Real world complex systems and cross-disciplinary research

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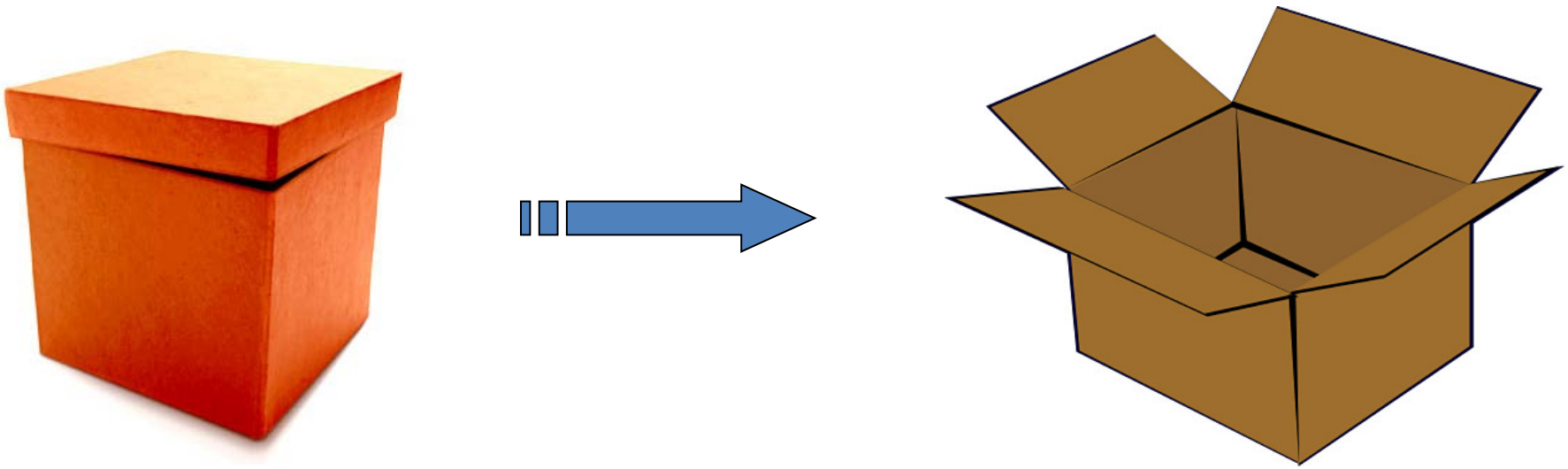
Complex Systems
Analysis

THE UNIVERSITY of York

from silos to interdisciplinarity

"***The world has problems while universities have disciplines***"

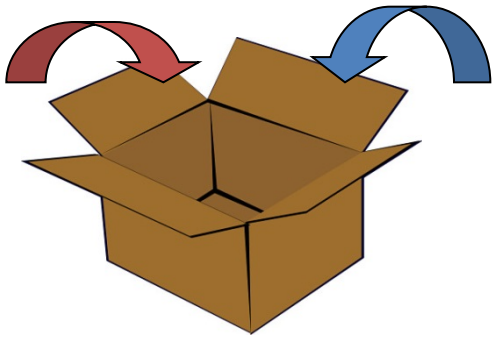
G. Wilson, *JWUF*, 2009



multidisciplinarity

[Nicolescu]

