chemical nature, cleanness, and dust) upon the deposition of dew and the determination of the dew-point.

(4) The behaviour of the wet-bulb thermometer, when covered with water, in an atmosphere of water vapour and of ice vapour.

(5) The influence of radiant heat on wet bulbs covered with ice or water.

(6) The increase of the reading of the wet-bulb thermometer due to any compression that may result from the formation of the ice film on the muslin covering; its dependence on the muslin rather than on the ice.

(7) The determination of the tension of water vapour and ice vapour at and below freezing.

(8) The rate of diffusion of ice vapour as distinguished from aqueous vapour, and also the rates of evaporation from ice and water at the same temperature.

(9) The condensation of vapour in a region free from solid nuclei, and after the temperature has been reduced to, or below, the point of saturation so that the vapour is in a state of unstable equilibrium.

(10) The change that can be produced in the pressure and temperature of a confined volume of *dust free* "dry saturated" steam or other vapour by the introduction of dust particles having various chemical and physical properties. This is the secret of the action of the "cloud engine" of Montgomery J. Storms.

(11) Invention of improved and practical methods of obtaining the moisture contents of the air—especially at low temperatures. —C. F. M.

(12) Invention of recording thermometers, barometers, and hygrometers adapted by their accuracy, their extreme lightness, and the quickness with which they respond to atmospheric changes, to be carried up by balloons and by kites in investigations into the condition of the higher atmosphere.—C. F. M.

(13) The development and perfecting of the art of constructing and flying kites with a view of rendering this practically applicable in investigations of the condition of the atmosphere at moderate elevations.—C. F. M.

(14) Invention of improved and practical devices for the registration of sunshine and cloudiness, both day and night.—C. F. M.

(15) Invention of devices recording exactly the beginnings and endings, amounts and rates, of precipitation, &c.—C. F. M.

(16) Explanation of the formation of ice-needles in gravelly soil, and determination of the amount of heat and moisture retained at the earth's surface by this formation.

(17) Explanation of the origin of the hollow tubes in the ice-needles and the similar hollow tubes in snow crystals and the analogous holes in hailstones.

(18) The connection between atmospheric conditions and the formation of snow crystals of different shapes and sizes.

(19) The radiating and conducting powers of layers of snow freshly fallen or old and granulated.

(20) The radiation and absorption of heat by dustless, dry air, and also by ordinary atmospheric air containing dust and vapour or ice particles.

(21) Investigation of the formula for computing the velocity and the pressure of the wind from various forms of anemometers, especially the whirling, the pressure, and the suction anemometers.

(22) Invention of the most convenient and cheapest form of nephoscope for determining either direction or velocity, or both these elements of the motion of the clouds.

(23) Investigation of the correction to be made to the record of the ordinary cylindrical rain and snow gauge for the effect of the wind in drifting the rain, and especially the snow

(24) Study of the temperature of the soil at different depths from the surface-layer down to three feet and under different conditions, as to moisture-content, sunshine, and wind.

(25) Invention of better methods of determining at any moment the temperature and moisture at any depth in the soil.

(26) Determination of the quantity of water evaporated from natural surfaces, especially ocean water, ice or snow, fresh water, and forests or cultivated fields, and its relation to humidity, temperature, and wind.

(27) Improvements in the actinometer and a series of determinations of the amounts of heat received at any point, both from the sun directly and from the clouds and the atmosphere by reflection or radiation.

(28) Observations of the polarisation and the intensity of blue sky light and comparison with optical theories.

(29) Instrumental methods for recording some of the various chemical effects directly produced by solar radiation, and which are of special importance in the growth of plants, the decomposition of the soil, and the purification of water.

(30) A series of determinations or, still better, a continuous record of the simultaneous differences of electric potential between the earth's surface, and several points in the free atmosphere, one hundred feet apart, vertically, meridionally, and prime-vertically.

(31) A similar series for several points beneath the earth's surface as to their electro-magnetic condition, and a correlation of the distribution of electric conditions with the electric currents in the air and the earth.

(32) A study of the scintillation of the stars and its relation to atmospheric conditions.

(33) A study of the apparent acoustic opacity of the atmosphere at certain places and times.

