

DERIVED PALINDROMES

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Consider the word AEGAEN. Read that word from left to right, next move the N to the left word edge and read the new word NAEGEA from right to left. Since the palindromic reading of AEGAEN is only possible by transposing one of its letters, AEGAEN is a derived palindrome.

In the AEGAEN example, NAEGEA was created by moving the rightmost letter to the left word edge. In other words a palindrome can be derived by moving the leftmost letter in a word to its right edge, e.g. GNOMON ('Part of a sundial'). These two kinds of derived palindromes are referred to below as Type A and Type B respectively. But there is a third variety as well: Words with an even number of letters which are decomposable into two-part tautonyms (e.g. PAPA) can be classified as Type A or Type B. I refer henceforth to words like PAPA as Type C.

| | |
|---|-----------------|
| Type A: Move the rightmost letter to the left word edge | example: AEGAEN |
| Type B: Move the leftmost letter to the right edge | example: GNOMON |
| Type C: Move either the leftmost letter to the right edge or the rightmost letter to the left edge | example: PAPA |

There is a particular variety of Type A derived palindromes I consider to be rather unspectacular, but which I list below nonetheless, namely, words consisting of a palindrome plus a regular inflectional ending, e.g. EKED, LEVELS.

Some of examples under investigation have been discussed in previous issues of this journal, but in a different context. See, for example, the articles by Lesslie Card and A. Ross Eckler ('Palindromic letter-sequences'; *Word Ways*, February 1974) and A. Ross Eckler ('Internal tautonyms'; February 1980). It will be clear from the examples I present below that derived palindromes as defined above constitute only a small subset of the type of examples discussed in those earlier publications. What is more, the earlier articles were not concerned with the three types of derived palindromes.

The purpose of this article is to present a relatively small set of examples illustrating the three types of derived palindromes described above. It is my hope that readers of *Word Ways* will be motivated to find additional examples. Section 1 concerns itself with palindromes derived by transposition of a single letter as described above. In section 2 I compare derived palindromes and conventional palindromes from the mathematical perspective. In section 3 I consider other types of derived palindromes.

1. Palindromes derived by transposition

The following examples are listed according to word length, from the smallest to the largest words. These items are palindromes derived by transposing a single letter from either word edge to the opposite word edge. Most of these examples can be found in the *Official Scrabble Players Dictionary*. Those words not listed in that source can be found in OED (online). The list I present below can easily be expanded with material from the latter source.

Three letter derived palindromes

Type B:

| | | | | | |
|-----|-----|-----|-----|-----|-----|
| ABB | BOO | ELL | INN | ODD | TEE |
| ADD | BRR | ERR | JEE | OFF | TOO |
| AFF | CEE | ESS | LEE | PEE | UMM |
| ALL | COO | FEE | LOO | POO | VEE |
| ASS | DEE | GEE | MAA | REE | WEE |
| ATT | EBB | GOO | MOO | ROO | WOO |
| BAA | EFF | IFF | NEE | SEE | ZEE |
| BEE | EGG | ILL | NOO | SHH | ZOO |

Type A:

| | |
|------|-----|
| AAH | OOF |
| AAL | OOH |
| E EK | OOK |
| EEL | OON |

Type A (regular inflection):

| |
|-----|
| AAS |
| OOS |

Four letter derived palindromes:

Type C:

| | | | |
|------|------|------|-------|
| BABA | GOGO | MAMA | YO-YO |
| CACA | HAHA | NENE | |
| COCO | JUJU | PAPA | |
| DADA | KAKA | TITI | |
| DODO | LULU | TOPO | |

Type B:

| | | | | | | | |
|------|------|------|------|------|------|------|------|
| AGOG | DELE | GURU | KATA | LIRI | MONO | RAJA | STET |
| BENE | DEME | HEBE | KAVA | LOBO | NADA | REDE | TORO |
| BOLO | DENE | HERE | KIWI | LOCO | NAJA | RETE | WERE |
| BOYO | DOJO | HOBO | KOBO | LOGO | NALA | ROTO | |
| BOZO | FEME | HOMO | KOLO | LUAU | NEVE | SEME | |
| CEDE | FETE | IMAM | KOTO | MERE | NIDI | SENE | |
| CERE | GALA | JAVA | KUDU | METE | NISI | SERE | |
| COHO | GAMA | JEFE | KURU | MIDI | PILI | SHAH | |
| DATA | GENE | JETE | LAVA | MINI | POCO | SOLO | |
| DEKE | GOBO | KANA | LAMA | MOJO | POLO | STAT | |

