INFORMATION THEORY AND PATTERN FORMATION IN BIOLOGICAL SYSTEMS

http://physics.ucsd.edu/students/courses/winter2015/physics273/

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Office: Urey Hall 7262
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Time and Location: Tue and Thu
09:30 am – 10:50 am
Mayer Hall 2623

Homework: Around 7 problem sets, with about a week to do each.

There will be a final project or an exam problem
Grade will be a combination of homework, final project/exam and participation

Historical perspective

Messages and information have been transmitted for a long while…

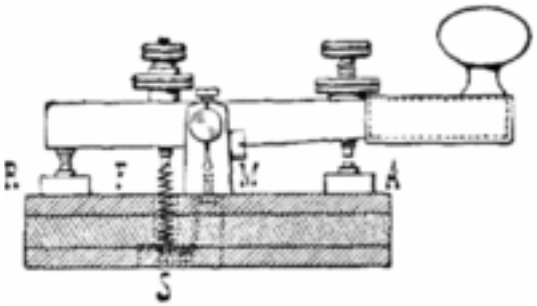
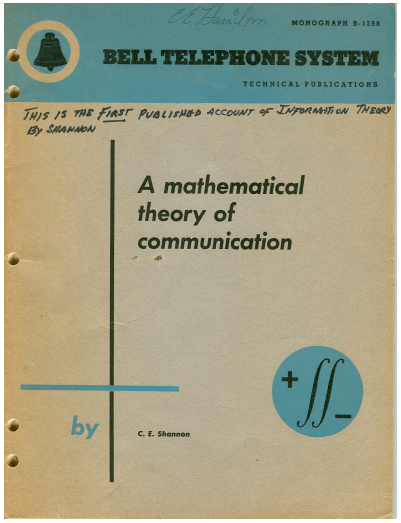


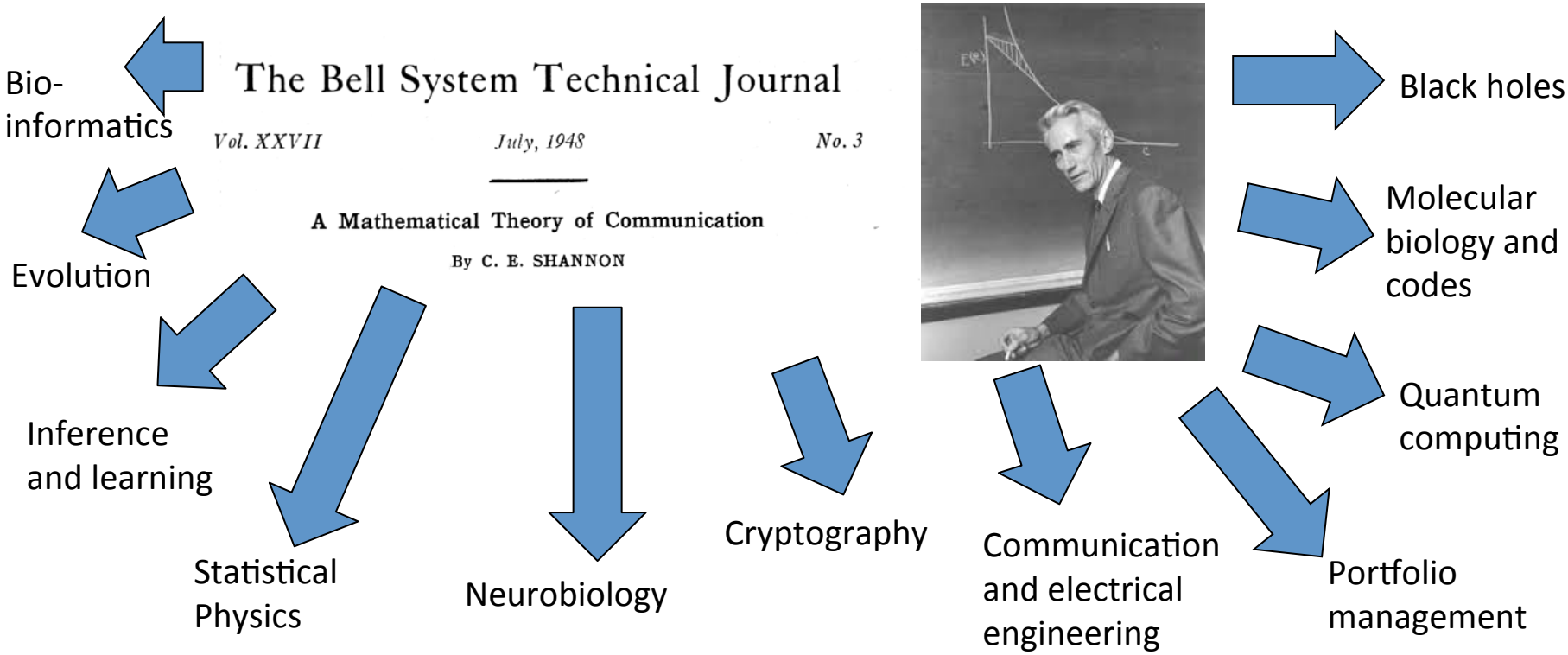
Fig. 6.

