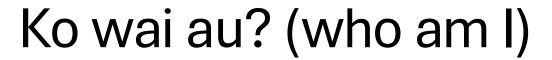
Secondary metabolites and science education in rural New Zealand

Theme 3: Difficult Biology Concepts Made Easy

Liam Hewson













- Master of Science Graduate, University of Otago
 - Bioactive secondary metabolites of a native tree
 - Science education in rural and indigenous communities
- Head Tutor & Executive Committee, New Zealand International Biology Olympiad

A grateful partner to indigenous communities







Disclaimer

• I'm a chemist – the usual reaction I get is, "wow, that's hard"

 But I explore biologically active molecules informed by phylogenetic & evolutionary relationships (and traditional knowledge) -> using chemistry to explore difficult biology concepts

Keep today visual & colorful – light on the chemistry



What will this talk be about?

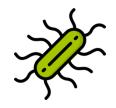
- Teaching difficult biology concepts to school students with little exposure to science
 - Antimicrobial resistance
 - Taxonomy and phylogenetic relationships
 - Morphological species identification
- Delivering science education in partnership with indigenous communities
- Enriching a first-year university curriculum with interdisciplinary teaching using drug discovery science



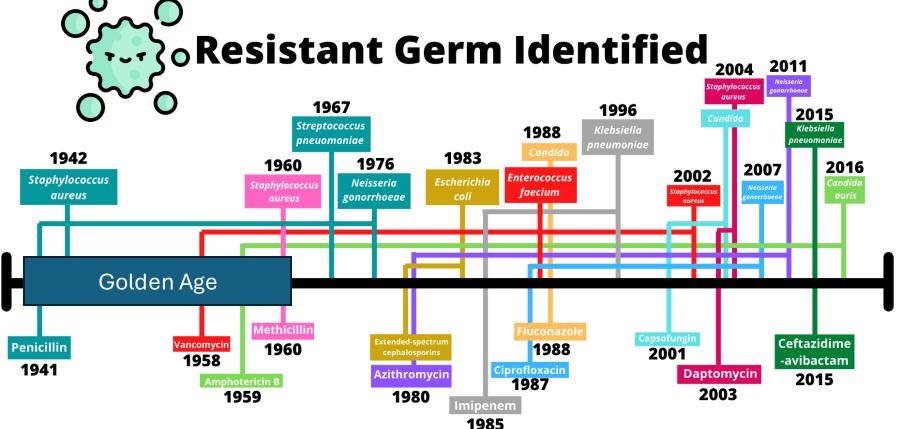
Background

Difficult Biology Concepts

The community context and science outreach



Difficult Biology Concepts: AMR



24 classes of antibiotic drugs

3 classes of antifungal drugs, resistance growing

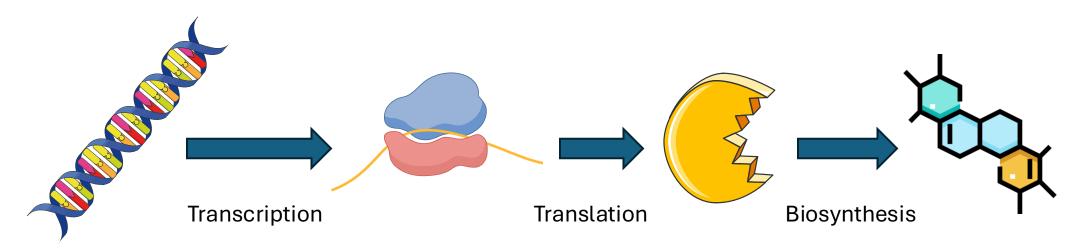


Antibiotic Approved or Released

Credit: CDC

Difficult Biology Concepts: biochem. variation

All natural molecules are genetically encoded



Chemical variation in each individual plant



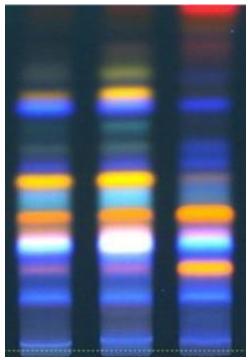
Credit: Biolcons



Difficult Biology Concepts: chemical factories

How do plants interact with the world?









Credit: Biolcons



Difficult Biology Concepts: Taxonomy



Kunzea ericoides Kānuka



Leptospermum scoparium

Mānuka

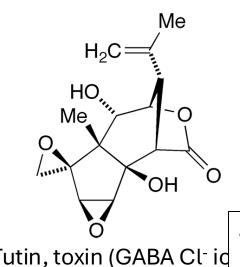
How do you convince a six-year-old these are different?

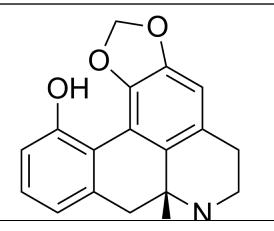
Credit: Weeds of Australia; Phil Bendle

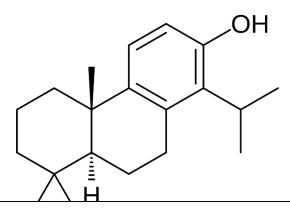
Biodiversity to natural product diversity: NZ

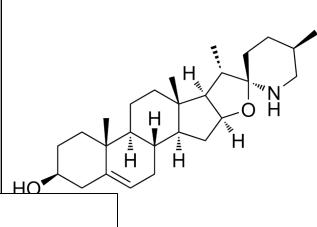












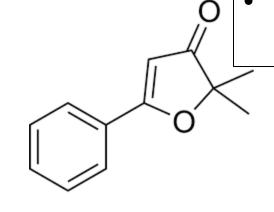
e, toxic steroid

Tutin, toxin (GABA Cl- id

~80% of NZ vascular plants endemic

~50% of NZ liverworts endemic

>15 bioactive natural product compound classes first from NZ



Bullatenone, antifungal

Aciphyllal, anti-TB

3A (plus enantiomer)

Bullataketal, cytotoxic

Polygodial, antifungal (spicy taste)

New Zealand – Disproportionate health outcomes



Relative Staphylococcus pyogenes infection rates in children

Presence of scabies = 23x more likely to develop rheumatic fever Credit: Webb & Wilson, 2013; Oliver et al., 2021; Abrha et al., 2020.



Chemistry Outreach: What is it?



- Programme run out of the Otago University Chemistry Department
- School and marae-based fun science practicals

 "Activities designed to inspire children with science and support teachers using student volunteers and their subject specific knowledge as part of an extended program"

A Ngāti Kahu kuia:

"The sizzle that goes with the sausage .."

