THE WORD-SURGEON'S COMPENDIUM

MAXEY BROOKE
Sweeny, Texas
A. ROSS ECKLER
Morristown, New Jersey

For years, logophiles have amused themselves by converting one word to another by various processes. Herein is an effort to bring some degree of order to this brand of wordplay.

As the title of the article indicates, the basic operations consist of deletion (the removal of a letter from a word to form another word, as in BRAND to BAND) and insertion (the addition of a letter to a word to form another word, as in SPAN to SPAWN). Note that these operations are not inverse: an n-letter word leads to a possible set of n deletion words, but to a much larger possible set of 26(n+1) insertion words. (In most cases, only a tiny fraction of these possibilities will actually form words.) More generally, deletion wordplay rapidly runs up against firm bounds (since one can delete only as many letters as the word contains), but insertion wordplay is more indefinite, since there is no firm limit to the number of letters that can be added.

Many interesting problems in word surgery involve a third operation, that of transposition (the rearrangement of the letters of a word to form a new word). Even though transposition can be defined in terms of the elementary operations of deletion and insertion, it seems worthwhile for simplicity of exposition to keep it as a separate option.

This article describes briefly a large number of word surgery problems, showing how they can be fitted into a deletion-insertion-transposition framework. The basic field is well-covered in the fourth chapter of Dmitri Borgmann's Language on Vacation (Scribner's, 1965); later developments can be found in Word Ways. To save space, Borgmann's book is referenced by DAB, and the volume and page number of Word Ways is given in the form 7-133.

DELETION

1. Beheadment: delete the first letter of a word to form another word, as in GLASS-LASS. Word-pairs such as this have been the solution to rhymed puzzles for centuries; Will Shortz cites a 1748 British beheadment (6-133) and an 1826 American one (8-31). However, the exhibition of beheadments apart from rhymed puzzles is of recent vintage (DAB). Work has concentrated on finding long words beheadable to a single letter, as ASPIRATE, OESTRONE, PRESTAMP and PRESTATE (6-202); or on finding the longest possible

word that can be singly beheaded, as P-REMISREPRESENTATION (6-198); or on finding the longest possible word that can be doubly beheaded, as I-D-ENTIFICATION (6-202). Other variants include double beheadments, as in IN-DI-VI-DU-AL-LY, and triple beheadments, as in BIO-GEO-CHE-MIS-TRY (6-203). Most of the recent work has been done by Ralph Beaman.

2. Curtailment: delete the last letter of a word to form another word, as in HEROINE-HEROIN. These have much the same history as beheadments. Long words curtailable to a single letter include ALBERTINES (DAB) and ANGELICALS (9-63). Setting aside the uninteresting cases of plurals and past tenses of verbs, the longest words that can be singly curtailed are ELECTROENCEPHALOGRAPH-Y and STEREOPHOTOMICROGRAPH-Y (9-62).

3. Terminal Elision: delete both the first and last letters of a word to form another word, as in STRIPE-TRIP. DEPILATIONS appears to be the longest that can be reduced to a single letter (DAB). As a variant, consider Altered Words: alternately curtail and delete letters to form new words, as in ASHAMED-SHAMED-SHAME-HAME-HAM-AM-A.

4. Letter Subtraction: delete one letter at a time from a word, in each case producing a new word, until only a single letter remains. Here the best effort appears to be that of Borgmann in 6-210: STRANGELINGS-STRANGELING-STRANGLING-STRANGING-STANGING-STAGING-SAGING-AGING-GING-GIN-IN-I, all from Webster's Second Edition.

5. Charitable Word: a word which can give up any single letter and remain a word, as SEAT: SEA, SET, SAT, EAT, introduced by Dave Silverman in 4-171. The longest known examples are PLEATS and CHAINS, in 5-53.

6. Stingy Word: a word which cannot be singly deleted to form another word, as IMPETUOUS, introduced by Mary Youngquist in 5-54. Since single letters are words, the shortest stingy word must be three letters long (for example, PRY).

7. Dismembered Word: a word whose letters can be removed in any order yielding other words at each step, as SHADE: SHAD, HADE, SHA, HAD, ADE, SH, HA, AD, DE, S, H, A, D and E, all found in Webster's Third. In general an n-letter word must be capable of producing $n(n+1)/2 - 1$ additional ones. Developed by Ralph Beaman, this is discussed in 7-168, 7-213 and 8-87 imperfect seven-letter solutions include GAMINES, ABASHED and MORALES (the latter lacking only one word, RAL, in Webster's Second).

