ULTRAVIOLET RADIATION AND LIVING PROCESSES.

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Various physical and chemical agents have been shown to be capable of influencing life processes in either of two directions, stimulating or inhibiting them, depending on the dosage used, and the degree of susceptibility of the tissue concerned. Ultraviolet radiation and visible light (plus the action of a sensitizing dye) are no exception. Radiation studies covering a five-year period, beginning at the Nela Research Laboratory in Cleveland, and continuing at the University of Chicago and at Woods Hole, Mass., have included the following types of experimental study: activation of eggs of star-fish and sea urchins by means of ultraviolet radiation[1,2] and visible radiation plus the action of a sensitizing dye;[3] stimulation of frog muscle and nerve by means of radiation in the same two spectral regions;[4] differential disintegration in Protozoa,[5] the lower Metazoa,[5] and early embryos[6];[7] modification of development in Arbacia[6],[8] Fundulus,[9] and the chick;[7] inhibition of the fertilizing capacity of Arbacia sperm;[10] inhibition of the fertilization reaction in Arbacia;[11] and the modification of the division rate in Paramecium.[12]

In the three first-named studies, there has obviously been stimulation of a passive system to an active one. In the case of egg-activation, ripe unfertilized echinoderm eggs were stimulated to develop without the addition of sperm, simply by the action of radiation upon the surface of the egg. Radiation, then, may be added to the long list of parthenogenetic agents, though its efficiency is relatively low when measured in terms of the numbers of free-swimming larvae produced. Activation is often incomplete, resulting only in membrane formation.

Radiation in either of the two above-mentioned spectral regions, when allowed to impinge directly upon the surface of an excised gastrocnemius muscle of a curarized frog will augment the twitching induced by the salt solutions in which the muscle is suspended, and will finally produce contractions. Under properly regulated conditions, these contractions may, within a short period of especial reactivity of the muscle, coincide fairly well with the time of flashing on of the light. In another series of experiments, radiation, impinging directly on the sciatic nerve of a nerve-muscle preparation stimulated the nerve. The impulse was carried by the nerve to the muscle and the latter contracted.

Obviously, the ripe unfertilized egg and the sensitized muscle are biological systems in dynamic equilibrium with their environment, yet are easily activable. Stimulating doses of radiation as used in the above experiments, rarely exceeded a period of duration of a few seconds in the ultra-violet experiments, and a few minutes when visible radiation was used in the presence of a sensitizing dye. When longer exposures are made, inhibition of normal life processes occurs, often resulting in death and disintegration.

Such a series of experiments were made with Stentor, Hydra, Planaria, Arbacia larvae, and chick embryos. The results may be summed up as follows: Those regions of the body which at the time of exposure, have the highest rates of physiological activity, are the first to die and disintegrate. The rate of disintegration is a function of the relative rates of physiological activity of the various body regions, and consequently there appear in the radiated organism, gradients of death and disintegration coincident, in general, with the metabolic gradients present. In other words, in lower animals and in early embryos, the disintegration gradient is a simple anteroposterior one, while in higher animals and later developmental stages, such simple gradients are obscured by the appearance of local regions of high physiological activity.

With sub-lethal doses of radiation, (i. e., doses which are not immediately lethal) it is possible to modify embryonic development. Such studies have been made with eggs of Arbacia (where exposures were made before and after fertilization, and in another series, where eggs were fertilized by radiated sperm); with eggs of Fundulus (radiated at various intervals after fertilization); and with hen's eggs, (where exposures were made for varying periods before incubation, and at different intervals after incubation.)

While the embryos appear characteristically modified according to species, the results agree in their main features, namely, the regions of the embryo, which at the time of exposure had the highest rates of physiological activity, are most readily modified in their development, and the liability to modification of specific region depends on the relative rate of this region as compared with that of the rest of the body. Embryonic development may be either accelerated or inhibited, depending upon the dosage of radiation employed. In either case, the regions of highest activity are the first to be modified. With accelerating doses, the resulting embryos exhibit the characteristics of differentially accelerated forms in which the most active regions have attained a relatively more rapid rate of growth than normally. With slight doses, differential recovery appears, while with longer doses, differentially inhibited forms result. The proportion of specific types of abnormalities produced varies with the period of development at which exposures are made, e. g., in Fundulus and in the chick, modification of development of the circulatory system, and of the sense organs and brain parts appears in the largest proportion when exposures are made early in development. Inhibitions of the developing tail region appears when exposures are made much later in development. The most favorable period for the production of modifications in the development of a particular organ appears to be just previous to the time when the organ makes its morphological appearance, that is to say, when the preprimordial stage is reached, such a region has a relatively high rate of physiological activity, and in consequence, is most intimately dependent on its environment for its subsistence, and most readily registers the results of any environmental change which produces a deleterious action on life processes.

Two other methods of studying the inhibitory action of ultraviolet radiation were made as follows: Arbacia sperm were radiated, and were found to lose their capacity for fertilizing normal eggs, as well as their agglutinability by normal egg-water; also, Arbacia egg-water loses its power of agglutinating normal sperm. The rate of loss of both these activities is a function of the dosage of radiation employed.

A series of experiments, now in progress, demonstrates the effect of ultraviolet radiation on the division rate of Paramecium caudatum. Here again, small doses, i. e., less than 5 seconds at a distance of 12 inches from the arc, stimulate the rate of division, while longer doses depress the rate. Inhibiting doses applied early in the division cycle may inhibit division to such an extent that the two daughter cells are unable to separate. There results therefore, a considerable proportion of "permanent" pairs. A second exposure, (and occasionally a third, where both members of the pair do not divide simultaneously,) will further inhibit the division of each of the components of a "permanent" pair, and may, in a small percentage of cases, produce "permanent" 3- and 4-celled Paramecia. Further study is being made of the optimum conditions for the production of 4-celled forms and of their behavior and viability.

In conclusion it may be stated that, (1) living organisms are differentially susceptible to radiation, and (2) that dosage is an important factor in determining whether such effects shall be stimulative or inhibitory in nature.

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