(3) With but a little training in technic, college freshmen have secured very good graphs with this apparatus.

(4) This machine, exclusive of the drum, has been constructed at less than one third the cost of a spring-driven kymograph, and the drum of the latter may readily be used for either, since but a few minutes are required to make the shift.

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SPECIAL ARTICLES

A NEW ARRANGEMENT FOR SHOWING THE DIURNAL VARIATION IN THE INTENSITY OF THE EARTH'S-SURFACE CHARGE AT A GIVEN PLACE

DURING the past seven years I have been recording a diurnal variation in the deflection of a quadrant electrometer inside a grounded-wire cage with one pair of quadrants grounded to the cage and to the city water-system of Palo Alto, the other pair insulated and the needle charged. Set up in this way the electrometer has shown both a solar and a lunar diurnal variation in deflection which varies with the seasons, being much greater at the equinoxes than at the solstices, which is not due to temperature, illumination or atmospheric pressure and which is sometimes greatly disturbed by solar activity and by auroras.

I have attributed this variation to the inductive effect of the electric charges of the sun and moon upon the earth's charge; but this explanation has not met with general approval, partly, at least, because it is quite commonly held that it is impossible that the sun as a whole can be highly electrified, though the tremendous charges in sun-spot regions are quite generally accepted.

One of the most plausible explanations of the phenomenon which have been offered, and the one which is most often proposed, is that it is due in some way to a diurnal variation in the electrical conductivity of the air. This has seemed the more plausible because a number of observers have recorded similar electrometer deflections which they have attributed to changes in atmospheric conductivity, due to penetrating radiations or other causes.

I have several times offered what seem to me to be conclusive objections to this interpretation of my observations, and I wish now to give a definite experimental proof that the phenomenon is not due to variations in atmospheric conductivity.

If a quadrant electrometer have one pair of quadrants and the needle grounded to the inside of a hollow conductor which is also grounded and have the other pair of quadrants connected to one pole of a constant battery, the other pole of which is also grounded to the inside of the hollow conductor, we have an arrangement in which the electrometer will not be disturbed by any changes in the conductivity of the air. The needle and one pair of quadrants must necessarily remain at the same electrical potential as the earth, and the charged quadrants must remain at a constant potential difference from the needle and the grounded pair.

An electrometer set up in this way shows the same diurnal variation in deflection as does the one which I have been using for the past seven years. Fig. 1

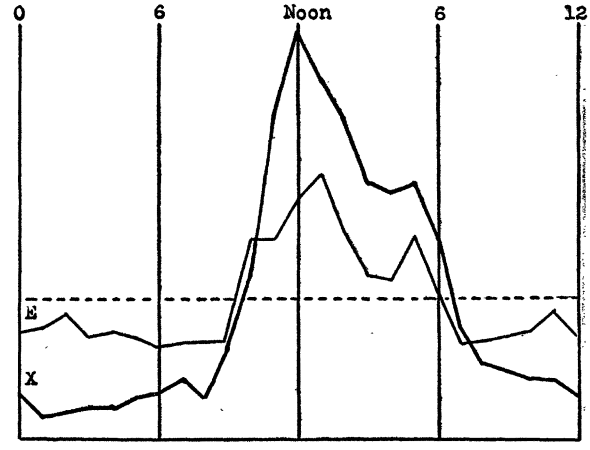

FIG. 1

shows the simultaneous mean diurnal variation for eight days of two electrometers standing upon the same pier and giving photographic records upon the same sheet. The two were charged from different batteries. Curve E was given by the electrometer with a charged needle, one pair of quadrants grounded and the other pair connected to an insulated conductor inside the cage, and Curve X was given by an electrometer with one pair of quadrants and the needle grounded and the other pair grounded through a constant battery. It will be seen that the deflection given by electrometer X was twice as great as that given by electrometer E.

The fact that the electrometer deflections have both a solar and a lunar diurnal period as well as a seasonal period shows that they are dependent upon the sun and moon, and their electrostatic nature will hardly be questioned. Also, the fact that the solar variation is several times as great as the lunar shows that they are not due to gravitational tides.

