the wider community, Brian was actively involved with the Rotary organisation and this was recognised with the award of the prestigious Paul Harris Award in 2004. In his retirement he was heavily involved in the University of the Third Age (U3A) and was chair for three years from 2013.

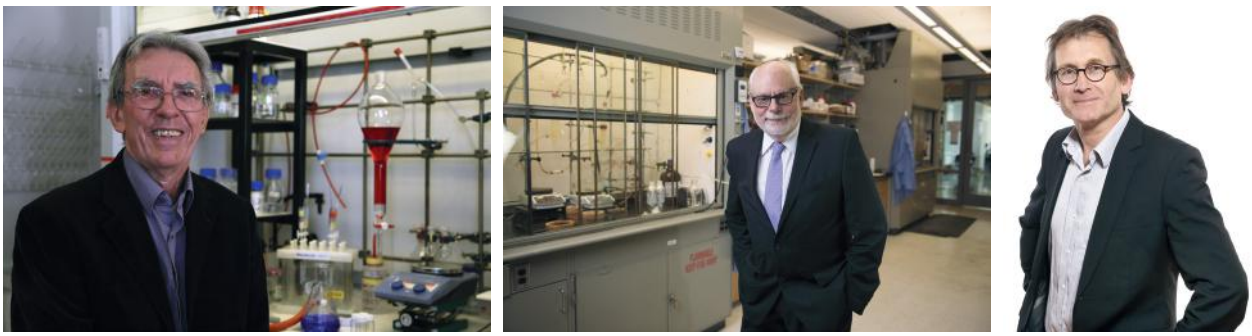
Lyall Hanton

The 2016 Nobel Prize in Chemistry

Brian Halton

School of Chemical & Physical Sciences, Victoria University, PO Box 600, Wellington
(email: *brian.halton@vuw.ac.nz*)

The Royal Swedish Academy of Sciences awarded the 2016 Nobel Prize in Chemistry jointly to Jean-Pierre Sauvage (University of Strasbourg, France), Sir J. Fraser Stoddart (Northwestern University, Evanston, USA) and Bernard (Ben) L. Feringa (University of Groningen, the Netherlands) on October 7 *for the design and synthesis of molecular machines.*



L-R: Jean-Pierre Sauvage (photo courtesy of Catherine Schrôder, University of Strasbourg) and Sir J. Fraser Stoddart (photo by Jim Prisching courtesy of Megan Fellman, Northwestern University). **Ben Feringa (photo by Stijntje de Olde, courtesy of the University of Groningen)**

Frenchman Jean-Pierre Sauvage, an Emeritus Professor of the University of Strasbourg and member of the French Académie des Science, Scotsman Sir Fraser Stoddart, an active academic at Northwestern University, and Dutchman Ben Feringa of Groningen University, have been awarded the 2016 Nobel Prize for Chemistry for their combined fundamental studies designing and synthesising molecules with controllable movements that can perform a task when energy is applied. These tiny organic and organometallic molecules have a promising future ahead as molecular machines that could target the transport of medications, store information in molecular computers and be light-operated molecular switches. The area of molecular machines was given international recognition last year in the Gordon Conference programme in the USA, and its future is predicted to form part of the core of chemistry and materials design within the next 15 years. This year's Nobel award serves to focus this even more.

Nature provides numerous protein machines that chemists and biochemists try to decipher. As in a contracting muscle, they intervene in many biological processes. By way of example, the kinesin proteins belong to a class of motor proteins found in eukaryotic cells. They move along microtubule filaments powered by the hydrolysis of adenosine triphosphate (ATP). The three Nobel Laureates have dedicated their careers to the synthesis of molecules that act like machines. Apart from the syntheses of the molecules themselves, the challenge has been to succeed in switching on and controlling the machine by means of physical, chemical, electronic or other signals in order to change the equilibrium of force between the atoms.[1]

The molecules that are employed for molecular motion are of three types, *catenanes* that comprise two or more interlocking rings, *rotaxanes* that involve a molecular rod that is threaded through a ring and then prevented from slipping off by capping the ends, and overcrowded alkenes that can rotate on photoexcitation (Fig. 1). The first catenane was synthesised by Wasserman[2] in 1960 and consisted of two C_{34} rings (**1**) (Fig. 2). It was followed in 1967 by Schill's rotaxane **2**, a $C_{24}N$ ring threaded with an aromatic,[3] and then **3**, a 30C ring threaded with decane-1,10-diol.[4] Rotaxane **3** (modified from ref. 4) was synthesised by the Harrisons and the ends were capped with triphenylmethyl groups in the same sequence that

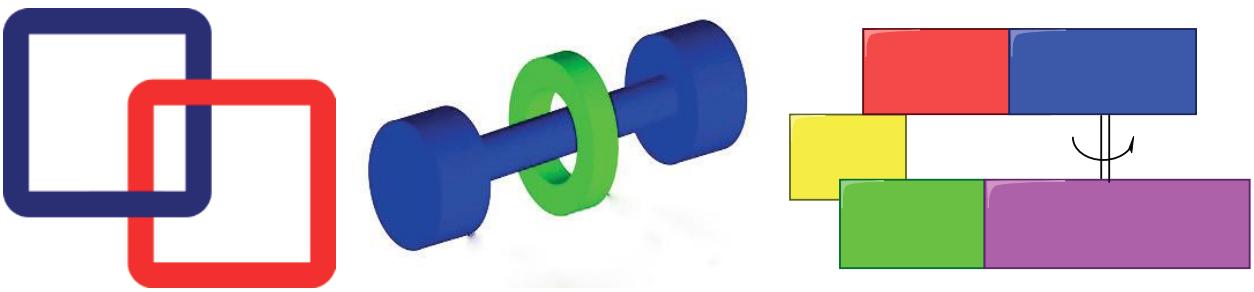


Fig. 1. Cartoons of a catenane (left) that depict two interlocked rings, a rotaxane (centre) with a macrocycle (green) over a rod (blue) carrying dumbbell shaped ends, and a sterically overcrowded alkene (right) whose upper component rotates clockwise on activation bringing the yellow box to the front.

threaded the chain through the ring; some 70 cycles were needed to give a viable quantity of the product.[4] None of these compounds was easily obtained, but the synthesis of **3** led the way to capped rotaxanes. A major step was taken by Jean-Pierre Sauvage in 1983 when he succeeded in linking two ring-shaped molecules together to form *catenane* **4** as shown in Scheme 1.[5] For a machine to be able to perform a task it must consist of parts that can move relative to each other. The two interlocked rings fulfilled this requirement exactly and indicated that motion of one ring about the other had to be a possibility; it paved the way for creating and regulating molecular motion. The developments in catenanes have been to the extent that the Olympic symbol has been transformed into the five interlocked ring molecular equivalent olympiadane (**5**) by Fraser Stoddart in 1994 (Fig. 3).[6]

