THE STRUCTURE OF LIPPMANN HELIOCHROMES.

[The following is an abstract of a very comprehensive investigation by Professor S. R. Cajal, of Madrid University, which was published in the "Revista de la Real Academia de Ciencias de Madrid," a German translation appearing in the current issue of the "Zeitschrift für Wissenschaftliche Photographie."]

Lippmann's heliochromes, as is well known, were founded on purely theoretical reasoning. They are interesting as a proof of the actual existence of light waves. For this reason photo-micrographs of sections of the same are valuable, as proving how far the plate can register them.

It is well known that the possible registration of these waves by a photographic plate was first pointed out by Zenker, and the results have therefore been universally called Zenker's laminæ The point is that, though theory says that these laminæ should exist, do they actually occur? Or, in other words, can one actually see them under the microscope? Obviously this is a difficult problem to solve, for we are close on the limits of microscopic resolution. Taking the case of green rays, their wave-length is 0.512 μ, a dimension which must be reduced to one-half, as the laminæ are half a wave length apart. For the spectral green, then, we have to resolve

Fig. 1.


Fig. 2.


Fig. 3.


Fig. 4.

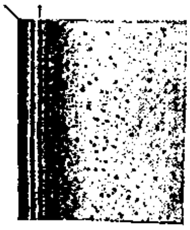


Fig. 5.

Fig. 6.

an interval of 0.237 μ (thousandths of a millimetre), which, according to Abbé's formula for central white light, $\delta = \frac{\lambda}{a}$ requires a numerical aperture of over 1.40, which is the practical limit yet attained with the Zeiss apochromats.[1]

It is true that with oblique lighting we can increase the resolving power, $\delta = \frac{\lambda}{2a}$ but, as Neuhauss has shown, this gives rise to diffraction phenomena, which obliterate the true lines, and may even cause reversal, as has been experienced by Senior and others. In spite of the difficulties, however, Neuhauss and Valenta alone have succeeded in obtaining excellent photo-micrographs.[2] Senior's results (3), as pointed out by Neuhauss, are far too thick, and are really diffraction stripes. Hitherto only spectral rays of greater wave-length have been attempted; mixed colours have not been attempted, nor have white and grey, to which most natural colours owe their luminosity, been attempted.

The examination of these points appeared extremely interesting, as it seemed possible to account for special phenomena, which mathematical calculations cannot explain. Thus the disappearance of white, but not coloured, portions through over-exposure, the general tendency towards red or dirty yellow, the appearance of white with excessive intensification, the general shift of the colours towards the more refrangible end of the spectrum when the pictures are rubbed, the frequent want of the complementary colours by transmitted light, the appearance of black or violet on rubbing the white, the extinction of the colours, except white and black, in varnishing, and so on.

Experimental Methods.

The methods employed by the author are briefly as follows:—


Fig. 7.


Fig. 8.


Fig. 9.

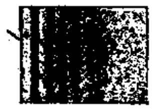


Fig. 10.

Fig. 11.

Fig. 12.

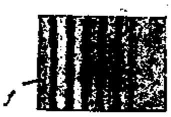


Fig. 13.

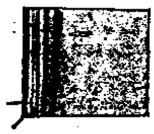


Fig. 14.


Fig. 15.


Fig. 16.


Fig. 17.

1. The plate is soaked in water and the film scraped or stripped off with the edge of a freshly broken piece of glass. If the film is not very thin this always takes place from the glass or in that part of the film which contains no laminæ. The author also uses collodionised glass.

[1] The objective of N. A. 1·60 with monobromonaphthaline immersion cannot be used, as one dare not imbed Zenker's laminæ in this solution.

[2] "Photography," January 3, 1902.

[3] When this was written, (June, 1906), the author says he was unaware that Dr. Hans Lehmann had also obtained photomicrographs of sections of Lippmann heliochromes (see "B.J.," November, 30, 1906, p. 946). Dr. W. Scheffer has also obtained photomicrographs of Lippmann plates.—Eds., "B.J."

and thirdly, because by development and intensification the two upper films far surpass the others in reflective power.

The most important experiments which support these views are simple and easy to interpret.

1. As already noted, and as Neuhauss states, rubbing the dry plate with a pad dipped in absolute alcohol causes the colours to shift towards the violet. The red becomes orange-red, then yellow, then green, and finally blue and violet, and these colours persist for an unlimited time in the dry plate, or if it is immersed in a benzole tank. This is explained by the erosion of the first lamina. If the friction is continued the violet disappears and the original colour appears. This will occur once or twice, but it is then so dark and dead that its action on the tint of the underlying part of the plate is almost nil. Friction beyond the fourth lamina produces complete disappearance of the original colour. Friction is therefore an excellent method of studying the functional action of individual zones.

The above phenomena are quite clear on the assumption that only the first two laminæ, or perhaps also the third after intensification, take part in the formation of the colour. As a matter of fact, rubbing with alcohol very slowly reduces the thickness of the first lamina, so that the distance between its surface and that of the second lamina is reduced, and therefore it has all values between the half wave length of the original colour and violet. If the first lamina is completely removed the surface of the gelatine is formed by any plane which is parallel to the first lamina. In this case the distance between the two reflecting planes, that of the surface of the plate and the second lamina, already smaller than the half wave length of the violet, and therefore no colour can be produced. If the third lamina is not sharply defined and does not possess sufficient reflective power, colour definitely disappears. In certain cases, however, the third and even the fourth lamina are effective, and then we have the original colour, but very dark and dead. Thus the colour of an orange, after it has disappeared through removal of the first lamina, appears, through interference between the second and third films, brownish or dark orange, when examined in the benzole tank.

2. The correctness of these views is shown by an examination of thin sections obtained by packing the gelatine criss-cross fashion with a scalpel. Treated thus, a red which had shifted into green showed that the first lamina only had become thinner; the appearance of the blue was coincident with its almost complete disappearance, and the reappearance of the red, assuming that the second and third laminæ were not damaged, took place when the friction was continued to the second interval. The original colour finally disappeared with the destruction of the second lamina.

3. As already stated, the brilliancy of the colour is independent of the thickness of the plate and number of the laminæ. Very brilliant colours are seen in quite thin plates of 4 to 5 pr. thickness.

This refers mostly to coloured objects, in which there are usually compound colours. With spectra photo-micrographs of anatomical preparations or, briefly, when pure or almost pure waves act on the plate, the deep lying laminæ are almost as well formed as the surface ones. Naturally in such cases friction only destroys the colours with the fourth or fifth lamina.

S. R. Cajal.

THE DONISTHORPE THREE-COLOUR PRINTING PROCESS.

