Topics in dynamical systems.

1) Energy transfer in biomolecules and molecular motors. How vested interests and misuse of power determine a science, and how to change that.

If you are interested in bioenergetics and molecular motors take a look at the work of Colin McClare, Nature 240, 88, 1972, + relevant forward and antecedent references, on muscle contraction. McClare and his work were vilified and trashed at the time by some influential members of the British scientific establishment, and he took his own life in 1977. His critics were completely wrong in my opinion. By their spurious arguments your knees would cool down as you walk up the stairs, and would approach absolute zero if the staircase were infinite. I do not know if McClare was completely right, but his work would be a good starting point for an interesting and fruitful project. I would also suggest searching the engineering literature for work related to motions and energy transduction through long freight trains â·‰ this is similar to the biopolymer problem. Apparently very long freight trains sometimes break into two or three pieces due to a growing instability propagating thro ugh the couplings. It would be useful to visit the rail operation at Bluff in Queensland, where coal trains of hundreds of wagons are assembled, and chat to the rail engineers there.

2) Burning the biomass to sequester carbon dioxide.

The burning of forests, woodlands, grasslands, and crops increases the carbon dioxide load of the atmosphere, right? Wrong. Our recent research on the fundamental physics and chemistry of cellulose combustion has provided a firm basis for a new idea: that programs of carefully managed biomass burning can actually sequester carbon dioxide stably. This is a counterintuitive notion, and no doubt will stir up controversy with all kinds of opinionated greenhouse bandwagoners and enviro-stasi, but the fundamental science behind it is sound, and in fact has been known for decades. Your job will be to show, through modelling, simulations, and experiments, that it can - and should - be done; and, if you are a gregarious type who thrives on publicity, argue, debate, and explain your results on science shows, as well as publish them in scientific journals. Intrigued? Contact me Rowena.Ball@anu.edu.au for more information.

3) Topics in dynamical systems, stability, and chaos.

Suitable for undergrad or honours students. In this project we will review aspects of the mathematics of dynamical systems, stability, and chaos within a historical framework that draws together the two major threads of its early development: celestial mechanics and control theory, and focusing on qualitative theory. From this perspective we will study how concepts of stability enable us to classify dynamical equations and their solutions and connect the key issues of nonlinearity, bifurcation, control, and uncertainty that are common to time-dependent problems in natural and engineered systems. Building on this foundation, we may investigate new problems involving stability of large complex networks, such as transport, communications, or ecological networks.

4) Fire, earth, air, & water.

With Andrew Sullivan of CSIRO-ENSIS. The Greek scientist and philosopher Aristotle taught that matter consists of four elements - fire, earth, air, and water. What complete archaic nonsense! Well... maybe not entirely. In the light of modern complex systems science it has to be admitted that those factors, and nonlinear interactions among them, do shape our environment to a large extent. For example, what determines patterns and rates of spread of wildland fires? Topography is one factor, and in this project you may analyse large imaging data sets for patterns and correlations that help design new fire management and planning practices. As a complementary study you may also investigate specific issues related to the roles of water and air in the chemistry and fluid dynamics of fuel thermal decomposition and combustion.

5) From chaos to structure in turbulent plasma and planetary flows.

There is a recent upsurge of interest world-wide in the self-structuring properties of quasi two-dimensional flows, motivated by the need to control transport in next-step fusion energy experiments and understand variations in planetary circulations mediated by climate change. What is the deeper physics behind the remarkable fact that in such flows ordered structures and patterns can arise from chaotic or turbulent fluid motions? Since thermodynamics tells us that disorder or entropy tends to increase, such behaviour may seem counterintuitive. In this project you will study equations of motion for planetary flows in the geostrophic approximation and for magnetic fusion plasmas in the electrostatic approximation, and compare and contrast the physics expressed by each system.

6) Fractal properties of Australiaâ·˙s river catchment boundaries.

The fractality of catchment boundaries for surface waters means that, near the boundaries, the flow dynamics exhibits sensitive dependence on initial conditions and a high degree of uncertainty. What are the consequences of this fine-scale boundary structure for predicting flood risk and management of water resources? In this project we propose to characterize the fractal properties of key parts of the Lake Eyre, Gulf of Carpentaria, and/or Murray-Darling river catchment boundaries with the aim of reducing final state uncertainty and improving predictability. Since the outcomes of this project will help to inform long-term policy on Australiaâ·˙s water resources, highly diplomatic engagement of diverse stakeholders and end users will be necessary (not surprisingly).