Information

Reading: *Complexity: A Guided Tour*, Chapter 3

Recap: Core disciplines of the science of complexity

Dynamics: The study of continually changing structure and behavior of systems

Information: The study of representation, symbols, and communication

Computation: The study of how systems process information and act on the results

Evolution: The study of how systems adapt to constantly changing environments

Information

Motivating questions:

- What are “order” and “disorder”?
- What are the laws governing these quantities?
- How do we define “information”?
- What is the “ontological status” of information
- How is information signaled between two entities?
- How is information processed to produce “meaning”?

Energy, Work, and Entropy

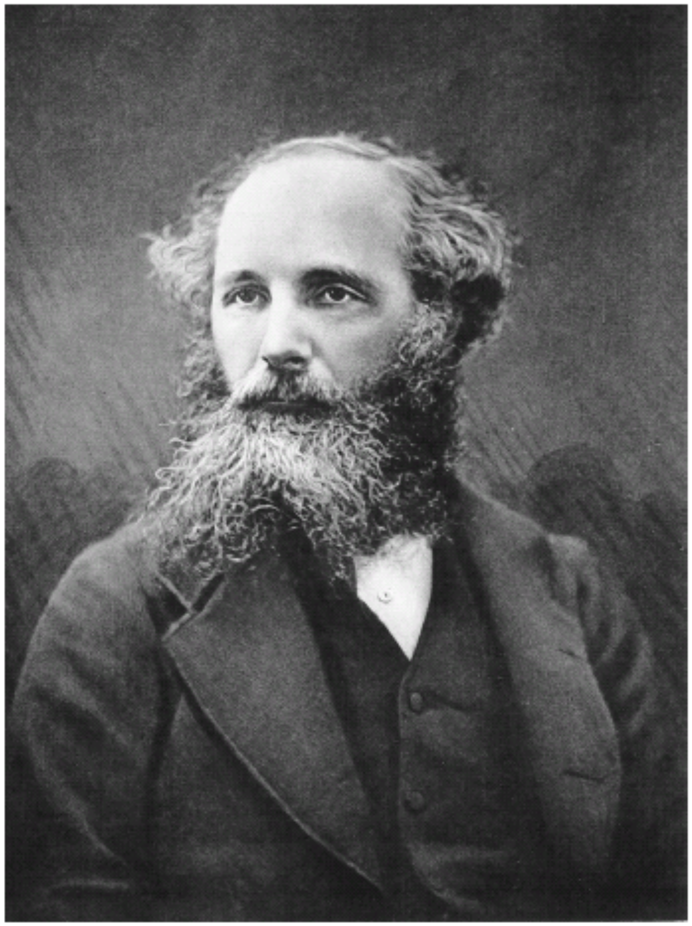
- What is energy?

- What is entropy?

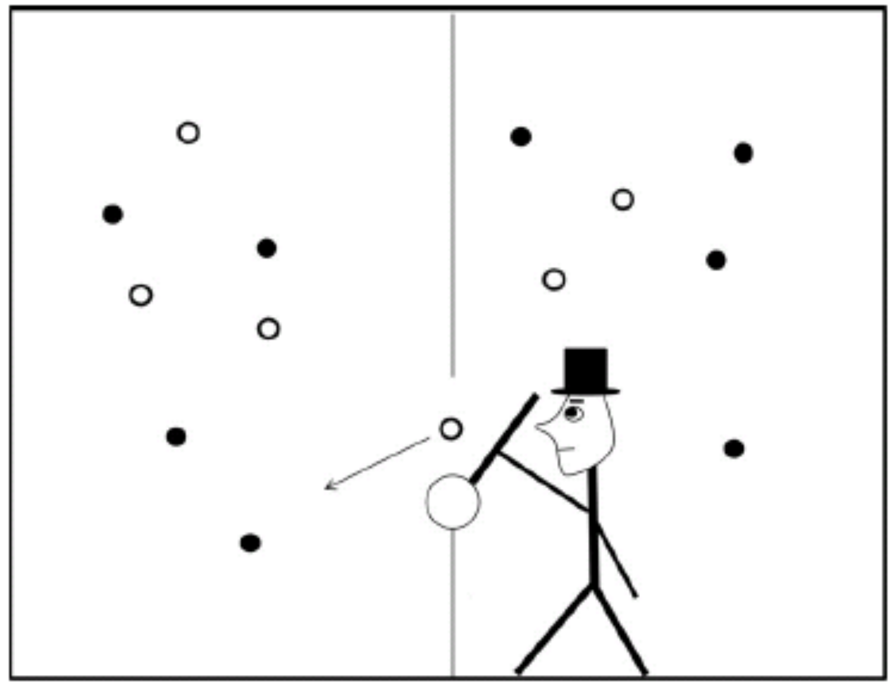
- What are the laws of thermodynamics?

