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Quantifying the evolutionary dynamics of language

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Supplementary Online Information

S1. Table of Irregular Verbs

In this section we present a table showing the modern descendants of the 177 Old English irregular verbs that we gathered from the literature. For each verb, we show the verb's state (regular is marked with a 0, irregular with a 1) in each form of the language: Old English, Middle English, and Modern English.

Since no single source presented enough verbs for our analysis, we used twelve different books and reference works[1−12]. Each irregular verb in each time period is attributed to one of these resources.

For verbs in the modern language, we determined regularity using the list appearing in the appendix of [12]. Forms marked as obsolete were excluded.

For several modern irregular verbs, a source was found indicating that the verb was irregular in Old English, but we could find no source indicating that the verb

was irregular in Middle English. Since regularization and 'irregularization' are both rare, we assumed that these verbs were also irregular in Middle English, although it is possible that the verbs regularized and then became irregular again. These verbs are marked with a 1 in Middle English, but no source is given.

Other than this case, verb state is listed based on presence or absence of the verb in our various historical sources for the given form of English.

Only verbs marked with a 1 in Old English (i.e., for which we have a source indicating that they were irregular in Old English) were used in the analysis appearing in the body of the paper. But in order to make this listing as complete as possible, we list all modern English verbs appearing as irregular in any time period, even ones which were not used in our analysis. For these additional verbs, note that a 0 in a given historical time period may be due to a lack of coverage in our reference works, not because the verb was actually regular in that time period.

We also show each verb's frequency in the modern language, computed using the CELEX database[13–14]. Frequencies shown are as a fraction of all verbs.

Grammatical and Lexical Resources Used

1. Baugh, A. C., & Cable, T. *A History of the English Language* (Prentice Hall, Upper Saddle River, 2002).

2. Bosworth, J. *The Elements of Anglo-Saxon Grammar* (Harding, London, 1823).

3. Emerson, O. F *A Middle English Reader* (MacMillan, London, 1909).

4. Harper, D. *Online Etymology Dictionary* (February, 2007) (http://www.etymonline.com).

5. Klipstein, L. *A Grammar of the Anglo-Saxon Language* (Putnam, New York, 1848).

6. Mitchell, B., & Robinson F. C., *A Guide to Old English* (Blackwell, Cambridge, 2001).

7. Mosse, F. *A Handbook of Middle English* (Johns Hopkins Press, Baltimore, 1952).

8. Smith, J. *Essentials of Early English* (Routledge, London, 1999).

9. Sweet, H. *An Anglo-Saxon Primer* (Clarendon Press, Oxford, 1887).

10. Wright, J. *An Elementary Middle English Grammar* (Oxford University Press, London, 1923).

11. Wright, J., & Wright, E. M. *Old English Grammar* (Oxford University Press, London, 1925).

12. Pinker, S. & Prince, A. On language and connectionism: analysis of a parallel distributed processing model of language acquisition. *Cognition* **28**, 73-193 (1988).

13. Burnage, G. *CELEX, a guide for users* (Centre for Lexical Information, Nijmegen, 1990).

14. Van der Wouden, T. in *Papers from the 3rd International EURALEX Congress* (eds Magay, T. & Zigány, J.) 363-373 (Akadémiai Kiadó, Budapest, 1988).

S2. Source Code

All of the Python source code used to transform the table in §S1 into Table 1 and Figures 1, 2, and 3 is available in a separate file, together with simple instructions for installing, browsing, and executing the code. These can be found at http://www.languagedata.org.

S3. The Irregular equation describes the decay of verbs

Here we introduce the Irregular Equation which describes the exponential decay of irregular verbs, and show how to derive the surface shown in Figure 3.

