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UPDATE

Calcium – the ultimate communicator

More than just a bone-strengthener, calcium plays a vital communications role in almost every type of cell. It is involved in the chemical signalling that controls muscle contractions, nerve firing, expression of genes, secretion of hormones, saliva and digestive enzymes, and many other functions.

The importance of calcium has been recognised for some time, and as the ability to measure calcium concentrations inside cells has improved, it has become clear that calcium signalling is a highly complex process.

Calcium concentrations inside cells oscillate in response to stimulation, and it is thought that in many cases the signal is carried, not by the size of the oscillation, but by its frequency. In many cells, calcium oscillations take the form of periodic waves, which can form complex patterns, such as rotating spirals or scrolls. These communicate a calcium signal from one end of a cell to the other. Calcium waves can also travel from one cell to another, to coordinate the responses of many cells.

Because of this complexity, mathematical models have played an important role in the study of calcium signalling. For the past 15 years, in a series of projects funded by the Marsden Fund, Professor James Sneyd from the Department of Mathematics at The University of Auckland and his colleagues have worked to unravel the mechanisms that cause calcium oscillations and waves, and to understand how their frequency and speed are controlled.

Their investigations have moved in two different directions. First, the models have proven to have interesting mathematical properties that can only properly be understood by the development of new mathematical techniques. Colleagues such as Dr Vivien Kirk (The University of Auckland) and Dr Martin Wechselberger (University of Sydney) are closely involved in this work.

Second, in collaboration with experimental groups in the US, the team has begun studying the mechanisms by which calcium oscillations and waves can be used to control cellular functions. This work is now funded by the National Institutes of Health (US), in projects that depend significantly on the work done in earlier Marsden-funded projects.

As an example, the team is studying how oscillations of calcium control the contraction of smooth muscle in airways. Airway smooth muscle is a rather unusual beast. Since its only known physiological function is to constrict the airway and hinder breathing, it has the peculiar status of being a cell type whose only clear function is pathological. The basic outlines of how contraction occurs are well known, but the devil lies in the details. Although initial data suggested that the frequency of calcium oscillation was the major determinant of contraction, mathematical models predict that calcium oscillations merely allow for the greatest possible contraction for a given calcium level. In other words, if an airway smooth muscle cell wants to use calcium to cause contraction, it can get the biggest bang for its calcium buck if calcium is oscillating, rather than steady. It is in these kinds of insights that mathematical modelling shows its power.

2008 funding results
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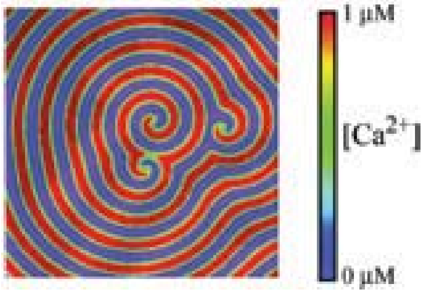
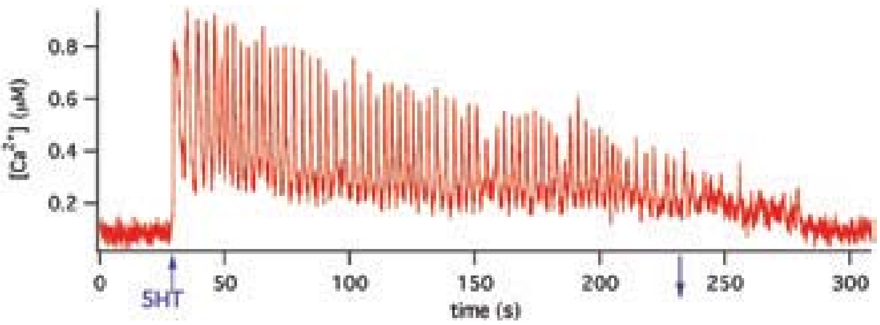
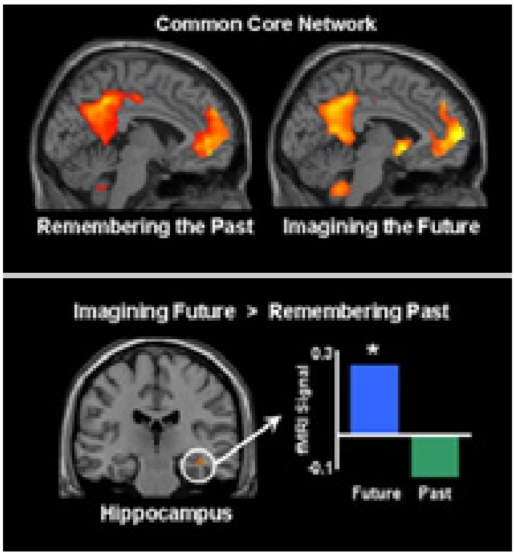