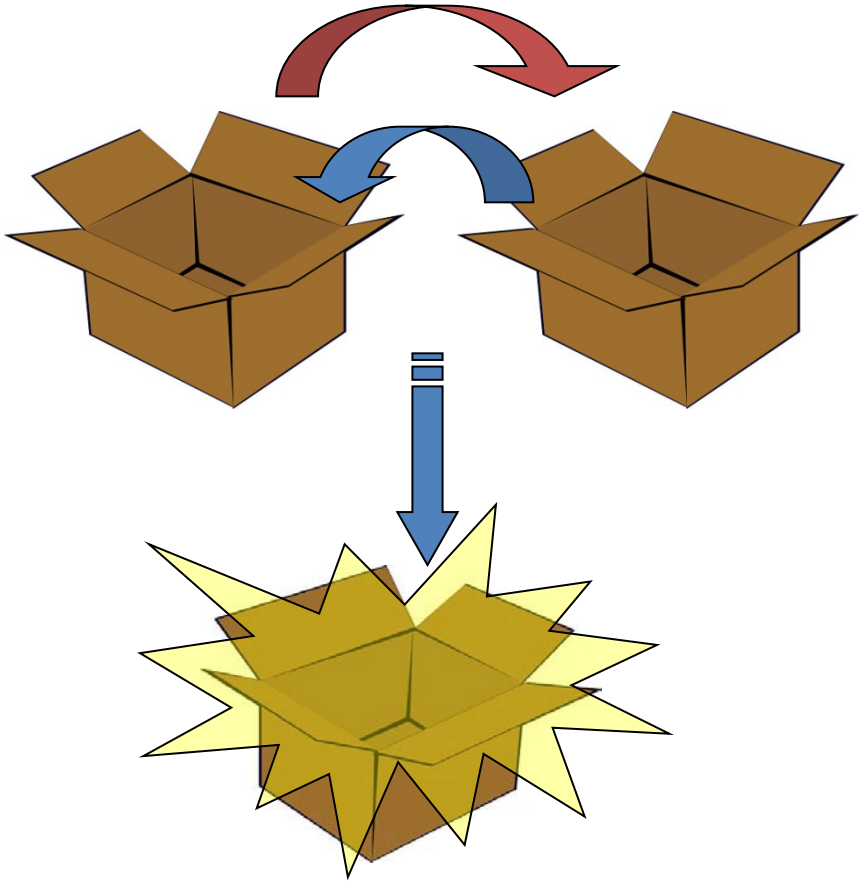
- studying a research topic in several disciplines simultaneously
  - a painting: art history and mathematical geometry
- goals: limited to the framework of (home) disciplinary research
  - others as a "service industry"



interdisciplinarity

[Nicolescu]

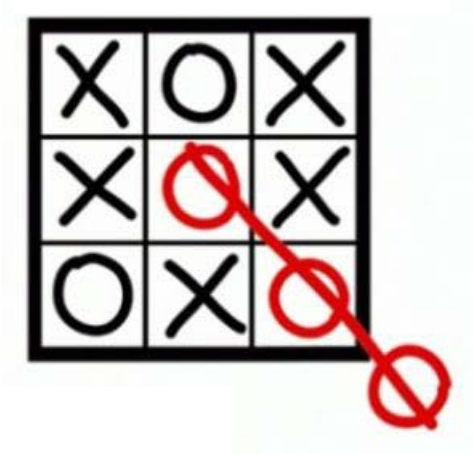
- goal: transfer of methods from one discipline to another
  - new capabilities, new approaches, even new disciplines



transdisciplinarity

[Nicolescu]

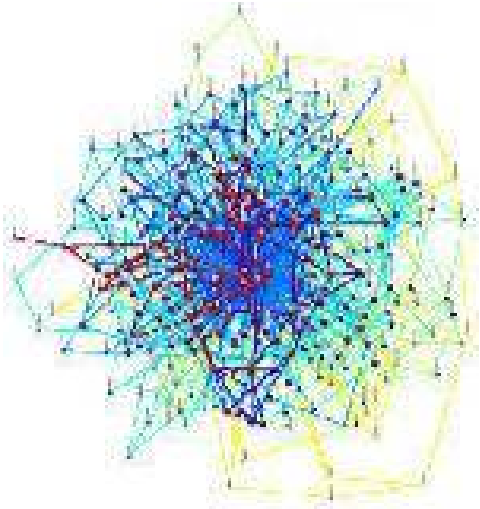
- between, across, *beyond* disciplines
- goal: "understanding the world" (not just one disciplinary view of it)
  - a unity of knowledge

