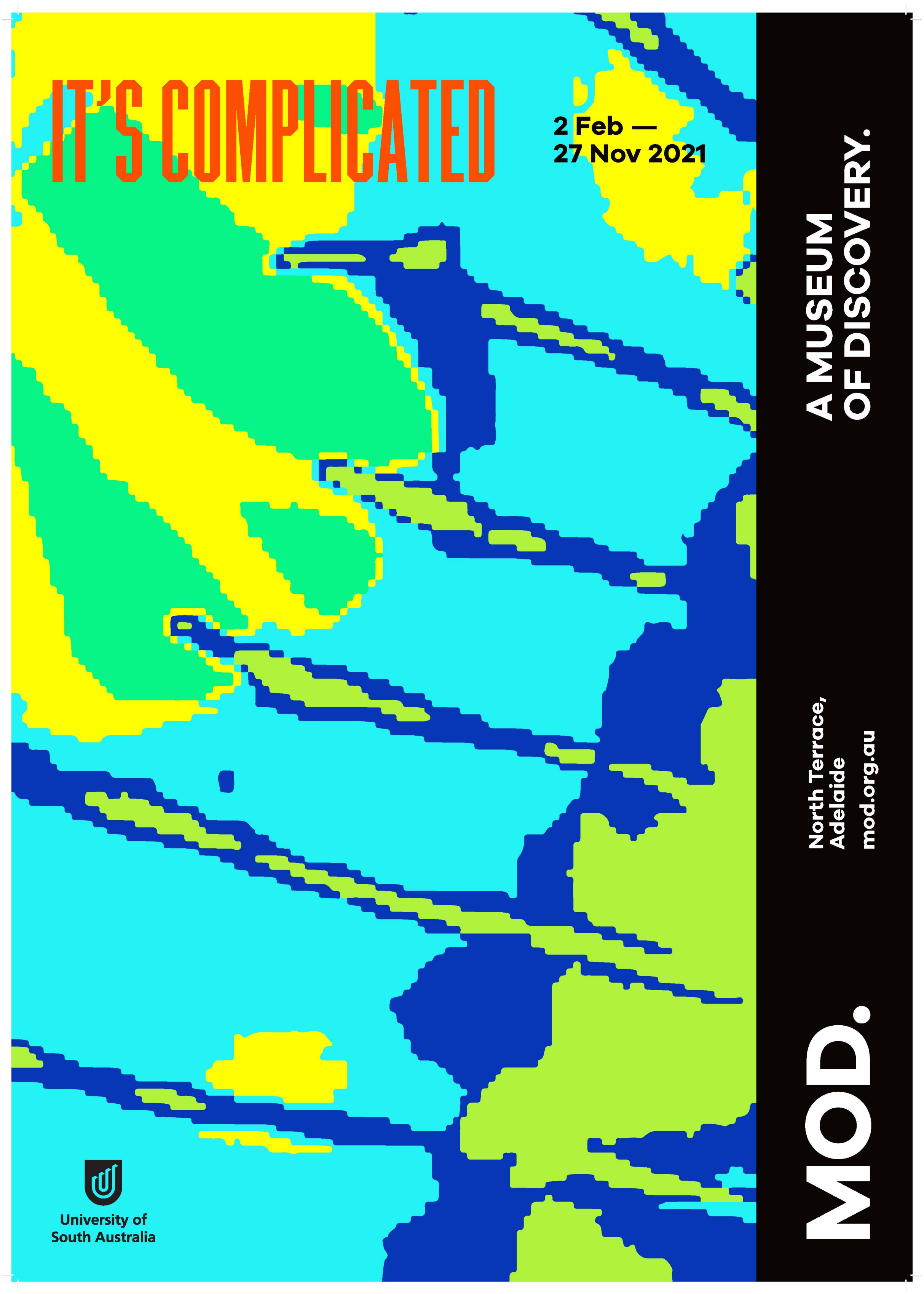
Teacher Guide



IT'S COMPLICATED

This time around, MOD. is focusing on dynamic interconnectedness. What is that? Well, it's **complicated**. Actually, it's **complex**. A system like your mobile phone is **complicated**. It may have lots of parts, but these parts are guided by simple rules which can be understood, predicted and reproduced. A **complex** system is different, and more than just the sum of its parts. Complex systems change over time, sometimes dramatically, and can lead to something entirely new and different.

All of this means that problems in complex systems are trickier to find solutions for. It also means that even well-thought out solutions can have unexpected and unintended consequences. Like trying to wipe out malaria but ending up with parachuting cats.

In an exploration of relationships between humans, nature, and technology, MOD. invites you to raise an octopus in a Tamagotchi-inspired simulation, design a home for sea creatures, or just try and predict chaos. From genetically modifying mozzies to hacking our own immune systems, and from building robots to making music, IT'S COMPLICATED pulls back the curtain on the seemingly simple and reveals just how complicated, and complex, the world can be.

What are complex systems?

In this exhibition we are exploring complex systems through the following seven principles. Each exhibit touches on these principles in different ways, and you can explore this further via the QR codes at each exhibit.

Principle	Icon	Description
Adaptation	 Octopus are excellent examples of adaptation, using remarkable intelligence, sight and camouflage to outsmart predators and prey.	**SHORT AND SHARP:** Complex systems change to better suit the environment. **KNOW MORE:** The ability for a system to change in response to imposed conditions is called adaptive plasticity. This gives a system resilience to varying environments as it has the capacity to "learn" from experience.
Co-evolution	 Clown fish have evolved resistance to the nematocysts and toxins of their symbiotic hosts, sea anemones.	**SHORT AND SHARP:** As species interact in a complex system, they evolve in response to each other. **KNOW MORE:** Co-evolution is likely to happen when different species have close ecological interactions with one another. It is one of the primary methods by which biological communities are organised.

Principle	Icon	Description
Criticality	 Dramatic population changes, such as an outbreak of plague-carrying rats, can result from a complex system reaching a critical tipping point.	**SHORT AND SHARP:** When a complex system reaches a tipping point, its state can change dramatically. **KNOW MORE:** Even a small input, such as a single grain of sand can cause the collapse of a pile of sand once enough grains have been poured on top.
Emergence	 Ants are autonomous units that react to, and communicate using, chemical stimuli. Despite a lack of centralised direction, ant colonies exhibit complex behaviour.	**SHORT AND SHARP:** Interactions between single parts of a complex system produce actions not able to occur by single parts alone. **KNOW MORE:** Interactions between units in a system determine properties like adaptation, not present in the subunits themselves.
Feedback		**SHORT AND SHARP:** A process in which the outputs of a complex system are circled back and used as inputs. **KNOW MORE:** A feedback loop occurs when an output of a system is routed back as an input, either directly or through other connections. These circuits or loops of cause-and-effect are usually positive or negative.

Principle	Icon	Description
	In relationships between units (dots) within a system, outputs (lines) from one unit can feed back into itself as inputs.	
Non-linearity		**SHORT AND SHARP:** Changes to one part of a complex system can lead to dramatically different changes in other parts. **KNOW MORE:** Due to positive and negative feedback loops between parts of a complex system, an input to a system is not always proportional to a later output. The example of a double pendulum is described above under non-linear systems.
	The butterfly effect refers to the metaphor of a tornado being influenced by minor inputs such as a distant butterfly flapping its wings several weeks earlier.	
Self-organisation		**SHORT AND SHARP:** Complex systems follow simple rules to reach more optimal or stable states. **KNOW MORE:** Self-organisation refers to the appearance of order in a disorganised system and arises from local interactions between parts. For example, a seemingly complex behaviour such as fish schooling can occur when each individual fish follows three simple rules: 1. Swim close to your neighbours, but 2. avoid crowding them, and 3. swim in the same direction they are.
	Bees behave according to social rules where individuals organise themselves into colonies to care for close relatives.	