- What is “the arrow of time”?

Maxwell's Demon



James Clerk Maxwell, 1831-1879



See Netlogo simulation

Szilard's solution

Leo Szilard, 1898-1964

Bennett and Landauer's solution

Rolf Landauer, 1927–1999

Charles Bennett, b. 1943

Entropy/Information in Statistical Mechanics

- What is “statistical mechanics”?
- Describe the concepts of “macrostate” and “microstate”

Ludwig Boltzmann, 1844-1906

Entropy/Information in Statistical Mechanics

- What is "statistical mechanics"?

- Describe the concepts of "macrostate" and "microstate".

- Combinatorics of a slot machine

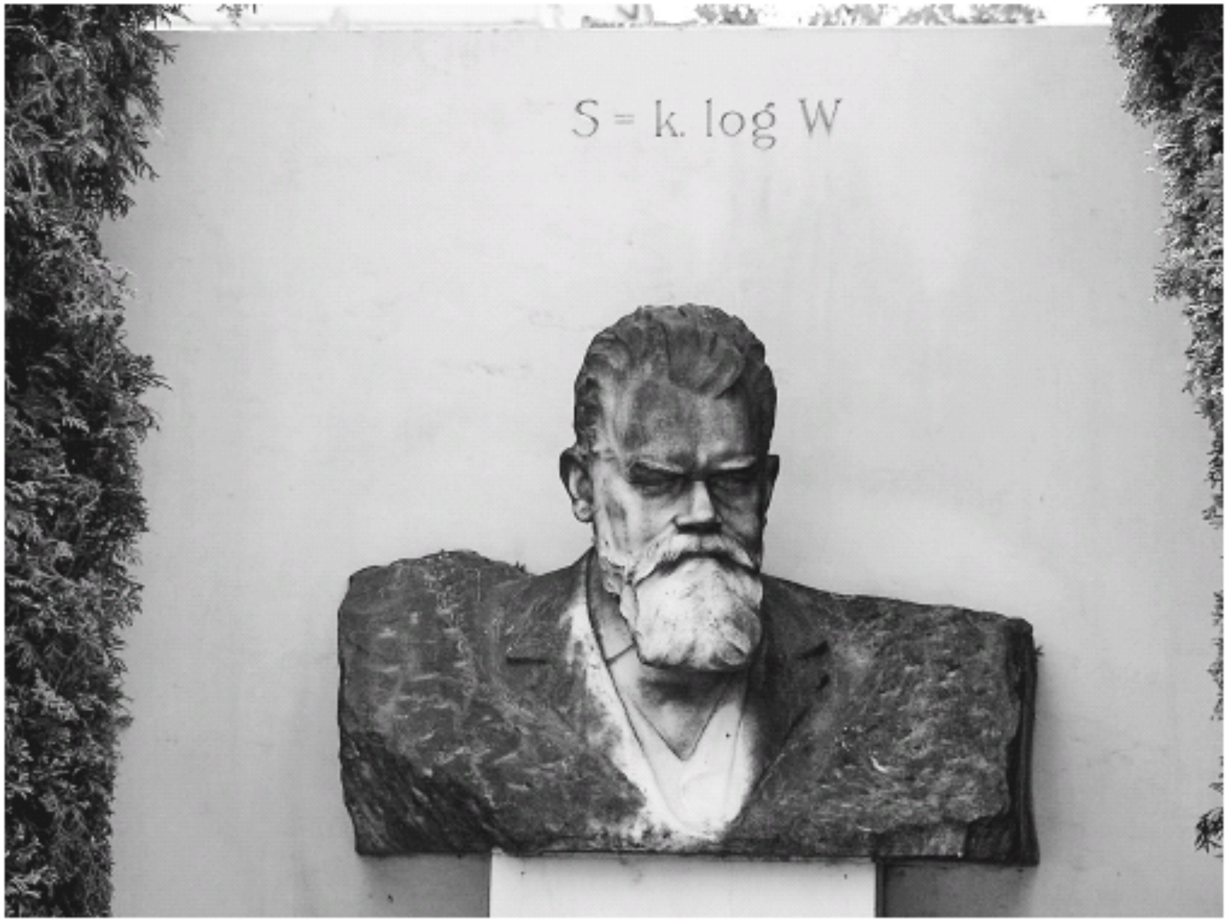
Possible fruits: apple, orange, cherry, pear, lemon
  - Microstates
  - Macrostates