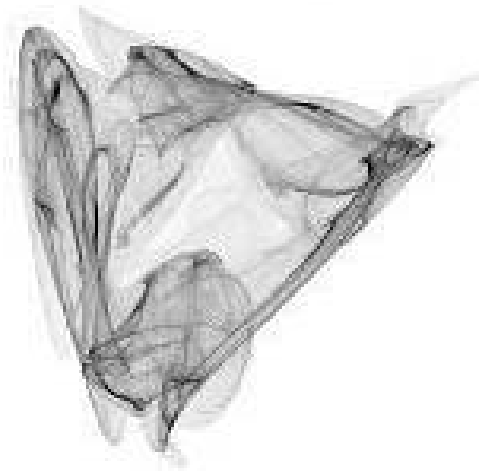


Challenges

systems, and complex systems

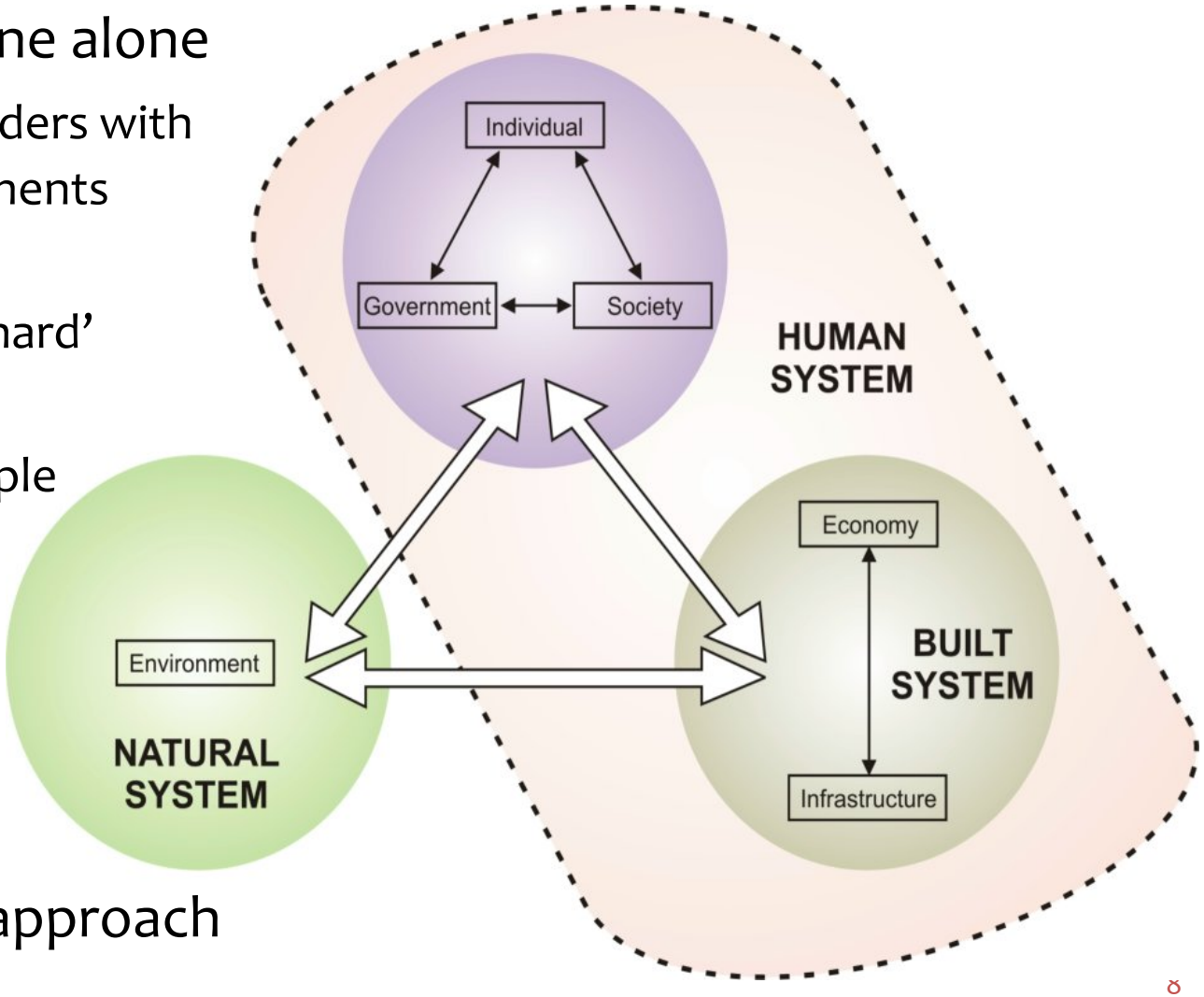
- system :
  - *a **set** of **interacting components** and **relationships***
  - *with high level **structure** and **behaviour***
  - *forming an **integrated whole***
- ***complex*** system – also :
  - strong local interactions resulting in global behaviour
  - heterogeneous mix of networks and hierarchies
    - physical, technical, social, …
  - feedback between levels
  - self-organisation
  - growth, adaptation, evolution, change
  - emergence and innovation
  - …