A newcomer in colour photography makes its appearance this month in the shape of the Donisthorpe process, which is the invention of F. W. Donisthorpe, and is introduced in the first place for the making of three-colour prints and transparencies, although the principle upon which it is based, and the materials used, are equally applicable in monochrome work. The Donisthorpe process, it should be explained, is a shortened method of producing a colour print upon a gelatine surface by abstraction of dye from a stained or dyed gelatine photographic image. It differs from other processes of a like character in the fact that the photographic surface which performs this service is simply the original colour-sensation negative, or, rather, set of three negatives. The preparation of the printing or transfer surface is therefore as direct as it can be, and is attained by treatment of the negatives in a special hardening solution which is the invention of Mr. Donisthorpe, and acts on the film in proportion to the amount of silver present.

The three constituent negatives are immersed in the permeating solution for about fifteen minutes, though considerable latitude is permissible not only as regards the duration of soaking, but also as to the strength of the solution. For harsh negatives the solution can be used half strength. The action of this solution is obviously a bleaching action on the silver image as well as a hardening action on the gelatine. It cannot be used the next day, as it spoils. The negatives are an intense blueish green, which becomes brighter by washing, this last operation requiring from five to seven minutes with an occasional rub of the film to remove the sediment which forms.

The negatives are then dyed in their respective baths. The blue negative takes from 10 to 15 minutes, the yellow from 15 to 20 minutes, and the red from 5 to 7 minutes. After dyeing the negatives have to be rinsed for about half a minute to remove superfluous dye, and then squeegeed to gelatinised paper, which has been previously softened in water. That the transference of the dye to the gelatine film takes about 15, 12 and 5 minutes respectively for the blue, yellow and red, which is the correct order of printing. Two or three pulls may be taken from the stained negative without re-staining.

There is considerable latitude in the staining process, as stronger or more dilute dyes and varying times of staining and transference will produce varying effects.

The particular class of negative which appears to be most suitable for this process is one rather soft with clear shadows. Over-developed negatives are quite unsuitable, and there is with them also considerable difficulty in superimposing the paper on the yellow and red stained plates, particularly the latter, it being necessary to shield the eyes from the direct light, and obtain superposition with a very strong light.

The above technical particulars should commend the process to the notice of colour workers, but it should be added that the method is equally applicable to the making of prints and transparencies of one colour only. A booklet, further descriptive of the process, is issued by Mr. Donisthorpe, at Combe Down, Bath, and should be obtained for the prices of the solutions, etc.

REDUCING THREE-COLOUR NEGATIVES.

The makers of "Sanzol" (Messrs. H. Edmund and Co., Ezra Street, Columbia Road, London, E.) have issued additional instructions for the use of this reducer in three-colour work. It may be mentioned that three-colour workers, such as Mr. H. J. Comley and others, have spoken highly of the evenness of reduction with "Sanzol." The following are the instructions:—

For Negatives Requiring Moderate Reduction Only.—After reducing three minutes with a normal "Sanzol" solution, rinse well under tap, and again apply the reducing solution, to which has been added a further five drops of nitric acid to each fluid ounce of solution, reduce again for two minutes and rinse under tap.

For Negatives Requiring Further Reduction.—Finish reduction with a fresh "Sanzol" solution, containing 25 minims of nitric acid to the fluid ounce of reducing solution made up.

If these instructions are carried out, very even reduction on all the gradations should result. After reduction, clear in the diluted ammonia bath and wash as usual.

If, owing to the temperature of the solutions, any trouble from frilling is experienced in the dilute ammonia bath, the negative may be well rinsed under the tap, after reducing, and before the ammonia bath.

The application of formalin, before reduction in hot weather, is, however, preferable, and will not be found to appreciably slow reduction.

The Colour Photography Exhibition.—The annual exhibition of the Society of Colour Photographers will be held at the house of the British Journal, 24, Wellington Street, Strand, London, W.C., from September 30 to October 26. Exhibits are invited from workers in all processes of colour reproduction, whether members of the society or not, and may consist of prints, transparencies, or objects of interest, such as series of constituent negatives with transparencies or prints from same. "Autochrome" transparencies will form a notable feature of the exhibition, special arrangements having been made for displaying them to the utmost advantage, and it is hoped that those workers who have obtained results on these plates will avail themselves of the opportunity of exhibiting them in the above collection. Entry forms and any further information may be obtained from the hon. secretary, Mr. H. J. Comley, Surrey House, Strond, Glos., to whom the forms, duly filled up, should be sent by Sept. 10, and exhibits should reach the "B.J." Offices by Sept. 13.

BLEACH-OUT PAPER PRINTS FROM COLOUR SCREEN-PLATES.

As the import of my paper on this subject on page 62 of the August "Colour Supplement" seems to have been only partially recognised by the Editors in their article on page 638 on the Warner-Powrie process, and has been altogether misrepresented by Dr. Mebes in his translation of the editorial article in "Der Photograph," No. 76, page 297, I find it necessary to refer further to the matter.

Dr. Mebes has made me responsible for asserting that it is a matter of impossibility to copy from an Autochrome or other mosaic plate upon our bleach-out paper (Uto emulsion). I certainly drew attention to the difficulties attending the copying of such mosaic screened plate upon bleach-out papers, but went on to show how I proposed to surmount those difficulties, and my experience since writing that article has confirmed my opinion.

Of all the colour-screen plates that have been proposed, I consider the autochrome plate to be the most difficult to print from, partly on account of the semi-opacity of the starch granules and partly on account of the tender nature of the emulsion film. Still, in spite of these special difficulties in the case of the autochrome plate, it is even now possible under the conditions I referred to in my paper to obtain fairly accurate copies from the autochrome plates, and as we are making continual improvements in our Uto emulsion, it will not be long before satisfactory results are obtained.

I had hoped to have been able to send some specimen autochrome prints to the present exhibition of colour-photography, but it is rather premature to come before the public. The two prints from window transparencies which we are sending will prove, however, that for such printing purposes the Uto emulsion as now prepared is satisfactory in the rendering of the colours.

Now, with regard to the Editors' article on the Warner-Powrie process, I must admit that I have been very favourably impressed with the ingenious method employed in making their screens, and with the results shown to me by Mr. Powrie. Relying upon Mr. Powrie's information that the cost of manufacture, in spite of the many coatings in volved, is only trifling, I recognise in this Warner-Powrie plate, with its many special advantages, a serious rival to the autochrome plate, as soon as the former can be placed on the market.

There is no doubt that this plate will lend itself much more readily to copy from upon our Uto emulsion than the autochrome plate does, both on account of the greater transparency of the coloured media, and of the almost mathematical adjustment possible in printing by means of the printing-frame with inclined mirrors.

I wish, however, to draw attention to the fact that this frame, as drawn and described by the Editors and attributed to Miss Warner and Mr. Powrie, is identical with the printing frame described in my article in the August Supplement, and shown by me in use with one of their lined screen positives to Miss Warner and Mr. Powrie at our factory in the month of August. Two opposite mirrors are simply taken away, as, of course, they are unnecessary in printing from lined screen plates.

