the observed frequencies correspond to the six possible symmetric and antisymmetric rotational oscillations of the two molecules present in the lattice cell.

The development of a zinc-amalgam lamp giving monochromatic radiations of high intensity free from disturbing satellites has enabled Dr. C. S. Venkateswaran to carry out spectro-interferometric investigations of great value on the scattering of light in gases, liquids and solids. The perfection of his experimental technique and the thoroughness of the research has enabled results to be obtained which are trustworthy, besides being of fundamental importance. The work has also been effectively followed up by Mrs. K. Sunanda Bai. Seven out of the fifteen papers in the symposium are devoted to the work of these authors. We reproduce in Fig. 2 an illustration from one of Venkateswaran's papers.

The work of Venkateswaran and Sunanda Bai shows clearly that the conclusions reached earlier by experimenters as well as theorists in this field need radical revision. The picture of the liquid state which now emerges presents little or no resemblance to that of a crystalline solid, the analogy being rather with the amorphous or glassy state. The more viscous the liquid or the lower its temperature, the more nearly does it approximate in its behaviour to a glassy solid. This statement, in fact, covers the experimental situation as revealed by the studies on the positions and intensities of the lines in the interferometer patterns, as well as their states of polarisation.

The so-called "internal" vibrations of the molecules which become manifest in light-scattering also receive attention in the paper of Nedungadi on naphthalene mentioned above. They form the principal theme of three studies with organic liquids contributed to the symposium by Venkateswaran and Pandya. Nedungadi's work shows clearly that the selection rules for these internal vibrations are determined primarily by the symmetry of the crystal in which the molecules are imbedded and only secondarily by the symmetry of the molecules themselves. It is also evident from the investigations that even in the liquid state, the vibrations of an individual molecule are strongly influenced by those of its neighbours.

Limitations of space permit only a brief mention of B. S. Satyanarayana's paper on the relation between fluorescence and light-scattering in uranyl salts. This is a preliminary report of a very promising investigation.

THE EFFECT OF CIRCULATION UPON THE WEIGHT OF METAL CURRENCY

BY

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IN contrast to the physical sciences, the social sciences allow, even now, the detection of quite important effects with the aid of comparatively simple apparatus and a certain amount of knowledge of modern statistical technique. The historical evidence of the demand for currency shown by the loss of weight of coins still in active circulation comes under this head. The same methods may be applied to hoards deposited in ancient times and recovered intact, thus giving the foundations of numismatics as a science.

The normal law of weight distribution may be assumed to hold for a set of coins honestly minted to a fixed legal standard in large numbers. The population mean may be taken as the supposed legal weight, the variance could be estimated by taking the number of rejections at the mint beyond the fixed "legal remedy" by which the coin is allowed to differ from legal weight. Supposing the minted weight distribution to be represented by I in Fig. 1 (and ignoring the absorption of the coinage), the effect of circulation will be to lower the mean and to increase the variance, as in II. Further circulation changes the curve to III, where only the heavier half has been drawn. Deviations from normality will become more strongly marked and the currency will tend to disappear from circulation. While the general case can be brought under the "homogeneous random process"[1] which is so