Key Messages

Exhibit	Principle	Provocation	Key Message
Operation Cat Drop	Criticality	What could go wrong?	There can be unexpected and unintended consequences of trying to fix a problem when a system is not fully understood.
Feeding Frenzy	Self-Organisation	Is there safety in numbers?	Individual fish following simple rules (i.e., stick near each other, swim in the same direction, and avoid collisions) results in complex group behaviour such as shoaling fish.
Chaos Machine	Non-linearity	Can you predict chaos?	Tiny changes in initial conditions have potentially large and unpredictable effects in complex systems, e.g., every time you spin the double pendulum, you get a different pattern.
Gene Drives	Criticality	What are the odds?	Gene drives are a new technology that can change the way a genetic modification is inherited – instead of a 50/50 chance of inheriting a gene, it pushes it to nearly 100%. This could be used to genetically modify mosquitos to make them resistant to malaria – the modern version of the cat drop experiment.
Octopus Estate	Adaptation	What's under the surface?	Ecosystems are complex places. There are numerous relationships with countless interactions and dependencies. Caring for an octopus demonstrates just this.
Crazy Little Thing Called BRUV	Adaptation	What's BRUV got to do with it?	There is more going on in the ocean than might be imagined. Even a nearby location like Glenelg contains weedy sea dragons, rock and spider crabs, zebrafish, moonlighters and schools of leatherjackets. BRUV lets us see it all.
Sea-habilitation	Co-evolution	How do we nurture nature?	Things humans have built can impact marine ecosystems in ways we might not expect. Find out what abandoned oil platforms, seawall tiles and native oyster reefs have in common.
Custom-Made	Feedback	How will you design the future?	The fourth industrial revolution will be customer led, autonomous, networked and there will be robots! Custom build and test your own vehicle.

Pneumatic Blooms (Opens May 2021)	Feedback	How will you react?	The way that new technologies like robots behave can influence our behaviour and vice versa. Given that human-robotic relationships are becoming increasingly common, it is useful to think about what these interactions might look like in the future.
Cave of Sounds	Emergence	What will emerge?	It is difficult to predict what will emerge when eight different musical instruments are played together in an unmediated collaborative experience.
Cell Invaders	Self-Organisation	How can you hack your body to kill cancer?	A new treatment called CAR-T uses a clever hack to harness your own immune systems capacity to track down and kill cancer cells that aren't meant to be there.
Kate Little	Emergence	Can you control chance?	Kate Little is a South Australian artist who combines patterns, randomisation and emergent properties of materials and data to offer new ways of thinking about relationships between humans, nature and technologies.
Always was, always will be our future(s)	Non-linearity	Why tell a story?	The world is a complex place. Stories help us make sense of how things are, how things were, and how things might be.

Operation Cat Drop

What could go wrong?

Problems in a complex system can be tricky to solve. The more moving parts there are, the harder it is to keep track of what's going on.

We might mean well but our solutions can have unintended outcomes. Like trying to wipe out malaria but ending up with parachuting cats.

<u>Delve Deeper</u>

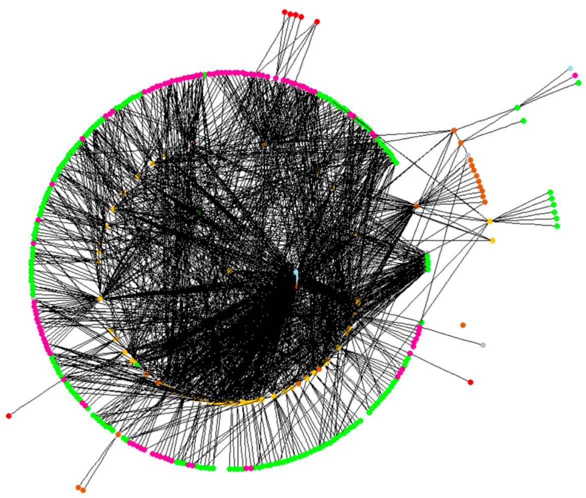
Operation Cat Drop is an example of how tipping points in populations of pests and predators can have sudden large impacts on complex systems. An increase in favourable conditions for rats, that allows disease to flourish, represents a dramatic change in the state of a system and demonstrates how nonlinear processes are important in the dynamics of pest outbreaks.

In the 1950's, people in Borneo suffered a malarial outbreak so the World Health Organisation (WHO) sprayed DDT to kill the malaria-carrying mosquitoes. The mosquitoes were killed but the DDT also killed wasps, geckos and cats, leading to a rat population explosion, along with outbreaks of typhus and plague. To cope with these problems, the WHO parachuted live cats into Borneo. This was Operation Cat Drop.

<u>Let's Complicate Things</u>

"Simple causal reasoning about a feedback system is difficult because the first system influences the second and second system influences the first, leading to a circular argument. This makes reasoning based upon cause and effect tricky, and it is necessary to analyze the system as a whole."
— Karl Johan Åström and Richard M. Murray, Feedback Systems: An Introduction for Scientists and Engineers

Food webs
The below example of a food web of grasshopper species hints at the complexity of one particular ecosystem. Each node represents a single species or a set of closely related species. The yellow represents grasshoppers, blue represents birds, tan represents mammals, purple represents pathogens, pink represents insects, nematodes, and spiders (parasites, parasitoids, and predators), red represents hyperparasites, and green represents plants. Grey nodes represent non-living material including leaf litter, dung, and dead arthropods.



Malaria control in Malaysia today
Today there is a new malarial threat with the increasing number of infections of so-called Monkey Malaria, which is a particular strain carried by macaque monkeys. This 'monkey-malaria' now accounts for 69% of malaria infections in Malaysia.

It's another example of interconnectedness, with areas that have experienced the largest deforestation strongly correlated to the number of people infected. The theory is that deforestation reduces the habitat of the macaque population and forces the monkeys to live closer to humans, thus increasing the chance of humans getting infected.

To fight this problem, a large interdisciplinary research team has started The Monkey Bar Project. This project uses drones to create detailed maps, built up from hi-res aerial photos, "to monitor changes in the landscape like the clearing of forests for agriculture, where there is primary or secondary forest or plantations."

The Monkey Bar Project has been using drones since 2013 to create these aerial maps. More recently though the team has turned to drones outfitted with infrared or thermal cameras to track the monkeys through the forest, hoping to have a rapid way of estimating how many monkeys are in a particular area "without having to wander around the jungle at night looking for them."

Discover more

Read
- Operation Cat Drop: the comic
- This paper, published in the American Journal of Public Health, explores the Operation Cat Drop in detail.

Watch
- Systems thinking – Operation Cat Drop

Listen
- Unintended consequences

Questions/discussion topics

- Which current and future technologies and areas of research have the potential to produce unintended consequences? (e.g., artificial intelligence, genetic engineering, particle physics, geoengineering)

UniSA study links

- Bachelor of Environmental Science

Feeding Frenzy

Is there safety in numbers?

