classes, &c. Thus an analysis of the grades of chest-girth of 255 boys before and after a three terms' course of compulsory gymnastics showed that the following improvement had been made. The numbers in the lower line give the percentage of the boys examined, who made the number of grades improvement indicated in the line above.

Improvement :—										
1 gr.	2 gr.	3 gr.	4 gr.	5 gr.	6 gr.	7 gr.	8 gr.	9 gr.	10 gr.	11 gr.
Per cent. :—										
11	11	12	10	7	6	4	4	1	4	1

This with the omitted fractions gave 73 per cent. of the boys who had made more or less marked improvement relative to the general mass of boys of their age, the improvement in some cases being very marked indeed.

An analysis of the growth of 161 boys by means of their grades showed that the scheme of growth corresponded to the scheme indicated by the curves in the diagram in 31 per cent. of the cases examined. There was a steady rise relative to this standard in 17 per cent.; a steady fall in 10 per cent.; a period of rise followed by one of fall, or *vice versâ*, in 18 per cent. In 9 per cent. the variation was erratic, and the remaining 15 per cent. probably belonged to the first group; but not within the limits of variation allowed.

In 68 per cent. the type of structure, as indicated by the relation of height to weight, was stable throughout the period examined; but in about one-fourth of these cases there was a considerable constant difference between the grades of height and weight, amounting in the most extreme cases to as much as eight grades.

The lesson drawn from these observations was that, in order to form a correct opinion relative to a boy's physical progress by means of his measurements, it is very desirable to keep a regular record of his growth, in order that the general scheme of his growth may be determined, and that any irregular fluctuations due to external and removable causes may be noted and properly dealt with. C. H.

The Giant Tortoises of the Galapagos.

I noticed in your issue of June 15 a paragraph about the Galapagos tortoises. I do not know if this information is of any interest, but during my residence in Hawaii I knew of two living there. One of them lived in a garden near Hilo, and belonged to the late Captain Thomas Spencer; I last saw it about 1880. The other one lived on the Waimea plains in a perfectly wild state, and I used frequently to come across it when out shooting. It used to wander about within a radius of three or four miles.

It was blind of one eye, and its shell had lichen growing on it, and it could move about with a man sitting on its back.

I last saw it in 1890, but it may possibly be still living; this, however, could easily be ascertained.

They were, I believe, brought to Hawaii from the Galapagos in whalers, and were of great age. If desired, I shall endeavour to find out if they are still alive. W. Herbert Purvis.

10 Alexandra Place, St. Andrews, Fife.

School Laboratory Plans.

College plans are not always safe precedents. Boys need more supervision. Can any of your readers advise as to the best arrangement of benches for a class of twenty-four to thirty boys, aged fourteen to seventeen, doing chemistry and physics with elementary quantitative experiments?

(1) Is the double back-to-back bench the best form? It may economise woodwork, but it makes the class face both ways, and attention to verbal instruction is less easy.

(2) Is the superstructure of shelving necessary? If qualitative analysis is not done, fewer bottles are needed. The superstructure hinders conversation across double benches, but it stops supervision also.

(3) What is the best way of arranging the benches so as to allow of supervision and keep wall spaces free for shelving? They may be (*a*) all round the wall, leaving no space for shelves and cupboards; or (*b*) single bench along two walls and double bench down the middle; or (*c*) across the room, double benches alternating with windows, well lighted but difficult to supervise; (*d*) central aisle with double bench extending to walls right and left; (*e*) double benches, lengthways, free from walls; (*f*) single benches, cross-ways, like the desks of an ordinary class-room.

I shall be grateful for any help or advice.

Bootham School, York, June 23. Hugh Richardson.

Pair of Brazilian Marmosets Breeding in England.

A pair of marmosets, which for the two past winters have had a free run of our greenhouse and garden (in Buckinghamshire), produced two young ones on May 24. They seem to thrive on freedom and exercise, and the young ones are now beginning to feed themselves. In hot weather they like to remain out all night, but at first they came in to their box in the greenhouse every evening, the male parent always carrying the twins on his back, their little round furry heads merely looking like small excrescences each side of his neck; and only handing them to the mother at feeding-times, and then carefully lifting them back with both hands and settling them into position, where they seem to cling on without being held.