Macrostate: "Three identical fruits"
- How many microstates?

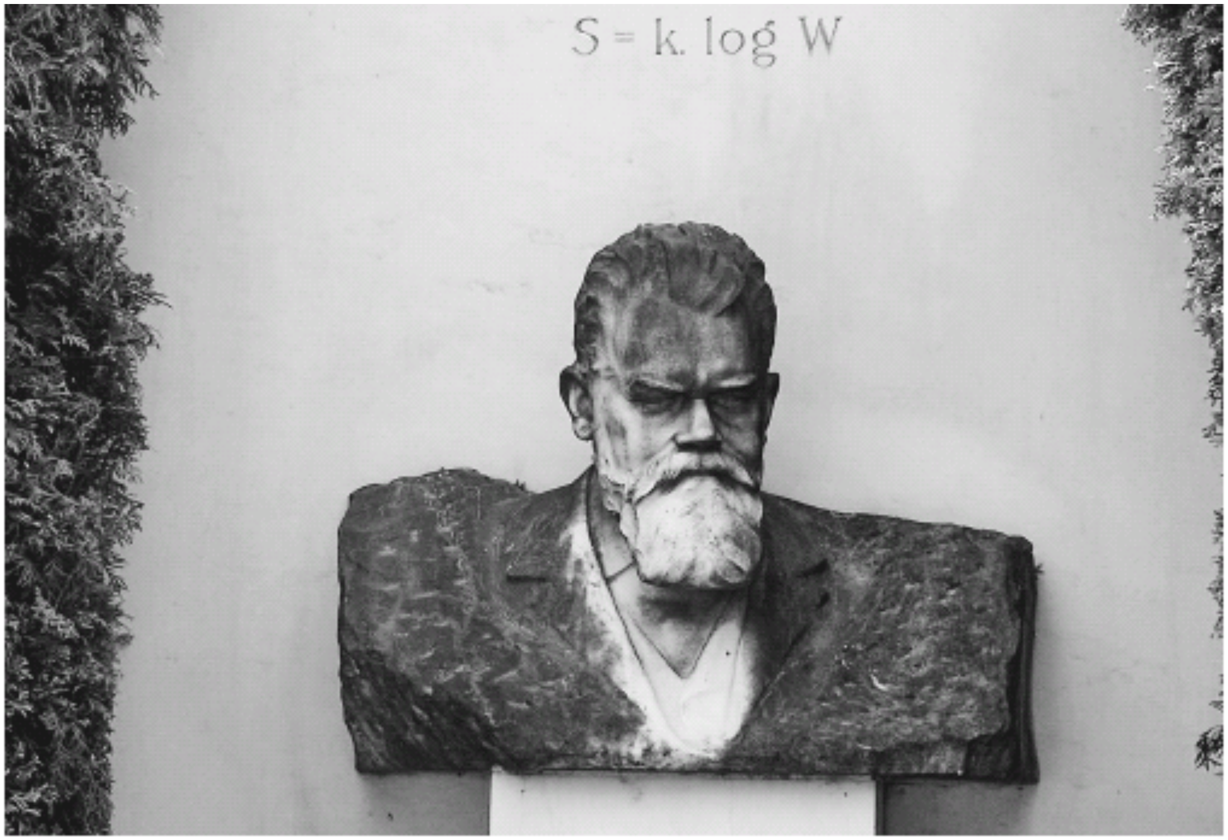
Macrostate: "Exactly one lemon"
- How many microstates?