That the principle involved is exactly the same, whether dealing with mosaic or lined-screen plates, can be seen by substituting in the third last paragraph of my paper the word *line* for dot or spot, which would thus read: "It is not difficult to see that a *line*, say underneath a green *line* in the original, will be bleached to green by the vertical rays, and be further bleached to white by the angular rays passing through adjacent red and violet *lines*. In the case of one-coloured areas in the original, the angular rays actually assist the printing by diffusion of the colour under the adjacent black *lines*." This description agrees entirely with that of the Editors regarding the Warner-Powrie claims for their printing apparatus.

In our patent application for this new printing frame the claims are made to cover not only mosaic but also linear-screened plates, and in practice the frames, which will be very soon placed on the market by a well-known German camera firm, will be made with the mirrors detachable to slide into the frame, so that they may be used for colour plates of either pattern.

Mr. Powrie employs the mirrors nearer the perpendicular than I have done. This is simply a matter of adjustment to the width of the lines, and the thickness of the celluloid film inserted between the coloured positive and the paper. In the case of the autochrome plates I generally employ a very thin celluloid film to prevent the paper sticking to the plate; otherwise it is preferable to have the paper in contact with the plate and use more slanting angular rays. The thickness of the emulsion film is probably sufficient separation from the screen in consideration of the minute size of the Lumière starch granules.

The Warner-Powrie screen has, of course, the great advantage that dimensions of the lines, etc., can be accurately measured. In the case of copying their positives by the reflected rays, the blue lines being only half the width of the others, would cover the half width of the red and green lines in the copy, the green lines would cover half the blue lines and the half width of the red lines, while the red lines would cover the other half of the blue lines and half the width of the green lines at each inclination.

DR. J. H. SMITH.

THE STRUCTURE OF LIPPMANN HELIOCHROMES.

III.

Analysis of White Plates Caused by Excessive Intensification.

The above results of the author's researches on the whites elucidate a phenomenon which is often observed before or after fixation, when a plate is intensified with perchloride and amidol, plus sulphite.

It has already been stated that the grains become larger, and, therefore, closer together. Consequently, the reflective power, particularly of the first lamina, which is most easily attacked by the reagents, is increased.

So long as the grains of the first metallic film possess a certain transparency the colour does not markedly alter, as part of the incident light reaches the second lamina and is reflected back. If, however, as is generally the case with a second intensification, the first film loses its transparency almost entirely, then the ratio of reflective power of the first two films is altered, as that of the first preponderates. The result of this is that the colour presents a dirty white appearance, and the want of transparency is greater the thicker the grains of the first lamina become. With great intensification the colours completely disappear, especially in the fully exposed parts, and the picture appears as though covered with a milky fog.

Figs. 7, 8, and 9 show the appearance of a section through almost pure green before and after intensification. Before intensification the laminæ are pale and fine-grained, and the metallic precipitate is absolutely wanting on the surface. (Fig. 7.) Therefore the light can penetrate to the second and third film, and their analytical and reflective actions are added together. It is quite different in Fig. 9, which is a section through the same colour after two intensifications. All films, especially the first, act like a white-producing mirror—that is to say, they contain extraordinarily coarse grains and have lost the best part of their transparency. Moreover, it can be seen that each film has become distinctly thicker. The limiting zone has given way to the mirror zone. Fig. 8 shows the same colour with one intensification.

The practical result of these researches leads one to formulate the rule that Lippmann photochromes should be intensified once to give good whites, but should never be intensified twice, as otherwise the first lamina will be converted into an opaque mirrorlike film, and therefore the chromatic interference which is specially produced by the second lamina can not longer take place.

Analysis of Over-Exposed Plates.

Even by mere examination an over-exposed picture shows a lustreless white, greyish or pinky, and more or less pure, but hard-silhouetted colours. Microscopic analysis explains this phenomenon, which is one of the most frequent defects in working Lippmann's process.

The laminæ of such plates consist of a thin yellowish and extraordinarily pale precipitate, which allows more light to pass to the underlying films than usual. The intervals also are more or less strongly acted upon; they show a delicate, light grey grain formation, so that the contrast between the laminæ and intervals is considerably decreased. (Fig. 13.) Finally, the first lamina is completely wanting or reduced to a pale indefinite stripe. (Figs. 12 and 13.) This paleness is more or less seen in the second lamina. The phenomenon naturally depends on the fatigue of the surface region of the sensitive film, which is so strongly solarised that it cannot be reduced to a dark colour.

Whites show in over-exposed plates a very pale and transparent mirror film, which with considerable solarisation may even be totally absent. The pale, small, yellowish and almost invisible grains possess no reflective power. Behind the mirror zone are various fine stripes without contrast, and an extended region of irregular and comparatively vigorous reduction which extends to the glass.

Change of Colour by Over-Development Intensification.

The least overstepping of the correct exposure leads, as will be seen later, to falsification of the colours and loss of the whites. Red and orange are exceptions, the two colours which from their poor photo-chemical action rather gain than lose with moderate over-exposure.

The colour values of the picture is also changed by over-deevlopment or intensification, even if the plates are correctly or slightly under-exposed. If the damage is not too great it can be equalised by cementing under a prism with Canada balsam, as then the gelatine loses a little water, and therefore the laminæ get nearer one another. If the fault exceeds certain limits, the colours are so falsified that neither in moderately oblique light nor in a benzole tank will the picture give the true colours.

Microscopic analysis shows that such colour changes are to be ascribed to a thickening of the first lamina, which then reaches the surface of the gelatine. Since by this thickening the difference in the path of the rays reflected from the surface and from the interior of the plate is enlarged, the same wave-length, even with normal, or almost normal, illumination, which produce the laminæ, will not predominate, as will light of a greater wave-length.

One of the most unpleasant and most frequent occurrences in Lippmann's process is the transition of the blue and violet into white. This change is due, not to a narrowing of the intervals, but only and alone to their lessened transparency, and especially that of the first, which then acts as an opaque screen. It is thus quite immaterial that the laminæ and the deeper-lying ones are sharply defined, or that the top one remains intact, the waves of light cannot actually penetrate to the lower laminæ, and therefore cannot produce interference. In plates examined without a prism and without the benzole tank, this trouble often appears if the blue shows well, because the limiting zone, as is easily seen, is the more troublesome the shorter the wave-length of the light.

If the tank does not remedy this fault, one can reduce the plate so as to enable the light to penetrate into the depths of the film. As a preventive the use of light screens has been suggested to reduce the energetic action of the shorter spectral waves. Such screens have been used by all experimenters, and especially by Neuhauss and Lehmann, with good results. The author uses a weak solution of aniline yellow with some erythrosine in collodion on the back of the plate; the use of the screen, which is rather expensive, is thus avoided. Also a screen absorbs a great deal of light, and if not of first-rate quality detracts from the purity of the pictures.

Falsification of the Colours Through Dampness of the Plates.