Morse ≈1840

Telegraph lines ≈1891



"The fundamental problem of communication is that of reproducing at one point, either exactly or approximately, a message selected at another point."

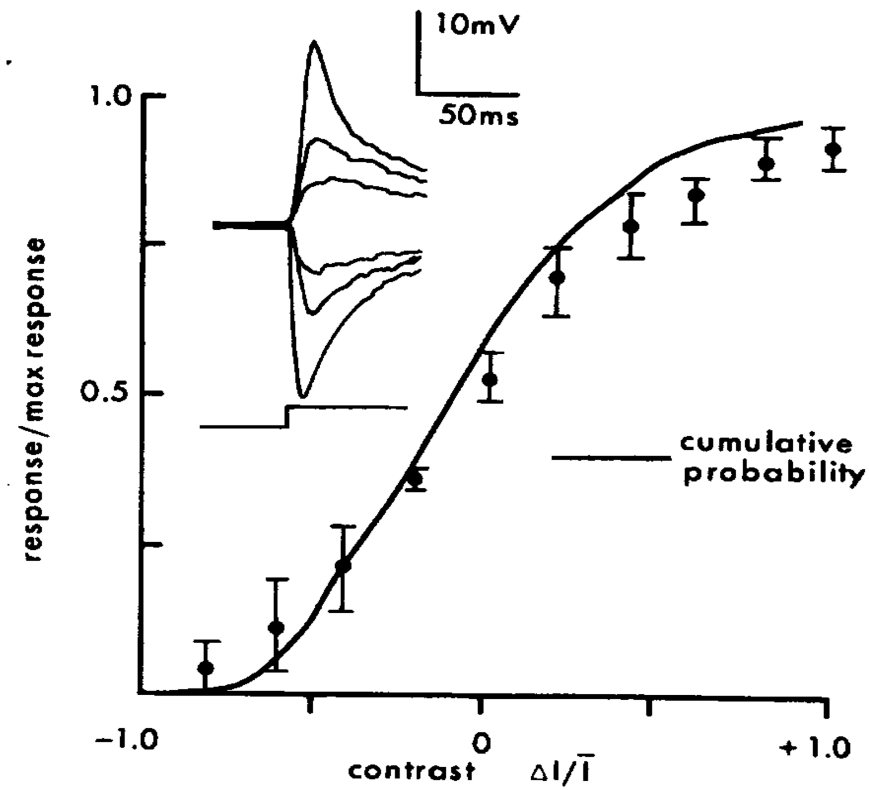


Introduction to information theory

- Definitions, examples and discussion of basic quantities: Shannon, joint, conditional and relative entropies; mutual information
- $H = -\sum p_i \log p_i$ and Shannon's grouping property
- Bits

