families are also comparatively few. The families so contributing are, however, among the most important and widely distributed in the vegetable kingdom; as also are some of the plants they contribute. As prominent examples may be mentioned, the *Gramineæ*, affording the cereal grains, a large proportion of the mixed herbage of grass-land, and other products; also the *Leguminosæ*, yielding pulse crops, many useful herbage plants, and numerous other products. As we have said, there does not seem to be an unsolved problem as to the sources of the nitrogen of other of our agricultural plants than those of the leguminous family. Obviously, however, it would be unsafe to generalise in regard to individual families as a whole, from results relating to a limited number of examples supplied by their agricultural representatives alone. Still, there is nothing in the evidence at present at command, to point to the supposition that there is any fundamental difference in the source of the nitrogen of different members of the same family, such as is clearly indicated between the representatives of the leguminous, and of the other families, supplying staple agricultural products. On the other hand, existing evidence does not afford any means of judging whether or not similar, or allied agencies to those now under consideration, or even quite different ones, may come into play in the nitrogen assimilation of the members of other families which contribute such a vast variety of vegetation to the earth's surface.

We have pleasure in stating that the conduct of the investigation has largely devolved upon Dr. N. H. J. Miller. He has been almost wholly responsible for the analytical work, as well as for the photographing, by which a permanent record, not only of the above-ground growth, but of the root-development of the experimental plants has been secured. It should be added, that Mr. J. J. Willis has materially assisted in the observation and noting on growth; also in the separation of the roots, mounting them for observation and for photographing, and in noting upon them.

II. "On Electric Discharge between Electrodes at different Temperatures in Air and in High Vacua." By J. A. Fleming, M.A., D.Sc., Professor of Electrical Engineering in University College, London. Communicated by Professor G. C. Foster, F.R.S. Received December 16, 1889.

(Preliminary Notice.)

It has been known for some time that if a platinum plate or wire is sealed through the glass bulb of an ordinary carbon filament incandescent lamp, this metallic plate being quite out of contact with

the carbon conductor, a sensitive galvanometer connected between this insulated metal plate enclosed in the vacuum and the external *positive* electrode of the lamp indicates a current of some milliampères passing through it when the lamp is set in action, but the same instrument when connected between the *negative* electrode of the lamp and the insulated metal plate indicates no sensible current. This phenomenon in carbon incandescence lamps was first observed by Mr. Edison, in 1884, and further examined by Mr. W. H. Preece, in 1885.* The primary object of the experiments described in this paper was the further examination of this effect, but the inquiry has extended itself beyond this range and embraced some general phenomena of electric discharge between electrodes at unequal temperatures, and in particular has revealed some curious effects in the behaviour of an electric arc taken between carbon poles towards a third insulated carbon on metal poles.

The first series of experiments had reference to the nature of the effect observed in the incandescence lamps having an insulated wire or plate placed in the vacuum.

If a platinum wire is sealed through the glass bulb of an ordinary carbon filament lamp and carries at its extremity a metal plate, so placed as to stand up between the legs of the carbon horseshoe without touching either of them, then when the lamp is actuated by a continuous current it is found that :—

(1.) This insulated metal plate is brought down instantly to the potential of the base of the negative leg of the carbon, and no sensible potential difference exists between the insulated metal plate and the negative electrode of the lamps, whether the test be made by a galvanometer, by an electrostatic voltmeter, or by a condenser.

(2.) The potential difference of the plate and the positive electrode of the lamp is exactly the same as the working potential difference of the lamp electrodes, provided this is measured electrostatically, *i.e.*, by a condenser, or by an electrostatic voltmeter taking no current,

