investigations—tendencies which (in my opinion) are likely soon to give way in part to those in the opposite direction.

My examination of these volumes has revealed remarkably few defects. The index will probably not prove to be as good as it might have been made, if one may judge from the omissions detected by looking occasionally to the index for references to interesting passages which were being read. One misses the "Classified table of contents" promised on the title page to the last volume but not supplied (at least in the copy I have and in one other which I consulted). The few pages required for this would have added greatly to the value of the work as a whole. But the defects are so few and the merits are so many that one should probably forget the former in his enjoyment of the latter. The distribution into articles is along the lines of an almost ideal arrangement; and the articles which I have read maintain generally a very high degree of excellence.

It remains to mention one other feature which should commend the work to all English speaking peoples. We may put this in the words of the editor, as given in the preface. "In the material structure of the New Volumes, and their sub-editing, the same note of Anglo-Saxon solidarity is struck as in the Eleventh Edition; and this is again emphasized by their being dedicated jointly to the two Heads of the English-speaking peoples, by express permission of King George V and President Harding. Nowhere except in Great Britain and the United States would it have been possible, under the world conditions of 1921, to find the standard of poise and perspective required in their construction." In concluding his preface, written after twenty-one years of continuous service as editor of the *Encyclopædia Britannica,* Hugh Chisholm says: "As architect both of the Eleventh Edition and of the superstructure which now converts it into the Twelfth Edition, it has been the present writer's privilege to be served by an international company of practical builders, supplying the world's best available materials and masonry; and he has been inspired by the ambition of cementing and adorning, in the completed edifice, that great movement for Anglo-American cooperation, on whose progress from strength to strength the recovery of civilization after the World War of 1914-19 must so largely depend."

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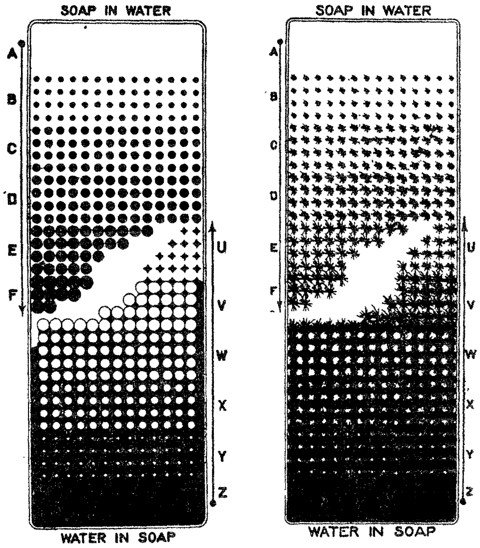
SPECIAL ARTICLES

ON THE ELECTRICAL RESISTANCE OF PHENOL WATER SYSTEMS AND OF PROTOPLASM

I

WE have tried to show in previous communications[1] that the characteristics of lyophilic colloid systems are best explained on the assumption that they are mutually soluble systems of the type phenol/water, butyric acid/water, etc.

Any lyophilic colloid system (like soap/water or protein/water) is, like phenol/water, capable of forming two types of solution, one of phenol in water and a second of water in phenol. When an ordinary soap/water system is permitted to cool, say from 100° to room temperature, it changes from the first of these two types of solutions to the second. In the course of such change two zones of mixed systems are passed which are of special significance. As shown



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[1] Martin H. Fischer and Marian O. Hooker, SCIENCE, xlviii, 143 (1918); Martin H. Fischer, SCIENCE, xlix, 615 (1919); *Chemical Engineer,* xxvii, 186 (1919); Soaps and Proteins, 64, New York, 1921.

in the diagrams of Figure 1 we pass from the original non-colloid, "molecular" or "ionized" "solution" of soap in water (zones A) through a first type of mixed system which is a dispersion of solvated soap in soaped-solvent (zones B, C, D, E) into a second which is a dispersion of soaped-solvent in solvated soap (zones V, W, X, Y). At the bottom lies the second type of true solution which we have called water in soap (zones Z). All the systems between the true solution at the top and the true solution at the bottom are, if the dimensions are correct, "colloid."

This concept explains readily the "peculiarities" of the so-called lyophilic colloid systems. Obviously it sets no limitations upon the nature of the materials that may make up such a colloid system and makes no specifications as to the nature of the forces which guarantee its stability. They are any or all which may appear or be operative whenever "solution" of any kind occurs. Electrical notions of colloid stability are at present particularly acceptable. But how can such be the dominant factors in those most typical lyophilic colloids which consist of nothing but nitrocellulose with ether and alcohol, agar-agar with water, or rubber with benzene? They are of minor significance even in those lyophilic colloid systems which are composed of an "electrolyte" and water (like soap/water). The most stabile of these systems show the least evidences of electrical charges. When such appear they are not the cause of the colloid behavior but the accidental consequence of having an overplus of "solvent" present in the system into which some of the soap has gone in true solution with secondary hydrolysis and electrolytic dissociation.

