disconcerting air of finality in the regularity with which the present book records agreements between the new experimental data and the new wave-mechanical theories. This, however, is not the fault of the book nor a peculiarity of x-rays as distinguished from other branches of the physics of electrons. The question whether we now know all that is very exciting about electrons may or may not be worth discussing elsewhere. Here the outstanding fact is that x-rays have been one of the most fruitful sources of evidence about electrons, not only in earlier decades but also in this last, and they probably have plenty more to tell us.

The authors' main objective, however, is not the ephemeral one of outlining the next research problems to be studied. Rather, as stated in their preface, "the main objective of "X-rays in Theory and Experiment" is to present a comprehensive view of the whole field, to call attention to those aspects which seem of most fundamental physical significance, and especially to discuss the theory of the phenomena in sufficient detail that their meaning can be appreciated." And very wisely, they do not go into all this detail at first. Instead, they make their first chapter an excellent preliminary of the whole field. Then for six chapters they go into details in a sort of life-history order, starting with the production of x-rays and following them through scattering, refraction and reflection to their photoelectric absorption. Finally there are two chapters on the interpretation of x-ray spectra and recent refinements in accuracy of measurements, and some mathematical appendices.

Throughout the book, the style is clear and logical. In the first chapter, the survey, the authors use practically no calculus, but they need none, because their objective there is simply to introduce the student to unfamiliar phenomena by qualitative descriptions. This chapter can be read with interest and understanding by any student who has done well enough in first-year physics to want more. From there on, however, free use is made of calculus, but only of such parts of it as a good student acquires in his first year in that subject; and the authors show remarkable consistency in subjecting the student to this much calculus on the slightest provocation but never letting themselves be tempted to overstep this limit.

Necessarily, this restricts the discussion of wave-mechanical theories very seriously. In many cases the less mathematically inclined students might get the impression that wave mechanics is like pulling rabbits out of a hat, and they might fail to appreciate the existence of wave functions that can be visualized and used for qualitative understanding of the theory and for intuitive thinking about what effects to look for next. But this will not happen to students who really want to learn. The fundamental principles of wave mechanics are stated and discussed early in the book, in connection with the production of x-rays, so the better students can see there that the next thing they need is more mathematical study and that the rewards for such study are great. Likewise in discussing the Compton effect (which by the way, the authors modestly call by other names), it is clearly proved that wave mechanics handles the free-electron case very simply and that for any quantitative explanation of scattering by bound electrons wave mechanics is absolutely essential. So even if it seems later to play the rôle of deus ex machina in decreeing queer absolute values for the angular momenta in atoms emitting spectral lines, the students who have the ability to learn more mathematics will be in no danger of lapsing into contentment with vector-model theories. No matter how strongly a reader may want wave mechanics to be carried further, therefore, he probably must admit that the place for that is in books primarily on wave mechanics rather than on x-rays, even as restricted to their place in theory and experiment, and that the choice of material in the theoretical discussions here is really excellent.

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SPECIAL ARTICLES

CONCANAVALIN A AND HEMAGGLUTINATION[1]

HAVING identified the substance in the jack-bean which agglutinates the red cells of certain animal species as the crystallizable globulin, concanavalin A,[2] we have attempted to explain the mechanism by which hemagglutination is brought about.

It has been found that neutral suspensions of higher fatty acids and of coconut, linseed, olive, almond and jack-bean oils are agglutinated by adding concanavalin A dissolved in salt solution. It therefore appeared possible that the lipids in the surface layers of erythrocytes might be similarly affected. However, suspensions of butter, castor oil, lecithin and cholesterol acetate are not agglutinated by concanavalin A and suspensions of lipids extracted from erythrocytes are only incompletely agglutinated.

We have observed that suspensions of rice starch,

[1] From the Department of Physiology and Biochemistry, Medical College, and the Department of Veterinary Bacteriology, Cornell University, Ithaca.

