## LETTERS TO THE EDITOR.

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### Flights of Rooks and Starlings.

I MAY be writing of what is so commonly known to naturalists as to be unworthy of record; the facts, however, are new to me. On a fine, still day last September I observed a large flight of rooks attended, as Gilbert White notes, by starlings. As they passed across the sky both rooks and starlings mounted higher and higher until they were lost to sight in the distance. Whatever may have been the occasion of the concourse, it was a subject of much interest to rooks in general, for solitary birds hurried by, cawing loudly, to join the main body. These belated individuals mounted in fairly regular spirals.

About a fortnight later I had the good fortune to be able to follow with powerful glasses a similar flight, but of rooks unaccompanied by starlings. As before, the mean movement in the still air was a steady oblique ascent, and the general impression that of a crowd of birds the individual movements of which were confused and irregular. This impression of confused flight was, however, probably wrong, for the few individual birds I was able to follow were undoubtedly rising in fairly regular spirals.

The surprising and, to me, novel character of the flight did not appear until the birds had risen to a height beyond the limits of unaided vision. The movements of individual birds then changed from the even sweep of the spiral to what can only be called trick flying. The wildest antics were indulged in, the commonest being a dive with closed wings, the bird sometimes rolling over and over. I could not fit the character of the movement to the hypothesis that the birds were darting after insects on the wing.

The two facts new to me were the height attained and the fact that a bird of such sedate manners as the rook should on occasion condescend to do "stunts."

W. B. HARDY.

The Athenæum Club, Pall Mall,
February 4.

### National Union of Scientific Workers.

THERE is appearing in your advertising columns an announcement relating to this Union; will you allow me space to explain its objects very briefly, but rather more fully than is possible in an advertisement?

There is a general agreement that it is imperative for the best interests of science that those who pursue it should possess greater political and industrial influence. The founders of our Union believe that they can attain that influence only by adopting the form of organisation which has proved effective in experience. That organisation involves the formation of a Union including, so far as possible, every professional scientific worker, and governed in a completely "democratic" fashion. It is such a Union that we are trying to form.

In the pamphlet for which everyone is urged to write further details of our aims and methods of attaining them are suggested. But we feel that no self-appointed body can possibly legislate permanently for a Union designed to embrace the whole world of science. Our immediate endeavours, therefore, are to set up a preliminary organisation which will lead to the summoning of a thoroughly representative general meeting having the authority necessary to set the Union on a permanent basis. The pamphlet is mainly devoted to an account of this organisation. Until it has done its work the constitution and policy of the Union will remain unsettled; we would urge accordingly that any divergence, except on the fundamental principle, from the views of the founders is an argument for, rather than against, taking part in the preliminary work.

One last point. We are often asked what is our attitude towards other societies, existing or proposed. Our answer is that, since none of them are both all-inclusive and democratically governed, none, according to our view, can do our work. But, of course, we recognise that there are other ways of advancing the cause of science which are being followed effectively by other bodies. We recognise further that our relations to these other bodies will need careful consideration and regulation; but to discuss exactly what the relations must be would be to exceed the space I can ask you to put at my disposal.

NORMAN R. CAMPBELL
(General Secretary N.U.S.W.).

North Lodge, Queen's Road, Teddington.

## THE GREEN LEAF: ITS SCIENTIFIC AND ECONOMIC EXPLOITATION.

THROUGHOUT the unnumbered ages which have witnessed the rise and fall of successive civilisations upon this planet, the one thing that has stood between mankind and extinction by lack of food has been the activity of the chloroplast of the green leaf. Perhaps, before equal time has again rolled over the world, the synthetic production of food may have been achieved, and man in all his intellectual glory may claim equality with the lilies of the field. Until then the fixation of organic carbon by "photosynthesis" in green cells must, by us, be regarded as the basal chemical happening of our planet. Thousands of years of empiric agriculture have enabled man to exploit this aspect of vegetation with remarkable success, but the problem of carbon assimilation found its way into the laboratory only at the end of the eighteenth century by the genius of Priestley, and its broad aspects were first formulated by the wisdom of De Saussure in 1812.

We may consider in this article what progress has been made with this matter, as a problem of pure and applied science, in the century that has elapsed since then. The recent appearance of a summary review of our knowledge of the subject by I. Jørgensen and W. Stiles[1] gives a good foundation for such consideration.