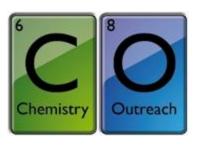
Developing a new generation of scientist communicators through effective public outreach

Mackay et al. (2020)



1) Hodgen, E. (2007). Competent learners @ 16: Patterns of development over time. Technical report 1. Wellington: New Zealand Council for Educational Research.

Outreach: Why do we do it?



- in terms of NZ;
- The NEMP (early 2000's) showed that there was a marked lack of enthusiasm for science in year 8 (~13 years old) school pupils
- The data also raised serious worries about school pupils perceptions
 of their abilities in science, especially at year 8 (especially in rural and
 semi-rural schools)
- A longitudinal study¹ showed lack of personal success creates a poor attitude to learning. These signs are seen in pupils as early as 10-12 years old
- A lack of interest in science that sets in at this age is likely to continue through further schooling and career aspirations are developed by 13-14 years old

Guiding principles

- Ages <12, but any ages
- Practical learning; rural, low socio-economic communities
- Curriculum aligned nature of science
- Longitudinal

- Fun!
- Novel and exciting



Chemistry Outreach

they teach."3



Pedagogy – Critical Exploration (Duckworth)

"Factors that influenced the students' attitudes towards Ou the Chemistry Outreach programme included the scientists' passion for science, a climate that accepted The errors, the positive power of peers, reciprocal relationships, trust, and humour all helped to forge the students' positive emotional connections with the science programme."

(Penrice G. 2016)

s, asking

school of

how

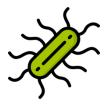


²⁾ Duckworth, E. 'The Having of Wonderful Ideas' & other essays on teaching & learning. (Teachers College Press, 1987

³⁾ Duckworth, E. Helping Students Get to Where Ideas Can Find Them. New Educ. 5, 185–188 (2009).

What have we done so far?

- T<mark>LC</mark> of kānuka leaf extracts/felt pen chromatography (alongside rongoa workshop by local tohunga)
- Density bottles, density layers
- Hydrogen fuel cells kits (courtesy of He Honoka Hauwai)
- Solar cell kits (courtesy of MacDiarmid Institute)
- Nitrate testing and nanoparticles for remediation
- Crystal growing
- "Oil, water, methanol"
- Biopolymers
- Painting with iron complexes
- Plant indicators and pH painting
- Cauldron of fire/whoosh bottle/hands on fire







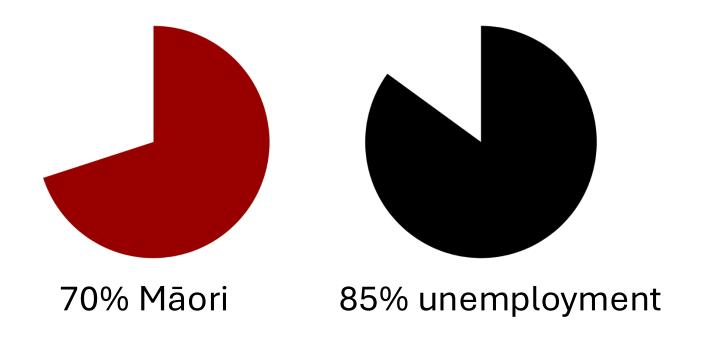




New Zealand context – Far North

Rural and remote population

Barriers in access to educational opportunity







A community outcome

 Pilot scheme 2022, 5 schools in 1 week ~350 pupils aged 5-18, it was a huge success and we were invited back for more trips







"I didn't understand what this science stuff is or why it's useful, I'm so proud of my mokos and the opportunity this is for them"

(Ngāti Kahu kuia)

Over 2.5 years

>2000 students 7 trips, 8 weeks cumulative time



A new Iwi partnership

- A partnership with Ngāti Kahu
- A region with the lowest average income per household in NZ
- History of poor engagement with scientists has damaged trust
- Arose from discussion around vaccine hesitancy and lack of trust in scientists









How to show biochemical diversity in school?

Case study 1: Thin Layer Chromatography to distinguish between plant specimens

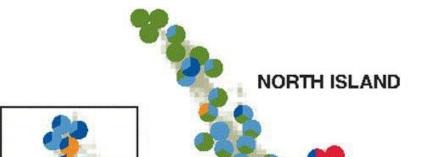
'Manuka Chemistry in the Community' aims

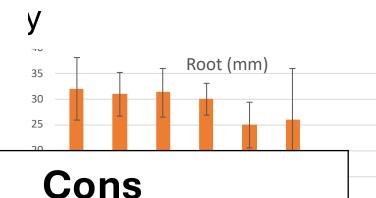
- Establish a set of experiments and resources for tauira to explore their local habitat – whether studying mānuka or other native plants
- Engage rural and Māori students in science, using the context of Mātauranga Māori and rural economies regarding mānuka
- Learning and developing new science skills from conducting their own investigations
- Increased understanding of mānuka chemotype distribution around New Zealand, with potential importance to the economy

Mānuka in Schools (2016)



- Linked grandi
- 10-15 year old
- Emphasis on





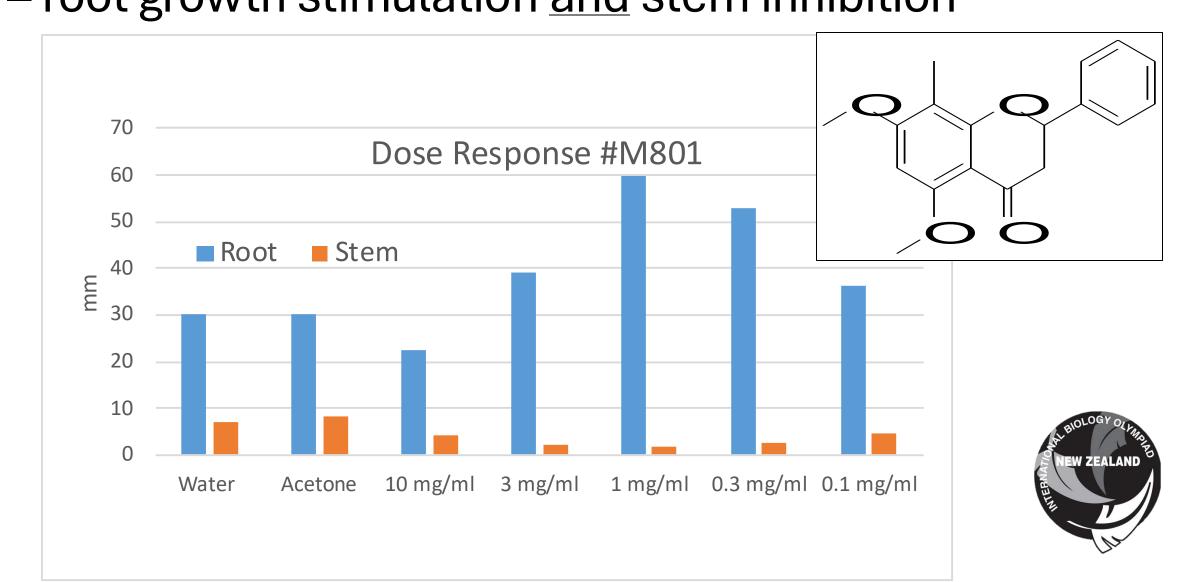
Pros Intuitive Safe for classrooms Combination of assay and chemical analysis



