UNIVERSITY OF Southampton

Engaging with Complexity

Level 4 Gallery, Hartley Library, 4 February– 6 March 2015

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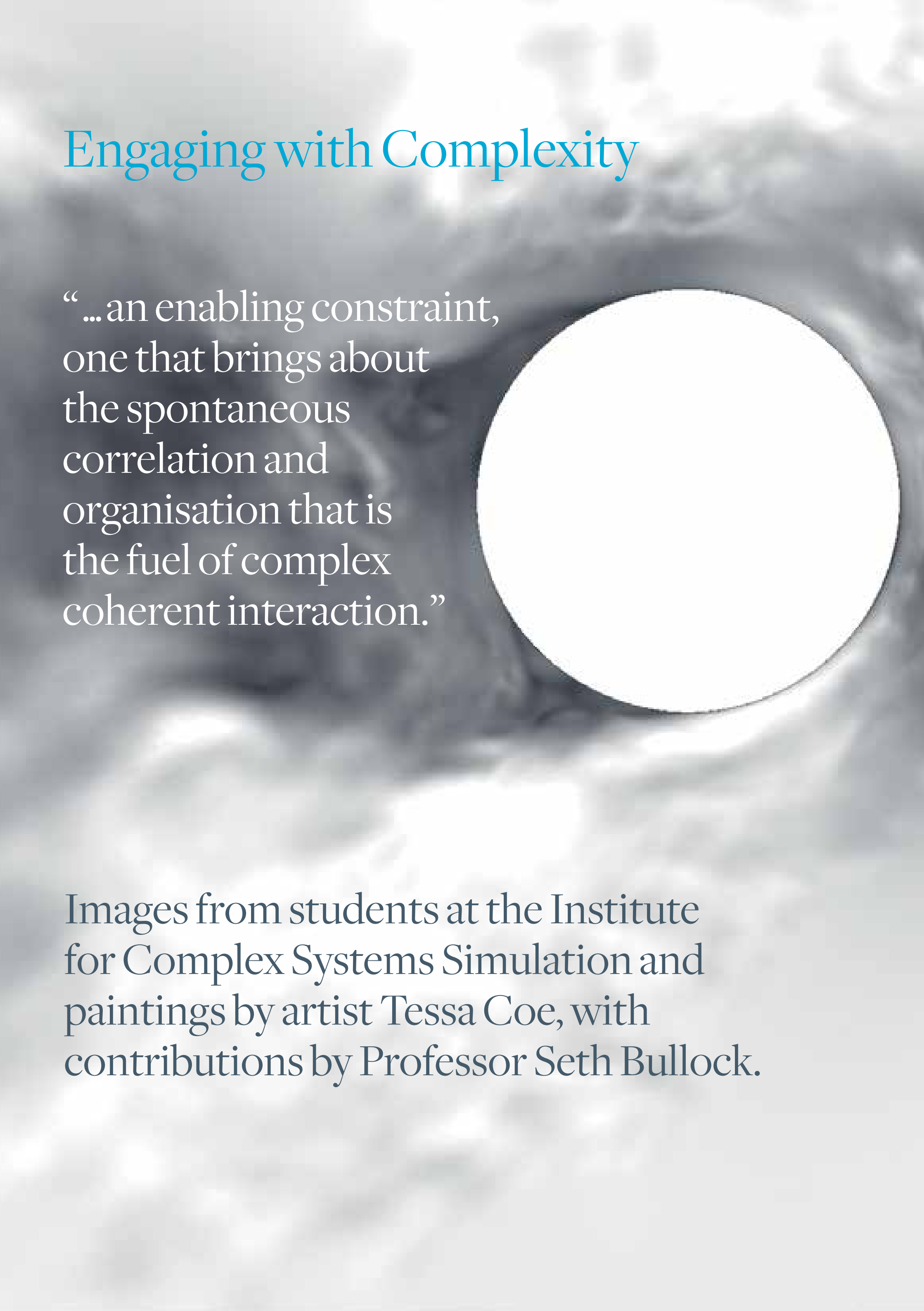
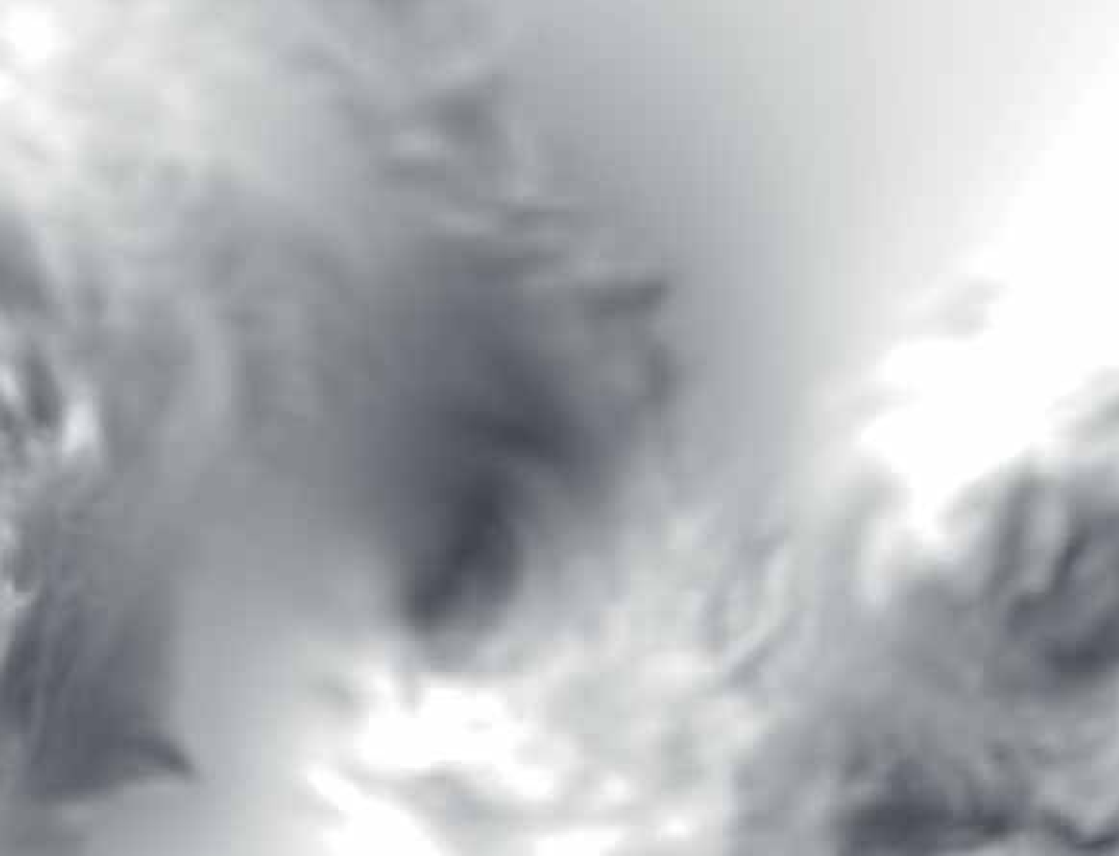


