Emergence

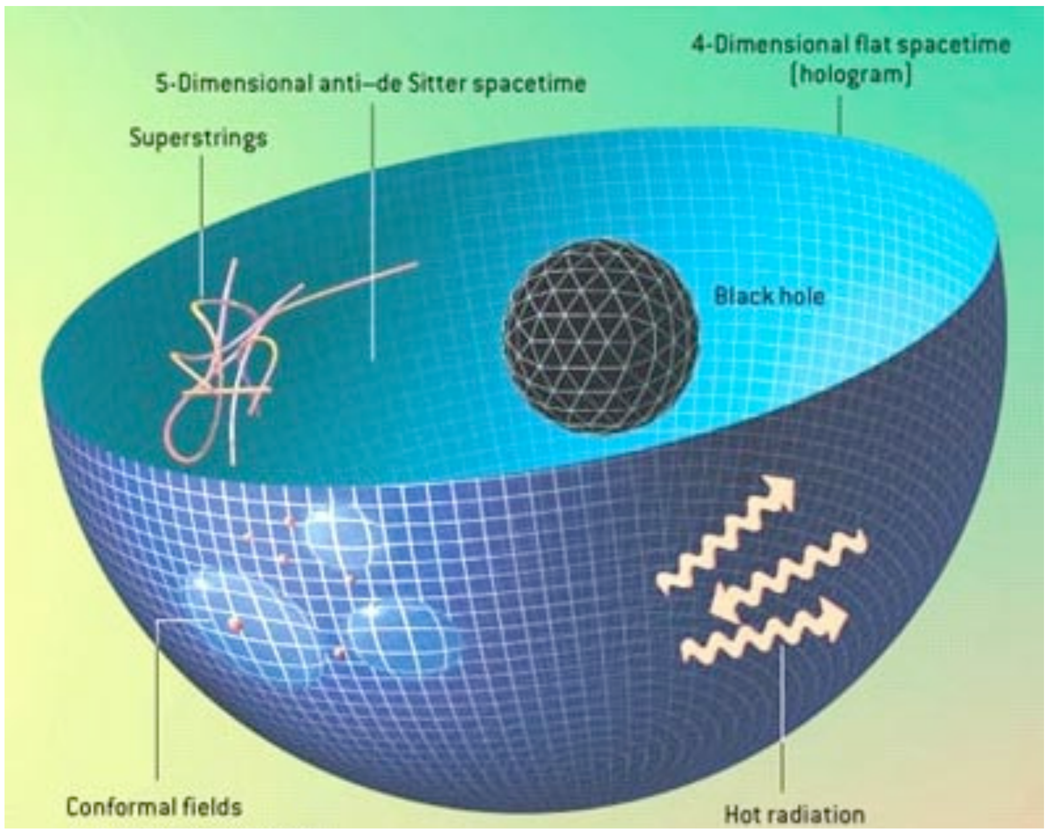
Part II: Coarse graining, Renormalization and all that

What is Emergence, again?

- (1) Simple to complex
- Pattern formation (e.g. Turing instability)

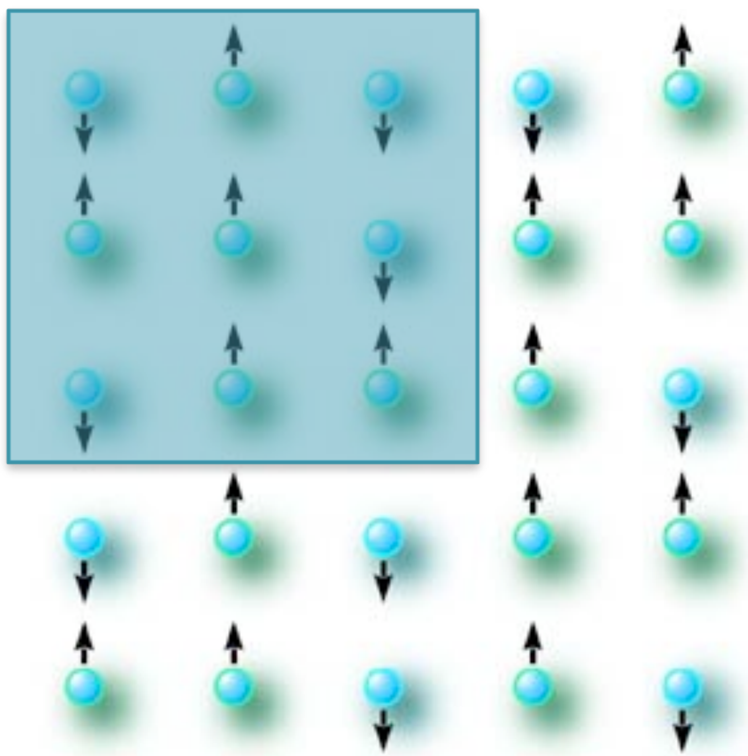
What is Emergence, again?