What do salmon, bees, parrots and sheep have in common? They all flock.

Flocking is when all the animals in the group move in the same direction. It might look fancy, but each animal is following a few simple rules. A fish will try to swim in the same direction as its mates without crashing into them.

Play the role of a predator and see how the school of fish responds to you.

<u>Delve Deeper</u>

Shoaling behaviour is an example of self-organisation arising from local interactions between parts of an initially disordered system.

For example, a seemingly complex behaviour such as fish schooling can occur when each individual fish follows three simple rules:

1. Swim close to your neighbours, but
2. Avoid crowding them, and
3. Swim in the same direction they are.

<u>Let's Complicate Things</u>

While the term flocking is used to describe collective animal behaviour in general, other terms are used when referring to specific organisms:

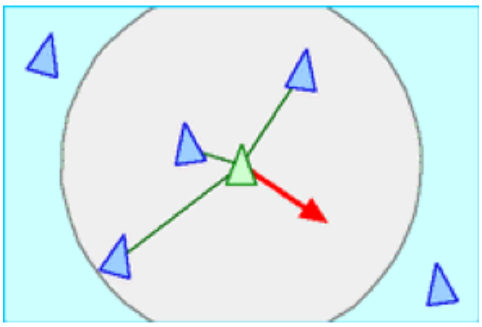
- Swarming for insects;
- Flocking or murmuration for birds;
- Herding for tetrapods;
- Shoaling (sticking together socially) or schooling (swimming in the same direction) for fish.

Boids

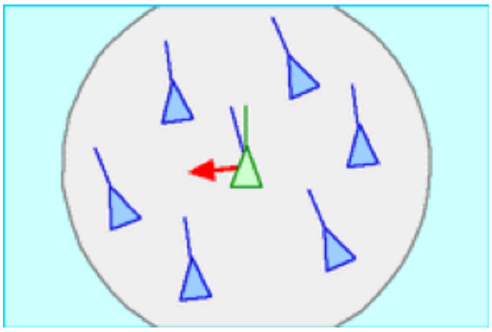
Flocking behaviour was simulated on a computer in 1987 by Craig Reynolds with his simulation program, Boids. His program simulates simple agents (boids) that are allowed to move according to a set of basic rules.

The three basic rules that govern the complex behaviour of flocking animals are:

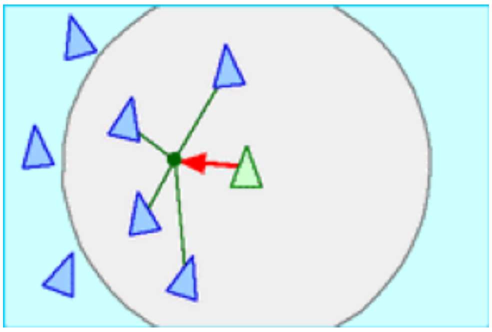
1. **Separation:** steer to avoid crowding your neighbours;



2. **Alignment:** steer towards the average heading of local neighbours;



3. **Cohesion:** steer to move toward the average position of neighbours.



There are many benefits to shoaling behaviour:

- **Defence against predators** through better predator detection and by diluting the chance of individual capture;
- **Enhanced foraging success** by the school assuming a parabolic shape, suggestive of cooperative hunting. A shoal of fish means many eyes are searching for food and fish monitor each other's behaviour closely such that feeding behaviour in one fish quickly stimulates food-searching behaviour in others;
- **Higher success in finding a mate** since shoals provide increased access to potential mates, i.e., finding a mate in a shoal does not take much energy;
- **Potential increase in hydrodynamic efficiency** in the same way that bicyclists may draft one another in a peloton.

Discover more

Watch

- Seal chasing a school of fish at Second Valley
- Fish schooling simulation with predator avoidance
- Footage of flocking starlings
- Coding adventures: Boids

Read

- Craig Reynolds' paper on flocks herds, and schools

Experiment

- Source code for a version of the boids algorithm is available on GitHub, what can you make?

UniSA study links

- Marine and Arid Environments
- Bachelor of Science or Mathematics

Chaos Machine

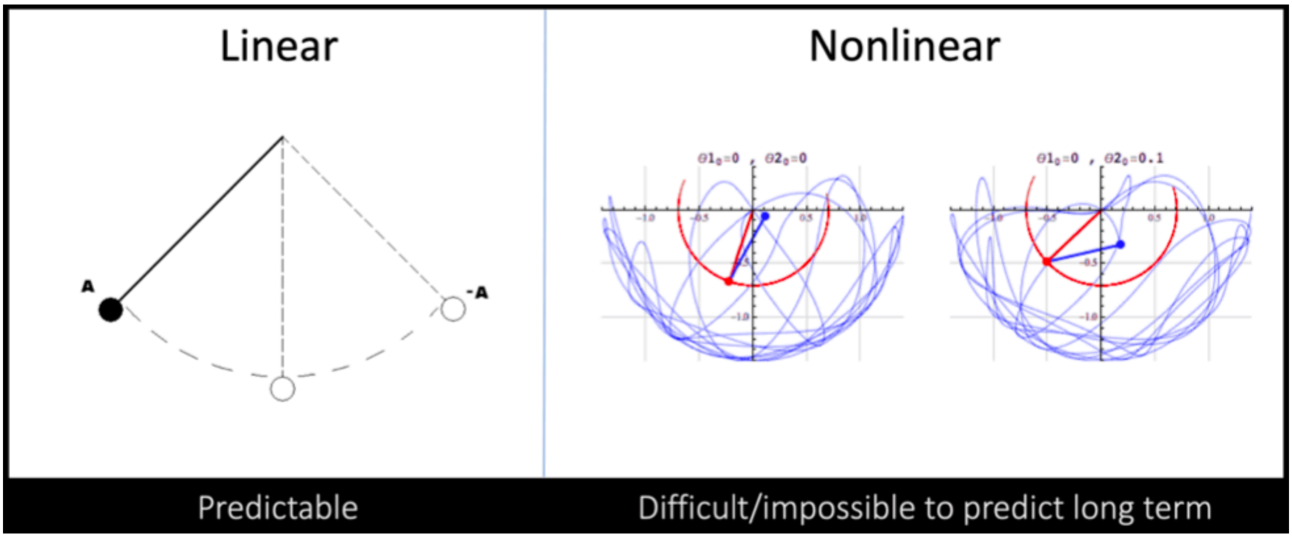
Can you predict chaos?

Double pendulums are strange things. One arm swinging from a fixed position is straight-forward enough. But add another arm to the first one and things start to get weird.

Predicting what a chaotic system will do is close to impossible, but don't let that stop you from trying.

<u>Delve Deeper</u>

A nonlinear system such as a double pendulum is highly sensitive to initial conditions. This means that even a minor change to an input (say the starting position of the pendulum's arms) can result in large differences in a later state (like the pattern traced by the arms).



A simple pendulum (linear system) on the left swinging back and forth; and two double pendulums (nonlinear systems) to the right, one with a slightly different starting position to the other.

Despite the behaviour of the double pendulum being deterministic—its future behaviour is fully determined by its initial conditions, with no random elements involved—predicting what pattern the arms will trace is extremely difficult, if not impossible.