* See 'Roy. Soc. Proc.,' vol. 38, 1885, p. 219. "On a Peculiar Behaviour of Glow Lamps when raised to High Incandescence."—In this paper Mr. Preece describes a very careful series of observations carried out with Edison incandescence lamps, and which cover the same ground as a portion of the experiments here described. The results given in (4), (7), and (11) confirm the facts which were first ascertained by him. He also arrived at the general conclusion that the phenomena so observed are due to an electric convection by matter projected from the incandescent carbon. By carrying up the working electromotive force of the lamp to a point productive of very high incandescence, he was able to measure the resulting current through a galvanometer connected between the positive lamp electrode and the middle plate corresponding to every degree of incandescence, and showed that, whilst increasing up to a certain point, the galvanometer current fell off rapidly soon after a certain critical temperature was reached, which corresponded to the appearance of a blue light or haze in the glass receiver.—[Jan. 14th, 1890.]

but if measured by a galvanometer the potential difference of the plate and the positive electrodes of the lamp is something less than that of the working lamp electrodes.

(3.) This absolute equality of potential between the negative electrode of the lamp and the insulated plate only exists when the carbon filament is in a state of vivid incandescence, and when the insulated plate is not more than an inch or so from the base of the negative leg. When the lamp is at intermediate stages of incandescence, or the plate is considerably removed from the base of the negative leg, then the plate is not brought down quite to the same potential as the negative electrode.

(4.) A galvanometer connected between the insulated plate and the *positive* electrode of the lamp shows a current increasing from zero to four or five milliampères, as the carbon is raised to its state of commercial incandescence. There is not any current greater than 0·0001 of a milliampère between the plate and *negative* electrode when the lamp has a good vacuum.

(5.) If the lamp has a bad vacuum this inequality is destroyed, and a sensitive galvanometer shows a current flowing through it when connected between the middle plate and either the positive *or* negative electrode.

(6.) When the lamp is actuated by an *alternating* current a *continuous* current is found flowing through a galvanometer, connected between the insulated plate and *either* terminal of the lamp. The direction of the current through the galvanometer is such as to show that negative electricity is flowing from the plate through the galvanometer to the lamp terminal. This is also the case in (4); but, if the lamp has a bad vacuum, then negative electricity flows *from* the plate through the galvanometer *to* the positive terminal of the lamp, and negative electricity flows *to* the plate through the galvanometer from the negative terminal of the lamp.

(7.) The same effects exist on a reduced scale when the incandescent conductor is a platinum wire instead of carbon filament. The platinum wire has to be brought up very near to its point of fusion, in order to detect the effect, but it is found that a current flows between the positive electrode of a platinum wire lamp and a platinum plate placed in the vacuum near to the negative end of that wire.

(8.) The material of which the plate is made is without influence. Platinum, aluminium, and carbon have been indifferently employed.

(9.) The active agent in producing this effect is the *negative* leg of the carbon. If the negative leg of the carbon is covered up by enclosing it in a glass tube this procedure entirely, or nearly entirely, prevents the production of a current in a galvanometer connected between the middle plate and the positive terminal of the lamp.

(10.) It is a matter of indifference whether a glass or metal tube is

employed to cover up the negative leg of the carbon; in any case this shielding destroys the effect.

(11.) If, instead of shielding the negative leg of the carbon, a mica screen is interposed between the negative leg and the side of the middle plate which faces it, then the current produced in a galvanometer connected between the positive terminal of the lamp and the middle plate is much reduced. Hardly any effect under the same circumstances is produced when the mica screen is interposed on that side of the metal plate which faces the positive leg of the carbon.

(12.) The position of the metal plate has a great influence on the magnitude of the current traversing a galvanometer connected between the metal plate and the positive terminal of the lamp. The current is greatest when the insulated metal plate is as near as possible to the base of the negative leg of the carbon, and greatest of all when it is formed into a cylinder which embraces without touching the base of the negative leg.

The current becomes very small when the insulated metal plate is removed to 4 or 5 inches from the negative leg, and becomes practically zero when the metal plate is at the end of a tube forming part of the bulb, which tube has a bend at right angles in it. Copious experiments have been made with metal plates in all kinds of positions.

(13.) The galvanometer current is greatly influenced by the surface of the metal plate, being greatly reduced when the surface of the plate is made small, or when the plate is set edgeways to the negative leg, so as to present a very small apparent surface when seen from the negative leg. In a lamp having the usual commercial vacuum, the effect is extremely small when the insulated metal plate is placed at a distance of 18 inches from the negative leg, but even then it is just sensible to a very sensitive galvanometer.