- (2) Complex to complex
- Qualitatively different degrees of freedom



What is Emergence, again?

- (3) Complex to Simple
- Reduction in degrees of freedom

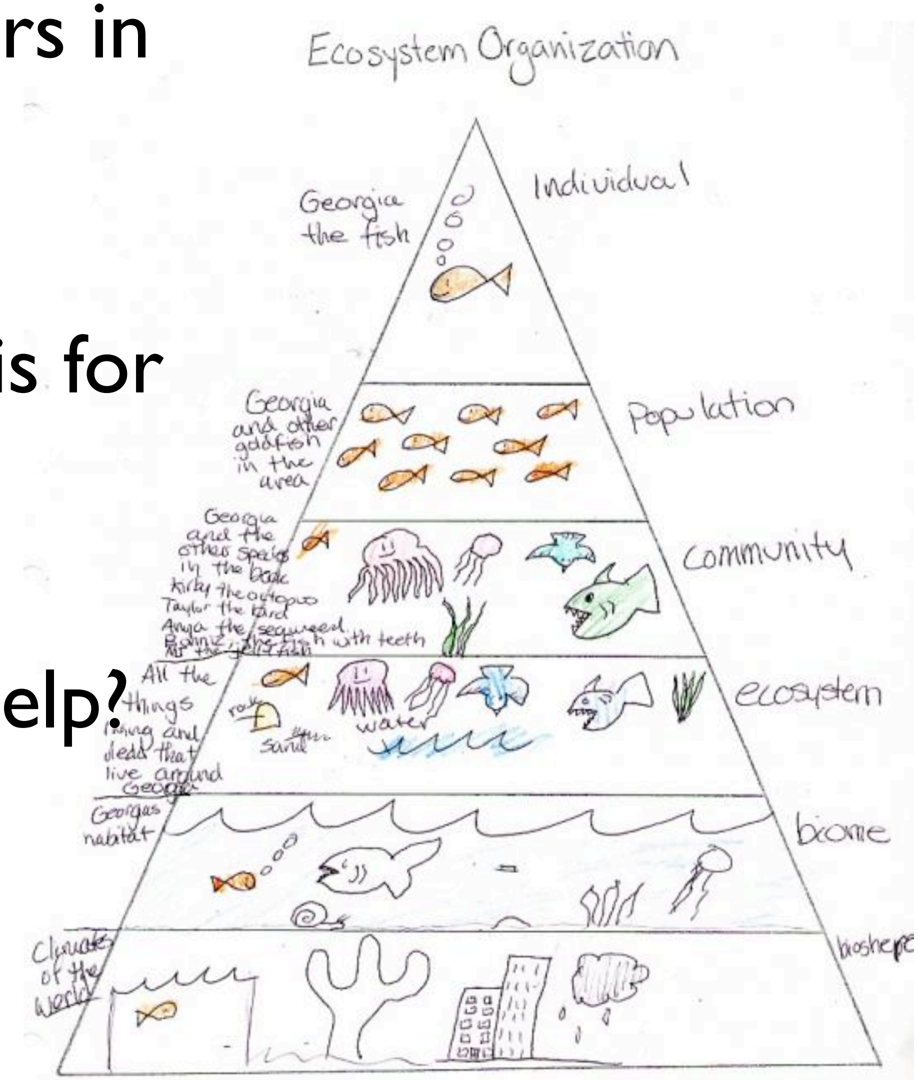


What is Emergence, again?

- Are these the same phenomenon?
- Is there a unifying principle?
- Why should we care?

What is Emergence, again?

- Aggregation occurs in nature
- We often take this for granted
- Can math tools help?



