ordinary diet with diuretics. But all patients will not or cannot tolerate the low-salt diet often necessary to prevent oedema. In these cases diuretics must be administered with a diet heavier in salt or possibly combined with a weekly saltless day, with unsalted thin oatmeal gruel or boiled rice as the only food.

Formerly one of the methods of treatment of patients with a predisposition to oedema was to reduce the consumption of fluid. When a low-salt diet is used, however, a reduction in the amount of fluid is not necessary; in fact, a fluid consumption which ensures fairly large diuresis (2-3 litres every 24 hours) seems to be the most effective, as an output of 2-3 litres of urine has been shown to give a larger excretion of salt. When allowing the patients plenty of water it must be borne in mind that some water is relatively high in sodium. In Copenhagen, for example, the sodium content of tap-water varies from 9 to 131 mg. per litre, with an average of 50 mg.

Finally, we should like to review the symptoms and signs in which improvement has been observed on a low-salt diet. The effect on the oedema was the easiest to demonstrate. The low-salt diet, and especially the combination of this diet with digitalis, mercurial diuretics, and sometimes ammonium chloride and urea, is the treatment which most readily causes the disappearance of oedema in patients suffering from heart failure. The most striking example of the effect of this treatment was seen in the case of a 64-year-old oedematous woman who lost 27.6 kg. in two months. Both *dyspnoea at rest* and *attacks of dyspnoea at night* often improve or cease altogether, generally after a few days' treatment. We observed good results in many cases, particularly in patients suffering from nocturnal dyspnoea. A number of patients who in spite of morphine had slept badly for a long time soon slept better with this treatment (see Case 4).

A true dehydration from a deficit of plain water, which is often found in oedematous patients, results in the symptoms of an intense thirst and a dry tongue. The symptoms may be present even if the patient's consumption of fluid has not been decreased, and these symptoms are often the first to disappear when the patient is put on a low-salt diet. This is a great relief to patients, but means that they must be encouraged to drink plentifully to ensure a fairly large diuresis.

The *blood pressure* in hypertensive subjects often falls during the treatment (Bang *et al.*, 1949).

With the diet used we did not observe any signs of a lack of salt—that is, fatigue or weakness—but many of the patients complained of the tastelessness or uniformity of the diet. There are, however, two diseases which necessitate care when using a low-salt diet: in cases of advanced kidney disease in which the kidneys are not able to retain sufficient sodium a low-salt diet may mean a definite deterioration of the condition of the patient, with hypochloraemia and acidosis; similarly, in cases of Addison's disease a low-salt diet may bring about a typical crisis.

Summary

Sixty-four patients suffering from congestive heart failure with oedema were, in addition to the usual treatment with confinement to bed, digitalis, and diuretics, treated with a low-salt diet (less than 1 g. of sodium chloride a day).

A detailed case history is given of four of the patients in whom the critical condition was not improved until they were transferred to a low-salt diet.

Follow-up studies were made on 50 of the cases in the series. Thirty-one had kept on with the low-salt diet, and 27 of these continued in as good health as on discharge, one was worse, and three had died.

The results are discussed, and the effects of mercurial diuretics and a low-salt diet are compared.

The restriction of the fluid intake is not necessary or beneficial for the patient with oedema on a low-salt diet.

In some cases of chronic kidney disease with loss of normal ability to conserve sodium, and in Addison's disease, sharp restriction of salt is contraindicated.

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RADIATION, LIGHT, AND ILLUMINATION*

BY

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The visual mechanism is normally stimulated by radiation lying within the comparatively narrow region of from 4,000 Å to 7,000 Å. In nature the source of this radiation is the sun. In the highly complicated structure of modern society, however, man has found it necessary to devise artificial means for the production of light. I shall therefore concern myself to some extent with radiation generally, but more particularly with the limited region in the radiant energy spectrum known as light to which the human eye responds and with artificial light sources.

In trying to present a picture of the evolution of modern light sources in historical perspective it is necessary to consider certain primary matters in connexion with radiation, light, and illumination. Whereas the eye has evolved through many ages under the continuous radiation from the sun, it has from the beginning of time been subjected to a more limited region of the visible spectrum in the perception of colour. It is this fact which led lamp-research physicists to believe that if in the course of the evolution of light sources they had to produce and put before the public lamps giving discontinuous spectra no harmful results would thereby occur.