(34) An explanation of the sounds attending large aerolites, and an explanation as to what may be learned therefrom regarding the upper atmosphere and in regard to the improvement of fog signals.

(35) A study of the formation of halos, parhelia, and corona, by the action of snow crystals and water-drops on sunlight.

(36) Investigation of the first step in the process of convection, as it occurs in the free atmosphere by which small currents of warm air, rising as slender rolls and whirls, mix with the cooler air, and are broken up within a few feet of the earth's surface; a determination of the limit at which such convection becomes inappreciable.

(37) A study of the larger convection currents, their relation to the horizontal motion, the extent to which they retard and accelerate the motions or increase and decrease the pressures in the upper and lower strata.

THE SENSES OF INSECTS.[1]

OF the five ordinary senses recognised in ourselves and most higher animals, insects have, beyond all doubt, the sense of sight, and there can be as little question that they possess the senses of touch, taste, smell, and hearing. Yet, save perhaps that of touch, none of these senses, as possessed by insects, can be strictly compared with our own, while there is the best of evidence that insects possess other senses which we do not, and that they have sense organs with which we have none to compare. He who tries to comprehend the mechanism of our own senses—the manner in which the subtler sensations are conveyed to the brain—will realise how little we know thereof after all that has been written. It is not to be wondered at, therefore, that authors should differ as to the nature of many of the sense organs of insects, or that there should be little or no absolute knowledge of the manner in which the senses act upon them. The solution of psychical problems may never, indeed, be obtained, so infinitely minute are the ultimate atoms of matter; and those who have given most attention to the subject must echo the sentiment of Lubbock, that the principal impression which the more recent works on the intelligence and senses of animals leave on the mind is that we know very little, indeed, on the subject. We can but empirically observe and experiment and draw conclusions from well attested results.

Sight.—Taking first the sense of sight, much has been written as to the picture which the compound eye of insects produces upon the brain or upon the nerve centres. Most insects which undergo complete metamorphoses possess in their adolescent states simple eyes or ocelli, and sometimes groups of them of varying size and in varying situations. It is difficult, if not impossible, to demonstrate experimentally their efficiency as organs of sight; the probabilities are that they give but the faintest impressions, but otherwise act as do our own. The fact that they are possessed only by larvæ which are exposed more or less fully to the light, while those larvæ which are endophytous, or otherwise hidden from light, generally lack them, is in itself proof that they perform the ordinary functions of sight, however low in degree. In the imago state the great majority of insects have their simple eyes in addition to the compound eyes. In many cases, however, the former are more or less covered with vestiture, which is another evidence that their function is of a low

[1] From an address on "Social Insects," delivered by Prof. C. V. Riley, as President of the Biological Society of Washington (Reprinted (slightly condensed) from *Insect Life*, vol. vii. No. 1.")

order, and lends weight to the view that they are useful chiefly for near vision and in dark places. The compound eyes are prominent and adjustable in proportion as they are of service to the species, as witness those of the common house-fly and of the Libellulidæ or dragon-flies. It is obvious from the structure of these compound eyes that impressions through them must be very different from those received through our own, and, in point of fact, the experimental researches of Hickson, Plateau, Tocke and Lemmermann, Pankrath, Exner, and Viallanes have practically established the fact that while insects are shortsighted and perceive stationary objects imperfectly, yet their compound eyes are better fitted than the vertebrate eye for apprehending objects set in relief or in motion, and are likewise keenly sensitive to colour.

So far as experiments have gone, they show that insects have a keen colour sense, though here again their sensations of colour are different from those produced upon us. Thus, as Lubbock has shown, ants are very sensitive to the ultra-violet rays of the spectrum, which we cannot perceive, though he was led to conclude that to the ant the general aspect of nature is presented in an aspect very different from that in which it appears to us. In reference to bees, the experiments of the same author prove clearly that they have this sense of colour highly developed, as indeed might be expected when we consider the part they have played in the development of flowers. While these experiments seem to show that blue is the bee's favourite colour, this does not accord with Albert Müller's experience in nature, nor with the general experience of apiarians, who, if asked, would very generally agree that bees show a preference for white flowers.