"…an enabling constraint, one that brings about the spontaneous correlation and organisation that is the fuel of complex coherent interaction."

Images from students at the Institute for Complex Systems Simulation and paintings by artist Tessa Coe, with contributions by Professor Seth Bullock.



Introduction

The artist and the scientist are often regarded as opposites. One is thought to value creativity, freedom, and self-exploration, while the other is understood to privilege rigour, rationality, and the discovery of truth. But of course in reality, both practices overlap in many respects. Scientists and artists both work to make sense of the world and their place in it, both being driven by a creative, curious imagination, and both choosing to be constrained by an evolving set of conventions and principles.

When a scientist makes a model or an artist paints, these constraints, imposed by the limitations of tools and materials, audiences, theories and ideas, space and time, *restrict* the scope of an activity, but in doing so they also *enable* it. They provide focus, drawing threads together, facilitating connections and conversations, canalising interactions – and, as a consequence, they can sometimes help to bring forth new forms of organisation and new understanding.

The collection of works exhibited here brings together several pieces by artist Tessa Coe. Tessa uses self-imposed informal constraints within her painting practice to help capture the stories that emerge from studies of real life biological systems. Her practice has been greatly enriched by discussions around the visualizations created by PhD researchers at the University of Southampton's Institute for Complex Systems Simulation. These images arise from computational modelling research into a variety of complex systems: from micromagnetic materials and heated fluids to termite colonies and nature reserves.