The concept of the solvated colloid as here outlined clarifies the concepts of *hysteresis, gelation capacity, swelling* and *syneresis.* Hysteresis is the expression of the fact that solution takes time, wherefore two mutually soluble substances can not quickly come to equilibrium. The point at which a lyophilic colloid "gels" is (zones F) that at which the solvated colloid phase becomes the external one. The system as a whole still carries at this point as an internal phase a solution of the colloid in the solvent. The combination marks the gelation capacity of a colloid with its solvent and is always greater than the solvation capacity of the colloid. The latter is a measure only of the solubility of the solvent in the colloid material. The increase in the volume of the latter as the solvent is taken up measures its ability to "swell." The zone Z in the diagrams covers the swelling capacity of a given material with its solvent; the gelation capacity embraces all the zones above this up to and including the zone V. As soon as this zone is passed the external solvated colloid phase may not inclose all the solution of colloid in solvent wherefore the system as a whole begins to sweat; in other words, exhibits the phenomenon known as syneresis. Colloid systems in which one of the mutually soluble materials is solid (diagram B) will obviously fail more easily to inclose adequately the internal phase than will such in which both materials are liquid (diagram A), wherefore colloids of the type sodium stearate/water, silicic acid/water, etc., show a greater liability to syneresis than more liquid ones like sodium oleate/water, rubber/benzene, etc.

II

Our various colloid-chemical studies during the past years have demonstrated the analogies which exist between the behavior of lyophilic (hydrophilic) colloids and living cells. Not only are the laws which govern *water* absorption or secretion[2] by the former identical with those which govern water absorption or secretion by living cells but the absorption and secretion of *dissolved substances*[3] is identical in both. The analogies between living matter and lyophilic colloid systems demand that the former find some place in the diagrams of Figure 1. The physico-chemical properties of protoplasm are such as place it definitely in the lower regions of the diagrams. Protoplasm is essentially, in other words, a solution of water in protoplasm. The more solid structures of the body never, normally, lie above the middle of the diagrams

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[2] Martin H. Fischer, Physiology of Alimentation, 268, New York, 1907; *Am. Jour. Physiol.*, xx, 330 (1907); *Pflüger's Arch.*, cxxiv, 69 (1908); *Ibid.*, cxxv, 99 (1908); *Ibid.*, cxxvii 1 (1909); *Ibid.*, cxxvii, 46 (1909); or in connected form in Oedema and Nephritis, Third Ed., New York, 1921.

[3] Martin H. Fischer, Oedema, 202, New York, 1910; or Oedema and Nephritis, Third Ed., 206, 301, 315, 367, 393, 640, New York, 1921.

and even such liquid protoplasmic structures as blood and lymph can not lie much above the level E. The more aqueous *secretions* from the body, on the other hand, like urine and sweat, approximate the level A (that of the true solutions) though even these, through admixture with colloid substances (colloid salts and proteins) are better comparable to levels like B or C. The physical chemists have for the most part sought the solution of physiological behavior by trying to rediscover in living matter the laws of the dilute solutions. But protoplasm does not lie in or near the levels A of the diagrams but nearest the levels Z. *The physico-chemical laws which govern systems of this type are those which are most likely to find unobjectionable applicability to protoplasm.*

III

The system phenol/water in its two phases, water-dissolved-in-phenol and phenol-dissolved-in-water yields in handy laboratory fashion the analogues respectively of the zones Z and A of the diagrams of Figure 1. Protoplasm is comparable to the solution of the water in the phenol; the secretions from the body to the solution of the phenol in the water. It is the purpose of this paper to discuss especially the electrical conductivity of the former.

1. Carefully purified phenol shows a very high electrical resistance (over 210,000 ohms) when measured in the customary fashion with a fixed pair of platinized platinum electrodes of the dip type (of the constant .0793) with a Wheatstone bridge arrangement and a telephone. The addition of water in increasing amount to such pure phenol progressively decreases its electrical resistance until when saturated with water (at 20° C.) it shows under laboratory conditions a resistance of not less than 21,000 ohms.

2. Our experiments were performed by adding to 50 c.c. of liquefied phenol 50 c.c. of water or the solutions to be discussed. It needs first to be pointed out that the phenol under such circumstances takes up the water and increases its volume. The phenol, in other words, "swells." When thus "swollen" through saturation with water the basal resistance of 21,000 ohms is registered. The addition of acid or alkali to the phenol/water system reduces the electrical resistance of the hydrated phenol phase. When enough of either is added the resistance of the phenol phase becomes so low as to approximate the values shown by solutions of phenol in water. At the same time that this change occurs the volume of the phenol phase also changes. Acid decreases it slightly but alkali progressively increases it. In common parlance the phenol "swells" more in the presence of an alkali than in pure water.