Touch.—The sense of touch is supposed to reside chiefly in the antennæ or feelers, though it requires but the simplest observation to show that with soft-bodied insects the sense resides in any portion of the body, very much as it does in other animals.

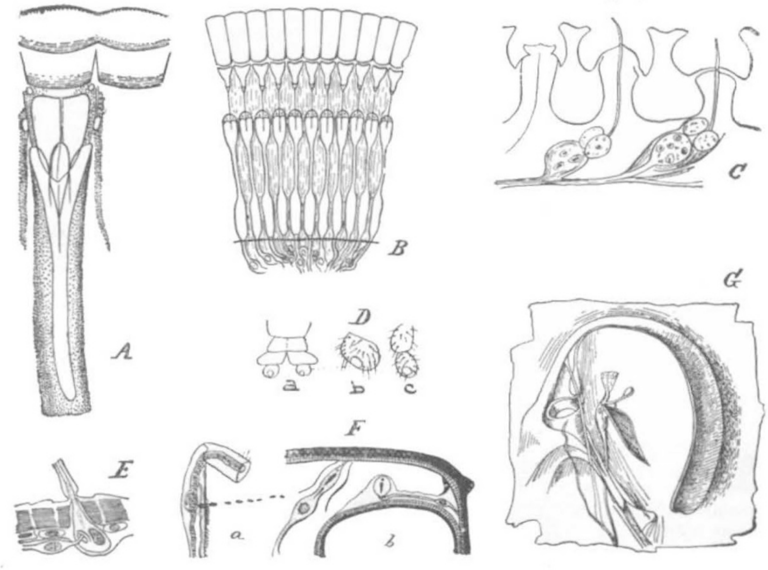

FIG. 1.—Sensory Organs in Insects: A, one element of eye of cockroach (after Grenacher); B, diagrammatic section of compound eye in insect (after Miall and Denny); C, organs of smell in Melolontha (after Kraepelin); D, *a*, *b*, sense organs of abdominal appendages of Chrysopila; *c*, small pit on terminal joint of palpus in Perla (after Packard); E, diagram of sensory ear of insect (after Miall and Denny); F, auditory apparatus of Meconema; *a*, fore tibia of this locust; *b*, diagrammatic section through same (after Graber); G, auditory apparatus of Caloptenus, seen from inner side, showing tympanum, auditory nerve, terminal ganglion, stigma, and opening and closing muscle of same, as well as muscle of tympanum membrane (after Graber).—All very greatly enlarged.

In short, this is the one sense which, in its manifestations, may be conceded to resemble our own. Yet it is evidently more specialised in the maxillary and labial palpi and the tongue than in the antennæ in most insects.

Taste.—Very little can be positively proved as to the sense of taste in insects. Its existence may be confidently predicated from the acute discrimination which most monophagous species exercise in the choice of their food, and its location may be assumed to be the mouth or some of the special trophial organs which have no counterpart among vertebrates. Indeed, certain pits in the epipharynx of many mandibulate insects and in the ligula and the maxillæ of bees and wasps are conceded by the authorities to be gustatory.

Smell.—That insects possess the power of smell is a matter of common observation, and has been experimentally proved. The many experiments of Lubbock upon ants left no doubt in his mind that the sense of smell is highly developed in them. Indeed, it is the acuteness of the sense of smell which attracts many insects so unerringly to given objects, and which has led many persons to believe them sharp-sighted. Moreover, the innumerable glands and special organs for secreting odours furnish the strongest indirect proof of the same fact. Some of these, of which the osmaterium in Papilionid larvæ and the eversible glands in Parorgyia are conspicuous examples, are intended for protection against inimical insects or other animals; while others, possessed by one only of the sexes, are obviously intended to please or attract. A notable development of this kind is seen in the large gland on the hind legs of the males of some species of Hepialus, the gland being a modification of the tibia, and sometimes involving the abortion of the tarsus, as in the European *H. hectus* (L.) and our own *H. behrensi* (Stretch.) The possession of odoriferous glands, in other words, implies the pos-

