Australian Government

Department of Defence

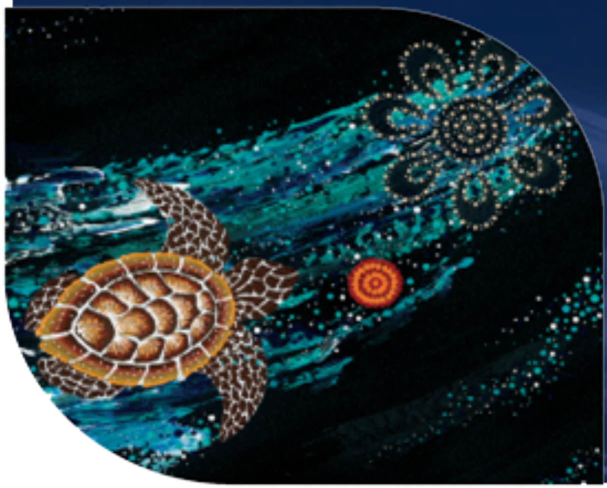
Science and Technology

Collaborative research to solve problems that require novel materials

Dr Ian Dagley

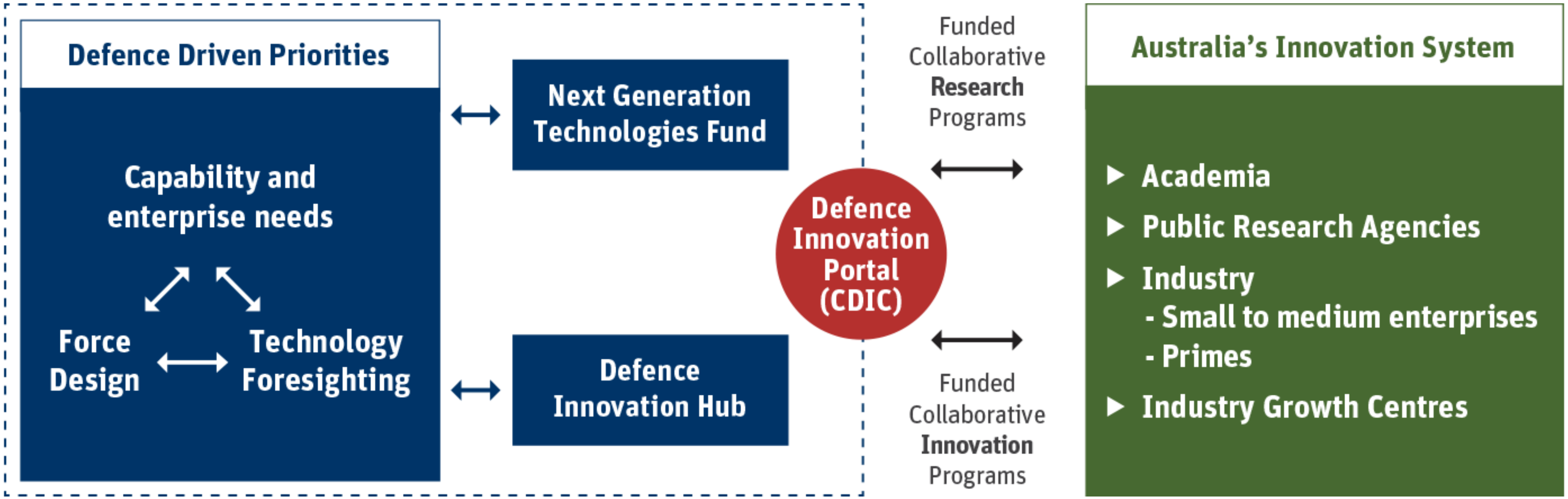
Chief Science Partnerships & Engagement Division

Defence Science and Technology Group



DST | Science and Technology for Safeguarding Australia

Defence Innovation System



$1.6 B for innovation initiatives over 10 years

Next Generation Technologies Fund - $730 M

Centre for Defence Industry Capability (Innov. Portal) - $230 M

Defence Innovation Hub - $640 M

Competitive advantages of collaborations

Speed to market
Faster product development by bringing together existing expert groups with the required complementary skills

Mitigating risk
Tackling higher risk/higher return projects and sharing the risk and costs
Reducing the technical and commercial risk by partnering

Growing complexity
Innovation increasingly at the interface between disciplines or skills
Require teams with a much wider range of skills than in one organisation

Next Generation Technologies Fund priorities

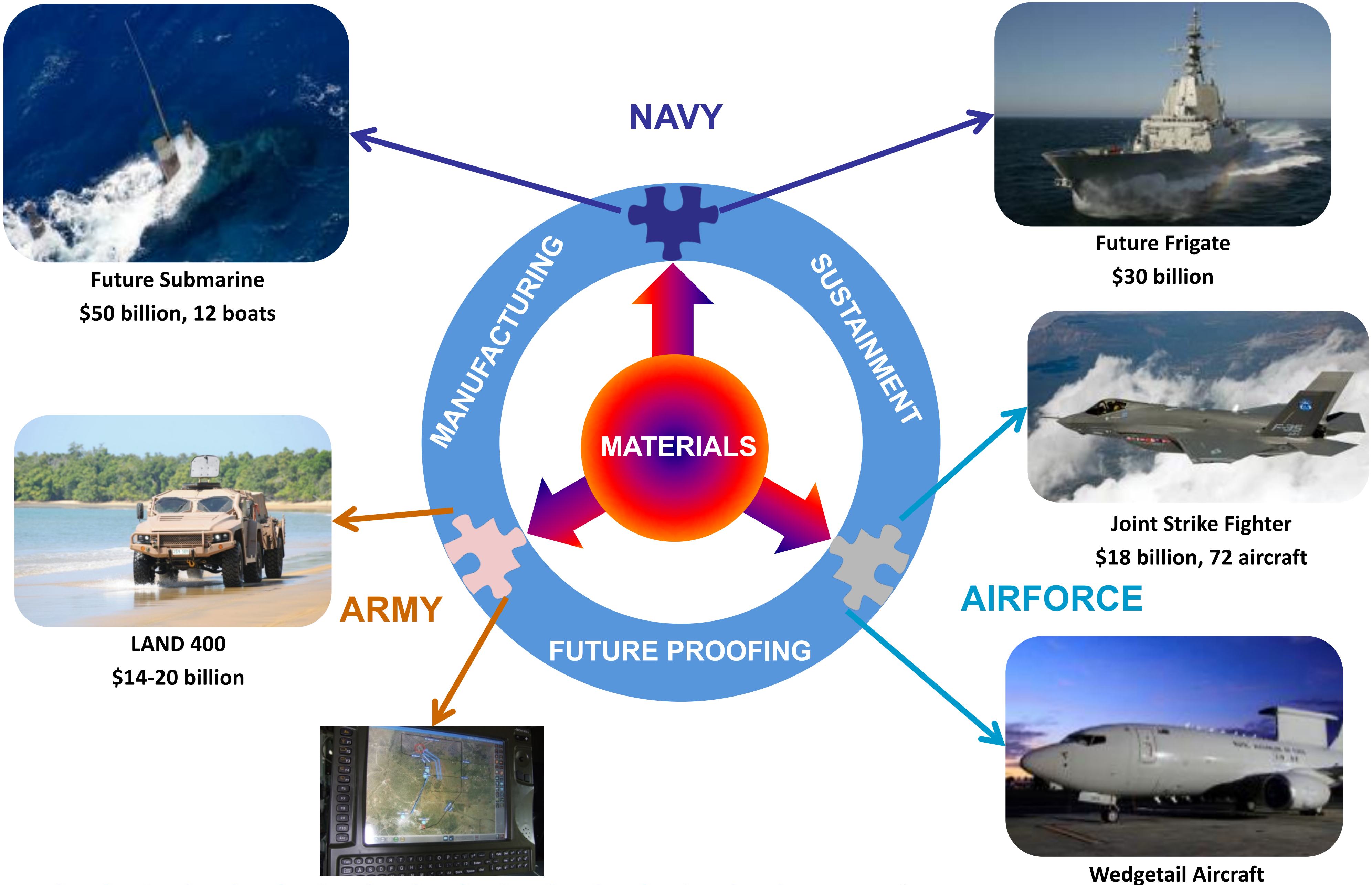
Common materials research challenge

Tailoring the architecture/ microstructure/composition of materials to provide the novel properties required to enhance Defence capabilities

