assumes the form of a mace, and later the anterior end further expands to form a relatively large disk, while the remainder of the original fibre persists as a slender ribbon-shaped appendage. As the head of the club enlarges to form a disk, it passes through an indistinct cup stage, which somewhat resembles the cups of the adult *Raia fullonica*, hence it may be inferred that in *Raia fullonica* the organ has been arrested in its development. The conversion of the muscular fibre into a club is largely caused by the increase at its anterior end of muscle corpuscles. These corpuscles eventually arrange themselves, either in front of the head of the club, to give rise to the electric plate, or they migrate backwards to form at the junction of the head of the club with its stem the alveolar layer. The striated layer, which is from the first devoid of nuclei, seems to be derived from the anterior striated portion of the club.

The gelatinous tissue between the disks and the connective tissue investing them, are derived from the embryonic connective tissue developing disks.

III. "On the Occurrence of Aluminium in Certain Vascular Cryptogams." By A. H. Church, M.A., F.C.S. Communicated by Dr. J. H. Gilbert, F.R.S. Received March 29, 1888.

Most of the older and fairly complete analyses of plant-ashes disclosed the presence of alumina in sensible quantities. Gradually, however, as analytical methods became more exact, it was generally recognised that this constituent had been derived from extraneous sources and not from the plants themselves; alumina had in fact been introduced by the employment of glass and porcelain vessels, of impure reagents, and of imperfectly cleansed vegetable products. Even when traces of this oxide were obtained in analyses conducted under the most favourable conditions, an adventitious origin was assigned to them, and so the item of alumina disappeared entirely from the tables of the constituents of plant-ashes. Yet there were some conspicuous exceptions, although these were confined to certain cryptogams. For Ritthausen in 1851 ('Journ. Prakt. Chem.,' vol. 53, p. 413) found "much alumina" in the ash of *Lycopodium complanatum*, Linn., while Alderholdt in 1852 ('Ann. Chem. Pharm.,' vol. 82, p. 111) determined the percentage of alumina in the ash of the same Lycopodium to be 51·85 in the plant when gathered in March, and 57·36 when collected in November. The same chemist found 26·65 per cent. of alumina in the ash of *Lycopodium clavatum*. Again, in 1856, Solms-Laubach found ('Ann. Chem. Pharm.,' vol. 100, p. 297) in the ash of *L. clavatum* 27 per cent. and in the ash of *L. complana-*

tum, var. *Chamæcyparissus*, 54 per cent. of alumina. These results, with others by Arosenius, are conclusive as to the occurrence in notable proportion of alumina in the ash of certain Lycopodia. But when Solms-Laubach records in the ash of *Selaginella kraussiana*, A. Br. (erroneously described as *Lycopodium denticulatum*) the occurrence of 2 per cent. of alumina, we may regard the observation as likely to be incorrect; the same remark applies to the supposed discovery of a similar proportion of this earth in the ash of *Aspidium filix-mas* and of *Athyrium filix-fœmina*. And when the ashes of these plants were examined by modern methods, and with all the precautions which improved analytical processes require, then alumina can scarcely be recognised qualitatively in them. In one of the species of *Selaginella*, however, which I examined, I found a weighable trace of alumina, namely, 0·26 part in 100 parts of the ash. This plant, grown at Kew, was *Selaginella martensii*, var. *robusta* (the *compacta* of A. Braun). The ash was large in amount, namely, 11·66 per cent. in the dry plant; besides the 0·26 per cent. of alumina in it, there was 41·03 per cent. of silica ('Chemical News,' vol. 30, 1874, p. 137). In pursuing this inquiry, I examined, with every possible precaution to ensure exactness, three British species of *Lycopodium* all obtained from the neighbourhood of Shap in Westmoreland, as well as the single species of Selaginella which belongs to Britain. This last plant, now known as *Selaginella spinulosa*, A. Br., was formerly called *Lycopodium spinulosum*; my supply came from Largo Links in Fifeshire. The following figures represent the percentages which I obtained :—

