traversed by the current. They show also that when these liquid non-conductors are mixed with the feeble conductor alcohol, the conductivity of the mixture is greater than that of alcohol alone, which offers at least a partial clue to the readiness with which such mixtures are decomposed by the copper-zinc couple.

The very considerable development of heat in these liquids, which conduct the electric current with great difficulty, is a circumstance worthy of notice. In these cases it is evident that it does not result from any chemical change, because the decomposition, if any thing at all, is utterly insignificant in amount.

II. "On the Protrusion of Protoplasmic Filaments from the Glandular Hairs of the Common Teasel (*Dipsacus sylvestris*)." By Francis Darwin, M.B. Communicated by Charles Darwin, F.R.S. Received January 30, 1877.

(Abstract.)

The protoplasmic structures described in the following communication are connected with the glandular hairs or trichomes found on both surfaces of the leaf of the common teasel (*Dipsacus sylvestris*). The trichomes are of two kinds, differing in a marked manner in shape. The form of gland from which alone the protoplasmic filaments issue is shown in the diagram. The gland consists of a multicellular pear-shaped head, supported on a cylindrical unicellular stalk which rests on a projecting epidermic cell. The whole structure projects about $\frac{1}{10}$ of a millimetre ($\frac{1}{250}$ inch) above the surface of the leaf.

The filaments issue from inside the gland-cells, reaching the surrounding medium by passing through the external cell-wall of the gland. The point where protrusion takes place is on the summit of the gland, and usually at the point of junction of several radiating cells at the centre of its dome-like surface. The act of protrusion is rapidly effected; a previously naked gland may be seen to send forth a minute thread of trembling protoplasm, projecting from its summit freely into the surrounding water. The filament grows by clearly visible increments, and may ultimately attain the length of nearly one millimetre. The filaments appear to pass through the substance of the external cell-wall of the glands, as no apertures to allow of their passage have been observed.

Under normal circumstances the filament presents the appearance of a delicate and elongated thread slightly clubbed at its free end, and animated by the perpetual tremble of Brownian movement. The distal end of the filament is often attached to the gland, thus forming a loop. Extremely delicate filaments of great length are often seen entangled in elaborate and complex knots, or several filaments may be seen issuing from a single gland.

The substance of which the filaments are composed is gelatinous, transparent, highly refracting, and devoid of granules. It is in a great measure soluble in alcohol, is stained by tincture of alkanet, and not blackened by osmic acid, and is coloured yellow by iodine. These reactions, when combined with results of various physiological tests, show that the filaments contain resinous matter in some way suspended in protoplasm.

The most remarkable point in the behaviour of the filaments is their power of violently contracting. The act of contraction commences by the filament becoming shorter and thicker at a number of nearly equidistant points, situated close together near the free end of the filament. The curious beading thus produced spreads rapidly down the filament, which ultimately runs violently together into a ball seated on the top of the gland. In other cases contraction takes place without any previous appearance of beading.

Filaments frequently break loose but retain their vitality, and are still capable of contraction although separated from their parent glands; and this observation is of importance, as proving that the movements of the filaments are not governed by forces residing within the glands, but that the filaments are composed of an essentially contractile substance.

The contraction of the filaments is produced by the following causes:—

Dilute acids (from 1 to $\frac{1}{5}$ per cent.)—Sulphuric, hydrochloric, acetic, citric, and osmic acids.

Dilute alkaline solutions ($\frac{1}{4}$ to $\frac{1}{2}$ per cent.)—Carbonates of ammonia, sodium, potassium.

Solutions of gold-chloride $\frac{1}{2}$ per cent., silver nitrate $\frac{1}{4}$ per cent., sulphate of quinine $\frac{1}{10}$ per cent., citrate of strychnia (about) $\frac{3}{4}$ per cent., camphor $\frac{1}{10}$ per cent., the poison of the cobra (about) $\frac{1}{4}$ per cent., iodine $\frac{1}{4}$ per cent.

Glycerine.

