both of these properties seem to be essentially connected with atomic volume and compressibility.

9. *Radial Velocities within the Great Nebula of Orion:* EDWIN B. FROST, Yerkes Observatory, University of Chicago.

We must alter our conceptions of the nebula as an enormous mass of quiescent gas, and regard it as seething with local whirlpools besides perhaps having a considerable motion of rotation as a whole.

10. *The Radial Velocities of the More Distant Stars:* WALTER S. ADAMS, Mount Wilson Solar Observatory, Carnegie Institution of Washington.

The radial velocity of stars increases rapidly with the proper motion, and only very gradually with the spectral type. This agrees with Eddington's hypothesis that the relation between velocity and spectral type may be a relation between velocity and distance.

11. *Localization of the Hereditary Material in the Germ Cells:* T. H. MORGAN, Department of Zoology, Columbia University.

The chromosomes not only furnish a mechanistic explanation of Mendelian heredity, but in the case of non-disjunction and in the case of the point-by-point correspondence between the linkage groups and the chromosomes, furnish a verifiable explanation of the results. In the case of crossing-over and of interference the chromosomes give us the only objective explanation of the results that has been as yet offered.

12. *Researches on the Chemical and Mineralogical Composition of Meteorites:* GEORGE P. MERRILL, Department of Geology, United States National Museum, Washington.

Abstract of extensive investigations which will appear as a memoir in the series of *Memoirs of the National Academy.*

13. *On the Representation of Arbitrary Functions by Definite Integrals:* W. B. FORD, Department of Mathematics, University of Michigan.

The function $f(x)$ is represented as the limit of a definite integral depending on a parameter when the parameter becomes infinite, or by a series of definite integrals.

14. *The Lymphocyte as a Factor in Natural and Induced Resistance to Transplanted Cancer:* JAMES B. MURPHY and JOHN J. MORTON, Rockefeller Institute for Medical Research, New York.

A marked increase in the circulating lymphocytes occurs after cancer-inoculation in mice with either a natural or induced immunity. When this lymphoid reaction is prevented by a previous destruction of the lymphoid tissue with X-ray the immune states are destroyed; hence the lymphocyte is a necessary factor in cancer immunity.

15. *Some Theorems connected with Irrational Numbers:* WILLIAM DUNCAN MACMILLAN, Department of Astronomy, University of Chicago.

The presence of the factors $i - j\gamma$ in the denominators of series arising in celestial mechanics does not affect the domain of convergence of the series, provided γ is a positive irrational number which satisfies a rather mild condition.

EDWIN BIDWELL WILSON

SPECIAL ARTICLES

ON HYDRATION AND "SOLUTION" IN GELATIN

I

THE importance of the swelling and of the "solution" of protein colloids for the interpretation of many biological phenomena has been emphasized repeatedly.[1] Thus, the laws governing the absorption of water by simple proteins like fibrin, gelatin, gluten, etc., and those governing the absorption of water by animal and plant tissues are identical. It has thus become possible to explain on a colloid-chemical basis not only the normal water content of cells and tissues, but also to account for the abnormally great absorption characteristic of excessive turgor, plasmoptysis, and edema. On the other hand, the changes characteristic of the "solution" of previously solid

[1] See Martin H. Fischer, "Œdema and Nephritis," second edition, New York (1915), where references to the older literature on this subject will be found.

colloids (as when gelatin "dissolves" under the influence of a rise in temperature) may be, and have been called upon to explain the origin of the albumin appearing in the urine in certain types of kidney disease, in the liquids which are squeezed off by heavily hydrated (edematous) tissues (the so-called "transudates"), etc.

On the basis of such concepts, excessive turgor, plasmolysis and edema may be defined as states of increased hydration of the (hydrophilic) body colloids, while albuminuria (when not simply due to gross rupture of blood and lymph vessels with escape of their contents) may be defined as a state of increased "solubility" of the kidney colloids. The causes of an edema or of an albuminuria are, in their turn, to be found in the condition or conditions which are capable of bringing about these physicochemical changes in the colloids of the body. As of dominant importance in this matter I have emphasized the abnormal production or accumulation of acid in the pathologically involved tissues, though as I have pointed out many times before, this need not be, and probably is not, the only cause for the observed colloid-chemical changes.

The almost constant association of edema with a "solution" of the body proteins (as, for example, a swelling of the kidney with an albuminuria) suggested from the first that the same cause might lie behind both. In order to prove that this is the case, I have not only described acid intoxication experiments on animals which result constantly in the production of an edema of the kidney (and other organs) and an albuminuria, but also observations on pure proteins (fibrin, gelatin, etc.) which show that the same acid which leads to the increased swelling also leads to "solution" of the proteins.