universal in application as to qualify for a law of nature, it suffices for comparatively short periods of time to take the average weight as a linear function of the date.
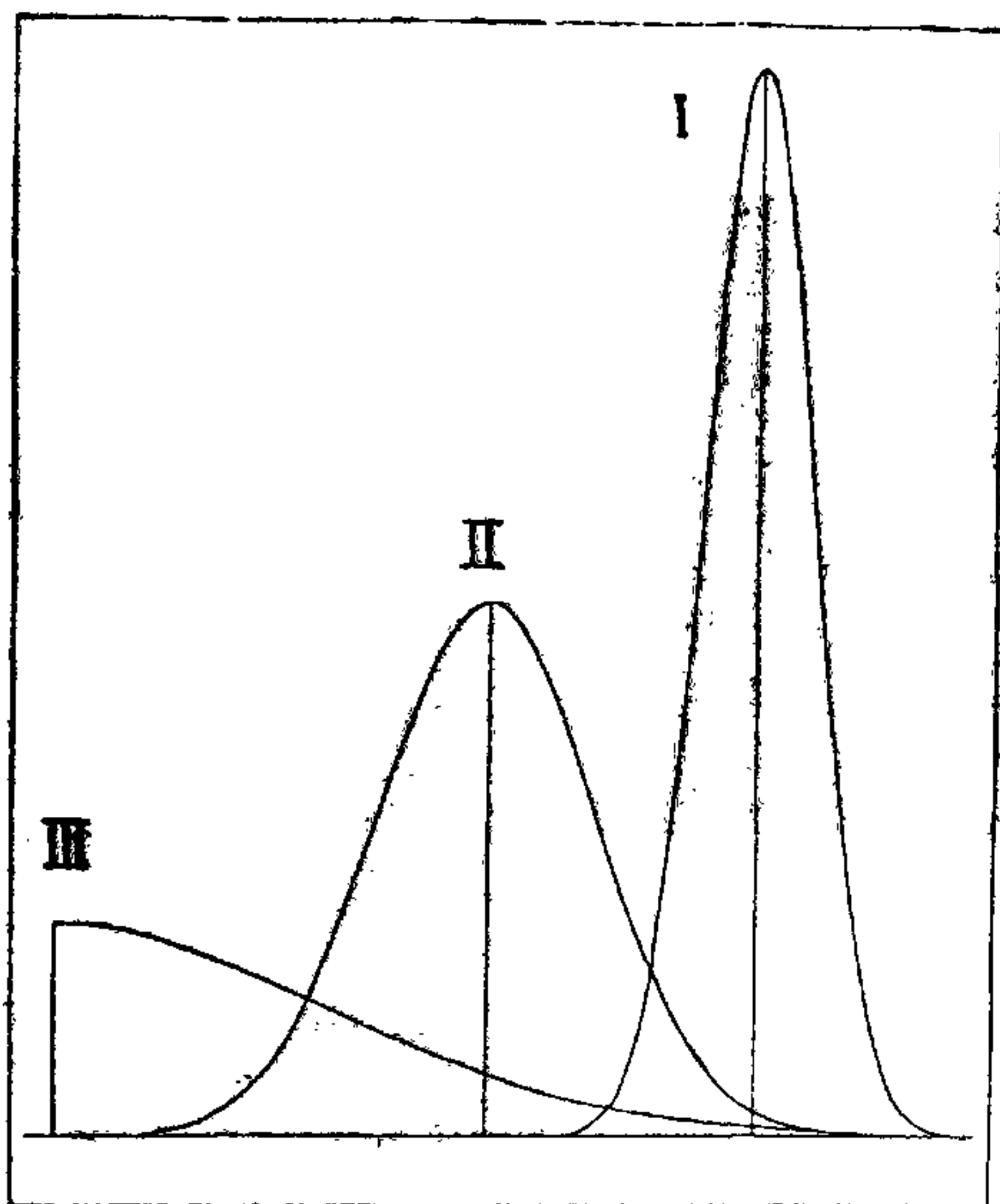

FIG. 1

Effect of circulation on weight

This theory was applied to a statistical analysis[2] of the earlier Taxila hoard (deposited *circa* 317 B.C.), but work on other ancient hoards of interest was prohibited by lack of access to the material and by the honoured custom of scattering most such material *unweighed* after a perfunctory study. So, the validity of the theory is here proved on modern coins from active circulation,[3] as a control measure. During March and April 1942, I gathered from some stores in Poona, from the great marketplace (*mandai*), and when not otherwise available, from the day's take over the counter of a local bank as many specimens as my finances permitted and my energy sufficed to weigh. These were stripped of the pieces whose date was illegible, or which were severely damaged by accident, or which did not ring true for the higher denominations. Experience shows that, as regards weight, coins of the latter two classes invariably differ in a marked fashion from the rest of their annual group; for the first, there was no choice. The effect of the two latter discards is to decrease the variance