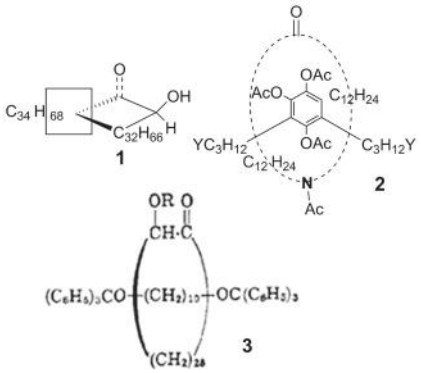
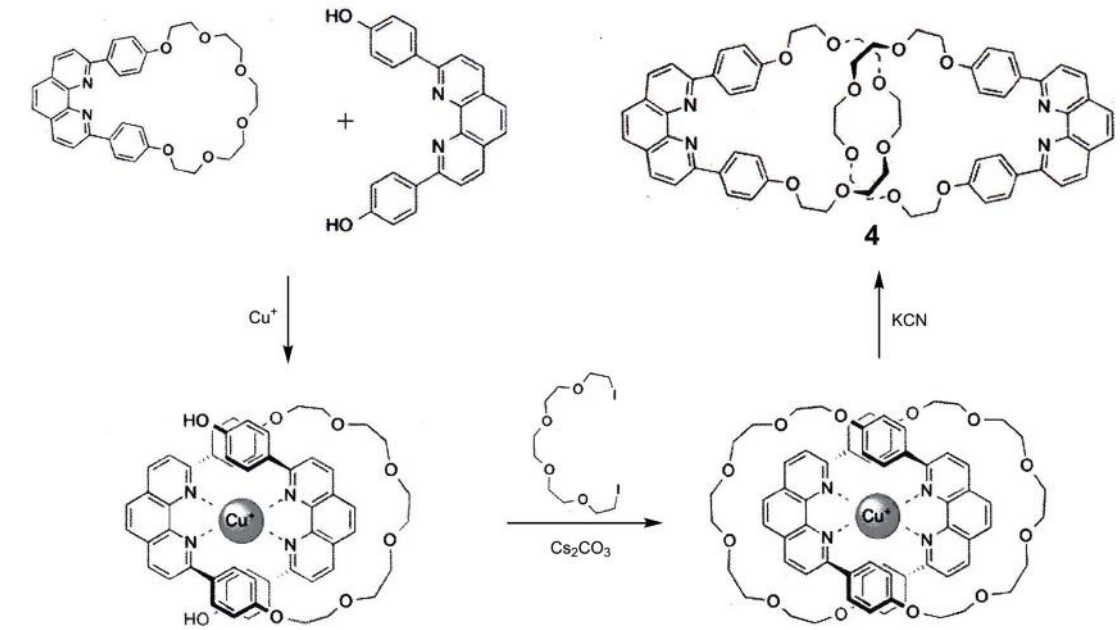


Fig. 2. The first catenane and rotaxanes.

The preparation of 5 utilises the straight forward method to prepare rotaxanes and catenanes developed by Stoddart and his coworkers. This is illustrated in Scheme 2 and was pivotal in the major step taken by Fraser in 1991 when he prepared the first rotaxane exhibiting transitional molecular motion (Scheme 3).[7] One very significant feature is the use of the electron deficient paraquat and dipyridyl dications as reagents to extend electron rich aromatic phenols into longer chain molecules. These chains can then be joined by strong covalent bonds but with the components held in the conformer needed for ring closure by non-bonding interactions that allow for preferen-



Scheme 1. The Sauvage catenane synthesis adapted from Fig.2, Ref. 1.

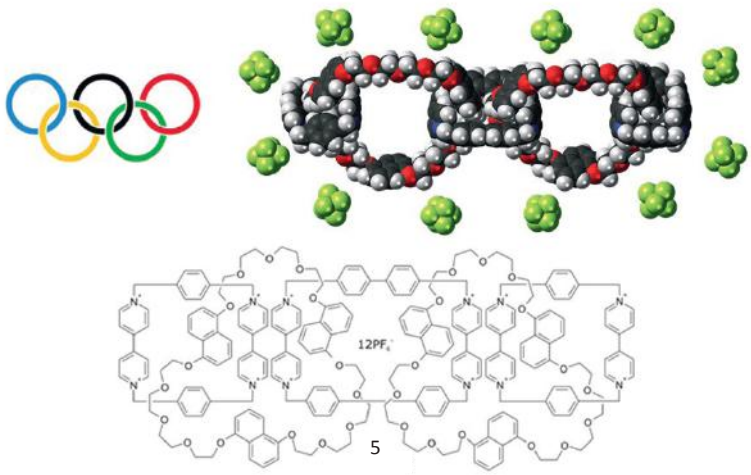
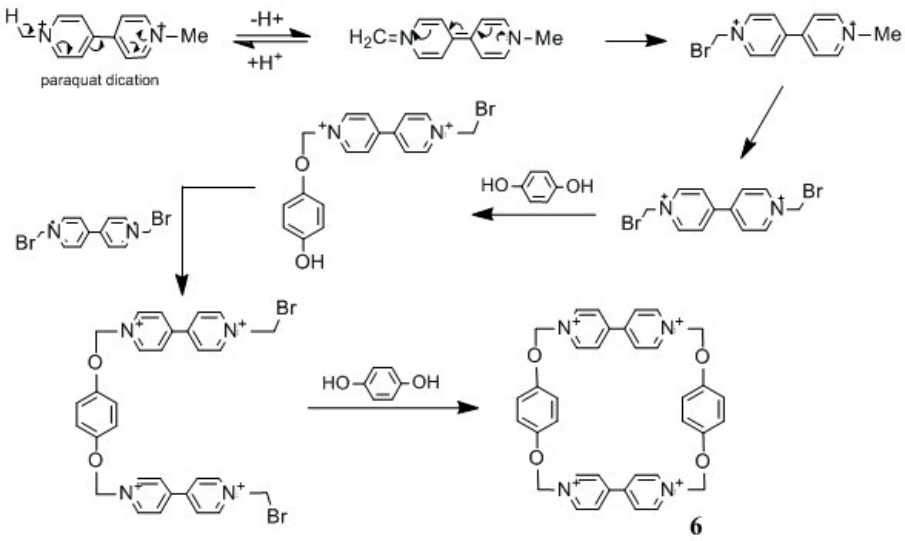
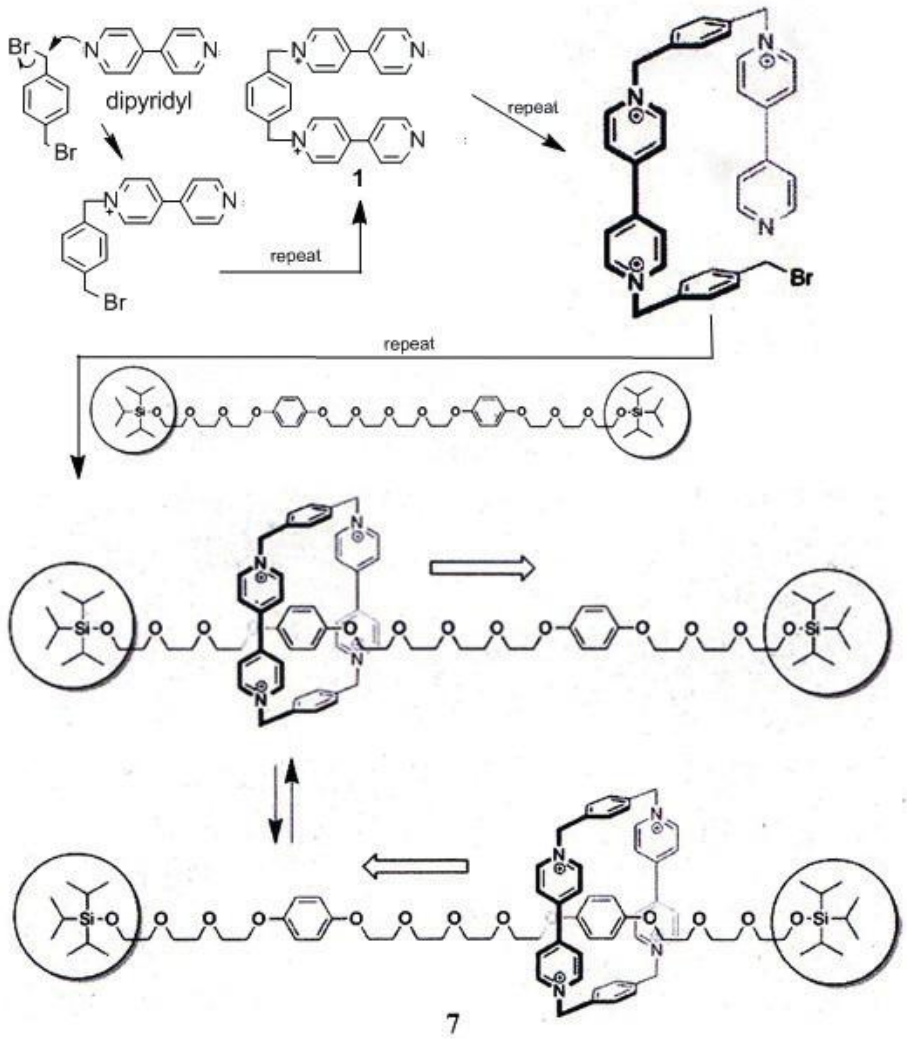


