about 50 times as effective (based on the ED_{50} values in the injection treatment), but this advantage of tepa is outweighed by the low toxicity of HMPA, whose minimum lethal dose, determined by oral feeding to rats, is 2640 mg per kilogram of body weight (*9*). The undiluted compound killed rats when administered orally at a dosage of 6400 mg/kg (*10*). The minimum lethal dose for domestic rabbits (administered through a stomach tube) is reported to be 1500 mg/kg (*11*).

Because of the structural similarity of HMPA and tepa, the sterilizing activity of hexamethylmelamine, an analog of tretamine, was investigated. The structures of the two compounds are presented in Fig. 2.

Because of the very low solubility of hexamethylmelamine in water, the injection technique did not give reliable results, but the topical application of an acetone solution was satisfactory. The results are given in Table 2.

The acute toxicity (LD_{50}) of hexamethylmelamine is reported (*12*) as 220 mg/kg for mice and 265 mg/kg for rats. According to the same report the compound does not produce any cytological alterations in the bone marrow of rats similar to those produced by nitrogen mustards.

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References and Notes

1. A. B. Bořkovec, *Science* **137**, 1034 (1962).
2. Tepa is tris-(1-aziridinyl)-phosphine oxide. Tretamine is 2,4,6-tris-(1-aziridinyl)-*s*-triazine. Apholate is 2,2,4,4,6,6-hexahydro-2,2,4,4,6,6-hexakis-(1-aziridynyl)-1,3,5,2,4,6-triazatriphosphorine.
3. C. Auerbach, *Ann. N.Y. Acad. Sci.* **68**, 731 (1958); A. L. Walpole, *ibid.*, p. 750.
4. A. B. Bořkovec and C. W. Woods, *Advan. Chem. Ser.* **41**, 47 (1963).
5. S. C. Chang and A. B. Bořkovec, *J. Econ. Entomol.*, in press; presented at the St. Louis meeting of the Entomological Society of America, 2–5 December 1963.
6. ED_{50} refers to the dosage required to reduce the hatch of eggs 50 percent as compared to that of the control.
7. The term "sterile male" as used in this report implies only that crosses between a sterile male and a normal female produce no progeny.
8. E. F. Knipling, *Science* **130**, 902 (1959).
9. Monsanto Chemical Co., Technical Data Sheets, Hexamethylphosphoramide, p. 2, 24 August 1956.
10. Eastman Chemical Products, Inc., Technical Data, Eastman Inhibitor HPT, p. 5, August 1961 (rev.).
11. T. R. Adkins, Jr., W. L. Sowell, F. S. Arant, *J. Econ. Entomol.* **48**, 139 (1955).
12. F. S. Philips and J. B. Thiersch, *J. Pharmacol. Exptl. Therap.* **100**, 398 (1950).

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Humoral Factor from the Brain Which Activates Gastric Motility

Abstract. *When the vagus nerves in the neck of the dog are cut and the ends toward the brain are stimulated, gastric contractions follow. These contractions are not abolished by section of the cervical spinal cord, section of anterior and posterior thoracic and lumbar spinal nerves, section of the splanchnic nerves, or paralysis or excision of the celiac plexus. Evidence for the existence of a humoral blood-borne substance originating in the brain was obtained by experiments with an isolated perfused head, by perfusion of isolated stomachs by donor dogs, by cross-perfusion between two dogs, and by plasmapheresis.*

We have observed that when both vagus nerves in the neck of a dog are severed, stimulation of the cut ends toward the brain is followed by a considerable degree of gastric motility. In order to analyze this phenomenon, we used various procedures; for example, cutting the splanchnic nerves, cutting anterior and posterior roots of the spinal cord, cutting the spinal cord at various levels in the neck and chest of the dog, and excising or paralyzing the celiac ganglia. In a few animals, none of these procedures abolished the contractions of the stomach which followed central vagus stimulation in the neck (*1*). For this reason, we began to suspect that a humoral substance might be liberated in the brain or medulla and then be carried by the blood to the stomach where it activates gastric motility. With the exception of a suggestion by Semba *et al.* (*2*) that such a substance might exist, we have been unable to find reports of previous work on such a substance.

To obtain evidence for the existence of this substance we used four different methods. In all experiments, the dogs were anesthetized with pentobarbital sodium. Blood pressure was recorded from a femoral artery with a Statham transducer on a Dynograph. Stomach motility was recorded by three fine plastic tubes inserted at various levels of the stomach and connected to individual Statham transducers arranged to record on the Dynograph.