Figure 2a shows that the number of verbs of a given frequency $I(\omega, t)$ decays exponentially over time. Thus we can define a frequency-specific regularization rate $d(\omega)$. Formally, the number of irregular verbs satisfies the following 'Irregular equation':

$$\frac{\partial I}{\partial t} = -d(\omega)I(\omega, t), \quad t, \omega > 0 \tag{1}$$

In Figure 2b, we observe that the decay (=regularization) rate scales as the square root of the frequency:

$$d(\omega) = \frac{a}{\sqrt{\omega}} \tag{2}$$

Using these two equations and knowledge of $I(\omega, t)$ at any one time point, it is possible to compute the distribution for all past and future times. For each of the three time points (Old, Middle, and Modern English) which we observed, this procedure yields a Zipfian ancestral distribution. The corresponding solution of (1) and (2) is:

$$I(\omega, t) = b\omega^{-\beta} e^{\frac{-a}{\sqrt{\omega}}t} \tag{3}$$

This solution is plotted in Figure 3, where the free parameters have been fit to the data by the method of least squares.

S4. Intra-rule dynamics resemble those of the irregular verbs as a whole

The irregular verbs fall into 7 classes, each of which descend from a conjugation rule of Old English. Here we show that the dynamics of these individual rules are similar to those of the irregular verbs as a whole.

We identified classes of Old English verbs based on [11] above. Following the approach of Figure 1, we plotted the number of verbs as a function of frequency, and examined decay rate for each frequency bin. Although the number of datapoints in each class was small, we observed that regularization rates depended on frequency,

usually with a scaling similar to that observed for the global dynamics. Slopes were consistent for Old-to-Modern and Middle-to-Modern, implying exponential decay within each frequency bin for each rule. These results held for classes II, III, VI, and VII. For classes I, IV, and V, we did not have sufficient data to perform the analysis. Two representative classes are shown in Figure S1.

S5. Usage frequency in Modern English and Middle English are similar

Because of the limitations on corpora from Old and Middle English, we used usage frequency from the CELEX corpus of Modern English as an approximate measure of frequency for all time periods[1,2]. This approximation is reasonable as long as most usage frequencies do not change by more than an order of magnitude, since the frequencies are primarily used for the purpose of constructing logarithmically distributed frequency bins.

To test this, we took a test set of 50 verbs from across the frequency spectrum, including both verbs that regularized and verbs that had not. For these 50 verbs, we compared usage frequency based on CELEX with usage frequencies in the Penn-Helsinki Parsed Corpus of Middle English[3]. The relative frequencies are plotted in Figure S2. Out of 50 verbs, only 5 showed a frequency change which was greater than 10-fold.

Resources Used

1. Burnage, G. *CELEX, a guide for users* (Centre for Lexical Information, Nijmegen, 1990).

2. Van der Wouden, T. in *Papers from the 3rd International EURALEX Congress* (eds Magay, T. & Zigány, J.) 363-373 (Akadémiai Kiadó, Budapest, 1988).

3. Kroch, A., & Taylor, A. Penn-Helsinki Parsed Corpus of Middle English, second edition (2000).

Figure Legends

Figure S1. Individual rules exhibit frequency dependent decay with a similar scaling to that found for irregular verbs as a whole. **a**, The evolution of 11 of Wright's Class II (ex., OE: *bēad/budon/boden*, *to command*) verbs. **b**, The evolution of 24 of Wright's Class VII (reduplicated) verbs. **c-d**, the regularization rates for class II (**c**) and class VII (**d**). Error bars reflect Poisson error in our frequency estimates. For both rules, the decay curves across the two periods have similar slopes. This implies that decay within each frequency bin is exponential. The slope is roughly .5 in both cases.

Figure S2. Usage frequency is relatively consistent over the last 800 years. We plotted relative usage frequency in Middle English, as determined by the Penn-Helsinki Parsed Corpus of Middle English, against relative usage frequency in Modern English, as determined by CELEX, for 50 verbs. In 5 cases, shown in red, the deviation was larger than 10-fold; other verbs are shown in blue. Highlighted regions indicate differences in frequency of less than 5-fold, and 5 to 10-fold, indicated by the two shades of blue. Thus historical changes in frequency are unlikely to substantially affect our results.