Methylated spirits.

Vapour of chloroform.

Heat. The temperatures at which the filaments contract are rather variable, but are all below 57° C.

Electricity. The induced current causes contraction.

Mechanical stimulation.—The filaments contract when pressure is made on the cover-glass.

The evidence derived from the experiments, of which the results are here briefly summarized, appears to be strongly in favour of the view that the filaments contain true living protoplasm, and that the sudden movement above described is a true act of contraction; for if the latter hypothesis is rejected, the only remaining view is that the filaments are so constituted as to be capable of undergoing coagulation, by which contractility is mechanically simulated. But it seems inconceivable that reagents of widely different natures, such as dilute solutions of acetic acid, of camphor, and

of gold-chloride, should produce identical chemical effects. Osmic acid is well known to kill protoplasmic structures without making them contract. This characteristic reaction holds good with the filaments of the teasel when treated with sufficiently powerful solutions of osmic acid (*e.g.* 1 per cent.). When killed in an extended position, they cannot be made to contract with strong acetic acid. This observation is of importance in another way; for it proves that the violent movements caused by dilute acetic acid are of a "vital," and not simply of a chemical nature. Moreover the general character of the reagents and other causes (such as heat, &c.) by which contraction is produced is quite consistent with the belief that the filaments are protoplasmic in nature.

An important series of phenomena are produced by the following fluids:—dilute solutions ($\frac{1}{2}$ or $\frac{1}{4}$ per cent.) of carbonates of ammonia, potassium, and sodium, and infusion of raw meat. If a filament under the microscope is treated with a drop of $\frac{1}{4}$ per cent. solution of carbonate of ammonia, the following changes occur. The filament contracts, but almost instantly recovers itself, and is once more protruded. The filament, however, does not regain its original form or general appearance: instead of consisting of thin elongated ropes of a highly refracting substance, it is converted into balloon-like or sausage-shaped masses of very transparent, lowly refracting matter. These transparent masses are remarkable for the spontaneous changes of form and other quasi-amœboid movements which occur among them.

Dilute infusions of meat cause a similar effect, astonishing quantities of transparent matter being produced.

It has been shown that the filaments are protoplasmic bodies, containing a large quantity of resinous matter. The question next arises, with what process in plant-physiology is the protrusion of filaments homologous?

The leaf-glands of the teasel are similar in general structure to many glandular hairs which produce resinous and slimy secretions, and, like these glands, they contain bright drops of secreted resin lying in the centres of the gland-cells; they also resemble many glandular hairs in being often capped with accumulations of secreted matter. Now these accumulations stain red with alkanet, yellow with iodine, and are largely soluble in alcohol; that is to say, they consist of substances which have the same reactions as the filaments. There is, in fact, no doubt that the caps of resinous matter on the teasel-glands are produced by the accumulation of dead filaments. According to this view, the act of protrusion is essentially a process of secretion: the resin issues from the gland-cells, mingled with a certain amount of true protoplasm; and it is only from the death of the living or protoplasmic part of the filaments that the resinous accumulation results. This view of the act of protrusion corresponds with the theory of secretion held by some physiologists, viz. that secreted matter is produced by the dissolution or death of proto-

plasm—that, for instance, the oil in a fat-cell is the result of the disintegration of a plastid or individualized mass of protoplasm formed in the cell by endogenous cell-formation.

The protrusion of protoplasmic filaments from the glands of the teasel appears to bear an obscure relationship to the phenomena of "aggregation" in *Drosera* and several other plants. In both processes we have homogeneous highly refracting protoplasmic masses, which undergo amœboid movements, and are in some unknown way connected with the absorption of nitrogenous matter. In *Drosera* the protoplasmic masses remain within certain cells; in *Dipsacus* they are protruded through the cell-wall.