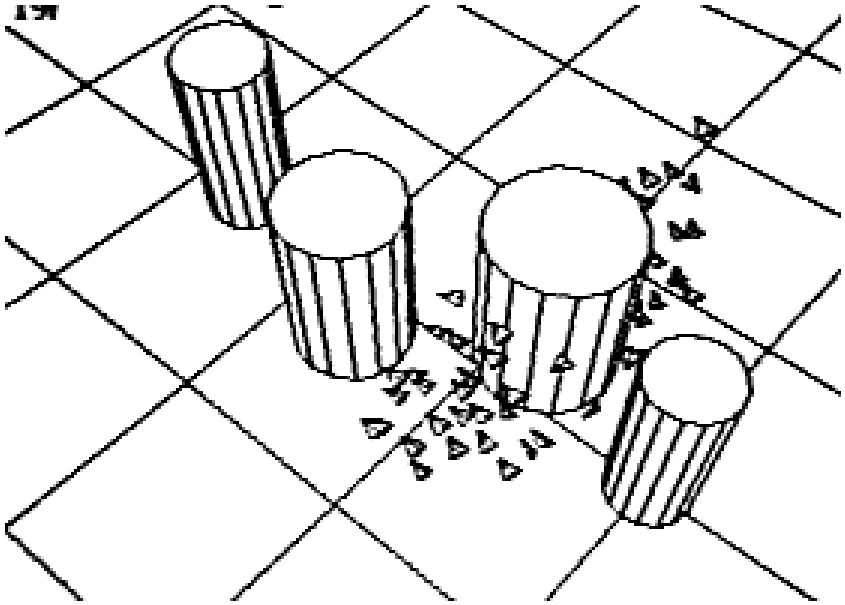
complex systems science

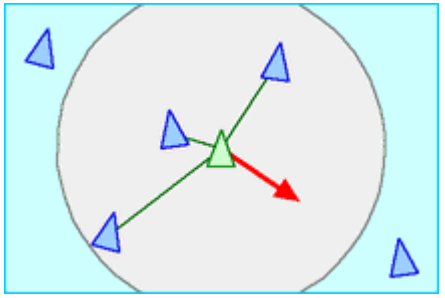
- a ***complex problem*** cannot be tackled by a single discipline alone
  - multiple stakeholders with differing requirements and goals
  - 'soft' social and 'hard' technical issues
  - issues from multiple natural and engineered domains
- it requires an ***interdisciplinary***, ***complex systems*** approach

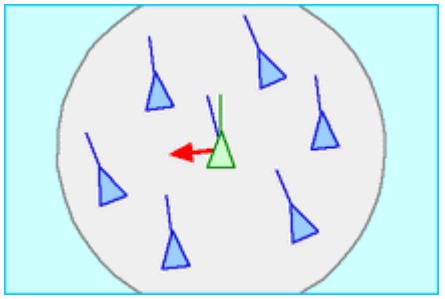


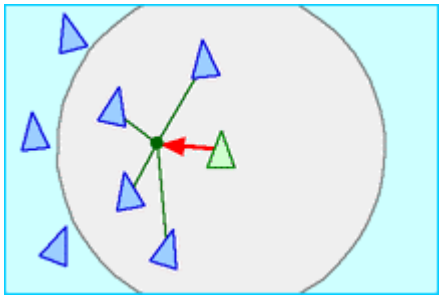
“simple” complexity

- **multiple homogeneous agents** + **simple interaction rules** = complex behaviours
- eg : “boids”