Table 1: Complete Data, Part 1

Verb	Old English	Middle English	Modern English[12]	Frequency
alight	0	0	1	$1.60 \cdot 10^{-5}$
arise	1^{5}	1^{7}	1	$3.28 \cdot 10^{-4}$
awake	0	0	1	$4.34 \cdot 10^{-5}$
bake	1^{2}	1^{10}	0	$1.27 \cdot 10^{-4}$
bark	1^{11}	0	0	$5.61 \cdot 10^{-5}$
be	1^{2}	1^{7}	1	$2.07 \cdot 10^{-1}$
bear	1^{5}	1^{8}	1	$5.78 \cdot 10^{-4}$
beat	1^{5}	1^{10}	1	$4.66 \cdot 10^{-4}$
become	0	0	1	$4.51 \cdot 10^{-3}$
befall	0	0	1	$1.96 \cdot 10^{-5}$
begin	1^{9}	1	1	$3.70 \cdot 10^{-3}$
behold	0	0	1	$2.65 \cdot 10^{-5}$
bellow	1^{5}	0	0	$2.77 \cdot 10^{-5}$
bend	0	0	1	$3.56 \cdot 10^{-4}$
beset	0	0	1	$1.90 \cdot 10^{-5}$
bid	1^{5}	1^{7}	1	$4.25 \cdot 10^{-5}$
bide	1^{2}	1^{10}	0	$3.92 \cdot 10^{-6}$
bind	1^{5}	1^{8}	1	$9.15 \cdot 10^{-5}$
bite	1^{5}	1^{7}	1	$1.48 \cdot 10^{-4}$
bleed	0	0	1	$1.30 \cdot 10^{-4}$
blend	1^{11}	0	0	$4.43 \cdot 10^{-5}$
blow	1^{5}	1^{7}	1	$4.55 \cdot 10^{-4}$
bow	1^{1}	1^{10}	0	$1.01 \cdot 10^{-4}$
braid	1^{5}	0	0	$1.51 \cdot 10^{-5}$
break	1^{2}	1^{7}	1	$1.23 \cdot 10^{-3}$
breed	0	0	1	$1.02 \cdot 10^{-4}$
brew	1^{5}	1^{10}	0	$3.23 \cdot 10^{-5}$
bring	1^{2}	1	1	$2.77 \cdot 10^{-3}$
build	0	0	1	$1.30 \cdot 10^{-3}$
burn	1^{11}	1^{11}	1	$4.76 \cdot 10^{-4}$
burst	1^{5}	1^{7}	1	$2.05 \cdot 10^{-4}$
buy	1^{5}	1	1	$1.38 \cdot 10^{-3}$
carve	1^{11}	1^{10}	0	$1.05 \cdot 10^{-4}$
cast	0	0	1	$2.22 \cdot 10^{-4}$
catch	0	0	1	$1.04 \cdot 10^{-3}$
chew	1^{5}	1^{10}	0	$1.09 \cdot 10^{-4}$

Table 2: Complete Data, Part 2

Verb	Old English	Middle English	Modern English[12]	Frequency
chide	1^5	0	0	$1.02 \cdot 10^{-5}$
choose	1^2	1^{10}	1	$9.69 \cdot 10^{-4}$
cleave	1^5	1^{10}	0	$2.26 \cdot 10^{-5}$
climb	1^5	1^7	0	$4.96 \cdot 10^{-4}$
cling	1^{11}	1^{10}	1	$1.47 \cdot 10^{-4}$
come	1^2	1^{11}	1	$1.06 \cdot 10^{-2}$
cost	0	0	1	$2.97 \cdot 10^{-4}$
creep	1^5	1	1	$1.40 \cdot 10^{-4}$
cringe	1^5	0	0	$1.41 \cdot 10^{-5}$
crow	1^5	1^{10}	0	$1.63 \cdot 10^{-5}$
cut	0	0	1	$1.03 \cdot 10^{-3}$
dare	1^2	1^3	0	$2.60 \cdot 10^{-4}$
deal	0	0	1	$5.65 \cdot 10^{-4}$
delve	1^8	1^3	0	$8.45 \cdot 10^{-6}$
dig	1^2	1	1	$2.16 \cdot 10^{-4}$
dive	1^5	1	1	$6.79 \cdot 10^{-5}$
do	1^2	1^8	1	$2.43 \cdot 10^{-2}$
drag	1^5	0	0	$2.61 \cdot 10^{-4}$
draw	1^5	1^7	1	$1.16 \cdot 10^{-3}$
dream	0	0	1	$2.02 \cdot 10^{-4}$
drink	1^5	1^7	1	$7.01 \cdot 10^{-4}$
drip	1^{11}	0	0	$5.52 \cdot 10^{-5}$
drive	1^2	1^7	1	$1.18 \cdot 10^{-3}$
dwell	0	0	1	$4.95 \cdot 10^{-5}$
eat	1^2	1^7	1	$1.56 \cdot 10^{-3}$
fall	1^5	1^7	1	$1.59 \cdot 10^{-3}$
fare	1^8	1^{10}	0	$1.54 \cdot 10^{-5}$
feed	0	0	1	$7.18 \cdot 10^{-4}$
feel	0	0	1	$4.67 \cdot 10^{-3}$
fight	1^5	1^7	1	$7.69 \cdot 10^{-4}$
find	1^5	1^7	1	$5.89 \cdot 10^{-3}$
flay	1^{11}	1^7	0	$7.85 \cdot 10^{-6}$
flee	1^2	1^7	1	$1.45 \cdot 10^{-4}$
fling	0	1^{10}	1	$1.28 \cdot 10^{-4}$
float	1^5	1^7	0	$1.76 \cdot 10^{-4}$
flow	1^5	1^{10}	0	$1.86 \cdot 10^{-4}$