Type A:

| | | | | | | | |
|------|------|------|------|------|------|------|------|
| AGAR | ANAL | DIDO | FIFE | IRIS | NINE | RARE | URUS |
| AJAR | ARAK | DUDE | GAGA | IWIS | OBOE | SASH | VIVA |
| ALAE | AWAY | EDEN | GAGE | LILT | OBOL | SASS | VIVE |
| ALAR | BABE | EVER | IBIS | LILY | ODOR | SISS | |
| ALAS | BABY | EWER | ILIA | MEMO | PIPE | SUSS | |
| AMAH | COCK | EYER | IMID | MIME | POPE | TETH | |

Type A (regular inflection):

| | | | | | | | |
|------|------|------|------|------|------|------|------|
| ABAS | DADS | EVES | GAGS | MOMS | PEPS | TATS | VAVS |
| AGAS | DUDS | EWES | GIGS | MUMS | PIPS | TITS | WAWS |
| ANAS | EKED | EXED | HAHS | NUNS | POPS | TOTS | WOWS |
| BIBS | EKES | EYES | HEHS | PAPS | PUPS | ULUS | |

Five letter derived palindromes:**Type B:**

| | | |
|-------|-------|-------|
| BELLE | GAMMA | MASSA |
| BENNE | HOLLO | MOTTO |
| CALLA | JINNI | POTTO |
| CANNA | KAPPA | SELLE |
| FEMME | LOTTO | VILLI |
| FESSE | MANNA | YOBBO |

Type A:

| | | | | | |
|-------|-------|-------|-------|-------|-------|
| ADDAX | ASSAI | EMMER | ANNAS | EGGED | OTTOS |
| ALLAY | ASSAY | EMMET | BABAS | ERRED | PEEPS |
| ANNAL | ATTAR | TEETH | BOOBS | ESSES | POOPS |
| APPAL | BOOBY | TOOTH | CACAS | KOOKS | TOOTS |
| ARRAS | COOCH | TOOTS | DEEDS | NAANS | |
| ARRAY | EGGER | | EBBED | NOONS | |

Type A (regular inflection):**Six letter derived palindromes:****Type B:**

| | | | | | |
|--------|--------|--------|--------|--------|---------|
| ACIDIC | GNOMON | ROCOCO | BEEBEE | KOODOO | YOO-HOO |
| ACINIC | HALALA | SEMEME | BOOBOO | MUUMUU | |
| ANILIN | KRONOR | UNEVEN | BOOHOO | PEEWEE | |
| ASSESS | MANANA | URETER | COOCOO | TEEPEE | |
| BANANA | PREFER | ZANANA | HOODOO | VEEPEE | |
| BREWER | PREYER | | HOOPOO | VOODOO | |

Type B (three-part tautonyms):

Type A:

AEGEAN MINIMA
 ARARAT REVERE
 DIVIDE REVERY
 GARAGE TOROTH
 KANAKA TOYOTA
 MADAME

Type A (regular inflection)

AZULAS KAYAKS REFERS
 BAZARS KAZAKS ROTORS
 CIVICS LEVELS SEVERS
 EBBED MADAMS TATARS
 EGGED MINIMS TENETS
 ERRED RADARS

Seven letter derived palindromes:**Type A:**

CARRACK NIMMING
 FRETTER NIPPING
 GRAMMAR SUFFUSE
 PRESSER TANNATE

TILLITE
 TREKKER

Type A (regular inflection)

HALLAHS MALAYALAMS
 PULLUPS NAURUANS
 TERRETS RACE CARS
 MURDRUMS ROTATORS

Type B:

KNAPPAN, CHALLAH

Eight letter derived palindromes:

The source for the first Type A example is the Meriam Webster Medical Dictionary.

Type A:

ADINIDAN
 SELFLESS

Type B:

IGNITING REDIVIDE
 PRO-TUTOR KAVAKAVA
 RETINITE

Nine or more letter derived palindromes:

DYSPEPSY
 SINONISM
 TARTRATE

Longest known example:

SENSUOUSNESS

It was noted above that Type A derived palindromes can be obtained by attaching regular inflectional suffixes (i.e. s or D) to palindromic bases. There are also Type B examples involving these regular inflectional endings. Here are the few examples I have found of four, five and six letter words belonging to this category:

Type B (regular inflection):

Four letters:

ASKS OSES
ASPS PSIS
ISMS USES
ISTS TSKS

Five letters:

USEES

Six letters:

ASANAS

This type of derived palindrome has proven to be rather elusive because the base word without the inflectional ending is not a palindrome. Whether or not the list with words ending in s can be expanded is a question I leave open for readers of this journal. I also leave open whether or not there are examples of this type ending in D. To date, I have found none.

