of succinylcholine caused marked changes in the neural effects on the heart, largest when the stimuli were submaximal, but also evident with maximal stimulation (Fig. 2*B*). However, total blockade of the effects of maximal neural stimuli required larger doses, ranging from 8 to 50 mg/kg (Figs. 1*C*, 2*C*). This total blockade was reversible (Fig. 1*D*, *E*). In all the Nembutalized preparations, sympathetic effects were eliminated before vagal blockade developed fully (Fig. 1*B*, *C*). In all five experiments with spinal, unanesthetized animals, on the other hand, vagal blockade developed somewhat earlier than did the sympathetic (Fig. 2*B*, *C*). There was also an increase in the basal cardiac rate with successive injections of the drug into the spinal animals (Fig. 2), whereas no marked changes of this occurred in the Nembutalized animals (Fig. 1).

Because of the different experimental conditions obtaining in the different tissues, the relative dosages of succinylcholine required for neuromuscular and cardiac blockade cannot be directly compared on the basis of the available data. In the cat, neuromuscular transmission is blocked for about 10 min by 0.25 mg/kg of the drug (*2*). On the other hand, 50 mg/kg is required to cause paralysis lasting 1 hr in the rabbit (*1*). As may be seen in Fig. 1*D*, *E*, 23 mg/kg of succinylcholine caused vagal blockade lasting ½ hr and sympathetic for 1½ hr. The cardiac actions of the drug described here therefore appear to be within the range of its pharmacological effects on other tissues.

Succinylcholine is a cholinomimetic agent that acts like acetylcholine or decamethonium (*6*) to depolarize muscle endplates prior to blocking neuromuscular transmission. Its blockade of vagal cardiac effects resembles the cardiac action of another "depolarizing" drug, nicotine, when the latter is applied slowly and in low concentration (*7*). In neither case is a slowing of the heart observed such as occurs with injections of acetylcholine or larger concentrations of nicotine. The vagal blockade caused by succinylcholine is therefore ascribable to depolarizing blockade of transmission from the preganglionic vagus to the intracardiac postganglionic parasympathetic fibers. Succinylcholine appears to lack the direct, "muscarinic" action of acetylcholine upon the cholinergic myocardial effector junctions, since large quantities of succinylcholine do not decrease, but rather increase, the rate.

Blockade of the cardiac effects of stimulating the postganglionic sympathetic inferior cardiac nerve can be instituted only at the appropriate myocardial effector junctions. Therefore, although the latter are predominantly adrenergic, the generally cholinomimetic agent succinylcholine also acts on these. Since the excitatory cardiac junctions probably develop depolarizing postjunctional (or postsynaptic) potentials, succinylcholine blockade of myocardial effects might come about through a depolarization of these junctions such as succinylcholine also produces at the cholinergic neuromuscular synapses (*8*).

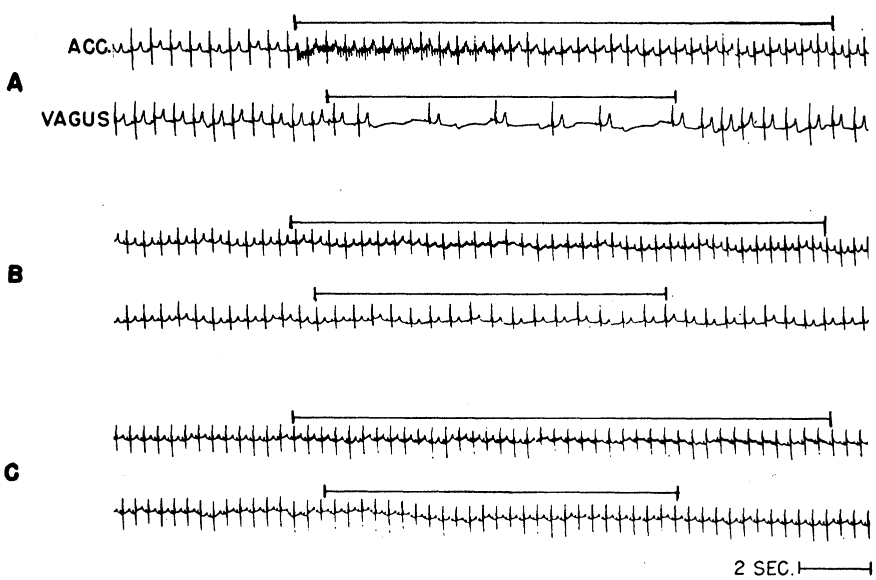

Fig. 2. Vagal blockade developing earlier than that of sympathetic stimulation in a spinal cat. Sequence as in Fig. 1. Bars indicate periods of stimulation. (*A*) Stimulating cardiac nerve produced a relatively small effect, an increase of 20 percent in rate; (*B*) 2 min after injection of 3 mg/kg succinylcholine; basal rate increased about 10 percent, but sympathetic stimulation again increased this by 20 percent; vagal stimulation became much less effective than before; (*C*) 2 min after complete blockade was instituted by an additional injection (15 mg/kg); basal cardiac rate, now 40 percent higher than originally, is not affected by stimulating either nerve.