Table 3: Complete Data, Part 3

Verb	Old English	Middle English	Modern English[12]	Frequency
fly	1^2	1^7	1	$5.17 \cdot 10^{-4}$
fold	1^5	1^3	0	$2.06 \cdot 10^{-4}$
forbid	0	1^7	1	$9.09 \cdot 10^{-5}$
foretell	0	0	1	$1.32 \cdot 10^{-5}$
forget	1^{11}	1^7	1	$9.22 \cdot 10^{-4}$
forgive	0	0	1	$1.77 \cdot 10^{-4}$
forgo	0	0	1	$2.71 \cdot 10^{-5}$
forsake	0	1^7	1	$1.20 \cdot 10^{-5}$
freeze	1^{11}	1^7	1	$2.41 \cdot 10^{-4}$
fret	1^2	0	0	$2.68 \cdot 10^{-5}$
get	1^2	1^7	1	$1.29 \cdot 10^{-2}$
give	1^2	1^7	1	$6.92 \cdot 10^{-3}$
glide	1^5	1^7	0	$3.50 \cdot 10^{-5}$
gnaw	1^5	1^{10}	0	$2.38 \cdot 10^{-5}$
go	1^8	1^8	1	$1.56 \cdot 10^{-2}$
grind	1^5	1^7	1	$1.48 \cdot 10^{-4}$
grip	1^5	1^{10}	0	$7.88 \cdot 10^{-5}$
grow	1^5	1^7	1	$1.84 \cdot 10^{-3}$
hang	1^2	1^7	1	$7.66 \cdot 10^{-4}$
have	1^2	1	1	$7.31 \cdot 10^{-2}$
hear	0	0	1	$2.73 \cdot 10^{-3}$
heave	1^2	1^{10}	1	$8.00 \cdot 10^{-5}$
help	1^2	1^7	0	$2.10 \cdot 10^{-3}$
hew	1^5	1^7	0	$5.43 \cdot 10^{-6}$
hide	0	0	1	$5.44 \cdot 10^{-4}$
hit	0	0	1	$5.41 \cdot 10^{-4}$
hold	1^2	1^8	1	$2.51 \cdot 10^{-3}$
hurt	0	0	1	$3.63 \cdot 10^{-4}$
keep	0	0	1	$3.56 \cdot 10^{-3}$
knead	1^{11}	1^7	0	$1.57 \cdot 10^{-5}$
kneel	0	0	1	$1.22 \cdot 10^{-4}$
knit	0	0	1	$5.10 \cdot 10^{-5}$
know	1^5	1^8	1	$1.14 \cdot 10^{-2}$
lead	0	0	1	$1.59 \cdot 10^{-3}$
leap	1^5	1^7	1	$1.65 \cdot 10^{-4}$
leave	1^8	1	1	$4.24 \cdot 10^{-3}$