<u>Let's Complicate Things</u>

Chaos Theory
A system's sensitive dependence on initial conditions is often referred to as the butterfly effect. The idea is that a butterfly flapping its wings in an Amazon rainforest can eventually, through countless compounding effects, cause a tornado in another country weeks later. This metaphor refers to the title of a talk called "Predictability: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" given in 1972 by Edward Lorenz, a meteorologist and the founder of modern chaos theory.

Causal determinism

Causal determinism (or physical determinism) is the philosophical view that any state (of an object or event) is completely determined by prior states.

In 1814, Pierre Simon Laplace published *A Philosophical Essay on Probabilities* where he articulated causal determinism:

“We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.”

Is the universe just one big double pendulum?

Discover more

Watch
- Three double pendulums with near identical initial conditions diverge over time, displaying the chaotic nature of the system.

Explore
- Interactive double pendulums
- Design your own double pendulum in this interactive simulation.

Read
- Short explanation and animation of a double pendulum

Listen
- Modal analysis of a Double Pendulum System

Questions/discussion
- Will the outcome be different or the same if you start the pendulum in the same position?
- What would happen if all variables could be made *exactly* the same the second time the pendulum started?
- Is the universe just one big double pendulum?

UniSA study links
Bachelor of Mathematics (Industrial and Applied Mathematics)
https://study.unisa.edu.au/degrees/bachelor-of-mathematics-industrial-and-applied-mathematics/dom

Bachelor of Mathematics (Data Science)
https://study.unisa.edu.au/degrees/bachelor-of-mathematics-data-science/dom

Gene Drive

How can you change a population?

Mosquitos are pretty annoying, but they also can be dangerous. They spread diseases around the world that impact almost 700 million people each year.

But what if we could change the genetic makeup of a mosquito to keep us safe? We can now genetically modify mosquitos so they can't spread malaria. In labs it's easy enough to make hundreds of new, malaria-proof mosquitos. But spreading genetic change in the wild is another thing. To change the genes of billions of wild mosquitos we need new technology: the gene drive.

<u>Delve Deeper</u>

So what exactly is a Gene Drive? There are different kinds of gene drives including ones that occur in nature, for example a bacteria that can infect mosquitos, called Wolbachia, that leaves them infertile. This is being applied to try and control dengue, another mosquito borne disease, in Queensland.

Synthetic gene drives use CRISPR/Cas9 technology to cut out specific target genes and replace them with a modified gene, using the cells own repair machinery to copy the modified gene.

<u>Let's Complicate Things</u>

Gene drives will only work in practice on:

- Sexually reproducing species;
- Rapidly reproducing species (insects/rodents/crops rather than slow growing trees or elephants!);
- Researchers have already successfully engineered CRISPR-based gene drives in mosquitoes, yeast and fruit flies.

How could gene drives be used?

- The extermination (or control) of mosquitoes that transmit malaria, dengue, and zika pathogens;
- eradicating invasive species such as the possum in New Zealand or European carp, cane toads or rabbits in Australia;
- To control agricultural pests like fruit fly.

As with any potentially powerful technique, there are risks of unintended consequences, e.g., a gene drive targeted to a local population could spread across an entire species. Wiping out a species might have wider ecological impacts.

Why is controlling mosquitos important?

- Mosquitoes are one of the deadliest animals in the world.
- According to the World Malaria Report 2018, there were 435 000 malaria deaths, 61% of which were children under 5.
- The worldwide incidence of dengue has risen 30-fold in the past 30 years, and more countries are reporting their first outbreaks of the disease.
- Zika, dengue, chikungunya, and yellow fever are all transmitted to humans by the *Aedes aegypti* More than half of the world's population live in areas where this mosquito species is present.

Discover more

Watch

- <u>The bold plan to end malaria with a gene drive</u>

Read
- Excellent summary in the New York Times
- Synthetic Gene Drives in Australia: Implications of Emerging Technologies
- If you want to get into the nitty gritty of how a gene drive works
- A world without mosquitos

Listen
- Feral science or solution? Unleashing gene drives

Questions/discussion

- If you could wipe out all the mosquitos on earth using gene drive technology, would you? Why/ why not?

UniSA study links

- Biophysics and Bioengineering

Octopus Estate

What's under the surface?

Deep in the ocean, there is an octopus lurking. A shark approaches. Will your octopus try to eat the shark? Or flee? Its life is in your hands now.

Care for an octopus and help it to thrive. But stay on your toes, it's an octopus-eat-octopus world out there, and you might not guess who's a threat.

Delve Deeper

Cephalopods are adaptable marine species and have the potential to support South Australia's growing need for sustainable seafood. However, many cephalopod species are poorly understood and it is crucial that the basics of their biology are first understood.

Let's Complicate Things

Octopus exhibit a number of traits that help them adapt to their environment and survive:

Camouflage
Octopus and other cephalopods can instantly change the colour and texture of their skin to match their surroundings.

Inking
When pursued by a predator, an octopus releases a dark pigment that briefly conceals the octopus. The "ink" also contains a chemical that inhibits the predator's sense of smell.

Jet Propulsion
In an emergency, octopus can move rapidly using jet propulsion, where they force water through a funnel to propel themselves in the opposite direction.

Other Adaptations
Octopus can also fit into tiny crevices because they lack skeletons, sacrifice a limb (which regenerates) to escape predators, and produce venom to paralyse prey.

Three ways to think about adaptation are:

1. Adaptation is the evolutionary process which enables an organism to live its best life in its habitat (e.g., octopus evolved from ancient marine molluscs with shells);
2. Adaptedness refers to how well an organism can live and reproduce in certain habitats (octopus can even edit their RNA (ribonucleic acid) sequences to adapt to their environment);
3. An adaptive trait is a feature that helps an organism to survive and reproduce (e.g., an ability to camouflage).

Discover More

Watch
- Do octopus dream? Watch the brilliant colour changes of a sleeping octopus
- Octonation on Instagram

Read
- UniSA marine scientist lands a big catch for fishing industry
- The Mind of an Octopus
- Octopus alter their RNA to adapt to their environment

Questions/discussion

- Have you seen My Octopus Teacher?

UniSA study links

- Marine and Arid Environments
- Bachelor of Science

Crazy Little Thing Called BRUV

What's BRUV got to do with it?

Squid drive-bys. Crabs riding sharks. Octopus tentacle slaps. There's a lot going on under the sea, we just aren't around to see it. But with Baited Remote Underwater Video (BRUV), researchers are starting to get an idea.

Scavengers might eat for free, but predators are always nearby. Get ready to explore how marine animals behave when they think no one is looking.

Delve Deeper

Baited remote underwater video (BRUV) is a system used in marine biology research. By attracting fish into the field of view of a remotely controlled camera, the technique records fish diversity, abundance and behaviour of species. Sites are sampled by video recording the region surrounding a baited canister which is lowered to the bottom from a surface vessel or less commonly by a submersible or remotely operated underwater vehicle. The video can be transmitted directly to the surface by cable or recorded for later analysis.

Let's Complicate Things

As a non-extractive technique, it offers a low environmental impact way of understanding changes in fish numbers and diversity over time. BRUV surveys were developed in Australia, and are now used around the world for a variety of projects. This is a low budget monitoring system that is less reliant on the availability of skilled labour and may make sustainable monitoring more practical, over the long term.

