Numbers in New Guinea

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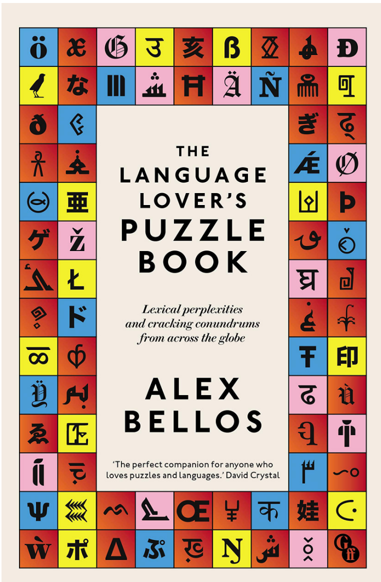

This puzzle from Alex Bellos ([1]) follows the themes in his new book, *The Language Lover's Puzzle Book* ([2]), which, among other things, looks at number systems in different languages. (See also his Numberphile video.[1])

Today is the International Day of the World's Indigenous People, which aims to raise awareness of issues concerning indigenous communities. Such as, for example, the survival of their languages. According to the Endangered Languages Project,[2] more than 40 per cent of the world's 7,000 languages are at risk of extinction.

Among the fantastic diversity of the world's languages is a diversity in counting systems. The following puzzle concerns the number words of Ngkolmpu, a language spoken by about 100 people in New Guinea. (They live in the border area between the Indonesian province of Papua and the country of Papua New Guinea.)

Ngkolmpu-zzle

Here is a list of the first ten cube numbers (i.e. 1^3, 2^3, 3^3, …, 10^3):

1, 8, 27, 64, 125, 216, 343, 512, 729, 1000.

Below are the same ten numbers when expressed in Ngkolmpu, but listed in random order. Can you match the correct number to the correct expressions?

eser tarumpao yuow ptae eser traowo eser

eser traowo yuow

naempr

naempr ptae eser traowo eser

naempr tarumpao yuow ptae yuow traowo naempr

naempr traowo yempoka

tarumpao

yempoka tarumpao yempoka ptae naempr traowo yempoka

yuow ptae yempoka traowo tampui

yuow tarumpao yempoka ptae naempr traowo yuow

Here's a hint: this is an arithmetical puzzle as well as a linguistic one. Ngkolmpu does not have a base ten system like English does. In other words, it doesn't count in tens, hundreds and thousands. Beyond its different base, however, it behaves very regularly.

1 https://www.youtube.com/watch?v=9p55Qgt7Ciw
2 http://www.endangeredlanguages.com/

This puzzle originally appeared in the 2021 UK Linguistics Olympiad (https://www.uklo.org/), a national competition for schoolchildren that aims to encourage an interest in languages. It was written by Simi Hellsten, a two-time gold medallist at the International Olympiad of Linguistics, who is currently reading maths at Oxford University.

My Solution

First I assigned letters to the words to make it easier to see patterns:

eser	*tarumpao*	*yuow*	*ptae*	*traowo*	*naempr*	*yempoka*	*tampui*
A	B	C	D	E	F	G	H

If these 8 letters represented digits, it would mean the base is at least base 7. But then I realized the "numbers" had too many digits for most of the cubes in something like base 7. I then grouped the letters in pairs and noticed that three letters, B, D, E showed up repeatedly at the end of the pairs. They could be powers of the base for the number system written out. (I hoped the language was not read from right to left.) F and B showed as singletons, so they must be perfect cubes.

AB CD AE A
eser tarumpao yuow ptae eser traowo eser

AE C
eser traowo yuow

F
naempr

FD AE A
naempr ptae eser traowo eser

FB CD CE F
naempr tarumpao yuow ptae yuow traowo naempr

FE G
naempr traowo yempoka

B
tarumpao

GB GD FE G
yempoka tarumpao yempoka ptae naempr traowo yempoka

CD GE H
yuow ptae yempoka traowo tampui

CB GD FE C
yuow tarumpao yempoka ptae naempr traowo yuow

I looked at some bases to see where two and only two base powers would be cubes. The base 10 cube numbers (i.e. 1^3, 2^3, 3^3, …, 10^3) are 1, 8, 27, 64, 125, 216, 343, 512, 729, 1000.

base 9: 9^3 9^2 9 1 → 729 81 9 1 (2 cubes)
base 8: 8^3 8^2 8 1 → 512 64 8 1 (4 cubes)
base 7: 7^3 7^2 7 1 → 343 49 7 1 (2 cubes)
base 6: 6^3 6^2 6 1 → 216 36 6 1 (2 cubes)
base 6: 5^3 5^2 5 1 → 125 25 5 1 (2 cubes)

So base 9, base 7, base 6, and base 5 are candidates. But I needed to keep in mind that the list had 4 4-digit numbers, 2 3-digit numbers, 2 2-digit numbers, and 2 1-digit numbers (with the caveat that all but one "single-digit" number represented a power of a base and so implicitly represented multiple digits). In the following table the numbers in parentheses represent calling a base-power multiple-digit number a single digit number.