Table 4: Complete Data, Part 4

Verb	Old English	Middle English	Modern English[12]	Frequency
lend	1^{11}	1	1	$1.47 \cdot 10^{-4}$
let	1^{11}	1^{7}	1	$2.33 \cdot 10^{-3}$
lie	1^{5}	1^{7}	1	$1.72 \cdot 10^{-3}$
light	0	0	1	$2.95 \cdot 10^{-4}$
lock	1^{11}	1^{7}	0	$3.33 \cdot 10^{-4}$
lose	1^{8}	1^{10}	1	$1.83 \cdot 10^{-3}$
low	1^{5}	0	0	$1.54 \cdot 10^{-5}$
make	0	0	1	$1.26 \cdot 10^{-2}$
mean	0	0	1	$3.96 \cdot 10^{-3}$
meet	0	0	1	$1.26 \cdot 10^{-3}$
melt	1^{5}	1^{10}	0	$1.31 \cdot 10^{-4}$
milk	1^{5}	0	0	$5.25 \cdot 10^{-5}$
mislead	0	0	1	$8.09 \cdot 10^{-5}$
mistake	0	0	1	$5.07 \cdot 10^{-5}$
mourn	1^{5}	0	0	$3.32 \cdot 10^{-5}$
mow	1^{11}	0	0	$2.53 \cdot 10^{-5}$
partake	0	0	1	$8.75 \cdot 10^{-6}$
plead	0	0	1	$1.02 \cdot 10^{-4}$
prescribe	1^{11}	0	0	$6.16 \cdot 10^{-5}$
prove	0	0	1	$8.07 \cdot 10^{-4}$
put	0	0	1	$4.35 \cdot 10^{-3}$
quit	0	0	1	$6.88 \cdot 10^{-5}$
reach	1^{2}	1^{3}	0	$1.38 \cdot 10^{-3}$
read	0	0	1	$2.02 \cdot 10^{-3}$
reckon	1^{2}	0	0	$1.18 \cdot 10^{-4}$
redden	1^{11}	0	0	$1.29 \cdot 10^{-5}$
reek	1^{5}	0	0	$1.38 \cdot 10^{-5}$
rend	0	0	1	$8.75 \cdot 10^{-6}$
ride	1^{2}	1^{7}	1	$3.07 \cdot 10^{-4}$
ring	0	0	1	$5.17 \cdot 10^{-4}$
rise	1^{5}	1^{7}	1	$1.05 \cdot 10^{-3}$
row	1^{5}	1^{10}	0	$2.23 \cdot 10^{-5}$
rue	1^{4}	1^{10}	0	$2.71 \cdot 10^{-6}$
run	1^{5}	1^{10}	1	$2.38 \cdot 10^{-3}$
rush	1^{2}	0	0	$2.75 \cdot 10^{-4}$
say	1^{2}	1	1	$2.31 \cdot 10^{-2}$