Similar falsifications of the colours appear in the use of too dry plates in damp weather. The correctly obtained and fixed laminæ become considerably further apart by absorption of atmospheric moisture, and the oft-noted fault of a shift of the colours towards the red is seen, and green becomes yellow, and yellow orange or red, and so on. In order to obviate this fault the plate should be brought into hygrometric equilibrium with the air. A somewhat dangerous remedy is reducing the grain of the laminæ with a reducer.[1]

The reverse phenomenon appears when the plates are placed in the benzole tank or mounted with a prism. The change of colour thus induced is towards the more refrangible end of the spectrum, and sometimes produces the shift of more than half a tone. For instance, the red becomes orange red, and orange yellowish. Blue and violet, on the other hand, are scarcely modified, or, rather gain, in power and purity.

This well-known phenomenon is based according to the author on the giving up of water by the gelatine to the benzole or to the Canada balsam, so that naturally the distance between the laminæ is decreased. In order to get over this difficulty development should be rather longer, so that the colours shift towards the red, or, still better, the plate should be warmed before exposure, and just before placing in the mercury slide, in a drying cupboard at 86 deg. Fahr.

Falsifications of the Colour Tones in the Darker Parts of the Plate.

With under-exposed plates or in places which correspond to the shadows of a coloured object, the picture shows, instead of the true colour rendering, another colour, and, as a rule, it is the opposite to the phenomena observed with over-exposed plates, the shift being towards the more refrangible end of the spectrum.

Thus the shadows of a head in sunlight are brownish-green or greenish-yellow, instead of the delicate rosy tint. An orange which is correctly reproduced on the illuminated side shows pure green in the shadows. (Fig. 16.)

These and other imperfections of dark or only briefly exposed objects can be ascribed, according to the author's researches, chiefly to fixation, the action of hypo or cyanide. Keeping to the example of the orange, the plate was, as a matter of fact, affected in the bright and dark parts by rays of different intensity, reflections from neighbouring objects being excluded, but in the strongly exposed parts there were formed numerous dense laminæ, whilst in the shadows these were fine and pale; in many cases there were only formed a small series of yellowish grains.

The cause of this phenomenon, which had already been observed by O. Cramer, is that in fixation there is more silver bromide dissolved out in the shadows the weaker the action of light, and therefore thin laminæ in the dark parts approach one another during drying; whilst in the brightly lit parts, which are therefore poorer in silver bromide, they scarcely alter their relative positions.

From this fact we may deduce the practical lesson that Lippmann plates should not be fixed, because the disappearance of the silver bromide causes a general reduction of the intervals and a consequent falsification of the colours.

According to the author's views complete fixation of the pictures, even when all other operations, such as exposure, development, intensification, etc., have proceeded normally, causes with normal, or almost normal, illumination at least, a slight shift in the direction of the more refrangible end of the spectrum, a fault which cannot be remedied, as mounting under a prism would only slightly increase the shift; and if this failure has been less frequently observed than the opposite one (that is, too great a distance between the laminæ), it is due to vigorous intensification, which compensates, to a certain extent, the contraction of the intervals between the laminæ, actually by thickening the first one.

It is obvious from the researches that the most frequent imperfections of Lippmann heliochromes is due to the almost unavoidable changes of the normal distance between the laminæ, a change caused by the mechanism of the photographic operations. Under certain conditions—complete fixation, too short exposure, too short development, etc.—the laminæ are too near one another, and the colours

[1] The reducers and especially dilute potassium cyanide solution when carefully used, restore the colours of over-developed or damp plates. But not only do the whites suffer severely, but after some time the grain bleaches very much, and the picture becomes worse. The author has therefore entirely given up the use of reducers. Only in individual cases does he use it locally to restore the blues and violets. This retouching is done on the wet plate with a fine brush dipped in weak potassium cyanide solution.

shift towards the blue. In other and much less frequently occurring failures the laminæ become thicker, the reflecting surfaces are further separated from one another, and the colours are then shifted towards the red.

Analysis of Pictures with Matt Faint Colours.

Many emulsions, in spite of great transparency, show a tendency to give only matt colours, and actually do not give white. A microscopical examination of such plates proves that the cause of this phenomenon is due to too little contrast between the laminæ and the intervals. The former are formed in sufficient number, but from their yellowish or bright greenish-grey colour are not sufficiently differentiated from the more or less grey intervals. The mirror zone which reproduces the white is very pale and transparent, and possesses no reflective power.

In order to obviate this very frequent fault, which unfortunately occurs with every third or fourth emulsion, the author has made many experiments and obtained successful results by alteration of the developer. To increase the contrasts between the laminæ and the intervals the following should be used:—

Potass. bromide 10 per cent. sol.	20 ccs.
Ammonia	1-1.5 ccs.
Pyro, 1 per cent. sol.	15 ccs.
Water	250 ccs.

and the general rule is: reduction phenomena appear very quickly in the intervals with an excess of ammonia, whilst the opacity of the laminæ is increased by an excess of bromide and pyro; but the laminæ ought not to be so opaque as to prevent the intensifying action of the deeper-lying ones.

Laminæ in Plates Exposed Without a Mercury Mirror.

The earlier experiments of Krone and the more recent ones of Rothé have proved the possibility of obtaining interference colours with Lippmann's plates without using a mercury mirror. The pictures thus made have only a faint brilliance, and require, moreover, much longer exposures. This is obvious, as the stationary waves are formed by interference between the incident light and the few light waves which are reflected from the surface between the gelatine and the air. The author has repeated the interesting experiment and obtained comparatively good results of the shorter wave-lengths, violet to green; far less satisfactory, however, were the reproductions of the red, orange, and yellow. Examination of sections show in all cases the presence of correct laminæ, which are few in number, however, and are separated by intervals which are not free from precipitate. Fig. 17 shows the section through the blue of such a result. The laminæ, only three or four in all, are composed of very fine grains. The second lamina is the best and darkest. In the limiting zone there is no precipitate, and this proves therefore that, as with the mercury mirror, the surface of the gelatine is identical with the first opposite phase plane.

The whites obtained in this way are also the same as those obtained with Lippmann's method; behind the dense thin mirror zone there are some fine laminæ, which, deeper down, degenerate into an irregular grey deposit.

Conclusions.

From his long and comprehensive researches on the structure of the Lippmann heliochromes the author comes to the following conclusions:—

1. As already recognised by Neuhauss the spectrum colours are produced by a series of metallic laminæ, separated from one another by colourless intervals. These films occupy a third or a half of the thickness of the gelatine. Near the free surface they are sharply defined and distinctly separate one from the other, the deeper they are the more diffuse and indistinct they become.

2. Between the first laminæ and the surface there is generally a clear zone, which corresponds to the first opposite phase or null point. Frequently through intensification this contracts considerably, or completely disappears.

3. The colours of natural objects give pictures, the structure of which agrees generally with that of the spectral colours.

4. The production of white is due to the formation of a dense metallic lamina, the mirror zone, with great reflective power, and composed of an opaque dark closely compacted precipitate. Then there are some fine closely contiguous stripes, which probably correspond to the short waves of the visible spectrum.