Their favourite garden house appears to be an old bird's nest, rather high up in a pink thorn-tree, some distance from the greenhouse. They very rarely come down to the ground, but the female will answer a call and come to feed from the hand. Bananas, milk and water, insects and young birds are the foods they like best. Dora Whitmore.

THE DIFFRACTION PROCESS OF COLOUR-PHOTOGRAPHY.

The production of colour by photography has been accomplished in two radically different ways up to the present time. In one, the so-called Lippmann process, the waves of light form directly in the photographic film laminæ of varying thickness, depending on the wave-length or colour of the light. These thin laminæ show interference colours in reflected light in the same way that the soap-bubble does, and these colours approximate closely to the tints of the original.

The technical difficulties involved in this process are so great that really very few satisfactory pictures have ever been made by it. The other, or three-colour process, has been developed along several distinct lines, the most satisfactory results having been produced by Ives with his stereoscopic "Krōmskōp," in which the reproduction is so perfect that, in the case of still-life subjects, it would be almost impossible to distinguish between the picture and the original seen through a slightly concave lens. The theory of the three-colour method is so well known that it will be unnecessary to devote any space to it, except to remind the reader of the two chief ways in which the synthesis of the finished picture is effected from the three negatives. We have first the triple lantern and the Kromscope in which the synthesis is optical, there being a direct addition of light to light in the compound colours, yellow being produced, for example, by the addition of red and green. The second method is illustrated by the modern trichromic printing in pigments. Here we do not have an addition of light to light, and consequently cannot produce yellow from red and green, having to produce the green by a mixture of yellow and blue. Still a third method, that of Joly, accomplishes an optical synthesis on the retina of the eye, the picture being a linear mosaic in red, green and blue, the individual lines being too fine to be distinguished as such.

The diffraction process, which I have briefly described in the April number of the *Philosophical Magazine*, is really a variation of the three-colour process, though it possesses some advantages which the other methods do not have, such as the complete elimination of coloured screens and pigments from the finished picture, and the possibility of printing one picture from another. The idea of using a diffraction grating occurred to me while endeavouring to think of some way of impressing a surface with a structure capable of sending light of a certain colour to the eye, and then superposing on this a second structure capable of sending light of another colour, without in any way interfering with the light furnished by the first structure. This cannot, of course, be done with inks, since if we print green ink over red, the result will not be a mixture of red light and green light, but almost perfect absence of any light whatever; in other words, instead of getting yellow we get black. Let us consider first how a picture in colour might be produced by diffraction. Place a diffraction grating (which is merely a glass plate with fine lines ruled on its surface) before a lens, and allow the light of a lamp to fall upon it. There will be formed on a sheet of paper placed in the focal plane of the lens, an image of the lamp flame, and spectra, or rainbow-coloured bands on each side of it. Now make a small hole in the sheet of

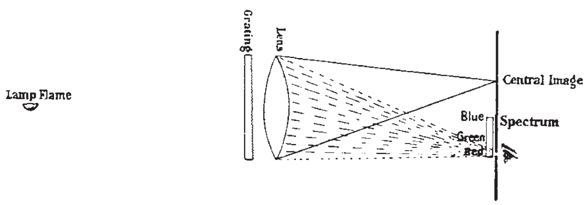

FIG. 1.

paper in the red part of one of these spectra. This hole is receiving red light from the whole surface of the grating, consequently if we get behind the paper and look through the hole we shall see the grating illuminated in pure red light over its whole extent. This is indicated in Fig. 1, where we have the red end of the spectrum falling on the hole, the paths of the red rays from the grating to the eye being indicated by dotted lines. Now the position of the spectra with reference to the central image of the flame depends on the number of lines to the inch with which the grating is ruled. The finer the ruling the further removed from the central image are the coloured bands. Suppose now we remove the grating in Fig. 1, and substitute for it one with closer ruling. The spectrum will be a little lower down in the diagram, and instead of the red falling on the hole, there will be green; consequently, if we now look through the hole, we shall see this grating illuminated in green light. A still finer ruling will give us a grating which will appear blue. Now suppose that the two first gratings be put in front of the lens together, overlapping as shown in Fig. 2. This combination will form two overlapping spectra, the red of the one falling in the same place as the green of the other, namely on the eye-hole. The upper strip, where we have the close ruling, sends

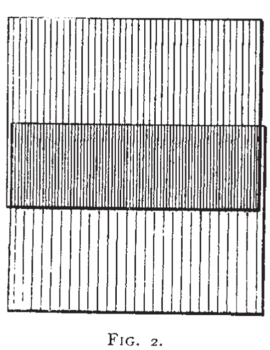

FIG. 2.

green light to the eye and appears green; the under strip, with the coarser ruling, sends red light to the eye and appears red, while the middle portion, where we have both rulings, sends both red and green light to the eye, and in consequence appears yellow, since the simultaneous action of red and green light on any portion of the retina causes the sensation of yellow. In other words, we have in superposed diffraction gratings a structure capable of sending several colours at once to the eye.

