

Why is there *Math* in my Archaeology?

John Justeson's "Limitations of Archaeological Inference: An Information-Theoretic Approach with Applications in Methodology"

**LIMITATIONS OF ARCHAEOLOGICAL INFERENCE:
AN INFORMATION-THEORETIC APPROACH
WITH APPLICATIONS IN METHODOLOGY**

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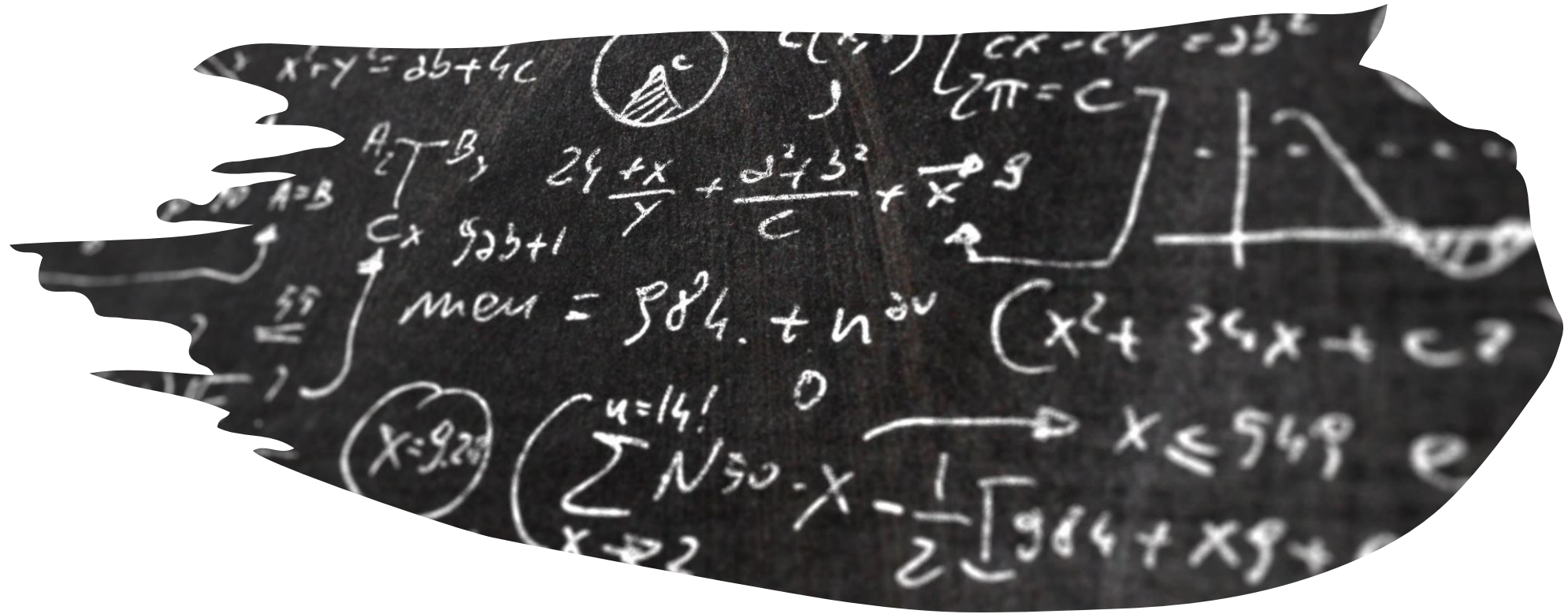
ABSTRACT

A framework is established for the application of information-theoretic concepts to the study of archaeological inference, ultimately to provide an estimate of the degree to which archaeologists, or anthropologists in general, can provide legitimate answers to the questions they investigate. Particular information-theoretic measures are applied to the design elements on the ceramics of a southwestern pueblo to show the methodological utility of information theory in helping to reach closer to that limit.

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Limits of Inference

- Limitations imposed by the degree of preservation of culturally significant remains and by the skewing of their relationships through time until their recovery
- Limitations on the interpretability of archaeological data for the cultural descriptions.



