Soren Peter Lauritz Sörensen.

A MEMORIAL LECTURE DELIVERED BEFORE THE CHEMICAL SOCIETY ON APRIL 4TH.

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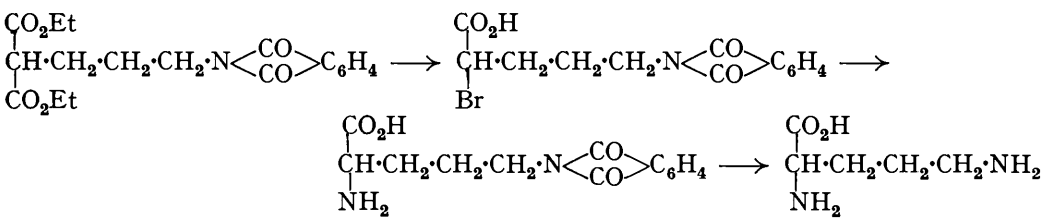
SCANDINAVIA, the home of the ionic theory, has given many great physical chemists to the world. Amongst these must be placed Soren Peter Lauritz Sörensen.

Sörensen, the son of Hans Sörensen, a farmer, was born at Havrebjerg on January 9th, 1868, and matriculated into the University of Copenhagen at the age of eighteen from the public boarding school of Soro Akademi. He had as a child a nervous disposition and after severe emotional disturbances was subject to attacks resembling epilepsy. During his formative years at school he stammered, but rapidly grew out of this complaint. Like most people of a highly strung and nervous disposition, he not only put up mental barriers to protect himself from the impact of the violent disturbances found in modern life, but also had to find a satisfying means of escape. This he attained in his work. Throughout his life Sörensen's scientific labours were characterised by his insistence upon attention to detail and to accuracy, traits uncommon in a man who had a real flair for experiment, for usually in such individuals these gifts are the result of subconscious cerebration rather than of volition. In the University, Sörensen studied chemistry under S. M. Jorgensen, who was particularly interested in the preparation and structure of complex inorganic compounds.

Three years after entering the University at the age of twenty-one Sörensen obtained a University Gold Medal for a historical essay on the development of the concept of the chemical radical. He obtained the University Gold Medal for the second time in 1896 and completed his University work in 1899 by submitting a thesis for the Doctorate on cobaltic oxalates. During his pre-doctorate period at the University he assisted in a geological survey of Denmark, and later became an assistant in the Polytechnic Chemical Laboratory and a chemical consultant to the Royal Naval Dock Yard. Whilst his work with Jorgensen was in the main preparative, any theoretical development being possibly stultified by the unfortunate controversy between his professor and Werner, yet it was during this period of his life that he developed interest in precise analytical methods, which were in fact the foundation on which his subsequent world-wide reputation was based. His investigations on the use of sodium oxalate as a volumetric standard can be regarded as a model of precise volumetric work.

At the comparatively early age of thirty-three, in 1901, Sörensen was appointed as Kjeldahl's successor to the Directorate of the Chemical Department of the Carlsberg Laboratory. It was in this laboratory that he became interested in the proteins and commenced his systematic investigations on these substances. His breadth of vision is well exemplified by the fact that he made his attack from two different directions, the synthetic and the analytic. Whilst it is true that the convergence of these two methods has not been effected even at the present time, it is remarkable how much this pioneer in a most complex field of organic and physical chemistry actually achieved.

We are indebted to Braconnot and Liebig for the discovery that two amino-acids, leucine and tyrosine, are almost invariably present in the decomposition products of proteins. A great advance was made by 1889 by Drechsel, who isolated strongly basic diamino-acids such as lysine and arginine from the products of protein hydrolysis. At the



end of the last century Fischer commenced his work on the synthesis of the amino-acids and in 1901—1902 successfully synthesised ornithine and lysine. Fischer converted phthal-

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imidopropylmalonic ester into phthalimido-α-bromovaleric acid by bromination. On replacement of the bromine by an amino-group with ammonia and removal of the phthalyl group by hydrolysis inactive ornithine was obtained.