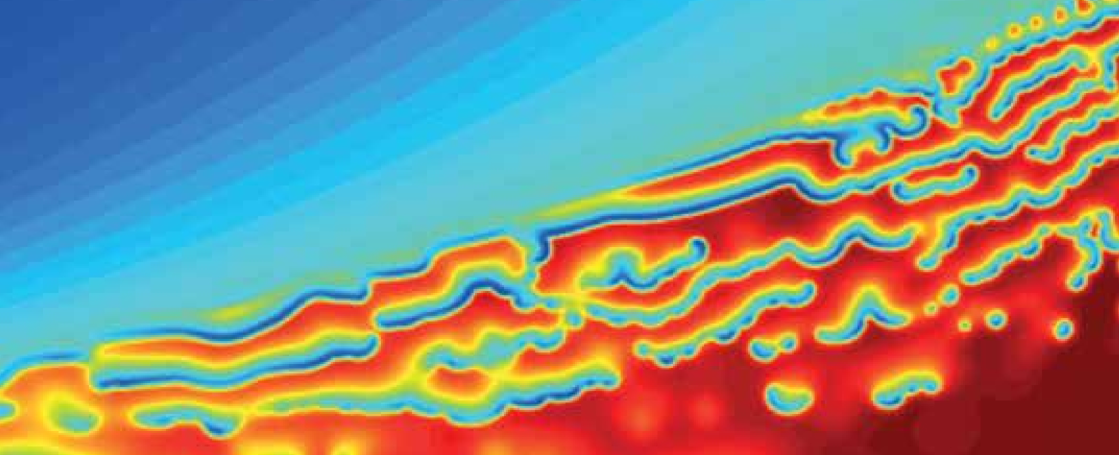
Visualization

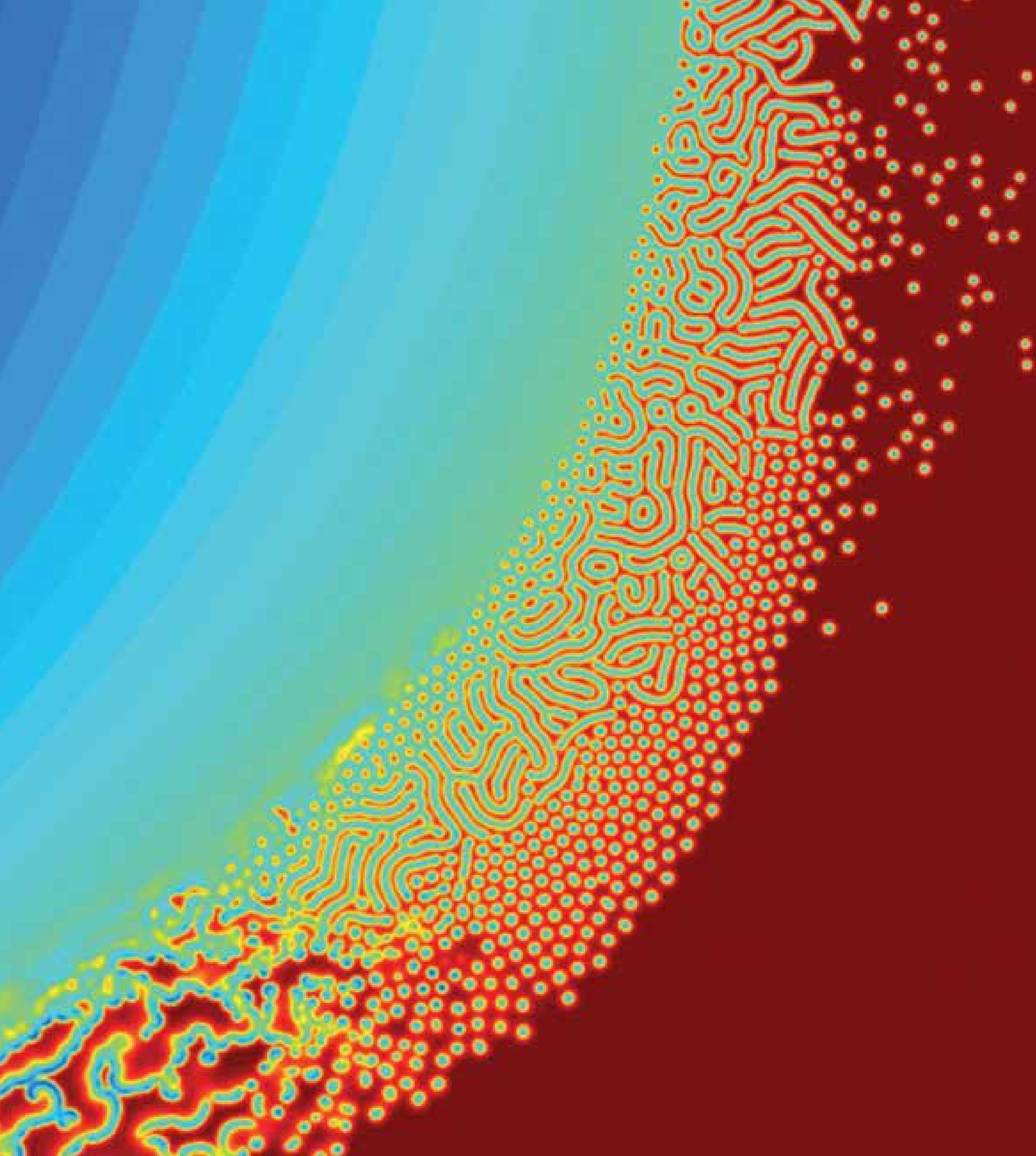
Within science, much visualization is "exploratory", often aiming to expose as much as possible of what we know about a target system to our powerful, pattern-hungry visual systems.

These exploratory images can be informal, complicated, messy and dense - they are personal rather than public. But when scientific insights must be shared, different visualizations are needed: simple, standardized, and hence intuitive and edifying.