Table 5: Complete Data, Part 5

Verb	Old English	Middle English	Modern English[12]	Frequency
scrape	1^{11}	0	0	$6.70 \cdot 10^{-5}$
see	1^{2}	1^{8}	1	$1.11 \cdot 10^{-2}$
seek	1^{2}	1	1	$6.48 \cdot 10^{-4}$
seethe	1^{8}	0	0	$2.59 \cdot 10^{-5}$
sell	0	0	1	$7.84 \cdot 10^{-4}$
send	0	0	1	$1.45 \cdot 10^{-3}$
set	1^{2}	1	1	$1.70 \cdot 10^{-3}$
sew	0	0	1	$6.07 \cdot 10^{-5}$
shake	1^{1}	1^{8}	1	$7.12 \cdot 10^{-4}$
shape	1^{1}	1^{7}	0	$9.18 \cdot 10^{-5}$
shear	1^{5}	1^{9}	1	$2.14 \cdot 10^{-5}$
shed	1^{8}	1	1	$8.27 \cdot 10^{-5}$
shine	1^{2}	1^{10}	1	$1.93 \cdot 10^{-4}$
shoot	1^{1}	1^{10}	1	$4.03 \cdot 10^{-4}$
shove	1^{4}	1^{10}	0	$6.49 \cdot 10^{-5}$
show	0	0	1	$2.53 \cdot 10^{-3}$
shrink	1^{11}	1^{7}	1	$1.09 \cdot 10^{-4}$
shrive	1^{8}	1^{3}	0	$1.81 \cdot 10^{-6}$
shut	0	0	1	$3.86 \cdot 10^{-4}$
sigh	1^{11}	0	0	$1.64 \cdot 10^{-4}$
sing	1^{2}	1^{7}	1	$4.24 \cdot 10^{-4}$
sink	1^{11}	1^{10}	1	$2.69 \cdot 10^{-4}$
sit	1^{2}	1^{7}	1	$2.70 \cdot 10^{-3}$
slay	1^{2}	1^{8}	1	$2.38 \cdot 10^{-5}$
sleep	1^{5}	1^{10}	1	$6.96 \cdot 10^{-4}$
slide	1^{5}	1^{7}	1	$1.89 \cdot 10^{-4}$
sling	0	1^{10}	1	$3.11 \cdot 10^{-5}$
slink	1^{11}	1	1	$9.06 \cdot 10^{-6}$
slip	1^{11}	0	0	$3.32 \cdot 10^{-4}$
slit	1^{8}	1^{10}	1	$1.81 \cdot 10^{-5}$
smite	1^{5}	1^{7}	0	$1.75 \cdot 10^{-5}$
smoke	1^{5}	0	0	$2.40 \cdot 10^{-4}$
sneak	0	0	1	$3.29 \cdot 10^{-5}$
snip	1^{11}	0	0	$9.96 \cdot 10^{-6}$
sow	1^{5}	1^{7}	1	$6.79 \cdot 10^{-5}$
span	1^{5}	0	0	$1.96 \cdot 10^{-5}$