MATERIALS SCIENCE

- **Metals**
- **Polymers**
- **Ceramics**
- **Composites**
- **Chemistry**
- **Characterisation**
- **Microstructure**
- **Structure-property**

MATERIALS ENGINEERING

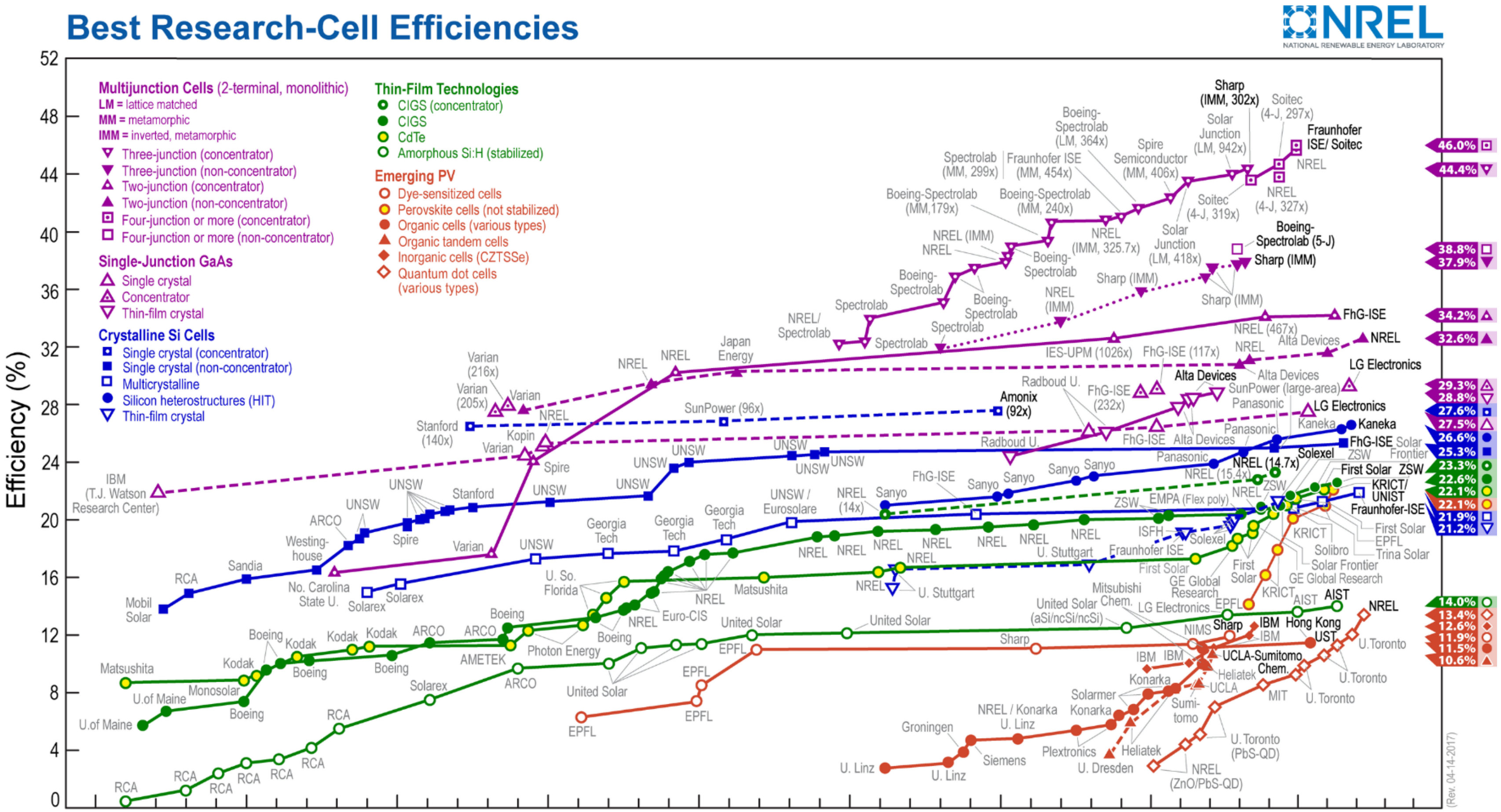

NAVY
Future Submarine
$50 billion, 12 boats
Future Frigate
$30 billion
MANUFACTURING
SUSTAINMENT
MATERIALS
FUTURE PROOFING
Joint Strike Fighter
$18 billion, 72 aircraft
AIRFORCE
LAND 400
$14-20 billion
ARMY
Wedgetail Aircraft

Polymers – a technology strength

- A critical technology for Australian manufacturing
- The most widely used advanced materials, great potential for product innovation
- A core strength of Australian manufacturing - $9 billion p.a.

Prime Minister's Science Prize 2011:
David Solomon and Ezio Rizzardo

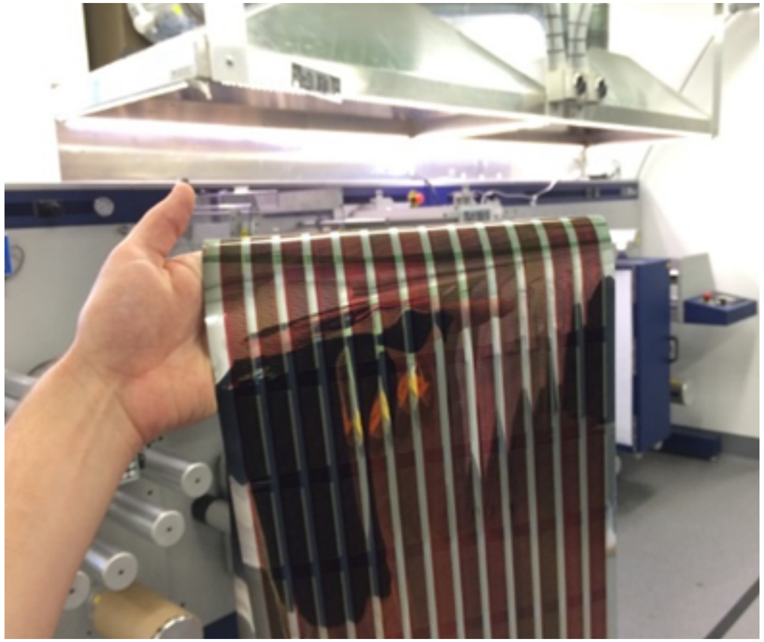
Solar cell efficiencies



C.J. Mulligan, M. Wilson, G. Bryant, X. Zhou, W.J. Belcher, P.C. Dastoor, “A Projection of Commercial-Scale Organic Photovoltaic Module Costs”, *Solar Energy Materials & Solar Cells*, **120**, 9 – 17, (2014).