base	**Cubes**										**#4-digit**	**#3-digit**	**#2-digit**	**#1-digit**	
											5 (4)	**2**	**2**	**1 (2)**	**list**
10	**1**	**8**	**27**	**64**	**125**	**216**	**343**	**512**	**729**	**1000**	**1 (0)**	**5**	**2**	**2 (3)**	**X**
9	**1**	**8**	**30**	**71**	**148**	**260**	**421**	**628**	**1000**	**1331**	**2 (1)**	**4**	**2**	**2 (3)**	**X**
8	~~**1**~~	~~**10**~~		~~**100**~~				~~**1000**~~							**X**
7	**1**	**11**	**36**	**121**	**276**	**426**	**1000**	**1330**	**2061**	**2626**	**4 (3)**	**3**	**2**	**1 (2)**	**X**

base	Cubes										#4-digit	#3-digit	#2-digit	#1-digit	
6	**1**	**12**	**43**	**144**	**175**	**1000**	**1331**	**2212**	**3213**	**4344**	**5 (4)**	**2**	**2**	**1 (2)**	✓
5	**1**	**13**	**102**	**224**	**1000**	**1331**	**2333**	**4022**	**5404**	**8000**	**6 (5)**	**2**	**1**	**1 (2)**	X

Base 6. The only viable candidate with the correct number of digits for the list is base 6. (Clearly lower bases will have too many 4-digit numbers and even some 5-digit or higher numbers.) Then B, D, E would be powers of 6, namely, 216, 36, 6 respectively. F would be 1. I substituted these base power letters in the appropriate positions.

base 10	1	8	27	64	125	216	343	512	729	1000
base 6	**1**	**12**	**43**	**144**	**175**	**1000**	**1331**	**2212**	**3213**	**4344**
	F	1E 2	4E 3	1D 4E 4	3D 2E 5	B	1B 3D 3E 1	2B 2D 1E 2	3B 2D 1E 3	4B 3D 4E 4
	F	FE G	AE C	FD AE A	CD GE H	B	FB CD CE F	GB GD FE G	CB GD FE C	AB CD AE A

I then filled in the remaining numbers with the appropriate letters to ensure they agreed with my letter representation of the list of words.

eser	*tarumpao*	*yuow*	*ptae*	*traowo*	*naempr*	*yempoka*	*tampui*
A	B	C	D	E	F	G	H
4	216	3	36	6	1	2	5

Here is the result for the cubes:

(Base 10) 1000	(Base 6) 4344	AB CD AE A *eser tarumpao yuow ptae eser traowo eser*
27	43	AE C *eser traowo yuow*
1	1	F *naempr*
64	144	FD AE A *naempr ptae eser traowo eser*
343	1331	FB CD CE F *naempr tarumpao yuow ptae yuow traowo naempr*
8	12	FE G *naempr traowo yempoka*
216	1000	B *tarumpao*
512	2212	GB GD FE G *yempoka tarumpao yempoka ptae naempr traowo yempoka*
125	175	CD GE H *yuow ptae yempoka traowo tampui*
729	3213	CB GD FE C *yuow tarumpao yempoka ptae naempr traowo yuow*

Bellos Solution

Here is Bellos's solution ([3]).

Ngkolmpu has a base 6 system. (Which is incredibly rare, and researchers believe may be a result of tallying yams[3]).

When looking at all the numbers you may have noticed that when the expression has more than one word, the penultimate word is always *traowo.*

Also, whenever the expression has more than three words, the word *ptae* always appears two words before *traowo.* And whenever the expression has more than five words, the word *tarumpao* always appears two words before *ptae*.

This patterns leads us to think that the structure of writing a number is:

A tarumpao B ptae C traowo D

Since *traowo* is more common than *ptae,* which is more common than *tarumpao*, we are led to the supposition that *traowo* is the base, *ptae* is the $(\text{base})^2$ and *tarumpao* is the $(\text{base})^3$.

[The equivalent in English would be that our word expressions are ‘A thousand B hundred C tens D.]

With this hypothesis, we need to find the base. If the base is 7, then *tarumpao* is 343. But there are five expressions with *tarumpao*, but only four numbers 343 or above, which means that *tarumpao* cannot be 343. The base must be less than 7.

If the base is 5, then *tarumpao* is 125. There are five expressions with *tarumpao*, but six numbers 125 or above, which means that *tarumpao* cannot be 125. The base must be more than 5.

The base must be 6, with *ptae* = 36, and *tarumpao* = 216.

Thus *naempr* is 1, and so on by comparing digits we get the full answer: [the expressions are listed in the order 1000, 27, 1, 64, 343, 8, 216, 512, 125, 729.]

Another way you could have made a reasonable guess that the base is 6 is to notice that there are 8 different Ngkolmpu words used. Since there are different words for the base, $(\text{base})^2$ and $(\text{base})^3$, the other five words are likely to be the other ‘single digits’: 0, 1, 2, 3, 4 and 5.

If you want to read more about Ngkolmpu, check out this blogpost by Matthew Carroll,[4] which explains how yam tallying could have led to the base 6 system. You will also learn the unique words for 6^4, and 6^5, which are 1296 and 7776.

References

[1] Bellos, Alex, “Can you solve it? Numbers in New Guinea”, *Alex Bellos’s Monday puzzle*, 9 August 2021 (https://www.theguardian.com/science/2021/aug/09/can-you-solve-it-numbers-in-new-guinea)

[2] Bellos, Alex, *The Language Lover’s Puzzle Book: Lexical perplexities and cracking conundrums from across the globe*, Guardian Faber, 2021

[3] Bellos, Alex, “Did you solve it? Numbers in New Guinea”, *Alex Bellos’s Monday puzzle*, 9 August 2021 (https://www.theguardian.com/science/2021/aug/09/did-you-solve-it-numbers-in-new-guinea)

[3] https://morph.surrey.ac.uk/index.php/2018/06/20/how-to-count-to-1296-in-ngkolmpu/

[4] https://morph.surrey.ac.uk/index.php/2018/06/20/how-to-count-to-1296-in-ngkolmpu/