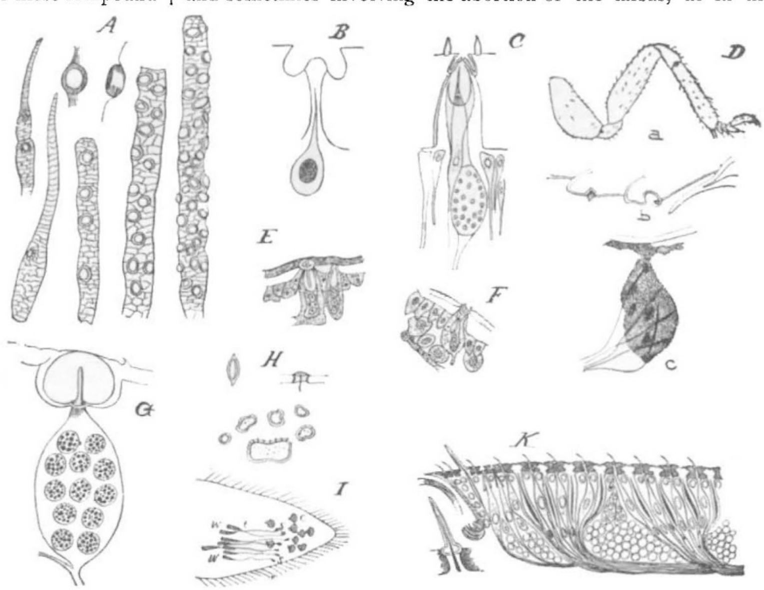

FIG. 2.—Sensory Organs in Insects: A, sensory pits on antennæ of young wingless *Aphis persicæniger* (after Smith); B, organ of smell in May beetle (after Hauser); C, organ of smell in Vespa (after Hauser); D, sensory organs of *Termes flavipes*; *a*, tibial auditory organ; *c*, enlargement of same; *b*, sensory pits of tarsus (after Stokes); E, organ of taste in maxillæ of *Vespa vulgaris* (after Will); F, organ of taste in labium of same insect (after Will); G, organ of smell in Caloptenus (after Hauser); H, sensory pilose depressions on tibia of Termes (after Stokes); I, terminal portion of antennæ of *Myrmica ruginodis*; *c*, cork-shaped organs; *s*, outer sac; *t*, tube; *w*, posterior chamber (after Lubbock); K, longitudinal section through portion of flagellum of antennæ of worker bee, showing sensory hairs and supposed olfactory organs (after Cheshire). All very greatly enlarged.

session of olfactory organs. Yet there is among insects no one specialised olfactory organ as among vertebrates; for while there is conclusive proof that this sense rests in the antennæ with many insects, especially among Lepidoptera, there is good evidence that in some Hymenoptera it is localised in an ampulla at the base of the tongue, while Graber gives reasons for believing that in certain Orthoptera (Blattidæ) it is located in the anal cerci and the palpi.

Hearing.—In regard to the sense of hearing, the most casual experimentation will show (and general experience confirms it) that most insects, while keenly alive to the slightest movements or vibrations, are for the most part deaf to the sounds which affect us. That they have a sense of sound is equally certain. but its range is very different from ours. A sensitive flame, arranged for Lubbock by the late Prof. Tyndall, gave no response from ants, and a sensitive microphone, arranged for him by Prof. Bell, gave record of no other sound than the patter of feet in walking. But the most sensitive tests we can experimentally apply may be, and doubtless are, too gross to adjust themselves to the finer sensibilities of such minute, active, and nervous creatures. There can be no question that insects not only produce sounds, but receive the impression of sounds entirely beyond our own range of perception, or, as Lubbock puts it, that "we can no more form an idea of than we should have been able to conceive red or green if the human race had been blind. The human ear is sensitive to vibrations reaching at the outside to 38,000 in a second. The sensation of red is produced when 470 millions of millions of vibrations enter the eye in a similar time; but between these two numbers vibrations produce on us only the sensation of heat. We have no especial organ of sense adapted to them." It is quite certain that ants do make sounds, and the sound-producing organs on some of the abdominal joints have been carefully described. The fact that so many insects have the power of producing sounds that are even audible to us, is the best evidence that they possess auditory organs. These are, however, never vocal, but are situated upon various parts of the body, or upon different members thereof.