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
Lycopodium alpinum	3·68	33·50	10·24
L. clavatum	2·80	15·24	6·40
L. Selago................	3·20	7·29	2·53
Selaginella spinulosa	3·44	none	6·67

All these results pointed unmistakeably to the conclusion that while alumina was an important mineral constituent of many species of *Lycopodium*, it was practically absent from Selaginella. This distinction was confirmed by an analysis of *L. cernuum*, which I subsequently made. This species belongs to a group of the genus *Lycopodium*, quite distinct botanically from the group to which *L. alpinum* and *L. clavatum* belong, and also distinct from the *L. selago* group and the *L. complanatum* group. The following are the figures yielded by this plant :—

	100 parts of ash contained	
	Al_2O_3.	SiO_2.
**Lycopodium cernuum*, Linn.	16·09	30·25

I found alumina (qualitatively) in the ash of another member of the *L. cernuum* group, namely, *L. casuarinioides*, Spring, from Mount Ophir, Malacca, but the quantity of material at my disposal was too small to admit of quantitative determination. So far my results were strongly confirmatory of my conclusion that alumina was characteristic of *Lycopodium*, and absent from *Selaginella*. But this opinion was soon seriously shaken by an analysis of two exotic species of *Lycopodium*, namely, *L. Phlegmaria*, Linn., and *L. billardieri*, Spring. These plants were examined with the following results:—

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
**Lycopodium Phlegmaria* ..	4·08	0·45	—
**L. billardieri*	5·46	trace	3·14

On obtaining these results I abandoned the further prosecution of the inquiry, it being obvious that alumina could no longer be regarded as a characteristic ingredient of the ash distinguishing *Lycopodium* from *Selaginella*. But when Mr. J. G. Baker's work on the 'Fern Allies' was published last year I turned to the classification of the ninety-four species of *Lycopodium* there described, and found that these last-named plants belonged to a group containing eighteen species, all of which are epiphytic! It was clear that, having no direct access to the soil, these plants could obtain alumina only from their living hosts, which in all probability contained none or mere traces. The anomalous absence of this constituent from these two Lycopodia was thus in a measure explained; at all events, it was proved that alumina was not essential to all the species of this genus.†

The present research was extended by examining plants more or less closely related to the two genera under discussion. Following the classification of Sachs ('Text-book of Botany,' edited by S. H.

* The analyses, in the present paper, to which an asterisk is prefixed, have not been previously published.

† The occurrence of a high proportion of alumina in the mineral constituents of those coals which give the smallest proportion of ash loses much of its significance when the mode of the formation of coal is considered. It is impossible to feel sure that this ash is essential and not intrusive. The so-called Lycopods of the Carboniferous Period are, moreover, now believed to belong to the *Selaginaceæ*. Of course it is possible that many of the plants of that remote geological epoch may have absorbed an element which their recent representatives refuse.

Vines, 2nd Ed., 1882), we have *Equisetum*, *Ophioglossum*, *Salvinia*, and *Marsilea*, on one side of *Lycopodium*, with *Psilotum* and then *Selaginella* on the other—omitting, however, several families, including the true ferns. The results were negative.

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
Equisetum maximum	20·02	none	62·95
Ophioglossum vulgatum ..	8·25	none	5·32
**Salvinia natans*	16·82	1·86	6·71
**Marsilea quadrifoliata* ...	11·66	0·54	0·88

The alumina found in *Salvinia* was probably due to the presence of traces of soil from which it was found impossible to free this floating water-plant. Both the Salvinia and the Marsilea were grown in the lily house, Kew, and I have to thank the Director of the Royal Gardens for the material which I submitted to analysis.

The genus *Psilotum* has been mentioned as botanically near to *Lycopodium;* it contains but two species, one of which was examined for alumina with a negative result.

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
Psilotum triquetrum	5·06	trace?	3·77

After *Psilotum* follows *Phylloglossum*, of which one species only has been recognised; this plant is too rare and too minute to be available for analysis; the same remark applies to the allied species *Tmesipteris tannensis*. *Selaginella* comes next, and then *Isoëtes*. An analysis of at least one of the species of this last-named genus is still a desideratum.

