SCIENCE:

A WEEKLY NEWSPAPER OF ALL THE ARTS AND SCIENCES.

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THE COMMITTEE ON SITES for the world's fair in New York in 1892 has recommended that the upper part of Central Park be taken for the purpose, to which shall be added some outlying unoccupied land. The point of special interest just now is that a considerable portion of the New York community object to any part of the park being used, maintaining that the upper portions are the most attractive of all, and, as is freely acknowledged by all, that these will have to be denuded of trees and scraped down to a more level surface by the city contractors, so as to ruin their beauty for a generation to come. It is to be said, also, that the lower parts of the park would be turned practically into little more than an entrance to the fair-grounds proper, thus depriving them of the character which draws so many to them on all holidays. The scheme has its advocates, however; and it is of course true that a part of its support is to be traced to the interests of real-estate owners, as would be the case if any other site were chosen, only here, the interests being the greater, the support is the more earnest.

MODERN PHOTOGRAPHY.[1]

THE occupant of this chair has a difficult task to perform, should he attempt to address himself to all the various subjects with which this section is supposed to deal. I find that it has very often been the custom that some one branch of science should be touched upon by the president; and I shall, as far as in me lies, follow this procedure.

This year is the jubilee of the practical introduction of photography by Daguerre and Fox Talbot, and I have thought I might venture to take up your time with a few remarks on the effect of light on matter. I am not going into the history of photography, nor to record the rivalries that have existed in regard to the various discoveries that have been made in it. A brand-new history of photography, I dare say, would be interesting, but I am not the person to write one; and I would refer those who desire information as to facts and dates to histories which already exist. In foreign histories perhaps we English suffer from speaking and writing in a language which is not understanded of the foreign people; and the credit of several discoveries is sometimes allotted to nationalities who have no claim to them. Be that as it may, I do not propose to correct these errors or to make any reclamations. I leave that to those whose leisure is greater than mine.

I have often asserted, and I again assert, that there should be no stimulus for the study of science to be compared to photography. Step by step, as it is pursued, there will be formed a desire for a knowledge of all physical science. Physics, chemistry, optics, and mathematics are all required to enable it to be studied as it should be studied; and it has the great advantage that experimental work is the very foundation of it, and results of some kind are always visible. I perhaps am taking an optimist view of the matter, seeing there are at least twenty-five thousand living facts against my theory, and perhaps not one per cent of them in its favor. I mean that there are at least twenty-five thousand persons who take photographs, and scarcely one per cent who know or care any thing of the "why or wherefore" of the processes, so far as theory is concerned. If we call photography an applied science, it certainly has a larger number who practise it, and probably fewer theorists than any other.

He would be a very hardy man who would claim for Nièpce, Daguerre, or Fox Talbot the discovery of photographic action on matter. The knowledge that such an action existed is probably as old as the fair-skinned races of mankind, who must have recognized the fact that light, and particularly sunlight, had a tanning action on the epidermis; and the women, then as now, no doubt took their precautions against it. As to what change the body acted upon by light underwent, it need scarcely be said that nothing was known; and perhaps the first scientific experiment in this direction was made rather more than a hundred years ago by Scheele, the Swedish chemist, who found, that, when chloride of silver was exposed to light, chlorine was given off. It was not till well in the forties that any special attention was given to the action that light had on a variety of different bodies; and then Sir John Herschel, Robert Hunt, Becquerel, Draper, and some few others, carried out experiments which may be termed "classical." Looking at the papers which Herschel published in the "Philosophical Transactions" and elsewhere, it is not too much to say that they teem with facts which support the grand principle that without the absorption of radiation no chemical action can take place on a body: in other words, we have in them experimental proofs of the law of the conservation of energy. Hunt's work, "Researches on Light," is still a text-book to which scientific photographers refer, and one is sometimes amazed at the amount of experimental data which is placed at our disposal. The conclusions that Hunt drew from his experiments, however, must be taken with caution in the light of our present knowledge, for they are often vitiated by the idea which he firmly held, that radiant heat, light, and chemical action, or actinism, were each of them properties, instead of the effects, of radiation. Again: we have to be careful in taking seriously the experiments carried out with light of various colors when such colors were produced by absorbing media. It must be remembered that an appeal to a moderately pure spectrum is the only appeal which can be legitimately made as to the action of the various components of radiation, and even then the results must be carefully weighed before any definite conclusion can be drawn. No photographic result can be considered as final unless the experiments be varied under all the conditions which may possibly arise. Colored media are dangerous as enabling trustworthy con-

[1] Address of Capt. W. De W. Abney, president of the section of mathematics and physics, of the British Association for the Advancement of Science, delivered before the association at its meeting recently (from *Nature*).

clusions to be drawn, unless the characters of such media have been thoroughly well tested, and the light they transmit has been measured. An impure spectrum is even more dangerous to rely upon, since the access of white light would be sure to vitiate the results.