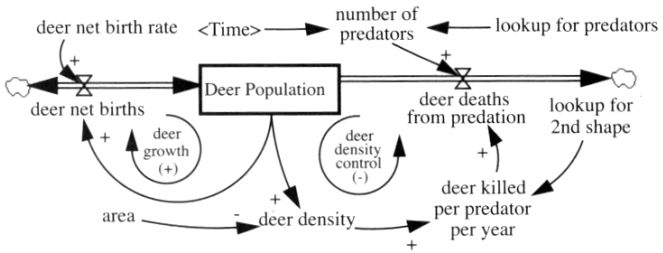


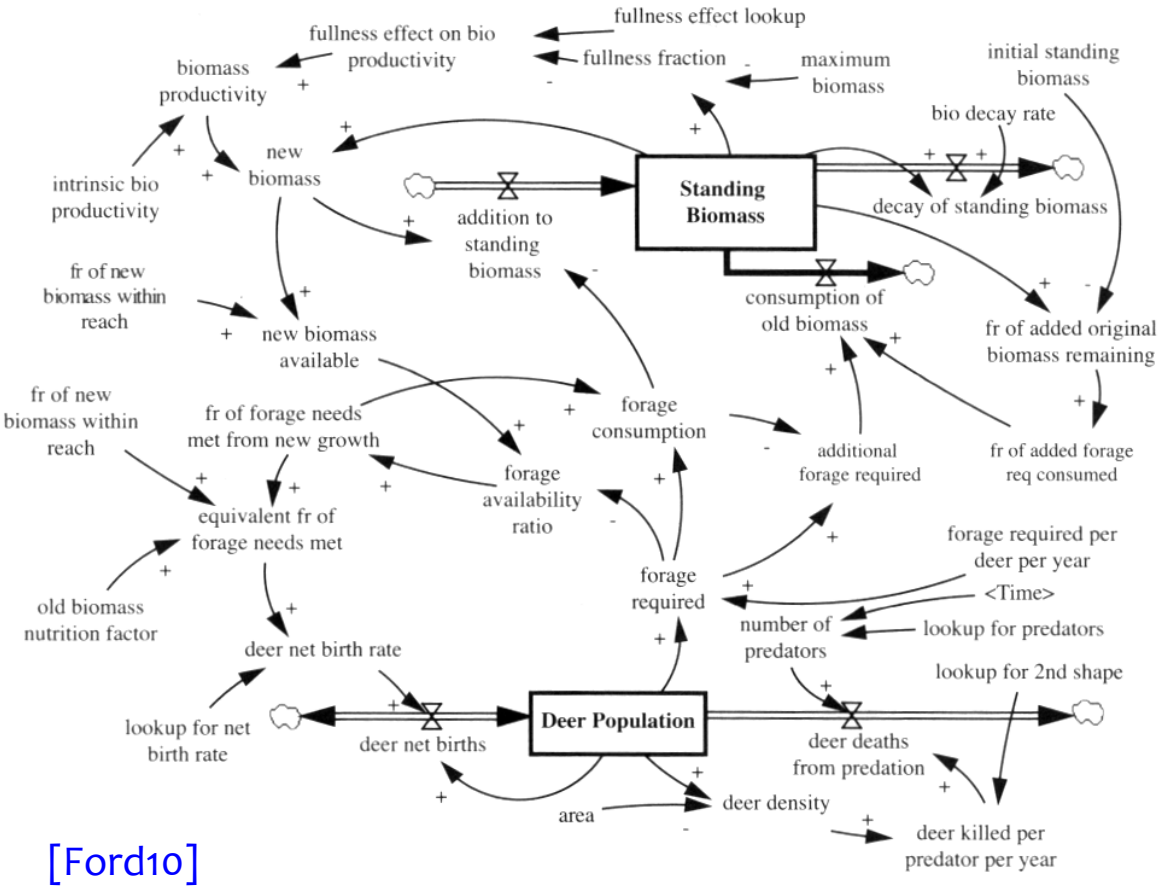
- but ***real world*** complexity isn’t simple!

real world "complicated" complexity

- multiple ***heterogeneous*** agents + ***complex environment*** + multiple ***complicated*** rules of interaction and ***growth*** = real world behaviours

- eg : deer populations





[Ford10]

complex systems ⇒ interdisciplinary working

- **multiple** domains
  - management, law, economics, engineering, psychology, systems biology, environment, …
- **multiple** techniques
  - experiments, mathematics, statistics, computer models, …
- no one person can be expert in all these!
- it takes ***time*** and ***effort*** to develop the necessary interdisciplinary teams

Process

YCCSA

- York Centre for Complex Systems Analysis
- we are an **interdisciplinary** team of 90+ staff and students
  - Biology – Chemistry – Computer Science – Electronics – English – Environment – History of Art – Management – Mathematics – Physics …
  - we have associate members from other universities :
    - Birmingham – Cambridge – Durham – Madrid – Manchester – Oxford – Warwick …
- we focus on real world complex systems requiring interdisciplinary solutions – and a **common** mindset :
  - **systems thinking**
    - "***the totality is not, as it were, a mere heap, but the whole is something beside the parts***" – Aristotle, ~350 BCE [tr. W. D. Ross 1924]
    - "***the whole is other than the sum of its parts***"

YCCSA problem domains, and tools

Socio-technical Systems

Resilient Systems

Fisheries

System Forensics

System Simulation

Ecosystem Interactions

Systems Biology

Robotics

Cancer

Gamification

Novel Computation

Immunology

...