If we add the third grating, we shall see the portion where all three overlap illuminated in white, produced by the mixture of red, green and blue light.

Three gratings with 2000 lines, 2400 lines, and 2750 lines to the inch, will send red, green and blue light in the same direction, or, in other words, to the same spot on the screen behind the lens.

Suppose, now, we have a glass plate with a design of a tulip, with its blossom ruled with 2000 lines to the inch, its leaves ruled with 2400, and the pot in which it is growing ruled with 2750 lines, and place this plate before the lens. On looking through the hole we shall see a red tulip with green leaves growing in a blue pot. Thus we see how it is possible to produce a coloured picture by means of diffraction lines, which are in themselves colourless. Those portions of the plate where there are no lines send no light to the eye, and appear black.

We have now to consider how this principle can be applied to photography. That photographs which show colour on this principle can be made, depends on the fact that a diffraction grating can be copied by contact printing in sun-light, on glass coated with a thin film of bichromated

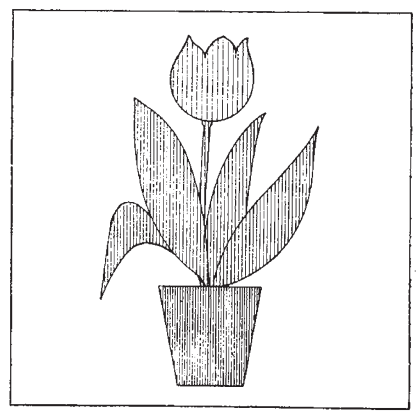

FIG. 3.

gelatine. The general method which I have found best is as follows. Three gratings ruled on glass with the requisite spacing were first prepared.[1]

To produce a picture in colour three negatives were taken through red, green, and blue colour filters in the usual manner. From these three ordinary lantern-slide positives were made. A sheet of thin plate-glass was coated with chrom gelatine, dried, and cut up into pieces of suitable size; one of these was placed with the sensitive film in contact with the ruled surface of the 2000-line grating, and the whole covered with the positive representing the action of the red light in the picture. An exposure of thirty seconds to sunlight impressed the lines of the grating on the film in those places which lay under the transparent parts of the positive. The second grating and the positive representing the green were now substituted for the others, and a second exposure was made. The yellows in the picture being transparent in both positives, both sets of lines were printed superposed in these parts of the picture, while the green parts received the impression of 2400 lines to the inch only.

The same was done for the blue, and the plate then washed for a few seconds in warm water. On drying it appeared as a coloured photograph when placed in front of the lens and viewed through the hole in the screen.

[1] These gratings were ruled for us on the dividing engine at Cornell University, through the courtesy of Prof. E. L. Nichols.

Proper registration during the triple printing is secured by making reference marks on the plates. A picture of this sort once produced can be reproduced indefinitely by making contact prints, since the arrangement of the lines will be the same in all of the copies as in the original. The finished picture is perfectly transparent, and is merely a diffraction grating on gelatine with variable spacing. In some parts of the picture there will be a double grating, and in other parts (the whites) there will be a triple set of lines. Having had some difficulty in getting three sets of lines on a single film in such a way as to produce a good white, I have adopted the method of making the red and green gratings on one plate, and the blue on another, and then mounting the two with the films in contact. It is very little trouble to multiply the pictures once the original red-green grating picture is made.