There are two main types of remote video technique which have been used to record reef fish populations. They can both be left free standing without the need of an operator. The first system uses one downward looking camera (D-BRUV), and the other uses either one (mono) or two (stereo) horizontally facing cameras (H-BRUV), and may use underwater lighting to illuminate the target area. Stereo BRUV recordings can use software analysis to determine the size of specimens. The colour of the lighting used for video may influence behaviour of the target species.

Discover More

Read
- Underwater magic: How to film camera-shy fish
- What is Big BRUVver up to? Methods and uses of baited underwater video
- What are we missing? Advantages of more than one viewpoint to estimate fish assemblages using baited video

UniSA study links

- Marine and Arid Environments
- Bachelor of Science

Sea-habilitation

How do humans nurture nature?

Old oil platforms might be junk in the sea, but now they have become thriving marine ecosystems. We could take them out, but that would disrupt these new habitats.

Humans can barely stop themselves from intervening with nature. Do we just need to butt out and let nature do its own thing?

Delve Deeper

Co-evolution is likely to happen when different species have close ecological interactions with one another. It is one of the main ways biological communities are organised.

Two organisms living in close relation is called symbiosis. Symbiotic relationships include:

1. Predator/prey (and parasite/host) – one species in the relationship benefits at the expense of the other(s);
2. Competition – this involves intra- and interspecies competition for resources like food or shelter;
3. Mutualism – both species gain benefit from the relationship.

Oil platforms, seawall tiles and shellfish reefs all provide habitat where species have close ecological interactions, for example the interactions on shellfish reefs where oysters excrete a mucus-like substance that is rich in nutrients and provides food for small shellfish that in turn provide food for larger fish.

Let's Complicate Things

Accidentally building marine habitats – what do we do with old oil and gas platforms?

There are over 2,000 wells and 30 platforms for oil and gas production off the Australian coast, many of which are coming to the end of their working life. Then there's the cost. Australia's decommissioning bill is expected to be $40 billion over the next 40 years.

Now we have to figure out what we should do with these massive structures. Are they trash? Or an ocean treasure?

Some of these structures have been in place for decades and are now home to a thriving marine community of corals, invertebrates and fish. It's not just that fish are attracted to these structures, researchers have found that they're acting as nursery sites – lots of fish are being born there. The benefits of leaving the structures in place include increasing numbers and biodiversity of marine life, benefits for recreational and commercial fishing (even if the sites themselves are default marine sanctuaries as they're not suitable for commercial fishers to come near them).

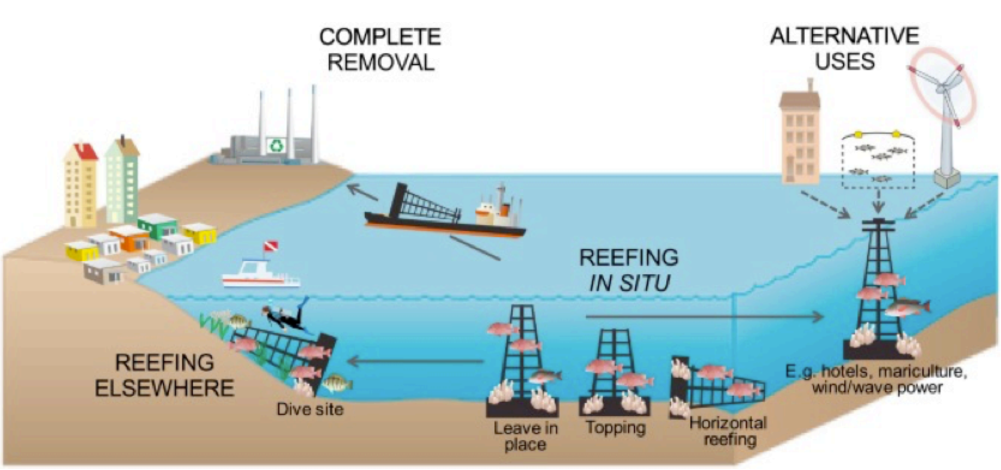


Image source: Peter Macreadie.

So what are the options? They can be removed completely, left in place or ‘reefed’ elsewhere. There are proposals to repurpose them into other uses like recreation facilities or alternative energy production facilities for wind or wave energy. There’s a platform in Malaysia that’s been turned into a hotel and dive resort.

Leaving them where they are though, is effectively dumping waste at sea. Just because something will grow on it doesn’t mean it should stay there. No one is suggesting that we start dumping all our old cars into the ocean just because they might form an artificial reef. There’s also the issue of leaching of toxic components from the structures into the surrounding environment too. And while they are home to an abundance of life, if they are attracting or supporting invasive species, is that the best outcome?

Deliberately building marine habitat – living sea wall tiles

A different approach is to deliberately design and install infrastructure for marine life to live and thrive on, particularly in areas that have been impacted a lot by human development like ports. Seawalls are an ever present structure in our intertidal environments and are not designed with shelter for native marine animals in mind. Normally a seawall is completely flat and devoid of crevices minimising the potential for colonising organisms. The aim of the living seawalls project is to begin developing a blueprint for how we can design marine infrastructure in the future.

The Reef Design Lab do just this, creating 3-dimensional seawall tiles that increase surface area and provide pooling water for sea life to live, hide, feed and breed within. The complex geometry encourages biodiversity. To date, 4 tile designs have been developed, mimicking microhabitats provided by rock pools, crevices and weathered sandstone (honeycombing and swim-throughs). There are currently seawall tiles installed in Sydney Harbour and at Port Adelaide.

Let nature do its own thing – shellfish reef restoration

Here in SA we don’t get tropical coral reefs – but we did use to have thousands of km of reefs made from shellfish – that is native oysters. Over time layers upon layers of shellfish formed natural reef structures home to lots of marine life. These were virtually wiped out over the 19th and 20th Century by overfishing, dredging, pollution and disease.

Today The Nature Conservancy is leading a project to restore native shellfish reefs to South Australia. In 2017-18 the Windarra Reef was created off Ardrossan on the Yorke Peninsula, and in 2020 the second major reef was started about 1km off Glenelg. The reefs are created by laying down limestone, as the oysters need a solid base to stick to (rather than sand for example). The limestone is then seeded with millions of spats – baby oysters.

Oysters are amazing creatures. Adult native oysters can filter more than 200 litres of water a day and excrete a mucus-like substance that is rich in nutrients and provides food for small shellfish that in turn provide food for larger fish, supporting a complex ecosystem rich in biodiversity. They also stabilise the sea bed and reduce coastal erosion.

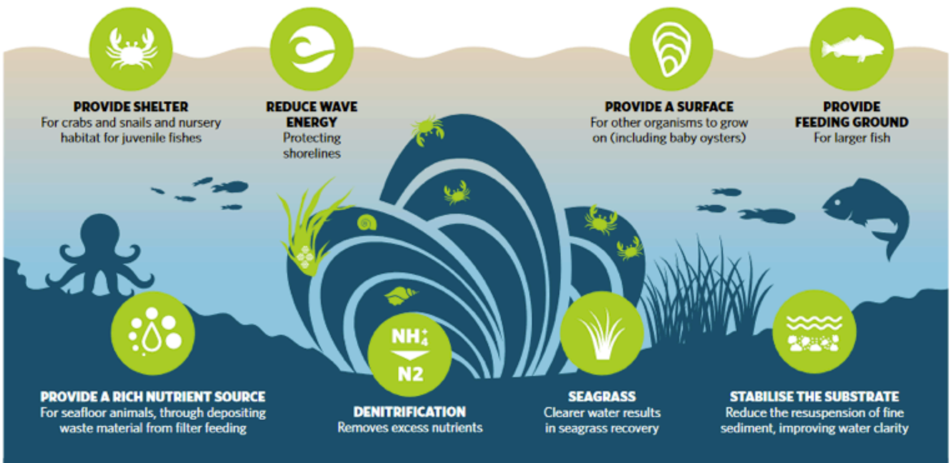


Figure 2.2: Ecosystem services provided by shellfish reef ecosystems

The Glenelg reef is part of The Nature Conservancy’s National Reef Building Project that aims to rebuild 60 reefs in six years across Australia.