I will now revert, still following the classification of Sachs, to the true ferns. In none of the British species have I been able to detect more than traces of alumina. But among the exotic Cyatheaceæ which Sachs places above the Polypodiaceæ, there seems to be a notable exception. Last year Mr. W. F. Howlett, of Pahiatua, Wellington, New Zealand, forwarded to Mr. Thiselton Dyer some specimens of the ashes of a tree-fern. He wrote, under date 22nd February: "The other day I found a half-burnt *Punga*, or tree-fern. The ashes were pure white, very tenacious, and retained the structure of the wood. They were obviously not in any way contaminated with accidental impurities, nor had they been rained upon. . . . I wrote to a chemical student who said the ashes were chiefly alumina. This is very new to me. Alumina is generally thought an accident, here it cannot be so. I do not know the species of tree-fern."

Mr. Howlett's specimen of ash was handed to me by Mr. Thiselton Dyer; the following results were obtained on analysing it, every precaution being taken to ensure an accurate result:—

	100 parts of ash contained		
	Al_2O_3.	SiO_2.	K_2O.
*Tree-fern, New Zealand........	19·65	12·96	15·1

This entirely unexpected discovery of nearly 20 per cent. of alumina (two determinations gave 19·8 and 19·5) in the ash of a tree-fern induced me to examine the ashes of known species of other Cyatheaceæ for this substance. Three specimens of the caudex of distinct species of these plants were furnished by the kindness of the Director of the Royal Gardens, Kew. Of these one only was sufficiently free from adventitious impurities to admit of trustworthy analysis. A cross section of the caudex of this plant, *Cyathea serra* from the West Indies, was sawn so as to preserve intact the whole of its pith as well as its fibro-vascular sheath. This section was broken up and burnt to a white ash, which amounted to 2·7 per cent. of the material dried at 100°. But it gave, on careful analysis, the merest trace of alumina.

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
**Cyathea serra*..........	2·70	0·20	12·65

Even this trace of alumina may have been extraneous, since the silica obtained was not entirely free from sandy particles (about $1\frac{1}{2}$ per cent. of the ash), although the material taken for the preparation of the ash was apparently perfectly clean.

Mr. Howlett forwarded, with the ash of the unknown tree-fern, a few grams of the caudex of a plant of *Cyathea medullaris.* The amount was quite insufficient for a satisfactory determination of the ash and its constituents, so I was obliged to content myself with a qualitative examination for alumina. The very small quantity of ash which I obtained on the incineration of these fragments of *C. medullaris* gave abundance of alumina. Indeed, I should not be surprised to find that the ash of the undetermined tree-fern was really that of this species of Cyathea. If this be the fact alumina will have been recognised, at present, in but a single species of tree-fern. Other genera of Cyatheaceæ, such as *Alsophila* and *Dicksonia*, may of course be characterised by the presence of this earth in notable quantities, but as yet analyses are wanting.

So far, it will be seen, alumina has been found in important quantities in a single tree-fern and in a number of different kinds of Lycopodium. The ash of another plant, however, contains over 2 per cent.

of this earth. I refer, not to a vascular cryptogam, but to a member of the great class of *Musci*. In the water-moss, *Fontinalis antipyretica*, alumina occurs among the ash constituents in a proportion which seems too large to be quite accidental. The specimens which I analysed were obtained in May from the Thames and Severn Canal, near Cirencester. After having been thoroughly cleansed they were analysed with the following results:—

	Percentage of ash in dry plant.	100 parts of ash contained	
		Al_2O_3.	SiO_2.
**Fontinalis antipyretica* ..	4·76	2·82	24·53

Further analyses of this plant and of its near allies are needed before a decisive conclusion can be drawn from this analysis.

In a previous paper, "Notes on the Occurrence of Aluminium in certain Cryptogams" ('Chemical News,' *loc. cit.*), I have detailed the various precautions which I have taken to prevent the intrusion of accidental traces of alumina during the analytical operations required for its determination. How far such precautions have been taken by the chemists who have recently investigated the occurrence of aluminium in certain vegetable products, I am not aware. But as the proportions of alumina obtained have been much smaller than those recorded by the earlier analysts, it may be assumed that the determinations are in general quite trustworthy. I now proceed to give a brief notice of the more important of these later inquiries, that it may be seen how their results differ from those to which attention has been directed in the present paper.

