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25. C. H. Andrewes, chairman of the Subcommittee on Viruses of the International Nomenclature Committee has signified to us his approval of the name *adenovirus*, indicating that it offers a great advantage and can be readily integrated with the proposed system of the Committee for Virus Nomenclature.

19 June 1956

Encoding Nonintegers in a General p-adic Number System

Without doubt the most common number system in use is the decadic system, which is more often called the decimal system and in which ten basic numbers (*base* or *radix* ten) 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 are used. But the decadic system is by no means the only possible number system. In fact, it is not even necessary that the radix of a number system be equal to or less than ten; it can be greater than ten. As an example, consider the number system with radix 11. Here a new symbol, say α, must be created as the eleventh basic number in addition to the ten in the decadic system, making the new list of basic numbers as follows: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, α. If one wishes to express the number 360 in this new system, one would have: $(360)_{10} = (2\alpha 8)_{11}$. We will call the number system with a radix p a p-adic number system.

Methods of converting integers in the decadic system to expressions in other number systems and vice versa by means of Euclid's algorithm are well known. However, little information seems to be available for converting nonintegers, numbers with decimal places in the decadic system. This note presents ways for encoding an arbitrary nonintegral number and a rational fraction in a general p-adic system.

Suppose it is desired to encode a nonintegral number in the decadic system into one in a p-adic system. The integral and decimal parts (parts preceding and following the decimal point, respectively) of the number must be converted separately. Euclid's algorithm or the continued division process can be applied to both parts, but the methods of application are different. For the integral part, the process is to perform successive divisions by p and collect the remainders in the reverse order; for the decimal part, it is necessary to perform successive divisions by p^{-1} and collect the remainders in the forward order. As an example, assume that $(7.3125)_{10}$ is to be encoded in the diadic system (radix 2). We will find that

$$(7)_{10} = (111)_2$$

and

$$(0.3125)_{10} = (0.0101)_2$$

Hence

$$(7.3125)_{10} = (111.0101)_2$$

It may also be proved that this conversion is unique.

It is clear that for integral numbers, the maximum number expressible with n digits in the decadic system is $(10^n - 1)$; this maximum number is $(2^n - 1)$ in the diadic system and $(3^n - 1)$ in the triadic system, and so forth. There is no simple relationship between a decimal number of a given number of digits in the decadic system and the number of necessary digits to express the same number in another system; it depends on the desired accuracy. For example,

$$(3.1416)_{10} = (11.00100100001111111110\ .\ .\ .)_2$$

All *fractionals* (numbers less than one and signified by a fractional point placed at the left of the number) that terminate or repeat cyclically can be expressed as proper rational fractions. Conversely, it is also true that all proper rational fractions can be written as fractionals which terminate or repeat cyclically; the period or cycle of repetition may sometimes be very long. These statements hold for the conventional decadic system as well as for the general p-adic system. Let it be desired to encode the rational fraction $(A/B)_{10}$, where A and B are integers prime to each other and $A < B$, in the diadic system. It is of course possible first to express the integral numerator and denominator, A and B, both in the binary code and then to divide. Division in the diadic system is similar to the operation in the decadic system except that only two basic numbers, 0 and 1, are involved in the former system. However, straightforward division may prove to be a laborious and discouraging process because one does not know when to expect periodicity or how long the period of repetition is, which can indeed be very long. Several important relationships are pointed out in the succeeding paragraphs which will greatly facilitate the encoding process. Reference to the diadic system is not to be taken as a limitation of the relationships.

1) If the denominator B is expressible as an integral power of 2, then the fraction $(A/B)_{10}$ when written as a fractional in the diadic system will terminate. This is easily seen, because if $(B)_{10} = 2^n$, then $(B)_{10} = (1000\ .\ .\ .\ .\ 0)_2$, 1 followed by n zeros in the diadic system. Hence

$$\left(\frac{5}{16}\right)_{10} = (0.3125)_{10} = \left(\frac{5}{2^4}\right)_{10} = \left(\frac{101}{10000}\right)_2 = (0.0101)_2$$

2) If the denominator B is expressible in the form $(B)_{10} = 2^k \cdot m$, where k is any positive integer including zero, and m is prime to 2, then the fraction $(A/B)_{10}$ when written as a fractional in the diadic system will repeat cyclically and indefinitely. This statement can be proved by the use of Euler's theorem on the congruence of numbers in number theory. It can be shown (*1*) that if integer p is relatively prime to integer m, then there are positive exponents s for which

$$p^s = 1\ (\text{mod}\ m)$$

This expression means that $(p^s - 1)$ is divisible by m. In the language of number theory, one would say that p^s and 1 are congruent modulo m. Rules exist for the determination of the smallest value of the exponent s and the period of the remainders. It suffices to say here that since m is prime to 2, it is possible to determine the smallest value of the exponent s such that $(2^s - 1) = Cm$.

