

Lectures 11, 12

- William Bialek: Fundamental physical limits on the performance of biological systems (2018)

"for the application of general theoretical principles of physics and information theory to help understand and predict how biological systems function across a variety of scales, from molecules and cells, to brains and animal collectives."

- Irene Giardina and Andrea Cavagna: Statistical physics of flocks and swarms (2021)

"For the incisive combination of observation, analysis, and theory to elucidate the beautiful statistical physics problems underlying collective behavior in natural flocks and swarms."

Giardina & Cavagna: the questions

Historically:

Why do individuals gather together to form groups?

Is there an evolutionary reason or biological function to grouping?

How do local interactions of individuals give rise to patterns, collective behavior on the large scale?

What distinguishes collective cooperativity from jamming?

Analogous systems in different contexts: birds, granular materials, robots, human crowds, stock market

Inverse problem: deduce the individual interactions from the large scale

Giardina & Cavagna: the discovery

Irene Giardina (PNAS **105**, 4 (2008) 1232-1237, 13:25-35:37; 40:20-59:11)

Interaction ruling animal collective behavior depends on topological distance

<https://www.youtube.com/watch?v=lym4GJsPJVQ>

- What was the scientific breakthrough?
- Can you identify a key insight(s) needed for the breakthrough?
- How do the findings align with or challenge existing models?
- What is the most speculative (least grounded in fact) conclusion drawn?
- What are some potential implications of their findings?

Collective behavior: Outlook

Andrea Cavagna (Personal history, 15 mins)

<https://www.youtube.com/watch?v=vDE3D8WJ7Wo>

Optional:

Irene Giardina (Personal history, 18 mins)

<https://www.youtube.com/watch?v=VYGfo9xM8iY>

Jennifer Zallen (cells in fruit fly) <https://www.ibiology.org/development-and-stem-cells/building-multicellular-structures-development-new-roles-toll-receptors/> (0-12 min)

Radhika Nagpal (collective artificial intelligence)

<https://www.youtube.com/watch?v=ObRocfcPhHU> (10 min)