Mr. H. Yoshida found alumina in the ash of Japanese lacquer, the latex of *Rhus vernicifera* ('Chem. Soc. Trans.,' 1883, p. 481). But the quantity is quite insignificant. A tree yields annually about 2·5 grams of lacquer, and this contains from 3 to 8 per cent. of the gum in which alone the alumina occurs. Mr. Yoshida found 5·1 per cent. of ash in this gum, and on analysing its ash detected alumina in it to the extent of 6·3 per cent. or thereabouts ('Chem. Soc. Trans.,' 1887, p. 748). Now let us see to what amount of alumina this corresponds per tree, assuming the maximum amount, 8 per cent., of gum above-named to be present in the latex. A single tree yields—

Gum	0·2	gram.
Ash in this gum........	0·01	,,
Alumina in this ash	0·00063	,,

that is, a single tree annually yields rather less than two-thirds of a milligram of alumina. In other words, the latex or lacquer contains 0·0025 per cent. of alumina. The chief point of interest connected

with this fact seems to lie in the concentration of the alumina in the gummy matter contained in the latex. It should be remarked here that a little alumina occurs in the ash of some samples of cherry-tree gum and of gum arabic; whether this substance be constantly present remains to be ascertained.

Quite recently Mr. H. Yoshida ('Chem. Soc. Trans.,' 1887, p. 748) has determined the amount of alumina present in the ash of some grains and seeds, as *Glycine Soja*, the soy-bean; *Phaseolus mungo*, the Mung-bean (the var. *radiatus*); rice, wheat, barley, two species of millet and buck-wheat. The highest percentage, 0·272, was observed in the ash of Italian millet; the lowest, 0·053, in the ash of the soy-bean. In none of these cases can alumina be regarded as a characteristic ingredient.

Mr. W. C. Young ('Analyst,' vol. 13, 1888, p. 5) confirms Mr. Yoshida's results as to the occurrence of alumina in wheat. This experimenter found, moreover, that this constituent is intimately associated with the gluten. In Vienna flour, containing 0·7 per cent. of ash, he found 0·0075 per cent. of phosphate of alumina, which corresponds to 0·45 per cent. alumina in the ash. This proportion may be in excess of the truth, for, in separating the alumina strong sodium hydrate solution was boiled in a glass vessel, while no mention is made of a blank analysis having been made to control the result.

The quantity of alumina found by L'Hôte ('Comptes Rendus,' vol. 104, p. 853) in grapes and in wine seems to be too small to be taken into account; it is a mere trace.

So far as the materials at one's disposal warrant any definite conclusions, it may, perhaps, be permissible to say, that aluminium is a characteristic and abundant constituent of the ash of many, if not of all, the species of terrestrial Lycopodia; that it is absent from Selaginella and from a number of other allied vascular cryptogams; that it is present in notable quantity in at least one species of tree-fern though practically absent from others; and that it occurs in insignificant amount (like many other elements) in almost every plant in which its presence has been carefully sought for. As to the state of combination in which alumina exists in those plants in which it occurs in mere traces, we have very little information, but in the cereal grains and pulses it is probably in combination with phosphoric acid. In Lycopodia John states that aluminium acetate occurs, Ritthausen speaks of the malate Arosenius of the tartrate. Anyhow it is easy to extract abundance of an organic salt of aluminium by exhausting dried and pulverised *Lycopodium alpinum* with boiling water. So, in some cases, at least, the alumina present in these plants does not exist, as silica does in *Equisetum* and other highly silicious vegetable structures, in an insoluble form. As to the physiological function, if any, of this element, it is rash to offer an opinion. It is just possible that it may

serve to some extent to neutralise the abundant organic acids of the plants in which it occurs, and thus assist, like the cognate element magnesium, in the metabolic processes of vegetation.