Macrostate: "At least 2 cherries"
- How many microstates?

Boltzmann's entropy, S



Boltzmann entropy of a macrostate: **natural logarithm of the number of microstates (W) corresponding to that macrostate** (you can ignore the “k”).



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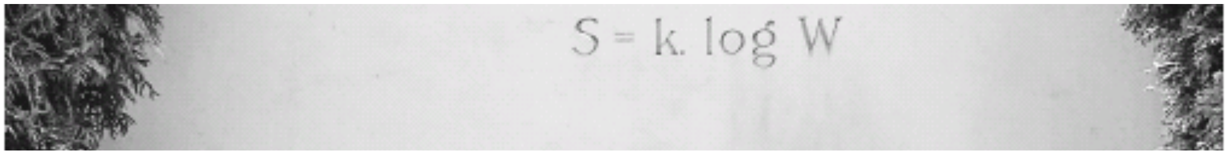
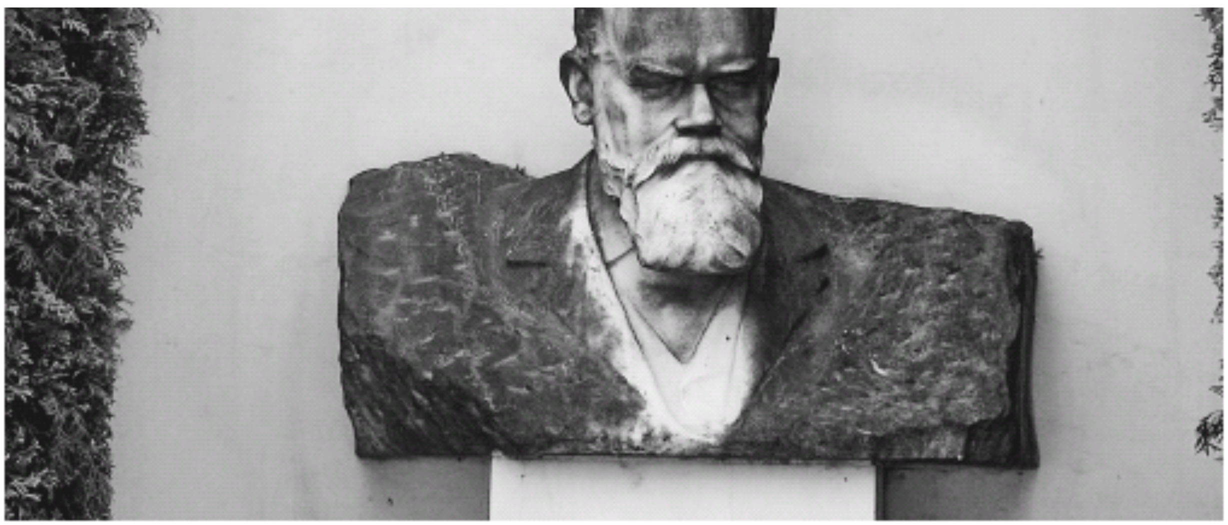


Aside: What is a "natural logarithm"?