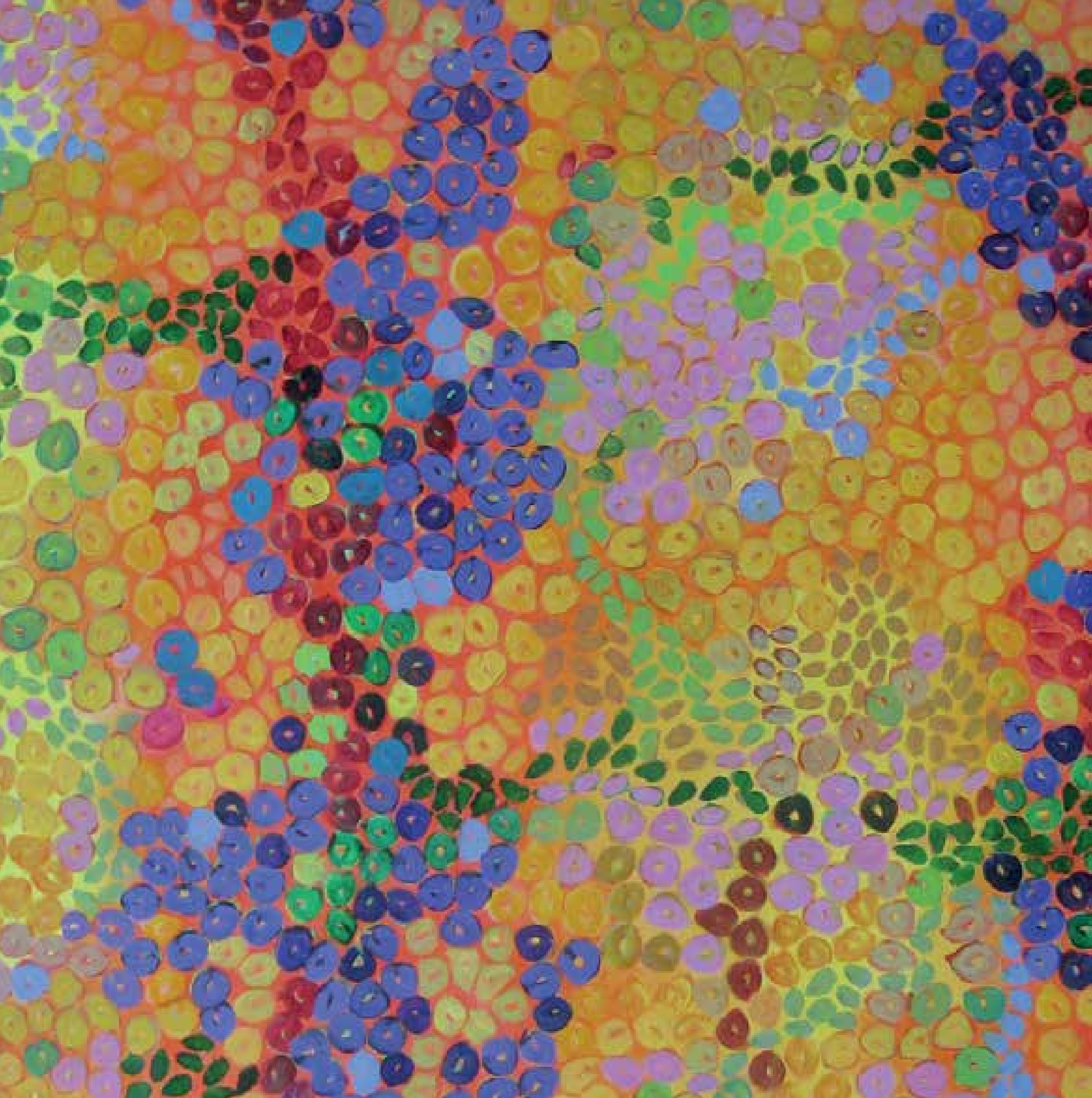
Complex, idiosyncratic visualizations are rarely successful at this latter stage, but when the insight being conveyed concerns system complexity itself, visualization choices become particularly challenging.

Tessa describes her painting practice as a journey, as many artists do. It usually begins with loose drawings and then moves to the canvas. Painting itself is a visualisation from within, repeatedly refined, destroyed, reinvented and re-experienced until finally offered to the viewer, for their mind's eye to peruse.





“Creating a visual representation of some idea or reality.”