Investigators have not been idle. The bibliography contains 250 entries, but these are not a tenth of the papers published, for our authors' intention is to ignore historical development and give only a critical account of those researches which mark the present advance line of knowledge on the many separate, but converging, roads by which this well-defended secret of Nature has been attacked. The authors are as severely critical as the commissioners on a military campaign. They have carefully thought over the aspects of the subject

[1] "Carbon Assimilation: A Review of Recent Work on the Pigments of the Green Leaf and the Processes connected with Them." By Ingvar Jørgensen and Walter Stiles. *New Phytologist* Reprint, No. 10. Pp. 180. (London: Wesley and Son, 1917.) Price 4s.

as one connected whole, and are impatient of the many individual attacks which have wasted half their effort by failure to keep contact with flanking movements by workers coming from other directions, who should be regarded as allies, but are often treated as rivals. This report ought to have a valuable effect in unifying research activity. No similar presentation of the subject has appeared before in any language.

A century of laboratory attack has driven several salients forward, of which perhaps three stand out conspicuously. We may briefly consider how far each has progressed, as reported in this pamphlet, and what may be expected of the future. These advances concern (1) the pigments of the leaf (chap. ii.); (2) the products of carbon assimilation formed in the leaf (chap. v.); and (3) the influence of external factors on the rate of carbon assimilation (chap. iv.).

In chap. vii. will be found set out those speculations that have any significance as theories of the assimilation process. During the process that takes place in the illuminated green cell, whereby carbon dioxide disappears and sugar appears, it is clear that, somehow or other, reduction and "synthesis" must take place; but even now it is quite unclear to what system of reactions this result is to be attributed. Many hypotheses have been put forward, and Baeyer's "formaldehyde theory" has been almost canonised as an eternal verity, yet there is really no good evidence for it. Its perennial attraction no doubt is due to its æsthetic simplicity. It appears now that the reaction must be much more complex (unless, as is possible, we are entirely on the wrong tack), and this is our excuse for the slowness of progress. A knowledge of the reacting system at work would be equivalent to storming the citadel of the whole defence, but so far no one has advanced a satisfactory hypothesis that can be put to the proof of experiment. We have still to advance by slow hammering tactics from various directions.

The advance that has been made in elucidating the nature of the pigments of the green leaf under the guidance of Prof. Willstätter really amounts to a shock attack, so continuous and rapidly widening has been the progress.

In 1864 Sir George Stokes stated that he had proved that the green matter of leaves consisted of two green and two yellow pigments, though he never published his evidence. In the last decade this conclusion has been finally established by the monumental research of Prof. Willstätter and his colleagues. Before Prof. Willstätter there was no clue to the real chemical nature of these two green pigments, and it could be hoped that when their chemistry was known the process of reduction of carbon dioxide would be elucidated.

The curious nature of the green and yellow pigments is now made quite clear; the greens are esters of a big alcohol molecule, phytol, and a tricarboxylic acid based on a nucleus of four pyrrole rings. Magnesium is also an essential constituent, not electrolytically dissociable, but believed to be directly united with the nitrogen. The difference between the two green pigments is simply this, that "chlorophyll *b*" contains one atom more of oxygen (and two less of hydrogen) than "chlorophyll *a*." In complete contrast to this complexity is the simplicity of the yellow pigments; "carotin" is an unsaturated hydrocarbon, and "xanthophyll" an additive oxidation derivative of it. Both the yellows, when isolated from the cell, spontaneously absorb oxygen in abundance. It is easy to assume that these differences of oxygen-potential occurring within both the green and the yellow pairs are significant for the reduction of carbon dioxide; but there is no evidence on this point at present.

A second line of attack into which much work has been put is the determination of the nature and amount of the carbon-containing substances which arise in the leaf as $CO_2$ disappears. Is the $CO_2$ quantitatively reduced to its theoretical yield of carbohydrates, or do other substances arise in "multiple photosynthesis"? The measurement of the $CO_2$ intake by the green leaf is not difficult, but difficulties attend the correction of this apparent photosynthesis for the amount of $CO_2$ simultaneously produced in the body of the leaf by respiration—an amount which is large at high temperatures, but must be known and added in for exact statements of photosynthesis. At the other end of the reaction the determination of the carbohydrates produced continues to present considerable difficulties, so that no one has yet managed to measure in one experiment both the initial $CO_2$ used up and the final carbohydrates produced whereby we might judge of their equivalence. Much discussion has taken place on the question of what is the first sugar to appear in photosynthesis, though this is largely a strife of ideas rather than of facts.

The identification and accurate determination of individual sugars and polysaccharides in a mixture of such bodies form a special field of analytical work the difficulties of which have been much lightened by recent English researches, set out in chap. v.; but these have not been fully overcome yet. Further, these carbohydrates have all to be extracted from the leaf unaltered by the enzymes that lie in wait for them in the cell, and finally not one determination, but two differential determinations are required to establish changes due to photosynthesis; one, at the beginning of the experiment, being on some other area of leaf that can be held to furnish a strictly comparable control. Progress in this important line of work waits upon absolutely trustworthy methods of extraction and analysis of carbohydrates.