Sörensen improved on this method and rendered it more general by coupling phthalimidomalonic esters with various halogen compounds. The products, after hydrolysis and

$$(CO_2Et)_2C<\begin{matrix}Na\\N<\begin{matrix}CO\\CO\end{matrix}>C_6H_4\end{matrix} + RCl \longrightarrow (CO_2Et)_2C<\begin{matrix}R\\N<\begin{matrix}CO\\CO\end{matrix}>C_6H_4\end{matrix}$$

decarboxylation, yielded amino-acids of the composition $NH_2{\cdot}CHR{\cdot}CO_2H$. The yields obtained were good and Sörensen effected the synthesis of ornithine, proline, arginine (δ-guanino-α-aminovaleric acid) and other amino-acids. His chief interest, however, lay in the analytical side. His first investigation in this field consisted in examining the accuracy of his predecessor's method of nitrogen determination, which had been subjected to considerable criticism. He showed that with proper precautions Kjeldahl's method was in fact extremely accurate. Even more exhaustive was Sörensen's examination of a method of neutralising the amino-groups in proteins and polypeptides by formaldehyde according to the reaction $\cdot NH_2 \longrightarrow \cdot N{:}CH_2$ prior to titration of the carboxyl groups present, a reaction introduced by Schiff. In a series of papers published under the title of Studies on Enzymes. I, the conditions for obtaining quantitative results were clearly laid down and thus the method was converted into a really quantitative one for following reactions such as proteolytic cleavage. Two years later, in 1909, appeared Sörensen's most remarkable paper " Studies on Enzymes. II ", a piece of work which must be considered one of the classics of exact physical chemistry. The important influence of acidity or basicity of the solution on the rate of enzyme action and on the stability of proteins had so impressed him that in this paper the subject of hydrogen-ion concentration was taken up with characteristic thoroughness. It had frequently been suggested that a new kind of chemistry should be introduced in which other laws peculiar to those of colloid chemistry should replace those of classical chemistry (cf. Loeb, " Die Eiweisskörper "). It was partly due to the fact that investigations on protein solutions had been made before methods for the exact determination of hydrogen-ion activities had been worked out that such extreme views found place in scientific literature. We are thus greatly indebted to Sörensen for his conservative outlook at a somewhat critical time in the development of colloid chemistry. It is, however, only fair to state that in many of the problems in which the colloid chemist is interested, he has to deal with non-reversible systems, *i.e.*, suspended dynamic processes, whilst classical thermodynamics in chemistry is applicable only to thermodynamically reversible processes.

In the first section the electrometric method of determining hydrogen ions is investigated. When a concentration chain is made up of platinum electrodes in contact with hydrogen gas at one atmosphere and two solutions of different hydrogen-ion concentrations, the electromotive force between the two electrodes is given by the well-known Nernst expression

$$\Delta V = \frac{RT}{F}\log\frac{f_1c_1}{f_2c_2} + \pi$$

where f_1 and f_2 are the activity coefficients of the electrolytes containing the hydrogen ions and π is the liquid junction potential. We note that the hydrogen-ion activity of any solution can be determined in terms of some standard solution and the experimental results give us directly the logarithm of the activity. Thus $[\overset{+}{H}] = 10^{-7}$ can be written $-\log[\overset{+}{H}] = 7$. Sörensen was quick to appreciate the value of expressing the acidity or basicity of a solution in terms of the logarithm of the concentration of hydrogen ions, writing $-\log[\overset{+}{H}] = P\overset{+}{H} = 7$, now replaced by p_H. Not only does it possess the advantage of typographic simplification, but the graphic representation of the effect of variation of hydrogen-ion concentration in terms of the logarithmic symbol on various properties which reflect the extent of dissociation yields a singularly symmetric curve with an abscissa of convenient range.