(14.) If a charged condenser has one plate connected to the insulated metal plate, and the other plate connected to any point of the circuit of the incandescent filament, this condenser is instantly discharged if the positively charged side of the condenser is connected to the insulated plate, and the negative side to the hot filament. If, however, the negative leg of the carbon horseshoe is shielded by a glass tube, this discharging power is much reduced, or altogether removed.

(15.) If the middle plate consists of a separate carbon loop, which can itself be made incandescent by a separate insulated battery, then, when this middle carbon is rendered incandescent and employed as the metal plate in the above experiment, the condenser is discharged when the negatively charged side of it is connected to the hot middle carbon, the positively charged side of it being in connexion with the principal carbon horseshoe.

(16.) If this last form of lamp is employed as in (4) the subsidiary carbon loop being used as a middle plate, and a galvanometer being connected between it and either the positive or negative main terminal of the lamp, then when the subsidiary carbon loop is cold, we get a current through the galvanometer only when it is in connexion with the positive main terminal of the lamp, but when the subsidiary carbon is made incandescent by a separate insulated battery, we get a current through the galvanometer when it is connected either to the positive *or* to the negative terminal of the lamp. In the first case the current through the galvanometer is a negative current, flowing from the middle carbon to the positive main terminal, and in the second case it is a negative current, from the negative main terminal to the middle subsidiary hot carbon.

(17.) If a lamp having a metal middle plate held between the legs of the carbon loop has a galvanometer connected between the negative main terminal of the lamp and this middle plate, we find that when the carbon is incandescent there is no sensible current flowing through the galvanometer. The vacuous space between the middle plate and the hot negative leg of the carbon possesses, however, a curious unilateral conductivity. If a single Clark cell is inserted in series with the galvanometer, we find that this cell can send a current deflecting the galvanometer when its negative pole is in connexion with the negative main terminal of the lamp, but if its positive pole is in connexion with the negative terminal of the lamp, then no current flows. The cell is thus able to force a current through the vacuous space when the direction of the cell is such as to cause negative electricity to flow across the vacuous space from the hot carbon to the cooler metal plate, but not in the reverse direction.

(18.) If a vacuum tube is constructed, having at each end horseshoe carbon filaments sealed into it, and which can each be made separately incandescent by an insulated battery, we find that such a vacuum tube, though requiring an electromotive force of many thousands of volts to force a current through it when the carbon loops are used as electrodes and are *cold*, will yet pass the current from a single Clark cell when the carbon loop which forms the negative electrode is rendered incandescent. It is thus found that a high vacuum terminated electrically by unequally heated carbon electrodes possesses an unilateral conductivity, and that electric discharge takes place freely through it under an electromotive force of a few volts when the *negative* electrode is made highly incandescent.

(19.) These experimental results above described led the writer to investigate, in the same manner, the electric arc between carbon poles taken in air. If an electric arc is formed, in the usual way, between carbon poles, and a third insulated carbon pole is allowed to dip into or touch the electric arc, or, better still, has the electric arc projected

against it by a magnet, it is found that this third or insulated pole is brought down almost to the potential of the negative carbon of the arc, and that a galvanometer connected between the third insulated carbon and the negative carbon of the arc indicates no current, but that if joined up between the positive carbon and the middle carbon a strong current of about an ampère or so is found to be passing. If an electric bell or an incandescent lamp is joined up between the third carbon and the *negative* carbon of the arc, they do not work ; but if the bell or the lamp is joined between the *positive* carbon of the arc and the third carbon, they are set in action by a strong current passing through them. These effects are produced, although the third carbon (which is best held at right angles to the other two forming the arc) is half or three quarters of an inch away from the positive and negative carbon, the sole condition being that the flame of the arc must touch or be projected by a magnet so as to touch this third carbon. We have, therefore, similar phenomena in the case of the arc and incandescence lamps.