Fig. 3. The Olympic symbol and Olympidane (5) taken from Wikipedia.



Scheme 2. The formation of a heterocycle **6** from the paraquat dication.

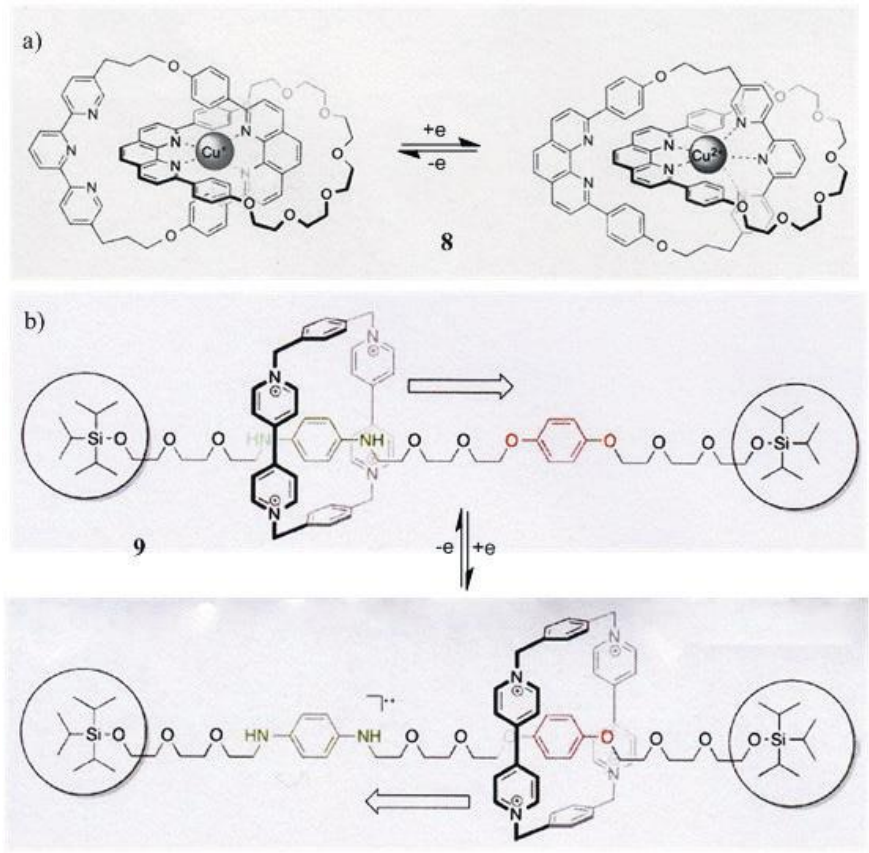


Scheme 3. The formation and first translational motion recorded in rotaxane **7** (adapted from Fig.4, ref. 1).

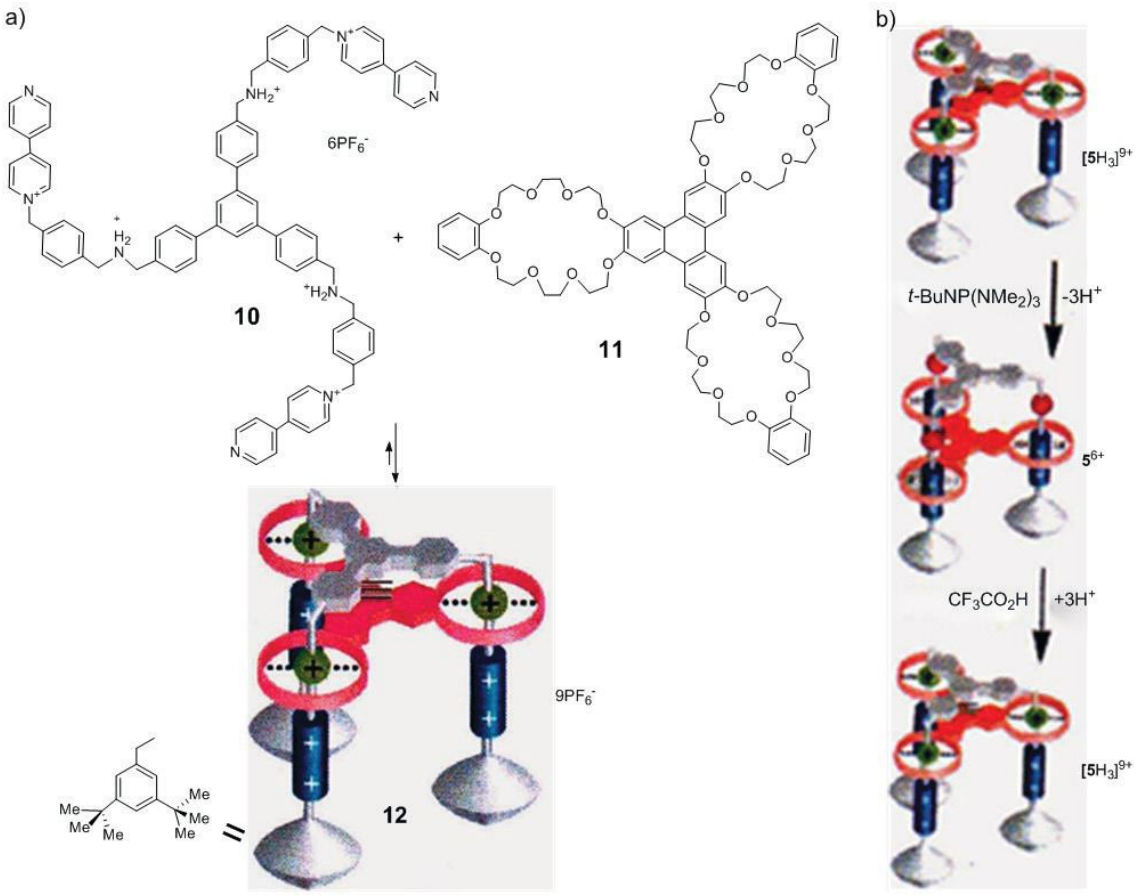
tial ring formation to, e.g. **6** in Scheme 2 and the heterocyclic ring of **7** in Scheme 3. These interactions are crucial in the product rotaxane holding the preferred conformer in place as illustrated by the tetra-aza ring being held around the diphenolic moiety in **6** yet allowing for shuttling from one phenolic site to the other.