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Artificial Light and the Human Eye

It seems probable that if, by the evolutionary process of time, part of the human body has come to function in a particular way and is then subjected for long periods to some other condition short-term or long-term damage may result. It was considered that the matter might be of importance in respect to the human eye in view of the evolution of modern electric-discharge lamps primarily intended for street lighting. The sodium lamp, for example, gives a practically monochromatic yellow light, while the high-pressure mercury lamp has dominant spectral lines in the yellow, green, and violet regions of the visible spectrum. There has thus been a break with tradition, as up to about 1930 practically all normal light sources gave continuous wavelengths similar in character to the radiation from the sun. It is interesting to record that after nearly twenty years' practical experience with these sources there is no evidence of damage to the visual mechanism. Indeed, a number of observers have reported an increase in the visual acuity under the light of the plain electric discharge.

If we study the spectrum of radiant energy we see at the short wavelength end the region of x rays merging into the ultra-violet region and ultimately into the visible spectrum. Beyond the visible spectrum the infra-red region extends until ultimately we reach the wavelengths which are used for radio transmission. It is a most interesting fact that practically all sources of light emit radiation extending far beyond the visible region and to that extent are less efficient in stimulating the visual mechanism than they would be if the radiation was confined within the 4,000 to 7,000 Å waveband. The research physicist, therefore, in considering the development of light sources has to be very conscious of the properties of the human eye. He has not only to consider the need for giving the maximum possible amount of radiation in the visible region but also the sensitivity curve of the normal eye and its differential response from the blue to the red end of the spectrum. If a given source of energy produced monochromatic light at 6,500 Å the efficiency of the source in terms of lumens per watt would be only one-tenth of the efficiency which would be produced by the same amount of energy radiating at 5,550 Å at the peak of the visibility curve.

Illumination Levels

If we look at these general facts from a mathematical point of view we find that a watt wholly converted into visible radiation will produce theoretically between 600 and 700 lumens. In other words, one watt converted into visible radiation at the peak of the luminosity curve would give about the same amount of light as a 40-watt tungsten-filament lamp. As, however, we are concerned in general with white or near-white light sources it is wise to consider what would happen if the whole of the radiant energy was emitted in the visible spectrum, but so distributed as to give white light.

If this ideal condition was attainable in practice the efficiency would be something of the order of 220 L/W. It is interesting to compare this value with that of 10 to 15 L/W for small incandescent tungsten-filament lamps of the type used in domestic premises and of 70 L/W or so for the efficiency of sodium lamps such as those used for street lighting. Somewhere between these two limits we have the efficiency of practically all electric

lamps in common use—for example, the efficiency of a modern fluorescent lamp is of the order of 40 to 50 L/W.

It was the development of the electric discharge lamp in the many forms now available to the public which enabled electrical energy to be more efficiently transformed into light than was possible with the tungsten lamp. These developments have reached maturity only within the last two decades, but, because of them, higher illumination levels have become economically possible and therefore to some extent they bear upon the work of the ophthalmologist.

When we try to trace the evolution of artificial-light sources we find evidence of early forms of the oil-wick lamp dating back more than 70,000 years. It is interesting to note that the modern oil-lamp is very little different in principle from the early forms discovered among the ruins of ancient civilizations. In each case a combustible oil burns at a wick and produces a flame which gives light.

The Electric Lamp

It is now more than one hundred years since the principles underlying the incandescent electric lamp were discovered. Very briefly the electric lamp depends on the fact that when an electric current passes through a conductor the temperature is raised. Under suitable conditions the conductor will incandesce and emit light. At first the distribution of radiant energy from the heated body lies entirely in the infra-red region, but at a temperature of the order of 500° C. the energy curve of the heated body intercepts the visibility response curve of the human eye and red light is seen. With further increases in the temperature of the incandescent body there is a gradual shift in the radiant energy spectrum towards the peak of the visibility curve. The effect of this shift is to cause the emitted radiation to become gradually more white and at the same time to produce an increase in the efficiency of light production as more of the radiant energy falls within the visible region.