If the standard hydrogen electrode be taken as one in which the hydrogen-ion activity is unity, we obtain $F(\Delta V - \pi)/\boldsymbol{R}T = p_{\mathrm{H}} + \log f$ for the solution under investigation. The problem of the activity coefficient, especially in electrolytes containing hydrogen ions, is one which has had a particular appeal to the Scandinavian scientists, as is revealed in the writings of Arrhenius, Bjerrum, Brönsted and Sörensen, and indeed Brönsted's formulation for the activity coefficient in terms of the ionic strength does not differ markedly from the expression subsequently obtained by Debye and Hückel. Sörensen, however, assumed that the hydrogen-ion concentration in 0·1N-hydrochloric acid or in a mixture of 0·01N-hydrochloric acid and 0·09N-potassium chloride could be calculated from conductivity data, obtaining 0·09165 (p_{H} 1·038) and 0·009165 (p_{H} 2·038) respectively. We now know that the activity coefficient f and the conductivity coefficient f_λ are by no means identical and that in 0·1N-hydrochloric acid the activity of the hydrogen ions is some 0·0841, giving a $p_{a\mathrm{H}} = 1{\cdot}075$. Thus for 0·1N-hydrochloric acid we obtain

$$p_{a\mathrm{H}} = p_{\mathrm{H}} + 0{\cdot}037 + \pi F/\boldsymbol{R}T$$

where p_{H} is the Sörensen value of the solution and π the liquid junction potential, which Sörensen later evaluated by a method due to Bjerrum.

The salt " errors " obtained by Sörensen in examining the behaviour of the hydrogen electrode in dilute hydrochloric acid in the presence of varying amounts of potassium chloride thus include both an activity coefficient and a liquid junction potential. Whilst numerous modern text books do not distinguish between the Sörensen exponent p_{H} and the activity exponent $p_{a\mathrm{H}}$, the latter is the one that is usually experimentally determined and it might prove desirable to redesignate p_{H} as the activity exponent, retaining $\mathrm{P}_{[\mathrm{H}]}$ or $\mathrm{P}_{\mathrm{H}}^{+}$ for the original Sörensen concentration exponent. It is worth noting that the most accurate value for the dissociation constant of water determined by the electromotive force method obtained by Sörensen, gave $K_{\mathrm{w}}^{18°} = 0{\cdot}73 \times 10^{-14}$, a value in close accord with the present accepted value. After examining the errors which could arise in the determination of hydrogen ions with the hydrogen electrode, he proceeded to investigate indicators and was responsible for introducing α-naphtholphthalein, an indicator possessing a p_{K} value in the neighbourhood of neutrality (range p_{H} 7·3 — 8·7). He greatly improved on the earlier work of Salm on the accuracy of the p_{H} determination by the indicator method.

The errors inherent in the method lie, first, in accuracy of matching colour and, secondly, in the computation of the relationship between colour and p_{H}. It is clearly preferable rather to match colours than to observe the appearance of or the commencement of a change in colour, as these are highly dependent on the physiological and psychological characteristics of the observer. A good example of this fact is to be found in the p_{H} limits of colour range for *p*-dinitrophenol recorded by different observers, Sörensen, Noyes and Fels. They are 5·0—7·0, 4·0—6·5 and 6·13—6·75 respectively. This point was recognised by Sörensen, who insisted upon comparative methods and proposed a standard series of colours for addition to coloured liquids in order to obtain matching shades. The only salt error which can be made the subject of exact calculations is that caused by change in the ionic activity coefficient; if f_0 and f_1 be the activity coefficients of the undissociated indicator (A) and that of the ions (A′), the colour of the solution is determined by (A)/(A′) and not by $f_0\mathrm{A}/f_1\mathrm{A}$; thus $\mathrm{A}/\mathrm{A}' = f\overset{+}{\mathrm{H}}/K \,.\, f_1/f_0$. The colour of an acid ion indicator thus indicates a less acid solution than reality in solutions of great ionic strength. In terms of the dissociation constant of the indicator

$$p_{a\mathrm{H}} = \log K + \log\left(\frac{A'}{A}\right) + \log \frac{f_1 \text{ indicator ion}}{f_0 \text{ indicator}}$$

where $p_{a\mathrm{H}}$ is the Sörensen index of the activity of the hydrogen ions. The activity coefficient of the indicator ions can be expressed in terms of the ionic strength μ by means of the equation

$$\log f_1 = -A\sqrt{\mu} + B\mu;$$

whilst the coefficient A depends only on the valency of the ions, the value of B possesses

different values for different ions and must thus be the subject of experimental determination. The following data obtained by Sörensen are of interest in this connection.