The next development was the preparation of molecules with different stations for the moving component (Scheme 3). These were both achieved in 1994, the catenane by the Sauvage group[8] and the rotaxane by Stoddart and his coworkers.[9] The Sauvage molcule **8** (Scheme 4a) gains its motion from oxidation of the Cu(I) ion to Cu(II) with coordination shifting from four to five and rotation of the penta-aza ring about 180° as shown. The Stoddart rotaxane **9** (Scheme 4b) moves from the diaminobenzene site to the diphenol position on *oxidation.* Both movements are reversed on reduction.

The work of the Stoddart group has advanced to, among other things, the synthesis and operation of a molecular elevator (Scheme 5).[10] The synthesis is based upon the rotaxane principles. As a trial, the group employed 1,3,5-tritolylbenzene with each benzyl unit bonded to a benzylamine to give a triamino trication (**10** without the dipyridylmethyl moieties; Scheme 5a) . This was allowed to complex with the three 24-atom-ringed triphenylene **11** to give a *superbundle* that had all the properties needed for an elevator. The hexacationic **10** and the tritopic **11** were then synthesised (Scheme 5) and found to complex analogously and give the 1:1 tris-rotaxane with each dipyridyl unit threaded through an oxa-macrocycle. Reaction with 3,5-di-*t*-butylbenzyl bromide 'caps' the ends of the dipyridy moieties to make the mechanically interlocked tris-rotaxane elevator depicted by **12**; it is only 3.5 x 2.5 nm in size. Each leg (blue; Scheme 5) has two different sites for the macrocyclic platform (red; Scheme 5) to move between. As depicted in Scheme 5b, the elevator is activated by an acid-base reaction that allows the platform to move between the floors that are separated by a distance of 0.7 nm, stopping at each level. The movements were confirmed by NMR spectroscopy and from acid/base electrochemical experiments in acetonitrile.



Scheme 4. (a) A catenane and (b) a rotaxane with rotational and translational motion, respectively (adapted from Fig. 5, ref. 1).



Scheme 5. The Stoddart rotaxane-based molecular elevator **12** (adapted from Figs. 2 and 3, ref.10).

The research by Stoddart and his colleagues has evolved to the extent that molecular-scale electronic devices based on catenanes and rotaxanes have moved towards molecular logic gates and memories,[11] as well as providing a photochemically driven molecular shuttle that forms the prototype for a molecular motor carrying a rotaxane stopper that is also the photosensitiser.[12] However, working with Prof James Heath of Caltech and employing millions of rotaxanes, the groups jointly produced a memory device.[13,14] Held between Si and Ti electrodes, the rotaxanes were able to be switched electrically from one state to another providing a molecular abacus containing some 160,000 bits each composed of hundreds of rotaxanes, the whole contained within ca. 13 μm and equivalent to some 100 gigabits per cm^2. Additionally, but significantly, advances in the biological sphere have been made with molecular actuators resembling muscles that comprise a [3]rotaxane and now provide a contraction/extension of up to 2.8 nm.[15]

Contributions to this area by Jean-Pierre Sauvage have also been significant. In 2000 he reported a daisy chain rotaxane depicted by the cartoon of Fig. 4a and comprised of two mutually entangled (squares) and capped (circles) rotaxanes. The actual ion **13^{2+}** gave a translational contraction/relaxation of about 2 nm.[16] It is achieved by removing the four-coordinate Cu^+ ion from the 1,10-phenanthroline moieties with KCN to give the neutral species, which with Zn^{2+} coordinates the terpyridine and phenanthroline units by pulling the terminal heterocycles inwards (Fig. 4b).

The contributions of Ben Feringa are highly significant and ingenious, using entirely different chemical processes and principles. He has provided a means to achieve a repetitive mono-directional motion using photochemical and thermal isomerisations as essential features as depicted in the third cartoon of Fig. 1. The work[17] employs two fundamental processes, photoisomerisation of a π–bond and the subsequent ability of the photo-isomer to rotate on thermal activation allowing for conformational change in an overcrowded alkene. This is illustrated in Scheme 6 where the overcrowded alkene *trans*-**14** (top left) on excitation at 280 nm (or above) at low temperature (-55°C) rotates the upper half clockwise (round arrow) to give *cis*-**15** (top right). This process is some 95% efficient and reverts to the starting isomer only on photolysis at 380 nm or more. Warming the solution of *cis*-**15** to 20°C then allows the overlapping benzenoid rings to pass each other to give the energetically more favourable conformer shown at the lower right. Photolysis of this causes another rotation of the top half of the molecule clockwise (round arrow, Scheme 6) to the *trans*-**14** at the lower left; this is 90% efficient. On warming to 60°C the methyl groups shown lower left pass the benzenoid rings to complete the cycle and regenerate the starting isomer in what is another downhill process. None of the photochemical or thermal reactions are reversible under the conditions employed, and so by performing the photolysis at 60°C or above the cycle proceeds through the three isomers to give a 360° rotation that can continue. Optical isomerism, *meso*-forms, and chirality associated with the two chiral centres are critical and it is only the (*R,R*) isomer that rotates as described. These are omitted from this discussion for clarity. Were the (*S,S*) isomer to be employed as starting material the rotation should be in the opposite direction. This design marked a major advance as both a light-driven structural molecular change and as a solution for unidirectional motion.[17]

Following their original report of the rotor, Feringa and his colleagues advanced the area further, for example by anchoring the static part of the rotor to a gold surface and employing different alkenes as shown in Fig. 5[18] and, most recently, by transporting a small molecule cargo (an acetyl group) in a light driven nanoscale device operating on the same principles.[19] Despite these various successes and those of others, it is the work of Feringa and his colleagues that is the most impressive.[20] It has led to the synthesis and chemical operation of the first nanocar – a molecule devised and constructed to move across a surface.

While Feringa has synthesised more than 50 molecular motors and now concentrates on their uses, the nanocar first appeared in 2011.[20] The essential motion comes from rotation about four fluorenylidene wheels in the same direction. It is dictated by the molecular chirality, triggered by photoisomerisation and continues from thermal inversion described above for **14**. The molecular chassis comes from a diphenylbutadiyne unit (ultimately) to provide **16**. The hexyl substituents attached to the benzenoid rings hold the molecular conformers of the wheels prior to thermal inversion following photochemical isomerisation of the fluorenylidene double bonds. This is illustrated schematically in substructure **17** and the car-like cartoon of Fig. 6.

These results gained international media publicity in daily newspapers and magazines and have been classified as one of science's major advances. With molecular rotation now possible there have been others who have provided a molecular nanocar. This is to the extent that in November 2016, after the Nobel announcement and the submission of this article, a nanocar race was scheduled to take place in Toulouse, France with five groups competing![21]

The return of the Nobel Prize for chemistry to the core of the discipline at this time is long overdue, is fully justified, and augers well for the future of our subject. It builds on the 2010 award for palladium-catalyzed cross couplings in organic synthesis (Heck, Negishi and Suzuki) and the 2005 prize for the development of the metathesis method in organic synthesis (Chauvin, Grubbs and Schrock).