3. At the same normality different alkalies are unequally effective in reducing the electrical resistance of hydrated phenol, potassium hydroxide, sodium hydroxide and calcium hydroxide being progressively less effective in the order named.

4. The addition of any single neutral salt to a phenol/water system also lowers the electrical resistance of the phenol phase but not as much as do acids or alkalies. The nature of the salt employed and its concentration, however, make a difference. With progressive increase in the concentration of any single salt there is at first a decrease in electrical resistance of the phenol phase to be followed later by an increase. The volume of the hydrated phenol phase is progressively reduced with successive increments in the concentration of the added salt. When salts of a common base but with different acid radicals or salts with a common acid but with different basic radicals are compared at the same molar concentration or at the same normality, they prove unequally effective in reducing the electrical resistance of hydrated phenol. While the radicals differ even within the same group it may be stated as a general truth that monovalent radicals decrease the resistance of hydrated phenol more than divalent radicals and these more than trivalent ones.

5. Since salts show differences in reducing the electrical conductivity of hydrated phenol it is an easy matter to demonstrate an "antagonism" between them. The gradual substitution of a bivalent salt (like calcium chloride) for the sodium chloride in a sodium chloride solution therefore "antagonizes" the electrical resistance-reducing effect of the latter.

6. The addition of anhydrous ethyl alcohol to a phenol/water system at first lowers the electrical resistance of the hydrated phenol (though not as markedly as does the addition of an electrolyte) and then increases it to twice

the figure characteristic of the pure hydrated phenol. But the effect of the alcohol upon the volume of the phenol phase is a progressive one, each added amount of alcohol increasing it. When different monatomic alcohols are compared, it is found that only the lower members bring about a decrease in the electrical resistance, all the higher ones increasing it. The lower alcohols also make the phenol phase "swell" more than the upper ones.

IV

These findings are of significance for a better understanding of certain aspects of cell behavior, more particularly the phenomena of "permeability" of "cell membranes" or of "protoplasm" in general. The attempt is still being made to understand these phenomena through some modification of Pfeffer and De Vries' osmotic concept of the living cell or Overton's lipoid membrane modification of it. The physico-chemical and biological objections which may be raised against either of these notions are too numerous to need repetition here. The living cell is capable of absorbing and secreting water, of absorbing and secreting the most varied types of dissolved materials, the two moving at times in the same direction and at times in the opposite direction. There can be no adequate physico-chemical concept of the living cell which does not contain within it the possibility of understanding all these characteristics at one and the same time. The volume of the hydrated phenol phase described above "swells" and "shrinks" when subjected to the action of alkalies or of salts, shows, in other words, the biological phenomena of plasmoptysis and plasmolysis, just as does any hydrophilic colloid (protein) or the living cell. But such a phenol system shows also the "strange" phenomena of permeability to dissolved substances so characteristic of living matter. It is quickly permeable, for example, to the most varied dyes; to another group of such or to iodine it is less permeable. While permeable to the salts, hydrated phenol takes these up most slowly and in certain instances practically not at all. Identical observations are characteristic of protoplasm and the living cell.

The high electrical resistance characteristic of living matter has always been difficult to understand as long as we held to the view that protoplasm was essentially a somewhat modified dilute solution. In spite of the conclusion that a physiological salt solution is supposed to be osmotically comparable with the salts dissolved in a living animal or its body fluids, the former will register only 1/5 to 1/35 the electrical resistance of the latter. This old biological truth can be understood only by denying to the salts found in protoplasm any large existence in uncombined form or by concluding that the cell is a different sort of solvent for these salts than is water. Experimental evidence supports both these conclusions. Aside from the fact that the electrolytes are for the most part "combined" with the protoplasmic constituents and are not "free" as in an ordinary salt solution, the high electrical resistance of protoplasm is further accounted for as soon as it is remembered that protoplasm is not a solution of protoplasmic material in water but of water in protoplasmic material, one comparable in other words, to the solution of water in phenol. The effects of acids, of alkalies, of single salts, of anesthetics, etc., all of which reduce the normal electrical resistance of living matter, are then to be understood in the same terms in which these factors reduce the electrical resistance of systems of the type, hydrated phenol. Even the physiological antagonism between different salts so characteristic of living matter reappears in the case of hydrated phenol.

V

What has been said above for phenol/water systems is true of many other mutually soluble systems. Quinoline, for example, behaves much like phenol and what has been said of these substances holds also for the lower fatty acids, the soaps and the various proteins.

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THE ORIGIN OF COLUMNAR HOLES IN WANDERING DUNES

The forests which existed on the New Jersey sand strands at Wildwood, Holly Beach, Peermont, South Atlantic City and South Seaside Park have been almost entirely destroyed, except at South Seaside Park and Peermont. The forest at the latter place has been invaded by wandering dunes, the highest of which are