Claude Shannon’s schematic diagram of a general communication system (1948: Figure 1)
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The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.
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Big idea #1:
Communication is a statistical problem
Various incarnations of Shannon's schematic for a general communication system in textbooks.

(a) Fano (1961: Figure 1.1). (b) Ash (1965: Figure 1.1.1). (c) Berger (1971: Figure 1.2.1). (d) two figures from Csiszár and Körner (1997: Figures 2.1 and 2.2). (e) MacKay (2003: Figure 1.6). (f) two figures from Cover and Thomas (1991: Figures 8.1 and 8.12). (g) Woodward (1953: 58). (h) Hancock (1972: Figure 1.1). (i) Richardson and Urbanke (2008: Figure 1.2). (j) Gatlin (1972: Figure 17). (k) Rényi (1984: 43).
[Fano, Transmission of Information, 1961.]
before we had the theory,... we had been dealing with a commodity that we could never see or really define. We were in the situation petroleum engineers would be in if they didn’t have a measuring unit like the gallon. We had intuitive feelings about these matters, but we didn’t have a clear understanding

– Jerome Wiesner (1953)
Certain Factors Affecting Telegraph Speed

By H. Nyquist

Theoretical Possibilities Using Codes with Different Numbers of Current Values

The speed at which intelligence can be transmitted over a telegraph circuit with a given line speed, i.e., a given rate of sending of signal elements, may be determined approximately by the following formula, the derivation of which is given in Appendix B.

\[ W = K \log m \]

Where \( W \) is the speed of transmission of intelligence,

\( m \) is the number of current values,

and, \( K \) is a constant.

If the following messages are equally likely, how many bits are being produced?

1. \{01101, 11101\}
2. \{1, 0\}
3. \{\mathcal{W}, \dot{X}\}
4. \{33333333333, 44444444\}
5. \{01, 10, 11, 00\}
6. \{000, 111, 110, 101\}
Big idea #2:
There is a notion of information rate, which can be measured in bits
Why is information theory not just applied probability? What is different from detection and estimation?
Generally thought of as given by nature
Generally up to the design of the engineer
• What is the best that one can do?

• How much can coding help?
Big idea #3:
Coding
https://www.youtube.com/watch?v=pHSRHi17RKM
30 April 1916
Analog Computing
A SYMBOLIC ANALYSIS 
OF 
RELAY AND SWITCHING CIRCUITS 

by 

Claude Elwood Shannon 
B.S., University of Michigan 
1936 

Submitted in Partial Fulfillment of the 
Requirements for the Degree of 
MASTER OF SCIENCE 
from the 
Massachusetts Institute of Technology 
1940 

(1939)
Secrecy

Communication

INFORMATION SOURCE → TRANSMITTER → NOISE SOURCE → RECEIVER → DESTINATION

MESSAGE → SIGNAL → RECEIVED SIGNAL → MESSAGE
Circuit Complexity

Fig. 13—Network giving all functions of two variables.
Artificial Intelligence

A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence

August 31, 1955
Tricks for formulating/solving problems
(principles of theoretical research)

1. Simplification: get rid of enough detail (including practical aspects) for intuitive understanding
2. Similarity to a known problem (experience helps)
3. Reformulate (avoid getting in a rut)
4. Generalize (more than opposite of simplify)
5. Structural analysis (break problem into pieces)
6. Inversion (work back from desired result)
Shannon a la Gallager

- Shannon was almost opposite of applied mathematicians
  - Applied mathematicians solve mathematical models formulated by others (perhaps with minor changes to suit their tools)
- Shannon was a creator of models — his genius lay in determining the core of the problem and removing details that could be reinserted later

- Shannon was interested in several problems at all times
- Shannon studied what was happening in multiple fields, but didn’t work on what many others were working on
- Shannon asked conceptual questions about everyday things
“Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem.”

- Claude E. Shannon (1948)
Modeling

Physical

abstract (or ignore) some physical costs and uncertainties

black-boxing

Informational
(Block diagrams can actually be a formal mathematical notation, e.g. through the use of Forney-style factor graphs.)
http://courses.engr.illinois.edu/ece563/
Syllabus

- Noisy twenty questions
Homework 0

• (a) Why are you taking the course?
• (b) What do you want to achieve in the course?
• (c) What, specifically, do you want to improve on through the course?
• (d) What do you hope success in the course will help you achieve in the future?
• (e) What is your favorite information system, and why?
Carnot established fundamental limits on efficiency of engines.

Shannon established fundamental limits of communication in the presence of noise.

Karaman and Frazzoli established a fundamental speed limit of flight in forests without crashing.
“Shannon himself told me that he believes the most promising new developments in information theory will come from work on very complex machines, especially from research into artificial intelligence.” [J. Campbell, Grammatical Man, 1982]

Information Flow in *C. elegans*

Nodes are neurons and edges are synapses, both electrical gap junctions and electrochemical synapses.
There are 302 nodes, 6393 chemical synapses, and 890 gap junctions.
Connectomics, the generation and analysis of neuronal connectivity data, stands to revolutionize neurobiology just as genomics has revolutionized molecular biology. Indeed, since neuronal networks are the physical substrates upon which neural functions are carried out, their structural properties are intertwined with the organization and logic of function.