Flexible solar cost

Calculated Module Cost ($\$/m^2$)
7.85



C.J. Mulligan, M. Wilson, G. Bryant, X. Zhou, W.J. Belcher, P.C. Dastoor, “A Projection of Commercial-Scale Organic Photovoltaic Module Costs”, *Solar Energy Materials & Solar Cells*, **120**, 9 – 17, (2014).

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RAFT Polymerization

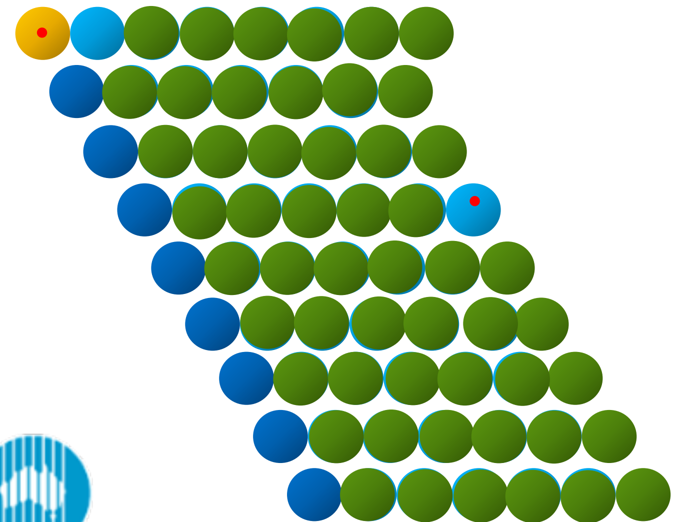
Simply add a source of radicals to a monomer (**M**) and a RAFT agent

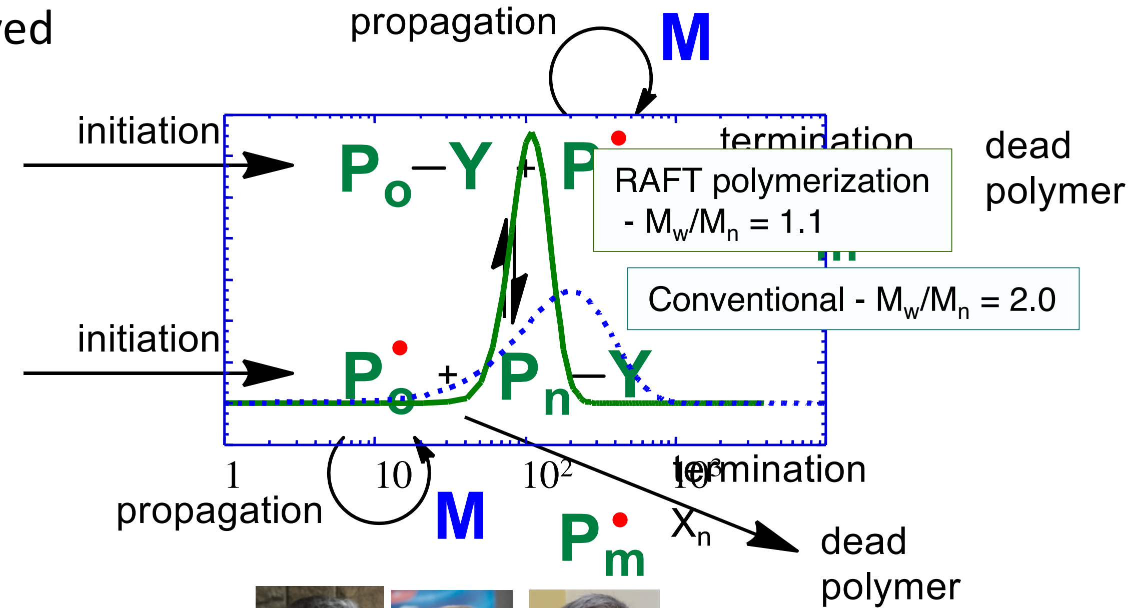
- Chains continuously initiated, propagate, and die (same number as in conventional polymerization)

However,

- More chains (number = moles of RAFT agent)
- On average, all chains grow simultaneously
- Narrow molecular weight distribution
- End-groups , (largely) preserved

Aust. J. Chem. **2005**, *58*, 379-410
Aust. J. Chem. **2006**, *58*, 669-92
Polymer **2008**, *49*, 1079-131
Acc. Chem. Res. **2008**, *41*, 1133-42
Aust. J. Chem. **2009**, *62*, 1402-72
Aust J. Chem. **2012** (in press)