If it were possible to produce an incandescent body which could be maintained at a temperature of the order of 6,500° K, then the maximum possible efficiency would be produced, as at this temperature the radiant energy distribution would peak about the region of maximum visibility—that is, at about 5,500 Å. With further increase in temperature above this value, if this were possible, there would be a gradual decrease in the efficiency of light production, as increasing amounts of radiation would be emitted in the ultra-violet region.

Increasing Efficiency

In the design of any light source, therefore, the lamp physicist is vitally concerned with producing those operating conditions which will enable the maximum percentage of the total input energy to be emitted in the visible region. In this connexion it is interesting to note that the first successful carbon-filament lamps made available in about 1879 by the work of Swan, in England, and Edison, in America, operated at about 1.4 L/W. Later, by depositing on the carbon filament a more coherent layer of carbon, it was found possible to increase the efficiency to about 4 L/W. The use of tungsten, operated in the form of a thin wire *in vacuo*, brought the efficiency to about 10 L/W for a lamp designed for a life of 1,000 hours. The advent of the gas-filled lamp enabled efficiencies of about 15 L/W to be obtained in a small lamp, while 25 L/W is a common

efficiency for a tungsten-filament projection lamp designed for a life of 50 to 100 hours.

The important thing to note in all these changes is that the progressive improvement in efficiency has been brought about by operating the filament at a higher temperature. It should be noted that, whereas tungsten has the highest melting-point of any metallic element, it cannot be operated above about $3,500^{\circ}\text{K}$ without the risk of fusing. This temperature is, however, still some $3,000^{\circ}$ below the maximum theoretical value for an incandescent body producing light with the optimum efficiency.

For a given lamp, while any increase in the filament temperature will result in increase in the efficiency of light production, it can be obtained only at the expense of a reduced life. This is a fact of nature which is not generally realized. In general the life of a tungsten filament varies inversely as the thirteenth power of the applied voltage. In more simple terms, if a tungsten-filament lamp designed for 230 volts is operated at 240 volts the life will be reduced to approximately one-half—that is, a lamp life of 1,000 hours will be reduced to 500 hours.

Practical Aspects

Our consideration so far has been limited to certain general points relating to the design of tungsten-filament incandescent lamps, and we must now consider one or two practical aspects. It is necessary in most types of incandescent lamp—and there are many hundreds of different types—so to design the tungsten filament that the light is emitted from a comparatively limited area within the lamp bulb. This limitation in area is generally effected by coiling the filament into a fine spiral. In this way about a yard (0.9 metre) of wire can be made into a helix only about 2 in. (5 cm.) in length for the single coil lamp and about 1 in. (2.5 cm.) in length for the coiled coil type. In projection lamps the filament coil may be further formed into a grid of either the single or the biplanar type.

Low-voltage lamps for projection purposes can now be made with very compact filament formations of high brightness. In the solid source type several short stiff filaments are mounted parallel to one another to form a rectangular unit which can be raised to a very high brightness. In the tungsten ribbon lamp the filament consists of a thin strip of sheet tungsten. In each of these cases the glass envelope, after exhaustion, is filled with an inert gas, generally argon. The purpose of the argon filling is to reduce the rate of evaporation of the tungsten during the life of the lamp and thereby to enable the filament to be operated at a higher temperature and efficiency.

In the special cap-fitting or hand lamps used by coal-miners the gas filling is now krypton, which because of its low thermal conductivity enables about 20% more light to be produced for a given wattage. If the still rarer gas xenon was available in quantity then a further gain could be produced with a xenon-filled incandescent lamp, but at the present time the price of this gas is prohibitive for such usage.

Electric Discharge Lamp

The power of emitting radiation when suitably excited is one of the most fundamental and characteristic properties of an atom. The discovery and identification of many elements has depended upon or been assisted by this phenomenon. Indeed, it is probably true that no

other property has contributed so much to our present state of knowledge of the structure of matter and of the elements of which it is composed.