(20.) When the electric arc is being projected against the third carbon, and has brought it down to the same potential, a galvanometer joined in between the two carbons shows no current ; but this space between the negative carbon of the arc and the third carbon possesses a unilateral conductivity, and will pass the current from a small battery of secondary cells one way, but not the other. The secondary battery when joined in series with the galvanometer sends a current, if its negative pole is in connexion with the negative carbon of the arc, and its positive pole, through the galvanometer, with the third carbon ; but if the secondary battery is reversed in position it sends no current. Negative electricity can pass along the flame-like projection of the arc *from* the hot negative carbon *to* the cooler third carbon, but not in an opposite direction.

(21.) If the arc is projected by means of a magnet for a long time against the third insulated carbon, it *craters* it out in the same fashion as the crater of the positive carbon, and the tip of this third carbon, where it has received the flame-like blast of the arc, is converted into graphite.

The same effects are observed if an iron rod is used as a third pole, and in this case the end is converted into *steel*, and rendered so hard as to be scarcely touched by the file when it has been quenched in water.

In seeking for an hypothesis to connect together these observed facts, the one which suggests itself as most in accordance with the facts is as follows :—

In the case of a carbon incandescence lamp when at vivid incandescence, carbon particles are being projected from all parts of the filament, but chiefly from the negative half of the loop. These carbon

molecules carry *negative* charges of electricity, and when they impinge upon a metal plate placed in the vacuum they can discharge themselves if this plate is positively electrified, either by being in metallic connexion with the positive electrode of the lamp or with a separate positively charged body. When the plate is simply insulated the stream of negatively charged carbon molecules brings down this insulated plate to the potential of the base of the negative leg, or to the potential of that part of the carbon conductor from which it is receiving projected molecules. These carbon molecules projected from an incandescent conductor can carry negative charges, but either cannot be positively charged, or else lose a positive charge almost instantly when projected off from the conductor.

In the case of the electric arc we must suppose that the negative carbon is projecting off a torrent of negatively electrified carbon molecules, and these, impinging against the positive carbon, wear out a crater in it by a sand-blast-like action.

The higher temperature of the positive carbon in a continuous current arc is thus explained as due to the impact of the carbon molecules projected from the negative carbon.

If the electric arc is diverted against a third insulated lateral carbon, the carbon blast from the negative carbon wears out a crater in it and brings it down to the same potential as itself. The actions going on in an electric arc may be considered to be somewhat as follows:—When the carbons are first put together, the resistance at the point of contact renders the extremities incandescent. When thus incandescent and separated, the electrification of each carbon is sufficient to begin the projection of molecules from both positive and negative carbons, probably most largely from the latter. The impact of the molecular stream from the negative pole raises the temperature of the positive carbon, and this again by radiation raises the temperature of the negative carbon end. The electromotive force is thus able to keep up a projection of negatively charged carbon molecules from the end of the negative carbon, which molecules are loosened from the mass by heat, and then move away by electric repulsion from the surface in virtue of the electric charge which they retain. It would seem as if a hot carbon molecule cannot retain a positive charge, and hence the potential difference between a third insulated carbon and the positive carbon of the arc is nearly the same as the potential difference of the positive and negative carbons of the arc. The rise of potential along the arc takes place very suddenly just in the neighbourhood of the crater of the positive carbon.

It has often been suggested that the electric arc contains a counter-electromotive force. It is questionable whether such experiments as those of Edlund ('Phil. Mag.,' vol. 36, 1868, p. 352) are entirely conclusive on this point.

It has been shown by other experimenters* that for arcs of varying length, but the same current, beyond a certain small initial length, the potential difference necessary to maintain the arc is proportional to the length of the arc plus a constant. This might thus be interpreted to mean that a certain proportion of the working electromotive force of the arc was employed in detaching the carbon molecules from the mass of the poles, and that the excess alone is represented by the current produced in an arc of definite length.