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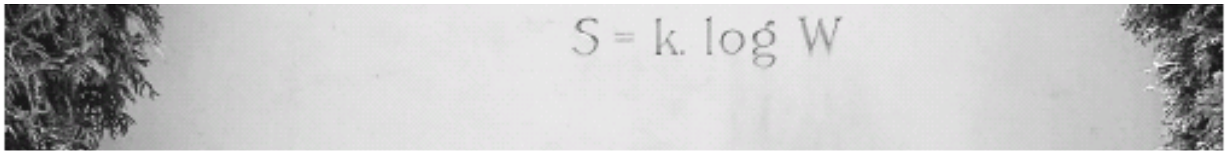

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Examples from slot machine.

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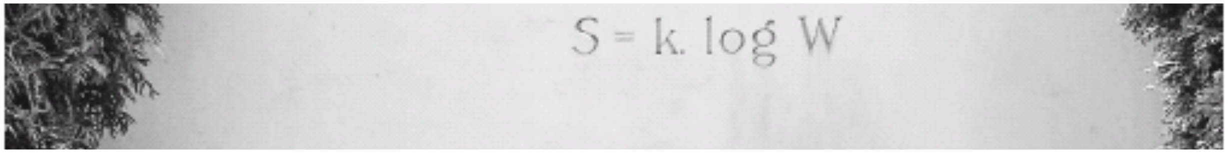

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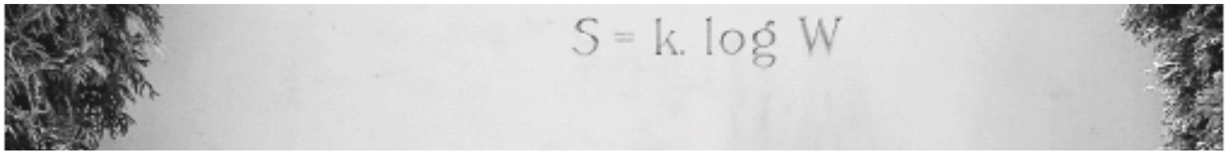

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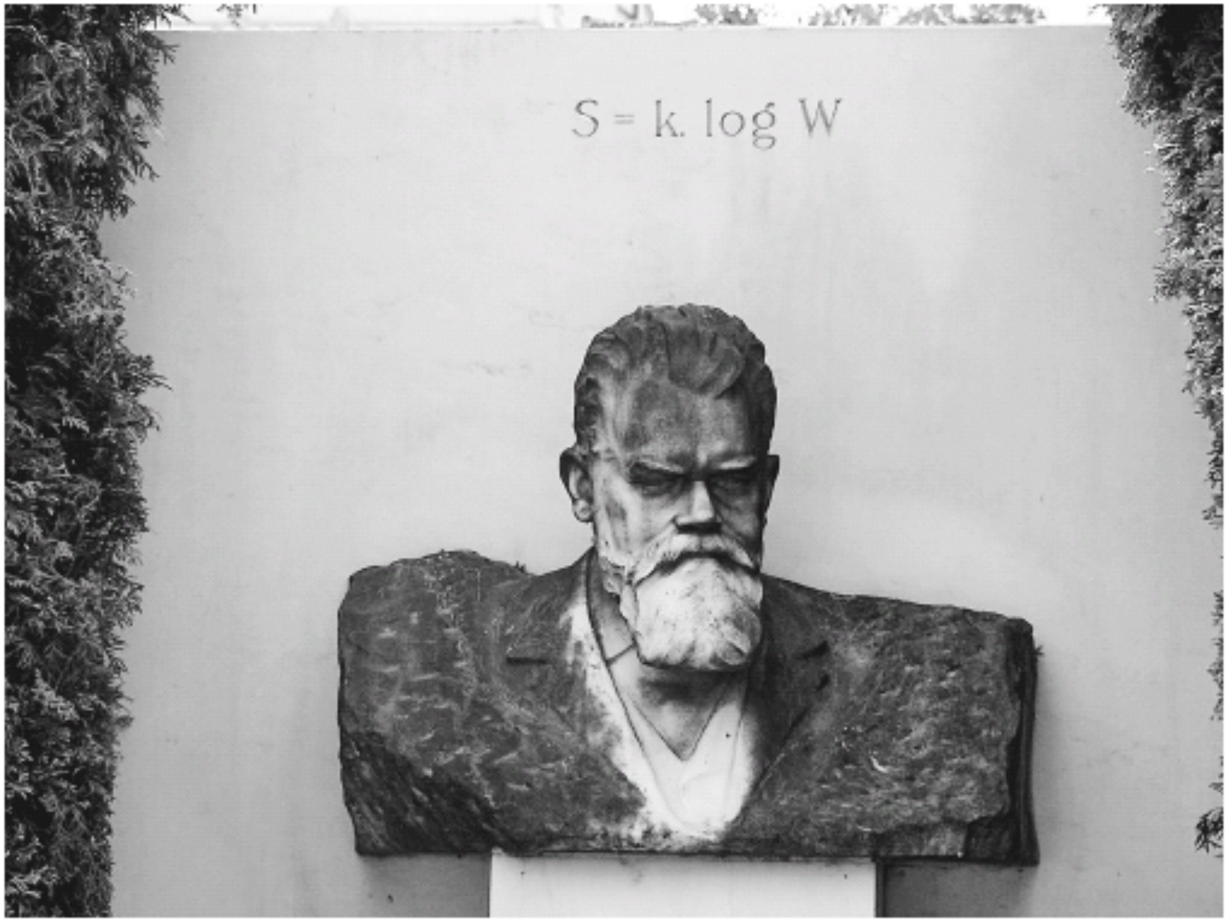
Second Law of Thermodynamics (*à la* Boltzmann):
Nature tends towards more probable macrostates