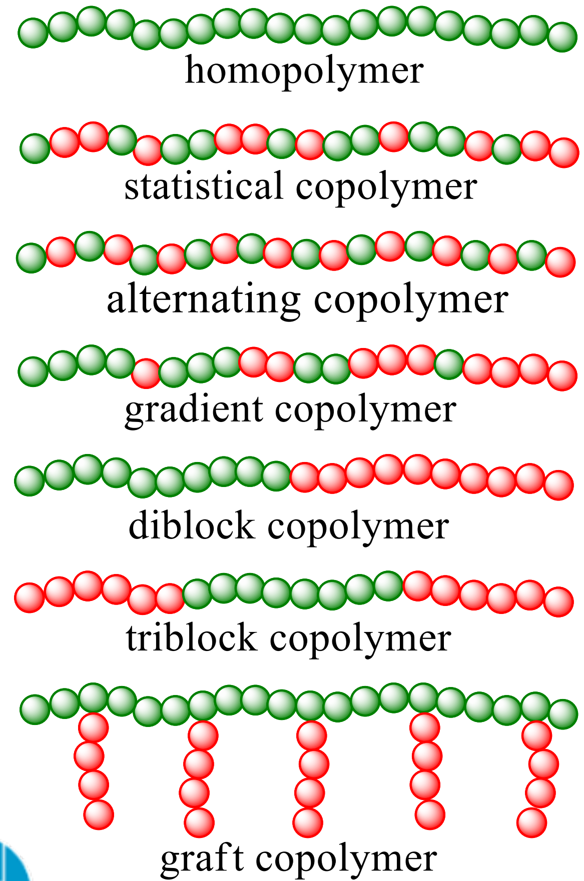


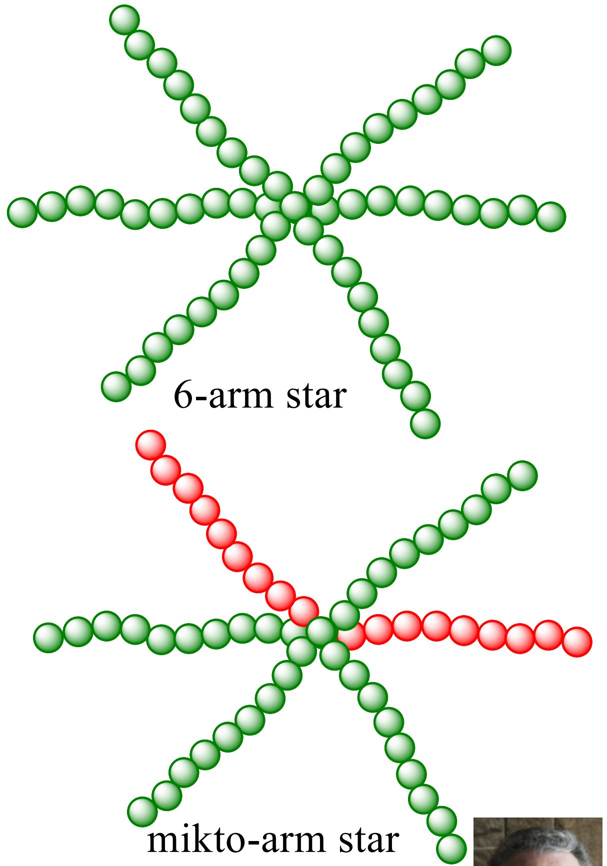


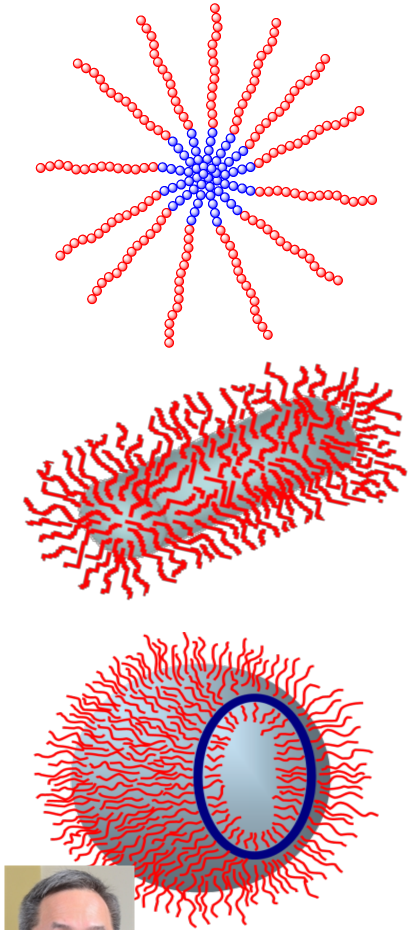
CSIRO

RAFT Architectures

A wide range or architectures can be formed by choice of RAFT agent and sequence of monomer additions or by self assembly or …







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RAFT Polymerization 2011-2017

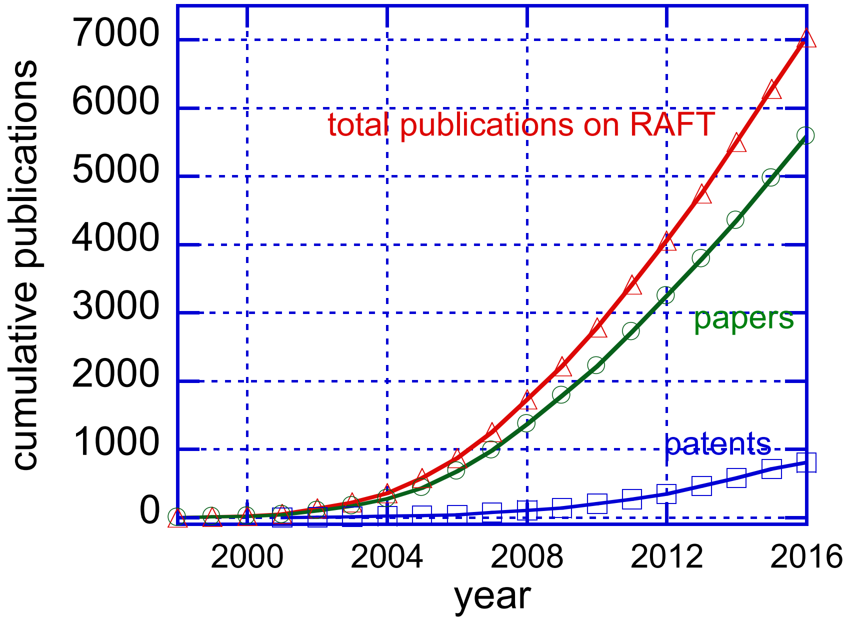
Rate of publication on RAFT continues unabated:

- >1/2 of publications on RAFT have appeared during last 5 years. Includes more than 3500 new journal papers and 500 patent families (Scifinder™)

Continued focus on applications:

- Biomedical
  - Polymer therapeutics, biopolymer conjugates, functional particles, delivery, targeting
- Industrial
  - Coatings, adhesives, elastomers, oil additives, rheology control agents, compatibilisers, surfactants
- Energy
  - Organic semiconductors, nanoparticles, quantum dots

Commercial availability of RAFT agents on scale



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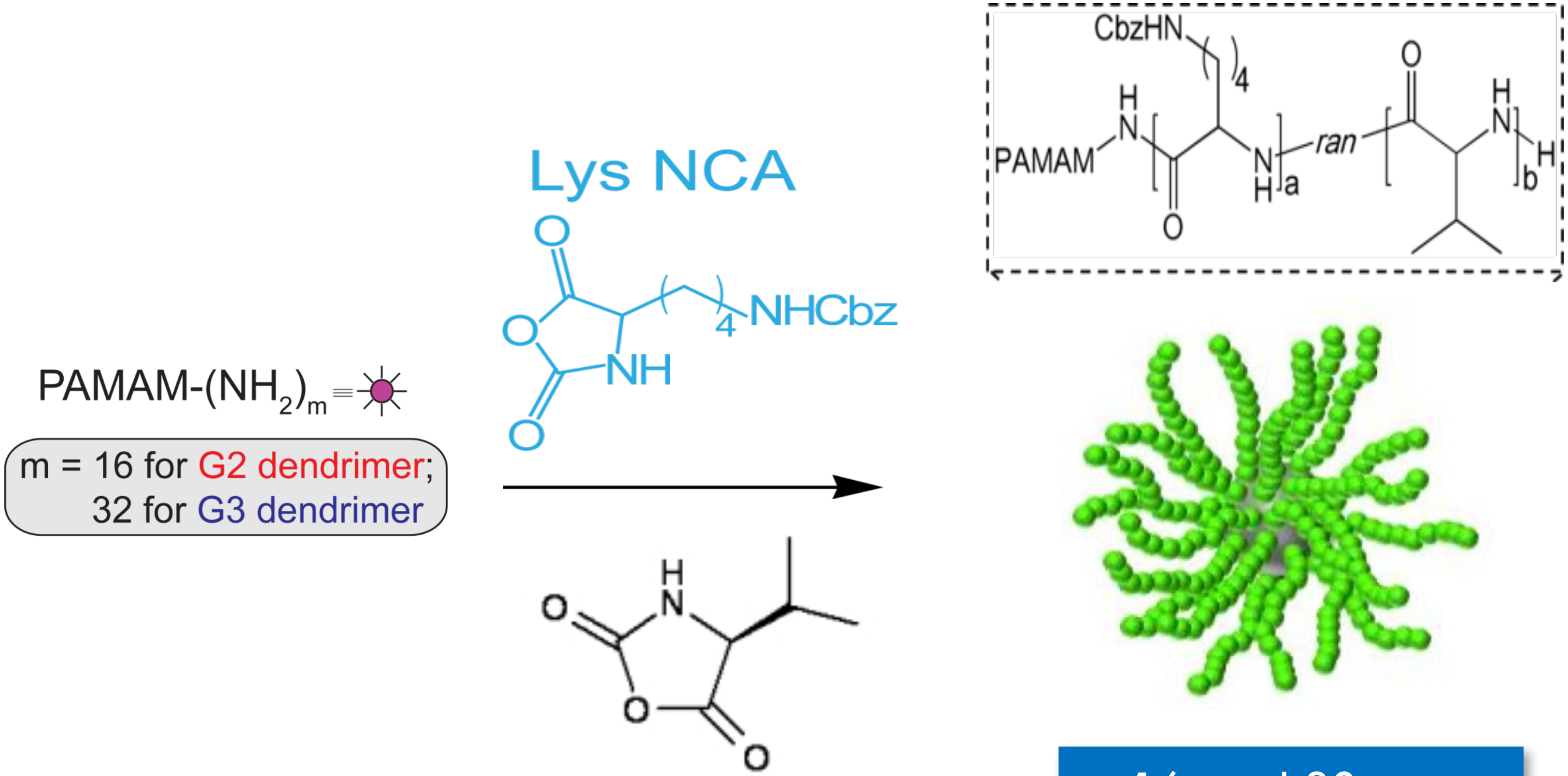
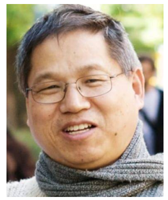
Using stars to overpower superbugs