INSERTION

1. Hydration: add a letter in front of an existing word to form another word, as in LASS-(C,G)LASS. Ralph Beaman exhibits a long double hydration in 6-201: EVOLUTIONIST-(D,R)EVOLUTIONIST,

and the more elaborate ANGLER-(W, R) ANGLER-(TW, WR) ANGLER. Obviously, many branching possibilities remain to be explored.

2. Hospitable Word: a word which remains a word after a suitable letter is inserted in any position, as CARES: SCARES, CHARES, CADRES, CARIES, CARETS, CARESS, introduced by Darryl Francis in 4-171. This is still the longest hospitable word known. A search for words that are both hospitable and charitable resulted in six four-letter examples by Tom Pulliam in 8-109: GORA, SALE, SELA, SILE, TAIN and TARA, all with respect to Webster's Second.

3. Hostile Word: a word which cannot be changed into another word by the addition of any letter in any position, as SYZYGY, introduced by Mary Youngquist in 5-54. It is not difficult to find long words that are both stingy and hostile. J and Q are the only one-letter hostile words with respect to the Pocket Dictionary, and there are none with respect to Webster's Second (5-109).

Many other interesting word problems involving the insertion of letters can be identified:

a. By analogy with multiple hydrations, multiple caudations can be explored.
b. Is it possible to find examples of each of the 26(n+1) different kinds of insertion words, for any value of n? This is analogous to the problem of finding a set of words in which all letters of the alphabet appear in all positions; note, however, that the word with the letter deleted must also exist.
c. For any word n letters long, how many other words can be generated by multiple insertions? What is the most fecund n-letter word of this type? (The only related work is on Kangaroo Words: the transmutation of a word into a synonym by the addition of letters, as in DIE-DEMISE or SON-SCION, described in DAB, 1-245 and 9-111.)
d. The Insertion Index of a word can be defined as the minimum number of inserted letters required to change a word to another word. What is the shortest word with an undefined insertion index -- i.e., which cannot be converted to another word by the arbitrary insertion of any number of additional letters?

COMBINED INSERTION AND DELETION

In the most general case, one deletes a letter in one position of a word and inserts another letter in another position of the word, as SPOUT-(SPUT)-SPURT. If the letter deleted is at the beginning of a word and the letter added is at the end, a Word Stair is formed. Word stairs were known to Henry E. Dudeney (see Problem 236 in 300 Best Word Puzzles, a 1968 reprint of his 1925 book The World's Best Puzzles), and indeed may be much older. The object is to extend the stair as far as possible without repetition of words; Dudeney gave a 43-step stair of three-letter words and cited the existence of one of

173 steps. The subject is introduced in 1-156, and in 3-48 Dave Silverman challenged readers to find the longest Pocket Webster word stairs possible (leading to WASHERAYETAGEMUD for three-letter words, and TSARIDESK for four-letter words). What is the longest word stair if repeated letters are not allowed?

However, most studies which combine insertion and deletion are limited to two special cases:

1. Letter Substitution: delete a letter in the ith position of a word and replace it with another letter in the ith position, as BLIND-(BLND)-BLOND. Word pairs such as this have been the solution to rhymed puzzles for at least 80 years, and probably longer (see A Key To Puzzledom, 1906); words differing in the initial letter are known as alphagrams, words differing in the second letter as betagrams, and so on. In the March 29, 1897 issue of Vanity Fair, Lewis Carroll introduced the concept of a Word Ladder, in which one word is changed to another by single-letter substitutions yielding words at each step: HEAD, HEAL, TEAL, TELL, TALL, TAIL. Various work in Word Ways has extended these concepts:

   a. A search for words using the vowels AEIOUY in rotation was introduced in 1-156 and continued in 8-190, 8-207 and 9-17; the best example so far appears to be DANE-DENE-DINE-DONE-DUNE-DYNE or PALE-PELE-PILE-POLE-PULE-PYLE. Palmer Peterson exhibited a full alphabetic substitution for three three-letter words in 5-120, using words from obscure sources.
   b. A list of all of the 325 different possible word pairs differing in a single letter (such as VALUE-VALVE for the U,V change) is given in 2-70.
   c. In 1-165, Rudolph Castown introduced two four-letter words, SINS and FATE, having the property that any four-step word ladder connecting these consisted of legitimate words. (This is equivalent to saying that the choice of one letter from each set of parentheses in (S,F) (I,A) (N,T) (S,E) forms a set of sixteen different words -- a concept generalized in 3-144, 3-211 and 4-15 to other than binary choice (Garble Groups).)
   d. Dave Silverman's Onalosi, in 3-108, is a word which will admit a letter-change in any position, as SHORES: CHORES, STORES, SHARES, SHOVES, SHORTS, SHORED. Six-letter and seven-letter examples are given in 4-171 and 5-54. If, on the other hand, a word cannot be changed to another word by a single letter-substitution in any position, it is called an Isolano (2-62, 3-108, 4-171). LLYN is a four-letter isolano with respect to Webster's Second.
   e. Much of the preceding material is discussed in a unified way in an article on Word Networks (6-67, 6-156), in which n-letter words differing in only a single letter are connected by lines in geometrical arrays. Some new questions raised there: What n-letter word has maximal ambiguity (that is, is connected by lines to the greatest number of other words)? What is the largest value of n such that two n-letter words with no letter-matches in corresponding positions can be joined by a minimum

(n-step) ladder? (For boldface Pocket Webster words, the answer is six: SETTLE-SETTEE-SETTER-BETTER-BATTER-BANTER-BANNER.)

2. Letter Movement: delete a letter from the ith position of a word, and place the same letter at the jth position, as STALE-(STAL)-STEAL. If one repeats the letter-movement operation sufficiently often, one can perform any transposition. Here, however, we focus on wordplay requiring movement of a single letter:

   a. Metallege: the exchange of two letters in a word to form another word, as in CONVERSATION-CONSERVATION (DAB, p. 99).
   b. Shiftwords: the movement of the first letter of a word to the end to form another word, as in TABLES-ABLEST. In 7-176, Dave Silverman called for long shiftwords not using -S or -ED endings; examples are given in 7-238, 8-47, 8-112 and 8-233, the best one being Dmitri Borgmann's LETHOLOGICA-ETHOLOGICAL. Tom Pulliam gave a large list of four-letter and five-letter double shiftwords (of the form EAT-ATE-TEA) in 8-173. Even longer double shiftwords are known (DAB, p.92).
   c. Cyclic transposal: a full set of shiftwords, as LAME-AMEL-MELA-ELAM. The five-letter example ESTER-STERE-TERES-EREST-RESTE (DAB, p.93) is the longest known, but it uses a number of obsolete words.

DELETION WITH TRANSPOSITION

Note that the position of the deleted letter no longer plays a role, since the letters of the reduced word are subsequently transposed.

1. Transdeletion (Letter Subtraction with Transposition): delete one letter at a time from a word and transpose the remaining letters to produce a new word, continuing until only a single letter remains, as in SCONE-NOSE-EON-NO-O. Transdeletions have been known for at least 80 years, and probably longer (see A Key To Puzzledom, 1906), as the solution to rhymed puzzles; curiously, Dudeney, in 300 Best Word Puzzles, independently discovered the concept and called it Expanding Words. Two good fourteen-step examples are given in DAB, and two more in 4-73, including COUNTERSALIENT-INTEROSCULATE-INTERLOCATES-INTERCOSTAL-CLARIONETS-CROTALINE-CAROLINE-AILERON-NAILER-LINER-NILE-LIE-EL-E. (Although this can easily be extended to fifteen by pluralization, a step with no transposition is regarded as defective.) It seems likely that diligent research can produce longer specimens.

2. Baltimore Transdeletion (Charitable Word with Transposition): delete each letter in turn from a word and rearrange the remainder to form another word, as in ASTRINGE: RESTING, GRANITE, ERASING, SEATING, STRANGE, GAITERS, RETINAS, STARING. This term was coined by L. M. N. Terry in 1904, according to A Key To Puzzledom. The largest known Baltimore

transdeletion was constructed by Dmitri Borgmann and reported (in a different context) in 1-213: CLARIONETS: STERCOLIN, RELATIONS, CONTRAILS, CONSERTAL, CREATIONS, SECTORIAL, LARCENIST, SECTIONAL, CROTALINE, CENSORIAL. A less satisfactory one can be constructed on INSPECTORIAL (with the doubtful words PROCLINEST and NECROPLAST). He has also constructed a four-way Baltimore transdeletion on ANGRIEST.