- Length of assay (1 week)
- Name of the last o between seed batches
- Separation (time & space) of biological/chemical analysis

0.05

Plant growth effects of mānuka leaf extracts – root growth stimulation <u>and</u> stem inhibition



What about kānuka?



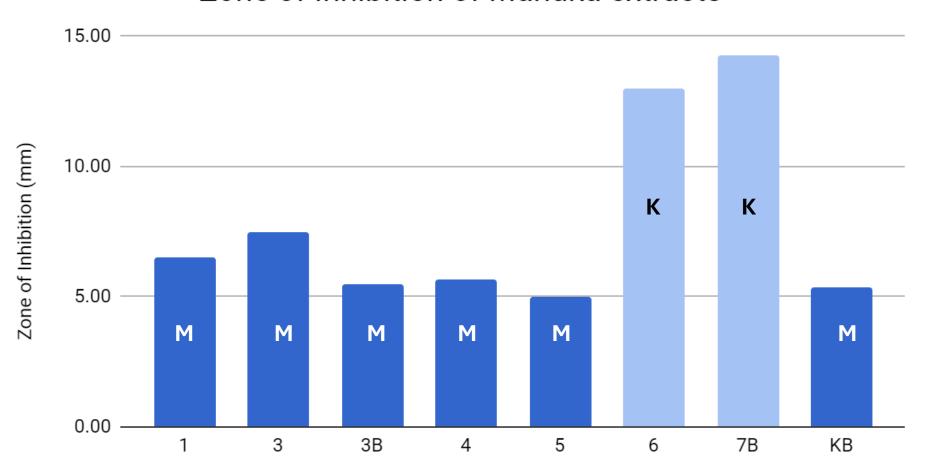
Kānuka, *Kunzea ericoides*

Disk diffusion assay (2018 School project)





Zone of Inhibition of Manuka extracts



M: Leptospermum scoparium,

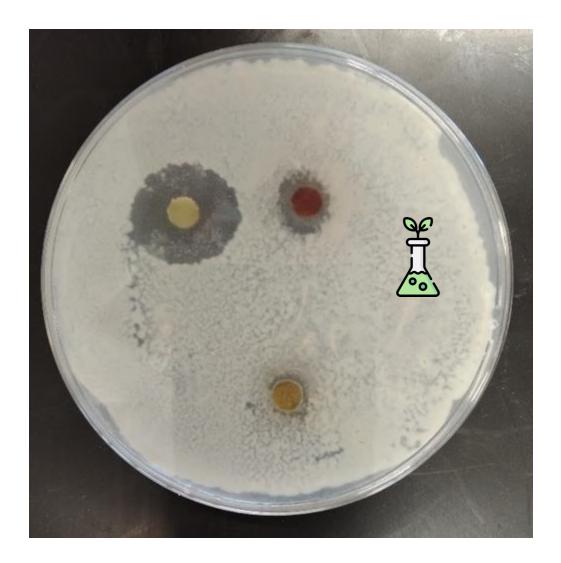
Mānuka

K: *Kunzea* ericoides, Kānuka



Solutions containing active compounds

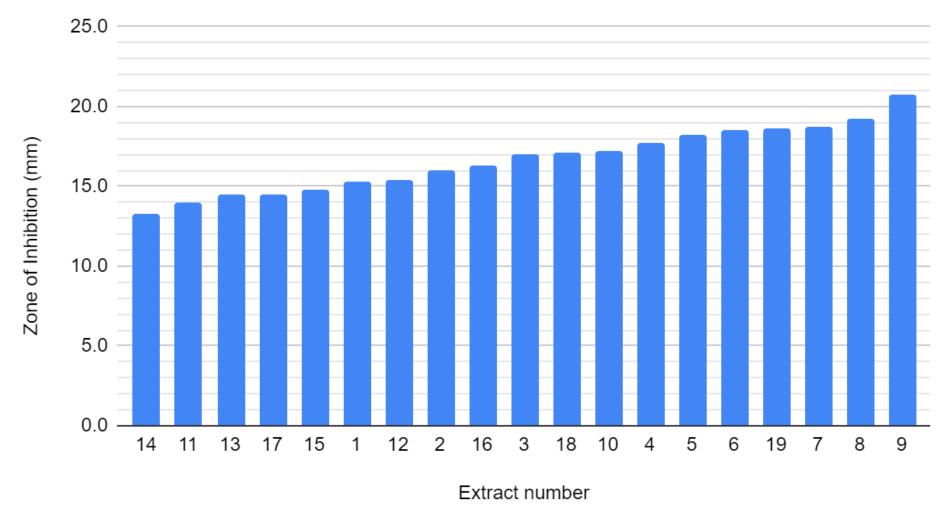
Antimicrobial effect varies by plant





2019 Kānuka trial

Zone of Inhibition of Kanuka Extracts

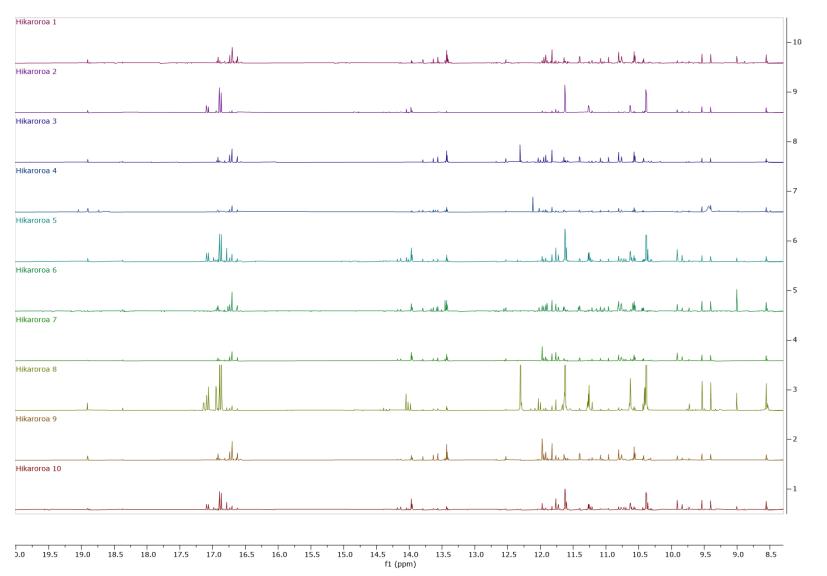


> Kanuka bioactivity substantiated across further samples





Diversity in kānuka metabolites – complex!



