

# The structure and evolution of language

Principles of Complex Systems

CSYS/MATH 300, Spring, 2013 | #SpringPoCS2013

Irregular verbs

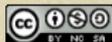
Word lifespans

Meanings

References

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# Outline

Irregular verbs

Word lifespans

Meanings

References

Language

Irregular verbs

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# Irregular verbs

Language

Cleaning up English:

“Quantifying the evolutionary dynamics of language”<sup>[2]</sup>

Lieberman et al., Nature, Vol 449, 713-716, 2007.

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- ▶ Exploration of how verbs with irregular conjugation gradually become regular over time.
- ▶ Comparison of verb behavior in Old, Middle, and Modern English.



# Irregular verbs

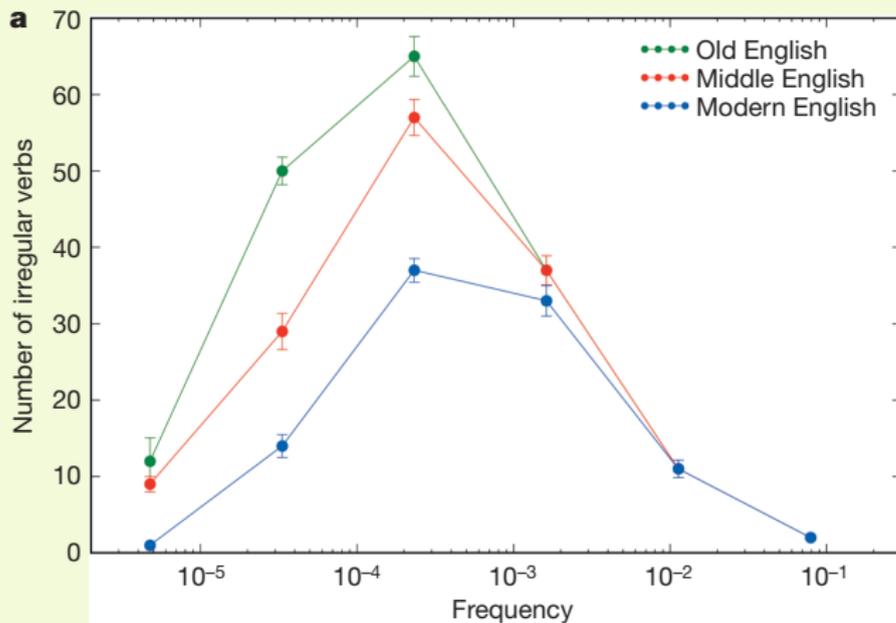
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- ▶ Universal tendency towards regular conjugation
- ▶ Rare verbs tend to be regular in the first place



# Irregular verbs

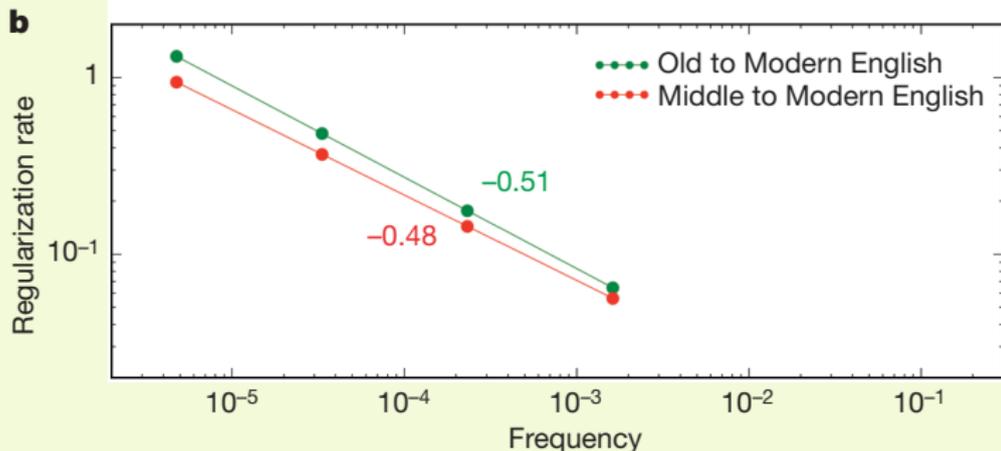
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- ▶ Rates are relative.
- ▶ The more common a verb is, the more resilient it is to change.