Image source: Nature Australia

Discover More

Watch
- The Living Seawalls Project
- Restoring Shellfish Reefs animation

Read
- The Living Seawalls project installation at Port Adelaide
- Reef Builder helps coastal communities recover
- Shellfish Reef Restoration project

Question/discussion

- Would you remove old oil platforms from the ocean? Why/why not?

UniSA study links

- Marine and Arid Environments undergraduate degree

Custom-Made

Are you ready for the revolution?

We are living in the fourth industrial revolution. Smart Things, sensors, and cloud computing are making our lives easier.

But what about robots? How will we work with them? UniSA Engineering students have been working with Dorna, our robot arm, to build custom-made racing cars. Now it's your turn, are you ready?

Delve Deeper

Throughout previous industrial revolutions, the work of humans has been augmented with machines in order to improve productivity, reduce workloads and operate in environments that are difficult or hazardous for people.

The fourth industrial revolution (Industry 4.0) shares these ambitions by focusing on the integration of distributed smart sensing, control and communication systems using cloud computing and real-time data storage/retrieval.

Let's Complicate Things

The first industrial revolution brought about a shift towards mechanical production using steam and water power as a method of actuation. The second revolution increased the movement of people and ideas through extensive railroad and telegraph infrastructure, and created mass production lines through increased electrification. The third revolution saw the rise of computers and digital electronics which enabled industrial robotics to perform single repetitive tasks.

The rise of physical systems which are connected to the digital world marks the fourth industrial revolution. Collaborative robotics, machine-to-machine and human-to-machine communication, artificial intelligence and machine learning, and smart sensors are being increasingly used to provide the consumer-led customisation of products.

Some main features of Industry 4.0 are:

- Autonomous robots
- Advanced human-machine interfaces
- The Internet of Things (IoT)
- Big data and cloud computing
- 3D printing
- Smart sensors
- Simulation (digital twins) and data visualisation
- Augmented reality and wearables
- System integration

Discover More

Watch
- What is Industry 4.0?

Read
- What Everyone Must Know About Industry 4.0
- Meet the Three Industrial Revolutions
- The Second Industrial Revolution: Timeline & Inventions

UniSA study links
- Mobile Autonomous Robotic Systems
- Engineering

Pneumatic Blooms (Launch May 2021)

How will you react?

The Hooded Lycrabot (*Flore pneumaticae*) is a synthetic organism that can detect heat from living things. When approached, a Lycrabot will react with a hissing display of colour.

Delve Deeper

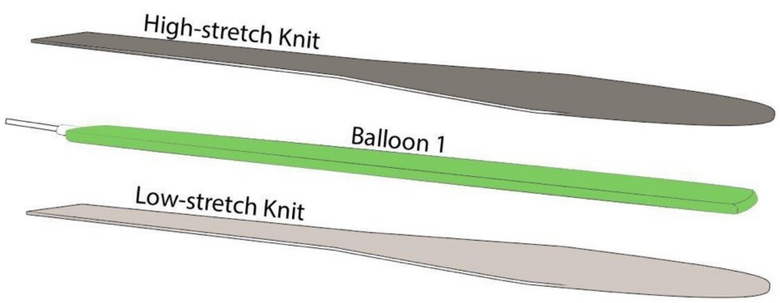
Pneumatic Blooms incorporates cutting-edge soft robotic research and development from leading technology institutes such as Harvard Biodesign Lab and Whitesides Research Group MIT. Soft robotics involve numerous STEM-relevant fields such as:

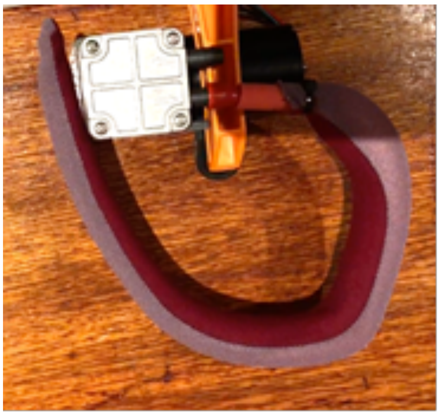
- Mechanical engineering (pneumatics)
- Electrical engineering (circuits, sensors, solenoids)
- Physics (fluid dynamics, reaction forces)
- Biomimicry and xenobiology
- 3D design and fabrication

Let's Complicate Things

Basic physics

1. When a balloon is constrained to a maximum volume, the energy that would have inflated the balloon instead gets transmitted to all surfaces that the balloon touches;
2. As the balloon inflates, the air pressure causes the high-stretch fabric to stretch more than the non/low-stretch fabric, leading to a curve in the actuator.
3. In order to maintain equilibrium, the actuator must take on an arc or curved shape.





Lycrabot actuators are constructed from:

- One-way stretch fabric – a polyester and spandex/Lycra blend
- Non/low-stretch fabric – vinyl polyester
- Latex rubber tubing

To constrain radial expansion, a fabric with one-way stretch properties is used. One-way stretch fabrics stretch significantly more in one direction than the other.

Discover more

Watch

- Starfish-inspired soft robot by Harvard University's Whitesides Research Group
- Soft robotic fish swims alongside real ones

Read

- Soft robotic fabrication guides

- Knit Textile Bending actuators that inspired Pneumatic Blooms

Listen
- Soft robotics podcast

Question/discussion
- What might some of the applications be for soft robotics?
- How would you design a soft robot?

UniSA study links
- Mobile Autonomous Robotic Systems
- Engineering

Cave of Sounds

What will emerge?

Music has existed as long as humans have. We use it to tell stories and to create bonds. Eight artists and hackers were tasked to create a new musical instrument. Some use shadows, some use light, some use your whole body.

Cave of Sounds is an experiment in unmediated musical collaboration.

Delve Deeper

Visitors interact with each instrument in a radically different way, embodying the dynamic and creative hacker scene that this piece of work emerged from. Each instrument was designed with simple and primal input methods in mind, much like the prehistoric music makers that inspired this project, yet are capable of producing diverse and complex sounds. The musical possibilities become even greater when played together.

Let's Complicate Things

Cave of Sounds began in November 2012 at London's Music Hackspace as part of Tim Murray-Browne's Embedded artistic residency with Sound and Music. The eight artists, led by Tim, each developed a musical instrument for what was, at the time, an imagined eight-piece ensemble.