Special Sense and Sense Organs.—While from what has preceded it is somewhat difficult to compare the more obvious senses possessed by insects with our own, except perhaps in the sense of touch, it is, I repeat, just as obvious to the careful student of insect life that they possess special senses which it is difficult for us to comprehend. The sense of direction, for instance, is very marked in the social Hymenoptera which we have been considering, and in this respect insects remind us of many of the lower vertebrates which have this sense much more strongly developed than we have. Indeed, they manifest more especially what has been referred to in man as a sixth sense, viz. a certain intuition which is essentially psychical, and which undoubtedly serves and acts to the advantage of the species as fully, perhaps, as any of the other senses. Lubbock demonstrated that an ant will recognise one of its own colony from among the individuals of another colony of the same species; and when we consider that the members of a colony number at times, not thousands, but hundreds of thousands, this remarkable power will be fully appreciated.

The neuter Termites are blind, and can have no sense of light in their internal or subterranean burrowings; yet they will undermine buildings, and pulverise various parts of elaborate furniture without once gnawing through to the surface; and those species which use clay, will fill up their burrowings to strengthen the supports of structures which might otherwise fall and injure the insects or betray their work. The bat in a lighted room, though blinded as to sight, will fly in all directions with such swiftness and infallible certainty of avoiding concussion or contact, that its feeling at a distance is practically incomprehensible to us.

Telepathy.—But however difficult it may be to define this intuitive sense which, while apparently combining some of the other senses, has many attributes peculiar to itself, and however difficult it may be for us to analyse the remarkable sense of direction, there can be no doubt that many insects possess the power of communicating at a distance, of which we can form some conception by what is known as telepathy in man. This power would seem to depend neither upon scent nor upon hearing in the ordinary understanding of these senses, but rather on certain subtle vibrations as difficult for us to comprehend as is the exact nature of electricity. The fact that men can telegraphically transmit sound almost instantaneously around the globe, and that his very speech may be telephonically transmitted, as quickly as uttered, for thousands of miles, may suggest something of this subtle power, even though it furnish no explanation thereof.

The power of sembling amongst certain moths, for instance, especially those of the family Bombycidæ, is well known to entomologists, and many remarkable instances are recorded. I am tempted to put on record for the first time an individual experience which very well illustrates this power, as on a number of occasions when I have narrated it most persons not familiar with the general facts have deemed it remarkable. In 1863 I obtained from the then Commissioner of Agriculture, Colonel Capron, eggs of *Samia cynthia*, the Ailanthus silkworm of Japan, which had been recently introduced by him. I was living in Chicago at the time, and in my garden there grew two Ailanthus trees, which were the cause of my sending for the aforesaid eggs. I had every reason to believe that there were no other eggs of this species received in any part of the country within hundreds of miles around. It seemed a good opportunity to test the power of this sembling, and after rearing a number of larvæ I carefully watched for the appearance of the first moths from the cocoons. I kept the first moths separate, and confining a virgin female in an improvised wicker cage out of doors on one of the Ailanthus trees. On the same evening I took a male to another part of the city, and let him loose, having previously tied a silk thread around the base of the abdomen to insure identification. The distance between the captive female and the released male was at least a mile and a half, and yet the next morning these two individuals were together.

Now, in the moths of this family the male antennæ are elaborately pectinate, the pectinations broad and each branch minutely hairy (see Fig. 5, *a.*) These feelers vibrate incessantly, while in the female, in which the feelers are less complex, there is a similar movement connected with an intense vibration of the whole body and of the wings. There is, therefore, every reason to believe that the sense is in some way a vibratory sense, as, indeed, at base is true of all senses, and no one can study the wonderfully diversified structure of the antennæ in insects,

