# The amusing and excellent law of Benford

## Principles of Complex Systems
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# Outline

# The law of first digits

## Benford's Law:

- First observed by Simon Newcomb [2] in 1881 "Note on the Frequency of Use of the Different Digits in Natural Numbers"
- Independently discovered by Frank Benford in 1938.
- Newcomb almost always noted but Benford gets the stamp
- $$P(\text{first digit} = d) \propto \log_b (d + 1/d)$$

  for numbers in base $b$

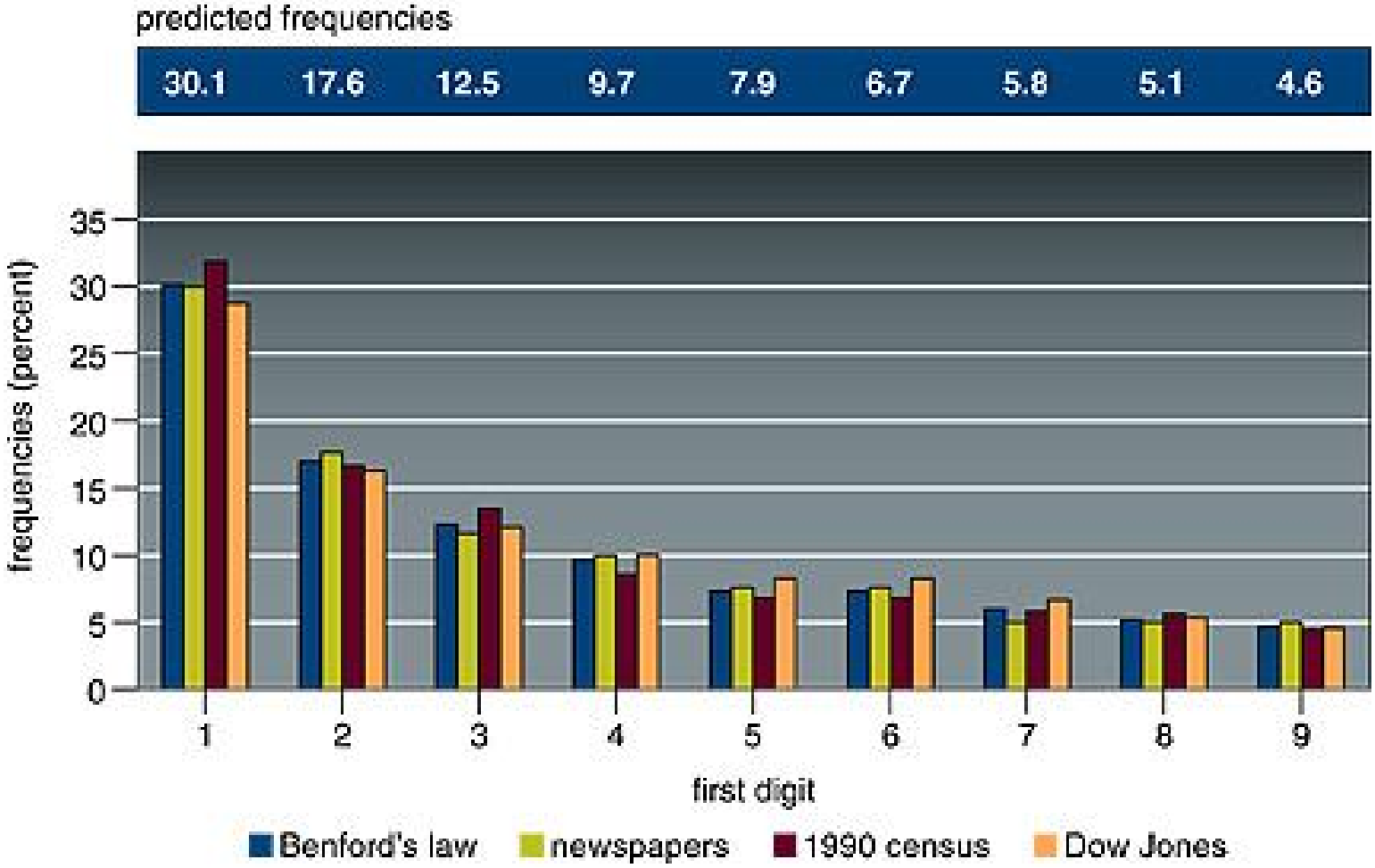
# Benford's Law—The law of first digits

## Observed for

- Fundamental constants (electron mass, charge, etc.)
- Utilities bills
- Numbers on tax returns
- Death rates
- Street addresses
- Numbers in newspapers

# Benford's Law

## Real data




From 'The First-Digit Phenomenon' by T. P. Hill (1998) [1]

# Essential story

- $$P(\text{first digit} = d) \propto \log_b (d + 1/d)$$
- $$P(\text{first digit} = d) \propto \log_b \left( \frac{d+1}{d} \right)$$
- $$P(\text{first digit} = d) \propto \log_b (d + 1) - \log_b (d)$$
- So numbers are distributed uniformly in log-space:

$$P(\ln x)\,\mathrm{d}(\ln x) \propto 1 \cdot \mathrm{d}(\ln x) = x^{-1}\,\mathrm{d}x$$

- Independent of actual base and units of measurement.
- Power law distributions at work again... ($\gamma = 1$)

# A different Benford





Not to be confused with Benford's Law of controversy:

- "Passion is inversely proportional to the amount of real information available."

Gregory Benford, Sci-Fi writer & Astrophysicist

# References I



T. P. Hill.
The first-digit phenomenon.
*American Scientist*, 86:358–, 1998.

S. Newcomb.
Note on the frequency of use of the different digits in natural numbers.
*American Journal of Mathematics*, 4:39–40, 1881.
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