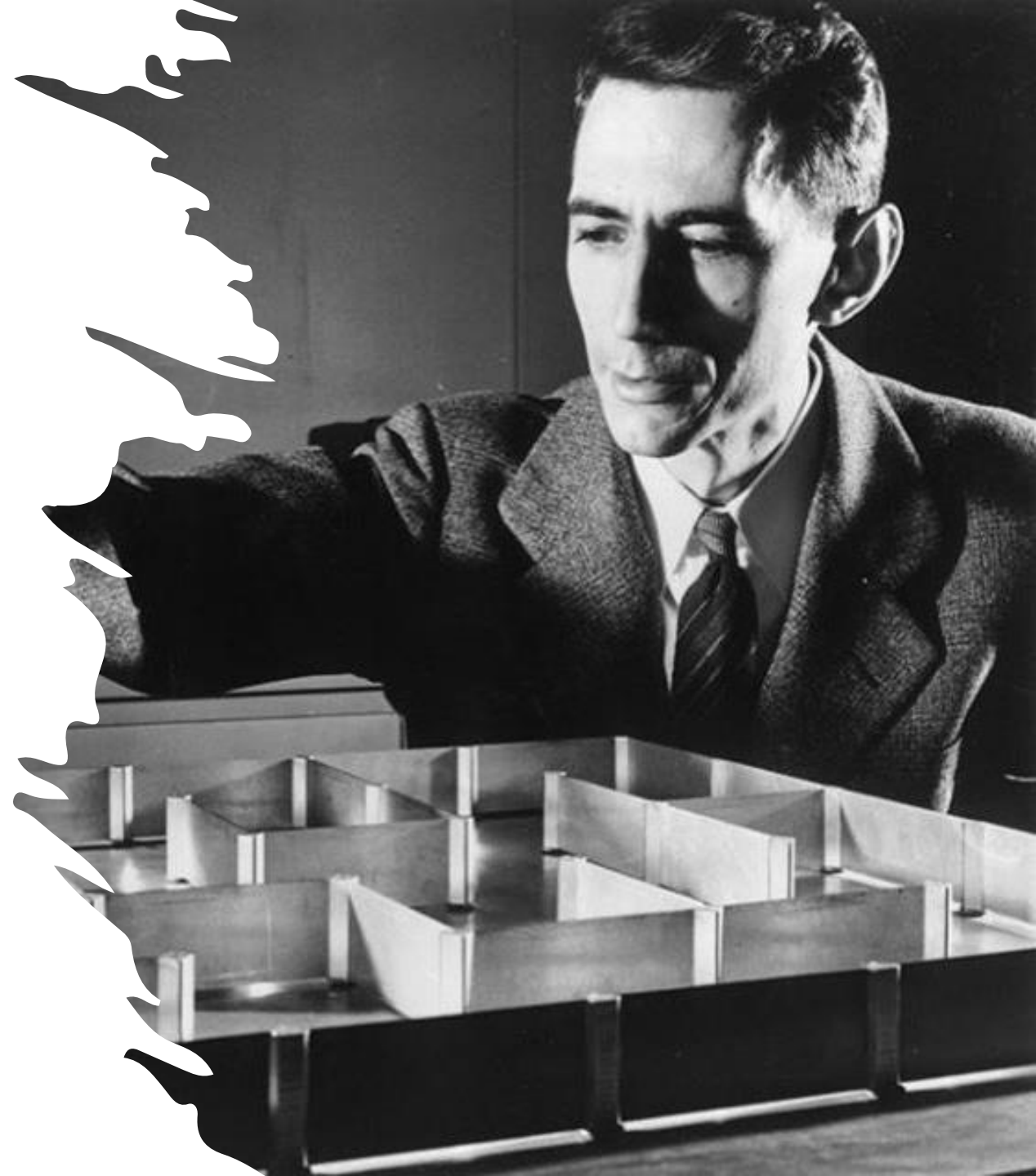
Part I: A Theoretical Framework

Understanding the Archaeological Record as an Information Problem

Information Theory

“The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is, they refer to or are correlated according to some system with certain physical or conceptual entities.”

– Claude Shannon



Information and Entropy

- limitations on the interpretability of archaeological data for the cultural descriptions
- the more events it would take, the less information each observation provides
- High entropy means a small amount of information attaches to each piece of data
- High information events allow discrimination to distinguish differentiable patterns
- Allows calculation of the amount of information per event as a metric
- Information is “the attribute of contrast”

$$H = - \sum_{i=1}^n p(x_i) \log_2 p(x_i)$$

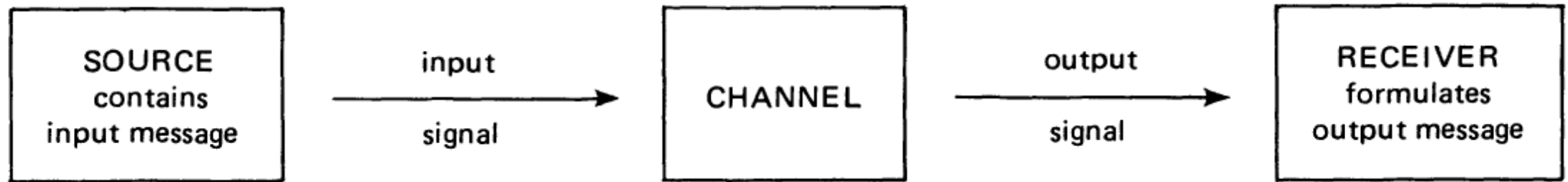
Limits of Inference

"If the empirically measured parameters are not consistent with the relationship between them that is required by the theory for a given material or behavioral system, then the data by which that system is to be interpreted cannot have a consistent susceptibility to decoding; that is, there will be no basis for deriving a coherent archaeological interpretation of the data that will accurately reflect the prehistoric situation."