within a year, so that the goodness of fit is actually reduced by this process and the theory stands confirmed even under the most unfavourable circumstances. The date on worn specimens could probably be restored by means of an examination of the crystal structure formed at the time of stamping, but I was unable to devise any method with the apparatus at hand. The pice were taken as they stood; for the other currency, modern specimens, minted in 1936 and after 1939, were in overwhelmingly large proportion, and subsamples had to be taken to reduce the numbers. The final selections were classified according to the date of the issue and each coin weighed to a tenth of a milligram. The time of the weighing was reduced by using a chainomatic analytical balance of Indian manufacture; the error of the (new) instrument was rather high— $\frac{1}{2}$ mgm.—but decreased with use. Proper checks were taken regularly, and the fourth place of decimals ignored in the statistical work; all means would have to be increased by half a milligram and Sheppard's corrections necessary for the variances of the data were to be used for purposes of estimation. The final stage was the statistical analysis of the weights by the methods of R. A. Fisher.[4]

With larger samples the estimates of composition and even of the actual weight and its variance would be more accurate; reliable information could be gained as to the proportion of counterfeits, mint-defective, dumb, and accidentally damaged coins in circulation. The variation between localities and local needs can also be estimated by the allocation of properly randomised samples to various regions. Finally, the residuals after fitting the regressions would be of great use in correlating the wear of various denominations to show the extent to which one type was supplementing another and enable a scientific distribution of currency to be made. Any method of currency control based on science, not on the fiat of authority, would have to consider these matters seriously. As for the weights of a large sample, the analytical balances will no longer be necessary; a histogram can be run off directly by setting the mint's automatic weighing machines in series and counting the number of coins not rejected at each step.

A look at the tables of analysis of variance shows at once that the results of

Analyses of Variance.   Regressions given only where significant

Unit: one milligram; y = weight in milligrams, x = date in years

Source	d.f.	sum-square	mean sq.	F
Æ Pies (Benares) 1912–1939; $y - 1599 \cdot 55 = 1 \cdot 955 \, (x - 1929 \cdot 12)$;				
regression	1	43015	43015	36·66***
deviations	23	.61528	2675·13	2·28**
within a year	198	232300	1173·23	$r = 0 \cdot 357$
Total	222	336843	1517·31	1·29*
Æ Pice (superseded) 1835–1906.				
regression	1	35969	35969	$(5 \cdot 95)^{-1}$
deviations	27	7133371	264198·92	1·234
within a year	99	21195723	214098·21	$r = -0 \cdot 0356$
Total	127	28365063	223346·95	1·0432
Æ Pice 1907–1941; $y - 4728 \cdot 86 = 9 \cdot 903 \, (x - 1928 \cdot 87)$				
regression	1	8574800	8574800	1663·96***
deviations	26	201108	7734·94	1·50
within a year	639	3292918	5153·24	$r = \cdot 843$
Total	666	12068826	18121·36	3·516***
N Annas 1908–1941; $y - 3803 \cdot 20 = 6 \cdot 545 \, (x - 1927 \cdot 70)$				
regression	1	3250147	3250147	1903·31***
deviations	26	132110	5081·15	2·975***
within a year	698	1191923	1707·63	$r = \cdot 843$
Total	725	4574180	6309·21	3·695***
N 2-Annas 1918–1941; $y - 5759 \cdot 2 = 8 \cdot 516 \, (x - 1931 \cdot 99)$				
regression	1	1890586	1890586	695·86***
deviations	16	71021	4438·81	1·63
within a year	315	855827	2716·91	$r = \cdot 819$
Total	332	2817434	8486·25	3·12***
AR 4-Annas 1904–1940; $y - 2857 \cdot 9 = 4 \cdot 615 \, (x - 1928 \cdot 098)$				
regression	1	725568	725568	459·70***
deviations	21	56104	2671·62	1·69
within a year	224	353551	1578·35	$r = \cdot 799$
Total	246	1135223	4614·73	2·92***
AR 8-Annas 1905–1941; $y - 5764 \cdot 83 = 5 \cdot 949 \, (x - 1928 \cdot 5)$				
regression	1	259759	259759	139·86***
deviations	21	31273	1489·19	$(1 \cdot 2472)^{-1}$
within a year	43	79865	1857·32	$r = \cdot 837$
Total	65	370897	5706·11	3·07***
AR Rupees[3] 1903–1920; $y - 11579 \cdot 86 = 4 \cdot 16 \, (x - 1913 \cdot 12)$				
regression	1	15423	15423	674·67***
deviations	16	1130	70·63	3·0898***
within a year	2868	65563	22·86	$r = \cdot 433$
Total	2885	82116	28·463	
AU Sovereigns 1900–1931.				
regression	1	72	72	2·382
deviations	11	776	70·54	2·333*
within a year	39	1179	30·23	$r = \cdot 1885$
Total	51	2027	39·745	1·315