# Irregular verbs

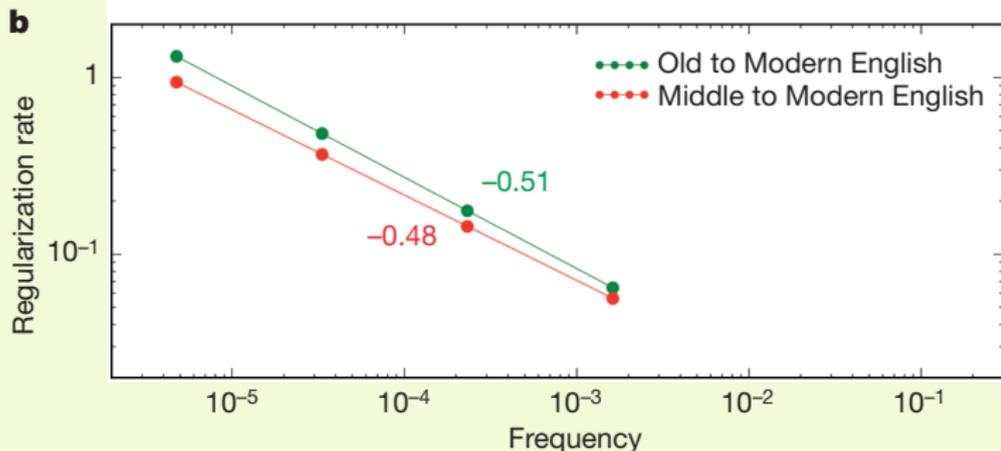
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# Irregular verbs

**Table 1 | The 177 irregular verbs studied**

Frequency	Verbs	Regularization (%)	Half-life (yr)
$10^{-1}$ -1	be, have	0	38,800
$10^{-2}$ - $10^{-1}$	come, do, find, get, give, go, know, say, see, take, think	0	14,400
$10^{-3}$ - $10^{-2}$	begin, break, bring, buy, choose, draw, drink, drive, eat, fall, fight, forget, grow, hang, <b>help</b> , hold, leave, let, lie, lose, <b>reach</b> , rise, run, seek, set, shake, sit, sleep, speak, stand, teach, throw, understand, <b>walk</b> , win, <b>work</b> , write	10	5,400
$10^{-4}$ - $10^{-3}$	arise, <b>bake</b> , bear, beat, bind, bite, blow, <b>bow</b> , burn, burst, <b>carve</b> , <b>chew</b> , <b>climb</b> , cling, creep, <b>dare</b> , dig, <b>drag</b> , flee, <b>float</b> , flow, fly, <b>fold</b> , freeze, grind, leap, lend, <b>lock</b> , melt, <b>reckon</b> , ride, <b>rush</b> , <b>shape</b> , shine, shoot, shrink, <b>sigh</b> , sing, sink, slide, <b>slip</b> , smoke, spin, spring, <b>starve</b> , steal, <b>step</b> , <b>stretch</b> , strike, <b>stroke</b> , <b>suck</b> , <b>swallow</b> , swear, sweep, swim, swing, tear, wake, wash, weave, weep, <b>weigh</b> , wind, yell, yield	43	2,000
$10^{-5}$ - $10^{-4}$	<b>bark</b> , <b>bellow</b> , bid, <b>blend</b> , <b>braid</b> , <b>brew</b> , cleave, <b>cringe</b> , <b>crow</b> , dive, drip, fare, fret, glide, gnaw, grip, heave, knead, low, milk, mourn, mow, prescribe, redden, reek, row, scrape, seethe, shear, shed, <b>shove</b> , slay, slit, smite, sow, span, <b>spurn</b> , sting, stink, strew, stride, swell, <b>tread</b> , <b>uproot</b> , <b>wade</b> , <b>warp</b> , wax, <b>wield</b> , wring, <b>writh</b> e	72	700
$10^{-6}$ - $10^{-5}$	<b>bide</b> , <b>chide</b> , <b>delve</b> , flay, hew, rue, shrive, slink, <b>snip</b> , <b>spew</b> , <b>sup</b> , <b>wreak</b>	91	300