5. The colours mixed with white show with their own laminæ a [illegible]film, filled with a metallic precipitate, the mirror zone.

6. In certain cases colours mixed with white show two kinds of laminæ: large stripes far removed from one another, which belong to the long waves of the predominant colour, and one or two fine pale films corresponding to the shorter wave-lengths.

7. The interference phenomena, through which the colours are produced in Lippmann heliochromes, can be ascribed actually to the action of the rays reflected from the first and second laminæ. The others have only a faint, but, to a certain extent, an intensifying action. Pure spectral colours are an exception in their formation: if the metallic precipitate is quite transparent, the deeper lying tones may also act.

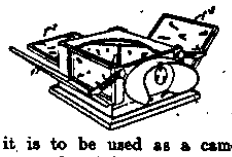
8. The good rendering of the colours is principally caused by the correct limiting and perfect transparency of the upper laminæ, as well as the normal value of the intervals. All causes, such as long exposure, over-development, incorrect intensification, etc., which upset the ratio of the two first laminæ as regards intensity and thickness, or such things as fixation and damp, which affect the size of the intervals, alter the true colours and cause false tonalities. From this it is obvious that the greatest difficulties of the Lippmann process are as follows: *a*, the distance of the individual laminæ produced in the plate by the coloured light during the exposure must be strictly kept, in spite of the contracting action of fixation and the expanding action of intensification; *b*, too little transparency and too great thickness of the first lamina must be avoided, although a certain opacity is essential for the correct reproduction of the bright tones. By careful, clean work the perfect balance of these two opposite requirements must be fulfilled by workers in interferential photography.

S. R. CAJAL.

Patents Chronology.

COLOUR FILTERS.—No. 4,365, 1902. These filters are made by cementing small strips of glass or similar material of uniform thickness to the edges of a glass plate so as to form a shallow trough or cell into which gelatine, isinglass, or other animal or vegetable gums dissolved in pure glycerine, together with an antiseptic and the necessary colouring matter, is poured. Whilst still warm a second glass plate is lowered on to the top, and the whole left to cool under pressure. This method is stated to give absolute uniformity of colouring and cheapness, so that large filters may be economically prepared. Arno Bauermeister, Leipsic, Germany.

PHOTOCHROMOSCOPES AND CAMERAS.—No. 3,476, 1902. A single or stereoscopic photochromoscope, in which the reflectors, which may be plain, coloured, or platinised, are arranged as shown in



the figure. If it is to be used as a camera, the reflectors, $f f^2 f^3$, may be removed and dark slides placed at the back and sides of the instrument. Thomas Knight Barnard, Hammersmith.

PRINTING PROCESS. — No. 9,184, 1902. Commercial baryta paper or other paper, which must be non-stretching and have "a rough matt surface," is rendered impermeable to aniline dye solutions by a preparation such as celluloid varnish. It is then to be coated with a bichromated colloid. If gelatine be used, then 8oz. of Nelson's No. 1 gelatine should be soaked in from 40oz. to 60oz. of water, the temperature raised, and enough chloral hydrate or other agent added to make the gelatine liquefy at about 70deg. F. Fish glue may be used, and four parts added to twenty parts of water, and one part of bichromate of potash. Casein is also very suitable. The support or paper, which should be temporarily mounted on glass, should be placed on a whirler, coated, whirled, dried, and exposed. After exposure the soluble colloid is washed away, preferably by immersion in a solution of the same colloid. The print is then rinsed, stained up with an aniline dye complementary in colour to the taking screen, dried and varnished.

2. The stripped film is immersed in alcohol and water, then in absolute alcohol, and finally for a few minutes in celloidine.

3. Fine sections are cut at right angles to the film and laid in water to swell.

Sometimes the water is replaced with glycerine, and the film stained with an aniline dye insoluble in water. After some experience one may use a still simpler plan, and that is to hack the damp film along and across with a sharp scalpel, to then cover the cut places with a coverglass, and examine in this way, when one or more pieces showing the laminæ will be easily seen.

The Grain of Plates.

Lippmann and others who work the process contend that the transparent emulsion in albumen or gelatine has no grain, or only such that as regards the wave-length of light it can be neglected. Neuhauss, however, proved the existence of a grain almost invisible before exposure, but which after development varied between 0.1 and 0.3 μ. The author considers this far too high an estimate, as it would be hardly possible with such a grain to register the half-wave length of violet light ($\frac{1}{2}\lambda = 0{\cdot}171\ \mu$). From various experiments, he believes that he is not far out in putting the size of the grain at 0.02 to 0.05 μ. (4).

The grain is spherical, of homogeneous appearance, and of a colour depending upon the duration of exposure, the hygrometric state of the atmosphere, and the developer. Generally, the grain of the less exposed parts is bluish grey; at the correctly exposed places it is of a light chestnut-brown colour; when over-exposed, fine greenish yellow or pale ochre-coloured grains occur. Strongly solarised parts are always a clear bright yellow. It may be as well to point out that these colours are not dependent on the wave-length of the light, but on the duration of the action of the latter; and they only appear on the intensified plates; the action of the mercury chloride is not only to enlarge the grain, but to give it a uniform character and opacity and a more or less grey tone. The colour of the grain alters also in rainy weather.

Hitherto the grain of the developed plate has been dealt with, but, as Neuhauss pointed out, a grain can be seen before exposure, but with extreme difficulty. The author was most successful with a film deeply stained with cyanine, oblique monochromatic illumination, and a Zeiss objective of N.A. 1.40. The spotless white and transparent emulsion will keep for several days unchanged by the direct action of light, a phenomenon which proves that the grain cannot suffer reduction or blackening except with the help of some photographic reducer.[5]

The Structure of the Plate in Pure Spectral Colours.

An examination of the sections through a pure or almost pure spectrum colour shows different zones; first a laminated zone, and then (below) an unlaminated zone. The structure depends on the thickness of the plate, the transparency of the emulsion, and the duration of exposure. Moderately thickly coated plates show the structure for about one-third or somewhat less of the total thickness of the gelatine, and the following parts may be seen: the limiting zone, which lies between the free surface and the first lamina, the Zenker laminæ, and finally the intervals or spaces.

The limiting zone in the blue and violet is very difficult to detect because it is so thin; in the red and orange, on the other hand, it is comparatively distinct as a very fine stripe which is almost free from grain formation, but the nearer one comes to the Zenker stripes, the more distinct the grain. Even in the red the examination of this zone is not easy—sections immersed in water have a refractive index so near that of water that even by oblique illumination it is almost impossible to see it. This is probably the reason why Neuhauss expressed doubts as to its existence. The author was enabled to see it by treating the film with an aniline dye, such as aniline blue, which is insoluble in water or by coating it with coloured varnish. Under these conditions, thanks to the coloured film, it can be plainly seen (Fig. 1). Its thickness in the swollen plates is about half an interval, but varies considerably, which may be caused by unequal expansion of the gelatine, and also to the varying thickness of the first lamina.