Snapshot of rotating spiral waves of calcium, computed from a mathematical model.



Oscillations of calcium concentration in an airway smooth muscle cell. From the laboratory of Michael Sanderson, University of Massachusetts Medical School, reproduced with permission.



Thinking about the future uses the same parts of the brain as remembering the past (top). However, the activity level is higher when imagining future events (bottom right).

Remembering the future

Principal Investigator: Dr Donna Rose Addis, Department of Psychology, The University of Auckland.

Why does memory, our ability to mentally travel back to the past and re-experience events in vivid detail, exist? Dr Donna Rose Addis from The University of Auckland may help find the answer to this question – in the future.

Memory research has traditionally focused on past events, but recent work has examined a new idea – that a crucial function of the brain is to use stored information to imagine, simulate and predict possible future events.

Research supports this hypothesis – imaging techniques have shown that thinking about the future uses the same parts of the brain as remembering the past; and individuals with memory loss have been found to have difficulty imagining future events.

This work has revealed a core brain network supporting both remembering the past and simulating the future. However, some regions of this network are more intensively engaged when simulating future events. Why might this be? Dr Addis aims to find out, by using brain imaging to identify the processes that drive this increased activity during future event simulation.

This research will help reveal how the brain utilises information stored in memory to simulate future events and aims to resolve a major question in this field: what is so special about future event simulation that this process engages the core network so strongly, more so than other thought processes such as remembering the past?

Dr Donna Rose Addis.

The work will therefore provide a more comprehensive understanding of how the brain draws upon details in our memories to simulate our futures.

The meals of moa

Principal Investigators: Dr Jamie Wood and Dr Janet Wilmshurst, Landcare Research; and Professor Alan Cooper and Mr Trevor Worthy, University of Adelaide.

What did moa and other large extinct birds eat? And what effect did their snacking have on our ecology?

In a land without large mammals, moa were the largest herbivores in New Zealand until their extinction about 600 years ago. Browsing by birds that weighed up to 240 kg undoubtedly had a significant influence on the ecosystems they inhabited; however, their diets are poorly known.

Examining the contents of moa coprolites (fossilised faeces) is one way to learn more about what they ate, but so far, only five have been investigated. The diets of several other extinct birds also remain unknown, even though these, too, are likely to have had a major impact on the vegetation in their habitats.

Dr Wood, a promising young scientist surrounded by a very experienced team of colleagues, will examine a large collection of 1500 coprolites from rock shelters across southern New Zealand. This collection includes large coprolites attributed to moa, and many smaller ones whose species of origin are currently unknown.

Rock shelter near the Clutha River, in Central Otago.

Dr Wood will extract and analyse DNA to determine which bird species deposited each coprolite. The preserved dung will then be examined for seeds and leaf fragments to see what plants the birds ate. A surprising amount of detail can be gained from this type of analysis, including diet data according to species, ecological zone, sex, and even season. This project will provide an unparalleled view of the interactions between lost birds and the plants they ate.

The team will also study soil from relatively unmodified forests across New Zealand, to examine how forest understorey composition has changed over the last thousand years (with moa; without large herbivores; and with introduced herbivores).

Overall, the study will dramatically improve reconstructions of ancient New Zealand and provide a comparison of the impacts of moa and introduced mammals.