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References and Notes

1. D. Bovet and F. Bovet-Nitti, *Scientia Med. Ital.* 3, 484 (1955).
2. E. J. de Beer *et al. Ann. N.Y. Acad. Sci.* **54**, 362 (1951).
3. H. Grundfest, *Ann. N.Y. Acad. Sci.*, in press.
4. The technical assistance of Gideon F. Gestring is gratefully acknowledged.
5. An account of the kinetics of these actions of succinylcholine in relation to the dosage of the drug on the parameters of the stimuli, as well as the interaction of succinylcholine and other drugs, is in preparation.
6. R. D. Burns and W. D. M. Paton, *J. Physiol.* 115, 41 (1951).
7. W. L. M. Perry and J. Talesnik, *ibid.* **119**, 455 (1953).
8. An analysis of the differential actions of the drug in the presence or absence of Nembutal is in preparation.

† Special research fellow, National Institute for Neurological Diseases and Blindness. Supported by Donner Foundation.
‡ Supported by grants from the Muscular Dystrophy Associations of America, National Science Foundation, United Cerberal Palsy Associations.

11 June 1956

Biological Decontamination of Fission Products

It is well known that phyto- and zooplankton are contaminated by radioactivity in fairly high concentrations. L. A. Krumholz (*1*) reported that *Volvox*, *Pandoria*, and *Euglena* acquired radioactivity that was 100 times greater than that of water containing fission products at White Oak Creek, Tenn. According to the report (*2*) of the research vessel *Shunkotsu Maru*, around Bikini Atoll in 1954, the extent of radioactivity detected in such zooplankton as copepods was 1000 times greater than that of the sea water that they inhabited. Although the mechanism of the accumulation of radioisotopes in plankton and the action of the radioisotopes in the organism are still vague, it is certain that plankton selectively accumulate specific radioactive elements from the water into their bodies. For example, Boss (*3*) announced that most phytoplankton had high selectivity of Y^{90} and *Carteria* of only $Sr^{89,90}$ from a culture medium containing $Sr^{89,90}$ and its daughter-product Y^{90}.

It has been reported (*4*) that *Aphanocapsa koordersii*, abundant in brackish lake water, are consumed by *Brachionus plicatlis* during the latter's breeding season, and the latter begin to perish with the decrease in the abundance of the former as available food and to sink to the bottom of the lake. If such a limnological process as this were applied artificially to water containing wastes of fission products, some economies in waste disposal might be effected.

A beaker containing 1 lit of water taken from a brackish lake (Cl = 4.42 percent), with fission products (batch No. 19 from the U.S. Atomic Energy Commission) subsequently added to give a concentration of 0.2 μc/lit (2×10^{-4} μc/cm³), was prepared as an original culture medium (*5*). In this medium, the population density of *Aphanocapsa* was found to be 4×10^{6} cell/cm³. Ten-cubic-centimeter samples of the culture were taken from the beaker after 3, 19, 44, 92, and 140 hours and were centrifuged every 15 minutes at 5000 rev/min to separate the precipitate (*Aphanocapsa*) from the upper water. Samples of *Aphanocapsa* and the upper water were dried in a stainless steel planchet, and their radioactivities were measured at a fixed distance below a Geiger-Müller tube (lead-shield thickness, 4 mg/cm²). The results of this experiment are shown in Fig. 1. It was found that about 30 percent of the radioactive elements present in the culture water was absorbed by *Aphanocapsa* under these experimental conditions.

The ability of *Aphanocapsa* to assimilate radioactive elements from the culture water was thought to be so completely exhausted after about 140 hours that the *Brachionus* were added into a beaker at the rate of five pieces per cubic centimeter. The beaker was kept in a thermal-constant box at about 20°C. After the adding, 10-cm³ of samples of the culture water were removed after 24, 43, 120, and 288 hours and separated under conditions previously described.

