spawning behavior to minimize exposure of the egg and embryo to deleterious light, more specific types of behavior have evolved in some forms for the same purpose. The covering of salmonid eggs with gravel from the stream bottom has already been described. Other fishes, with adhesive, demersal eggs, lay them under projecting stones or in crevices between them, on the stems and leaves of higher aquatic plants, or in clumps of algae. Some fishes build elaborate nests which cover the eggs and embryos. Still others lay their eggs in the empty shells of mollusks and remain coiled about them while they develop. Similar variations in spawning behavior occur in other aquatic animals besides the true fishes.

Aside from this adaptive spawning behavior, the eggs and embryos themselves have also become adapted to help withstand the injurious effect of visible light. Such adaptations would be the development of structures to disperse light or to prevent penetration of lethal rays. In the newly fertilized egg and in the early embryological stages, the small oil globules distributed throughout the yolk could help to disperse light. In later embryological stages the irregular surface of the embryo itself might contribute to this dispersion. The newly fertilized egg and the yolk and embryo of later stages are commonly tinged with yellow. This would act as a filter, permitting mostly the less lethal yellow light to penetrate. In the late stages of embryological development in fishes, large melanophores are common over such sensitive portions of the body as the brain, spinal cord, and abdominal cavity. Large xanthophores are frequently associated with these melanophores. Nicol (*4*) also reports that the chromatophores in decapod larvae and mysids are organized in definite neural and visceral groups.

If the hypothesis that visible light is potentially lethal to the fertilized egg and developing embryo of oviparous aquatic vertebrates and invertebrates is assumed to be correct, it can be concluded that all adaptations tend to minimize the lethal effect of the light, but do not give complete protection against it. The degree of mortality of the eggs and embryos caused by exposure to deleterious visible light would vary with changes in the environment. Years in which the spawning season extended over a period with clear, sunny weather comparatively free of wind and rain might result in unusually clear water, greater penetration of lethal visible light, and poor survival of the progeny of many aquatic forms. Year-class fluctuations in aquatic organisms have been attributed to changes in a wide variety of biological and physicochemical conditions such as food, predation, disease, temperature, salinity, and currents. Yet frequently such fluctuations have shown either no relationship to or a poor correlation with these factors. It is suggested that in these instances visible light intensity might have been the unknown factor influencing year-class fluctuation.

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28 December 1960

Formation of Free Radicals in Tritiated H_2O and D_2O Ice

Abstract. By using tritium as an internal source of radiation, electron spin resonance spectra may be obtained for samples contained in glass without the usual disturbing effects due to irradiated glass. The production of OH and OD radicals in tritiated H_2O and D_2O ice may be readily demonstrated with this technique.

Most of the available data on the production of free radicals in H_2O and D_2O ice have been provided by electron spin resonance studies of samples irradiated by cobalt-60 γ-rays at liquid nitrogen temperature (*1, 2*).

By using tritium, the effects of much higher linear energy transfer may be investigated. Moreover, a given sample may be irradiated and its electron spin resonance spectrum may be examined, both in the same glass tube; thus one may obtain "pure" spectra of the materials under test without the usual disturbing effects due to irradiated glass.

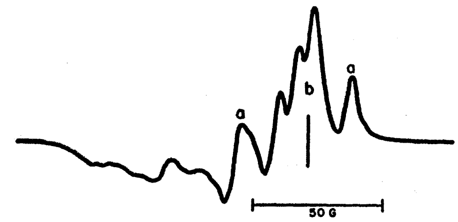

Fig. 1. OH doublet (*a*) and OD triplet (*b*) in electron spin resonance spectrum of tritiated H_2O and D_2O ice. The vertical line indicates the position of DPPH line. Field increases toward the right.

An example of an electron spin resonance spectrum induced by Tβ-particles is shown in Fig. 1. The spectrum, representing the absorption derivative curve, has been recorded at liquid nitrogen temperature with an X-band Varian ESR spectrometer, model V4500, for a tritiated mixture of activity 1 c/ml, containing 80 percent H_2O and 20 percent D_2O.

The sample was kept over the period of about 2 weeks in liquid nitrogen, and the total dose of energy absorbed was 2.9×10^{20} ev/ml. Between the external peaks (Fig. 1, *a*) of the doublet, with separation approximately 40 gauss and *g*-value about 2.01, is situated a triplet (Fig. 1, *b*) with separation of 6 gauss.

By comparison with the data reported for cobalt-60 γ-rays (*2*), the doublet and triplet may be interpreted as due to OH and OD radicals, respectively (*3, 4*).

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3. A full description of these experiments and the production of H and D atoms in tritiated, acidified H_2O and D_2O is in preparation.
4. We are pleased to acknowledge financial assistance from the National Research Council of Canada.

2 December 1960