II

It is a commonly accepted view that the "solution" of a protein represents but the extreme of that which in lesser degree is called swelling. So far as I know, it has been held almost universally that sufficient hydration, results as a matter of course, in "solution." A warning against the general adoption of this view has been sounded before.[2]

I have recently been working on gelatins at concentrations and at temperatures near their gelatin and melting-points. Working in this region has yielded results which prove conclusively that *the phenomena of hydration (swelling) and of "solution" in protein gels, while frequently associated, are essentially different. Hydration is to be regarded as a change through which the protein enters into physicochemical combination with its solvent (water); "solution," as one which can be most easily understood at the present time as the expression of an increase in the degree of dispersion of the colloid.* The experiments show that the increase in degree of dispersion is, on the whole, antagonistic to the hydration process, in that more finely dispersed colloid particles seem incapable of holding as much water as coarser ones.

For the experiments I used a commercial gelatin very low in salts which previous experiments had shown to be capable of great swelling with maintenance of form. Even so dilute a mixture as an 0.8 to 0.9 per cent. solution of the stock gelatin would set into a solid mass when left to itself for a few hours at 25° C. The experiments were carried out with 2 per cent. gelatin. This formed a very stiff gel upon which the effects of different added substances were then studied. The conclusions from such studies may be summed up as follows:

1. The addition of acids and alkalies to gelatin markedly *decreases* its tendency to gel.
2. The addition of acid or alkali will not only prevent gelation of a liquid gelatin but it will at the same concentration make a solid gelatin liquefy.
3. The addition of proper amounts of various salts to acid- or alkali-gelatins which in themselves would never gel leads to their prompt gelation, in other words, the salts antagonize the liquefying action of the acid or alkali.
4. The salts show an optimum in their in-

[2] See Martin H. Fischer, "Œdema and Nephritis," second edition, 433, 444, New York (1915).

hibitive effects upon the liquefying influence of acids and alkalies.

5. At the same concentration different salts are unequally effective in their power of producing gelation in liquid acid- or alkali-gelatins. Speaking generally, trivalent radicals are more active in this regard than bivalent ones, and these than univalent ones.

6. A quantitative relationship exists between the liquefying power of an added acid and the antagonistic action upon this of a salt. Gelatin mixtures containing a definite concentration of some salt, and solid when a certain concentration of an acid is established in them, begin to soften and finally to liquefy as the acid concentration is raised.

7. Other substances besides acids and alkalies favor the liquefaction of gelatin. Urea, pyridin, and the amins are found in this group.

III

These experiments have a bearing upon certain problems in colloid-chemistry and in biology and medicine. Under the former heading they bring the first proof, as far as I know, that hydration and solution in proteins is not the same thing. We seem to be justified in the assumption that gelatin is a chemical substance capable of existing in different degrees of association or polymerization. Depending upon the temperature and other changes in its environment, the degree of this association, and hence the size of the particles of which the gelatin is composed, may be greatly varied. At higher temperatures, under the influence of acids and alkalies, etc., the particles become small, while under the reverse conditions they become larger. With these changes in size they change their physicochemical properties so that under the former circumstances they are liquid and clear, while under the latter they become solid and opalescent. The particles seem capable of absorbing most water (becoming most heavily hydrated) when they have a medium diameter. Entirely neutral gelatin (in which the particles are large) therefore absorbs some water, which on the addition of acid (which multiplies the particles and makes them smaller) is increased. On further addition of acid, however, the particles decrease in size to beyond that optimal for swelling. In this region the mixture, as a whole, begins to liquefy and shortly thereafter begins to show prominent evidences of going into "solution."

In "swelling" experiments this region corresponds with that where with progressive increases in the concentration of acid the steadily mounting curve of water absorption begins to fall. It really means that the division of the gelatin particles has progressed beyond the point at which they hold their greatest amount of water.

The addition of salts to gelatin increases the size of the particles and in so doing brings them back toward the region more nearly optimal for hydration. As the salt makes the gelatin stiffer its opalescence again increases.[3]

From a biological point of view these experiments bring renewed evidence of the protein nature of the reactions in living cells in which an antagonism is observed between acids (or alkalies) and neutral salts. They also show why with a gradually mounting degree of acid intoxication in living matter, more and more salt is necessary to keep the affected proteins in a given physical state; in other words, why in clinical medicine more than "physiological" salt solutions, namely, so-called "hypertonic" ones, must be used in order to reduce an edema, an albuminuria, or similar states. Why salts with bivalent or polyvalent radicals have so long been recognized as of special aid in these practical clinical problems is also evident from these experiments.