In the case of the incandescence lamps the hypothesis of the projection of negatively charged carbon molecules from the incandescent conductor, to which the name of *molecular electrovection* may be given, will suffice to explain all the various different effects produced by varying the surface, position, and distance of the metal plate against which they impinge, and also the nullifying effect of shielding this plate from the negative leg of the carbon.

That this molecular discharge goes on chiefly from the negative leg is additionally proved by the greater erosion which takes place in the deposit of carbon on the negative leg when the carbon is uniform and traversed by a continuous current.

The hypothesis that a carbon molecule detached from an incandescent carbon surface in a high vacuum can only convey away a negative charge, reconciles also the above described observed effects in which a negative discharge can be made *out* of a hot surface of carbon more easily than a positive discharge. When an electromotive force is applied to two metallic terminals or electrodes sealed into a good vacuum, it is well known that a certain initial electromotive force has to be applied before any electric current begins to flow through the gas at all. It seems conclusively proved by Mr. Crookes's researches that the nature of an electric discharge through a high vacuum consists in a torrent of electrified particles proceeding from the negative electrode. If this is the case the initial electromotive force required to begin a discharge through such rarefied gas would naturally be reduced by heating the negative electrode, so as to favour and assist the detachment of the charged molecules of that electrode. The effect of heating the negative electrode in facilitating discharge through vacuous spaces has previously been described by W. Hittorf ('Annalen der Physik und Chemie,' vol. 21, 1884, p. 90—139), and it is abundantly confirmed by the above experiments. We may say that a vacuous space bounded by two electrodes—one incandescent, and the other cold—possesses a unilateral conductivity for electric discharge when these electrodes are within a distance of the mean free path of projection of the mole-

* See Professors Ayrton and Perry, 'Proceedings of the Physical Society,' vol. 5, p. 201.

cules which the impressed electromotive force can detach and send off from the hot negative electrode.

This unilateral conductivity of vacuous spaces having unequally heated electrodes has been examined by MM. Elster and Geitel (see 'Wiedemann's Annalen,' vol. 38, 1889, p. 40), and also by Goldstein ('Wied. Ann.,' vol. 24, 1885, p. 83), who in experiments of various kinds have demonstrated that when an electric discharge across a vacuous space takes place from a carbon conductor to another electrode, the discharge takes place at lower electromotive force when the carbon conductor is the negative electrode and is rendered incandescent.

III. "A Milk Dentition in *Orycteropus*." By OLDFIELD THOMAS, Natural History Museum. Communicated by Dr. A. GÜNTHER, F.R.S. Received December 12, 1889.

[Publication deferred.]

Presents, January 9, 1890.

Transactions.

Berlin:—Deutsche Chemische Gesellschaft. Berichte. 1889. Nos. 7–16. 8vo. *Berlin.* The Society.

Königliche Preuss. Akademie der Wissenschaften. Sitzungsberichte. Januar–Juli, 1889. 8vo. *Berlin.* The Academy.

Brussels:—Académie Royale de Médecine. Bulletin. Sér. 4. Tome III. Nos. 5–10. 8vo. *Bruxelles* 1889. The Academy.

Académie Royale des Sciences. Bulletin. Sér. 3. Tomes XVII–XVIII. Nos. 5–11. 8vo. *Bruxelles* 1889. The Academy.

Cambridge:—Philosophical Society. Proceedings. Vol. VI. Part 6. 8vo. *Cambridge* 1889. The Society.

Edinburgh:—Royal Society. Proceedings. Vol. XVI. Pages 257–384. 8vo. *Edinburgh* 1889. The Society.

Florence:—R. Biblioteca Nazionale Centrale. Bollettino delle Pubblicazioni Italiane. Giugno—Dicembre, 1889. 8vo. *Firenze;* Codici Palatini. Vol. I. Fasc. 9–10. Codici Panciatichiani. Vol. I. Fasc. 2. 8vo. *Roma* 1889. The Library.

London:—Anthropological Institute. Journal. Vol. XIX. Nos. 1–2. 8vo. *London* 1889. The Institute.

British Museum. Catalogue of Printed Books.—Academies and Periodical Publications. Folio. *London* 1885–86. The Trustees.