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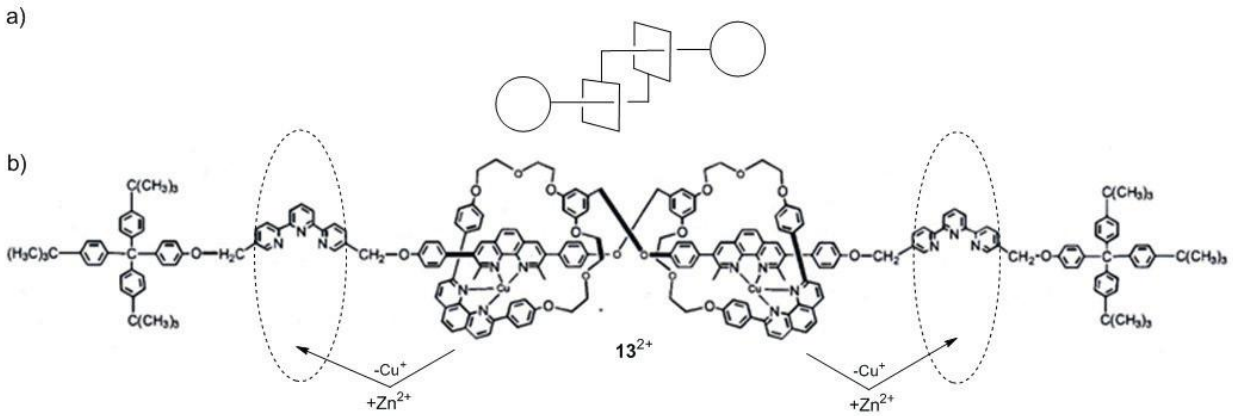
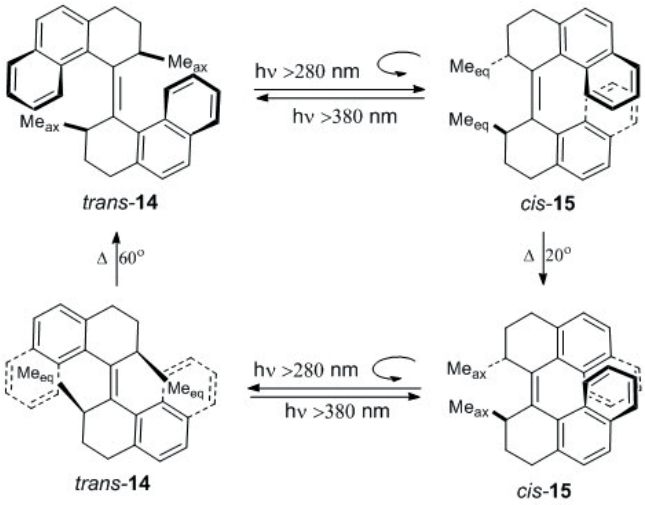


Fig. 4. a) A daisy-chain rotaxane cartoon and b) the Sauvage ionic muscle 13^{2+} adapted from Scheme 2, ref. 14; broken circles indicate the coordination site following loss of Cu^{+} and gain of Zn^{2+} and results in contraction.



Scheme 6. The Feringa photoisomerisation-thermal cycle for molecular motion.

Fig. 5. A molecular motor on a gold surface.

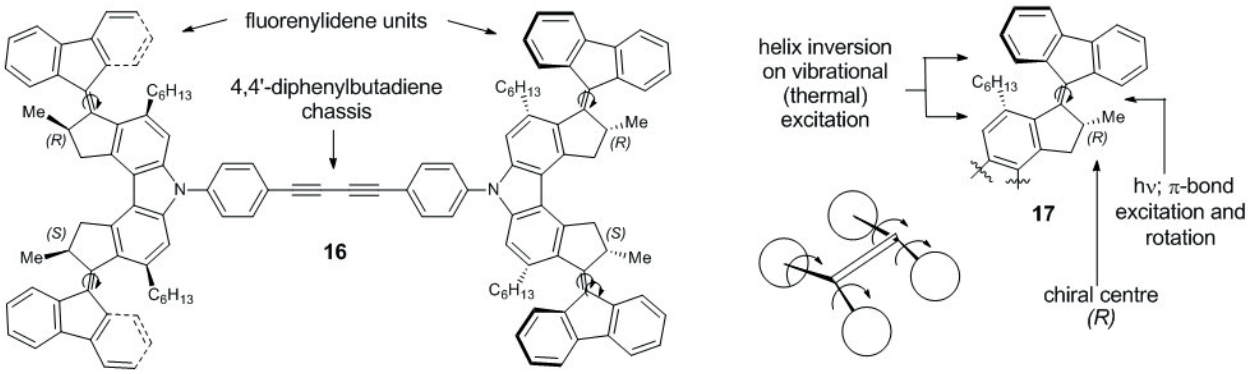


Fig. 6. The first nananocar 16 that comprises fluorenylidene wheels and a diphenyl butadiyne chassis; see ref. 20.

5131-5133.

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How to read a patent specification

Tim Stirrup

Baldwins Intellectual Property, PO Box 5999, Wellesley St, Auckland *(*email*: tim.stirrup@baldwins.com)*

Abstract

Most countries require patent applications to have an abstract which summarises the invention. It is mainly used for patent searching purposes and is published with the application's bibliographical information on the respective office's patent search website. If applicable, abstracts also include a chemical formula relevant to the invention.

It's probably fair to say that most scientists never read patent specifications. If they do have occasion to come across one, they are generally appalled at the wordiness, bold statements claiming everything under the sun, and general incomprehensibility of the text. However, as with any technical or legal document, there is a method to the madness. There are distinct practices that have evolved over the years to meet legislative requirements and ensure that the patent is less vulnerable to challenges.

Patent specifications (and the claims in particular) are key to determining whether you infringe patent rights in a particular country, i.e. whether you have "freedom to operate". They are also an invaluable resource to gain knowledge to guide your own R&D, or gather intelligence on other people's activities.

What is a patent specification?

A patent specification is a written description of an invention that includes details of how to make and use the invention. Patent specifications are published by the national patent office and can generally be accessed through the patent search portal on their website. For example, specifications for granted New Zealand patents can be accessed through the Intellectual Property Office of New Zealand (IPONZ) website.[1] Australian patent specifications can be accessed from IP Australia's website.[2]

The key principle of the patent system is that the inventor discloses their invention to the public, and in return the state grants the inventor a limited term monopoly right over the invention. To satisfy the disclosure requirement, the specification includes a description of the invention (see below). The actual monopoly right granted to the inventor is set out in strictly defined terms in the claims of the specification (see below). In this way, the patent specification is essentially a *quid pro quo* contract between the inventor and state.

Patent specifications are intended to be read and understood by a person with a good technical understanding of the field of the invention. The legal terminology used to describe the intended reader is a "person of skill in the art", or simply a "skilled person". This hypothetical person has a good understanding of the technical background of the invention and would understand key terminology and practices used in the field.