$$\left(\frac{A}{B}\right)_{10} = \frac{A}{2^k \cdot m} = \frac{AC}{2^k(2^s - 1)} = \frac{AC}{2^{k+s}}\left(\frac{1}{1 - 2^{-s}}\right)$$

The last expression can be easily written in the diadic notation; and the appearance of the second factor indicates clearly the existence of an infinite geometric progression with ratio 2^{-s}. As an example, suppose one desires to express the rational fraction $(5/14)_{10}$ as a fractional in the diadic system. Now

$$B = 14 = 2^1 \cdot 7$$

whence $k = 1$ and $m = 7$. It is obvious here that the exponent of 2 modulo 7 (smallest value of s to make 2^s and 1 congruent modulo 7) is 3. Hence $2^3 - 1 = 1 \cdot 7$ with $C = 1$, and

$$\left(\frac{5}{14}\right)_{10} = \frac{5 \cdot 1}{2^{1+3}}\left(\frac{1}{1 - 2^{-3}}\right) = \frac{2^2 + 2^0}{2^4}(1 + 2^{-3} + 2^{-6} + 2^{-9} + \ .\ .\ .)$$

It follows directly that

$$\left(\frac{5}{14}\right)_{10} = \frac{101}{10000}(1 + 0.001 + 0.000001 + 0.000000001 + \ .\ .\ .)_2 = (0.0101\mathit{101}101101\ .\ .\ .)_2$$

The italicized part is a typical cycle and it repeats indefinitely.

This method is quite general and is applicable to other systems as well as to the diadic system. If $p=3$ (triadic system), $B=14=3^0\cdot 14$ with $k=0$, $m=14$. The exponent of 3 modulo 14 is 6 ($s=6$), and $3^6-1=52\cdot 14$, $C=52$.

$$\left(\frac{5}{14}\right)_{10} = \frac{5\cdot 52}{3^6}\left(\frac{1}{1-3^{-6}}\right) = \frac{100122}{1000000}\,(1+0.000001+0.000000000001+\ldots)_3 = (0.100122\mathit{100122}100122\ldots)_3$$

The expression for $(5/14)_{10}$ as a fractional in the triadic system also repeats indefinitely with the italicized part as its period.

If the numerator 5 is divided directly by the denominator 14 in the decadic system, one has

$$\left(\frac{5}{14}\right)_{10} = (0.357142857\mathit{142857}1428\ldots)_{10}$$

This is also a periodic affair with the italicized part as its period; it could have been obtained in the same manner as for the diadic and triadic systems illustrated previously. The process of encoding rational fractions into fractionals in the general p-adic system is somewhat more laborious than that of encoding an integer, but it is not necessary that the rational fractions be converted into decimals in the decadic system first.

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Reference

1. See, for instance, J. V. Uspensky and M. A. Heaslet, ***Elementary Number Theory*** (McGraw-Hill, New York, 1939), Chap. 8.

21 March 1956

Some Serotoninlike Activities of Lysergic Acid Diethylamide

In 1954 Woolley and Shaw (*1*) proposed that serotonin was of importance in the maintenance of normal mental functions. The reason for this idea was that a variety of chemical compounds (ergot alkaloids, harmala alkaloids, yohimbine, certain synthetic analogs of serotonin, and so on) had been found to cause mental disturbance in animals (including man) and could be shown to act as antimetabolites of serotonin when they were tested on smooth muscles. Thus various ergot alkaloids had been shown to act as antimetabolites of serotonin on sections of carotid arteries (*2*) and on isolated rat uteri (*3*). The most active of the ergot derivatives when tested on these isolated tissues was lysergic acid diethylamide (LSD-25).

Because LSD-25 was also remarkable for its high activity in causing hallucinations in human beings (*4*), the aforementioned hypothesis seemed reasonable. The LSD-25 and other hallucinogens, which were demonstrably antimetabolites of serotonin, were pictured as causing their effects on mental processes by bringing about a deficiency of serotonin in parts of the brain. Such pharmacologically produced deficiency of serotonin was evidently the cause of the action of these drugs on the smooth-muscle preparations, and the same explanation might be applied to nerve tissue. Indeed, some of the synthetic antimetabolites of serotonin were shown to act on glial cells of the brain cultured *in vitro* much as they did on smooth-muscle preparations (*5*). However, this idea of the mental effects arising from a deficiency of serotonin in the brain is a working hypothesis. The notion that the drugs bring about a cerebral excess of the hormone, rather than a deficiency, also must be considered (*6*).

