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## Maximum Limit on the Number of *Science* Papers Man Can Write

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### Abstract

“*Science*” journal is one of the world’s top academic journals. Many researchers are trying to publish their work in *Science*, and only a few selected novel papers are accepted. However, we think that this kind of process cannot continue forever. In this paper, we show that there is a limit to the number of *Science* papers that can be written. Therefore, the day will come when *Science* cannot publish new papers anymore. Using a similar method, we estimate the maximum limit on the number of pop songs that can be composed. By extending our discussion to all kinds of digital contents, we derive a mathematical expression for the maximum number of digital contents of a certain type that can be created. These results imply that someday man will not be able to produce new papers or new digital contents anymore. This conclusion raises deep philosophical questions.

**Keywords:** Limit of contents, Digital contents, Maximum number of music, Maximum number of papers, Limit of development

### 1. Introduction

*Science* is a peer-reviewed journal published by the American Association for the Advancement of Science (AAAS), and one of the world's top academic journals. It was first published in 1880 and currently is issued weekly [1]. It covers all fields of science and has published many important novel research works throughout its history. However, can this continue forever? Or, to put it more precisely, can “new” papers appear in *Science* forever? Here, we show that there is a limit on the number of papers that can be written in *Science*. We also roughly estimate such maximum number of papers and the “final day” when *Science* will not be able to publish new papers anymore.

We also extend our discussion to all kinds of digital contents including pop songs [2], movies, and books. We derive a mathematical expression for the maximum limit on number of any kinds of digital contents. These results imply that someday man will not be able to produce new papers or new digital contents anymore. The research of this paper gives us deep philosophical meanings.

### 2. Maximum limit on the number of *Science* papers

According to the guidelines for authors [3], *Science* research papers are limited to 4500 words. By surveying several *Science* papers, we found this corresponds to roughly 30,000 characters, including blanks. Most of those characters are English letters and Arabic numerals. In this paper, we only consider English letters, Arabic

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numerals and blanks, to simplify the estimation. Therefore, each character can be one of the 26 letters of the English alphabet, one of the 10 Arabic numerals, or a blank – i.e. there are 37 possible choices for each character.

Thus, the number of distinct possibilities for a paper of 30,000 characters is  $37^{30,000}$ , because for each character one can choose between 37 options, and such selection is repeated 30,000 times. In other words, the maximum number of *Science* papers is roughly  $37^{30,000}$ . If we approximate that figure by using  $37^{30} \approx 10^{47}$ , we conclude that the maximum number of different *Science* papers is roughly  $37^{30,000} = (37^{30})^{1000} \approx (10^{47})^{1000} = 10^{47,000}$ .

For the purposes of this estimation, two papers are regarded as different even if they differ by just a single character. Therefore, if we consider the typical, real-world rules about plagiarism, the maximum number of *Science* papers is further decreased. Moreover, in our estimation we implicitly assumed that any random combination of letters is meaningful. If, on the contrary, we consider only currently meaningful English words, the maximum number of *Science* papers is reduced again. The reason why we admitted all possible combinations of letters is that we want to account for the chance of new words in the future.

For comparison, in this paragraph, we will estimate the maximum number of *Science* papers when considering only currently meaningful English words. Although it is not easy to pin down the exact number of English words, according to the Oxford English Dictionary [4], there are more than 600,000. Here, taking into account Latin words or exotic words that come from other languages, we assume that the number of English words is around 1,000,000 ( $=10^6$ ). That is, there are  $10^6$  possible choices for each English word. As a *Science* research paper is limited to 4500 words, the maximum number of *Science* papers will be  $(10^6)^{4500} = 10^{27,000}$ . By only considering currently meaningful English words, the maximum number of *Science* papers is thus reduced  $10^{20,000} (= 10^{47,000}/10^{27,000})$  times with respect to the previous estimation.

Someone may insist that the figures or tables of two papers can still be different even if all their characters are the same. However, although figures or tables are different, we may not say that the two papers are really distinct if the characters that compose their introduction, description, discussion, and conclusion are all equal. Further, the maximum number of possible figures and tables is also limited, because they are digital data; and, as it will be later discussed, the number of all kinds of digital data is limited. Therefore, even if we accept the difference of figures and tables as sufficient to distinguish two papers, there still exists a maximum number of *Science* papers, albeit larger.