- Sonicsphere by Panagiotis Tigas — A palm-sized sphere with an embedded wireless gyroscope that you can use to warp and charter spaces of heavy digital timbres.
- Joker by Wallace Hobbes — A punchy drum kit you play by tapping your fingers onto conductive tape.
- The Animal Kingdom by Daniel Lopez — A world of sounds you awaken and shepherd by casting hand shadows in the shape of animals onto a tabletop, which are read and interpreted by an interior camera.
- Generative Net Sampler by Tadeo Sendon — Experimental audio samples, created from digital field recordings of the internet, are triggered as you move through invisible cylindrical trigger zones, detected using a 3D camera.
- Lightefface by Kacper Ziemianin — A deep drone you control by shining lamps over 24 light sensors, each of which modulates the intensity of a different harmonic of a fundamental frequency.
- Campanology by Dom Aversano — Generative rhythms derived through the mathematics of church bell ringing patterns, controlled through free movement of your hands using a 3D camera.
- Mini-Theremin by Susanna Garcia — Using hand gestures, you control a DIY theremin running through a pitch-tracker, turning it into a controller to mangle noise synthesis.
- Wind by Tim Murray-Browne — A breathy flute sound you play by moving your hands around your body through a grid of harmonious notes, sensed using a 3D camera.

Discover more

Watch
- The Cave of Sounds – with description from Tim Murray-Browne

UniSA study links
- Diploma in Music
- Music Performance
- Music Production

Cell Invaders

How can you hack your body to kill cancer?

Could the answer to treating cancer be found in your own blood?

Upstairs in this very building, researchers are investigating CAR-T therapy. This new treatment hacks your immune system to turn it into a cancer killer.

Enter the blood stream, Magic School Bus style, and check it out from the inside.

Delve Deeper

There's no single cure for cancer, because each cancer is a complex system.

Cancer is out-of-control growth of cells in the body. But it's not disorganised. Rather than growing as a random blob, cancer cells are able to self-organise in ways that help them grow, for example by blocking out immune cells or making their own blood vessels to be able to feed themselves.

Let's Complicate Things

Chimeric antigen receptor T cell (CAR-T) therapy harnesses the body's immune system to fight cancer.

CAR-T cells are made from a patient's own T cells, key cells of the immune system. The T cells are isolated from a sample of the patient's blood and then genetically modified to express a chimeric antigen receptor (CAR) on their surface. The CAR is targeted to recognise a specific marker on the surface of cancer cells.

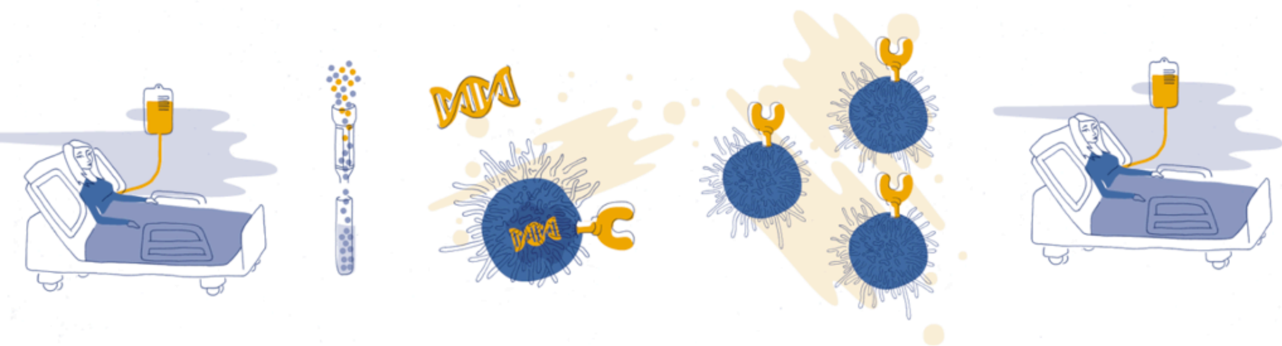


Image: process of CAR-T therapy. 1. Take blood from patient. 2. Separate out the T-cells. 3. Genetically engineer the T-cells by introducing a gene for a receptor (CAR) that's specific to the patient's cancer. 4. Grow up the CAR-T cells. 5. Inject the genetically engineered CAR-T cells back into the patient. Source: Carina Biotech

Cancer is complex

Cancer is a complex system, where lots of elements interact in a non-linear and unpredictable manner. A tumour can be viewed as an emergent, self-organising property of a complex system within the body.

T-cells are killers

T-cells are a vital component of our immune system that can detect and kill abnormal cells that might be infected or cancerous. Cancers can only grow once they escape detection of the immune system by modifying their surface proteins.

Hacking your own immune system

CAR-T therapies start with taking the patients own blood and genetically engineering their T-cells so they can recognise, target and kill the cancer. See this video for a good summary.

Cancer cells can be hard to get to

CAR-T therapies have been developed and approved for blood cancers like leukaemia where it's easier for the injected cells to find and destroy the cancer cells, which are also circulating in the blood.

It gets harder when dealing with a solid tumour – it's difficult to get out of the blood vessels to where the cancer is, and it's difficult for the CAR-T cells to get to the cells in the middle of these tumours. Carina Biotech are developing CAR-T cell therapies especially for solid tumours.

Side effects – cytokine storms and suicide switches

In CART-T therapies, toxicity and efficacy go hand in hand. If it's working, there will be side effects. If the immune system goes into overdrive it can result in a complex cascade of events known as a 'cytokine storm' which can (and has) led to fatal adverse events in some trials.

Once CAR-T cells have been delivered, there's no way to get them out again. As a living drug, it's not like a normal medicine that will eventually be metabolised and leave the body, once they're in – they're in! So if something goes wrong researchers are now engineering CAR-T cells to have a 'suicide switch' – a way of inducing the cells to die off with the addition of a small molecule drug.

Ethical considerations for CAR-T cell therapies

- **Safety concerns (see side effects above).** In clinical trials for the two currently available treatments, all patients reported adverse side effects with 84-95% experiencing severe side effects (including 6 deaths across both trials). While these deaths were mostly attributable to 'cytokine storms', there are other severe neurological side effects which are significant and still not well understood.
- **Managing expectations and hype.** There is a lot of excitement about the possibilities of CAR-T therapies, but still uncertainty about the long-term benefits and risks, like how long patients will stay in remission. You don't want to see what has happened in the stem cell industry – where a growing number of unproven therapies are aggressively marketed to vulnerable patients. Currently the treatment is one of last resort.
- **Equitable access both financially and geographically.** CAR-T therapies are expensive. CAR-T cell therapy treatment in Australia was only approved for use by the Therapeutic Goods Administration in December 2018, at a cost of $598,000 per patient. In the US Novartis, which produces Kymriah to treat paediatric leukaemia, offer the drug in an unusual pay-for-performance model where patients who do not respond within the first month after treatment do not have to pay. This is also just the cost for the therapy, not the management of expected adverse events. Even at the clinical trial level, the demand for slots in trials far exceeds capacity, which runs the risk of privileging some groups over others.

Discover more

Watch
- Tessa Gargett- UniSA's fight against cancer
- How to biohack your cells to fight cancer

Read
- How scientists built a living drug to kill cancer

- The Science behind CAR-T Therapy
- A new approach to fighting cancer could reduce costs and side effects

Listen
- Discovery Matters Podcast

UniSA study links
- Bachelor of Medical Science

Kate Little

Can you control chance?