When we begin to inquire as to the function of the filaments, the answer seems at first to be sufficiently plain; but this is very far from being the case. The connate leaves of the teasel form cup-like cavities, which become full of rain and dew and in which many drowned insects accumulate. The glands at the base of the leaves are thus exposed to a highly nitrogenous fluid. And since such fluids are known to produce a remarkable effect on the filaments exposed to them, it seems probable that the filaments are in some way connected with the assimilation of food material. It seems probable that, either with or without the assistance of their filaments, the glands do absorb some nitrogenous matter; for changes of their cell-contents occasionally occur which can only thus be interpreted. But on account of the rarity and uncertainty of these aggregation changes *within the glands*, but little weight must be allowed to the phenomena as a proof of the absorbing capacity of the glands. Some other points in the structure of the plant render it almost certain that the connate leaves are specially adapted to serve some useful purpose. Kerner is probably right in believing that the "cups" of the teasel are of use to the plant in keeping off nectar-stealing ants and other wingless insects; but unless this is their only function, it seems probable that the connate leaves have been to a certain extent adapted for the capture of insects whose decaying remains are absorbed by the plant. The leaves are smooth and steeply inclined, and form a pair of treacherous slides leading down to a pool of water.

It is worthy of note that the leaves of the first year's growth, which do not form cups, are not smooth, but bristle with long sharp hairs; moreover in *Dipsacus pilosus* the leaves (of the second year's growth) are not sufficiently connate to form cups, and they also are rough with hairs. These facts seem to show that the smoothness of the second-year leaves in *D. sylvestris* is a specially acquired quality. Another special point of structure in *D. sylvestris* may be noted. The stems are everywhere armed with sharp prickles, except where they are covered by the water in the "cups;" and here they are quite smooth, so that no ladder of escape is afforded to the drowning victims. Even if we grant from the above considerations that the filaments protruded from the

glands are in some way connected with the absorption of nitrogenous matter from the putrid fluid in the cups, we are far from understanding the whole of the problem; for precisely similar *filament-protruding* glands are found on the seedling leaves of *D. sylvestris* and on the second year's leaves of *D. pilosus*; and as no "cups" are formed in either of these cases, the filaments cannot be connected with absorption of the products of decay. The only view which suggests itself is that the filaments absorb ammonia from the dew and rain. Recent researches have shown that certain leaves have the power of absorbing an appreciable quantity of ammonia; and this fact lends some probability to the view above advanced.

To recapitulate. Protoplasmic filaments are protruded from the leaf-glands of the teasel; and the only theory which seems at all capable of connecting the observed facts is the following:—That the glands on the teasel were aboriginally (*i. e.* in the ancestors of the Dipsacaceæ) mere resin-excreting organs; that the protoplasm which comes forth was originally a necessary concomitant of the secreted matters, but that, from coming in contact with nitrogenous fluids, it became gradually adapted to retain its vitality and to take on itself an absorptive function; and that this power, originally developed in relation to the ammonia in rain and dew, was further developed in relation to the decaying fluid accumulating within the connate leaves of the plant.

III. "On the Magnifying-power of the Half-prism as a means of obtaining great Dispersion, and on the General Theory of the 'Half-prism Spectroscope.'" By W. H. M. Christie, M.A., Fellow of Trinity College, Cambridge. Communicated by Dr. Huggins. Received January 25, 1877.

On account of the oblique incidence of the rays on the isosceles prism and the consequent diminution of the aperture of the collimator, a "half-prism," formed by dividing an isosceles prism by a plane perpendicular to the base, has frequently been employed for the commencement of the train of prisms, and also for the end, though apparently without due consideration of the effect of the "half-prism" on the dispersion of the other prisms preceding in the train. This is a matter of some importance; for it will be found that when the angles of incidence and emergence are unequal (as in the half-prism), the angular separation between two pencils of parallel rays is increased or diminished according as the angle of emergence is greater or less than the angle of incidence. In consequence of this the angle between the pencils corresponding to any two lines in the spectrum, *e. g.* the two D lines, will be increased by passing through a half-prism (independently of the effect of ordinary dispersion) if the perpendicular face be turned towards the slit. At the same time the