Since most of my previous statements in regard to this phenomenon have been declared impossible by *a priori* physicists, I have no doubt that this one will

share the same fate, but every physics laboratory has facilities for testing it.[1]

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THE BACTERIAL LIGHT ORGAN OF CERATIAS

PIERANTONI[1] and Zirpolo[2] were the first to describe living bacteria as the normal source of light in the luminous organ of an organism, *Sepiola,* a squid. Basing their opinion on this, they have attempted to show that such bacteria are the source of light, not only in this squid, where the bacteria are found in the open lumen of the gland, but also in many other luminous organs where the objects supposed to be bacteria are those hitherto identified as secreted granules of luciferin that operate *in situ* in the cells that formed them or in the lumen of the gland or after being ejected from the gland.

While the writer agrees that the bacterial origin of the light has been fairly well proven in the case of *Sepiola,* he does not agree with the idea that the light granules in these other forms are bacteria, but is convinced that they are secreted granules of luciferin formed by the specific light cells of the organ.

Harvey[3] in studying the luminous organ of the fish *Katablephron* describes the content of this gland as a mass of luminous bacteria and although he was unable to cultivate them the case seems to be pretty well established. Y. Yasaki[4] has made a more detailed study of the light organ on the tip of the lower jaw of the fish *Monocentris japonicus* and has proved more definitely that the light is produced by living bacteria harbored by this gland. Recently, Harms[5] has described the remarkable case of an East Indian fish *Equula,* which has developed a light organ from the epithelium of the esophagus. Here again the light seems to take its origin from bacteria that live in masses in the lumen of the gland. Full weight is given to this discovery by Harms' ability to demonstrate the bacteria as constituting the major bulk of the content of the gland.

The writer has been studying the open gland found on the tip of the anterior dorsal fin ray of a species of *Ceratias,* and again it seems certain that the light from this organ is produced by bacteria which fill a large portion of its lumen. Owing to the rarity of this fish and the difficulties under which it must always be secured (it is a deep sea form captured dead by the dredge or tow net) it has been impossible to study the organ in any natural condition. But the bacteria have been seen and its agreement in structure with the bacterial light organs of the other four forms seems to identify its function with theirs.

This organ on the fin ray of *Ceratias* is evidently an ectodermal invagination whose fundus consists of several thousand acini arranged in the form of a hollow sphere and discharging inward through their ducts into a central chamber. From this chamber the contents of the gland pass distally through an aperture in the spherical line of glands into a second and more distal chamber and from this latter again into a third chamber from which a small duct leads to the exterior. A second small duct also leads out from the second chamber and opens to the exterior, close to the other duct, on the distal and anterior surface of the total organ.

The entire organ, as has been described by Brauer, is quite globular in shape and is invested, as is the rest of the body, with a deeply black, pigmented layer which would shut in all light produced internally except near the distal extremity where a circular zone is wanting in pigment altogether. In life this "illuminating zone" must be quite transparent and the only surface of the organ from which light rays could emerge.

[1] Since the above article was in the hands of the publishers I have modified the experiment in a still more striking and conclusive manner. A quadrant electrometer has one diagonal pair of quadrants removed and the metallic needle suspension connected to the remaining pair. The instrument thus becomes a very sensitive electroscope which, when charged, will give a rotation of the needle. The system thus formed is insulated upon amber supports inside a brass case which is inside of and connected with an earthed wire cage. Set up in this way, after being discharged to the inside of the wire cage, with no battery or artificial charge near it, and doubly protected from outside induction, the needle undergoes a double deflection each day, due to a negative charge on the instrument in the day time and a positive charge on it at night. The deflections are not due to temperature, barometric variations or changes in illumination. Their magnitude has been greater than is caused by charging the instrument to 150 volts. They seem to be due to a positive charge on the day side of the earth and a negative charge on the night side, which charges can not be shared with the insulated instrument.

[1] Pierantoni, U., "Gli organi simbiotici e la luminescenza batterica dei Cefalopode," Pub. Staz. Zool., Napoli, Vol. 20, p. 105, Tav. 6–8, 1917.

[2] Zirpolo, G., "I batteri Fotogeni degli organi luminose de *Sepiola intermedia* Naef.," 1918.

[3] Harvey, E. N., "The Production of Light by the Fishes *Photoblephron* and *Anomalops,*" Pub. No. 313, Carnegie Inst. of Washington, pp. 43–60.

[4] Yasaki, Y., "On the Nature of the Luminescence of the Knightfish, *Monocentris japonicus* (Houttum)," *Journ. of Exper. Zool.,* Vol. 50, No. 3, April, 1928.

[5] Harms, J. W., "Bau und Entwicklung eines Eigenartigen Leuchtorgans bei *Equula spec.,*" *Zeit. f. Wiss. Zool.,* Vol. 131, first part, 1928.