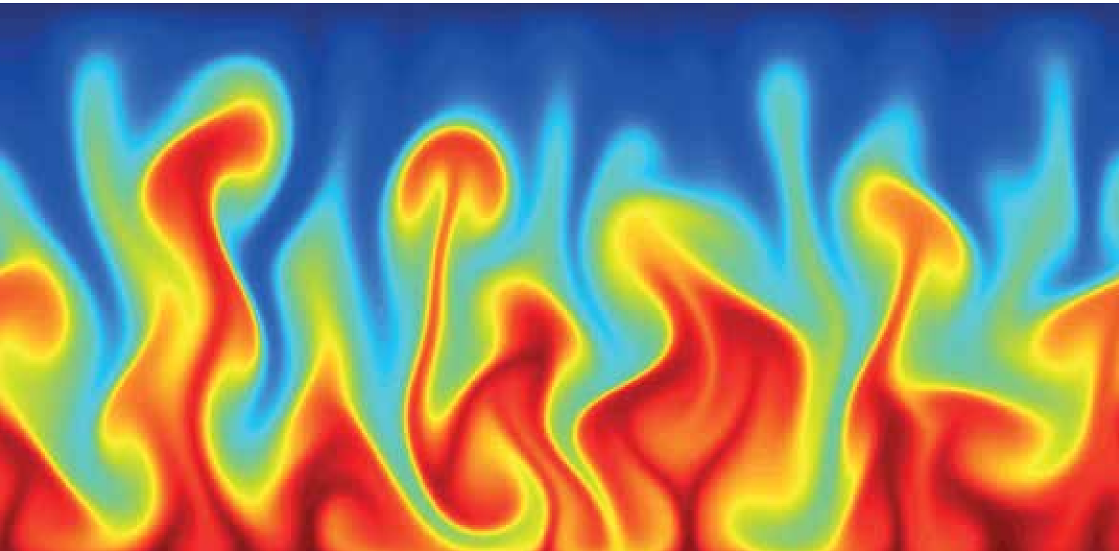


“A fresh canvas for a painter is his or her universe. It’s a space to inhabit, to make a mark, to explore her latest curiosity. Being let loose in such a way is both utterly beguiling and quite daunting. Without some glimpse of your path to tread, one can be left floundering; the end results muddled, muddied and worthy only of the bin. However you play the game of mark and counter mark on the surface of a painting, the conversation between the painter and the painted surface proceeds through the mind’s eye, where the path leads. The work shown here are my experiments, my personal simulations of some biological environment. My path to tread has simple motifs, in colours that I allow to interact according to simple schemes. My world, my rules. The back of my mind knows a little about real complex systems, but the artist in her small universe can only distil this and work on, until my overarching wish to be surprised by a final glimpse of an order that I did not consciously create, is realised.”

Tessa Coe

“Despite appearances, this is a simple physical system: a fluid that is being heated from below and cooled from above. It is experiencing a violent, transient phase called a bifurcation. The build-up of heat near the lower boundary causes fluid to expand and rise. However this does not happen in a homogeneous way. Small, random fluctuations of density mean that certain fluid regions rise faster than others. Rising into colder fluid means that they accelerate faster and this process feeds back on itself. The result is a set of ‘competing’ plumes racing towards the ceiling of their enclosure. In the end only two will survive the opening furore, forming two approximately round, rotating ‘rolls’, perpetually disturbed by small non-linear outbursts and fluctuations, but always acting to deliver heat from bottom to top. One key unknown is this: what exactly limits the rate at which the system achieves this heat transfer? A simple question, but a complete answer still eludes us.”