my observations are highly favourable to the theory. Where deviations from the linear regression become significant, they are immediately explicable. The pies being not current in Poona bazaars had to be imported from Benares where they are gathered from the shops before Hindu holidays by the frugal pious, distributed to beggars, and revert to the shops immediately after. This can hardly be called active circulation; as an aside, be it noted that in places like Benares simple bits of copper can be and are still used to substitute for the lower currency: for Benares, the Butwal "pice"; almost any ancient coin in most of the purely agrarian districts of India.

The Poona pice fall into two classes, the weight of the denomination having been

materially reduced in 1907, apparently to 75 grains. In fact, all pice of my 1906 sample fall into either the 4-gram or the 6-gram group, without a single specimen of 5 grams; the mean for this year is very significantly lighter by the *t*-test than for previous years, heavier than for succeeding years; the variance by the *z*-test is significantly greater than those before or after. This seems to indicate that some of the 1906 pice were minted to the lower weight. Thus, the pre-1907 coins have been withdrawn for the greater part or have otherwise tended to disappear from circulation. Only the unworn specimens have managed to survive, whence neither the regression nor the deviations from it are of any significance. For the nickel one anna coins, the deviations from regression are caused entirely by the oldest issues: Edward VII, 1908–1910. For these, no less than 15 out of a total of 38 had illegibly worn dates, a proportion fourteen times that of the George V issues. The 23 coins retained were, naturally, heavier than the average for their groups, somewhat after the fashion of III in Fig. 1. A precisely similar effect is to be seen in the Taxilan coins of more than ten reverse marks. A recalculation of the anna data discarding the Edward VII issues immediately reduces the deviations from linear regression to insignificance, so that the deviations are to be assigned to our mechanism of selection. We can thus state a law of wear for metal currency: *For coins in active circulation, the loss of average weight is proportional to the age. But the oldest coins of a series tend to be above the regression weight and for currency not in active circulation" or an issue which is superseded, the significance of the regression tends to disappear.*

An even more striking result is that *the correlation coefficient for currency in active circulation over comparable periods of time is independent of the denomination.* Except the pies, the older pice, rupees, and sovereigns all the remaining correlation coefficients do not differ significantly from the population value of $\varrho = 0.838$, estimated by pooling the observed values after Fisher's *z* transformation.[5] The correlation for the 4-anna bits is somewhat low, but there have been disturbing factors at work here: the 1917–1918 specimens show unusual wear and nickel 4-anna bits (not included in this study) were minted in 1919,

1920, 1921. In stating such a "law" for currency weights, other things must be equal: minting variances must not be great in comparison with those caused by wear, the currency must have been minted over about the same period, and must have circulated in the same locality over about the same time. As a matter of fact, 2,886 rupees of 1903–1920 issue sampled at Poona in 1940 gave me a correlation of ·43 and deviations from linearity were insufficient to explain this entirely different value. The reason for the difference, however, is very simple. It is known that r^2 is the ratio of sum square due to regression by the total sum square. Our theory requires that the variances increase with age, which means that for coins longer in circulation, the residual sum square takes up a greater proportion of the total, thus depressing the correlation. Even the pice of our sample show a correlation compatible with that of the rupees when calculated only from the 1907–1920 issues in the sample. It is a feature of the data that when the calculations are made from year to year on the basis of the weights, the correlation coefficient is found to increase steadily with the date of the last issue to its maximum value at the end; this holds for all denominations provided the oldest issues do not contain overweight survivors in large proportion and the regression is really significant.