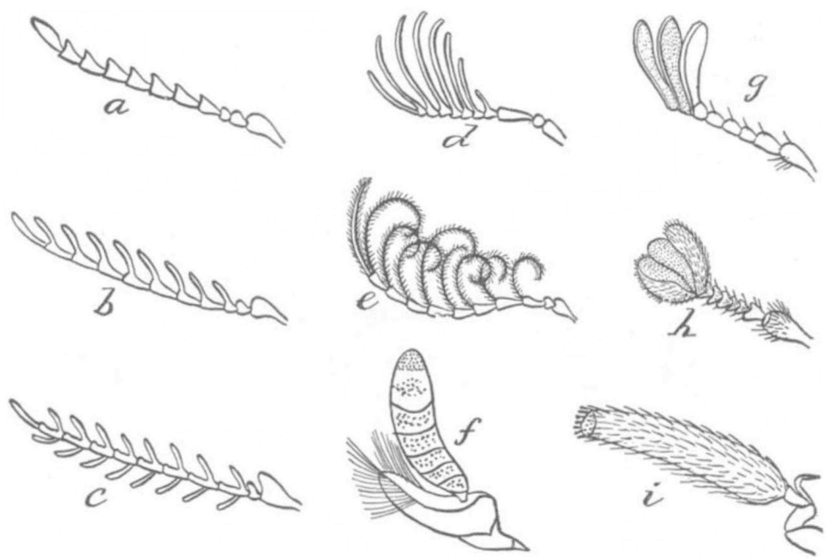

FIG. 3.—Some Antennæ of Coleoptera: *a*, Ludius; *b*, Corymbites; *c*, Prinocyphon; *d*, Acneus; *e*, Dendroides; *f*, Dineutes; *g*, Lachnosterna; *h*, Bolbocerus; *i*, Adranes (after Le Conte and Horn).—All greatly enlarged.

especially in males, as very well exemplified in some of the commoner gnats (see Fig. 5, *d*, *e*), without feeling that they have been developed in obedience to, and as a result of, some such subtle and intuitive power as this of telepathy. Every minute ramification of the wonderfully delicate feelers of the male mosquito, in all probability, pulsates in response to the piping sounds which the female is known to produce, and doubtless through considerable distance.

There is every justification for believing that all the subtle cosmic forces involved in the generation and development of the

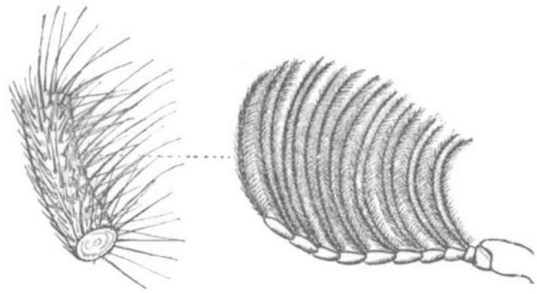

FIG. 4.—Antenna of male Phengodes with portion of ray.—Greatly enlarged (original).

highest are equally involved in the production and building up of the lowest of organisms, and that the complexing and compounding and specialisation of parts have gone on in every possible and conceivable direction, according to the species. The highly developed and delicate antennæ in the male Chironomus, for instance, may be likened to an external brain, its ramifying fibres corresponding to the highly complicated pro-

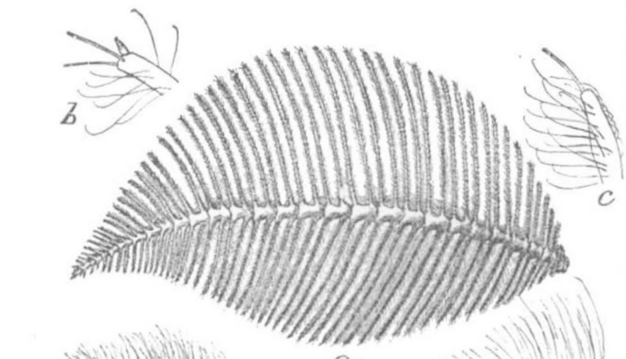

FIG. 5.—Some Antennæ of Insects: *a*, Telea polyphemus, male, × 3; *b* and *c*, tip of the rays of same—still more enlarged; *d*, Chironomus × 6; *e*, section of same—still more enlarged (original).

cesses that ramify from the nerve cells in the internal brains of higher animals, and responding in a somewhat similar way to external impressions. While having no sort of sympathy with the foolish notions that the spiritualists proclaim, to edify or terrify the gullible and unscientific, I am just as much out of sympathy with that class of materialists who refuse to recognise that there may be and are subtle psychical phenomena beyond the reach of present experimental methods. The one class too readily assumes supernatural power to explain abnormal phenomena; the other denies the abnormal, because it, likewise, is past our limited understanding.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Harkness Scholarship in Geology has been awarded to Arthur William Rogers, of Christ's College.