Viruses

Complex Systems Science

Networks

Statistics

Bio-inspired Search

Spectroscopy

Mathematical Modelling

Computational Modelling

Swarm Engineering

Narratives

YCCSA's three stage approach

- our process for building **collaboration**, **trust** and **respect**

1. **coming together**
2. **thinking together**
3. **working together**

- developed through EPSRC "Bridging the Gaps" TRANSIT funding, 2008

stage 1 : coming together

- YCCSA process for building collaboration, trust and respect

- weekly “cake” seminars
  - 2 hour format
- reading groups
  - scientists / arts & humanities
- visitors
- workshops, …

- goal : to **learn** each others disciplinary languages and cultures

stage 2 : thinking together

- YCCSA process for building collaboration, trust and respect
- learning the system domain, from the different perspectives
- small, risk-free projects
  - YCCSA summer school
  - pump priming feasibility studies
- goal : to **co-create** research topics, proposals and projects

stage 3 : working together

- YCCSA process for building collaboration, trust and respect

- funded projects
- co-supervising research students across disciplines
  - CS/Biology ; Chemistry/CS ; Maths/Biology ; Electronics/CS ; …
  - goal : teams of students

- goal : to **do *transformative research***

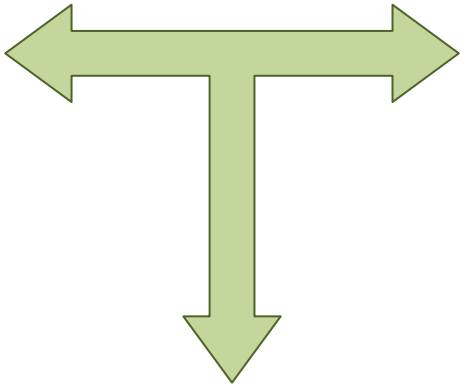
"I have never seen any scientific group working so well together and where communication is flowing so effortlessly across disciplines. What you have is truly remarkable."

— Dr Paolo Dini, Senior Research Fellow,
Dept Media and Communications, London School of Economics

Benefits

btw, it's not for everyone!

- what kind of researcher **are you** / **do you want to be**?
  - all kinds are valid / valuable!
  - all kinds have costs and benefits
- research progress : guarantees *v* excitement
  - incremental development
    - "standing on the shoulders of giants"
  - radical novelty
    - breaking a path through unknown jungle
- disciplinarity : depth *v* breadth
  - single discipline
  - multidisciplinary
  - interdisciplinary
  - transdisciplinary



benefits to research students

- YCCSA research students are fully integrated into our research culture and research activities

- "**YCCSA students are an excellent advertisement for interdisciplinary research … they feel supported and empowered to achieve high-quality research**"

  – external review report

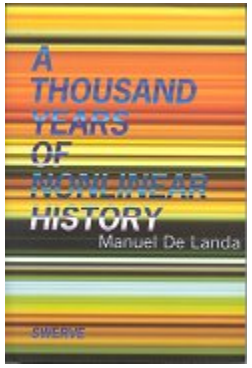
- "**It is an advantage to have to explain research to non-specialists as the questions raised tended to be more unique and challenging.**"

  – YCCSA research student

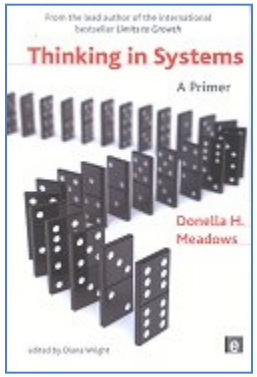
benefits of interdisciplinary working

- interesting way to work
  - it you like that sort of thing …
- no one is expert in all domains and techniques
- so, everyone has something to learn from everyone else
  - ***no room for monster egos***
    - everyone learns : students can teach their supervisors
    - learn to be comfortable saying "I don't understand"
  - ***joy of learning***, and of building a shared understanding
- excitement of research that is ***other than the sum of its parts***

further reading



- Manuel De Landa. *A Thousand Years of Nonlinear History*. Zone Books. 1997



- Donella H. Meadows. *Thinking in Systems: a primer*. Earthscan. 2008

- Basarab Nicolescu. The transdisciplinary evolution of the University. 1999.