The pictures are viewed with a very simple piece of apparatus, shown in Fig. 4, consisting of a lens cut square like a reading glass, mounted on a light frame provided with a black screen perforated with an eye-hole through which the pictures are viewed. The colours are extremely brilliant, and there is a peculiar fascination in the pictures, since if the viewing apparatus be slowly turned so that its direction with reference to the light varies, the colours change in a most delightful manner, giving us, for example, green roses with red leaves, or blue roses with purple leaves, a feature which should appeal to the impressionists. The reason of this kaleidoscopic effect is evident, for by turning the viewing

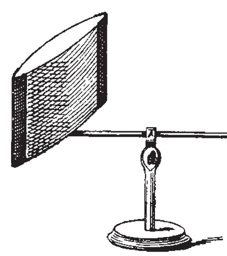

FIG. 4.

apparatus we bring the eye into different parts of the overlapping spectra.

It is possible to project the pictures by employing a very intense light, and placing a projecting lens in place of the eye behind the perforation in the screen. Of course a very large percentage of the light is lost, consequently great amplification cannot well be obtained. I have found that sun-light gives the best results, and have thrown up a three-inch picture on a four-foot sheet so that it could be seen by a fair-sized audience.

By employing a lens of suitable focus it is possible to make the viewing apparatus binocular, for similar sets of superposed spectra are formed on each side of the central image by the gratings, so that we may have two eye-holes if the distance between the spectra corresponds to the interocular distance.

It is interesting to consider that it is theoretically possible to produce one of these diffraction pictures directly in the camera on a single plate. If a photographic plate of fine grain were to be exposed in succession in the camera under red, green, and blue screens, on the surfaces of which diffraction gratings had been ruled or photographed, the plate on development should appear as a coloured positive when seen in the viewing apparatus. I have done this for a single colour, but the commercial plates are too coarse-grained to take the impression of more than a single set of lines. With specially made plates I hope to obtain better results.

R. W. WOOD.

LOCAL UNIVERSITY COLLEGES FOR LONDON.

THE adequate provision of university education for London is by no means the simple and straightforward task which some people seem to imagine. From whichever of the many possible points of view the question of the education of London is considered, the anomalous position which has to be assigned to the greatest city in the world is the most noteworthy result of the investigation. If, for instance, an endeavour is made to estimate the comparative facilities offered for higher instruction in the metropolis with those to hand in other countries and in our own large provincial towns—judged on a basis of population—the results arrived at are as remarkable as they are interesting and instructive. The population of Scotland in 1896 was 4,186,849; yet located at Edinburgh, Glasgow, Aberdeen and St. Andrews are four well-equipped and largely endowed universities; while, in addition to these, is to be found at Dundee a college providing university education, and, though working with St. Andrews, in receipt of an annual grant of 1000*l*. from the Treasury. The population of the county of London was last year 4,504,766. If, as is done in the University of London Act, 1898, the towns within thirty miles of the university buildings are included, the population must be placed at a very much higher figure, viz. about six millions and three-quarters.

So that, keeping well within limits, and running no risk of any charge of exaggeration, the inhabitants of this metropolitan area may be said to considerably outnumber those of Scotland. When the universities and university colleges provided for this immense population are enumerated the total is ludicrously small. There is no teaching university, and but three university colleges—University College, King's College, and Bedford College. Of course, there are other colleges in London; but, in defining university colleges reference is made to the Treasury Minute of June 2, 1897, dealing with the grant in aid of the university colleges of Great Britain.

At University College there were in the faculties of Arts, Laws, and Science, in the session of 1895-6, 747 students, including engineering students. At King's College, during the same session, there were in Arts and Science 284 day students, 305 evening students, and 315 lady students. At Bedford College, the number of students throughout the same period numbered 176. The total number of persons receiving instruction of university standing in officially recognised institutions was consequently not much over 1500 during the year 1895-6.

If the populations up to date of the eight large towns in England provided with university colleges be added together, the total obtained is about 3,233,765. Similarly, Wales, with a population in 1891 of 1,501,163, has three university colleges, now together constituting the University of Wales. Not only in comparison with Scotland, therefore, but also by the side of Wales and the English provinces, London is seen to be extraordinarily deficient in properly authorised establishments the prime duty of which is to provide university instruction.

It may be urged at this stage that the work of the University of London Commission now being performed will, as it is intended it shall, completely alter the present unsatisfactory aspect of things, and that ere long provisions which will satisfy the most earnest advocate of higher education will be provided. But valuable as the coordination of effort which is likely to result from the inauguration of the new University of London will be, it can hardly be contended that to confer new powers upon certain existing colleges, and to rearrange the work of the staffs of institutions which have previously proved inadequate, will be a complete solution of the proper provision of university instruction for nearly seven millions of people.