"Information in this case will be a particular type of information, namely, the description of the cultural system."



The Idea of an Information “Channel”



“...the archaeologist is in the position of the code-breaker tapping a channel with whose code he is not fully familiar...”



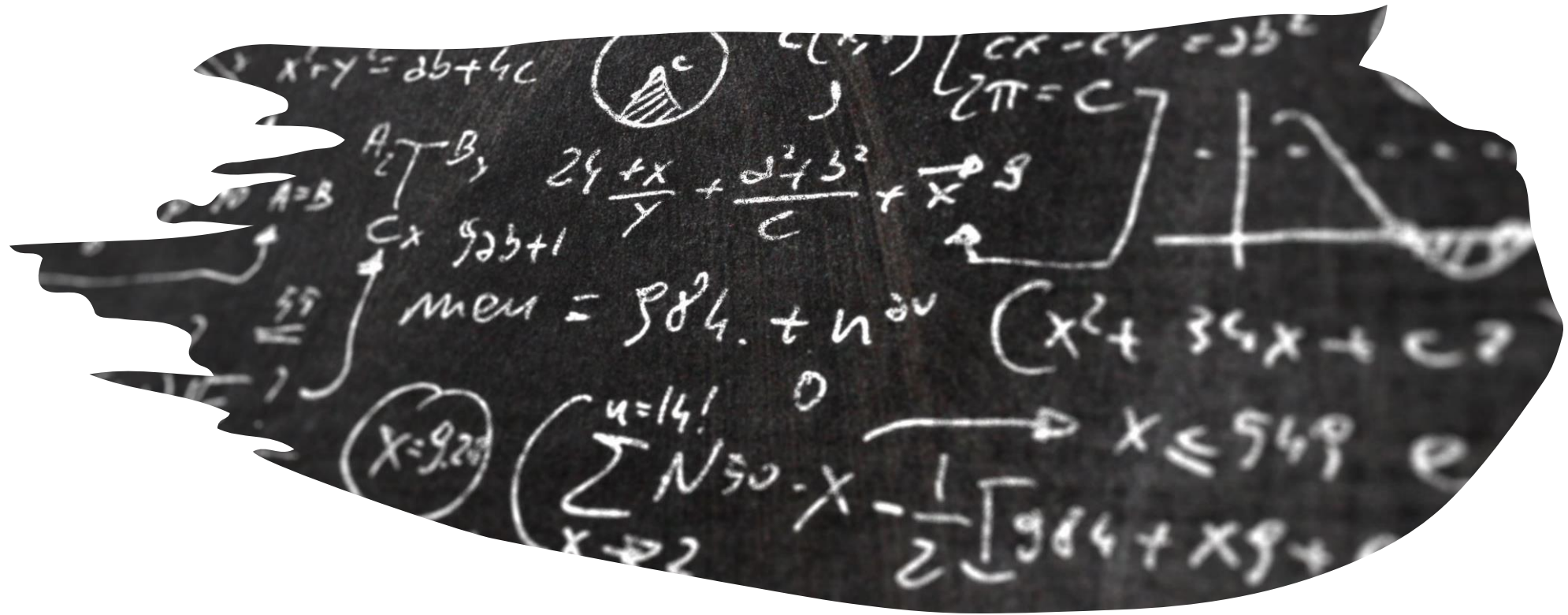
An Archaeological “Channel”

- A message is “encoded” by the selection of material objects, attributes, or features
- A “signal” of these attributes is “transmitted” through the processes of materializing these intentional selections of meaningful attributes
- This transmission passes through the “channel” of the archaeological record
- Some degraded form of this signal is received through the process of archeological investigation
- The degradation of the signal is comprised by “noise” that renders some part of the message ambiguous due to interference
- The *information* is the unambiguous portion of the signal that can be reasonably decoded

What is the Capacity of a Channel?