Boltzmann's entropy, S



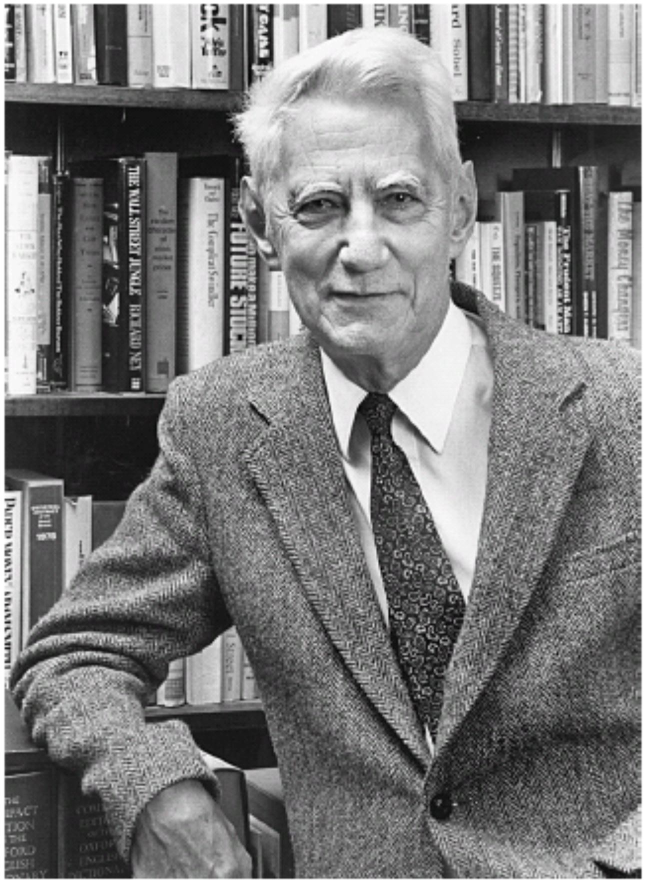
What does this have to do with the "arrow of time"?