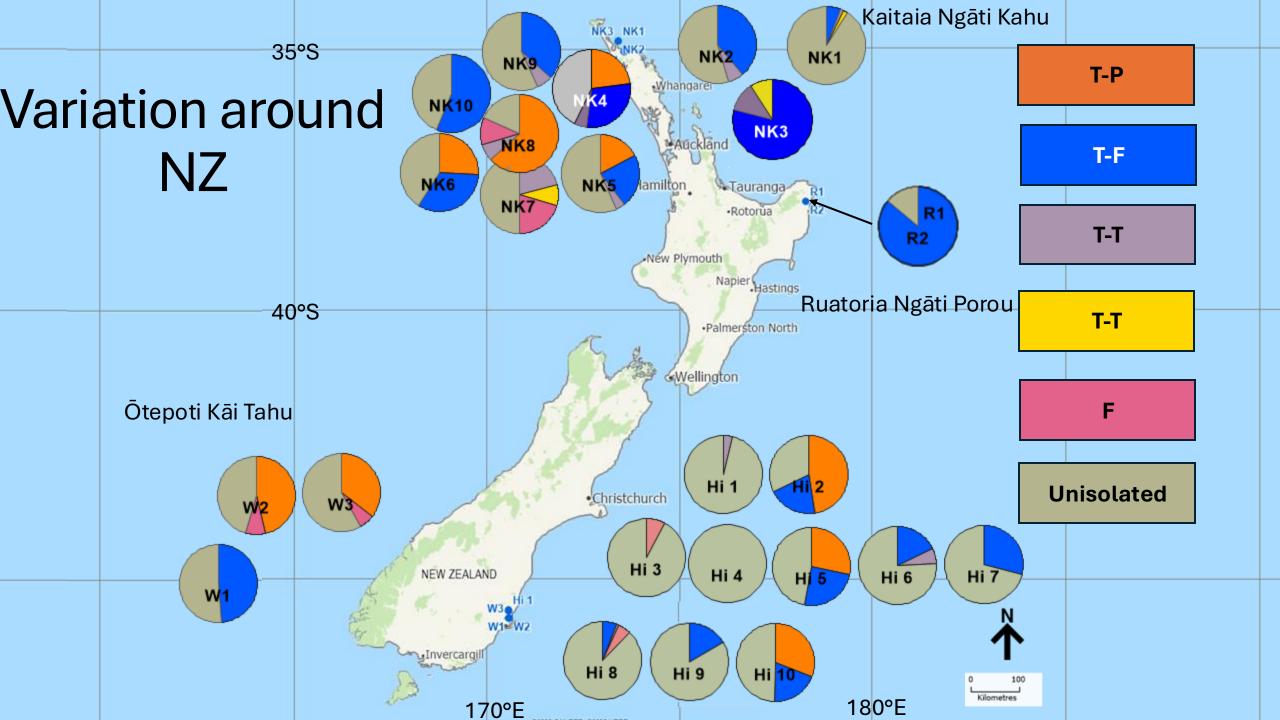
Pretty complex NMR profile

Difficult to understand by eye

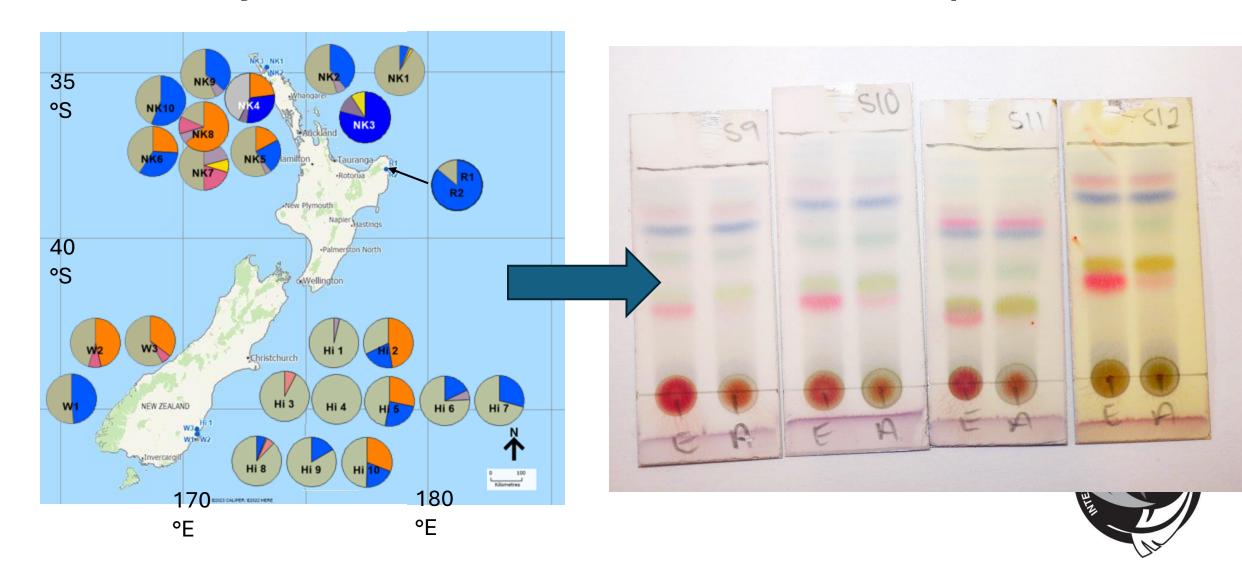
But provides a molecular fingerprint for various bioactive compounds

Needle in a haystack!





Diversity in kānuka metabolites – complex!