Dr. Stuart Bartlett



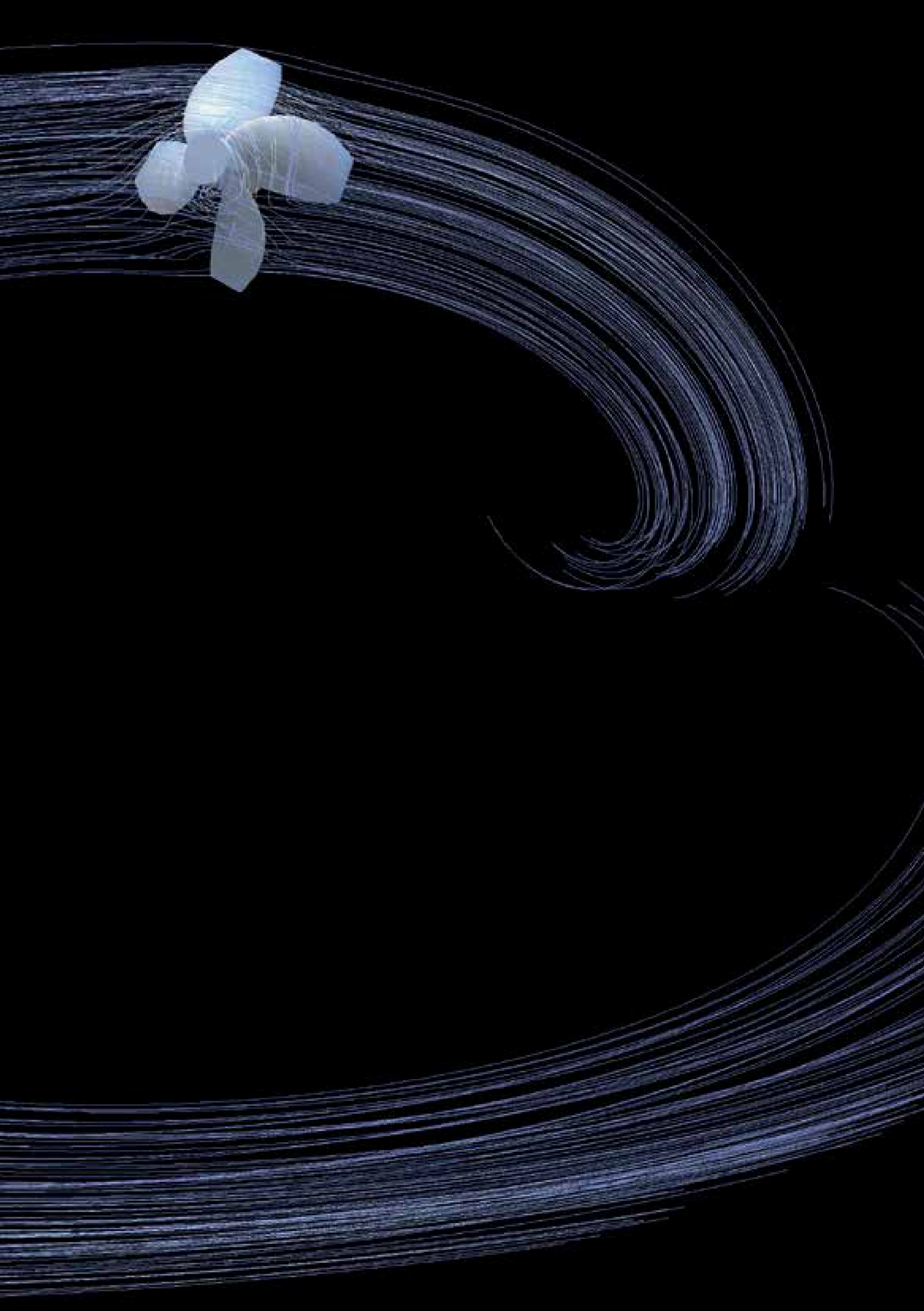
What Is Complexity?

Complex systems such as living cells, brains, financial markets, and ecosystems are made up of many interacting parts that together give rise to interesting system-wide “emergent” behaviours that are hard to predict and explain. Cells metabolise, brains think, markets bubble and ecosystems evolve. By contrast, when some marbles interact together in a bag, they are just some marbles.

For complex systems, a small perturbation (e.g., a single molecule binding to a cell wall) can result in a disproportionately huge systemic change: a cell division, a brainwave, a market crash, a new species. By contrast, adding an extra marble to the bag of marbles only changes it proportionately, i.e., by a similarly small amount. It turns out that the difference between the simple and the complex stems primarily from this disproportionality, or “non-linearity”, in a system’s interactions.

In non-linear systems, the whole is more than merely the simple sum of the parts. Rather, when the parts come together, genuinely new phenomena arise. Examine the properties of a single marble and you are well on your way to understanding the whole bag - more marbles are just more of the same. But this isn’t true of neurons. A single neuron does not think, but a brain does - “more is different”.

This makes complex systems particularly challenging to understand. But if we care about problems ranging from cancer to consciousness, or about the resilience of the financial and environmental systems that we all rely upon, then we will have to get much better at dealing with them.



Going further...

Places to find more about creativity, complexity, constraints and simulation:

The Origins of Order, Stuart Kauffman.

Turtles Termites and Traffic Jams, Mitch Resnick.

Complexity: A Guided Tour, Melanie Mitchell.

At Home in the Universe: The Search for the Laws of Self-Organization and Complexity, Stuart Kauffman.

The Computational Beauty of Nature, Gary William Flake.

Emergence: From Chaos to Order, John Holland.