Quick review of logarithms

- $\log_{10}$
- $\ln$
- $\log_2$
- $\log_a b = \log_{10} b \,/\, \log_{10} a$

  $= \log_n b \,/\, \log_n a$ for any n

Shannon Information / Entropy



Claude Shannon, 1916-2001

What were his motivations for defining/studying information?

What is a “message source”?

Boltzmann Entropy

$$S(state) = k \ln W$$

Measured in units defined by *k* (often "Joules per Kelvin")

Shannon Information

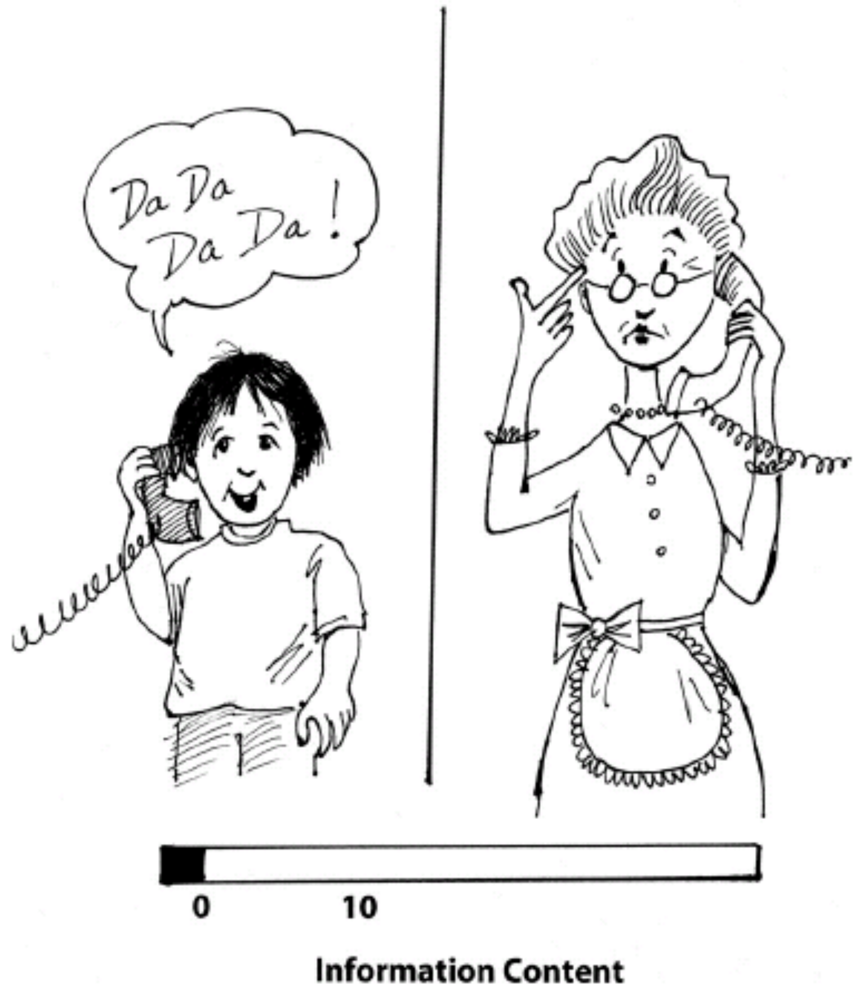
$$H(message\,source) = -\sum_{i=1}^{N} p_i \log_2 p_i$$

Measured in "bits"

Message source has *N* "miscrostates" (or "messages", e.g., words).

p_i is the probability of message *i*.

Messages: {Da}



$$H(Nicky) = -\sum_i p_i \log_2 p_i$$

Messages: {300 words}

$$H(Jake) = -\sum_i p_i \log_2 p_i$$

Netlogo Information-Content Lab

Go over Week 2 homework

Projects Schedule

- By Tuesday, October 18: Project “abstract” due
- By Thursday October 20: Feedback from me
- Week of October 24: Present project abstract to class
- Month of November: Time in class for help on projects
- December 9: Final paper due

Brainstorming on projects