Perhaps one of the most puzzling phenomena to be met with in photography is the fact that the range of photographic action is spread over so large a portion of the spectrum. The same difficulty, of course, is felt in the matter of absorption, since the one is dependent on the other. Absorption by a body we are accustomed, and indeed obliged by the law of the conservation of energy, to consider as due to the transferrence of the energy of the ether wave-motion to the molecules and atoms comprising the body by increasing the vibrations of one or both.

In the case where chemical action takes place, we can scarcely doubt that it is the atoms which in a great measure take up the energy of the radiation falling on them, as chemical action is dependent on the liberation of one or more atoms from the molecule; while, when the swings of the molecules are increased in amplitude, we have a rise in temperature of the body. I shall confine the few remarks I shall make on this subject to the case of chemical action. The molecule of a silver salt, such as bromide of silver, chemists are wont to look upon as composed of a limited and equal number of atoms to form the molecule. When we place a thin slab of this material before the slit of the spectroscope, we find a total absorption in the violet and ultra-violet of the spectrum, and a partial absorption in the blue and green, and a diminishing absorption in the yellow and red. A photographic plate containing this same salt is acted upon in exactly the same localities and in the same relative degree as where the absorption takes place. Here, then, we have an example of, it may be, the vibrations of four atoms, one of which at least is isochronous, or partially so, with the waves composing a large part of the visible spectrum. The explanation of this is somewhat obscure. A mental picture, however, may help us. If we consider that, owing to the body acted upon being a solid, the oscillations of the molecules and atoms are confined to a limited space, it probably happens that between the times in which the atoms occupy, in regard to one another, the same relative positions, the component vibrations of, say, two of the atoms vary considerably in period. An example of what I mean is found in a pendulum formed of a bob and an elastic rod. If the bob be made to vibrate in the usual manner, and at the same time the elastic rod be elongated, it is manifest that we have a pendulum of ever-varying length. At each instant of time the period of vibration would differ from that at the next instant, if the oscillations were completed. It is manifest that increased amplitude would be given to the pendulum-swings by a series of well-timed blows differing very largely in period. At the same time there would be positions of the pendulum in which some one series of well-timed blows would produce the greatest effect. In a somewhat similar manner we should imagine that the ethereal waves should produce increased amplitude in the swing of the atoms between very wide limits of period, and, further, that there should be one or more positions in the spectrum when a maximum effect is produced. I would here remark that the shape of the curves of sensitiveness, when plotted graphically, of the different salts of silver to the spectrum, have a marked resemblance to the graphically drawn curves of the three color-sensations of the normal eye, as determined by Clerk Maxwell. May not the reason for the form of the one be equally applicable for the other? I only throw this out as evidence, not conclusive indeed, that the color-sensitiveness of the eye is more probably due to a photographic action on the sensitive retina than to a merely mechanical action. That this is the case, I need scarcely say has several times been propounded before.

The ease with which a silver salt is decomposed is largely, if not quite, dependent on the presence of some body which will take up some of the atoms which are thrown off from it: for instance, in chloride of silver we have a beautiful example of the necessity of such a body. In the ordinary atmosphere the chloride is, of course, colored by the action of light; but if it be carefully dried and purified, and placed in a good vacuum, it will remain uncolored for years in the strongest sunlight. In this case the absence of air and moisture is sufficient to prevent it discoloring.

If in the vacuum, however, a drop of mercury be introduced, the coloration by light is set up. We have the chlorine liberated from the silver and combining with the mercury vapor, and a minute film of calomel formed on the sides of the vessel.

