

# Complexity Science

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**Aim:** Put into context the notion of complexity.

**Learning outcomes** – After the presentation you should know:

- the difference between reductionism & complexity science
- various examples of systems displaying complexity
- how to pursue complexity science studies at Imperial.

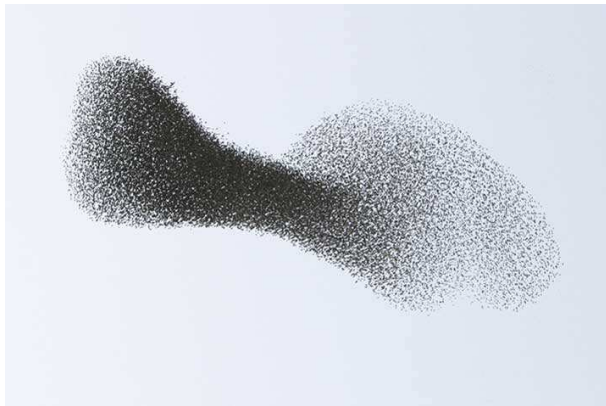
## Outline

- 1 Reductionism vs complexity science (holism)
- 2 Examples of systems displaying complexity
  - Flocking birds – behave ‘as one’
  - Fireflies – synchronise and flash in unison
  - Internet – network with non-trivial structure emerges
  - Network of interacting species – biological extinctions
  - Stock market – large fluctuations emerge spontaneously
- 3 How to study complexity science at Imperial?

- **Reductionism** – dominating approach in the 20th century.  
Philosophical position:  
The complex world is **nothing but** the sum of its parts.
- True for systems consisting of **non-interacting** parts.
- False generalisation: If we understand the smallest objects, we understand everything – Just combine the lego-blocks.  
String theory → Particle physics  
→ Astrophysics  
→ Geophysics  
→ Biology  
→ Humans  
→ History, Economics
- In practice, impossible to connect the disciplines, so scientists worked only within each discipline.

- **Complexity** – dominating approach in the 21st century?  
Philosophical position:  
The complex world is **more than** the sum of its parts.
- True for systems consisting of interacting parts that influence (indirectly) one another.
- **Complexity science** is the study of systems consisting of many (locally) interacting units that give rise to **emergent behaviour** which cannot be understood by studying a single unit in isolation.

- Flocking birds – they have no leader. The ability of starlings to shift shape 'as one' is an emergent collective behavior.



National Geographic, July 2007.

Photo by Manuel Presti.

Reductionism vs complexity science (holism)

Examples of systems displaying complexity

How to study complexity science at Imperial?

Flocking birds – behave 'as one'

Fireflies – synchronise and flash in unison

Internet – network with non-trivial structure emerges

Network of interacting species – biological extinctions

Stock market – large fluctuations emerge spontaneously

- A tree ablaze with fireflies in Indonesia blinks on and off as each insect adjusts its flashes to match the others.



National Geographic, July 2007.  
Photo by Mitsuhiro Imamori.

Minden Pictures.

Reductionism vs complexity science (holism)

Examples of systems displaying complexity

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Flocking birds – behave 'as one'

Fireflies – synchronise and flash in unison

Internet – network with non-trivial structure emerges

Network of interacting species – biological extinctions

Stock market – large fluctuations emerge spontaneously

- Internet – network with structure emerges spontaneously.

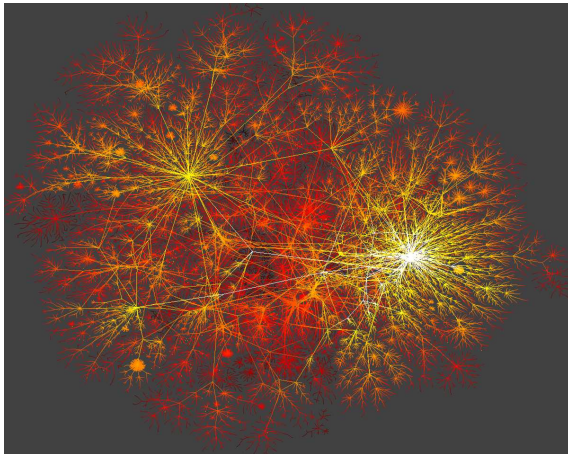


Figure courtesy of K.C. Claffy.



Reductionism vs complexity science (holism)

Examples of systems displaying complexity

How to study complexity science at Imperial?

Flocking birds – behave 'as one'

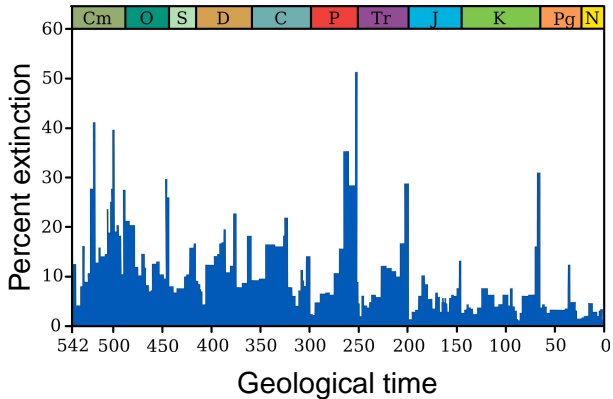
Fireflies – synchronise and flash in unison

Internet – network with non-trivial structure emerges

Network of interacting species – biological extinctions

Stock market – large fluctuations emerge spontaneously

- Biological extinctions over last 542 million years.



Reductionism vs complexity science (holism)

Examples of systems displaying complexity

How to study complexity science at Imperial?

Flocking birds – behave 'as one'

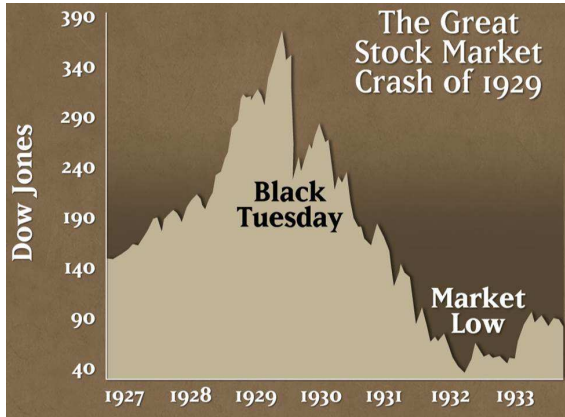
Fireflies – synchronise and flash in unison

Internet – network with non-trivial structure emerges

Network of interacting species – biological extinctions

Stock market – large fluctuations emerge spontaneously

- Fluctuations in the Dow Jones index



- **Undergraduate studies at Imperial.**
  - BSc degree – 3 year degree.  
BSc (1 semester) project in year 3.
  - MSci degree – 4 year degree  
MSci (2 semester) project in year 4.
  - For the UG degrees, possible to choose option courses:  
Eg. “Complexity & Networks”; “Statistical Mechanics”.
- **Postgraduate studies at Imperial.**
  - MSc in Complexity Science – 1 year degree.  
Probably available from October 2015 onwards.
  - PhD studies – 3.5 year degree.

Thank you for listening!  
Questions are most welcome!