cards indicating the buildings occupied, the special signposts in the streets, and the throngs of badged visitors hurrying from section to section compel attention and interest. In Southampton, even towards the end of the meeting, many members had failed to discover the remote or obscure position of some of the centers, and there is little doubt that many of the inhabitants were unaware that the association was holding its meeting in their town. The corporate feeling of the associates was greatly impaired, and there was much less than the usual opportunity for scientific men in different branches to come into contact. The discussions suffered from the same multiplication and the same disadvantages. There is a further and serious disadvantage, initially due to increasing subdivision, and accentuated at Southampton by its local geography; confusion arises in the public mind about the authority behind some of the pronouncements made. What is taken for the voice of corporate science in session may be little more than the vagaries of a group of specialists or even of faddists. If it be thought necessary to preserve the subdivisions, two steps might be taken. In the first place no invitation should be accepted unless it is certain that compact accommodation can and will be supplied; and, secondly, the number of papers should be reduced and their quality should be more seriously investigated beforehand. Such an arrangement would leave time for a limited number of carefully arranged discussions to which scientific men of several branches could contribute, and, if possible, for at least one or two great discussions in a central meeting-hall where the whole association would be assembled in plenary session.—*The Times,* London.

THE USE OF TEMPERATURE COEFFICIENTS IN THE INTERPRETATION OF BIOLOGICAL PROCESSES

THE measurement of temperature coefficients has found a wide vogue in biology, so much so that at least three books have been written on the subject, two of which do little more than summarize the extensive literature. In addition to these, ten years ago Arrhenius[1] published a short work in which he attempted to show the approximate correspondence of the temperature coefficients of living processes with those of chemical reactions. Doubtless Arrhenius did not expect his statements to be taken too seriously. He was content to show a general similarity in the temperature coefficients of chemical and biological processes. During the last year Crozier and his coworkers, as well as one or two other biologists, have enthusiastically taken up the subject and have sought to identify the temperature coefficients of living processes with those of specific chemical reactions.[2]

In general these authors have followed a principle first stated by Blackmann[3] and then developed by Pütter.[4] According to this principle, in any biological performance it is the slowest process of the entire group of processes that controls the speed of the ensemble. Crozier perhaps regards this as an obvious truth, for he makes no reference either to Blackmann or Pütter. In his investigations he seeks to identify the controlling process by comparing its temperature coefficient with the temperature coefficient of chemical reactions as they have been studied for the most part in test tubes.

On the face of it this is scarcely a sound procedure, for two reasons.

In the first place, the temperature coefficients of various reactions are usually known only in pure water. In protoplasm the speed of reaction and the temperature coefficient of the reaction would be modified by the viscosity of the protoplasmic medium. This point was recognized many years ago by Snyder,[5] who lists a number of references to show the effect of viscosity on reaction velocity and temperature coefficients. Other authors who may be consulted are Grummell[6] and Callow.[7]

Moreover, it is obvious that protoplasm is a heterogeneous system. It seems hardly safe to apply to such a system the data on the reaction velocity in homogeneous systems. It is true that for some reactions the reaction velocity for a heterogeneous medium is the same as it would be if the reaction were proceeding in a homogeneous medium. In other cases this is not true. Freundlich[8] distinguishes the two types of reactions and gives names to both. Fortunately Warburg[9] has discovered a method of determining which type of reaction is involved in any particular case. He has shown that at least some of the chemical reactions occurring in living cells are of the type in which the heterogeneity of the medium exerts an influence. The temperature coefficient of

1 Arrhenius, 1915, "Quantitative Laws in Biological Chemistry," London.

2 Crozier, 1924, *Jour. Gen. Physiol.*, VII, 123, 189, Proc. Nat. Acad. Sci., X, 461; Crozier and Frederighi, 1924, *Journ. Gen. Physiol.*, VII, 137, 151; Crozier and Stier, 1925, *ib.*, 429, 571; Glaser, 1924, *ib.*, 177; Cole, 1925, *ib.*, 581.

3 Blackmann, 1905, "Annals of Botany," XIX, 281.

4 Pütter, 1914, *Zeitsch. f. allgem. Physiol.*, XVI, 574.

5 Snyder, 1911, *Amer. Jour. Physiol.*, XXVIII, 167.

6 Grummell, 1911, *Jour. chim. phys.*, IX, 143.

7 Callow, 1915, Trans. Far. Soc., XI, 55.

8 Freundlich, Kapillarchemie, 3te Aufl., Leipzig 1923, pp. 187–204 and 305–315.

9 Warburg, 1921, *Biochem. Zeitschr.*, CXIX, 134; see also Freundlich, *l.c.*

the reaction would then be influenced by conditions dependent on the heterogeneity of the medium. It is quite futile therefore to attempt to apply to these reactions the temperature coefficients determined for homogeneous systems or for systems of differing heterogeneity.