One further observation may be hazarded. It remains to be seen whether the study of the periodic function which connects the atomic weights with the general properties of the elements will throw any light upon the relations subsisting between vegetation and the few elements necessary for its development. It seems that the position of aluminium in Mendelejeff's third periodic series decidedly favours the view of the peculiarity of its occurrence in certain plants, taken in the present paper. It stands between magnesium and silicon, two elements of which the physiological *rôle* is, to say the least, obscure; while of one of them—silicon, we may affirm that it is not an essential plant-food. Its occurrence in the ashes of various plants is indeed more general and more abundant than that of aluminium, but appears to be quite as capricious; and a point of difference as to the state in which these two elements are found in plants is obvious. Aluminium occurs mainly if not entirely in the form of soluble organic salts, silicon in the form of insoluble silica.

In considering this aspect of the periodic law one cannot help being struck with the low atomic weights of the essential elements of plants. If we exclude certain cases of apparently casual and accidental absorption (of such elements as bromine, iodine, copper, zinc and arsenic) it will be noticed that Mendelejeff's Series I, II, III and IV, having a range of atomic weights from 1 to 56, comprise all the essential elements, even if we include manganese, chlorine, silicon and

Elementary Plant-Food and the Periodic Law.

Series I.	Series II.	Series IV.
	(Lithium = 7·0)	POTASSIUM = 39·1
	(Beryllium = 9·1)	CALCIUM = 40·0
	(Boron = 11·0)	(Scandium = 44·0)
	CARBON = 12·0	(Titanium = 48·1)
	NITROGEN = 14·0	(Vanadium = 51·3)
	OXYGEN = 16·0	(Chromium = 52·3)
	Fluorine = 19·0	*Manganese* = 55·0
HYDROGEN = 1.		IRON = 56·0
	Sodium = 23·0	
	MAGNESIUM = 24·0	
	Aluminium = 27·1	
	Silicon = 28·3	
	PHOSPHORUS = 31·0	
	SULPHUR = 32·0	
	Chlorine = 35·5	
Series I.	Series III.	

aluminium. The identity of the position occupied by fluorine in Series II with that of manganese in Series IV perhaps admits of correlation with the occurrence of these elements in plants.

The table (p. 128) illustrates the preceding observations, and shows the periodic position of aluminium—the element primarily under discussion. For the sake of distinctness the elements generally believed to be essential to the higher plants are printed in capitals, the elements of doubtful necessity in italics, and those which, if they occur at all in plants are certainly accidental, in ordinary type enclosed in brackets.

Postscript.—Since writing the above paper I have found that the ash from the caudex of another tree-fern (*Alsophila australis*) contains a very large quantity of alumina. The specimen analysed was from Tasmania. I have also detected more than mere traces of alumina in the ash of the caudex of *Dicksonia squarrosa.*

IV. "On the Nature and Limits of Reptilian Character in Mammalian Teeth." By H. G. SEELEY, F.R.S., Professor of Geography in King's College, London. Received April 4, 1888.

Approximations between reptiles and mammals have been recognised in many parts of the skeleton.* They are most marked between certain genera and orders of the two classes. The oldest known fossil representatives of both groups certainly approximate closer towards each other in all known parts of skeletons than do the orders which survive; so it may be a legitimate induction that, in an earlier period of geological time, the characters of both groups were so blended, that there existed neither the modern reptile, which has specialised by losing mammalian attributes, nor the modern mammal, which has specialised by losing the skeletal characters which have come to be regarded as reptilian. The most ancient mammals exhibit, in the known parts of their skeletons, resemblances to Monotremes, Edentates, Insectivores, and apparently Carnivores; and it is among these orders that the closest correspondence is found, bone for bone, with reptiles. Therefore, if an attempt were made to predict on an inductive basis, the kind of dentition which the earliest mammals which existed would show, it might be expected to be in harmony with the mammalian and reptilian characters of their skeletons. On the same basis it might be suspected that existing mammals, with

* "Resemblances between the Bones of typical living Reptiles and the Bones of other Animals;" "Similitudes of the Bones, &c.," 'Journal of the Linnean Society, Zoology,' vol. 12, 1874, pp. 155, 296.