May 20 the *Actæa* was in 6° 50′ S. and 104° 2′ E., and on the morning of that day a "peculiar light green colour" was observed in the sky to the east-south-east, while "from east to east-north-east there was a dark blue cloud, which reached from the horizon to the zenith." "About 2 p.m. it was quite dark. What appeared to be a rain squall rose up from the east, but, instead of rain, a kind of very fine dust commenced to fall, and very soon everything was covered; ships, sails, rigging and men were all dust colour; nothing could be seen 100 yards off. The fall continued steadily all night, and stopped about 9 a.m. on Monday the 21st. When we saw the sun it looked like dull silver. At noon we were in lat. 8° 15′ S. and long. 102° 28′ E., distant from Java Heads about 170 miles. The sky all round remained a dusty hue, and small quantities of dust again fell during the night. The sky did not assume a natural appearance till the 23rd." At a meeting of this Society held on July 12, the Secretary called attention to Capt. Walker's letter, and said there was little doubt that the dust in question had come from Krakatoa, as, according to a note in NATURE of June 7, a volcano in that island was in full eruption. From that time accounts of pumice and ashes observed in the Indian Ocean had been extracted from log-books, and they showed that on several occasions vessels had passed through fields of pumice long before the great eruptions of August 26 and 27. After that month the reports became more frequent, and they still continued, the latest being from the vicinity and shores of Mauritius, where, since the middle of February, large quantities of pumice had been seen. It would appear, however, that fields of pumice had passed Mauritius long before February, for "a large quantity of pumice-stone and lava was washed up on the beach at Durban (Natal) on October 23." According to the reports received, fields or lanes of pumice had been observed in different parts of the Ocean from 105° to 48° E. and 6° to 12° S. Farther south the extent in longitude had been apparently less.

That the remarkable sunrises and sunsets which had been observed over a great part of the world after August 27 were due to matter ejected from Krakatoa seemed to be generally admitted. The few who objected to the volcanic dust theory had not proposed any other theory that so completely accounted for the facts. The presence of vapours and finely-divided dust at certain elevations would, as a consequence of known physical laws, produce all the chromatic effects that had been seen and described, and it was known that immense quantities of matter had been shot up from Krakatoa. Similar phenomena had been witnessed by observers between whom and the sun volcanic dust passed, as on the occasion of an eruption of Cotopaxi a few years ago. But it was not necessary to go so far back. From May 20 to 22 last, after an eruption of Krakatoa, Captain Walker, as already stated, observed that to the east-south-east the sky was of a light green colour, that on the 21st the sun looked like dull silver, that the sky all round was of a dusty hue, and that it did not assume its natural appearance till the 23rd. That was perhaps the earliest instance of the chromatic effects of the Krakatoa dust and vapours. Immediately after the eruptions of August 27 they were more intense and on a greater scale. At the Seychelles on the 27th the sky, according to Mr. Estridge, was hazy all day. The sunset on that day was gorgeous; the sky was lurid all over, and beams of red light stretched from over St. Anne's to nearly the horizon. At sunset on the 28th the sun looked as it did through a fog on a frosty day in England. On the morning of the 29th the sun at 7 a.m. was more like a full moon than anything else. According to other letters from the Seychelles the sun for a whole week appeared dim. At Rodrigues, according to Mr. Wallis, whose report was written on August 31, the sky at north-west on every evening since the 27th had a very threatening and strange appearance of a deep purplish red colour, which lasted till 7.15 p.m., and which, with the disturbances of the sea water, caused much fear and excitement. Similar phenomena were observed on the same evenings at Diego Garcia and St. Brandon, and for several days the sun looked as if partially obscured. At Mauritius the sky was overcast throughout the whole of the 27th, and it was observed and noted at the time that there was an unusual dimness. On the evening of the 28th there was a gorgeous sunset, the first of a long series of remarkable colorations and glows, which had already been described. Observations of these optical phenomena had been taken daily during nearly the last nine months whenever the weather permitted. Knowing what had been observed on board of the *Actæa*, and that Krakatoa had been in eruption, these extraordinary sunsets and sunrises were attributed to the presence in the upper strata of the air of finely-divided matter, and probably gases and vapours, from Krakatoa, and subsequent events confirmed that opinion. It was difficult to explain phenomena which had been identical under all conditions of weather, and in many distant places, by any purely meteorological causes. To the meteoric dust theory it might be objected that it was purely an hypothesis almost, if not wholly, unsupported by facts. No unusual number of meteors had been seen. No extraordinary glows had been observed at or near the times of the great meteoric showers of November 1866, and November 1872. Moreover one would suppose that if the earth had for months been passing through volumes of meteoric dust the chromatic effects would have appeared simultaneously wherever the sun rose and set. But such had not been the case. Upon the whole there seemed to be a preponderance of evidence in favour of the volcanic dust theory. The objection that the quantity of matter was insufficient was not a formidable one, for the effects did not depend merely upon the quantity of matter that had reached the higher regions, but also upon its form and degree of tenuity. A few pounds of matter might be spread over thousands of square miles. As to the objection that it was difficult to conceive how even finely-divided matter could remain so long in suspension, it might be remarked that, independently of the possibility of the particles being electrified, the lower strata of the atmosphere might be denser than the foreign matter in the upper strata. The extraordinary sunsets and sunrises which were observed in 1783-84, and which Arago and others ascribed to volcanic dust, were said to have lasted eleven months. Those of 1883-84 would probably last fully as long. Within the last few weeks there had been at Mauritius a considerable increase in the intensity and duration of the glows.