Patent specifications are usually split into the following parts which are described in more detail below:

- Abstract
- Background
- Summary of the invention
- Detailed description of the invention
- Claims
- Figures

Background

The background outlines the field of technology into which the invention falls and describes the state of the art before the patent filing date. This body of knowledge and literature is referred to as the "prior art". Typically the background also notes the limitations or problems with current technologies. This sets the scene for the new invention to solve the problems identified.

Summary of the invention

This section includes statements which set out the key features of the invention which the inventor believes are novel and inventive over the prior art. Each different embodiment (example) of the invention should be identified in this section. If the invention is a combination of steps of a method, or features in a particular configuration, these combinations/configurations should be specifically defined.

The statements in this section typically mirror the wording of the claims. Since the patent claims define exactly what must be done to infringe the patent, they must contain clear, unambiguous language. If there are words used in the summary of the invention which would be ambiguous when read by the skilled person, those words should be defined in the detailed description of the invention.

Detailed description of the invention section

The detailed description of the invention (or simply, the description) includes a detailed discussion of the features of the invention and how it would be made and used. It should also contain definitions of any terms used in the specification that may be ambiguous to a skilled person. The description often continues the narrative from the background. For example, it may state how the invention solves the problems previously identified, or list benefits of the invention over the prior art.

As an example take a new chemical compound for repelling mosquitos. The description should include details of the compound itself and any isomers, salts etc. Information on how the compound is made, stored and used should also be included.

It is important to describe alternatives and variations of features so that a broader claim scope can be justified. For example, where functional groups could be substi-

tuted without affecting the core functionality of the compound as a repellent, these functional groups should be identified and details of optional substituents provided.

Working examples of the invention are also typically included within the description. Examples are important to demonstrate to the reader that the invention has been made and works as a mosquito repellent as promised. Patent examiners may only grant a patent if scientific evidence supporting the invention is presented in the specification.

For our mosquito repellent, the examples may provide synthesis routes and analytical data identifying the compound and its structure. Experimental data may also be included showing behavioural aversion to the compound by mosquitos. Data may be provided for different mosquito species to show that the compound is not species-specific. It is important to note that the data and experimental work does not need to be to a peer review level with a high degree of statistical significance. However, it does need to be sufficient to show that the invention works.

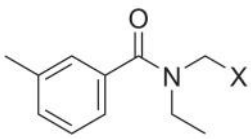
Claims

The claims are the key part of the specification because they define exactly what a person must do to infringe the patent. In this way, they define the scope of the patent itself.

The claims are a list of numbered statements found after the description. They consist of a preamble and one or more features which outline the novel and inventive features of the invention. For chemical compound inventions it is allowable to include the chemical structure in the claim itself and define the functional groups of the formula.

For example, a claim to a novel mosquito repellent may read as follows:

A compound of formula I:



where X is selected from methyl, ethyl or propyl.

In this case, the preamble of the claim is a "compound". This imparts to the reader an understanding of the type of invention that is being claimed. Patent claims may have any preamble but it should be a clearly understood term that effectively categorises the invention. For example, some common preambles include a product, a process, a use, a composition.

The features of this claim are the formula and the definition of X. To be allowable, these features must be novel and inventive over the prior art.

To infringe this claim (and therefore the granted patent itself), a third party must make, use, sell or import the compound into the country where the patent is granted.

Figures

The figures show graphical representations of the invention (or parts of it), or data which supports the invention (e.g. graphs or modelling data). The figures usually appear at the end of the specification and generally include alphanumeric reference labels which are referred to in the description.

It is important to note that the figures only show examples of the invention and should not be relied on to assess the scope of protection. It is the claims that define the extent of the monopoly.

Conclusion

Understanding patent specifications is an important skill for any researcher or technology manager. This primer gives a basic overview of a complex and constantly evolving topic to enable you to read and make sense of patent specifications relevant to your field of technology.

If you have any queries regarding intellectual property related matters (including patents, trademarks, copyright or licensing), please contact Tim.

References

1. Intellectual Property Office of NZ website: https://www.iponz.govt.nz/
2. IP Australia website http://pericles.ipaustralia.gov.au/ols/auspat/

Dates of Note

January

21 *Conrad **Bloch*** was born this day in 1912. He was the German-born American biochemist who shared (with Lynen) the 1964 Nobel Prize for Physiology or Medicine for discoveries concerning the natural synthesis of cholesterol and fatty acids. It was he who identified the chemical process by which the body turns acetic acid into cholesterol and discovered the point at which it is possible to regulate the amount of cholesterol the body produces. He also found that high blood levels of cholesterol cause fatty deposits on the inner walls of arteries.

24 *Morris William **Travers***, the English chemist who worked with Sir William Ramsay in London and discovered krypton in 1898, was born in 1872. The name derives from the Greek word for *hidden* as it was from a fraction separated from liquid air that it was identified.

*Joseph-Achille **Le Bel***, the French chemist and first to present a theory on the relationship between molecules and how they absorb or reflect light was born into a wealthy family and built his own laboratory and suggested that optical activity is due to an asymmetric (chiral) carbon atom and is the cofounder of stereochemistry with van't Hoff.

*Paul **Walden***, the Latvian chemist who discovered the Walden inversion while teaching in Riga, died this day in 1967.

25 *Ilya **Prigogine***, the Russian-born Belgian physical chemist who received the Nobel Prize for Chemistry in 1977 for his contributions to non-equilibrium thermodynamics, was born 100 years ago today.

26 This day in 1932 saw the US Patent Office receive an application for the cyclotron from *Ernest Orlando **Lawrence*** as a *Method and Apparatus for the Acceleration of Ions*.

28 *Robert W. **Holley***, the American biochemist who shared (with Nirenberg and Khorana) the 1968 Nobel Prize in Physiology or Medicine for independent research that helped to decipher the genetic code and explain how the genetic information stored in the DNA of a cell controls the synthesis of proteins, was born this day in 1922.

29 *Lewis **Urry***, the Canadian-American chemical engineer who invented the ubiquitous alkaline battery and, later, lithium batteries, was born in 1927.

February

1 The first commercial scientific hand-held calculator, the HP-35, was released this day in 1972.

*Antoine A. B. **Bussy***, the French chemist who was first to describe a method to isolate magnesium, died this day in 1882.

*John **Glover***, the English chemist who developed in 1859 the Glover Tower to reclaim useful chemicals during the manufacture of sulfuric acid, then the most important industrial chemical, died 200 years ago in 1817.

5 *Lafayette Benedict **Mendel***, the American biochemist whose discoveries concerning the value of vitamins and proteins helped establish modern concepts of nutrition, was born in 1872.

6 *Max Ferdinand **Perutz***, the Austrian-British biochemist who shared the 1962 Nobel Prize for Chemistry (with Kendrew) for the X-ray diffraction structure of haemoglobin, died in 2002.

7 This day marks the 10th anniversary of *Alan **MacDiarmid***'s death. He would have been 90 years old today.

8 It was in 1932 that *James **Chadwick*** discovered the neutron.

This day in 1672 saw Isaac Newton read his first optics paper before the Royal Society in London.

10 *Lawrence Joseph **Henderson***, the American physiologist and biochemist who discovered the chemical means by which acid-base equilibria are maintained in nature, died this day 75 years ago (1942).

11 *Thomas **Edison*** was born this day in 1847.

12 *Moses **Gomberg***, the Russian-born American chemist who initiated the study of free radicals in chemistry when he first prepared the triphenylmethyl radical in 1900, died in 1947.

This day in 1912 saw *Robert **Millikan*** begin collecting data from his famous oil drop experiment.