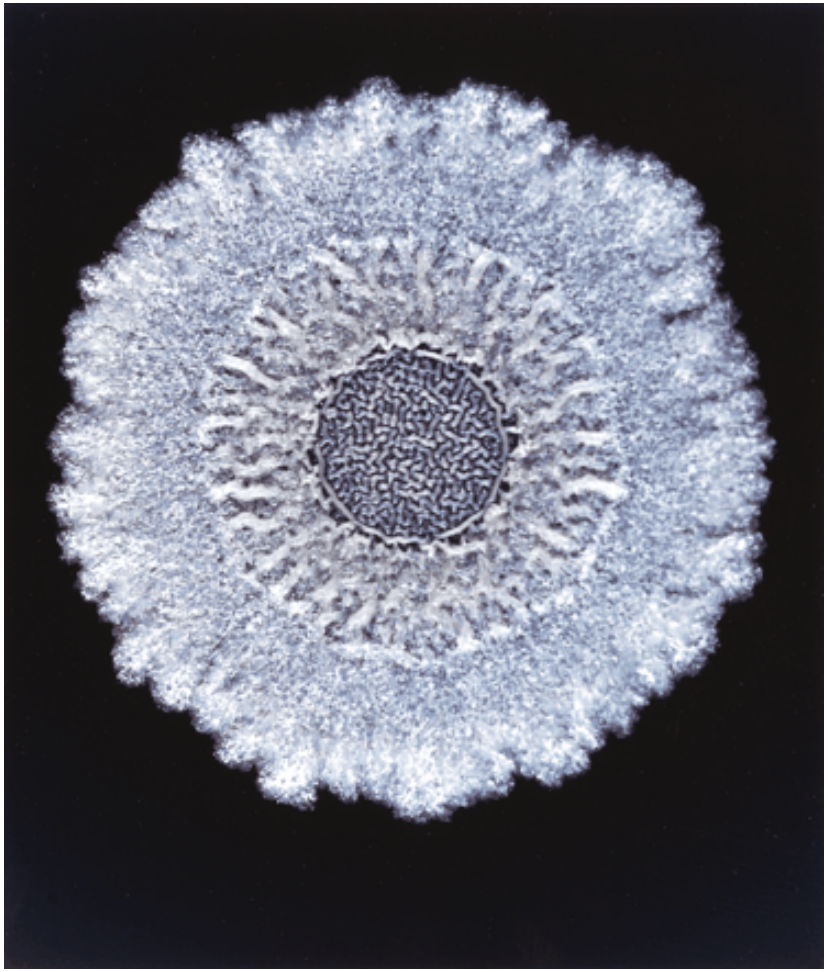
Cover & Thomas, Elements of Information Theory

Information transmission in Large Monopolar Cells of the blowfly visual system (Laughlin)



Prediction yielded by
Max I(contrast input signal, firing rate output signal)

Kelly's horse races, proportional betting and bacterial growth



W+H=constant

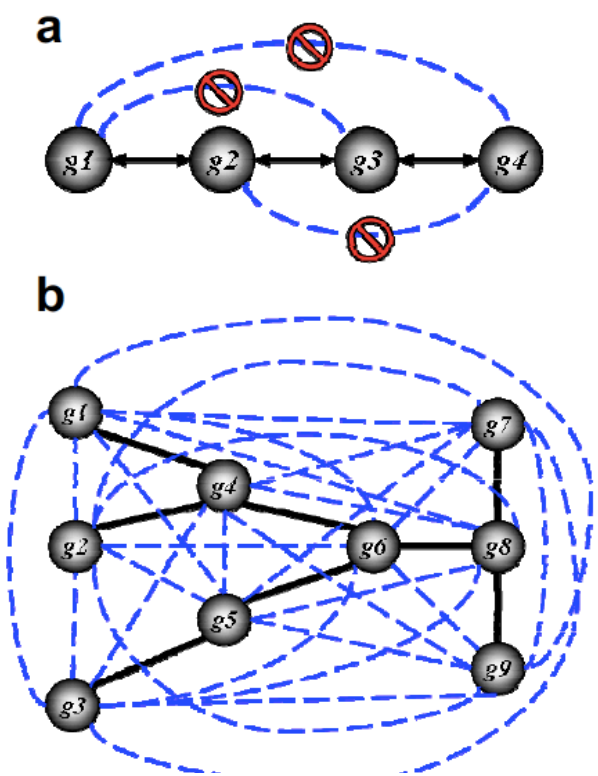
W=wealth expected growth
H=entropy of estimated outcomes

