Radio-activity and Normal Physiological Function.

BY

V. H. BLACKMAN.

THE radio-active substances, or radio-elements as Soddy calls them, are characterized by the spontaneous and continued discharge of rays or particles which are projected from them with various speeds, sometimes with a velocity as great as that of light. The view put forward by Rutherford and Soddy in 1903, that this peculiar activity is due to a process of atomic disintegration, is now universally accepted. The rays projected are of three types— α -rays, β -rays, and γ -rays, some elements like radium and uranium giving off all three, while others exhibit only a single kind.

The α -rays or particles are projected with great velocity, but are easily absorbed by thin sheets of metal. The α -particle is now known to be a helium atom (at. wt. = 4) carrying two unit charges of positive electricity; hence the term *positive* rays is applied to them. The β -rays are more penetrating than the α ones; they are known as *negative* rays, for they consist of negatively charged particles, in fact they are electrons. The γ -rays are similar to X-rays, being light waves of very short wave-length, only one-thousandth of that of visible light.

One would expect that the rays projected from the radio-elements would have a marked physiological action, and we find that they will coagulate protein, will cause 'burning' of the skin, and other deleterious physiological actions. It is also well known that radio-active substances have been used in the control of cancer, and that plants are markedly affected by exposure to these substances.

Most of the radio-active elements, like radium, actinium, and thorium, have high molecular weights and are not normally found in either animals or plants, so that their radio-active processes cannot be considered part of the normal physiology of the organism. In 1907, however, it was shown by Campbell and Wood that radio-activity is not confined to the heavy elements, but that potassium and rubidium emit β -rays; those of potassium having a penetrating power about equal to those of uranium, but of an intensity only about one-thousandth of that of an equal weight of that element. Now potassium is an element which is a constituent of the bodies

of all living organisms, so that the question naturally arises of the importance in normal physiological processes of the β -particles, or electrons, which are continually being shot off from the atoms of potassium. In 1915 H. Zwaardemaker, a Dutch worker, took up this question in relation to animal physiology and carried out a number of observations. He has recently given in English an account of his work in the 'Journal of Physiology' (vol. liii, p. 273-89, Feb. 1920). As his results are of fundamental importance for plant as well as animal physiologists, it seemed important that some brief résumé of them should appear without delay in a botanical journal.

Potassium in a quantity of about 40 grm. is found in the human body and is also an important constituent of the blood, where it occurs in the ionic state, the amount being estimated at about 1 grm. The importance of potassium for the beat of the heart is easily shown by experiments on the frog's heart. If the heart is supplied with Ringer's solution (NaCl 0.67 per cent., NaHCO_3 0.02 per cent., CaCl_2 0.02 per cent., KCl 0.01 per cent.) it will beat for hours; if the potassium is omitted from the solution the pulsation ceases in about 30 minutes. Zwaardemaker took advantage of this well-known fact to obtain information as to how far the action of the potassium ion is to be referred to its radio-active power.

It was shown many years ago that rubidium could replace potassium in Ringer's fluid, but these two elements are not only both radio-active but chemically very similar, so that such a result throws no light on the problem in question. If, however, potassium could be replaced by a radio-active element of entirely different chemical nature, such as one of the heavy radio-elements, the physiological importance of radio-activity would be demonstrated. Zwaardemaker therefore set himself to determine if substances like radium, uranium, and thorium could replace potassium in Ringer's fluid. One difficulty is that of the concentration of the substance that is to be used, for, clearly, what is required is not equivalent molecular, or ionic, concentration, but what Zwaardemaker calls 'aequiradio-activity'. Rutherford has determined the intensity of the physical radio-active effects of the various radio-elements, and from these data the required strength of the substance to be used was estimated. Potassium, as already stated, emits β -rays of only one-thousandth the activity of the β -rays of the same quantity of uranium; radium again is 10^{-9} times as active in this respect as potassium.

From such data Zwaardemaker calculated the amount of radio-element to be added to the Ringer's fluid to expose the heart-muscle to the same intensity of radiation by β -rays as when the normal potassium is used. Armed with this knowledge, Zwaardemaker in 1917 succeeded in demonstrating that uranium, thorium, and radium, when added in aequiradio-active quantity, can replace potassium in Ringer's fluid, not only enabling the heart to continue beating, but restoring the pulsation of a heart which has

stopped from the absence of potassium. Later, ionium was added to the list, and also lanthanum and cerium, which, owing to contamination with actinium, appeared to possess a trace of radio-activity. The gaseous emanation (Ramsay's niton) which escapes from radium when it is kept in aqueous solution was also investigated. This element, which emits α -particles, was also found to restore pulsation to a heart which has been brought to a standstill through absence of potassium. Attempts were made to replace potassium by some non-radio-active element, but all attempts were a failure except in the case of caesium, to which, however, radio-activity has been repeatedly ascribed.¹

These results were sufficiently striking, but the question naturally arose as to how far the disintegrating atom was concerned in the process; i.e. whether the corpuscular radiation alone could excite or restore the heart's function. This question was answered in the affirmative by the still more striking experiment of bringing a glass bulb, containing mesothorium giving off β -rays, near a heart which had been rendered motionless by perfusion with potassium-free Ringer's fluid. The pulsation was found to return invariably, sometimes in as short a time as three minutes. It was also proved later that the α -radiation from polonium was in some cases competent to restore pulsation to a heart.

It will be noticed that the potassium emits β -radiation (negative), while the heavy elements which can replace it emit to a large extent α -radiation (positive). The heart can thus be stimulated equally well by substances emitting either the negative or the positive rays. It was also observed that when substances emitting both α - and β -radiation are supplied to the heart together, they have an antagonistic action, and in appropriate concentrations can be made to neutralize one another.

The capacity of the heavy radio-elements to replace potassium and the corresponding antagonism has also been observed recently by other workers in connexion with the retention of sugar by the kidney and in a certain number of other physiological processes.

The mode of action of these corpuscular radiations is not clear. The charged particles as they shoot along will act by induction, detaching everywhere electrons from their atoms; they also transfer kinetic energy, and when they come to rest, on, say, some colloidal complex of the cell, they will transfer their electric charge and so may set free some ion absorbed on the surface.² Whatever the nature of the action, Zwaardemaker concludes that 'radio-activity is a mighty biological factor capable of restoring a lost function'.

¹ It is possible that we have in the frog's heart a physiological test of radio-activity even more sensitive than the physical methods at present available.

² The radiation of the fixed potassium of the heart muscle appears to be inactive; the reason for this is not clear.

In view of the fact that potassium is an essential constituent of the plant, these results are clearly of great importance to botanists; it may be that the importance of potassium in the life of the plant may in part be explained by its radio-active power. In the minuteness of the dose of the heavy radio-active elements required compared with that of potassium, and in the ease with which a toxic concentration is reached, may be the explanation of the conflicting results obtained by the addition of radio-active earths to soil. In any case, however, Zwaardemaker's result would in no way suggest the superiority of such earths over simple potassium fertilizers.

Physiologists will welcome the deeper analysis of biological processes which Zwaardemaker has achieved, yet it must be admitted that they increase still further the difficulty of envisaging his subject which faces the worker in the field of either animal or plant physiology. To the equipment of ordinary physics and chemistry which such a worker should bear has been added of late years a knowledge of many aspects of physical chemistry, of colloid chemistry, and of some of the more special branches of electrical science; to this heavy burden must now be added a knowledge of radio-active phenomena.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
LONDON, S.W. 7.

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