[2] J. B. Sumner and S. F. Howell, *Jour. Immunology*, in press.

corn starch and baker's yeast are readily agglutinated by A and that boiled starch is precipitated by A. Glycogen is very completely precipitated at neutrality. As little as 0.01 mg of glycogen in 5 cc of solution eventually forms a perceptible haziness after adding a few mg of concanavalin A. At first it appeared likely that the agglutination of erythrocytes might be due to a reaction between concanavalin A and the glycogen present. Cow erythrocytes are not agglutinated by A, but after adding traces of glycogen, A agglutinates them readily. However, agglutinatable red cells, such as those of the horse, dog and cat, appear to contain too little glycogen to permit this hypothesis to be accepted. Furthermore, the agglutination of such cells is not prevented by previous incubation with salivary or pancreatic amylase, as would be expected if glycogen were the substance reacting.

We have found that the erythrocytes of the horse, dog and cat, after laking, give a fairly heavy precipitate with concanavalin A, whilst laked cow, goat, sheep and human erythrocytes, which are not agglutinatable, or which are agglutinated with difficulty by A, give no such precipitate. Evidently the erythrocytes which agglutinate do so because of the production of this precipitate. We have not yet succeeded in isolating the substance which forms the precipitate. It is thermolabile and appears to be a protein, but is not hemoglobin.

Joos[3] has claimed that the agglutination of bacteria by immune serum is dependent upon the production of a chemical compound, and we believe that the agglutination of erythrocytes is caused by the formation of an insoluble compound composed of the unknown substance, or substances, and concanavalin A. The unknown substance can not be said to exist in the dissolved state; nevertheless we consider it to be an hydrophyllic colloid. Upon addition of concanavalin A, chemical combination occurs and a hydrophobic compound is formed. This hydrophobic compound offers no impediment to agglutination if salt is present. The red cells of the cow do not contain a substance capable of combining with concanavalin A, but are assumed to contain a hydrophyllic colloid which prevents spontaneous agglutination. When glycogen is added to cow cells, it is adsorbed upon their surfaces and subsequent addition of A forms a hydrophobic compound. If amylase is added to cow cells thus agglutinated, the glycogen is rapidly digested and the cells can be partly resuspended by shaking.

The most difficult point requiring explanation is why hydrophyllic substances present in the surfaces of erythrocytes prevent spontaneous agglutination. We assume that such hydrophyllic compounds attract films of water which act as envelopes and thereby prevent neighboring cells from making contact.

We wish to express our appreciation to the Sackett Fund Committee for financial assistance in this research.

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[3] A. Joos, *Zeit. für Hygiene*, 36: 422, 1901.

CHANGES IN THE POSITION OF CHICK EMBRYOS AFTER THE EIGHTEENTH DAY OF INCUBATION[1]

IT has been demonstrated repeatedly that many chick embryos dying on the eighteenth day of incubation or later, and examined generally on the twenty-second day, are not in the normal position for hatching. New evidence indicates that there is a decided change in the position of the chick embryo after the eighteenth day of incubation and that certain of the previously designated malpositions found in chick embryos are but a natural occurrence in normal development.

Extensive studies have been made by various investigators on the frequency of these so-called embryonic malpositions in the egg of the domestic fowl. In general embryos dying on or after the eighteenth day of incubation have been grouped together, according to their respective positions. Such a classification assumes that no profound change would take place in the position of the embryo after the eighteenth day of incubation. That such is not a correct assumption will be pointed out in this study.

The eggs examined in the present investigation were from a group of inbred single comb White Leghorns with an inbreeding coefficient ranging from 25 to 78 per cent., non-inbred White Leghorns and from a White Leghorn and Light Brahma cross. A total of 1,011 live embryos were available for examination. The eggs were divided into two lots and incubated at two different periods. The seven positions studied were classified as follows: I, normal hatching position; II, head between thighs; III, head in small end of egg; IV, head turned to left; V, normal but beak away from air cell; VI, feet over head, and VII, normal but head above the wing.

In the first phase of this study 51 live embryos were examined on the nineteenth day of incubation and only 7.8 per cent. of these were in the normal hatching position. More were in position VII, which is normal, except that the head is above the wing instead of under it. Fifty per cent. of the embryos were in either position II, III or IV. On the twentieth day of incubation 50.1 per cent. were in the normal hatching position, while 32.9 per cent. were in position VII. Only 16.1

[1] Journal Paper No. J-192 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 54.