2. Some math

Readers may wonder whether or not the number of possible derived palindromes for any given word length is the same as the number of possible palindromes for words of the same length. In fact, the answer to this question needs to distinguish between words containing an odd number of letters and those with an even number. Consider by means of illustration the number of possible three letter palindromic words. In a language like English with an alphabet consisting of 26 letters, there are 26 possible choices for the letter occupying the first of the three slots, 26 possible choices for the second slot, but only one choice for the third, since that letter is identical to the first. We therefore have $26 \times 26 \times 1 = 676$ possible three letter palindromes. For three letter derived palindromes (Type A) we have 26 choices for the first slot, 26 for the third but only one choice for the second, since it will be the same as the first. There are therefore $26 \times 1 \times 26 = 676$ derived palindromes (Type A). The same procedure will also reveal that number of possible three letter derived palindromes of Type B is 676, although I do not demonstrate this here. Using the same procedure, the number of possible four letter palindromes is $26 \times 26 \times 1 \times 1 = 676$. Consider now the number of possible four letter derived palindromes (Type A): There are 26 choices for the first slot, 26 for the second, only one for the third (which is the same as the first) and 26 for the fourth. This means there are $26 \times 26 \times 1 \times 26 = 17,576$ possible four letter derived palindromes. I have summarized these figures in the following chart, which also includes the calculations for palindromes and derived palindromes consisting of two, five and six letters:

| number of letters | type of word | possible number |
|-------------------|--------------------|-----------------|
| 2 | palindrome | $26^1=26$ |
| 2 | derived palindrome | $26^2=676$ |
| 3 | palindrome | $26^2=676$ |
| 3 | derived palindrome | $26^2=676$ |
| 4 | palindrome | $26^2=676$ |

| | | |
|---|--------------------|----------------|
| 4 | derived palindrome | $26^3=17,576$ |
| 5 | palindrome | $26^3=17,576$ |
| 5 | derived palindrome | $26^3=17,576$ |
| 6 | palindrome | $26^3=17,576$ |
| 6 | derived palindrome | $26^4=456,976$ |

(The numbers listed in the final column for ‘derived palindromes’ refer to only to derived palindromes belonging to Type A or Type B, but not to Type C. For the latter, the number of possible palindromes for any given word length is identical to the number of possible palindromes for words of the same length, although I do not show this here. The number of possible derived palindromes for Type A and Type B words involving regular inflectional endings is different from the numbers indicated in the final column of the chart because that type of example poses restrictions on the number of possible inflectional endings.)

Although the chart does not constitute a rigorous proof, it suggests that the number of possible palindromes will always be the same as the number of derived palindromes for words consisting of the same number of letters, provided that the number of letters is odd. If the number of letters is even, then the number of possible derived palindromes will always be equal to the number of possible palindromes of that letter type multiplied by 26.

3. Other types of derived palindromes

Since there are three logical ways of manipulating the sequencing of letters in any given word (deletion, insertion, transposition), it follows that there should be three types of derived palindromes, but within each of those three categories, a multitude of subcategories suggest themselves as well. For example, in section 1 I discussed palindromes derived by transposition of a letter at one word edge to the opposite end of the word, but there could be palindromes derived by moving the second letter to the right edge, the second letter to the left of the last letter, the third letter to the right edge etc.

Consider the three logical types of derived palindromes mentioned above. In the following I concentrate on palindromes derived by transposing, deleting or inserting a single letter at one edge of the word:

Type of derived palindrome:

Example:

Transposition:

AEGEAN

Deletion:

PREFER

Insertion:

TOO

Palindromes derived by deletion are easily obtainable from the examples presented in section 1: If the deletion of a consonant at the edge of a word yields a palindrome (e.g. PREFER > REFER), then the example involves a palindrome derived by deletion. In fact, the majority of the examples in section 1 cannot be included among the list of palindromes derived by deletion because the

omission of a letter at one edge of the word does not always result in an (occurring) palindrome. For example, the deletion of the G in GNOMON gives us NOMON, which is not an English word.

Similar generalizations hold for palindromes derived by insertion. In the example listed above, TOO is not a palindrome, but if the letter T is inserted at the right edge, then the palindrome TOOT has been created. Only a subset of the palindromes derived by transposition in section 1 also qualifies as palindromes derived by insertion.

I do not provide a list of palindromes derived by deletion or insertion. The curious reader will construct these lists for herself.

Palindromes derived by transposition are quite different from palindromes derived by deletion or insertion: The movement of a letter in the former must crucially occur after the act of reading the word from one edge of the word to the opposite edge, but before the act of reading the same word in the opposite direction has commenced. By contrast, palindromes derived by deletion or insertion can only be derived palindromes if the relevant change (deletion or insertion) takes place before one has read the word from left to right and then from right to left. The distinction between the two types of derived palindromes is illustrated in the following two examples. I state explicitly in the left-hand column the various acts and the order in which they must occur:

| | |
|---|----------|
| | ‘AEGEAN’ |
| (1) Read word from left to right: | AEGEAN |
| (2) Move rightmost letter to left edge: | NAEGEA |
| (3) Read word from right to left: | AEGEAN |
| | ‘REFER’ |
| (1) Delete one letter at left edge: | REFER |
| (2) Read word from right to left: | REFER |
| (3) Read word from left to right: | REFER |