The third significant advance that has been made is that towards an understanding of the influence and mode of interaction of the many external and internal factors that can influence the rate of photosynthesis. The control or measurement of the external factors of illumination (sunshine or artificial light), temperature, and $CO_2$ supply require elaborate apparatus and considerable physical experience in the fields of radiometry, photometry, scientific illumination, thermo-electric measurement of leaf temperature, etc. Of internal factors the amount of chlorophyll and the degree of openness of the stomata are sometimes significant.

When the magnitudes of the three external factors are known or controlled, there arises the important question of the nature of their interaction when the magnitudes of them vary independently—a problem which has been elucidated largely by English investigations. In any possible combination of these factors, the rate of photosynthesis at any moment is not an expression of their combined magnitude, but only of the magnitude of a particular one of them acting as a "limiting factor" to the rate of functional activity. Which of the factors happens to be the limiting factor in any combination of them can be determined experimentally by application of the principle that increase of the magnitude of the limiting factor, and of this factor only, can increase the rate of photosynthesis.

With high rates of photosynthesis, yet a new factor has to be brought into account, as internal causes produce a regular falling off of the power of photosynthesis from moment to moment of time. Until the internal causation of this is fully explained it may pass by the non-committal name of the "time-factor."

There is yet another important aspect of our attack on the problem of photosynthesis which is still in its infancy, and that is the "energetics" of the process, dealt with in chap. vi. of the pamphlet.

The essential human value of the chloroplast activity lies, of course, over and above the indispensable accident that its products are edible, in the high energy content of these carbohydrates. Therefore, the energetic aspect of the process is the fundamental one, and the whole problem should be investigated on this basis. This involves measurement of the energy incident on the leaf-surface, with determinations of the amount transmitted, or reflected, or used in transpiration, as compared with the fraction stored up in photosynthesis, which last finds expression in the increased heat of combustion of unit-area of leaf-surface enriched by carbon assimilation. In this field of work progress can be made only by elaborate physical apparatus and critical determination of physical constants.

Let us now turn to the economic aspect of photosynthesis regarded as a problem of industrial or applied science. In these times, when cereal food supply threatens to become a limiting factor to the endurance or free existence of nations, the question of what science can do to multiply the number or heighten the activity of the chloroplasts subserving the cause of humanity acquires a poignant interest.

It cannot be said that the physiological study of chlorophyll activity has yet enabled any improvement to be made in the applied science of agriculture. The conditions of present-day agriculture are too little intensive, and not yet such as to make it worth while to attempt to exploit the researches of plant physiologists. Cultivation of new acreage, selection of types, and increase of transport facilities are the present solutions of the limitation factor of carbohydrate food supply.

The utilisation of researches on the augmentation of photosynthesis would be of profound importance in the imaginary case of a self-contained or strictly isolated community of limited acreage, a wealthy and intelligent community with a large population on a small area of soil for sunshine or artificial illumination. Their problem would have to be solved on the basis of investigations on the factors controlling photosynthesis of the type we have already mentioned.

In such a community the relation between plant physiology and agriculture would become something like that holding now between human physiology and medicine. To-day every progress in human physiology is eagerly correlated with medicine, and lavish endowment and encouragement are extended to pure physiological science on account of its generally recognised applicability to medicine. The outlook of medicine and hygiene is, however, individual, and not commercial; there is a desire to save every life and continue the activity of every individual, however worthless it may be to the community. With agriculture and plant communities there is no such outlook, and with regard to any application of plant physiology it is required that the intensification of the synthetic activity of the plant aimed at shall pay economically.

We see, then, that it is probable that the main cereal crops will for a long time be left to the mercy of natural vagaries of light, heat, water, and carbon dioxide, but minor activities of intensive food cultivation are now utilising deliberate or unconscious control of one or more of the factors of photosynthesis. It becomes, therefore, highly important that there should be carried out a comprehensive investigation of the physiology and energetics of carbon assimilation dealing with the possibilities of intensive photosynthesis under all artificial combinations of factorial conditions. From what we have said as to the complexity of this matter it is clear that no one or even two investigators are likely to have all the special chemical, physical, and physiological experience required for rapid progress, so that this would have to be an organised combined research, and continued over a number of years with good equipment and liberal endowment.

In conclusion we may express the opinion that, in the eyes of all who know the results of modern work on chlorophyll, Germany has acquired lasting credit for her great achievement with this difficult and elusive problem. Under the inspiration of Prof. Willstätter many workers have striven for years in the National Research Institute, and thousands of pounds have been spent, on a novel type of investigation involving tons of leaf material. Their credit is not the less for this, that the results have not at once proved to be of economic importance: one more province of ignorance has been strenuously conquered and annexed to the empire of knowledge.