Taonga Natural Products Outreach Concepts Nature of Science & Investigations



Plants as a chemical factory

Rongoā, Mātauranga and traditional use

Chemical fingerprint – variation

Felt Pen Chromatography



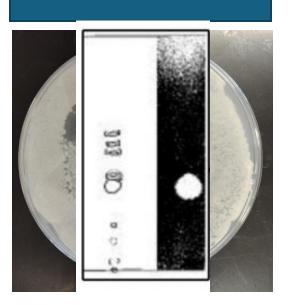
TLCs

Differ same
Impo spots
Plant chem
Varia
Jants

TLC Visualisation

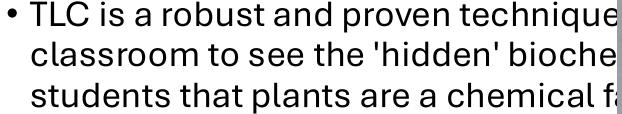
- Our che
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Bioassay

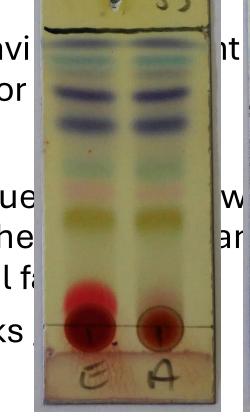


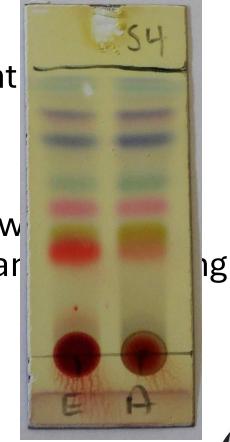


 Yes! We can link different plants havi bands to their biochemical profile or



Using vanillin stain smells and looks





• Developed a robust TLC method to distinguish within species

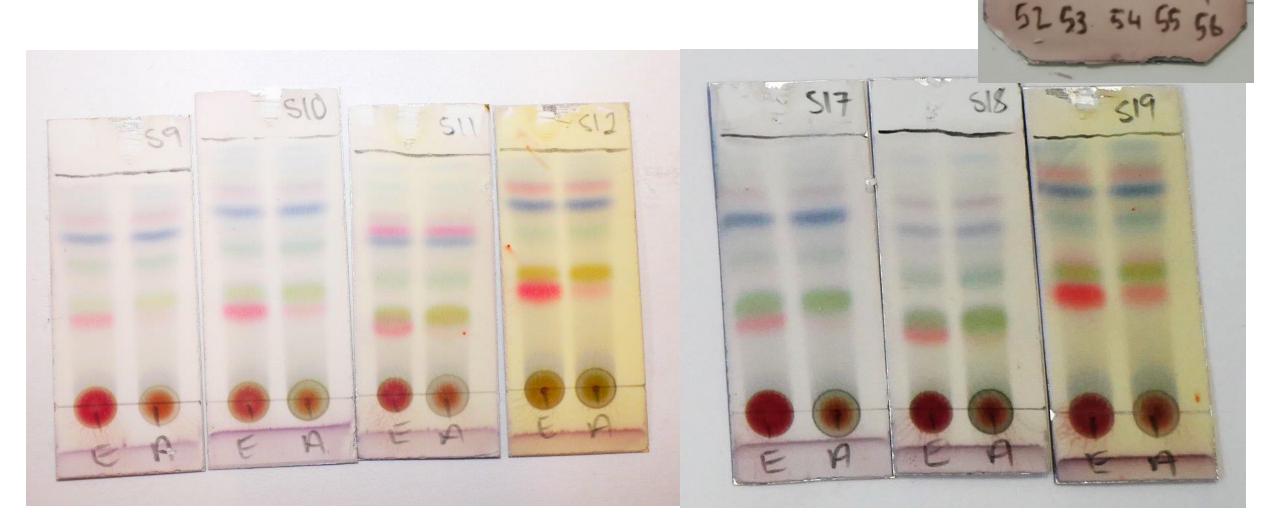
How far can we take this?





NEW ZEALAND

Different biochemicals

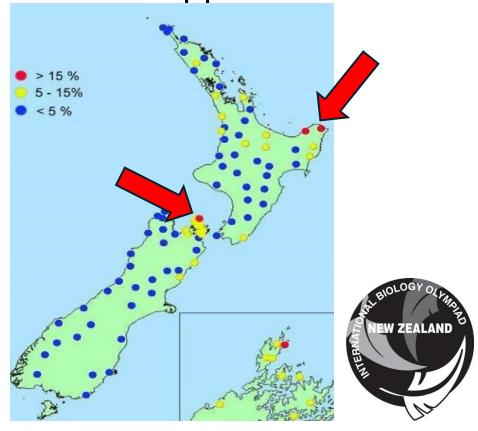






• Kānuka (*Kunzea ericoides*) and Mānuka (*Leptospermum* scoparium) are both Myrtaceae species, similar in appearance

 Important to distinguish – NZ mānuka industry >\$10 million NZD



Credit: Douglas et al. (2004)

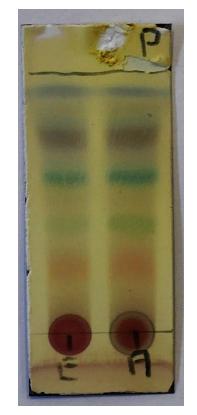
Can we distinguish Mānuka and Kānuka?

- Yes!
- (they look more different with other visualization techniques)

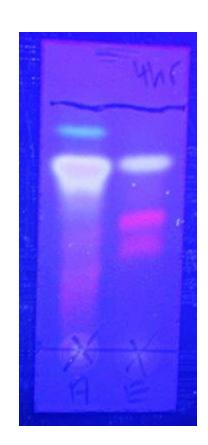




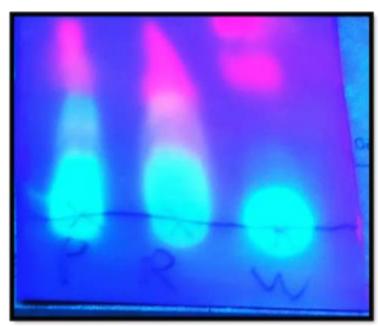
What about other species?