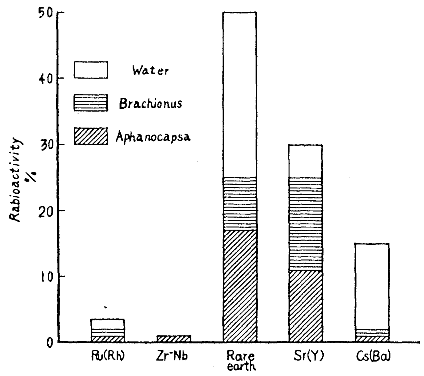

Fig. 2. Uptake of various radioactive elements from water containing fission products by *Brachionus* and *Aphanocapsa.*

As is shown in Fig. 1, *Brachionus* had not only consumed *Aphanocapsa* that had accumulated radioactive elements to a considerable concentration but had, itself, accumulated radioactive elements from the culture water. In this case, where *Aphanocapsa* were consumed by *Brachionus,* only about 1 percent of the initial population density of the former remained after 120 hours. The breeding of *Brachionus* reached a maximum after 120 hours also, and these organisms suddenly perished owing to lack of food and sank to the bottom of the beaker. This aspect is illustrated by the dotted lines of Fig. 1. Corpses of *Brachionus* on the bottom of the beaker had concentrated about 65 percent of the radioactivity in the original culture water. However, after 288 hours, the radioactivity of the culture water had again increased owing to natural decomposition of the corpses.

The radiochemical group separations were carried out for the original culture water, *Aphanocapsa,* and corpses of *Brachionus* by use of an ion-exchange technique. After ashing in an electric furnace at about 600°C and treatment with HCl, samples were absorbed on an ion-exchange bed of Amberite 120 (30 to 60 mesh) and separated into each chemical group by the method of Thompkins (*6*). The samples of culture water were analyzed for $Sr^{90}(Y^{90})$, $Cs^{137}(Ba^{137m})$, and rare-earth elements and were found to have 30 percent, 15 percent, and 50 percent, respectively, of these chemicals. *Aphanocapsa* and corpses of *Brachionus* were also analyzed for each chemical group by the same method. The results of this series of experiments are shown in Fig. 2.

If the population density of *Aphanocapsa* could be increased and a species of phytoplankton found that accumulates Cs selectively, this limnological process might be of use in the decontamination of radioactive wastes.

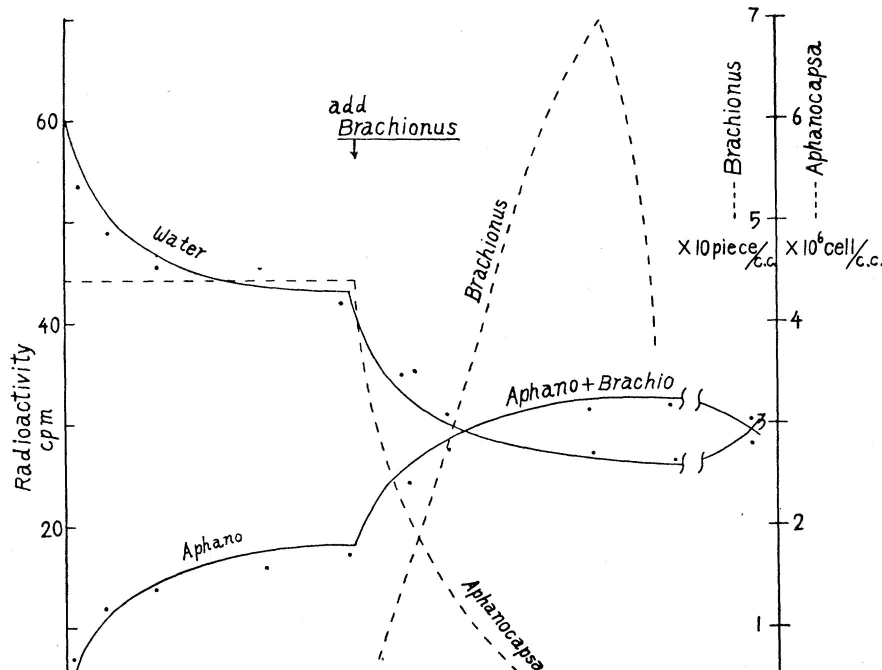

Fig. 1. Relationship between time and radioactivity for culture water and plankton.

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References and Notes

1. L. A. Krumholz, "A summary of findings of the ecological survey of White Oak Creek, Roane County, Tennessee, 1950–1953," *AEC ORO-132,* Oak Ridge, Tenn. (1954).
2. T. Kawabata, *Japan. J. Med. Sci. and Biol.* 8, 347 (1955).
3. W. R. Boss, "Accumulation of radioactivity in marine invertebrate and vertebrate animals," presented at the meeting of Radiological Survey in Tokyo between Japan and the U.S.A. (Dec. 1954).
4. T. Ito, "Report of faculty of fisheries, Prefectural University of Mie" (1956), vol. 2, p. 156.

5. We wish to express our sincere thanks to Takashi Ito, and Toshio Iwai for their encouragement throughout the experiments. This work was supported by a special research grant from the Japanese Ministry of Education.

6. Thompkins, Khym, Cohn, *J. Am. Chem. Soc.* **69,** 2769 (1947); Honda, Sasaki, Natsume, *Japan Analyst* **4,** 240 (1955).

3 May 1956