Whereas the samples show that the variances are in general decidedly greater for the older issues, the samples do not allow the question of linear increase of the variance with age to be effectively discussed except for the post-1906 pice. The only method I can see that would test this would be (1) to calculate the linear regression from the sample variances, giving each the weight of its degrees of freedom, (2) apply the χ^2 test, noting that the ratio of the observed to a hypothetical variance should be distributed as χ^2/n. From the total number of degrees of freedom, two have to be subtracted for the fitting. The pice variances only, when all are tested by this method, show linear increase with age; on the whole, the pice are statistically the most satisfactory denomination—in spite of evidence of heavy corrosion of three specimens by fatty acids—because no one rings them, counterfeits and hoarding are absent, change of hands regular.

Brass ½ annas, annas, and two annas of

1942 issue just reached circulation at the time of the study, so that no disturbing effect was obvious on the rest of the currency, whatever the future may show. The data gives: ½ annas—$n = 53$, $m = 2·9125$ gm. $s^2 = 786·88$ mgm.^{2}; annas—$n = 38$, $m = 3·8851$ gm., $s^2 = 3934·51$ mgm.^{2}; 2 annas—$n = 22$, $m = 5·8023$ gm., $s = 7773·6$ mgm.^{2} The two last fit very well into their respective lines of regression and analysis of variance. It is not likely that the debasement will cause any disturbance due to hoarding, though the rate of wear will naturally change. For, the silver alloy had already changed nearly three years ago from 11/12 to 6/12 fine; even the nickel of Geogre VI appears to differ from the older composition. Even with the pure metal used for each denomination, including the rupee, the currency would have a value of metal well below its denomination, hence the change to brass only emphasizes the most universal of all numismatic laws, the inevitable trend towards debasement in times of stress. For our purpose there is a far more serious effect visible in the samples. The minting since 1939 shows a decided increase in variance, and the occurrence of overweight specimens shows that the old legal remedy (from 1/40 for copper to 1/200 for silver) has been relaxed in practice, whatever the law at present. If this tendency was present in the coins struck during the last Great War (1914–1918), or during the depression years, it is certain to upset the linearity of variance increase, without affecting the law for mean weights. Whether the tendency towards cruder striking of the coins with regard to weight is manifested in other countries and periods before great changes of structure will also have to be studied with this example in mind.

[1] A. Kolmogoroff, *Math. Annalen*, 1931, **104**, 415–458.

[2] D. D. Kosambi, *New Indian Antiquary*, 1941, **4**, 1, 49.

[3] ——————, *Current Science*, 1941, **10**, 372.

[4] R. A. Fisher, *Statistical Methods for Research Workers* [7th ed.], ex. 42.

[5] *Ibid.*, ex. 33.

[6] The gold sovereigns have had almost no circulation, but if just two more specimens, dated 1887, 1897 (and used regularly for worship) are added to the sample accepted, the correlation takes the very highly significant value of ·64, with very highly significant deviations from regression.

AN UNUSUALLY LONG-LIVED DUST DEVIL AT POONA ON THE 27th MARCH 1942

BY

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A DUST devil was observed to persist from about 12·00 hrs. to 15·45 hrs. I.S.T. near the Central Agricultural Meteorological Observatory at Poona on the 27th March 1942. Fig. 1 shows a map of Poona and its environs; the track of the dust devil is shown by the dotted line. On the right hand side may be seen the confluence of the two rivers Mutha and Mula. 'O' is the position of the Observatory from which the dust devil was continuously under observation. The position of the dust devil at different times during its unusually long life is indicated by the letters A, B, C, D and E in Fig. 1.

At 12 noon the dust devil appeared at the point A. Its diameter was apparently about 20 to 30 ft. and its top at an elevation of about 20° to 25°. During the interval 12·00 hrs. to 14·45 hrs. the dust devil moved very slowly from the point A to the point B which is about two miles due north of the Observatory. During its passage from A to B, a distance of two miles *across* the line of sight, the dust devil might have moved slightly at intervals *along* the line

3