Method.	p_H in H_2O.	p_H in 0·1N-KCl.	p_H in 0·3N-KCl.
Electrometric	2·01	2·01	2·05
Methyl-violet	2·22	2·04	1·91
Methyl-green	2·28	2·05	1·89
Methyl-yellow	1·99	2·04	2·04

Sörensen even explored the small variation in p_H of a solution introduced by the addition of the indicator itself.

A more serious error which arises in the determination of the p_H in biological fluids was also exposed in the Carlsberg laboratories, *viz.*, the protein error. Indicators, especially those which are of the colloidal electrolyte type, *e.g.*, Congo-red, may be adsorbed, both neutral molecule and ion, by the protein. With unequal adsorption and the ratio varying as we move to either side of the isoelectric point of the protein, it is easy to understand how the protein error may vary in magnitude with the nature both of the indicator and of the protein, and with the p_H of the solution. *p*-Nitrophenol is the one indicator least affected by protein error. The following figures from Sörensen's data indicate the magnitude of the protein errors :

Method.	p_H in presence of albumin.	p_H in presence of gelatin.	p_H in presence of invertin.
Electrometric	5·34	4·98	5·69
Sodium alizarinsulphonate	5·61	5·97	5·85
p-Nitrophenol	5·39		5·75
Methyl-red	4·75		

In another section of this paper Sörensen gives an account of the preparation of suitable mixtures, termed " Tampons " by Fernbach in 1900 and translated " buffer ", for the accurate adjudgment of the p_H of a solution, and we are indebted to him for his careful analysis of the buffering ranges of the borates, citrates, phosphates and glycine. It is a matter of some interest that, although several new buffer salts have been introduced since Sörensen's time, his choice of salts still remains at the present time the favourite of many workers.

In addition to the hydrogen electrode Sörensen made an exhaustive study of Biilmann's quinhydrone electrode. Certain organic oxidation–reduction systems possess the property of being electromotively active, the system quinone–quinol being the first and prototype of many subsequently examined.

The electromotive reaction involved may be written :

$$C_6H_4O_2 + 2\overset{+}{H} + 2e \rightleftarrows C_6H_4(OH)_2$$

whence

$$\Delta V = e_0 + \frac{RT}{2F} \log \frac{f_0[C_6H_4(O_2)]}{f_{0_1}[C_6H_4(OH)_2]} + 0{\cdot}059p_H \text{ (at } 25°)$$

The ratio of quinone to quinol can be kept constant by utilising the sparingly soluble dissociable quinhydrone.

The salt errors in this electrode are introduced by the fact that salts affect the solubilities and hence the activities of quinone and quinol to unequal extents, *i.e.*, f_0/f_{0_1}, but according to Sörensen's measurements with chlorides and sulphates the error is not serious below 0·5M, being only $0{\cdot}01p_H$ for 0·1N-hydrochloric acid made up to 0·2M with sodium chloride. The protein errors of this electrode, which are appreciable, were examined by Sörensen's colleague and successor, Linderstrom-Lang.

Whilst the p_H of dilute solutions of weak acids, bases and hydrolysable salts can be readily derived from simple equations based upon the law of mass action, the evaluation of the p_H of an ampholyte by this method is not so simple. Sörensen required this information in his investigations on the isoelectric points of glycocoll, alanylglycine and phenylalanine. In glycocoll ampholyte $k_a = 1{\cdot}8 \times 10^{-10}$, $k_b = 2{\cdot}7 \times 10^{-12}$ and consequently the isoelectric point $p_H = 6{\cdot}09$.