Quite apart, however, from these analytical aspects the facility with which radiant energy can be produced under the influence of an electrical discharge is being turned to ever-increasing usefulness in modern discharge lamps and electron tubes. In lamps of the low-pressure type in which the discharge appears to fill the tubular vitreous envelope the electrodes generally terminate quite close to the ends of the tube. On the other hand, especially in some of the very high pressure mercury-vapour lamps, the discharge occupies only a very small proportion of the volume of the containing vessel and generally takes place at the approximate centre of a spherical bulb.

The geometry of the lamp is determined by the desired electrical and luminous characteristics. In practically any shape or size of bulb some luminous effects would be produced by an electric discharge through a gas or metallic vapour, but in general the efficiency would be very low and the lamp performance poor. Only by the most careful study of the peculiar requirements of each type of discharge has the present range of highly efficient lamps been evolved. For example, one class of mercury-vapour lamp operates inside an exhausted outer jacket to assist in the development and maintenance of the required mercury pressure, while another type of lamp must be operated in a stream of running water.

In all modern metallic-vapour lamps a low pressure of inert gas is introduced into the bulb after it has been exhausted and processed to facilitate ignition of the discharge and for other purposes. This inert gas filling, generally introduced at a pressure of only a few millimetres of mercury, is of course in addition to the metallic filling, which may be sodium or pure mercury or an alloy of mercury with cadmium or zinc, according to the class of lamp. For special-purpose lamps elements other than those mentioned may be introduced either to provide the principal gas or vapour or as additives to the primary radiating element.

The first phase in the development of the modern electric discharge lamp, which is designed in most cases for operation from alternating current mains and with a choke-stabilized arc, may be considered to have lasted not more than a decade. During that period, beginning in about the year 1930, the principal electric discharge lamps were of two main classes—mercury-vapour lamps operating at pressures of the order of one atmosphere with smaller lower-wattage lamps at higher pressures, and sodium lamps emitting light from the electrically excited resonating atom at comparatively low temperatures.

In the second phase of development several important new types of lamp have found practical applications, and their introduction has widened the field of research and stimulated activity in other directions. Practical forms of high-brightness projector-type lamps have been produced in wattages already as high as 15 kW. and with arc-brightness values greater than that of the carbon arc. The 1939–45 war gave impetus to work on flash discharge lamps, and a number of standardized types are now available. The favourable properties of the high-current density discharge through certain rare gases stimulated development work, which led to the evolution of a new type of discharge lamp—the gas arc. An electrically excited gas or metallic vapour usually

radiates only at certain definite wavelengths characteristic of its nature. According to the conditions of operation the radiant energy may be emitted at relatively few wavelengths or the emission may extend over a wide waveband and may be manifested as a complex assemblage of spectral lines.

Role of the Atom

To assist in understanding the way in which radiation is produced from the electrically excited atom we may visualize some mental picture such as that of the Rutherford-Bohr conception, in which the atom is likened to a miniature solar system. The nucleus of the atom, though occupying only a very small proportion of the volume, is responsible for practically the whole of the mass and consists in most cases both of protons and of neutrons. In the neutral atom, around the nucleus and arranged in certain orbits of movement, are electrons equal in total number to the number of protons. In considering the mechanism of gaseous ionization and the means by which the atom transforms electrical into radiant energy we are concerned with the electrons exterior to the nucleus and not with the nucleus itself.

In a normal gas-discharge or metallic-vapour lamp the emitted radiation is the sum of contributions from innumerable atoms far enough apart from each other to behave as separate entities. Any particular atom at a given instant of time will probably be emitting radiation at a different wavelength from that being emitted by its nearest neighbour, but each quantum of radiation will occur at a wavelength characteristic of the atom.

The radiation which is ultimately perceived or measured results from the summation of a very large number of small contributions from the individually excited atoms which together emit the complete spark spectrum. The relative quantities of radiation at each wavelength will be proportional to the number of atoms undergoing the responsible transition at a given time. It will therefore be appreciated that the conditions of excitation will affect the likelihood of occurrence of particular transitions within the atom and therefore the relative intensity of the radiation at each of the dominant wavelengths. The number of atoms radiating simultaneously in any excited gas is, however, so tremendous that under any given set of conditions the composition of the radiation will be constant.