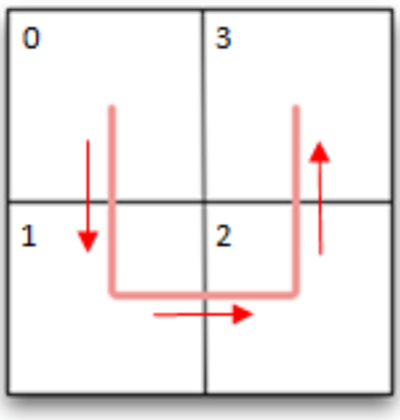
What happens when you combine patterns, randomisation and emergent properties of materials and data?

South Australian artist Kate Little creates artworks that draw from mathematics, textiles and music to offer new ways of thinking about relationships between humans, nature and technologies.

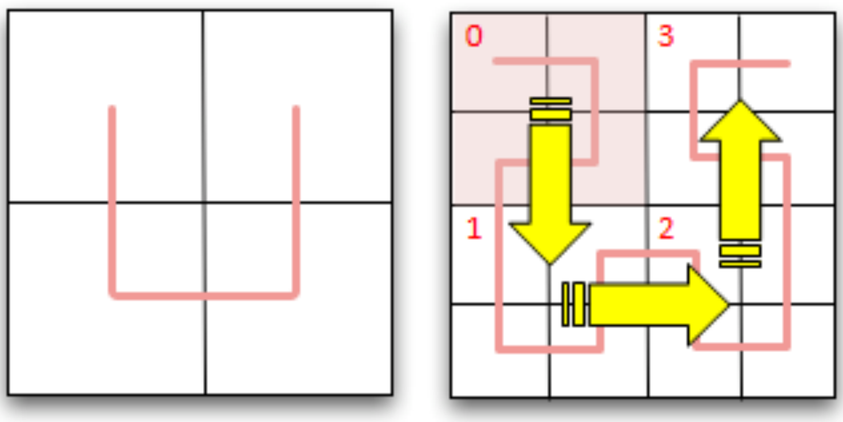
<u>Delve Deeper</u>

There are a selection of works along the corridor that have been created using the Hilbert Curve, a continuous fractal space-filling curve.

What does that mean? Space filling means you can think of it like trying to drape a string that covers all the squares of a grid without crossing over itself. And fractal means if you zoom in and look closely at a section of a higher-order curve, the pattern you see looks just the same as itself.

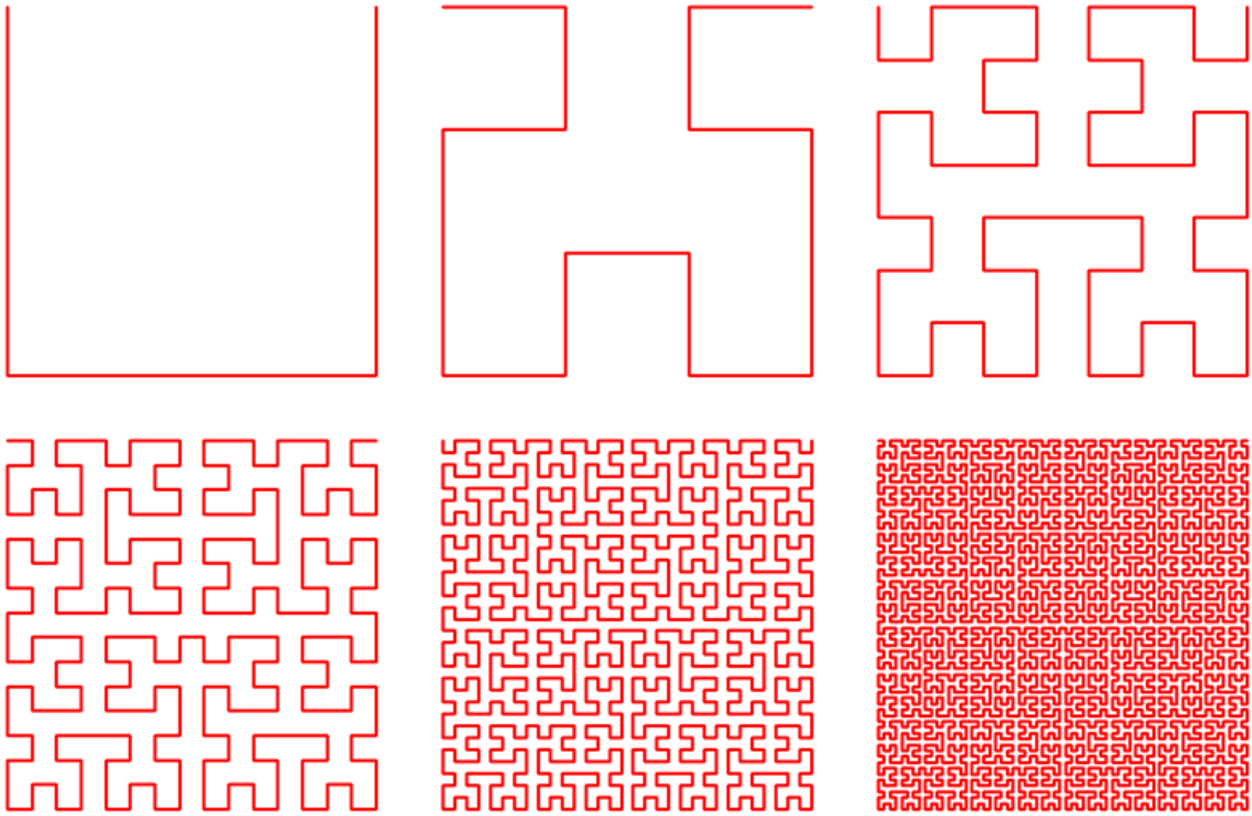


This is the basic U shape of a Hilbert curve in a 2 x 2 grid.



If you double this to a 4 x 4 grid, each containing the U shape that passes through all four quadrants of the grid.

This is a recursive pattern that can repeat and repeat giving you patterns like this:



These have applications in spatial databases and mapping, and also in graphics processing.

Discover More

Read
- Kate Little Art
- Crinkly curves -- Some curves are so convoluted they wiggle free of the one-dimensional world and fill up space

UniSA study links
- Bachelor of Mathematics (Industrial and Applied Mathematics)
- Bachelor of Mathematics (Data Science)
- Bachelor of Contemporary Art
- Bachelor of Art and Design (Honours)

Always Was, Always Will Be Our Future(s)

Why tell a story?

The world is a complex place. Stories help us make sense of how things are, how things were, and how things might be.

Discover stories written by First Nations authors weaved throughout the exhibition, that invite you to reimagine the future of our world and others.

Delve Deeper

Stories define the people who tell them; they are an expression of ourselves. In a neurological sense, stories assist the human brain in navigating the world. Stories allow us to test out new ideas and scenarios in a safe way before deciding how to act in reality. Stories help us break down large systems into accessible combinations of stories.

Indigenous Futurism are speculative fictions written by Indigenous authors. Echoing Afrofuturism, these stories confront, challenge, and subvert norms associated with colonial and racist genre tropes. Instead, these stories take inspiration from the strength of First Nations knowledge systems, world views, stories, language, and traditions to reimagine this world, and others.

Discover More

Watch
- All stories matter – The need for afrofuturism

Read
- The disasters were designed by us – How to tell a story about a complex system

Listen
- Indigenous Futurism and Aboriginal Territories in Cyberspace

Question/discussion
- Do you enjoy a good story? Why? What makes a good story? How does it help us learn or think differently about the world?

UniSA study links
- Bachelor of Arts (Creative Writing and Literature)