An equal spirit of organised research and munificent endowment in this country should enable us to raise here, on the basis of existing English pioneer work, a similar monument of research on the physiology and energetics of carbon assimilation. F. F. B.

## THE ADOPTION OF THE METRIC SYSTEM.

AN account of the position of the subject of the adoption of the metric system in this country was given in NATURE of August 30 last. That the question is being very seriously considered by the controllers of our larger industries is clearly indicated by the two papers on the subject read recently before the Institution of Electrical Engineers. In the paper, "A Case for the Adoption of the Metric System (and Decimal Coinage) by Great Britain," by Mr. A. J. Stubbs, the multiplicity of standards—and, worse still, variations from these standards—is so clearly shown that one is not surprised that the writer should arrive at the conclusion that the change must come, and that delay but increases the difficulties of the change. The final conclusion, *"Do it now,"* will meet with unqualified approval from those who feel that the change is urgently needed.

Very different is the paper from Mr. Llewelyn B. Atkinson on "The 'Pros and Cons' of the Metric System." Broadly speaking, it is a paper "damning with faint praise." Starting from the three possible systems, namely, (1) the British system, (2) the metric system, (3) the C.G.S. or absolute system, the writer proceeds to discuss the questions of (*a*) decimalisation, (*b*) the actual magnitudes involved, and (*c*) policy. The main point made is that there is always so much to be said for the other side that everything is questionable. The further difficulty of the enormous number of readjustments of tolls, rates, dock dues, wage lists, etc., which would have to be made, is emphasised.

If our object were simply to criticise this paper rather than most seriously to urge the adoption of the metric system in the full light of all the difficulties actually known to be involved, we should simply ask Mr. Atkinson to produce his British system—say, for the textile industries; and in reply to the difficulty raised respecting the readjustment of tolls, rates, etc., we would suggest that the sooner the whole of the agricultural and commercial worlds of this country receive the shaking up that such a change would give them the better. But the paper is too good to be thus summarily dismissed.

The question of decimalisation admittedly resolves itself into a careful weighing up of the pros and cons. That uniformity, accuracy, and speed make a strong trio in favour of the decimal system is, however, beyond question. If proof of this be required it may be readily obtained from those who have worked in both British and Continental mills and works.

The question of the actual magnitudes involved is complicated by reference to the varying weights of the bushel of wheat, of barley, of oats, etc. This is typical of the whole trend of the paper. Whatever standards of measurement be adopted, the same difficulty will be in evidence. This approximates any two systems to one another in the sense that it involves them in a common difficulty—but does it therefore leave them equally useful for world service? If there were a chance of either Japan or China adopting any such British system as could be speedily designed, there might be something in the argument. But is there?

The question of policy is debated rather from the point of view of Britain holding certain markets by the imposition and retention of her peculiar weights and measures—in other words, by the methods employed by some of our machinists, who purposely adopt their own peculiar standards in order that they may absolutely bind to themselves any firms once depending upon them for machinery. Does not this savour far too much of subterfuge? And where subterfuge comes in, in the long run efficiency goes out.

From this point of view international coinage and rates of exchange form an interesting study. If the time ever comes when the spirit of scientific finance, rather than the spirit of "opportunism," dominates industry, then will commerce have made possibly the greatest step forward on record.

In the final paragraph of his paper Mr. Atkinson asks for some indication of how the change can in practice be effected in the case of the textile industries. This change was definitely made and the metric system employed in the textile industries department of the Bradford Technical College for more than a year. The experiment revealed the simplicity of the change, and has materially influenced the views of the writer of this article on the possibilities of the metric system in the textile industries. That the cotton section of the textile industries will profit least from the proposed change is certain, since it already possesses many of the advantages conferred by a world-wide system; but surely it will join hands with its less fortunate associates in advocating a change which to those with long vision seems almost likely to be the factor deciding our fate in the commercial warfare looming ahead.

But perhaps the deficiencies of outlook in evidence in Mr. Atkinson's paper may best be attributed to an apparent lack of appreciation of the questions of mentality (or psychology) involved. Every mathematical problem solved—be it simple or complex—serves in two ways. Directly, it gives the particular answer required; and indirectly, it incorporates itself into the intuitive faculty of the thinker. Thus each problem solved will naturally tend either to strengthen or to weaken the intuitive mathematical faculty. A multiplicity of standards with many haphazard variations will inevitably tend, through confusion of precept, to suppress, and ultimately entirely to eliminate, the intuitive mathematical faculty; whereas scientific standardisation will tend to promote that type of brain culture which ultimately resolves itself into