Out of Control: The New Biology of Machines, Social Systems and the Economic World, Kevin Kelly.

The Santa Fe Institute, **www.santafe.edu**

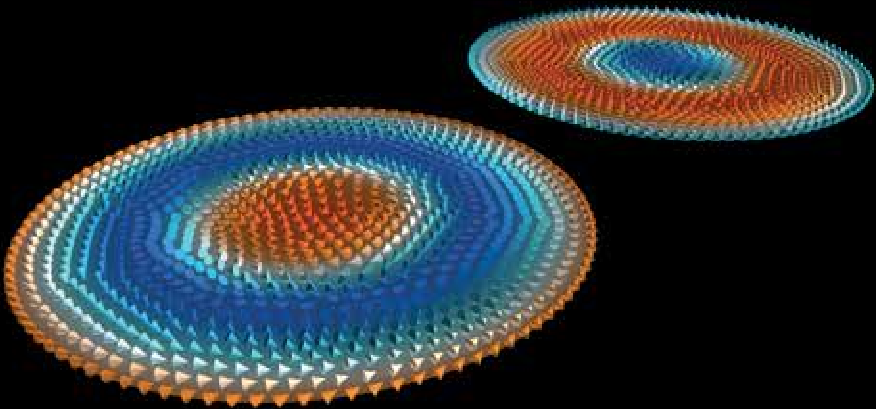
The Institute for Complex Systems Simulation, University of Southampton, **www.icss.soton.ac.uk**

Tessa Coe, **www.tessacoe.co.uk**

Complexity Digest, comdig.unam.mx

The Centre for Complexity Science, Imperial College London, **www.complexity.org.uk**

Complexity Explorer, **www.complexityexplorer.org**



"...the trick is then working creatively within those constraints"

David Byrne, musician

List of works

1. *Jaguar territory formation in two connected nature reserves*, Angela Watkins and Jason Noble (Agent-Based Model)

2. *Randomly grown planar network*, Garvin Haslett (Planar Growth)

3. *Magnetic Skyrmions encoding two different states*, David Cortes, Marijan Beg, Hans Fangohr (Finite Element Simulation)

4. *Basins of attraction in random fields*, Iain Weaver (Differential Equations)

5. *Protocells*, Stuart Bartlett (Cellular Automata)

6. *Maternal drinking disclosure game in extensive form*, Jono Gray (Agent-Based Model with Learning Agents)

7. *Population dynamics in a modified Haystack Model*, Jordi Arranz (Evolutionary Simulation Model)

8. *Turbulent flow around cylinders*, Jack Weatheritt (Flow Simulation Methodology)

9. *Fluid flow through a propeller*, Aleks Dubas (Finite Volume Simulation)

10. *Self-organised construction by termites*, Nick Hill (Agent-Based Model and Pheromones)

11. *Convection in a heated fluid* (11a) *and Gray Scott structures* (11b), Stuart Bartlett (Reactive Lattice Boltzmann Model)

Paintings by Tessa Coe
(all are fine art acrylic on canvas):

A. *Feet in the Clouds*

B. *Early Days*

C. *Wings to the Mind*

D. *Heartbeat*

E. *Life's Samba*

F. *Of Streams and Swarms*

G. *An Adequate Poetry*

H. *Fragment*

I. *A Flourishing*

J. *The Importance of Place*

Many thanks to Anne-Marrie Steel and Jane Birkin at the Hartley Library, to Tracey Cantlie at the ICSS, to the Hansard Gallery for loan of the display screens, to Big Stuff for the printing, to Jason Noble and Hans Fangohr, to Malcolm Coe, and to all of the doctoral students involved in helping the exhibition to come together: Jordi Arranz, Stuart Bartlett, Marijan Beg, Ed Butler, David Cortes, Bob De Caux, Aleks Dubas, Jono Gray, Garvin Haslett, James Heppell, Nick Hill, Iza Romanowska, James Snowdon, Nick Synes, Angela Watkins, Jack Weatheritt, Iain Weaver, and Elisabeth zu Erbach Schoenberg.

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