Delicate experiments show that not only is this absorbent almost necessary when the action of light is so strong or so prolonged that its effect is visible, but also when the exposure or intensity is so small that the effect is invisible and only to be found by development. The reason for this absorbent is not far to seek. If, for instance, silver chloride be exposed to light *in vacuo*, although the chlorine atoms may be swung off from the original molecule, yet they may only be swung off to a neighboring molecule which has lost one of its chlorine atoms, and an interchange of atoms merely takes place. If, however, a chlorine absorbent be present which has a greater affinity for chlorine than has the silver chloride which has lost one of its atoms, then we may consider that the chlorine atoms will be on the average more absorbed by the absorbent than by the subchloride molecules. The distribution of the swung-off atoms between the absorbent and the subchloride will doubtless be directly proportional to their respective affinities for chlorine, and so for the other salts of silver. If this be so, then it will be seen that the greater the affinity of the absorbent for the halogen, the more rapid will be the decomposition of the silver salt. This, then, points to the fact that if any increase in the sensitiveness of a silver salt is desired, it will probably be brought about by mixing with it some stronger halogen absorbent than has yet been done.

The question as to what is the exact product of the decomposition of a silver salt by the action of light is one which has not as yet been fully answered. For my own part, I have my strong beliefs and my disbeliefs. I fully believe the first action of light to be a very simple one, though this simple action is masked by other actions taking place, due to the surroundings in which it takes place. The elimination of one atom from a molecule of a silver salt leaves the molecule in an unsatisfied condition, and capable of taking up some fresh atom. It is this capacity which seemingly shrouds the first action of light, since when exposure is prolonged the molecules take up atoms of oxygen from the air or from the moisture in it. Carey Lea of Philadelphia has within the last three years given some interesting experiments on the composition of what he calls the photochloride of silver, which is the chloride colored by light, and Professor Hodgkinson has also taken up the matter. The conclusions the former has drawn are, to my mind, scarcely yet to be accepted. According to the latter experimentalist, the action of light on silver chloride is to form an oxidized subsalt. This can hardly be the case, except under certain conditions, since a colored compound is obtained when the silver chloride is exposed in a liquid in which there is no oxygen present.

This coloration by light of the chloride of silver naturally leads our thoughts to the subject of photography in natural colors. The question is often asked when photography in natural colors will be discovered. Photography in natural colors not only has been discovered, but pictures in natural colors have been produced. I am not alluding to the pictures produced by manual work, and which have from time to time been foisted on a credulous public as being produced by the action of light itself, much to the damage of photography, and usually of the so-called inventors. Roughly speaking, the method of producing the spectrum in its natural colors is to chlorinize a silver plate, expose it to white light till it assumes a violet color, heat till it becomes rather ruddy, and expose it to a bright spectrum. The spectrum colors are then impressed in their natural tints. Experiment has shown that these colors are due to an oxidized product being formed at the red end of the spectrum, and a reduced product at the violet end. Photography in natural colors, however, is only interesting from a scientific point of view, and, so far as I can see, can never have a commercial value. A process, to be useful, must be one by which reproductions are quickly made: in other words, it must be a developing and not a printing process, and it must be taken in the camera; for any printing process requires not only a bright light, but also a prolonged exposure. Now, it can be conceived that in a substance which absorbs all the visible spectrum the molecules can be so shaken and sifted by the different rays, that eventually they sort themselves into masses which reflect the particular rays by which they are shaken; but it is almost — I might say, quite — impossible to believe that when this sifting has only been commenced, as it would be in the short exposure to which a camera picture is submitted, the substance deposited to build up the image by purely chemical means would be so obliging as to deposit in that the particular size of particle which should give to the image the color of the nucleus on which it was depositing. I am aware that in the early days of photography we heard a good deal about curious results that had been obtained in negatives, where red brick houses were shown as red, and the blue sky as bluish. The cause of these few coincidences is not hard to explain, and would be exactly the same as when the red brick houses were shown as bluish, and the sky as red, in a negative. The records of the production of the latter negatives are naturally not abundant, since they would not attract much attention. I may repeat, then, that photography in natural colors by a printing-out process — by which I mean by the action of light alone — is not only possible, but has been done, but that the production of a negative in natural colors from which prints in natural colors might be produced, appears, in the present state of our knowledge, to be impossible. Supposing it were not impracticable, it would be unsatisfactory, as the light with which the picture was impressed would be very different from that in which it would be viewed. Artists are fully aware of this difficulty in painting, and take their precautions against it.