The experiments also explain why injured tissues pass, as a rule, through a primary period of swelling into a second one of softening. Under the influence of the acids (and similarly acting substances) brought into play by the injurious agents the tissues first swell, but as the acid content rises protein dissocia-

[3] As will be shown in another communication, most of these statements hold for other proteins also. It is well to emphasize even here, however, that the salts tend to increase the size of the particles and thus dominantly to *favor* hydration under certain circumstances only in gelatin.

tion becomes more prominent, betraying itself by the greater tendency of the tissues to liquefy and, since hydration is now less, by softening.

The experiments also bear upon the problem of digestion and that special phase of it known as autolysis. The first changes observable in these reactions consist of swelling, followed by softening and dissolution of the proteins acted upon. Acids and alkalies have long been known to favor these initial steps in proteolysis, while salts have been known to inhibit them. Their action has usually been laid to the effect upon the enzymes themselves. As has been pointed out before,[4] acids, alkalies and salts produce at least as large and probably their greatest effects upon the proteins undergoing digestion. The important practical and theoretical bearings such considerations have upon laboratory practise and in the every-day problems of the hanging of meat, its preservation by salting, the prevention of putrefaction, etc., is self-evident.

The experiments also reemphasize the necessity of interpreting in the simpler language of colloid-chemistry the mass of experimental material now jumbled under the heading of "permeability" studies. It means little to say that under the influence of acids or of substances which in living cells produce acid effects (like the anesthetics) the "permeability" of the "plasma" membranes surrounding cells is increased so that albumin gets out or salts get in. Not only are plasma membranes figments of the imagination, but nothing is gained by heaping "permeability" properties upon them. "Permeability" is a physiological concept which needs itself to be explained. The proteins throughout a cell (not only in its hypothetical overcoat) can under the influence of acids, for example, be made to absorb water, to absorb salt,[5] to soften and to give off albumin. And as all these effects can be reduced through the addition of various salts, there would seem to remain little reason to ignore for the interpretation of well-known biological facts the simple principles of colloid-chemistry.

MARTIN H. FISCHER
JOSEPH EICHBERG LABORATORY OF PHYSIOLOGY IN THE UNIVERSITY OF CINCINNATI

[4] Martin H. Fischer and Gertrude Moore, *Am. Jour. of Physiol.*, 20, 330 (1907).

[5] Martin H. Fischer, *Jour. Am. Med. Assoc.*, 64, 325 (1915).

SOCIETIES AND ACADEMIES

SECTION OF BIOLOGY AND GEOLOGY

ACADEMY OF SCIENCE AND ART OF PITTSBURGH

DURING the year 1914–15 the Section of Biology and Geology of the Academy of Science and Art of Pittsburgh held fifteen meetings with an average attendance of about 150 members. The general topic under discussion was Evolution and the following papers were presented:

October 6, 1914. Dr. Frank Schlesinger, Director of the Allegheny Observatory: "Evolution of the Universe."

October 20. Professor Henry Leighton, of the University of Pittsburgh: "The Earth's History and Development."

November 3. Dr. Chas. R. Fettke, of the Carnegie Institute of Technology: "The History of the Rocks."

November 17. Dr. A. E. Ortmann, of the Carnegie Museum: "The Direct Evidence for Evolution."

December 1. Dr. O. E. Jennings, of the Carnegie Museum: "The Evolution and Ecology of Plants."

December 15. Dr. A. E. Ortmann: "Evolution in Animals."

January 5, 1915. Professor L. E. Griffin, of the University of Pittsburgh: "Embryology in its Relation to Evolution."

January 19. Dr. W. J. Holland, Director of the Carnegie Museum: "Paleontology."

February 2. Professor Roswell H. Johnson, of the University of Pittsburgh: "Experimental Evolution."

February 16. Mr. O. A. Peterson, of the Carnegie Museum: "The Evolution of Man."

March 2. Mr. George Seibel: "The Evolution of Society."

March 16. Professor L. E. Griffin: "Ant Behavior."

April 6. Professor Gardner C. Basset, of the University of Pittsburgh: "Heredity."

April 20. Dr. H. B. Davis, principal of the Training School for Teachers: "Evolution in Education."

May 18. Rev. Charles E. Snyder: "The Evolution of Religious Thought."

CHARLES R. FETTKE,
Secretary