13 *Étienne-François **Geoffroy***, the first to recognize the relative fixed affinities of reagents for one another, was born this day in 1672.

16 It is 80 years today since *Wallace **Carothers*** received his patent for the synthetic fibre nylon (US Patent 2,071,250).

18 *J. Robert **Oppenheimer***, the American theoretical physicist and science administrator, noted as director of the Institute for Advanced Study at Princeton and the Los Alamos laboratory during the atomic bomb development, died this day 50 years ago.

20 *Henri **Moissan***, the French chemist who received the 1906 Nobel Prize for isolating fluorine, died in 1907.

*Robert **Huber***, the German biochemist who (with Deisenhofer and Michel) received the Nobel Prize for Chemistry in 1988 for recording the three-dimensional structure of a protein complex essential to photosynthesis in bacteria, was born in 1937.

22 *Friedrich Wilhelm **Strassman***, the German physical chemist who (with Hahn and Mietner) discovered neutron-induced nuclear fission in uranium in 1938, was born in 1902.

27 *James **Chadwick***'s paper on the discovery of the neutron appeared in *Nature* 80 years ago today (Feb. 27, 1932, p. 312).

28 *Alexander **King***, the Scottish chemist who pioneered environmental awareness, warning of the dangers to the environment from extensive industrial development, died 10 years ago.

March

2 *Edward U. **Condon***, the American physicist remembered for the Franck-Condon principle, was born in 1902.

3 The first North Sea gas was piped ashore to BP's Easington terminal on the east Yorkshire coast 50 years ago today (1967).

This same day in 1977 had the first Freon-cooled Cray-1 supercomputer shipped to Los Alamos Laboratories in the US.

4 *Ira **Remsen***, the American chemist who co-discovered saccharin and was the inaugural Professor of Chemistry at Johns Hopkins University, died in 1927. He is the only person buried on the campus with his ashes held behind a plaque in Remsen Hall. According to legend, those undergraduates who rub the plaque the night before their chemistry exam will do well.

6 *Harry **Coover***, the American chemist who invented *Super Glue*™, was born 100 years ago today.

7 *Arthur Rudolf **Hantzsch***, the German chemist who devised the synthesis of substituted pyridines when aged 25, was born in 1857.

*John **Kellogg*** served the world's first cornflakes to his patients at a mental hospital in Battle Creek, Michigan in 1897.

9 *Abraham **Darby***, the first to successfully smelt iron ore with coke, died 300 years ago today.

10 *Jeremias B. **Richter***, the German chemist known for his law of equivalent proportions enunciated during his study of chemistry during his spare time in the Prussian army and while earning a PhD in mathematics, was born in 1762.

*F. Sherwood **Rowland***, the Armenian chemist who shared the 1995 Nobel Prize for Chemistry (with Molina and Crutzen) for research on the depletion of the ozone layer, died 5 years ago.

11 *Archibald Scott **Couper***, the Scottish chemist who proposed the tetravalency of carbon and the ability it has to bond with itself to form long chains independently of Kekulé, died in 1892.

12 *Charles **Friedel***, of Friedel-Crafts fame, was born this day in 1832.

Sir *William **Bragg***, the noted pioneer crystallographer, died in 75 years ago in 1942.

15 *Nevil Vincent **Sidgwick***, the English theoretical chemist who made significant contributions to the theory of valency and chemical bonding, died 65 years ago (1952).

16 150 years ago the *Lancet* published the first of a series of articles by *Joseph **Lister*** on his discovery of antiseptic surgery.

18 *Marcellin **Berthelot***, the French chemist who helped found the study of thermodynamics, died in 1907.

This day in 1987 saw the discovery of high-temperature superconductivity announced at a packed meeting of the American Physical Society in New York City. The phenomenon, discovered in 1911, was formerly known to occur only at 4 K when all electrical resistance in a metal sample disappeared. The 1986 discovery showed that a ceramic material was a superconductor at a temperature of more than 30 K.

19 Prince *Louis-Victor **de Broglie***, the French physicist and 1929 Physics Nobel Laureate known for his research on quantum theory and for the discovery of the wave nature of electrons (during his PhD), died in 1987.

21 *David **Keilin***, Russian-British biochemist who discovered cytochromes, was born in 1887.

*Alfred **Einhorn***, the German chemist who developed procaine (Novocain) in 1905 while working with the research group of Adolf von Baeyer, died 100 years ago today.

23 In 1962, the first inert gas compound was made by *Neil **Barlett***. Platinum hexafluoride was reacted with xenon to form $XePtF_6$, a yellow-orange solid that was stable at room temperature. Xenon is now classed as a *noble* gas.

24 Sir *John Cowdery **Kendrew***, the English biochemist who shared (with Perutz) the 1962 Nobel Prize for Chemistry for their studies of the structures of globular proteins, was born 100 years ago today.

German scientist *Robert **Koch*** declared to the Berlin Physiological Society that he had discovered the bacillus responsible for tuberculosis this day in 1882.

25 *Friedlieb Ferdinand **Runge***, the German chemist considered the father of paper chromatography, died 150 years ago today.

27 *Otto **Wallach***, the German awarded the 1910 Nobel Prize for Chemistry for identifying terpenes, was born in 1847.

*Paul **Lauterbur***, the 2003 recipient of the Physiology and Medicine Nobel Prize (with Mansfield) for discoveries concerning magnetic resonance imaging, died 10 years ago today.

*Jaroslav **Heyrovský***, the Czech recipient of the 1959 Nobel Prize for Chemistry for his discovery and development of polarographic analysis in 1922, died 50 years ago today.

28 *William Francis **Giauque***, the Canadian-born American physical chemist and 1949 Chemistry Laureate for his studies in chemical thermodynamics and the behaviour of matter at very low temperatures, died in 1982.

29 *John Robert* ***Vane***, English biochemist, who shared the 1982 Nobel Prize for Physiology or Medicine (with Bergström and Samuelsson) for the isolation, identification, and analysis of prostaglandins, was born in 1927.

30 *Crawford W.* ***Long***, a physician of Georgia, was the first to use ether as an anaesthetic during a minor operation 175 years ago today (1842).

Friedrich ***Hund*** of Hund's Rule fame died 20 years ago.

April

4 *Friedrich Wilhelm* ***Ostwald***, the Russian-German physical chemist who essentially single-handedly set physical chemistry into a distinct branch of chemistry, died in 1932.

Jeremias B. ***Richter***, the German chemist who discovered the law of equivalent proportions, died in 1807.

This is also the day in 1932 after five years of effort that *C. Glen* ***King*** isolated vitamin C at the University of Pittsburgh.

7 *Francesco* ***Selmi***, the Italian chemist and toxicologist who is considered one of the founders of colloid chemistry, was born 200 years ago today.

In 1827, *John* ***Walker***, an English pharmacist, recorded his first sale of the friction match he had invented the previous year.

9 This is the day in 1812 that Humphry Davy delivered his farewell lecture in the Theatre of the Royal Institution, the day after he was knighted.

10 *Robert Burns* ***Woodward*** was born this day, 100 years ago. Apart from his numerous complex natural products syntheses that included vitamin B12, he evolved the concept of conservation of orbital symmetry with Hoffmann.

Peter Dennis ***Mitchell***, the British 1978 Nobel Laureate in Chemistry who helped to clarify how ADP is converted into the energy-carrying ATP in the mitochondria of living cells, died in 1992.