The nearest approach to success in producing colored pictures by light alone is the method of taking three negatives of the same subject through different-colored glasses, complementary to the three color-sensations which together give to the eye the sensations of white light. The method is open to objection on account of the impure color of the glasses used. If a device could be adopted whereby only those three parts of the spectrum could be severally used which form the color-sensations, the method would be more perfect than it is at present. Even then, perfection could not be attained, owing to a defect which is inherent in photography, and which cannot be eliminated. This defect is the imperfect representation of gradation of tone. For instance: if we have a strip graduated from what we call black to white (it must be recollected that no tone can scientifically be called black, and none white), and photograph it, we shall find that in a print from the negative the darkness which is supposed to represent a gray of equal mixtures of black and white by no means does so unless the black is not as black nor the white as white as the original. The cause of this untruthfulness in photography has occupied my attention for several years, and it has been my endeavor to find out some law which will give us the density of a silver deposit on a negative corresponding with the intensity of the light acting. I am glad to say that at the beginning of this year a law disclosed itself, and I find that the transparency of a silver deposit caused by development can be put into the form of the law of error.

This law can be scarcely empiric, though at first sight it appears that the manipulations in photography are so loose that it should be so. It is this very looseness, however, which shows that the law is applicable, since in all cases I have tried it is obeyed. That there are theoretical difficulties cannot be denied, but it is believed that strictly theoretical reasoning will eventually reconcile theory with observation.

This want of truth in photography in rendering gradation, then, puts it out of the range of possibility that photography in natural colors can ever be exact, or that the three-negatives system can ever get over the difficulty.

One of the reproaches that in early days was cast at photography was its inability to render color in its proper monochromatic luminosity. Thus, while a dark blue was rendered as white in a print (that is, gave a dense deposit in a negative), bright yellow was rendered as black in a print, or nearly so (that is, as transparent or nearly transparent glass in the negative). To the eye the yellow might be far more luminous than the blue, but the luminosity was in the photograph reversed. I need scarcely say that the reason of this want of truth in the photograph is due to the want of sensitiveness of the ordinarily used silver salts to the least refrangible end of the spectrum. Some fifteen years ago Dr. H. W. Vogel announced the fact that when silver salts were stained with certain dyes they became sensitive to the color of the spectrum, which the dyes absorbed. This at once opened up possibilities, which, however, were not at once realized, owing perhaps to the length of exposure required when the collodion process was employed. Shortly after the gelatine process was perfected, the same dyes were applied to plates prepared by this method, which, although they contained the same silver salts as the old collodion process, yet *per se* were very much more sensitive. A new era then dawned for what has been termed "isochromatic" and "orthochromatic" photography. The dyes principally used are those belonging to the eosine group and cyanine; not the ordinary cyanine dye of commerce, but that discovered by Greville Williams. For a dye to be of use in this manner, it may be taken as an axiom — first propounded by the speaker, it is believed — that it must be fugitive, or that it must be capable of forming a silver compound. The more stable a dye is, the less effective it is. If we take as an example cyanine, we find that it absorbs in the orange and slightly in the red. If paper or collodion stained with this coloring-matter be exposed to the action of the spectrum, it will be found that the dye bleaches in exactly the same part of the spectrum as that in which it absorbs, following, indeed, the universal law I have already alluded to. If a film containing a silver salt be dyed with the same, it will be found, that, while the spectrum acts on it in the usual manner, — viz., darkening it in the blue, violet, and ultra-violet, — the color is discharged where the dye absorbs, showing that in one part of the spectrum it is the silver salt which is sensitive, and that in the other it is the coloring-matter. If such a plate, after exposure to the spectrum, be developed, it will be found that at both parts a deposit of silver takes place; and, further, when the experiment is carefully conducted, if a plate with merely cyanine-colored collodion be exposed to the spectrum and bleached in the orange, and after removal to the dark-room another film containing a silver salt be applied, and then a developer, a deposit of silver will take place where the bleaching has occurred. This points to the fact that the molecules of a fugitive dye, when altered by light, are unsatisfied, and are ready to take up an atom or atoms of silver; and other molecules of silver will deposit on such nuclei by an action which has various names in physical science, but which I do not care to mention. This is the theory which I have always advocated; viz., that the dye by its reduction acts as a nucleus on which a deposit of silver can take place. It met with opposition; a rival theory which makes the dye an "optical sensitizer" — an expression which is capable of a meaning which I conceive contrary to physical laws — being run against it. The objection to what I may call the nucleus theory is less vigorous than it has been, and its diminution is due, perhaps, to the more perfect understanding of the meaning of each other by those engaged in the controversy. To my mind, the action of light on fugitive dyes is one of the most interesting in the whole realm of photography, as eventually it must teach us something as to the structure of molecules, and add to the methods by which their coarseness may be ascertained. Be the theory what it may, however, a definite result has been attained, and it is now possible to obtain a fair representation of the luminosity of colors by means of dyed films. At present the employment of colored screens in front of the lens, or on the lens itself, is almost an essential in the method, when daylight is employed; but not till some dye is discovered which shall make a film equally sensitive for the same luminosity to the whole visible spectrum will it be possible to make orthochromatic photography as perfect as it can be made. The very fact that no photograph of even a black and white gradation will render the latter correctly, must of necessity render any process imperfect, and hence in the above sentence I have used the expression "as perfect as it can be made."