Now, we will estimate the final day when *Science* will not be able to publish “new” articles anymore, assuming that the maximum number of *Science* papers is  $10^{47,000}$ . As previously mentioned, *Science* is published weekly, and each issue contains four research articles on average. This means that *Science* publishes about 200 research articles in a year. Therefore, the final day for *Science* will be in  $10^{47,000} / 200 = 5 \times 10^{46,997}$  years. In other words, *Science* will not be able to publish any “new” papers after  $5 \times 10^{46,997}$  years. Our estimation is summarized in Table 1.

Some people may think that  $5 \times 10^{46,997}$  years is too far from now. However, the important point is that there exists a limit on the possible number of *Science* papers and, if human history continues, the day will come when *Science* will not be able to publish new papers anymore.

**Table 1. Estimation of the limit on the number of *Science* papers**

Item	Estimated Value
Number of characters in a <i>Science</i> paper (including blanks)	30,000
Possible choices for each character	37 (including English letters, Arabic numerals and the blank)
Maximum number of <i>Science</i> papers	$37^{30,000} \approx 10^{47,000}$
Number of <i>Science</i> papers in a year	200
Final day for <i>Science</i>	In $10^{47,000} / 200 = 5 \times 10^{46,997}$ years

### 3. Maximum limit on the number of pop music

The conclusion in the previous section is indeed not limited to the *Science* magazine, but can be applied to any kind of digital content, including books, pictures, music, movies, etc. In this paper, we will discuss the case of pop music as an example. Do you think that versioning in pop music occurs just because the original song is too good? Perhaps, the reason is rather that the number of songs man can compose is limited. These days, pop music is produced and saved in digital media, and can be presented as an MP3 file. For sampling rates up to 160 kHz, the MP3 file size of most pop songs of about four minutes is less than 5 Mbytes.

Then, the maximum number of four-minute pop songs is limited to the number of possible digital files of 5 Mbytes (= 40 Mbits). As there are two possible choices for each bit (0 or 1) and such selection should be repeated 40,000,000 times, the maximum number of pop songs will be  $2^{40,000,000}$ . If we use the approximation  $2^{10} \approx 10^3$ , this number becomes  $2^{40,000,000} = (2^{10})^{4,000,000} \approx (10^3)^{4,000,000} = 10^{12,000,000}$ . Our estimation about pop music is summarized in Table 2.

In this estimation, two songs are considered different even if their MP3 files differ by just a single bit. Therefore, if we consider the typical rules about plagiarism, the maximum number of songs will further decrease.

**Table 2. Estimation of the maximum number of pop music**

Item	Estimated Value
Typical file size of a pop song (MP3)	5 Mbytes = 40 Mbits
Maximum number of pop songs	$2^{40,000,000} \approx 10^{12,000,000}$

### 4. Maximum limit on the number of any kinds of digital contents

This limit on the number of songs applies, more generally, to any kind of digital content. Using the same method as for the pop music, the maximum number of digital contents of a certain type that man can produce is expressed as

$$N_{MAX} = 2^K, \quad (1)$$

where K is the typical file size of the digital contents in bits. For example, the maximum number of two-hour movies, which typically need 2 Gbytes (= 16 Gbits), is  $2^{16,000,000,000}$ . Once more, in this definition two movies are considered as different even if they differ by just a single point in a scene, so the maximum number of movies will be smaller if we consider the typical rules about plagiarism.

Because of the limit given by Equation (1), scientists and artists will have increasing difficulties to write “new” papers and create “new” digital contents including music, books, pictures, and movies in the future, if human history continues. It is possible that we will create a new, more complex language system that allows us to write more new papers. Similarly, we may be able to create new recording systems better than the current, so that we can produce more new music. However, if the new language and music recording systems are based on discrete-state elements (such as characters or bits), the number of new materials will still be limited.

Ultimately, the day will come when man cannot further produce new papers or new music. What should we do if we cannot create “new” things anymore? Will it be the end of mankind?

## 5. Conclusion

In this paper, we showed that there is a limit on the maximum number of *Science* paper and any kinds of contents made digitally. We also estimated the maximum number and proposed the general mathematical expression of the maximum number of any kind of digital contents. Therefore, the day will come eventually when man cannot further produce new scientific papers or new digital arts including music, movie, etc. And also, scientists and artists will have more and more difficulties to make new contents as human history continues.

The problem presented in this paper raises deep philosophical questions, such as what we will do when we are not able to create new things anymore, of extreme relevance for the digital age in which we live.

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