Turning now to the structure of the atom itself, it has been mentioned that radiation from the electrically excited atom is produced by electronic changes in the atom. The nature of these changes is here discussed in a little more detail. The definite orbits in which the electrons progress around the nucleus are among the most fundamental characteristics of the atom, and even when an electron is removed by the process called ionization the remaining electrons are not free to take up random positions relative to the nucleus. The outer or valence electrons, however, revolving in orbits most remote from the nucleus, can be disturbed by very high speed electrons and can therefore receive extra energy, enabling them to take up transitory positions more remote from the nucleus. An electron so affected will, however, remain at its new energy level for a period of time much less than one-millionth of a second, after which it returns to its former state and in so doing emits radiation. The magnitude of the pulse or quantum of radiation then produced will depend in part on the extent of the original jump—that is, on the energy level

to which the particular electron was raised by the primary collision, and, as stated above, a number of possibilities can arise.

It has been found that a simple relationship exists between the wavelength of the emitted radiation and the voltage difference between the energy levels within the atom between which the valence electron will fall in each transition:

$$\text{Wavelength} = \frac{1.2336}{V_d, \text{ microns}}$$

In resuming its normal position in the unexcited atom the electron may not return to the ground state in a single jump, but may do so in a series of two or more steps. Much of the longer-wavelength radiation from atoms such as mercury are due to these stepped returns as distinct from single jumps from the excited state to the non-excited or ground state. The only transitions which produce light in the visible region are those between two excited states, while all electron jumps from an excited state to the ground or normal level produce radiation outside the visible region.

It is interesting, therefore, to note that under certain conditions of excitation the mercury atom can produce visible light efficiently. These conditions must obviously be those in which the minimum number of transitions directly to the ground state occur and the maximum number of transitions between higher energy levels take place. This fact will perhaps be more apparent on studying the formula given above, when it will be seen that visible radiation between 4,000 Å and 7,000 Å is produced only by transitions involving energy levels separated by between 3 and 1.8 volts—quite a narrow region. As the resonance potential of mercury is 4.68 volts it is clear that the wavelength of the resultant radiation is well down in the ultra-violet region.

The Fluorescent Lamp

It is a well-established fact that low pressure or low concentration of ions in a gas discharge, and low current density, favour the production of resonance radiation, and that higher pressures and current densities favour the intermediate transitions from higher energy levels. Applying these facts to the case of mercury vapour we see that, if efficient production of ultra-violet radiation is the requirement, then the mercury-vapour pressure should be low, as should the current density.

This fact is utilized in the design of the modern fluorescent lamp. By the use of a very low vapour pressure of mercury a high percentage of the input energy is emitted as 2,537 Å radiation. This radiation can then be transformed into visible light by a coating of a suitable inorganic phosphor on the inner surface of the glass tubing containing the discharge. In this country the principal lamp-makers now use a calcium halo-phosphate, which can be made to yield visible light of either white or near-white colours according to the proposed usage of the lamp.

Mention has been made in various journals of the use of beryllium compounds in fluorescent lamps. It should be noted that zinc beryllium silicate is not used by the leading lamp manufacturers in this country. It is true, however, that potential dangers arising from this compound in the U.S.A. and elsewhere have been greatly exaggerated.

Another line of development in the last decade has resulted from increased interest in high-current-density discharges through the rare gases, particularly through

xenon. As a result of this work flash discharge tubes have been made available which will produce intense flashes of light of very short duration suitable, among other things, for the photography of the human eye. These tubes are energized from a condenser charged to a high voltage. They emit in addition to the complex line spectrum of xenon a large amount of continuous radiation similar to that from an incandescent body. A further development has been the production of a continuously burning gas arc in which xenon is electrically excited to a high level. In the xenon lamp of either the flash or the gas arc type the light is white and is produced at a comparatively high efficiency.

Conclusion

Modern light sources fall, therefore, into four principal groups, each of which has distinct characteristics: (1) Incandescent sources in which the light is emitted by virtue of the temperature of a heated body. (2) Metallic-vapour discharge lamps in which the electrical excitation of the metallic vapour by the electric discharge causes the emission of characteristic radiation from the metallic ion. (3) Fluorescent lamps in which the primary radiation is produced from the low-pressure mercury discharge, but in which its radiation is absorbed by inorganic fluorescent compounds which are caused to glow with visible light. (4) Gas discharge lamps in which one or other of the rare gases is excited by the passage of the electric discharge; in this case the discharge may be of very short duration as in the repeating flash tube, or it may be a continuous discharge of high current density as in the gas arc.