We wish now to report some testing procedures in which LSD-25 acted like serotonin rather than as an antagonist. These procedures employed the isolated heart of the clam (*Venus mercenaria*) and the anesthetized dog. Welsh has shown that serotonin stimulates the heart of *V. mercenaria* and causes an increase in the amplitude of the beat. He also reported that this action of the hormone was antagonized by LSD-25 (*7*). We have attempted to repeat this latter observation but have found that, instead of acting as an antiserotonin, LSD-25 (*8*) acted like serotonin. Similar observations have been communicated to us by H. Hoagland. Discussion of our results with Welsh has shown that he now finds the same phenomenon with *V. mercenaria* obtained in America. His earlier findings had been with a European variety. Here, then, is an isolated organ for which LSD-25 acted like serotonin and in which it was more potent, weight for weight, than the hormone itself.

A second situation in which LSD-25 acted like serotonin was in raising the blood pressures of anesthetized dogs. In such animals the intravenous injection of serotonin causes a transient rise in pressure. It is well known that, depending on the dose, the rate of injection, and the individual character of the animal, one may see other responses, such as a fall in arterial pressure preceding the rise, or one may see a sharp rise superimposed on the initial fall, followed by a secondary rise (*6, 9, 10*). This same variability has now been seen in responses to LSD-25. Both pressor and depressor phases could be observed (Fig. 1). Six dogs were anesthetized with Nembutal and calibrated with serotonin as previously described (*10*). They were then tested with graded doses of LSD-25, in-

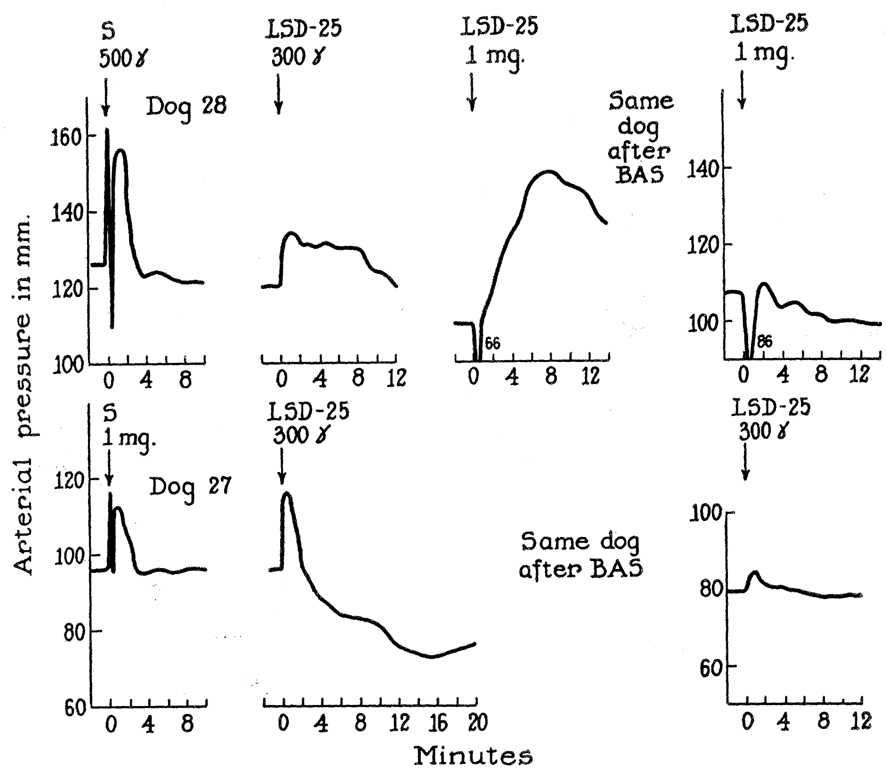

Fig. 1. Arterial pressure responses of dogs intravenously given serotonin (S) and LSD-25 before and after the antimetabolite of serotonin (BAS). Fifty milligrams of BAS was injected intravenously 1 hour before the last dose of LSD-25. Numbers under the profound pressure drops indicate the lowest pressure obtained.