Valine NCA

16- and 32-arm
Star Polymers



Lam, S. J. *et al. Nat. Microbiol.* **2016**, 1, 16162

Using stars to overpower superbugs

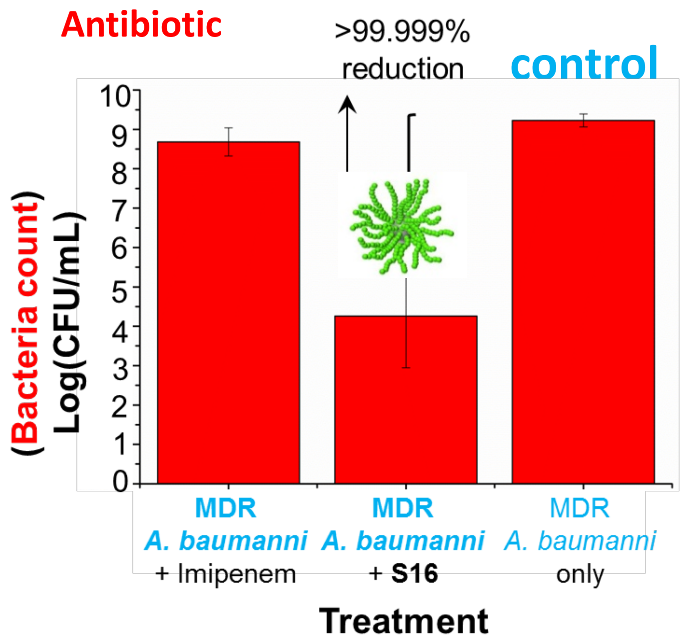
In vitro (mouse): 110 times less toxic to red blood cells

	Red blood cell (μg/mL)	Multi-drug resistant *A. baumannii* (μg/mL)
Star16	2552	70.3 ± 10.2
Star32	3386	63.5 ± 2.2

Therapeutic indices on tow mammalian cells (MBC50[a]/IC50)

	HEK293T	H4IIE
Star16	102	52
Star32	171	139

[a] MBC50 based on tests against MDR *A. baumannii*.



Treatment	Survival rate
Untreated	50%
Imipenem	50%
S16	100%

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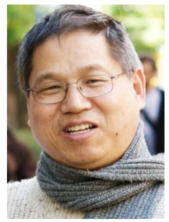
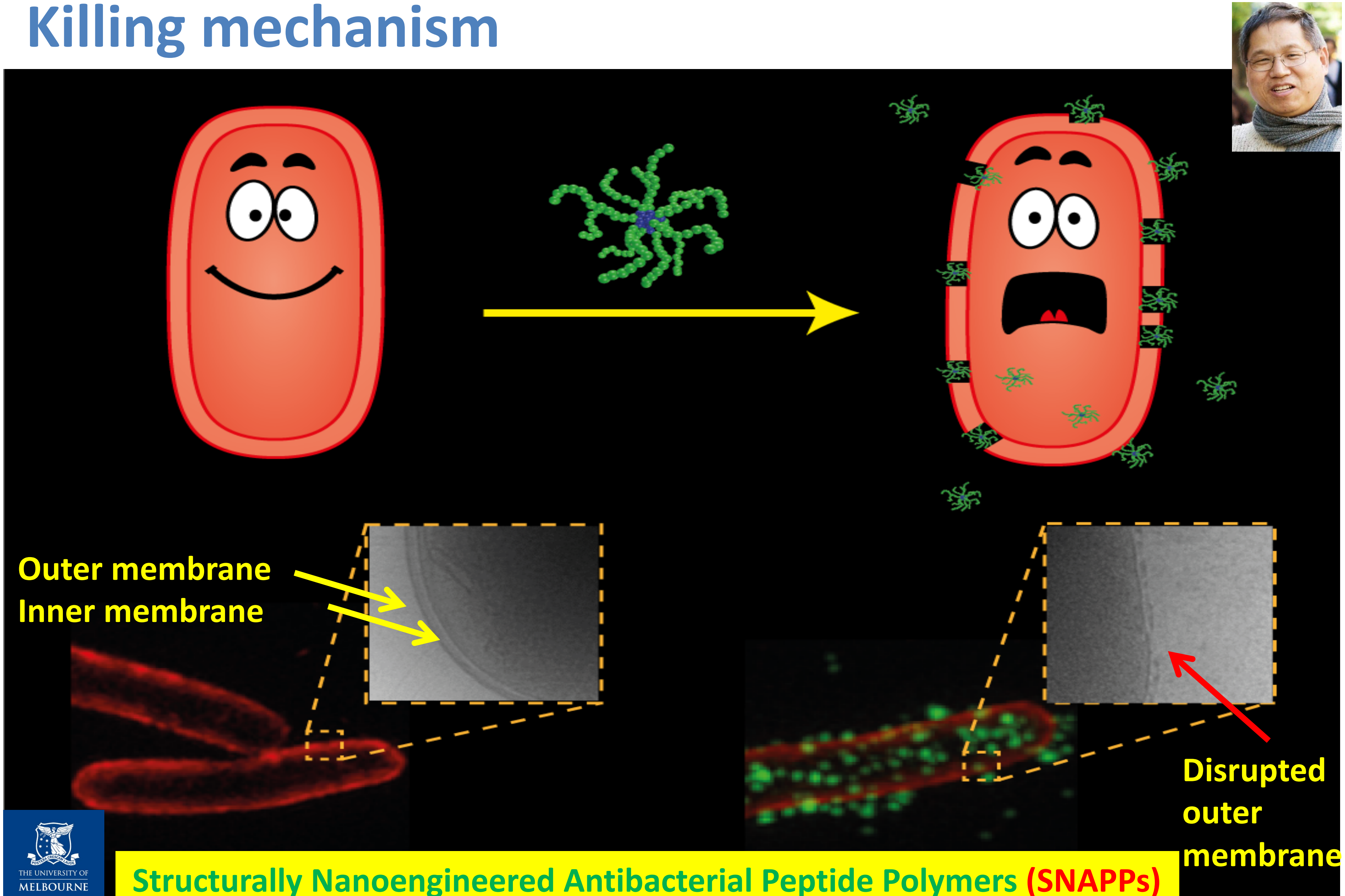
Lam, S. J. *et al. Nat. Microbiol.* **2016**, 1, 16162