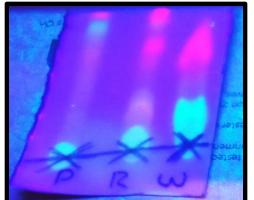
Pōhutukawa Metrosideros excelsa

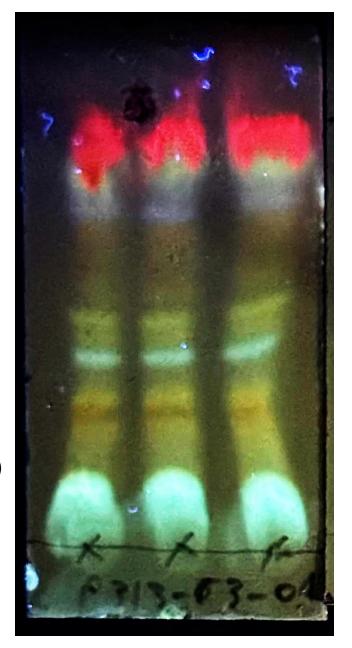


Lichen From a tree



Harakeke (*Phormium tenax*) and wharariki (*Phormium cookianum*)





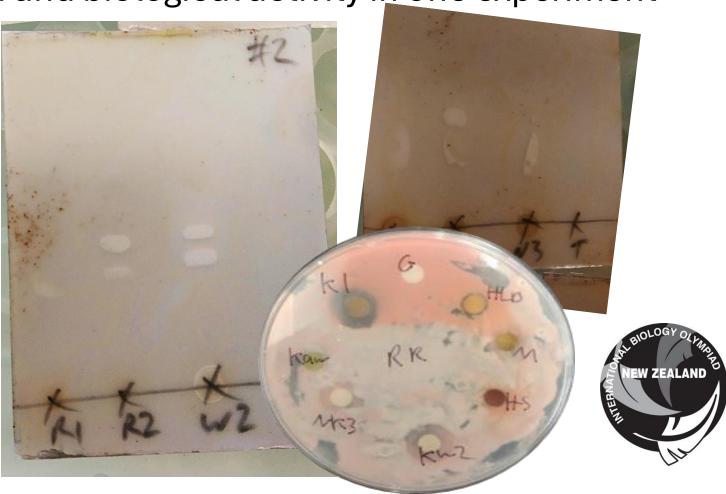
Credit: Amelia Glen-Gaul, Josh Bristowe

Integration of bioassay – kānuka bioactives

Link biochemical variation and biological activity in one experiment







Does this approach work to engage & educate?

Local and meaningful science

"we love when we see you guys turn up, it's like ooo what cool science are we going to do?" Oturu school teacher

"it's the science guys!!!"

chanting "science, science, science".

"when we went to the rūnanga – WOW! their engagement in that was massive! ... how often do you manage to get the adults enthusiastic about this stuff, wanting to know more and do more and get more involved – that was my highlight".

"I didn't understand what this science stuff is or why it's useful, I'm so proud of my mokos [mokopuna] and the opportunity this is for them."



"I want to do more outreach trips"

Feedback

- "Even the naughty ones were engaged... real good engagement school bully and another person that used to disrupt everything, fully engaged". (Hewson, 2024)
- "nah, not interested, don't wanna be here; end of that thing [day of outreach at Taipā Marae] she came up to every one of us and was like 'yeah, you guys are awesome, I loved it, I'm really thinking about doing science now". (Hewson, 2024)
- Children introduce us to parents in supermarkets as 'our scientists', we get invites to school performances, parents come up to us to say hello in the chip shop and supermarkets.

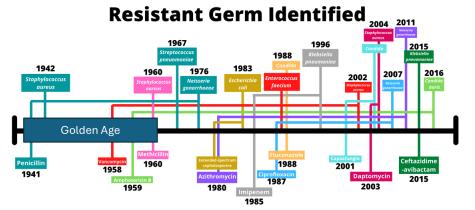


Drug discovery lab

Bringing pharmaceutical science into the classroom

Difficult Biology Concepts





24 classes of antibiotic drugs

3 classes of antifungal drugs, resistance growing



Antibiotic Approved or Released

Credit: CDC

Difficult Biology Concepts

How do plants interact with the world?

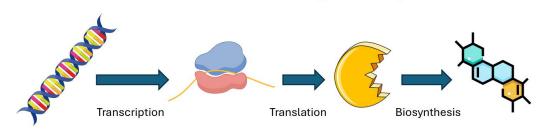






Difficult Biology Concepts

All natural molecules are genetically encoded

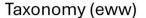


Chemical variation in each individual plant



Credit: Biolcons

Difficult Biology Concepts







Kunzea ericoides

Leptospermum scoparium

How do you convince a six-year-old these are different?

Credit: Weeds of Australia; Phil Bendle

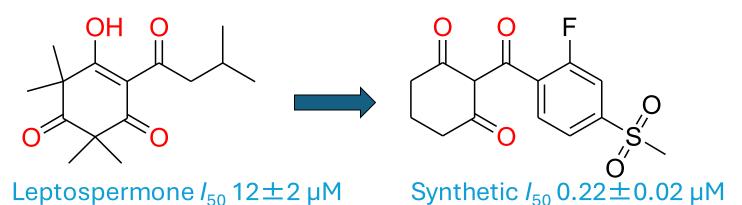






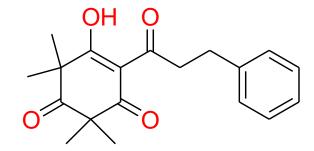
- Taxonomy informed bioactivity: Myrtaceae fruitful bioactive family
- In NZ mānuka science, rich history of traditional uses by Māori

Herbicidal

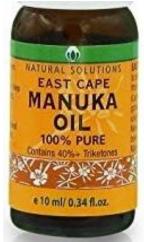




Antimicrobial



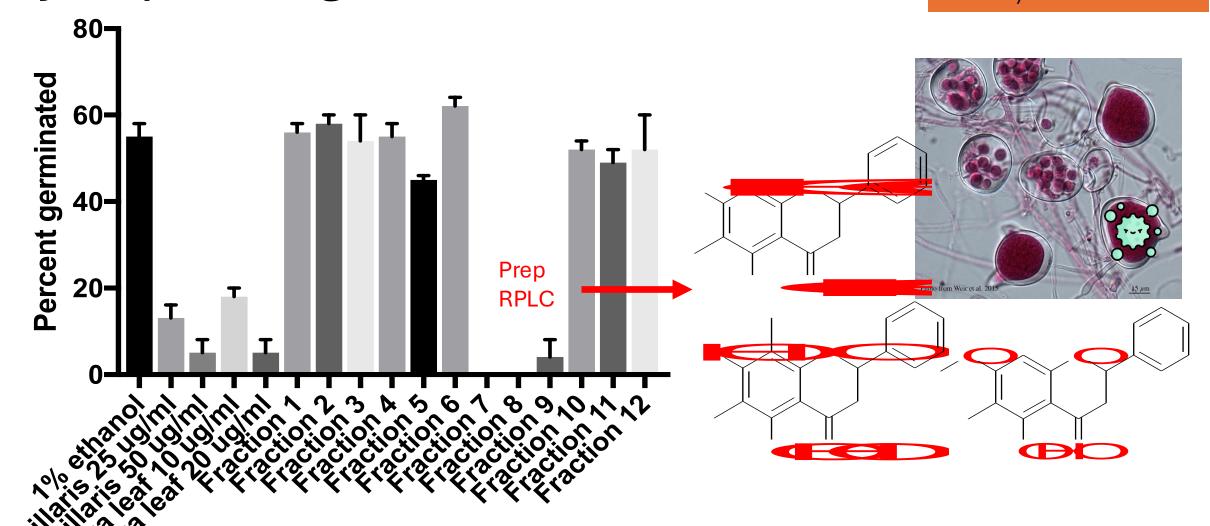
Grandiflorone
MIC 32 mg/mL vs
VRE, Staph. aureus