Mr. J. S. Gardiner, of Caius College, has been chosen to occupy the University's table at the Naples Zoological Station for six months from October 1.

The Newall Observer reports that the fine spectroscope designed for use with the Newall Telescope is now ready, and that the preliminary trials of it have been satisfactory. The mounting has been made by the Cambridge Scientific Instrument Company, and the optical parts by Mr. Brashear, of Alleghany.

Mr. F. Darwin, Mr. W. G. P. Ellis, Prof. Liveing, Mr. T. B. Wood, Prof. M. Foster, Mr. A. Eichholz, Mr. A. E. Shipley, Mr. C. Warburton, Prof. Hughes, Mr. P. Lake, Mr. O. P. Fisher, Mr. J. Owen, Mr. R. Menzies, and Mr. C. B. Fisher, have been appointed Examiners in the Science and Art of Agriculture for the University Diploma. The examination will be held in July.

Sir David L. Salomons, Bart., has founded, in connection with Caius College, a Scholarship in Engineering. The first award will be made in October. The value of the Scholarship is £40 a year for three years. The Salomons Scholar must become a candidate for the Mechanical Sciences Tripos. Applications for further information should be made to the Tutors of Caius College.

THE Conference on Technical Education held at the Society of Arts last Thursday, resulted in the adoption of the following resolution:—"That in the opinion of this meeting it is desirable that provision should be made for examination and inspection in the subjects of instruction undertaken by technical instruction committees but not at present included in the schemes of the Science and Art Department, the City and Guilds of London Institute, and the Society of Arts, and that with the object of giving effect to the same this conference recommends that a representative committee be appointed to draw up a report and prepare recommendations on the whole subject."

SCIENTIFIC SERIALS.

American Journal of Science, June.—The preparation of perchloric acid and its application to the determination of potassium, by D. Albert Kreider. The difficulty attending the removal of the potassium in the ordinary preparation of this acid from potassium chlorate may be overcome by using the sodium salt instead. The insolubility of chloride of sodium in strong hydrochloric acid, with the aid of the acid-proof Gooch crucible, affords a means for the liberation of the perchloric acid and the removal of the greater part of the sodium in one operation. Sodium chlorate is heated until it gives off oxygen. When all the possible oxygen has been given off, and only the chloride and the perchlorate remain, the residue is treated with strong hydrochloric acid and filtered. The perchloric acid is thus liberated, and the sodium precipitated as chloride. The liquid is decanted, and undergoes the same operation again. The solution, containing hydrochloric and perchloric acids and a small amount of sodium chloride, is evaporated till the former acid is driven off and the heavy white fumes of the perchloric acid appear. It is then ready for potassium determinations, with which the small residue of sodium does not interfere. The filtering is done by means of a Gooch crucible, and the operation requires less time and attention than the old process, and is much less dangerous.—Mode of growth and development of the grapholitic genus *Diplograptus*, by R. Ruedemann By the possession of a pneumatocyst and the arrangement of the reproductive organs at the bases of the stipes, the colonial stocks of *Diplograptus* have a general similarity to those of certain *Siphonophoræ*, while the chitinous structure of the hydrothecæ and gonangia can only be referred to the Sertularians. It thus becomes evident that the genus *Diplograptus*, like so many palæozoic fossils, has the combined properties of different groups, thus giving valuable hints in regard to the common ancestors of those groups.—On the elevation along the Rocky Mountain range in British America since the close of the Cretaceous period, by Dr. G. M. Dawson. In the mountains, the cretaceous rocks have been involved in all the flexure, faulting, and overthrust suffered by the Palæozoic; and both in the mountains and foothills these rocks are found at all angles up to vertical, and even overturned.