These observations confirm, at least in principle, the often-observed fact, that the surface of the gelatine forms the first interval, and that the reflecting surface of the mercury is thus in immediate contact with the gelatine during exposure.[6]

As the limiting film is only a fraction of a wave-length thick, it is easy to understand why the light reflected from the surface interferes with that from the laminæ, and why a prism is necessary or the heliochrome must be placed in a cell filled with benzole or xylol to eliminate this surface reflection.

The Zenker laminæ consist, as required by theory, of a metallic precipitate which is thicker in the middle than the sides. It must not be overlooked that in the dry plate the laminæ are very close together, and that they have great density and considerable reflective power. In the unintensified plates the colour of the grains is bright brownish yellow, in the intensified grey or coffee brown.

The number of the laminæ differs considerably. In many cases it varies, as pointed out by Neuhauss, between four and six, and depends on the intensity of the light, the duration of the exposure, and the transparency of the gelatine. Generally, the author thinks that there are more in brilliant pure colours as in the solar spectrum than in the mixed colours of natural objects. He has some spectra showing thirteen and more laminæ, which reach to the glass and show the colours from both sides. The same effect has been met with in some histological heliochromes.[7] There are exceptions, and as a rule the number of laminæ is only five, six, or eight.

The thickness of the laminæ is everywhere the same, as is also that of the intervals. Their intensity and the sharpness of their edges decrease the further they are from the surface of the plate. This fact, as will be seen later, is very important. Figs. 2 and 3 show that the first lamina is the most distinct, and, as a rule, more sharply defined on the edge. Then follows the first interval, which is the purest and most colourless—that is, the freest from silver—of all; then the second lamina, dense and sharply defined; then the second interval, which is almost as clean as the first. Behind these the contrasts between the laminæ and intervals are less distinct as the intervals become filled with precipitate, till the final region is reached, in which the laminæ disappear, as does also the silver precipitate (Fig. 1d).

As will be seen later, the relative intensity of the first laminæ varies according to the duration of exposure and the degree of intensification. In normal plates the two first laminæ are practically the same intensity and thickness; in over-exposed plates the first lamina, in consequence of photo-chemical fatigue, is weaker or disappears altogether. In this case the second or third are the strongest.

The film without laminæ varies considerably as regards thickness. In very thin plates it is almost or entirely wanting. In moderately thick plates, as in Figs. 1 and 2, it may be two-thirds to one-half of the total film. As a rule it is without silver grains, though here and there some may be seen which possibly correspond to over-sensitive bromide of silver. If the exposure is too long, or the plate is developed too much, this region is filled with a fine yellowish or light brown coloured precipitate of coarse particles. This very frequently happens in the pure red or yellow. The appearance of the section through the other colours is, independent of the function of the wave-length, practically the same. Fig. 2 shows a section through the blue at λ 0.475 μ. The extraordinary thinness of the limiting zone and the comparatively great fineness of the laminæ will be noticed. In many sections the author thinks that

[4] He speaks here of the emulsion which will register all colours up to violet. That which will only record red and yellow has a much coarser grain.

[5] This was first observed by Lüppo-Cramer and also by Neuhauss in 1903, therefore one can do away with the useless operation of fixing and the consequent reduction of the intervals between the laminæ. Lehmann also does not fix the plates.

[6] This fact is opposed to Rothé's assumption that the laminæ are due to the light reflected from a film of air between the mercury and the gelatine ("Compt.-Rend'.," 1904, pp. 565-7). If this was so the reflection of the incident light would take place from a substance with lower refractive index than that of gelatine, therefore there must be formed a maximum and not a minimum on the surface of the gelatine. This is never the case with correctly exposed unintensified plates.

[7] Professor Cajal uses this process for obtaining heliochromes of histological and pathological sections.—EDS. "B. J."

there are less laminæ in the blue and violet than in the more refrangible colours. It is difficult, however, to follow these fine laminæ, and it may be merely a case of coincidence (Figs. 2 and 12).

The Analysis of White and Grey.

These are two most important colours, and from a careful consideration of all the literature on the subject, and the study of many sections, the author comes to the conclusion that *the formation of pure white is produced by intensification of the images.*

Without intensification—that is, without the artificial production of coarse grain—it is not possible to obtain pure whites, for these require a closely compacted, opaque film with metallic lustre. As will be seen from Fig. 5, the whites consist of three regions, the mirror zone, the laminated zone, and that which is characterised by diffuse reflection the rear zone.

It is characteristic for white or grey, or all colours containing an admixture of white, that the limiting zone disappears. In its place, and in place of the first lamina, there appears a new dense dark film of great metallic reflective power, 5a and 6a. This lamina, sharply defined on both sides, contains large spherical metallic grains packed close together, and of a dark brown colour. The general rule is that the more brilliant the white, the more opaque and compacted is this region, which, if the plate is not intensified, is only a bright transparent yellow or light brown, with distinct spaces between the grains.

This observation is important, for it proves that to obtain whites there must be (1) a metallic reflecting precipitate in the limiting zone, and (2) complete opacity of the first lamina, which combines with the limiting zone to form a morphological unit. The result is that nearly the whole of the incident light is reflected, and the few rays which do get through into the deeper parts of the plate cannot produce interference. Behind the mirror zone there is a very fine interval, and a series of very dark, extremely thin, closely compacted stripes (Fig. 5b). These stripes are never wanting, even if the white of the object is very pure. If the white is mixed with pink, cream, or bright blue, they are more numerous than in neutral grey. It is very significant that the distance between these laminæ is extremely small—about the same as for violet and blue; sometimes a difference in thickness and separation can be seen as though they were caused by light of differing wave-lengths. They are so fine that it is difficult to see them in a plate that is not swollen in water.

The author does not consider that these phenomena are contrary to theory. The thickness of the mirror zone on the surface of the gelatine is probably due to the combined action of the ultra-violet rays. The grain of the emulsion is too coarse to give regular periodic laminæ, but only diffuse deposit. On the other hand, the blue and violet of greater wave-lengths are registered, if only partly, whilst the comparatively coarse stripes which appear between the fine ones are perhaps the maxima for the long waves green, red, and yellow for which the chromatic sensitising is least.*

The preponderance of violet in the image of white depends probably on the rapidity of development. Then appears a phenomenon similar to that which is observed when a plate exposed for only a short time is exposed again for a much longer time: on development only the longer-exposed picture is seen. Perhaps also the greater attraction of the violet maxima for the developer comes into play, and the places corresponding to red and yellow scarcely act. There appears then the well-known action of contrast, which is frequently observed on ordinary plates, namely, an extremely bright margin round a vigorously developed place.