Symmetry

- Ising Model

- m(x) => -m(x)

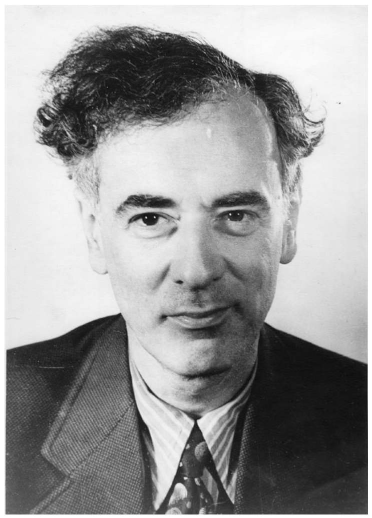
$$\uparrow\ \downarrow\ \uparrow\ \downarrow\ \downarrow\ \Longleftrightarrow\ \downarrow\ \uparrow\ \downarrow\ \uparrow\ \uparrow$$

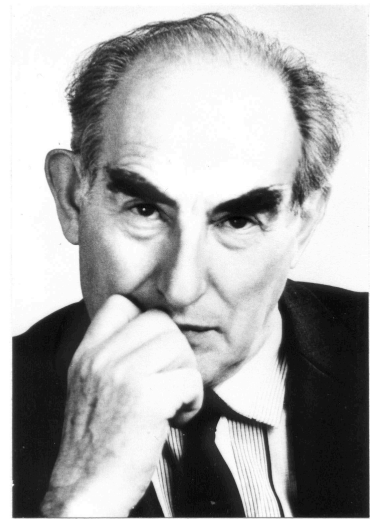
- Configuration changes but we know fundamental rules should stay the same

Symmetry

- What about more complex symmetries?
- Rotational symmetry
- $m(x) = (m_1(x), m_2(x))$
- Rotational matrices form a *group*

Landau and Ginzburg

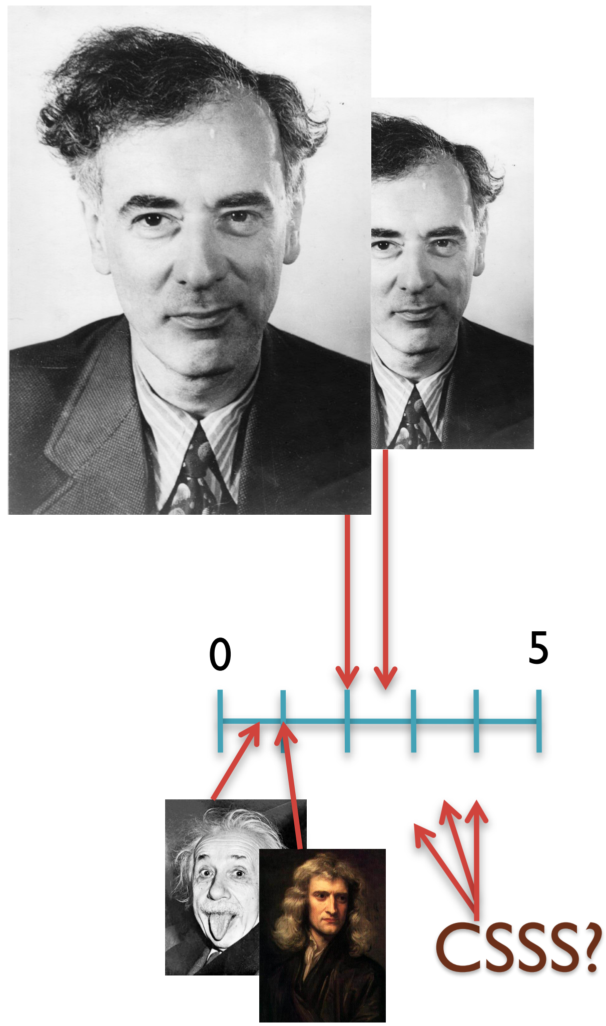




Nobel 1962

Nobel 2003

Landau and Ginzburg



Mean Field Theory

- Any system with the right symmetry, same Landau-Ginzburg theory

- But infinitely many parameters?