Data Processing Inequality and Applications to Bioinformatics

$$X \longrightarrow Y \longrightarrow Z$$

$$I(X,Z) \leq I(X,Y)$$

No miracles: if you process data, e.g. Z=f(Y) you cannot create extra information even though you might illustrate it much more clearly

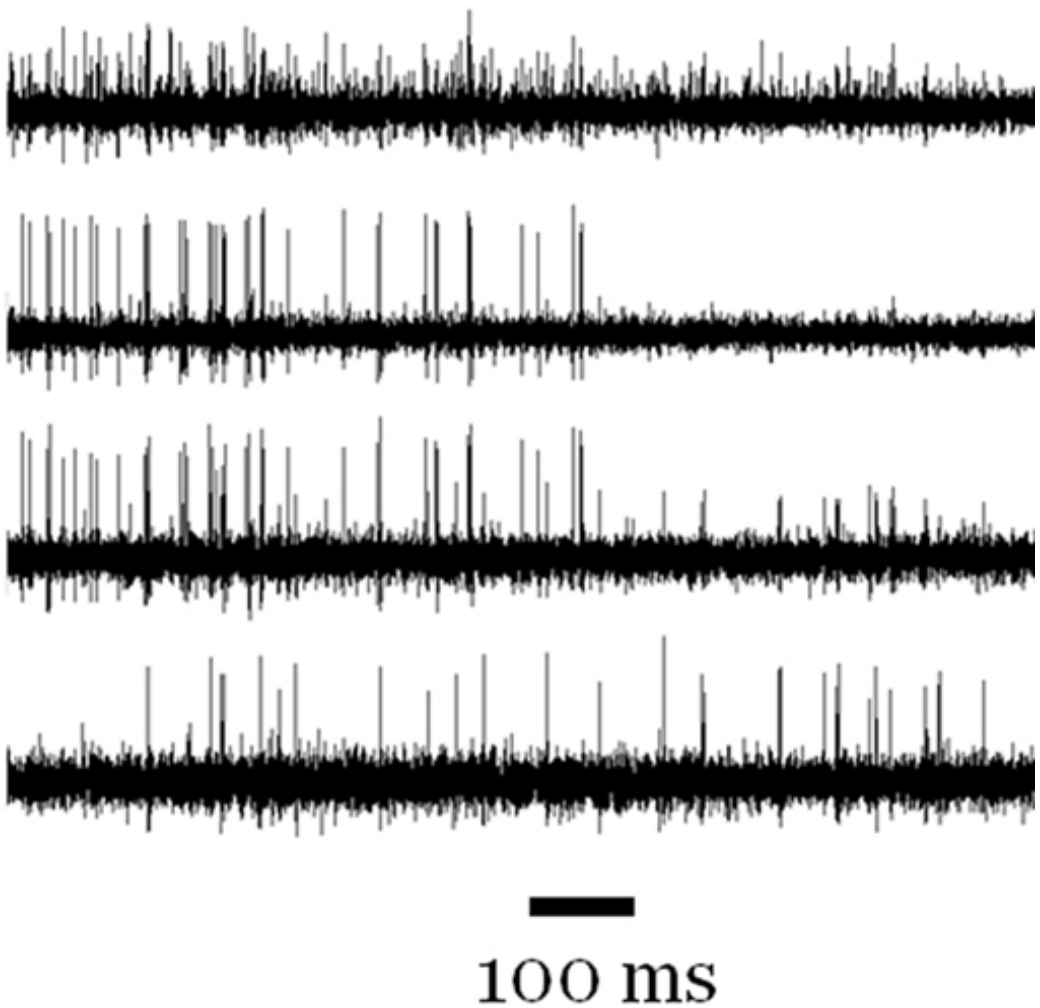


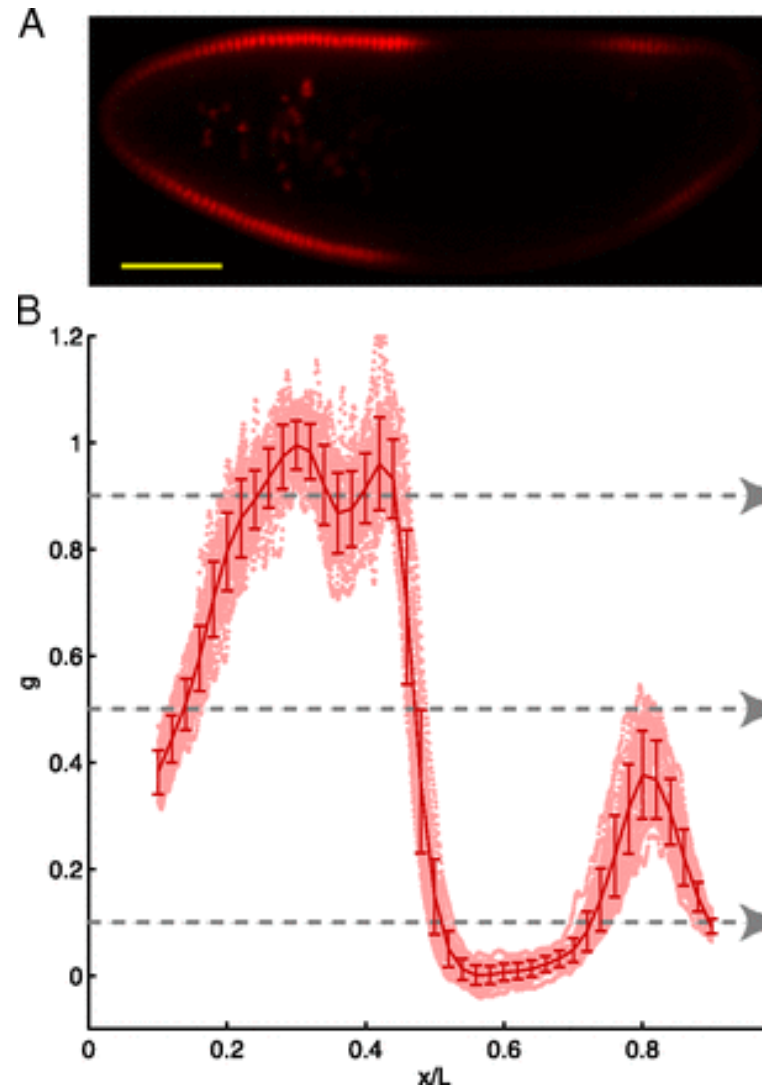
ARACNE: An Algorithm for the Reconstruction of Gene Regulatory Networks in a Mammalian Cellular Context

Adam A Margolin[1,2], Ilya Nemenman[2], Katia Basso[3], Chris Wiggins[2,4], Gustavo Stolovitzky[5], Riccardo Dalla Favera[3] and Andrea Califano*[1,2]