None of these different types of light sources seems to have characteristics which will eventually make it supersede the others. All have a particular contribution to make in the production of artificial light for the many varied purposes for which it is required.

HAEMOLYTIC DISEASE OF NEWBORN DUE TO IMMUNE ANTI-A AGGLUTININ

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The importance of ABO blood-group incompatibility as a cause of haemolytic disease of the newborn has given rise to considerable controversy during the past few years; some have even doubted the existence of the hazard. However, new tests for sensitization and refinements in technique have furnished ample evidence that such incompatibility does at times produce a definite clinical condition. There is also no doubt that ABO incompatibility between mother and foetus has a sparing effect on Rh response and reduces the risk of Rh sensitization where Rh incompatibility exists.

Pickles (1949), in reviewing the recorded cases, has emphasized that rigid criteria should be complied with before an alleged case of ABO sensitization is accepted

as such, and has stressed the necessity for stringent tests to exclude all other abnormal antibodies, and for proof, by a positive direct Coombs reaction, of adsorption of the antibody on the affected baby's erythrocytes. Such criteria are now minimum requirements in specialist laboratories. Additional confirmatory tests include parallel titrations in saline and serum or albumin at different temperatures, especially 4° C. and 37° C. (Hubinont, 1949). Boorman *et al.* (1949) have also carried out differential agglutination tests of survival rates and have shown that cells of the type in question are eliminated abnormally rapidly. Mollison and Cutbush (1949) have reported similar results.

In our experience the condition is relatively common in Bantu races, in whom it is probably as important as Rh sensitization, as only 5% of the Bantu are Rh-negative and the incidence of classical Rh sensitization is correspondingly low; moreover, distribution of the Rh subgroup is very different from that in Europeans (Zoutendyk, 1947). Similar results among negroes in the United States have been reported by Wiener, and he has also described two cases treated by exchange transfusion (Wiener *et al.*, 1949).

The following case demonstrates the importance of ABO incompatibility and emphasizes that the obstetric history may, in fact, be worse than in the case of Rh incompatibility, as in the latter state the first pregnancy almost invariably ends successfully provided that the Rh-negative mother has never received Rh-positive blood even in minimal amounts by any route.

Case Report

The patient, aged 24, had been married for 18 months when her first pregnancy ended in an abortion at 14 weeks. Serological investigations were not made because at that time blood-grouping and Rh-testing were not routine procedures. However, complete investigations were carried out on the blood of the patient and her husband in December, 1948, when the second pregnancy had progressed to 14 weeks. The reactions were as follows:

	Group	Anti-C	Anti-D	Anti-E	Anti-c	Anti-M	Anti-N	Blood Type
Patient	O _{A₁}	+	+	-	+	-	+	O CcDe N _{A₁} CcDe N
Husband	A ₁	+	+	-	+	-	+	

It will be seen that, apart from the difference in the ABO grouping, the reactions are identical. No abnormal saline or albumin agglutinins were demonstrable in the wife's serum against a wide range of Group O test cells both of known type and of others taken at random, and the indirect Coombs test was negative in every instance. The anti-A titre, however, as ascertained against the husband's red cells, was 1/10,000 at 37° C. The anti-B titre was 1/50, which is normal.

The abnormally high anti-A titre at 37° C. was considered to be of obstetric significance, and systematic investigations and titrations were tentatively planned for 32, 36, and 38 weeks. Unfortunately the patient went into labour at 31 weeks and, although the foetal heart had been heard 24 hours previously, a stillbirth resulted. Investigations on the cord blood showed that the baby belonged to Group A₁, but in other respects the reactions were the same as those of the mother. The maternal serum agglutinated the baby's cells to a titre of 1/20,000 in saline and 1/50,000 in serum. The anti-B titre remained unchanged at 1/50. The baby's red cells gave a strongly positive direct Coombs reaction. Exhaustive tests of the maternal serum on a representative panel of Group O cells in saline, serum, and albumin and by the indirect Coombs method failed to reveal irregular antibodies.