- The archaeological “channel” is the passage of cultural information from the intentional agents in the past (Source) to the interpretations by the archaeologist (Receiver) transmitted through the medium of the archaeological record (Channel)
- The *capacity* of the channel is a measure of the ability of a channel to transmit information
- If the observations of the receiver are not consistent with the capacity of the channel, then the information cannot be adequately decoded
- In effect, we can calculate whether the observed information carries enough *information* to be interpretable

$$C = \max_{\pi} \left\{ \sum_j \left[\sum_i \pi_i w(j|i) \log_2 \sum_i \pi_i w(j|i) - \sum_i \pi_i w(j|i) \log_2 w(j|i) \right] \right\}$$



Part II: Application of Information-theoretic Measures

Addressing the Problem of Archaeological Inference through Information Metrics

Applications of Information Measures

- Determine if the frequency of design elements on ceramic vessels constituted an interpretable system of encoding
- Determine if the empirical observations of those frequencies indicated information loss due to noise
- Determine if the classifications of those design elements constitute an adequate system for decoding the signal...
- ... and calculate the *efficiency* of that classification system in terms of ambiguity in discriminating differences

Implications

- Methods allowed the application of quantitative measures to otherwise qualitative assessments:
 - Estimate the frequency of various types, features, and attributes of incomplete samples
 - Estimate the “noise” of the archaeological signal... otherwise known as site integrity
 - Determine if the observed attributes indicate an intentional system of encoding information... i.e., are we, in fact, identifying a real pattern or just an “artifact” of our classifications of them
 - Determine the best fit between competing systems of categorization
- Showed that, in theory at least, there are no *inherent* limitations to inference... only the effects of noise and improper *decoding*

A Hidden Gem...

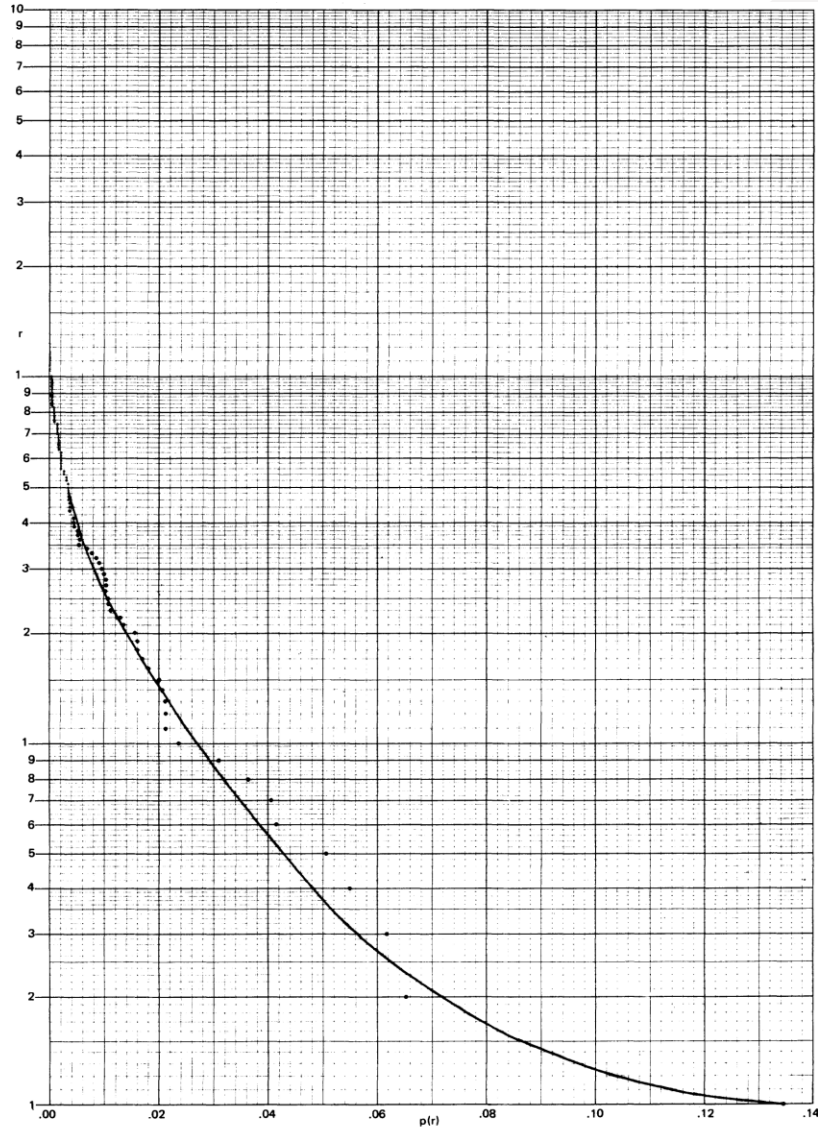


Fig. 4. Rank-frequency graph.

- The encoding of archaeological information follows a power-law distribution
- Power-law distributions are innately related to a specific type of relationship between features
- “Small-world Networks” are a special type of graph structure, in which the number of connections between nodes follows a power-law
- Small-world networks exhibit a special phenomenon of hub and bridge nodes
- Essentially, archaeological information exhibits the same innate structure as social networks