3. Transbeheadment (Beheadment with Transposition): delete the initial letter of a word and rearrange the others to make a new word, continuing until only a single letter remains. An eleven-letter example is given in DAB.

4. Transcurtailment (Curtailment with Transposition): delete the terminal letter of a word and rearrange the others to make a new word, continuing until only a single letter remains. An eleven-letter example is given in DAB.

INSERTION WITH TRANSPOSITION

Note that the position of the inserted letter no longer plays a role, since the letters of the augmented word are subsequently transposed.

1. Alphabetic Transaddition: take the letters in a word and successively add each letter of the alphabet, transposing the augmented set to form another word. This problem was introduced by Dave Silverman in 4-115; solutions based on the words SERE and DARE are given in 5-105. Unfortunately, this problem is difficult to do without admitting words from gazetteers and other non-dictionary sources. As an aid, 4-248 called for the compilation of dictionary word pairs differing (after transposition) only in the rare letters J, Q, X or Z (as SEXUAL-SQUEAL).

2. Transdeletion Index (Insertion Index with Transposition): for any word, what is the minimum number of letters that must be added, and the collection transposed, to form another word? The transdeletion index is always greater than or equal to the insertion index, and for some words does not exist. How short can a word be and not have a transdeletion index? In 4-109, SYZYGY is suggested; WUZZY qualifies if hyphenated words (as FUZZY-WUZZY) are not allowed.

3. Transadditional Word Set: take a given word and find all possible longer words which include the letters of the original word (the inverse of the well-known word game, often found in newspapers, in which one is challenged to make words out of the letters contained in a target word). In this issue, Darryl Francis finds the transadditional word set of OLYMPIC (with the added restriction that the added letters in each case also be transposable to a word).

COMBINED INSERTION AND DELETION WITH TRANSPOSITION

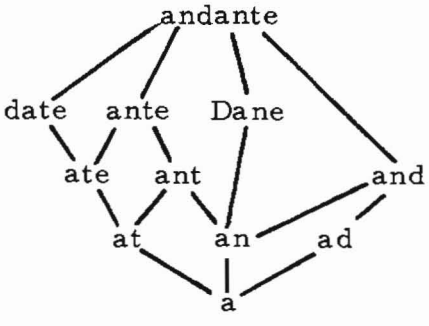
1. Substitute-Letter Transposition (Word Ladder with Transposition): change one letter in a word to another one, and rearrange these to

form a new word, as in PALINDROME-PROCLAIMED-PLEROMATIC-COMPLAINER-... This is discussed in DAB. Unless the word is quite long (say, 12 letters or more), it is likely that one n-letter word can always be changed into another n-letter word by this method.

2. Word Progression (Word Stair with Transposition): select t different letters from the alphabet and arrange them on the perimeter of a circle; for each group of n adjacent letters, rearrange the letters to form a word. An example (for t = 8, n = 4) is given in Dmitri Borgmann's Beyond Language (Scribner's, 1967), in Problem 26: NOLARECI: LOAN, ORAL, REAL, CARE, RICE, NICE, COIN, LION. Note that when t = n+1, this is a Baltimore transdeletion. In 1-215, the largest known values of t corresponding to n from 2 through 6 are exhibited.

3. Word Dice (Garble Group with Transposition): label three three-sided "dice" with nine different letters so that, no matter which sides are uppermost, a word can be formed. In 6-108, Dave Silverman gives the solution (B,E,P), (A,I,O) and (R,T,L). This problem can be generalized to other numbers of sides and numbers of dice, or even to mixtures of dice with different numbers of sides; furthermore, the restriction that all letters be different can be eliminated.

In thinking about word surgery, it may be helpful to visualize problems in terms of a network of words -- one-letter words on one level, two-letter words on the next higher level, and so on -- in which a higher word is connected to a lower one only if the letters of the lower one appear in proper order in the higher one, and no intermediate words can be inserted. A very small part of the network of Pocket Webster words will help to make this clear:



All words in this network, with the exception of ANDANTE, have many additional lines connecting them to other higher words.