It will be noticed also that D, F, A generate $\frac{B\flat}{16}$, or red, yellow, blue generate indigo-blue. A, C, E generate $\frac{F}{16}$, or blue, violet, orange generate yellow. I need not increase the length of my paper by more examples, but leave the field open to all who choose to test the above formula as regards its application to combinations of colour.

In conclusion, I wish to make the following suggestion.

Should it be admitted that the musical scale, in its perfect division into intervals under the law of harmonical progression, finds its counterpart in Newton's rings rather than in the prismatic spectrum, would not a spectroscope, constructed so as to give the image of these rings, be a more perfect instrument for the comparison of colours than that in present use? We might also have a double spectroscope, capable of giving the images of the secondary rings produced by the refraction of homogeneous light, the cube roots of whose diameters give the series which corresponds to that of the musical scale.

We should in this way be able to know the melody which corresponds to the light of any particular star, provided that the light be strong enough to produce the images of the secondary rings.

W. S. OKELY

Rome, February 18

Analogy of Colour and Music

AT the close of my short article on the Analogy of Colour and Music, published in your journal of January 13, I ventured to ask for the opinion of physicists on the subject. Accordingly I, for one, am much indebted to the many able contributors who thereupon addressed you. The correspondence having apparently ceased, I will now ask your permission to say a few words.

Although I do not attach too much importance to the closely approximate ratios, given in my paper, between the wave-lengths of colour and the notes of the diatonic scale, yet I think nothing said by your correspondents seriously affects my main argument.

The most important objection is that urged by Mr. Monro (NATURE, No. 14), who regards the correspondence of the two ratios as a mere coincidence, depending on the mode by which Prof. Listing obtained his scale of wave-lengths of the colours. By an ingenious calculation, Mr. Monro shows that Listing most probably "divided his spectrum into seven equal parts upon some scale which varies inversely as the wave-lengths ; . . . so that it nearly corresponds with the ratios of the musical scale because these approximately form a harmonic progression." When I wrote my article I had not read Listing's paper, but, as stated, quoted his numbers from a recent memoir by Thalen. The perusal of his original paper shows me that Listing obtained his numbers in the following manner, which I think Mr. Monro will see confirms his calculation, but overrides his criticism:—

Employing pure spectra, and using every precaution, Listing experimentally determines the transition places and the central region of each colour, Fraunhofer's lines being used as landmarks. The observations are repeated upon the normal spectrum obtained by diffraction, and are checked by the independent observations of others, and by repetitions at different times. In this way the remarkable fact is disclosed that the numbers of vibrations at the transition spots form an *arithmetical progression* throughout the entire series of colours. For reasons given he adopts the following scale of colours—brown, red, orange, yellow, green, cyanogen, indigo, and lavender, and states as a law that this series can be physically expressed by an arithmetical progression of eight numbers, in which the last is the double of the first. He then proceeds to discover the constant factor by which this series can be turned into absolute values. After considerable care, and upon grounds fully detailed, he selects 48½ billions as the number of vibrations per second expressing the range of each colour. The possible error he shows to be ± 0·038—taking billions as unity—and this, though apparently a large error, is actually less than ⅓th of the interval between the two D lines.

The number of vibrations corresponding to the extreme limit of colour at the red end, he fixes, upon Helmholtz's and Angstrom's authority, at 363·9 billions per second, or a wave-length of 819·8 millionths of a millimetre. By adding to the former number half the colour interval—namely, 24¼ billions—the normal centre of the first colour is obtained; 48½ billions added to that gives the centre of the next colour, and so on. These, and also the limits of each colour, are tabulated along with the corresponding wave-lengths.

Listing closes his paper with the statement of a general law, that while the successive vibrations of the series of colours in the spectrum form an arithmetical progression, the same is also true of the logarithms of the vibrations corresponding to each musical note in the so-called chromatic scale. Hence he concludes that although physiologically and pyschologically there may be differences, yet there is an indisputable *physical* basis for the analogy between tones and colours. From this very imperfect outline it will be seen that the entire memoir is a remarkable one, and I am surprised no translation of it has appeared. It is certainly the most important contribution to the analogy that I have met with, and renders my little paper on the subject quite unnecessary.

Mr. Okely, writing to the next number of NATURE, gives some additional evidence in favour of the analogy, but thinks my process of taking the mean of the limiting wave-lengths of each colour, in order to obtain the average wave-length, is "very rough." Mr. Okely does not tell us what he would do in such a case, but turns aside to become the champion of the widths of Newton's rings, charging me with having treated too summarily this old and famous ally of the analogy. But to this, my next critic, Mr. Sedley Taylor, replies, although other considerations also influenced me in neglecting this analogy.

Mr. Taylor, however, believes that he has deprived my comparison of any serious importance, for the following reason :—In the musical scale, he observes, "a very slight departure from accurate pitch in any concord provokes a harsh dissonance;" but "any part of any one colour-division produces an equally harmonious effect on the eye," because "in the spectrum there is very little, if any, change of tint except close to the extremities of any one colour." Whilst it would be certainly unwise to push the analogy too far, I think Mr. Taylor is here mistaken. There *is* a very material difference of tint in different parts of any one colour in the spectrum. Regarded alone, any region of the spectrum, like any single musical note, is, of course, equally agreeable ; but it is not the case that an equally harmonious effect on the eye is produced by the combination of *any* part of any one colour-division with some other colour.

Mr. Stuart, in an interesting letter, points out a close relationship, discovered by Prof. Mossotti, between the intensities of the light in different parts of a normal spectrum and the notes of the diatonic scale. Finally, Dr. Chaumont, in an early part of this discussion, showed, what indeed had been noticed elsewhere, that if the ratios I give be accepted, then the once-called primary colours, red, yellow, and blue, correspond to the notes of the common chord ; whilst the modern triad, red, green, and blue, correspond to the tonic, sub-dominant and dominant, that is to say, to the three notes which in music constitute the fundamental base of the scale.

In addition to what has been brought forward in this correspondence, there are some valuable remarks on the analogy in one of Dr. Thomas Young's memoirs, "Philosophical Transactions, 1802" ; in Chevreul's work on the "Principles of Harmony of Colour" ; in a recent brochure by Dr. Macdonald on "Sound and Colour" ; and, lastly and chiefly, in §19 of Helmholtz's "Physiological Optics." In this last a list is given of authorities who have written on the subject since the time of Newton.

Reviewing what has been done in this matter, there are therefore, I believe, many good grounds for asserting the existence of a physical basis for the analogy between colour and tone. Opposed, it is true, are many mental differences : such, for example, as that of the judgment, which is far more prompt and correct in determining a colour than a note ; then also colour primarily involves only the conception of *space*, music the conception of *time*. Nevertheless against all this we may place the facts that the source of harmony in colour, as in music, is purely a question of *relative* impressions ; and a painting and a melody evoke a succession of ideas that have a remarkable similarity.

Woodlands, Isleworth, March 13 W. F. BARRETT

THE METROPOLITAN MAIN DRAINAGE

THE magnitude of the underground works of London is scarcely understood by the public in general. They occasionally hear of this or that sewer or pumping station being completed, but as the greater portion of