EVIDENCES OF THE EXISTENCE OF LIGHT AT GREAT DEPTHS IN THE SEA[1]

THE evidences of the presence of light and its quality and source at great depths are of much interest. At present very little experimental knowledge in regard to these questions is available. That light of some kind, and in considerable amount, actually exists at depths below 2000 fathoms, may be regarded as certain. This is shown by the presence of well-developed eyes in most of the fishes, all of the cephalopods, most of the decapod Crustacea, and in some species of other groups. In many of these animals, living in 2000 to 3000 fathoms, and even deeper than that, the eyes are relatively larger than in the allied shallow-water species; in others the eyes differ little, if any, in size and appearance, from the eyes of corresponding shallow-water forms; in certain other cases, especially among the lower tribes, the eyes are either rudimentary or wanting in groups of which the shallow-water representatives have eyes of some sort. This last condition is notable among the deep-water gastropods, which are mostly blind; but many of these are probably burrowing species; and it may be that the prevalent extreme softness of the ooze of the bottom, and the general burrowing habits, are connected directly with the habits or rudimentary condition of the eyes in many species belonging to different classes, including Crustacea and fishes. Such blind species usually have highly developed tactile organs to compensate for lack of vision.

Other important facts bearing directly, not only on the *existence*, but on the *quality*, of the light, are those connected with the coloration of the deep-sea species. In general, it may be said that a large proportion of the deep-sea animals are highly *coloured*, and that their colours are certainly *protective*. Certain species, belonging to different groups, have pale colours, or are translucent, while many agree in colour with the mud and ooze of the bottom; but some, especially among the fishes, are very dark, or even almost black; most of these are probably instances of adaptations for protection from enemies, or concealment from prey. But more striking instances are to be found among the numerous brightly-coloured species belonging to the echinoderms, decapod Crustacea, cephalopods, annelids, and Anthozoa. In all these groups, species occur which are as highly coloured as their shallow-water allies, or even more so. But it is remarkable that in the deep-sea animals the bright colours are almost always shades of orange and orange-red, occasionally brownish red,

[1] From a paper in *Science*, July 4, on "Results of Dredgings in the Gulf Stream Region by the U. S. Fish Commission."

purple, and purplish red. Clear yellow, and all shades of green and blue colours, are rarely, if ever, met with. These facts indicate that the deep sea is illuminated only by the sea-green sunlight that has passed through a vast stratum of water, and therefore lost all the red and orange rays by absorption. The transmitted rays of light could not be reflected by the animals referred to, and therefore they would be rendered invisible. Their bright colours can only become visible when they are brought up into the white sunlight. These bright colours are therefore just as much protective as the dull and black colours of other species.