From this it would appear as though the formation of white on those parts of the plate affected by light of every wave-length, is not due to the admixture and fusion of the reflective action of many different laminæ, as assumed by Lippmann, but exclusively to the reflective powers of a dense, opaque, dark surface film, on the opacity of which the brilliancy of the colour depends. Consequently, neither the fine laminæ within the plate nor any interference phenomena (since the density of the mirror zone makes this impossible) have anything to do with the appearance of white.

* If the mirror zone is formed more easily in slow plates, this is due to the fact, already mentioned, that these plates are specially sensitive to the shorter waves. The unequal behaviour of the plate with the green, red or orange, which, unfortunately, frequently happens, is due to the addition of the same quantity of erythrosine, cyanine and glycine red to the emulsion. The whites are then frequently not pure, but tinged with red or yellow.

That the author is correct is proved by the following phenomena:

1. If the white places are rubbed, their brilliancy decreases without colour appearing; only when the mirror zone is completely removed does white disappear and blue or a more or less dark grey of violet or bluish tinge appear. In the first place there always appears a greenish blue tone, the formation of which, as shown by micrographic examination of the rubbed parts, must be ascribed to the mirror zone becoming thinner. As soon as this zone is removed there appears a dirty indefinite violet, which persists till the plate becomes quite transparent. This last fact proves that the whites are caused by the action of the violet rays.

2. Oblique illumination of Lippmann heliochromes produces, as is well known, a shift of the colours towards the more refrangible part of the spectrum. Orange-red becomes yellow, green, blue, and so on, and this shift is the more distinct the greater the angle of incidence. This change of the picture in oblique light depends on the laminated structure of the gelatine, and is easily explained by the increase of path, which the waves of shorter wave-length than double the intervals must traverse. Inclination of the plate to the incident light produces no change in white, a certain proof that this colour does not depend on laminar formation.

3. Neither varnishing the picture, nor slight swelling, nor testing in a benzole tank have any influence on pure white, which is thus sharply differentiated from other colours. This is also an indirect proof of the absence of the limiting zone above the mirror zone. Impure whites or greys will naturally alter in tint under a prism or oblique incident light.

Explanation of the Figures.

Fig. 1.—Section through pure or almost pure red. Swollen in water and examination with a Zeiss apochromat, N.A. 1.40,0 2 mm. focus. Central white light, *a* the limiting zone, *b* first Zenker lamina, *c* second interval, *d* deeper lying laminæ. with indefinite edges, *e* unlaminated zone.

Fig. 2.—Section through the blue, in the reproduction the deeper lying laminæ are badly drawn. Conditions of examination as in Fig. 1.

Fig. 3.—Section through the red in dry—that is, in gelatine not swollen in water. Examination in Canada balsam. Central monochromatic light.

Fig. 4.—Section through greenish yellow. Same conditions as in Fig. 3. The limiting zone and the grains in the individual laminæ cannot be seen.

Fig. 5.—Section through pure brilliant white. Swollen gelatine. *a* opaque mirror zone, *b* the fine stripes lying under the mirror zone.

Fig. 6.—Section through yellowish white, *a* mirror zone, *c* fine stripes, *d* laminæ corresponding to the yellow.

Figs. 7, 8, and 9.—The action of intensification on the colour.

Fig. 7 shows the unintensified colour, the stripes are too dark in the reproduction.

Fig. 8.—The same colour intensified once in a sublimate bath.

Fig. 9.—After two intensifications. It will be observed how the scarcely visible grain in Fig. 7 becomes thick and dark in Fig. 9.

Fig. 10.—Red. The thickness of the first laminæ was reduced by friction, so that blue and green stripes appear.

Fig. 11.—Section through bright green, which by over-exposure and over-development has become white; *b* mirror zone, *c* fine stripes belong to the white; the other laminæ belong to the green.

Fig. 12.—Section through over-exposed blue. The paleness of the laminæ *e* and the absence of the mirror zone will be noticed.

Fig. 13.—Section through over-exposed orange. The first lamina *f* is wanting, and the second is also rather pale.

Fig. 14.—Section through bright blue mixed with white; *a* mirror zone, *b* fine secondary laminæ.

Fig. 15.—Section through bright lemon yellow. The first laminæ represent the phase of conversion into the mirror zone.

Fig. 16.—Section through under-exposed and over-developed green, which corresponds to the shadow side of an orange. The fineness and transparency of the laminæ, which are somewhat too dark in the reproduction, will be noted.

Fig. 17.—Section through the blue in a plate exposed without a mercury mirror.

(*To be continued.*)

THE STRUCTURE OF LIPPMANN HELIOCHROMES.

II.

Colours Mixed with White.

Compound tones, such as grey, pink, cream, light blue, etc., formed by admixture of a principal colour with white, occur very frequently, and the artistic value of the reproduction depends to a great extent on the correctness of the tonality of the latter. One may assume *à priori* that the compound colours possess a better mirror zone, which gives the white, and secondly laminæ with intervals corresponding to the principal colour. This actually is the case, and proof is afforded in the section of a yellowish white (Fig. 6). The surface of the plate shows the thin transparent mirror zone. Close behind is a fine pale stripe (c), which perhaps belongs to the violet or blue, and then two or three thick lines separated from one another by wide intervals which correspond to the laminæ of the yellow.

Irregularities in the intervals between the laminæ are frequently observed with compound colours; sometimes they are due to illusion and to unequal absorption of water. In those cases in which the water has acted for a long time and the finer lines are nearer to the surface, the different thickness and distance of the laminæ must be ascribed to the registration of different waves. Neither with compound colours nor pure white are all spectrum waves to be distinguished

Bluish, reddish, and greenish white have a similar structure; all these colours show with the mirror zone a laminar system and their optical effect is added to the reflection from the mirror zone.

For the chromatic interference, as with pure colours, only the two first—or, as noted above, in the case of a fine secondary strip (Fig. 11c) the three first laminæ—are used. The colour thus formed is weakened by the somewhat disturbing reflection of white from the mirror zone. That the surface film, in spite of its paucity in precipitate, causes weakening of the colour is proved by rubbing or scraping the plate, for then the whitish tinge disappears and the dominant colour appears much more strongly, and if the scraping is continued it is shifted towards the more refrangible end.

After the author's views as above had been published, he heard of Lehmann's work on the same subject, but the results of the two workers are not in agreement.

According to Lehmann, white is formed not, as assumed by Lippmann, by the confusion of the incident light of various vibrations from the laminæ, but by reflection from two laminæ corresponding to complementary colours. As proof of this assumption, Lehmann advances (1) the possibility of obtaining photo-micrographs under special experimental conditions of the registration of two synchronous waves; (2) the spectroscopic examination of the light reflected from the whites of a picture placed in a benzole tank. In the latter case he observed that the whites of the picture did not, as the whites in nature, emit a continuous spectrum, but a discontinuous one, or a continuous spectrum with two or three distinct maxima preponderating. From this Lehmann concludes, in agreement also with Pfaundler,* that the plates do not possess the power of registering simultaneously a greater number of waves of varying vibration, but only two or three, and he explains the formation of white and grey by the well-known property of the retina of synthesising to white when two complementary colours act on the rods.