The mass law leads to an equation containing the fourth power of the hydrogen-ion activity:

$$\frac{K_a}{[H]} + \frac{K_b[H]}{K_w} + 1 = \frac{C\left(\frac{K_a}{[H]} - \frac{K_b[H]}{K_w}\right)}{[H] - \frac{K_w}{[H]}}$$

where C is the concentration of ampholyte.

Sörensen succeeded in obtaining an effective solution to the equation by insertion of the experimental values of maxima and minima in the differential. In the last section of this remarkable piece of work, Sörensen gives examples of application of these methods of accurate determination of p_H to the enzyme reactions of invertase, catalase, and pepsin. This is, in fact, the commencement of what is now a large chapter in biochemistry and we are indebted to many workers in Scandinavia, especially Euler, for the continuation and extension of the work.

The wide influence which " Studies in Enzymes. II " exerted on the scientific world is well exemplified by a small anecdote. At the beginning of term some young Danish students observed a bewildered Chinese wandering about in Copenhagen. Apparently he could only speak Chinese with a few words of English. After lengthy cross-examination the word " physiology " was recognised, but the names of Danish scientists pronounced in Danish fashion produced no response. Finally a student wrote " p_H " on a piece of paper and was gratified to observe that it met with immediate recognition. The Chinese student was taken to Sörensen's laboratory, where he was, in fact, expected.

The stage was now set for Sörensen to commence work on the proteins, and it may be said that it was the stress laid on the importance of the salt content and p_H of a solution containing protein that permitted Sörensen to become the pioneer in physical chemistry of the proteins.

We must recollect that early in the century the late Sir William Hardy had noted that isoelectric serum protein when diluted or dialysed was no longer isoelectric and that " ionic globulin " appeared as an opalescent cloud; this and similar observations led him to believe that the original protein was not a mixture, but a complex which was broken down into artificial products, the composition of which depended on the degree of dilution and nature of the salts present. Hardy's observation appears to have been neglected until Sörensen took it up again. On re-examining the point, he discovered that with several purified proteins, especially serum albumin, dissolved in dilute salt solutions the amount of protein in apparent solution varied with the amount of solid phase present; likewise by proper fractionation he obtained a series of crystalline albumins with different chemical and physical properties which could be recombined again to yield a protein with the properties and composition of the original.

The serum albumin thus behaves as if it were not a simple mixture but a system of dissociable complexes from which, under such conditions when the solubility product of any one particular complex is exceeded, it is precipitated. The composition of the precipitate will thus vary with the salt content and p_H of the solution, which affect the concentration and solubility of all the possible complexes to different extents.

We thus arrive at the concept of a division of proteins into two classes: those which are formed of dissociable complexes united by residual valencies, such as serum albumin or casein, and those which are stable units, such as hæmoglobin, egg albumin, keratin, trypsin, and pepsin.

Svedberg's centrifugal analysis of the soluble proteins reveals the fact that the group of proteins which appear monodisperse with molecular weights some multiple of 34,500 are only so within certain limits of p_H and break down, frequently reversibly, on alteration of the p_H of the solution. The system hydrated egg albumin, water, ammonium sulphate with either ammonia or sulphuric acid in excess is a four-component system. Previous investigators had suggested that the solubility of the protein was dependent upon the quantity of solid protein present and thus an exception of the prediction of Gibbs' phase rule. Since the separation and determination of the composition of the pure crystalline phase is not

possible by direct methods, Sörensen and his colleagues devoted much time and great skill to developing indirect methods of analysis. It was found that the crystals separating contained both excess water of hydration, some 0·22 g. per g. of egg albumin, and under certain conditions excess of either sulphate or ammonia. When this cause of variation of composition of the mother liquid was eliminated, the solubility was found to be independent of the amount of solid phase present.

Sörensen succeeded in preparing globulin-free egg albumin, following with a slight modification Hopkins' method of crystallisation at the isoelectric point from saturated ammonium sulphate.