The delineation of the spectrum is one of the chief scientific applications to which photography has been put. From very early days the violet and ultra-violet end of the spectrum have been favorite objects for the photographic plate. To secure the yellow and red of the spectrum was, however, till of late years, a matter of apparently insurmountable difficulty; while a knowledge of that part of the spectrum which lies below the red was only to be gained by its heating effect. The introduction of the gelatine process enabled the green portion of the spectrum to impress itself on the sensitive surface; while the addition of various dyes, as before mentioned, allowed the yellow, the orange, and a portion of the red rays to become photographic rays. Some eight years ago it was my own good fortune to make the dark infra-red rays impress themselves on a plate. This last has been too much a specialty of my own, although full explanations have been given of the methods employed. By preparing a bromide-of-silver salt in a peculiar manner, one is able so to modify the molecular arrangement of the atoms that they answer to the swings of those waves which give rise to these radiations. By employing this salt of silver in a film of collodion or gelatine, the invisible part of the spectrum can be photographed, and the images of bodies which are heated to less than red heat may be caused to impress themselves upon the sensitive plate. The greatest wave-length of the spectrum to which this salt is sensitive, so far, is 22,000 λ, or five times the length of the visible spectrum. The exposure for such a wave-length is very prolonged; but down to a wave-length of 12,000 it is comparatively short, though not so short as that required for the blue rays to impress themselves on a collodion plate. The color of the sensitive salt is a green-blue by transmitted light. It has yet to be determined whether this color is all due to the coarseness of the particles, or to the absorption by the molecules. The fact that a film can be prepared which by transmitted light is yellow, and which may be indicative of color due to fine particles, together with an absorption of the red and orange, points to the green color being probably due to absorption by the molecules. We have thus in photography a means of recording phenomena in the spectrum from the ultra-violet to a very large wave-length in the infra-red, — a power which physicists may some day turn to account. It would, for instance, be a research worth pursuing to photograph the heavens on a plate prepared with such a salt, and search for stars which are nearly dead or newly born; for in both cases the temperature at which they are may be such as to render them below red-heat, and therefore invisible to the eye in the telescope. It would be a supplementary work to that being carried out by the brothers Henri, Common, Roberts, Gill, and others, who are busy securing photographic charts of the heavens in a manner which is beyond praise.

There is one other recent advance which has been made in scientific photography to which I may be permitted to allude; viz., that, from being merely a qualitative recorder of the action of light, it can now be used for quantitative measurement. I am not now alluding to photographic actinometers, such as have been brought to such a state of perfection by Roscoe, but what I allude to is the measurement and interpretation of the density of deposit in a negative. By making exposures of different lengths to a standard light, or to different known intensities of light, on the same plate on which a negative has to be taken, the photographic values of the light acting to produce the densities on the different parts of the developed image can be readily found. Indeed, by making only two different exposures to the same light, or two exposures to two different intensities of light, and applying the law of density of deposit in regard to them, a curve is readily made from which the intensities of light necessary to give the different densities of deposit in the image impressed on the same plate can be read off. The application of such scales of density to astronomical photographs, for example, cannot but be of the highest interest, and will render the records so made many times more valuable than they have hitherto been. I am informed that the United States astronomers have already adopted the use of such scales, which for the last three years I have advocated, and it may be expected that we shall have results from such scaled photographs which will give us information which would before have been scarcely hoped for.