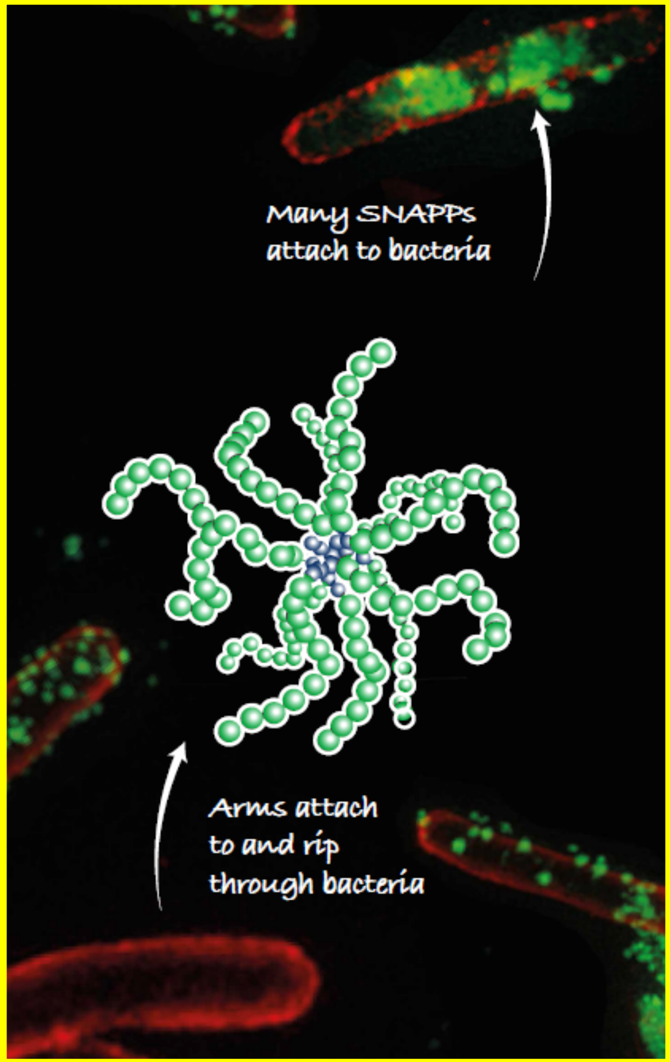
Killing mechanism



SNAPPs summary

- SNAPPs exhibit ***sub-µM*** activity against Gram-negative and Gram positive multi-drug resistant bacteria
- No observed ***resistance from*** bacteria so far
- SNAPPs are the first examples of a ***synthetic antimicrobial polymer*** in clearing superbug infections ***in vivo***
- SNAPPs work via a ***multimodal mechanism***

Recently, BBC "Future Now" listed SNAPPs as one of 6 grand ideas to fight the end of antibiotics (by Erin Biba, 11 October 2017)



SUPERBUGS: THE FIGHT FOR OUR LIVES,
Science Museum, London,
(9 November 2017 – Spring 2019)

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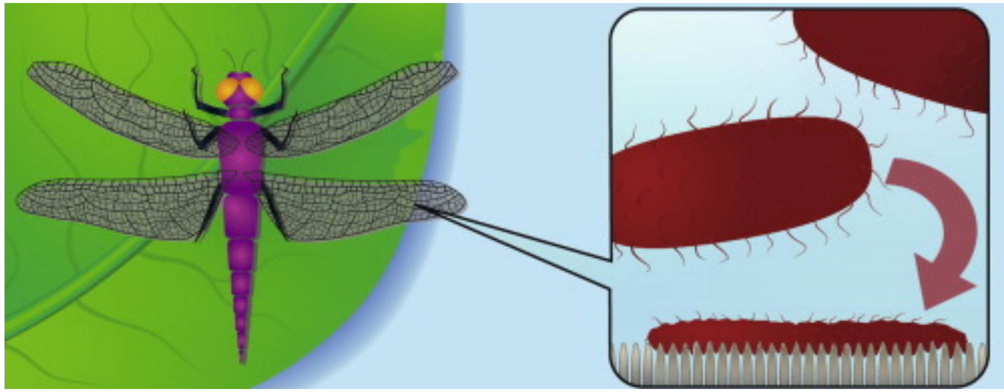
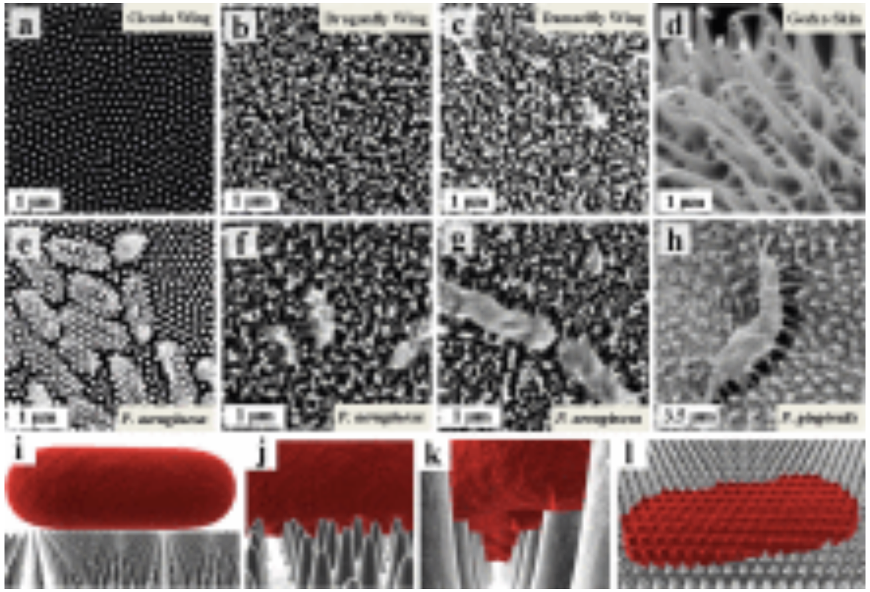
Nano-structured antimicrobial surfaces: from nature to synthetic analogues





Both *D. bipunctata* wings and black silicon have hierarchical structures comprising clusters of adjacent nanoprotrusions. Both are highly bactericidal against all tested Gram-negative and Gram-positive bacteria, and endospores, and exhibit estimated average killing rates of up to ~450,000 cells min^{-1} cm^{-2}. The bactericidal effects are mechanical and independent of chemical composition.

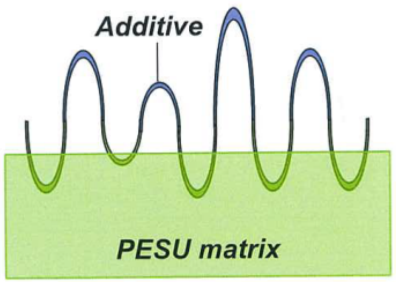
Segregating polymer additives for membranes

Need:

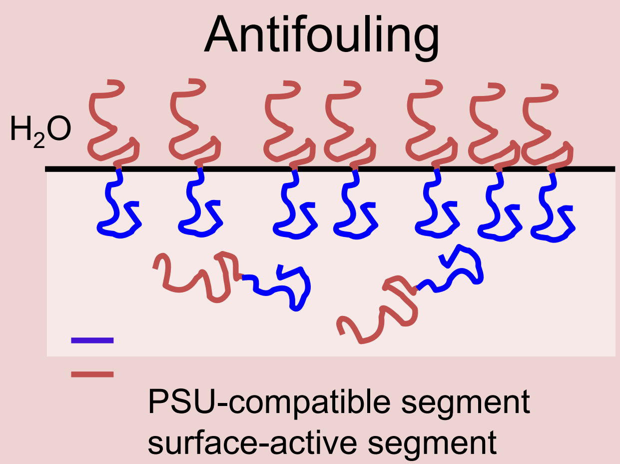
- Biofouling of membranes a major cause of loss in performance

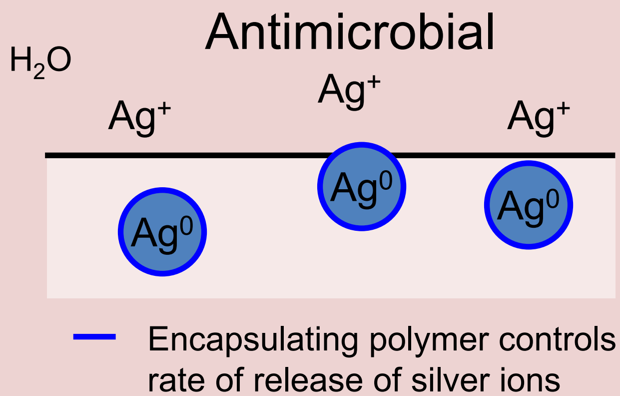
Achievements:

- Seven patents
- Technologies licensed to BASF



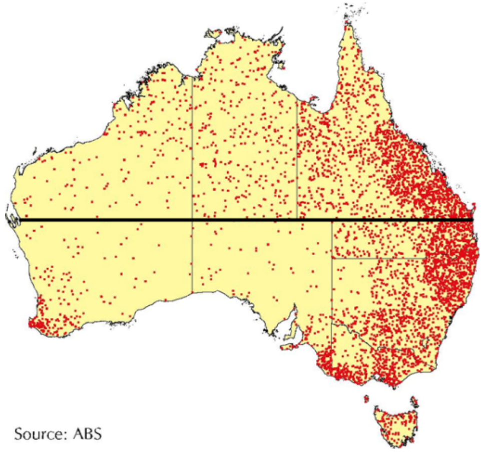
Additive: PSU-PEO-polysiloxane copolymer





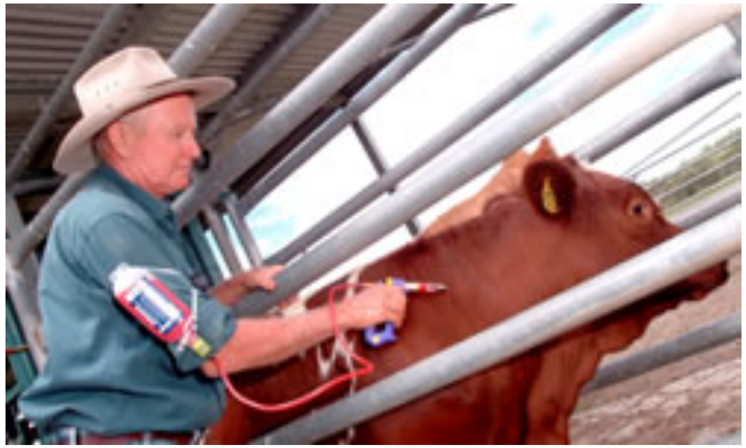
Single injection vaccine for cattle tick

Need:
- Annual muster industry standard in northern Australia
- Tick infestation Australia’s highest cost endemic cattle disease
- 9.3 million cattle at risk
- Estimated impact $146M p.a.



Source: ABS

Achievements:
- Two patented single injection technologies
- Elevated antibodies in sheep trial (300 days)
- Planned cattle trials