In 1662, *Robert* ***Hooke*** read his first publication, a pamphlet on capillary action, to the Society for the Promoting of Physico-mathematical Experimental Learning.

12 *Georges* ***Urbain***, the French chemist who first isolated lutetium, the last of the stable rare earths, was born in 1872.

George ***Wald***, the American biochemist awarded the 1967 Nobel Prize for Physiology or Medicine (with Hartline and Granit) for discoveries concerning the primary physiological and chemical visual processes in the eye, died in 1997.

14 *Alan Graham* ***MacDiarmid*** was born this day in 1927.

Frank Henry ***Westheimer***, the Harvard organic chemist who studied reaction mechanisms, isotopes and oxidation with a landmark study of chromic acid oxidations, died in 2007.

16 It is 25 years since thalidomide was reported by Johns Hopkins medical researchers to improve the survival rate of patients given bone-marrow transplants.

19 *Glenn T.* ***Seaborg***, the American nuclear chemist who had the element he discovered named after him whilst still alive, was born in 1912.

Charles ***Darwin*** died in 1882.

20 *Pierre* and *Marie* ***Curie***, isolated 1 g of radium, the first sample of the radioactive element in 1902; it was refined it from eight tons of pitchblende ore.

In 1862, the first pasteurisation test was completed by *Louis* ***Pasteur*** and *Claude* ***Bernard***.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

Advancing Chemistry Worldwide

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IUPAC Announces the Names of the Elements 113, 115, 117, and 118

Elements 113, 115, 117, and 118 are now formally named nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og)

Research Triangle Park, NC (USA): On 28 November 2016, the International Union of Pure and Applied Chemistry (IUPAC) approved the names and symbols for four elements: nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og), respectively for element 113, 115, 117, and 118.

Following a 5-month period of public review, the names earlier proposed by the discoverers have been approved by the IUPAC Bureau. The following names and symbols are officially assigned:

Nihonium and symbol Nh, for the element 113,

Moscovium and symbol Mc, for the element 115,

Tennessine and symbol Ts, for the element 117, and

Oganesson and symbol Og, for the element 118.

In concordance with and following the earlier reports that the claims for discovery of these elements have been fulfilled [1,2], the discoverers have been invited to propose names. Keeping with tradition, the newly discovered elements have been named after a place or geographical region, or a scientist. The ending of the names also reflects and maintains historical and chemical consistency: "-ium" for elements 113 and 115 and as for all new elements of groups 1 to 16, "-ine" for element 117 and belonging to group 17 and "-on" for element 118 element belonging to group 18.[3] The recommendations will be published in the IUPAC journal *Pure and Applied Chemistry* (http://dx.doi.org/10.1515/pac-2016-0501). For further information please see: www.iupac.org/iupac-announces-the-names-of-the-elements-113-115-117-and-118.

IUPAC Secretariat P.O. Box 13757 Research Triangle Park, North Carolina 27709 USA
T+1 919 485 8700 F +1 919 485 8700 secretariat@iupac.org www.iupac.org

The name nihonium with the symbol Nh for element 113 was proposed by the discoverers at RIKEN Nishina Center for Accelerator-Based Science (Japan); the name came from Nihon which is one of the two ways to say "Japan" in Japanese, and literally mean "the Land of Rising Sun".

Moscovium with the symbol Mc for element 115 and tennessine with the symbol Ts for element 117 were proposed by the discoverers at the Joint Institute for Nuclear Research, Dubna (Russia), Oak Ridge National Laboratory (USA), Vanderbilt University (USA) and Lawrence Livermore National Laboratory (USA). Both are in line with tradition honoring a place or geographical region. Moscovium is in recognition of the Moscow region and honors the ancient Russian land that is the home of the Joint Institute for Nuclear Research, where the discovery experiments were conducted using the Dubna Gas-Filled Recoil Separator in combination with the heavy ion accelerator capabilities of the Flerov Laboratory of Nuclear Reactions. Tennessine is in recognition of the contribution of the Tennessee region of the United States, including Oak Ridge National Laboratory, Vanderbilt University, and the University of Tennessee at Knoxville, to superheavy element research.

Lastly, and in line with the tradition of honoring a scientist, the name oganesson and symbol Og for element 118 was proposed by the collaborating teams of discoverers at the Joint Institute for Nuclear Research, Dubna (Russia) and Lawrence Livermore National Laboratory (USA) and recognizes Professor Yuri Oganessian (born 1933) for his pioneering contributions to transactinoid elements research. His many achievements include the discovery of superheavy elements and significant advances in the nuclear physics of superheavy nuclei including experimental evidence for the "island of stability".

Comments from the general public, during the 5 month period were many. Apart from many full agreements, comments were received suggesting other names, in some cases accompanied by petitions from large groups of people. However, these suggestions could not be accepted, given the fact that under the current guidelines only the discoverers have the right to propose names and symbols. Questions were also received about pronunciation of the names and the translations into other languages. Members of the chemistry community also raised the concern that Ts is one of the two commonly used abbreviations for the tosyl group. Recognizing however that many two-letter abbreviations have multiple meanings —even in chemistry, and for example Ac and Pr— the conclusion was made that the context in which the symbols are used, makes the meaning unambiguous.

"Overall, it was a real pleasure to realize that so many people are interested in the naming of the new elements, including high-school students, making essays about possible names and telling how proud they were to have been able to participate in the discussions," said Professor Jan Reedijk, President of the Inorganic Chemistry Division. He added *"It is a long process from initial discovery to the final naming, and IUPAC is thankful for the cooperation of everyone involved. For now, we can all cherish our periodic table completed down to the seventh row."*

"The names of the new elements reflect the realities of our present time" said IUPAC President Professor Natalia Tarasova, *"universality of science, honoring places from three continents, where the elements have been discovered—Japan, Russia, the United States—and the pivotal role of human capital in the development of science, honoring an outstanding scientist—Professor Yuri Oganessian".*

The exploration of new elements continues, and scientists are searching for elements beyond the seventh row of the periodic table. IUPAC and the International Union of Pure and Applied Physics (IUPAP) are establishing a new joint working group whose task will be to examine the criteria used to verify claims for the discovery of new elements.

References:

[1] P.J. Karol, R.C. Barber, B.M. Sherrill, E. Vardaci, T. Yamazaki, Pure Appl. Chem. 88 (2016) 139; http://dx.doi.org/10.1515/pac-2015-0502
[2] P.J. Karol, R. C. Barber, B. M. Sherrill, E. Vardaci, T. Yamazaki, Pure Appl. Chem. 88 (2016) 155; http://dx.doi.org/10.1515/pac-2015-0501
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About IUPAC:

IUPAC was formed in 1919 by chemists from industry and academia. Since then, the Union has succeeded in fostering worldwide communications in the chemical sciences and in uniting academic, industrial and public sector chemistry in a common language. IUPAC is recognized as the world authority on chemical nomenclature, terminology, standardized methods for measurement, atomic weights and many other critically evaluated data. In more recent years, IUPAC has been pro-active in establishing a wide range of conferences and projects designed to promote and stimulate modern developments in chemistry, and also to assist in aspects of chemical education and the public understanding of chemistry. More information about IUPAC and its activities is available at www.iupac.org.

For further information, contact Dr. Lynn M. Soby, Executive Director, IUPAC, at executivedirector@iupac.org or lsoby@iupac.org.