In principle this coincides with the author's conclusions as to the formation of two kinds of laminæ; but the question does not appear to the author to be experimentally proved, for, as will be seen later, the deeper lying laminæ do not, or only in rare cases, help to produce the colours.

Lehmann's conclusions have caused the author to repeat his experiments, and he comes to the conclusion that brilliant whites are due entirely to the first mirror zone and not to laminæ. The following are also advanced in favour of the author's views, and much against Lehmann's:—

a. If the whites are rubbed with a pad dipped in alcohol till the mirror zone disappears, there appears first blue violet, although the opacity of the metallic particles is appreciably reduced when examined by transmitted light. If the picture is still further rubbed till quite transparent, the white never appears when it is put in the benzole tank. The colours behave quite differently as they reappear.

b. If a very thin plate is used so as to prevent the formation of the unlaminated zone, all the *colours* will be visible when the plate is looked at from the back, but *white* is never seen.

c. If a plate is left, without varnishing, exposed to the air for some months, the whites are the first to disappear, probably on account of oxidisation. This rapid alteration can be explained by the fact that the mirror zone, as already pointed out, lies absolutely on the surface of the gelatine.

d. Everything which attacks the surface of the gelatine of the developed plate, such as washing, friction, deposition of mercury oxide on the sensitive film, etc., prevents the appearance of the whites, whether the plate is examined in air or benzole.

e. In under-exposed plates, if no colour of the longer wave-lengths green, yellow, and red has acted, nothing but a brilliant white is obtained on intensification, especially if slow-acting plates are used. On the assumption that two complementary colours, for instance red and green or yellow and violet, have been registered, this formation of white is incomprehensible.

f. Whites also appear on plates which have been exposed without the mercury mirror, and in which the laminæ are extremely thin. The white obtained by intensification is as brilliant as in pictures obtained under the ordinary conditions.

g. White is also obtained by the intensification of pictures taken on non-orthochromatised plates.

h. The examination of white in oblique light, that is, under the glass prism, shows, as already mentioned, not the least qualitative change, whilst all other colours are shifted towards the greenish blue. It should also be noted that whilst red, in passing into blue-green, misses the orange-red, yellow, and bright green, the blue only slightly shifts towards the violet. This result, which can be easily explained mathematically, is not in favour of Lehmann's theory. If the white is actually formed by the action of two reflecting laminæ belonging to two complementary colours, as, for instance, red and green, it is not obvious why, in the shift of the red into blue-green and the green into dark blue, that is in the shift into two colours which are no longer complementaries, the white does not shift into a more or less distinct blue, and therefore disappear as white.

i. Later experiments on thin sections have proved that the fine lines at equal distances which belong to the whites do not as a rule exceed three, and that, apart from the transparent intervals behind the mirror zone, the spaces between the laminæ are filled with a diffuse precipitate.. Under these conditions the interference action of such laminæ must be nil, even if the incident light reaches them.

k. Finally, spectroscopic examination of the pure whites shows a continuous image without gaps, which is more or less similar to the continuous spectrum from a white object. What is the difference, asks the author, between his and Lehmann's spectral examination?

* "Drude's Annalen," 1904. See also "B.J.," October 12, 1906, p. 807.

The author thinks that Lehmann did not test pure brilliant whites, as obtained by intensification on slow, fine-grained plates, but the half-white with a bluish or violet tinge, which usually appears in fact plates without intensification.[10] This pseudo-white, when examined in the benzole tank, appears somewhat better, but can never be compared with the white obtained by Lippmann, Neuhauss, and the author under the stated conditions—that is, treatment with sublimate and an amidol developer after weak development. This assumption appears to be all the more likely as the author's spectroscopic examination of the dirty grey on quick plates without intensification, as in Kranseder's plates, made according to Lehmann's formula,[11] shows that the spectrum actually does possess maxima.

The author was never able to obtain satisfactory colours before he learnt how to intensify, but since then he has obtained whites, in all sorts of subjects, which are purer and more vigorous than in the best black and white photograph.

Analysis of the Grey and Dark Parts.

The dark tones, or those mixed with black, are dependent, according to theory, on the fineness and transparency of the laminæ. If, for instance, we examine a dark green, as in Fig. 16, we shall see that the mirror is quite absent, and that in its place is a colourless plane. Noteworthy also is the small number of laminæ, only four or five, and especially their extraordinary transparency and light yellow colour. In many cases the laminæ appear to consist of a single row of yellowish grains. The intervals are clean, comparatively large, and quite free from precipitate. Under such conditions it is obvious that the plate will reflect only a small part of the incident light, and also allow the dark background of the asphalt on the back of the plate to shine through. Naturally, the colour will be much darker the paler the laminæ. Dark colours also appear very stable when the plate is rubbed, a fact which is easily understood when one bears in mind the extraordinary transparency of the laminæ which take part in the interference.

Brilliancy and Purity of the Interference Colours.

Everyone who has worked at all with the Lippmann process will have observed the great differences in the purity and brilliancy of the colours. Some very transparent plates reproduce the whole of the spectrum in brilliant pure tones; other emulsions give all the colours, but dead and impure; others again as though covered with a grey or white fog. Some fairly sensitive plates, which give otherwise good colours, convert the white into grey, violet, or cream; others again give certain colours, usually red, orange, and yellow, fairly well, but are totally wanting in green, blue, and violet.

In order to understand these phenomena, one must bear in mind that Zenker's exact theory is only carried out under defective conditions, due chiefly to the special nature of the photochemical actions. The laminæ are not absolutely smooth and sharply defined, nor are they everywhere of equal thickness, also they do not possess that uniform perfect transparency which theory requires, so that all may take part in the interference of the incident white light.

The brilliancy and intensity of the interference colours depends, at least so it is generally assumed, on the perfection of the lamellar structure of the plate, and the purity and brilliancy of the colours is greater the greater the number of the reflecting laminæ. Broadly this view is correct, but theory does not coincide with practice. The author states that many of his pictures of great brilliancy and truth possess only three or four especially brilliant and correct reflecting laminæ, whilst others with ten or twelve regular distinct laminæ gave less bright pictures. The brilliancy of the colours thus depends not on the quantity, but the quality of the laminæ and intervals.

From some hundreds of very careful observations the author comes to the conclusion that in most cases the colour is due to the reflection and interference of light from the two uppermost laminæ. The deeper-lying ones have very little to do with the formation of the colours, in the first place because they receive but little light, and therefore can only reflect little; secondly, because they have not sharp limits and are not separated by perfectly colourless intervals, so that the light cannot be properly analysed, but only diffused;

[10] As a matter of fact Lehmann states in his book that he never intensifies.

[11] The author's experiments with Lehmann's plates with the special filter have given excellent results as regards speed and colour rendering. All attempts to obtain a good white were failures. Further, the colours are somewhat dead-looking.