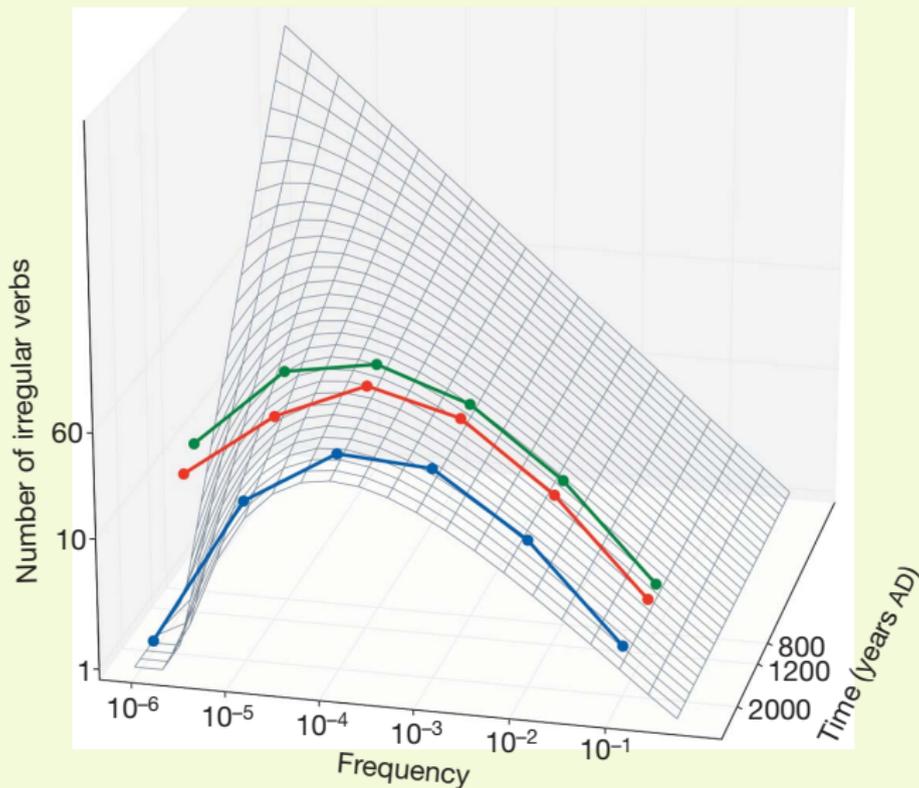
177 Old English irregular verbs were compiled for this study. These are arranged according to frequency bin, and in alphabetical order within each bin. Also shown is the percentage of verbs in each bin that have regularized. The half-life is shown in years. Verbs that have regularized are indicated in red. As we move down the list, an increasingly large fraction of the verbs are red; the frequency-dependent regularization of irregular verbs becomes immediately apparent.

- ▶ **Red** = regularized
- ▶ Estimates of half-life for regularization ( $\propto f^{1/2}$ )



# Irregular verbs

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- ▶ Projecting back in time to proto-Zipf story of many tools

# Word meanings

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## Preliminary findings on word frequency and number of meanings