The isoelectric point as defined by Hardy, *i.e.*, absence of mobility of a solution of ovalbumin in an electric field, is found when the solution is adjusted to p_H 4·8, but in such a solution, Sörensen pointed out, whilst the protein possesses no net charge, the number of hydrogen and hydroxyl ions set free (or adsorbed) will only be equal if no other ions are involved; and in ammonium sulphate solutions this is not the case. Again, the majority of proteins possess more acid than basic groups. He accordingly defined the isoionic point as that p_H at which the combination of the protein with acid and with base in the ammonium sulphate salt solution is equal. He found the isoionic point of crystalline ovalbumin to be at p_H 4·58; hence at the isoelectric point of p_H 4·8 the crystalline ovalbumin is obtained as the sulphate. This can be partly converted into the chloride or other salt by washing with a salt solution suitably adjusted to the p_H. These suggestions of Sörensen concerning the isoelectric and isoionic points of egg albumin were tested and confirmed at a later date by Tiselius and applied by Adair to hæmoglobin. The isoionic point is unaffected by the concentration of the protein or of the added salt over a considerable range of concentrations and it is thus important as a means of characterising the proteins.

Sörensen was the first to refine osmotic methods to the point where reliable osmotic pressures could be obtained for proteins, and with this material he showed, *inter alia*, that two solutions in ammonium sulphate of the same p_H and composition exerted identical osmotic pressures, and that, since proteins were amphoteric, the osmotic pressure was dependent on the p_H.

In the theoretical part of the work, Sörensen discusses Donnan's theory, and shows that as a consequence of this theory, it is possible—but not certain—that all of the observed osmotic pressure should be attributable to the protein, in systems where the protein is not far from the isoelectric point, and the salt concentration is high. He also discusses the methods for calculating the molecular weight of protein in a mixed solvent, in accordance with the formula

$$\pi = (RT/V_0)(N_e + \tfrac{1}{2}N_e^2 + \tfrac{1}{3}N_e^3 . . . . .)$$

where N_e is the molar fraction of egg albumin, and V_0 is the mean molal volume of the solvent.

He found experimentally that the osmotic pressure was a continuous function of the concentration of protein, hydrogen ions and salts and the data led him to the conclusion that the particles of egg albumin underwent aggregation with increase in the concentration of ammonium sulphate.

Sörensen obtained the value 44,000 for the molecular weight of egg albumin in 4·36% ammonium sulphate. It is interesting to note that, from one series of experiments with egg albumin in distilled water on which he did not lay much stress, he deduced a tentative value of 34,000, a figure which has subsequently been widely accepted as a definitive one; many authors, using either centrifugal or diffusion measurements, succeeded in obtaining the same value. Adair's more recent careful work, however, in phosphate and acetate buffers suggests that this low value is in fact not correct, for Adair obtained values in the neighbourhood of 46,000.

More recent ultra-centrifugal values in which sufficient time is given for attainment of equilibrium give 44,000 as the preferred value, and at the time of writing 45,000 can be taken as the best value for the molecular weight of egg albumin.

Sörensen's osmometric work on serum albumins and serum globulins led him to his conception of reversible dissociable systems which I have already referred to. It is of

interest to note that in the course of his work on horse serum albumin he isolated three fractions differing in solubility but of the same size and with the same titration curves. He made a tentative calculation of 45,000 for the molecular weight as a mere estimation of the order of magnitude. Burke's as well as Adair's more recent observations show that Sörensen's experimental data are consistent with the value of 70,000 obtained by them.

The importance of this osmometric work cannot be over-estimated, for it laid down the fundamental conditions, both theoretical and experimental, necessary for exact work and showed that the laws of solution were applicable to proteins, which must thus be regarded as macromolecules and not as micellar systems. We are thus indebted to Sörensen for first filling in the gap between the particulate suspensions examined by Perrin and the ordinary molecular solutions. As we know, this pioneer work has been brought to fruition by the careful work of Adair in this country.