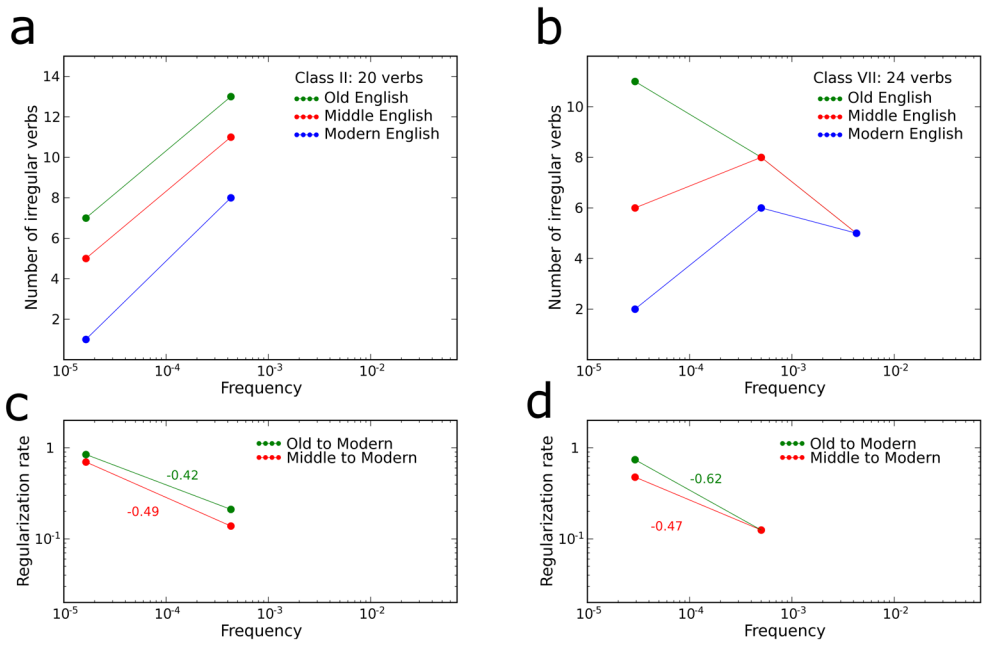
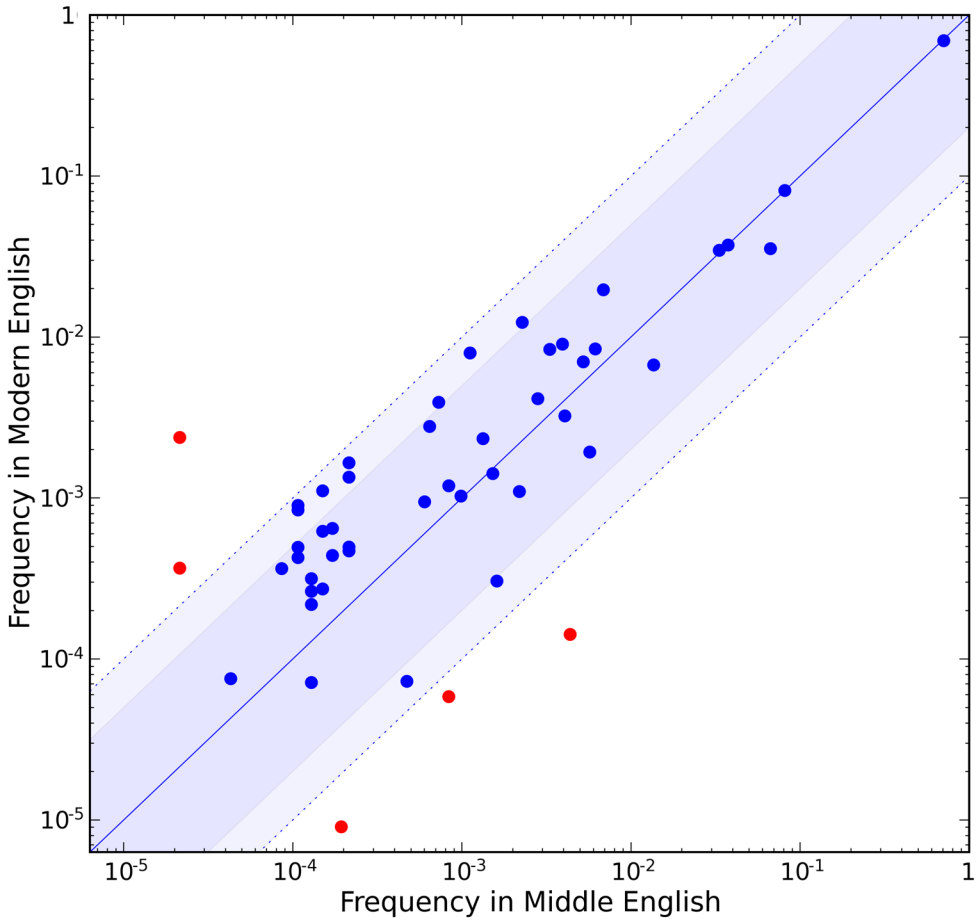
Table 6: Complete Data, Part 6

Verb	Old English	Middle English	Modern English[12]	Frequency
speak	1^{11}	1^{7}	1	$2.00 \cdot 10^{-3}$
speed	0	0	1	$9.00 \cdot 10^{-5}$
spend	0	0	1	$1.52 \cdot 10^{-3}$
spew	1^{5}	0	0	$1.23 \cdot 10^{-5}$
spill	0	0	1	$9.72 \cdot 10^{-5}$
spin	1^{2}	1	1	$1.38 \cdot 10^{-4}$
spit	0	0	1	$8.45 \cdot 10^{-5}$
split	0	0	1	$1.80 \cdot 10^{-4}$
spread	0	0	1	$4.76 \cdot 10^{-4}$
spring	1^{5}	1^{7}	1	$1.82 \cdot 10^{-4}$
spurn	1^{5}	0	0	$1.32 \cdot 10^{-5}$
stand	1^{2}	1^{7}	1	$2.52 \cdot 10^{-3}$
starve	1^{5}	1^{3}	0	$1.09 \cdot 10^{-4}$
steal	1^{5}	1^{7}	1	$2.84 \cdot 10^{-4}$
step	1^{5}	1^{3}	0	$3.11 \cdot 10^{-4}$
stick	0	0	1	$5.08 \cdot 10^{-4}$
sting	1^{5}	1^{10}	1	$4.56 \cdot 10^{-5}$
stink	1^{5}	1^{7}	1	$2.17 \cdot 10^{-5}$
stretch	1^{2}	1^{3}	0	$3.65 \cdot 10^{-4}$
strew	1^{6}	1	1	$3.11 \cdot 10^{-5}$
stride	1^{11}	1^{7}	1	$6.79 \cdot 10^{-5}$
strike	1^{8}	1^{7}	1	$6.03 \cdot 10^{-4}$
string	0	0	1	$2.92 \cdot 10^{-5}$
strive	0	1^{10}	1	$7.15 \cdot 10^{-5}$
stroke	1^{11}	0	0	$1.01 \cdot 10^{-4}$
suck	1^{5}	1^{10}	0	$1.94 \cdot 10^{-4}$
sup	1^{11}	1^{10}	0	$6.64 \cdot 10^{-6}$
swallow	1^{11}	1^{10}	0	$1.79 \cdot 10^{-4}$
swear	1^{11}	1^{7}	1	$1.73 \cdot 10^{-4}$
sweep	1^{5}	1	1	$2.76 \cdot 10^{-4}$
swell	1^{5}	1^{10}	1	$8.15 \cdot 10^{-5}$
swim	1^{5}	1^{10}	1	$2.52 \cdot 10^{-4}$
swing	1^{8}	1^{7}	1	$3.02 \cdot 10^{-4}$
take	1^{5}	1^{7}	1	$1.03 \cdot 10^{-2}$
teach	1^{2}	1	1	$7.72 \cdot 10^{-4}$
tear	1^{2}	1^{7}	1	$3.32 \cdot 10^{-4}$