BMC Bioinformatics 2006, **7**(Suppl 1):S7

Entropy of spike trains and expression profiles

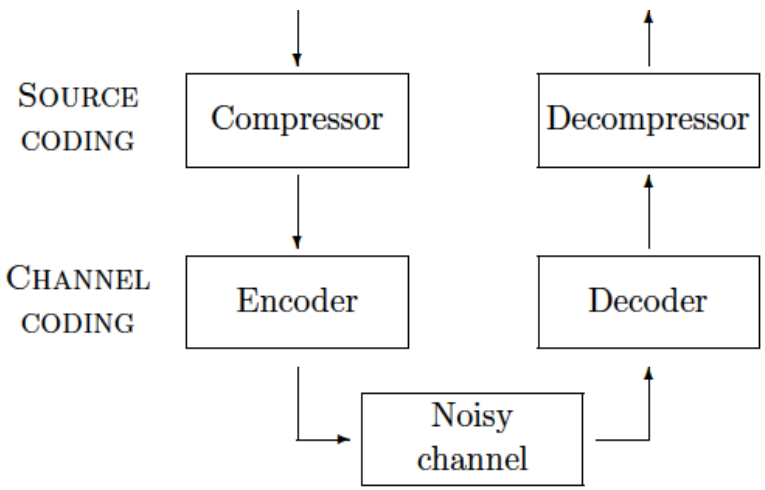




Specific points we shall cover along the way

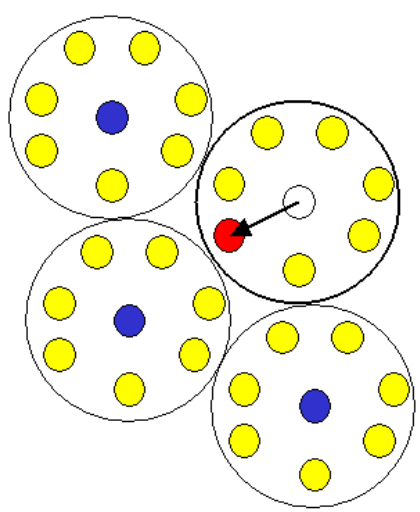
- Asymptotic Equipartition Property and source coding theorem
- Joint typicality
- Measuring entropies from real data
- Entropy rates and Markov processes
- Length of messages and entropy. Compression codes?
- Water-filling solution and optimal frequency responses
- Fisher information and inference

Shannon's channel theorem



Transmission **with no error** in the presence of noise!