In this sketch it would be impossible even to enumerate the contributions which this indefatigable worker made to biochemical problems by his physico-chemical method of approach. I might refer to two only of especial interest. Towards the end of his life he carried out with his wife, Margrethe Sörensen, experiments on the solubility of the complex carbon monoxide–hæmoglobin in ammonium sulphate and also investigated certain lipo-proteins. If the albumin fraction is separated from serum by means of half-saturated ammonium sulphate at p_H 3·8, it is found to be quite soluble in water at p_H 7 but to contain lipids such as lecithin and cholesterol esters. From this lipo-albumin the lipids cannot be extracted with ether until the complex is destroyed by hot alcohol. The linkage between lipid and protein was regarded by Sörensen as a non-polar or residual valency one. It is interesting to note that similar stable complexes can be formed in monolayers and the parts played respectively by the London dispersive forces and the dipolar electrostatic interaction can be evaluated, no evidence for a true covalent linkage being obtained.

In his capacity of Director of the Carlsberg Laboratories, especially in later years when he had so many outside interests and State demands on his time, he covered a remarkable amount of ground, being blessed with an exceptionally good memory and a flair for systematic organisation. One gathers from conversation with many of his co-workers, both native and foreign, that whilst at times he might be severe and demand hard work, he had that great gift of real enthusiasm for science which made him a great leader.

Sörensen's interests were wide. In addition to his scientific work he contributed to many technical and industrial processes and was Chairman of the Board of Directors of the Danish Spirit Industry, the Danish Yeast Industry and the Danish Explosives Factories Ltd. His influence on biology and medicine was great, not only on account of his own work, but also from the fact that he invited large numbers of foreign scientists to share his hospitality in the well-equipped Carlsberg Laboratories. He took a personal interest in medical problems, his name frequently appearing as examiner of Doctorate Theses. He likewise contributed to our knowledge of the treatment of digestive troubles, diabetes and epilepsy. Sörensen was responsible in no small way for the place that Danish publications now hold in the world's medical and scientific literature.

He became President of the National Academy of Sciences and many honours were conferred upon him. As far as English Scientific Societies are concerned, he was made an Honorary Foreign Member of our Society in 1920, an Honorary Corresponding Member of the Institute of Brewing in 1927 and an Honorary Member of the Society of Chemical Industry in 1931.

Finally one might mention that he was for many years President of Denmark's Air Raid Defence Society.

He died at the age of seventy-one after about a year's illness and by his death the world loses a perfect example of a man whose devotion to scientific accuracy and consistency should serve as an example to many who, claiming to be scientific in this ever-accelerating age of speed, serve their science badly by neglecting the solid in their search for the superficial and spectacular. Those who are not scientists might well pause and reflect on the high standard of living in Scandinavian countries due in great measure to the concern of such scientists as Sörensen in the State, and to the State in appreciating the rôle of science in industry and agriculture. Here we have much to learn from Scandinavia. It may well

be that the spirit of science endows scientists with an essentially Grecian outlook on life. Large modern States in which representative government exists are essentially Roman in concept and in design. The administrative machinery of such States is such as to permit of a greater degree of co-operative service than is possible in the newer systems based on the "Fuehrer Prinzip" which appear to involve essentially an impressed and devolutionary Platonism. Whilst it is possible in this system to achieve a ready application of known scientific principles in all the activities of the State, it does essentially stultify the growth of scientific thought, if not cause its eventual cessation. The advantage to be gained by its adoption is clearly only temporary and we must, for a solution, find some method of preserving the Greek spirit in a Roman body, an elastic member in a rigid frame-work. We see from Sörensen's life that this has been possible in Denmark. The more highly developed and organised a large State becomes, the more difficult it appears to foster that co-operative spirit which is the best method by which Science can aid the State and still remain true to its ideals. This is our immediate problem.

I am deeply indebted to Prof. K. Linderstrom-Lang and to Dr. G. S. Adair for the assistance that they have given me in furnishing me with many details concerning Sörensen's life and work.