Mean Field Theory

- Good point: universal
- $M \sim (T - T_c)^{1/2}$
- Bad point: wrong

Coarse Graining & Renormalization

Kenneth Wilson
Nobel 1982

Coarse Graining & Renormalization

Molecular Renormalization Group Coarse-Graining of Electrolyte Solutions: Application to Aqueous NaCl and KCl

Alexey Savelyev and Garegin A. Papoian*

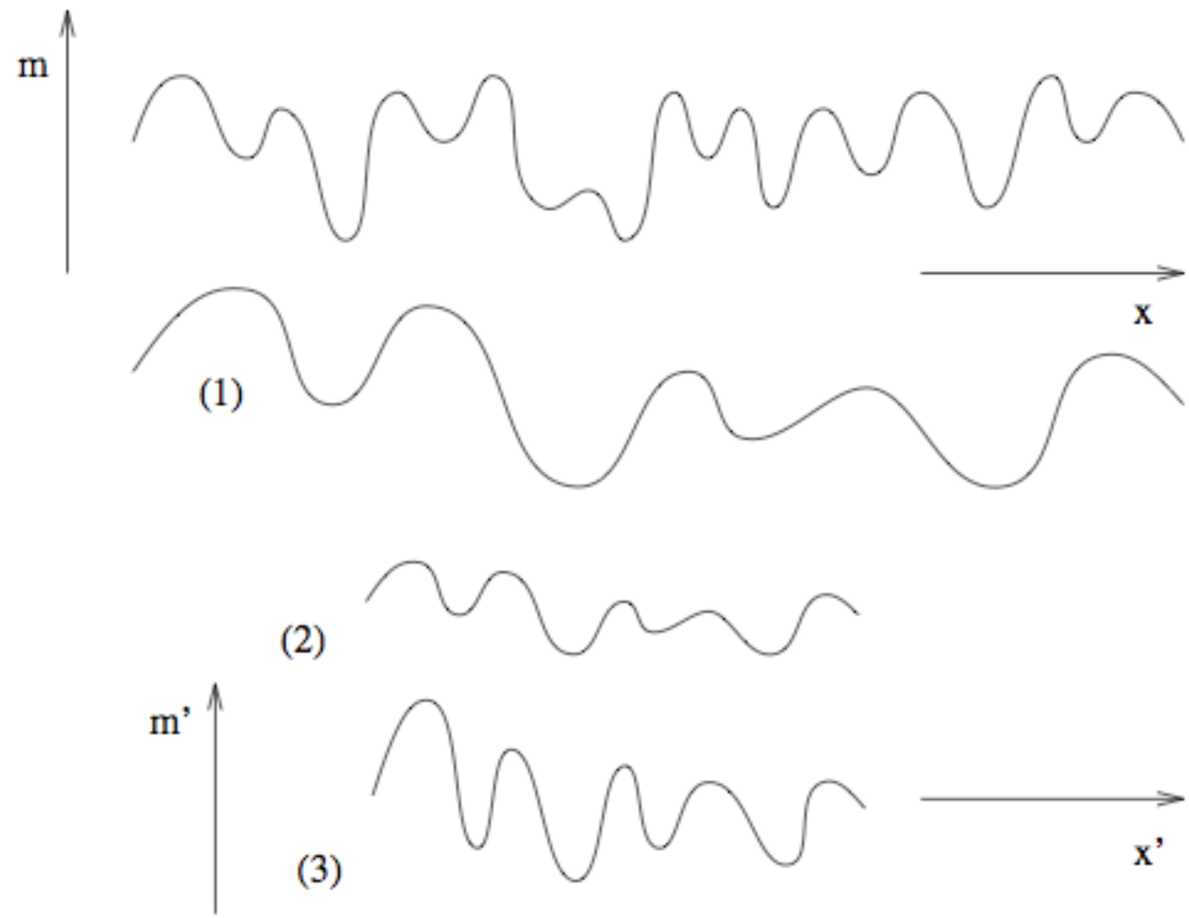
Renormalization Relations for Scale Transformation In Ecology

Bruce T. Milne and Alan R. Johnson

Renormalization group of probabilistic cellular automata with one absorbing state

M. J. de Oliveira and J. E. Satulovsky

Coarse Graining & Renormalization



Coarse Graining & Renormalization

- How does this help us?
- Many systems mapped onto same behavior under coarse-graining
- Signatures: power-law scaling (or asymptotically power-law at large scales)

The Species-Area Relationship

- Number of distinct species as a function of area
- Extinction Estimates
- Also: genetic diversity, artifact-area relationship…

The Species-Area Relationship