25% screening hits using traditional knowledge (compared to 8% without)

Phythophora agathidicida work - Kānuka

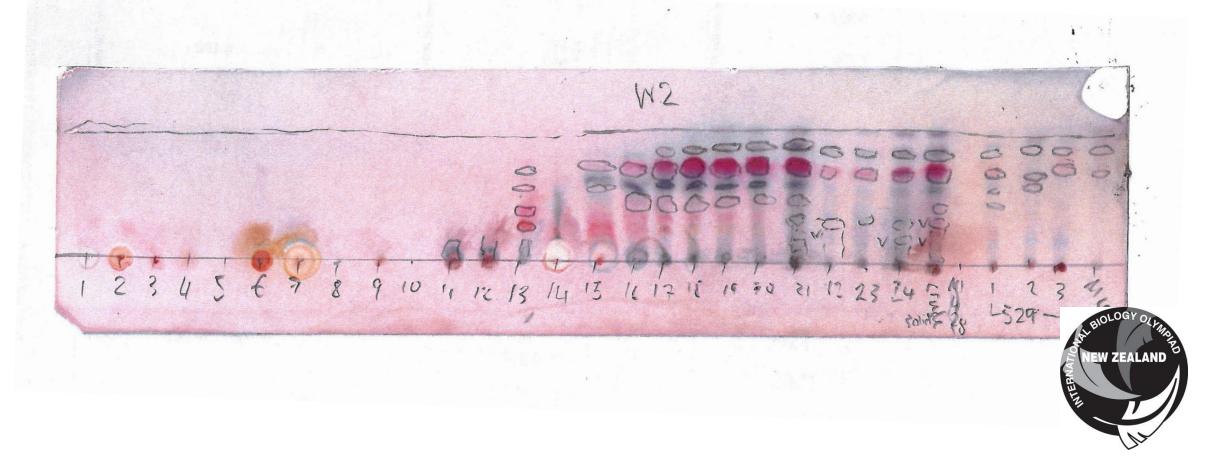


Traditional knowledge informing scientific 'discovery' of antimicrobial agents

Credit: Lawrence et al. (2019)

Interdisciplinary lab experience

Pedagogy – research-informed teaching laboratory



Why do we use medicines?

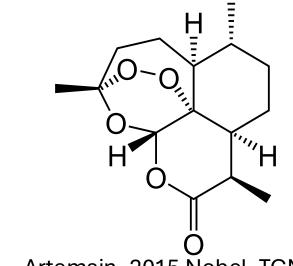
What happens when they become ineffective?

Where do medicines come from?

Addressing (antimicrobial) resistance through considering plants as chemical factories

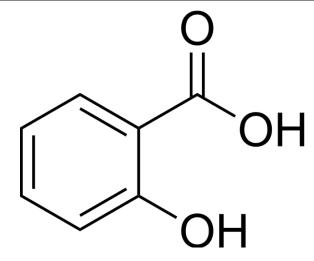


From Nature – the best chemist!



Artemsin, 2015 Nobel, TCM, antimalarial

Statins, cholesterol, fungi



Salicylic acid, willow, pain

Morphine, analgesic, poppies

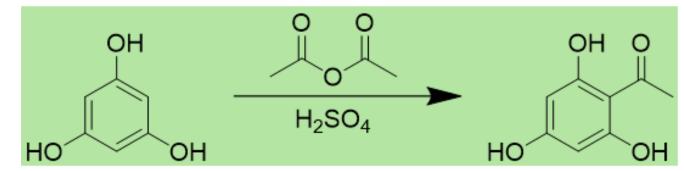
Taxol, anticancer, yew tree

Polygodial, spicy, horopito

Today's lab – synthesis of new antibacterial / antiviral compounds

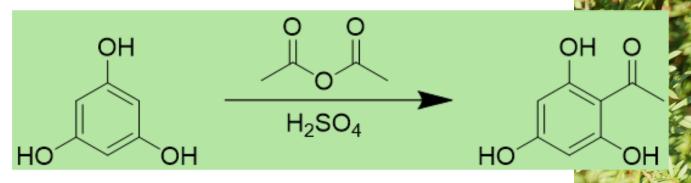
Found once in kānuka

So, let's chop some bits off and make it into a model system – most of the core pieces



- Based on some ideas from 1943
- You guys are the first to trial this lab, before even our first-year uni students!
- Testing out this lab idea to see if it is interesting and fun (drug discovery, hello!)
- Instead of chopping trees down & with a green chemistry approach