Nor is it by any means certain that the speed of biological processes is controlled by the speed of some one or more chemical reactions. In his attempt to answer the question Kanitz points out that a number of physical factors have exactly the temperature coefficient of chemical reactions. To the list cited by Kanitz[10] it may be well to add a process which is perhaps of great importance for biological activities. It has been shown that some coagulative processes have the temperature coefficient of a chemical reaction.[11]

The recent determination of the temperature curve of protoplasmic viscosity[12] may be of use in deciding the question as to whether the speed of living processes is controlled by chemical or physical forces. In some cells at least, as the temperature rises to 15° the viscosity increases. With further increase in temperature there is for a time a decrease in viscosity. If the speed of protoplasmic activity in general were controlled by one or more chemical reactions we would expect that the temperature coefficient of this reaction or reactions would be less below 15° than above 15°.[13] In many instances this is exactly the opposite of the truth. It has often been shown that the temperature coefficient of many biological processes is greater below 15° than above 15°. Kanitz[14] cites numerous cases, the phenomenon was emphasized by Mlle. Filon,[15] who quotes earlier references, and within the last year it has once more been elaborately emphasized by Crozier. But this argument does not settle the question. It could be supposed, as Pütter does, that as the temperature is raised, at some critical point a reaction with lower temperature coefficient may become the slowest reaction and take the place of the reaction with higher temperature coefficient which previously held this position. Such an explanation would not hold for those cases in which the temperature coefficient increases at a critical point. Cases of this sort apparently occur, as Pütter points out. But even so it might be possible to explain all types of cases on a purely chemical basis if we care to assume with Pütter that the speed of biological processes may to some extent be determined by chemical reactions which tend to retard the biological process.

It is rather astonishing to find Crozier[16] using the Blackmann-Pütter concept to explain cases in which as the temperature rises past a critical point, the controlling reaction is shifted from one with a relatively low temperature coefficient to one with a relatively high temperature coefficient. As the temperature rises we would have the reaction with relatively high temperature coefficient growing increasingly more rapid than the reaction with relatively low temperature coefficient. Crozier assumes that it may become slower. This is evidently a contradiction in terms. There are also other surprising deductions in Crozier's papers. Again and again he advances the hypothesis that oxidations and other biological processes are controlled by reactions in which H or OH ions are the sole catalysts. Such a hypothesis does not fit in very well with the prevailing notion that enzymes play at least some part in practically all biological reactions.

Finally it may be well to again sound the note of caution so frequently voiced by older students of temperature coefficients. The problem is far from simple, it is highly complex. The determination of the temperature coefficient of the entire ensemble of more or less unrelated chemical and physical phenomena involved in the movement of an ant or the duration of life of an insect larva, the comparison of this average temperature coefficient with the temperature coefficient of a single chemical reaction occurring in a totally different sort of a medium, may be interesting as a mathematical exercise, but it can hardly be assumed that any information so gained or that any immediate development of these widely-used methods of attack "may lead to an extremely important method of identifying reactions in undisturbed living matter."[17]

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[10] Kanitz, 1915, "Temperatur und Lebensvorgänge," Berlin.

[11] See Freundlich, *l.c.*, p. 640.

[12] Heilbrunn, 1924, *Amer. Jour. Physiol.*, LXVIII, 645.

[13] For as the temperature rises to 15° the viscosity increase would tend to slow the reaction and as the temperature rises above 15° the viscosity decrease would tend to hasten it. But it must be remembered that the viscosity changes in protoplasm may involve only the grosser elements and that such changes might have little effect on the velocity of chemical reactions.

[14] Kanitz, *l.c.*

[15] Filon, 1911, *Jour. de physiol. et de path. gen.*, XIII, 19.

[16] Crozier, *l.c.*

[17] Crozier, 1924, *Jour. Gen. Physiol.*, VII, 189.

SPECIAL ARTICLES

A NEW SOURCE OF POSITIVE IONS

IN researches with positive ions, considerable difficulty has been met in obtaining a satisfactory source of the required ions. Actually, there has been no source of positive ions which can compare to the present source of electrons in regard to constancy and ease of control.