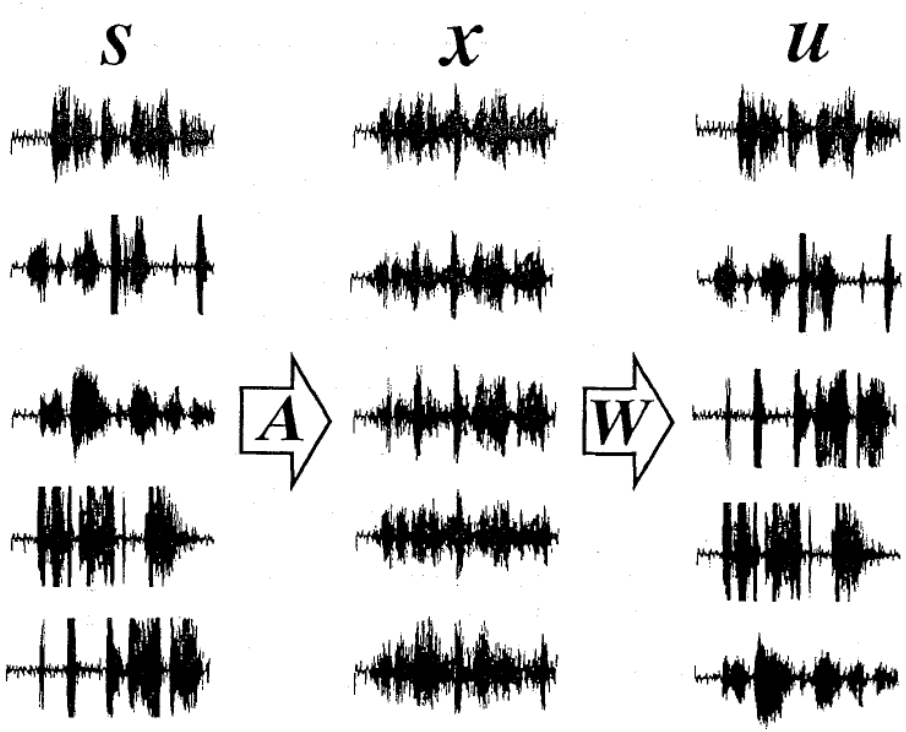
Rate ≤ Channel Capacity



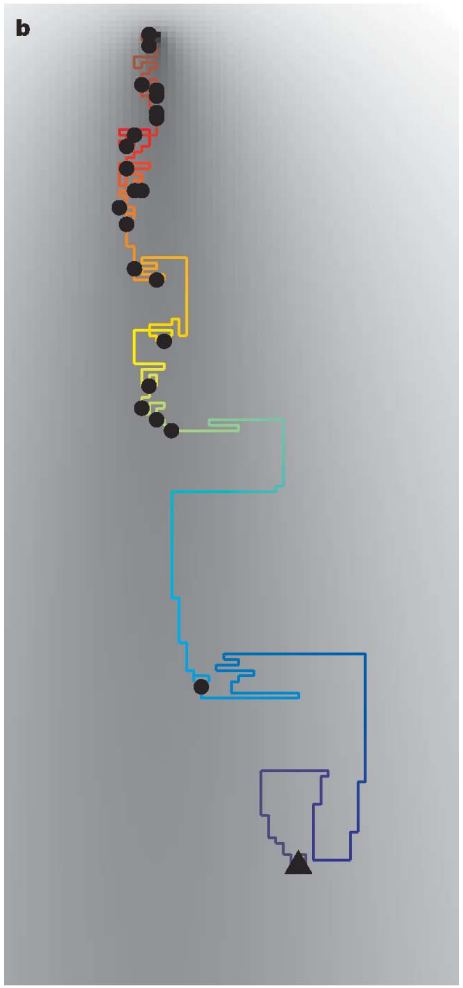
The corrupted word still lies in its original unit sphere. The center of this sphere is the corrected word.

Exploiting information to perform functions

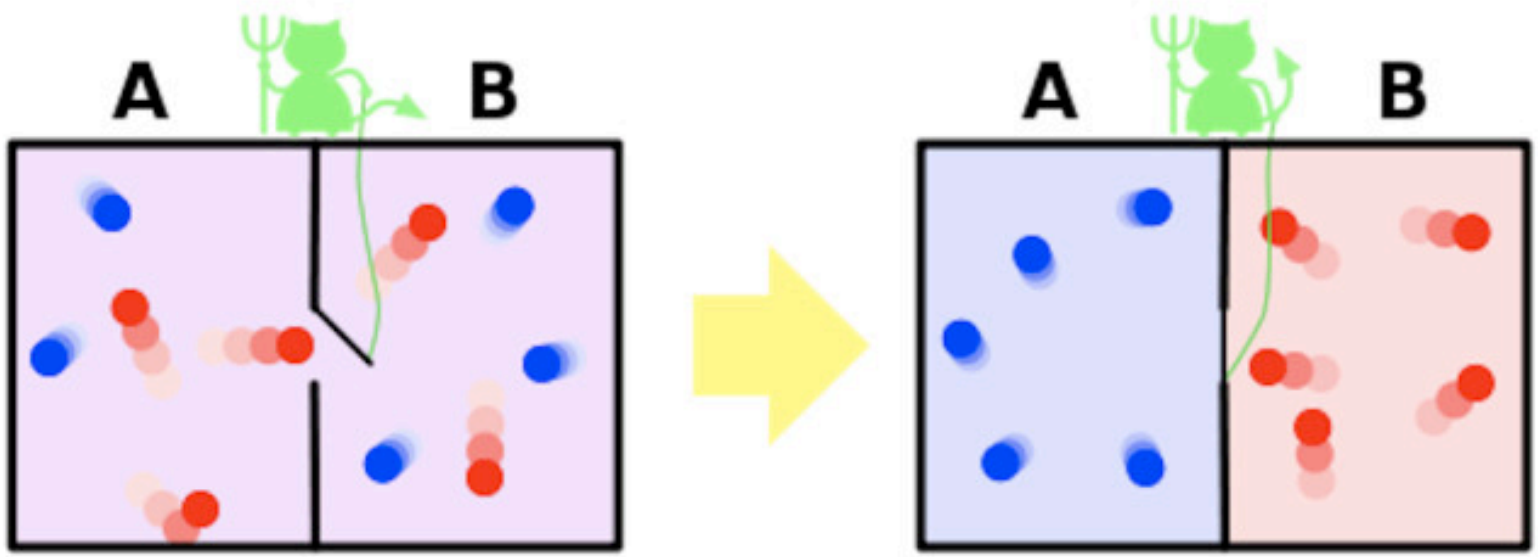
Infomax and ICA



Infotaxis



Information and non-equilibrium statistical physics



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Experimental Observation of the Role of Mutual Information in the Nonequilibrium Dynamics of a Maxwell Demon

Pattern Formation

Turing mechanism for pattern formation

Waves (biological): pushed, pulled and all that