The deep-sea star-fishes are nearly all orange, orange-red, or scarlet, even down to three thousand fathoms. The larger ophiurans are generally orange, orange-yellow, or yellowish white, the burrowing forms being usually whitish or mud-coloured, while the numerous species that live clinging to the branches of gorgonians and to the stems of Pennatulacea are generally orange, scarlet, or red, like the corals to which they cling. Among such species are *Astrochele lymani*, abundant on the bushy orange gorgonian coral, *Acanella normani*, often in company with several other orange ophiurans belonging to Cphiacantha, &c. *Astronyx loveni* and other species are common on Pennatulacea, and agree very perfectly in colour with them. These, and numerous others that might be named, are instances of the special adaptations of colours and habits of commensals for the benefit of one or both. Many of the large and very abundant Actiniæ, or sea-anemones, are bright orange, red, scarlet, or rosy in their colours, and are often elegantly varied and striped, quite as brilliantly as the shallow-water forms; and the same is true of the large and elegant cup-corals, *Flabellum goodei*, *F. angulare*, and *Caryophyllia communis*,—all of which are strictly deep-sea species, and have bright orange and red animals when living. The gorgonian corals of many species, and the numerous sea-pens and sea-feathers (Pennatulacea), which are large and abundant in the deep sea, are nearly all bright coloured when living, and either orange or red. All these Anthozoa are furnished with powerful stinging organs for offence and defence; so that their colours cannot well be for mere protection against enemies, for even the most ravenous fishes seldom disturb them. It is probable, therefore, that their invisible colours may be of use by concealing them from their prey, which must actually come in contact with these nearly stationary animals in order to be caught. But there is a large species of scale-covered annelid (*Polynoë aurantiaca*, Verr.) which lives habitually as a commensal on *Bolocera tuediæ*, a very large orange or red actinian, with unusually powerful stinging organs. Doubtless the worm finds, on this account, perfect protection against fishes and other enemies. This annelid is of the same intense orange colour as its actinian host. Such a colour is very unusual among annelids of this group, and in this case we must regard it as evidently protective and adaptive in a very complex manner.

It has been urged by several writers, that the light in the deep sea is derived from the phosphorescence of the animals themselves. It is true that many of the deep-sea Anthozoa, hydroids, ophiurans, and fishes are phosphorescent; and very likely this property is possessed by members of other groups in which it has not been observed. But, so far as known, phosphorescence is chiefly developed in consequence of nervous excitement or irritation, and is evidently chiefly of use as a means of defence against enemies. It is possessed by so many Anthozoa and acalephs which have, at the same time, stinging organs, that it would seem as if fishes had learned to instinctively avoid all phosphorescent animals. Consequently it has become possible for animals otherwise defenceless to obtain protection by acquiring this property. It is well known to fishermen that fishes avoid nets, and cannot be caught in them, if phosphorescent jelly-fishes become entangled in the meshes; therefore it can hardly be possible that there can be an amount of phosphorescent light, regularly and constantly evolved by the few deep-sea animals having this power, sufficient to cause any general illumination, or powerful enough to have influenced, over the whole ocean, the evolution of complex eyes, brilliant and complex protective colours, and complex commensal adaptations.

