are unknown to the quaternionist. It is a suggestive fact that both Gibbs and Jahncke, in order to develop their respective systems, found it necessary to introduce quite other kinds of products of vectors—products which are as different from one another as each is from the quaternion product, and yet have not the geometrical significance of Hamilton's creation.

There is an idea in some minds that there is a rivalry between vector analysis and quaternions. There is nothing of the kind. There is a quaternion vector analysis and a crowd of other vector analyses known best by the names of their authors, such as Grassmann, O'Brien, Gibbs, Heaviside, Bücherer, Jahncke, Henrici, Peano, Macfarlane, &c., no two of whom, curiously enough, agree with one another. Of all these, Hamilton's is the only vector analysis associative in its vector products. The importance of this associative law does not, of course, appear so long as we restrict ourselves to products of two vectors only, and, as a matter of fact, many vector analysts never really get to higher products. When, however, three or more vectors are to be combined, the associative law must be fulfilled if simplicity and flexibility of operation are to be retained. The vector analysis which admits the associative law in product combinations *is* the quaternion vector analysis, however it may be disguised by arbitrary symbolism and notation. C. G. KNOTT.

Edinburgh University, September 21.

I ALSO deplore the use of the current but misleading phraseology which Prof. Knott points out. Quite certainly Prof Knott's more detailed statement should be substituted in the interests of "terminological exactitude."

THE WRITER OF THE REPORT.

Remarkable Rainbow Phenomena.

WHEN I read Mr. Spence's interesting letter (p. 516), it occurred to me that the appearance of the second primary rainbow was due to the reflection of the sun from the sea. The apex of this second bow would be above that of the first bow, the angular distance between the apices being about equal to double the sun's altitude at the time of the observation.

Taking approximate figures, I make Deerness to be in longitude eleven minutes of time west of Greenwich, and in latitude 59° north. Assuming Mr. Spence's times to be Greenwich times, the sun's altitude at 6h. 30m. p.m. was about 4°, so that the angular distance between the apices of the bows would be about 8°, a result differing but little from Mr. Spence's estimate of 5° or 6°. As the sun sank this distance would diminish.

I should be glad to know if Mr. Spence observed any difference in the intensity of the light. One would expect the higher bow to be the fainter of the two, as it was due to a reflected sun, though the loss of light by reflection would be diminished by the very low altitude of the sun. By Fresnel's formula, the reflected sunlight would be to the direct sunlight in the ratio of 13 to 20. If we neglect the slight polarisation of this reflected light, these numbers will also express the relative brightness of the higher and lower bows, other conditions being alike.

Probably the most remarkable case on record is that of the octuple rainbow, seen in 1841, by the late Mr. Percival Frost, from the top of Dunstaffnage Castle, near Oban. The sea, both behind and before the observer, was perfectly smooth. Four bows were seen in the sky, viz. ordinary primary and secondary bows due to direct sunlight, and, above these, primary and secondary bows due to sunlight reflected from the water behind the observer.

Seen in the water in front were also four bows, inverted by reflection. These bows were not images of the first four, but images of four bows that could have been seen in the sky had the water been removed and the observer brought down vertically to a position as far below the sea-level as the actual observer was above it. The eight bows formed four intersecting circles. For further details and an illustration reference should be made to NATURE, vol. xli. (p. 316). C. T. WHITMELL.

Invermay, Hyde Park, Leeds, September 29.

Suspended Germination of Seeds.

THE letter of "H. B. P." in NATURE of September 27 (p. 540), while giving an interesting instance of the sudden appearance of the foxglove on a bare hill in the north country, does not appear to be conclusive as to the seedlings having developed from long-buried seeds. They might have originated equally well, it appears to me, from wind-blown seeds being conveyed to a recently disturbed soil, where they had an opportunity of germinating, and where they were not subject to the competition of other and stronger species. On the extensive shingle deposit near Dungeness, in Kent, one of the earliest species to appear on the newly deposited shingle is the foxglove. The first is usually the oat-grass *Arrhenatherum avenaceum*, and the third is often the wood-sage *Teucrium Scorodonia*; the seeds of all these must have come from some considerable distance, and it is not suggested that the plants arose from long-buried seeds.

I am by no means asserting that seeds may not under suitable conditions remain dormant for considerable periods, but we want instances to prove this in which other factors have been carefully and completely eliminated. This does not appear to be the case in the above instance, where it is also possible that the seeds produced in the summer may have been blown into the interstices of the wall, the disturbance of which led to their dispersal over the site, and this might account for the absence of the seedlings from the neighbouring turf-surface which had also been disturbed, and which should have yielded them had the seeds been blown from the dry capsules of the plant after the destruction of the wall in the spring.

Yardley Lodge, Oxford. G. CLARIDGE DRUCE.

The Rusting of Iron.

HAS anyone inquired whether the rusting of iron may not be associated with some micro-organisms? The facts that oxygen, water, and carbon dioxide are necessary; that iron does not rust when immersed in boiling water and then sealed up; that certain solutions are said to inhibit rusting (*e.g.* potassium ferrocyanide, a poison), and that certain other solutions encourage rusting (*e.g.* ammonium chloride and perhaps sea-water, compare the composition of plant-culture solutions); that iron is a constituent of chlorophyll, and that rusty nails sometimes cause blood-poisoning, all these facts suggest a case for inquiry. There is, I think, an iron bacterium noted in some of the bacteriological books. The precipitation of iron carbonate might conceivably hold a place in the life of some organism corresponding to the precipitation of calcium carbonate by foraminifera.

HUGH RICHARDSON.

12 St. Mary's, York, October 1.

Colour Illusions.

WITH reference to Mr. T. Terada's letter in your issue of September 27 (p. 540), I noticed some similar effects while making experiments with a form of colour top last year. An old gramophone motor forms a very convenient way to observe this, and by using various discs painted in different rings and segments many curious optical effects may be seen.

I was, in fact, trying to see whether the effect of the persistence of vision could not be used to indicate the speed, and, to a certain extent, it can no doubt, but the effect is not sufficiently definite, and there is too much of the personal equation present to make it of practical use. If a disc is painted in two or more rings, and each ring is divided into a different number of segments, in colours or black and white, it is well known that each ring will become a uniform colour above a certain speed, according to the number of segments; the effect takes place at about forty alternations per second. Very interesting stroboscopic and complementary colour effects may be obtained in this way, some of which I have not seen mentioned yet; the complementary colours only appear at a certain speed, and show best in sunlight; the effect is peculiar—almost iridescent sometimes. B. J. P. R.

October 3.