Today's lab

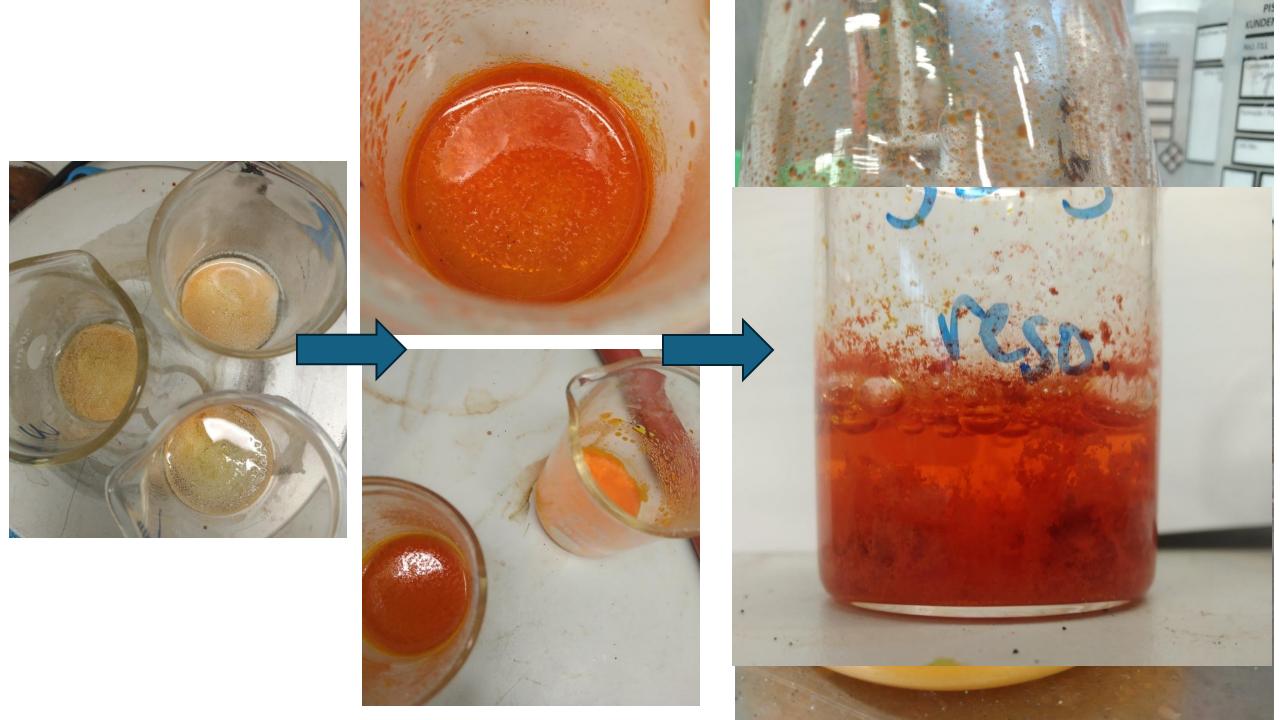


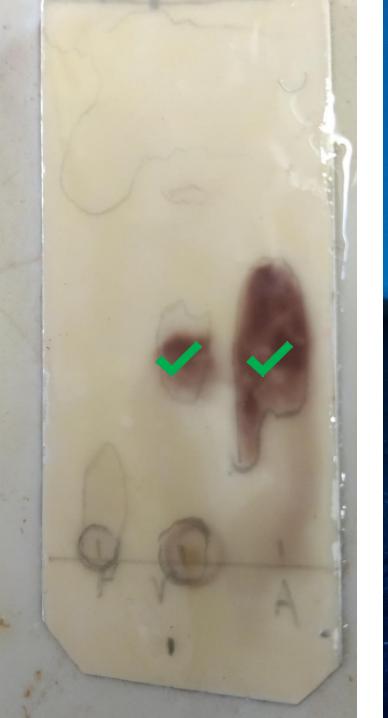
- Do the chemistry make our products!
- What have we made / did we make something?
 - Observations
 - o TLC
 - NMR (we can do 13C NMR)
- Purify our product
 - ○UV-vis
 - \circ IR

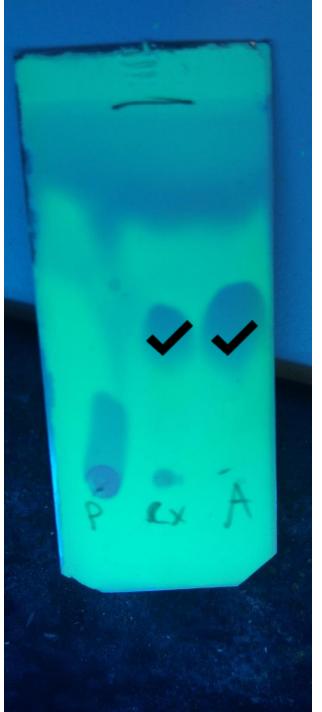
Respecting the taonga (treasured) plant

Scaled up supply of the compound

Ensuring we don't cut down plants

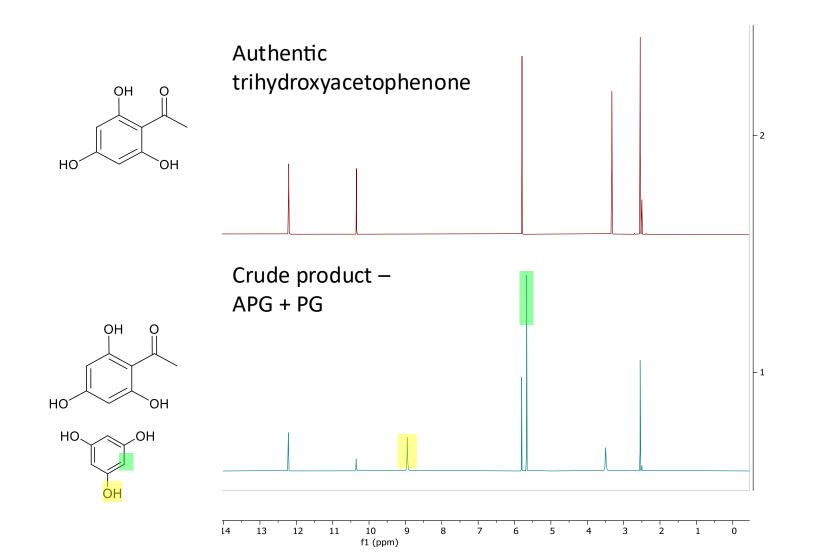








Synthesis of acyl phloroglucinol analog – Hoesch Reaction





Bloor acyl phloroglucinol – literature antiviral properties;

Antibacterial vs *Staph. aureus* and *Strep. pyogenes*

So what?

- Difficult bio concepts made easy through chemistry showing:
- Plants **make a range** of biochemicals to defend themselves and interact with the world
- ****
- Different plants have different chemistry due to their genetic differences (Geno > Chemo)
- We can distinguish species by the properties of their chemistry
- We can use these active compounds to combat pathogens and AMR, inspiring synthesis and finding new drugs from nature

Acknowledgements

- Māori partners
- Dr Dave Warren
- Josh Bristowe
- Prof. Nigel Perry
- Amelia Glen-Gaul
- Plant & Food Research Group, Bioeconomy Science Institute
- Chemistry Department, University of Otago
- Senior Smeaton Scholarship for Experimental Science







Secondary metabolites and science education in rural New Zealand

Theme 3: Difficult Biology Concepts Made Easy

Liam Hewson