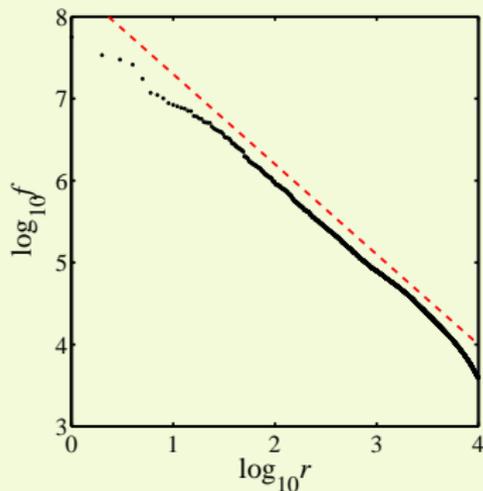
- ▶ Corpus: 10,000 most frequent words from Project Gutenberg
- ▶ # meanings for each word estimated using [dictionary.com](http://dictionary.com) (田)
- ▶ Friends: perl, regular expressions, wget.



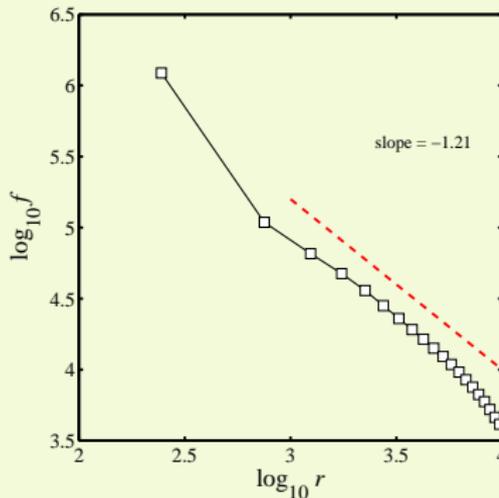
# Word meanings

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**A.**



**B.**



**A.** Word frequency versus rank, slope  $\alpha \sim -1.2$  corresponds to a frequency distribution with  $\gamma \sim 1.8$ .

**B.** Relationship between average number of meanings and average frequency (bins are by rank, with each circle representing 500 words). Slope of 1/3 lower than Zipf's 1/2 [5].

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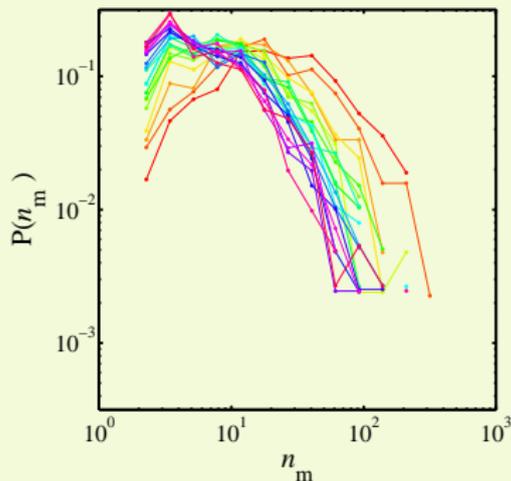
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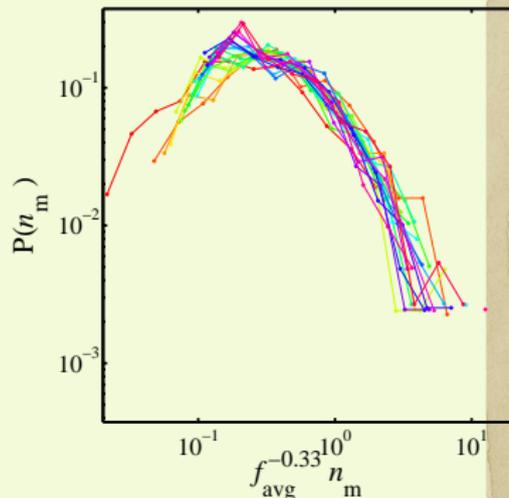
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**A.**



**B.**



- ▶ Scaling collapse for meaning number distribution
- ▶ Each curve corresponds to approximately 500 words group according to rank (1–500, 501–1000, ...).
- ▶ With normalization

$$P(n_m) = f^{-1/3} G\left(f^{-1/3} n_m\right).$$