It seems to me probable that more or less sunlight does actually penetrate to the greatest depths of the ocean in the form of a soft sea-green light, perhaps at two thousand to three thousand fathoms equal in intensity to our partially moonlight nights, and possibly at the greatest depths equal only to starlight. It must be remembered that in the deep sea, far from land, the water is far more transparent than near the coast. A. E. VERRILL

ARTIFICIAL LIGHTING[1]

IN early times but a small fraction of our forefathers' lives was spent under artificial light. They rose with the sun and lay down to rest shortly after sunset. During the long winter evenings they sat round the fire telling stories and singing songs of love and war; the fire-light was sufficient for them, except occasionally during grand feasts and carousals, when their halls were lighted by pine-wood torches or blazing cressets. But, as a rule, after sunset they lived in semi-darkness.

From that early period, as man has advanced in civilisation, in the thirst for knowledge derived from books, and in following the gentler pursuits which demand an indoor life, there has been a steady increase in that fraction of our lives which is spent under light other than that of the sun. But the improvement in the quality of the artificial light has been very slow. The ruddy lights and picturesque shadows so faithfully handed on to us by Rembrandt's pictures show us very graphically what our poets have called "the dim glimmer of the taper" of those days. A few years before the introduction of gas, Argand, by his improvements in the burners of oil lamps, enabled our fathers to see for the first time a comparatively white light, but as far as the matter we to-day propose to discuss is concerned, viz. the effect of artificial lighting, and more particularly electric lighting, on our health, we need only consider the reign of artificial light as it commenced with the general use of gas and petroleum, for then and only then could it be said to affect our health.

Prior to the introduction of the electric light we have been accustomed to consider every hour spent under artificial light as an hour during which all conditions are less favourable to perfect health than they would be during daylight. Can we now hope to ameliorate this condition of things through the agency of electricity? Before we can discuss this question I must point out to you the chief differences which exist between hours of work or recreation spent in daylight and under artificial light. In the former case we live in abundance of light. The sunlight itself exercises a subtle influence on our bodies; that mixture of heating and chemical rays which when analysed form the solar spectrum, and combined form the pure white light of daylight, is needed to enable all animal and vegetable organisms to flourish in the fullest conditions of healthful life.

In nearly all cases when the sun is up, the functions of life are in the state of fullest activity, and when it sets they sink into comparative repose. In daylight life wakes, in darkness life sleeps. In addition to the abundance of pure white light, the heat attending is only that necessary for health. The air remains unvitiated, except by our own breathing. On the other hand, when working under artificial light, we have these conditions all altered in degree:

1. We have an insufficient light; a scale of lighting by gas or by electricity which would be pronounced excessive at night-time is still far inferior to average daylight.

2. All artificial lights, whether produced by combustion, as in the case of candles, oil, gas, and petroleum, or by the incandescence of a conductor by the means of electricity, produce heat; this heat, in proportion with the light afforded, is enormously in excess of the heat given by sunlight. Electricity, as you will see hereafter, is far the best in this respect, but even it is inferior to sunlight.

3. All these same illuminants, excepting electricity, contaminate the air and load it with carbonic acid, sulphur, and other compounds—all injurious to the health and to the general comfort of the body. It will be convenient to consider the effects—first, on our health generally; second, on our eyesight in particular. I have already called your attention to the fact that that proportion of coloured rays which, when combined, form white sunlight, is that best suited to healthy life. It is necessary too to that sufficient and proper stimulus to the organic changes which go on in our bodies, and which we call a state of good health. The various artificial lights differ very widely from sunlight in this respect, that they are all more or less deficient in the rays at the violet end of the spectrum, commonly called the actinic rays, and which most probably exercise a very powerful effect on the system. It is the want of a due portion of these violet rays which makes all artificial light so yellow. Even the light of the electric arc, which is richer in these rays than any other, is still on the yellow side of sunlight. The incandescent electric light is next best in this respect; next in order come gas, petroleum, and the various oil lamps. No doubt some of you will

[1] Lecture delivered at the Health Exhibition by Mr. R. F. B. Crompton