Table 7: Complete Data, Part 7

Verb	Old English	Middle English	Modern English[12]	Frequency
tell	0	0	1	$5.75 \cdot 10^{-3}$
think	1^2	1	1	$1.08 \cdot 10^{-2}$
throw	1^5	1^7	1	$8.63 \cdot 10^{-4}$
thrust	0	0	1	$1.05 \cdot 10^{-4}$
tread	1^5	1^8	0	$6.52 \cdot 10^{-5}$
undergo	0	0	1	$9.63 \cdot 10^{-5}$
understand	1^2	1	1	$1.57 \cdot 10^{-3}$
uproot	1^{11}	0	0	$1.72 \cdot 10^{-5}$
upset	0	0	1	$1.26 \cdot 10^{-4}$
wade	1^5	1^{10}	0	$4.50 \cdot 10^{-5}$
wake	1^5	1^7	1	$3.56 \cdot 10^{-4}$
walk	1^5	1^{10}	0	$1.67 \cdot 10^{-3}$
wash	1^5	1^{10}	0	$5.02 \cdot 10^{-4}$
warp	1^8	0	0	$1.72 \cdot 10^{-5}$
wax	1^5	1^7	0	$2.44 \cdot 10^{-5}$
wear	0	0	1	$1.31 \cdot 10^{-3}$
weave	1^{11}	1^7	1	$9.39 \cdot 10^{-5}$
wed	0	0	1	$4.22 \cdot 10^{-6}$
weep	1^5	1^7	1	$1.50 \cdot 10^{-4}$
weigh	1^5	1^7	0	$1.62 \cdot 10^{-4}$
wet	0	0	1	$2.41 \cdot 10^{-5}$
wield	1^5	0	0	$3.68 \cdot 10^{-5}$
win	1^8	1	1	$8.34 \cdot 10^{-4}$
wind	1^5	1^7	1	$9.45 \cdot 10^{-5}$
withdraw	0	0	1	$2.34 \cdot 10^{-4}$
withstand	0	0	1	$3.53 \cdot 10^{-5}$
work	1^2	1^3	0	$2.99 \cdot 10^{-3}$
wreak	1^5	1^7	0	$7.24 \cdot 10^{-6}$
wring	1^5	1	1	$3.62 \cdot 10^{-5}$
write	1^4	1^8	1	$2.51 \cdot 10^{-3}$
writhe	1^5	1^7	0	$3.92 \cdot 10^{-5}$
yell	1^8	0	0	$1.17 \cdot 10^{-4}$
yield	1^8	1^3	0	$9.93 \cdot 10^{-5}$

Lieberman-Michel Figure S1



Lieberman-Michel Figure S2