Cooperative Research Centre for POLYMERS

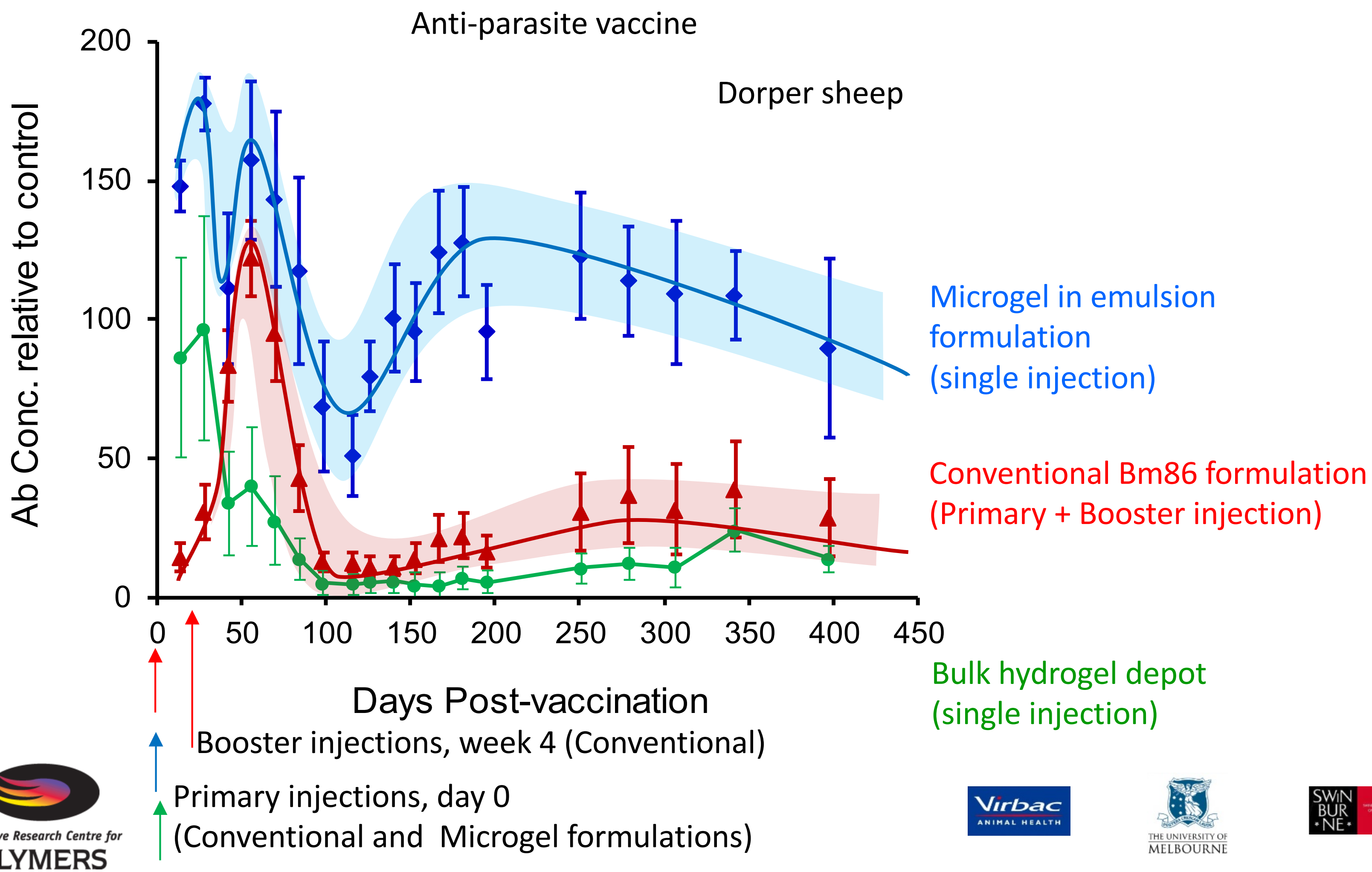
Virbac ANIMAL HEALTH

THE UNIVERSITY OF MELBOURNE

SWIN BUR NE

Single Injection Micro-hydrogel gives Persistence in Large Animal trial

Serological immunological response and duration of immunity

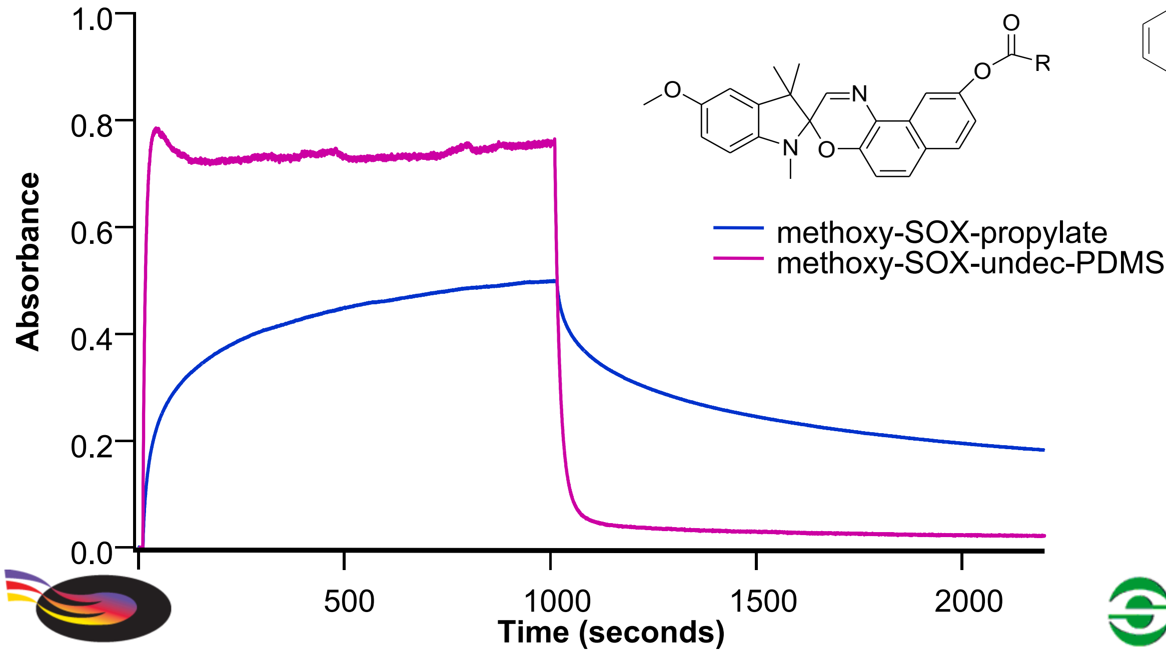


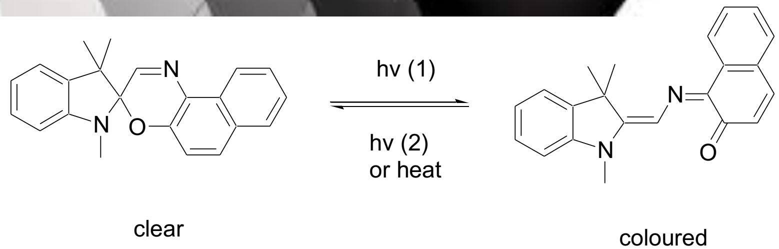
Cooperative Research Centre for POLYMERS

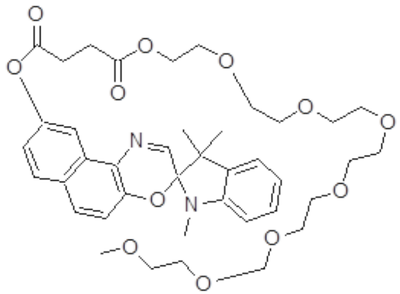
Fast switching photochromic dyes

Need:
- Photochromic lenses are slow to respond to changes in light conditions

Achievements:
- Technology results in rapid response
- Protected by four patents
- Licensed to SOLA then sold to dye producer





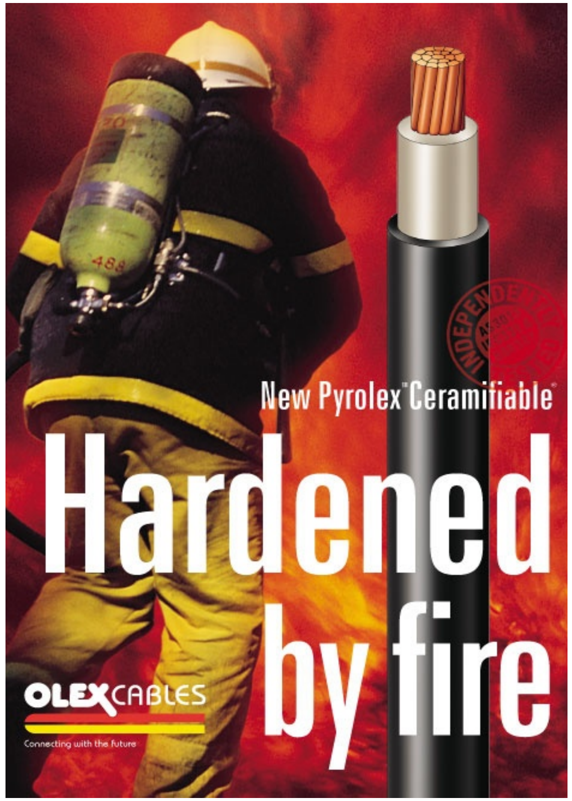


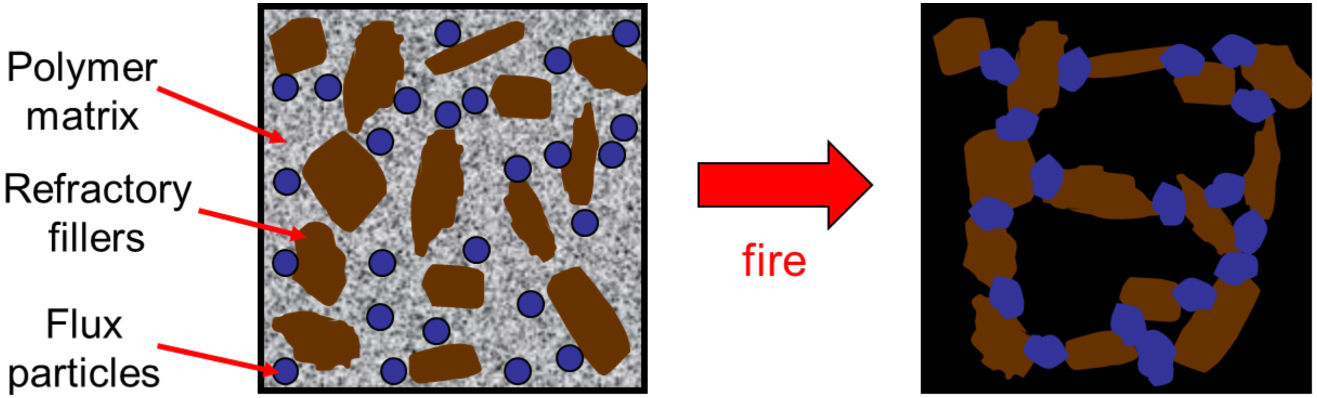
Cooperative Research Centre for POLYMERS

Ceramifying polymers

Need:
- Eliminate tape from fire performance cables
- Reduce production costs
- Competitive edge for Australian company against imports

Achievements:
- World first cable technology
- Protected by 4 patents
- Licensed to Olex for cable applications
- Ceramifiable cables used in major infrastructure, e.g. MCG, Austin Hospital





Example:
Silicone polymer + mica
$\rightarrow$ SiO_2 + silicate + K_2O

Cooperative Research Centre for POLYMERS

Olex a Nexans company · MONASH University · UNSW · CSIRO · DSTO

10 Critical success factors for R&D collaborations

1. Addressing a major (emerging) need
2. High impact (e.g. productivity gain) and commercial payback
3. Novelty of approach
4. Challenging objective: targeting breakthrough, not incremental, advances
5. World class (multidisciplinary) team with the required skills

10 Critical success factors for R&D collaborations

6. Engaged commercial partner - clear path to market
7. Include as many elements of the supply chain as possible
8. Identified target product properties, benchmark performance
9. Regular reality checks, stage-gate reviews
10. Collaborative culture: trust, teamwork, communication, commitment

Company engagement

Collaborate with companies that have:

- identified the market need
- identified its high commercial potential
- the required production and distribution channels
- commitment to commercialising the technology

→There is a clear commercialisation strategy for each research project

→There is a high probability that the research will lead to products