One word as to a problem which we may say is as yet only qualitatively and not quantitatively solved. I refer to the interchangeability of length of exposure for intensity of light. Put it in this way. Suppose that with a strong light, *L*, a short exposure, *E*, being given, a chemical change, *C*, is obtained: will the same change, *C*, be obtained if the time is only an *n*th of the light, *L*, but *n* times the exposure? Now, this is a very important point, more particularly when the body acted upon is fairly stable; as, for instance, some of the water-color pigments, which are known to fade in sunshine, but might not be supposed to do so in the light of an ordinary room, even with prolonged exposure. Many experiments have been made at South Kensington as regards this, more especially with the salts of silver; and it is found, that, for any ordinary light, intensity and exposure are interchangeable, but that when the intensity of light is very feeble, say the $\frac{1}{1000000}$ of ordinary daylight, the exposure has to be rather more prolonged than it should be supposing the exact interchangeability always held good. But it has never been found that a light was so feeble that no action could take place. Of course, it must be borne in mind that the stability of the substance acted upon may have some effect; but the same results were obtained with matter which is vastly more stable than the ordinary silver salts. It may be said, in truth, that almost all matter which is not elemental is in time, and to some degree, acted upon by light.

I should like to have said something regarding the action of light on the iron and chromium salts, and so introduced the subject of platinotype and carbon printing, the former of which is creating a revolution in the production of artistic prints. I have, however, refrained from so doing, as I felt that the president of Section A should not be mistaken as the president of Section B. Photogravure and the kindred processes were also inviting subjects on which to dwell, more especially as at least one of them is based on the use of the same material as that on which the first camera picture was taken by Nièpce. Again, a dread of trenching on the domains of art restrains me.

Indeed, it would have been almost impossible, and certainly impolitic, in the time which an address should occupy, to have entered into the many branches of science and art which photography covers. I have tried to confine myself to some few advances that have been made in its theory and practice.

The discovery of the action of light on silver salts is one of the marvels of this century, and it is difficult to overrate the bearing it has had on the progress of science, more especially physical science. The discovery of telegraphy took place in the present reign, and two years later photography was practically introduced; and no two discoveries have had a more marked influence on mankind. Telegraphy, however, has had an advantage over photography in the scientific progress that it has made, in that electrical currents are subject to exact measurement, and that empiricism has no place with it. Photography, on the other hand, has labored under the disadvantage, that, though it is subject to measurement, the factors of exactitude have been hitherto absent. In photography we have to deal with molecules the equilibrium of whose components is more or less indifferent according to the process used. Again, the light employed is such a varying factor that it is difficult to compare results. Perhaps more than any other disadvantage it labors under, is that due to quackery of the worst description at the hands of some of its followers, who not only are self-asserting, but often ignorant of the very first principles of scientific investigation. Photography deserves to have followers of the highest scientific calibre; and, if only some few more real physicists and chemists could be induced to unbend their minds and study the theory of an applied science which they often use for record or for pleasure, we might hope for some greater advance than has hitherto been possible.

Photography has been called the handmaid of art: I venture to think it is even more so the handmaid of science, and each step taken in perfecting it will render it more worthy of such a title.

ELECTRICAL NEWS.

Recent Fatalities from Electricity.

ONE death and several serious injuries from electric-light wires have occurred during the past two weeks. Some days ago the eight-year-old son of Charles Kern of Baltimore came in contact with an electric-light wire while looking out of a window, lost his balance, and fell to the street. A New York daily newspaper, alluding to the fact, stated that the boy was "fairly lifted out of the room, and hurled into the street;" all of which is interesting, if true. John Powers, an employee of The Brush Electric-Light Company, thoughtlessly took hold of a live wire with one hand, and with the other made an excellent ground connection with the Elevated Railroad structure on East 34th Street. He was standing on a step-ladder at the time; and the shock of the fall, not the current, killed him. Some days after this occurrence a poor vagrant,