In our first method, the head was isolated completely from the body except for both carotid arteries and both external jugular veins. The blood vessels were painted with phenol or absolute alcohol in order to destroy the nerve fibers. The cut ends (toward the head) of the vagus nerves were stimulated and, within a few seconds, distinct stomach motility occurred.

In the second method, the stomach was isolated. The celiac axis and the portal vein of dogs were intubated. Hemostasis was accomplished by ligation of all bleeding vessels, and the stomach was removed from the body. In the neck of a heparinized dog to be used as a donor, both vagi were severed and the ends of the nerves toward the head were attached to electrodes. Both internal jugular veins were ligated. Both external jugular veins were ligated and cut above the ligature, and the ends toward the head were intubated with both ends of a Y tube, the straight end of which passed the blood through an oxygenator; the oxygenated blood was circulated by a Sigma pump through the isolated stomach by way of the celiac axis, and returned from the portal vein to a femoral vein of the donor.

When the ends of the vagi of the donor were stimulated, the isolated stomach exhibited multiple contractions, often vigorous, equivalent to a height of 2 to 50 cm of water in 60 percent of these experiments. There was a short latent period of a few minutes and the contractions persisted for 2 to 30 minutes.

In the third method, blood was assayed. In a dog used as donor, both internal jugular veins and one external jugular vein were ligated in the neck. The other external jugular vein was severed, the distal end ligated, and the end toward the head intubated. Blood from the head was thus collected with heparin in 150-ml portions, was centrifuged, and the red cells were injected back into the donor in a suspension of saline or dextran. This procedure was performed twice before, twice during, and twice after stimulation of the ends of the vagus nerves which had been severed in the neck. The plasma was immediately frozen in a thin layer and lyophilized. A dog to be used for assay was prepared so that gastric motility could be recorded from three levels of the stom-

ach. The lyophilized plasma was dissolved in 30 ml of saline and 10 ml of this solution was injected into a carotid artery. Within a short latent period, distinct contractions of the stomach appeared. Injections into the carotid artery of control samples obtained from the donor without vagus stimulation or injection of saline or dextran did not produce contractions of the stomach.

In the fourth method, "cross-circulation" experiments were performed. Two dogs were heparinized and their internal jugular veins and one external jugular vein were ligated. The other external jugular vein was cut, its peripheral end ligated, and its end coming from the head connected to a femoral vein of the other dog. Cross circulation was regulated with flowmeters, so that one dog would not bleed out into the other one. In dog A, both vagi were cut in the neck and their ends toward the head attached to electrodes; when these were stimulated, the stomach of dog B showed distinct multiple contractions after a latent period of a few minutes. The contractions sometimes lasted up to half an hour, but usually they lasted 5 to 10 minutes. The state of the blood pressure (rise, fall, no change) following stimulation of the vagus nerves did not correlate with contractions of the stomach. Stimulation of the end of a cut femoral nerve did not produce contractions of the stomach.

The results of these experiments give evidence which supports the suggestion that a humoral factor is liberated in the brain of a dog upon stimulation of the cut ends of the vagus nerves. Experiments in which animals are hypophysectomized and in which drugs with blocking action are used may reveal the nature of this humoral factor that stimulates the stomach.

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References and Notes

1. N. C. Jefferson, T. Arai, T. Geisel, Y. Kuroyanagi, H. Necheles, *Physiologist*, August (1963); N. C. Jefferson, Y. Kuroyanagi, T. Geisel, H. Necheles, *Science* **140**, 810 (1963).
2. T. Semba, H. Mishima, T. Hiaoka, M. Okamoto, T. Goto, H. Sasaki, *J. Hiroshima Med. Assoc. Original Ser.* **10**, 665 (1957) (in Japanese with English summary).
3. Work supported by U.S. Public Health Service grant AM 06078-01-02 G.M. Our department is supported in part by the Michael Reese Research Foundation.

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Decontamination of Potato Tubers Containing Cesium-137

Abstract. *Stirring for 16 hours at 26° to 35°C of peeled and sliced tubers in a solution consisting of 1.2 percent KCl and 0.16 percent NaCl and containing a cation-exchange resin in the mixed K^+, Na^+ form effected Cs^{137} removals exceeding 95 percent. Neither nutritional value nor palatability of the tubers was adversely affected.*

Heavy and either widespread or local contamination of the biosphere with fission products might necessitate attempts to limit the intake of long-lived radionuclides by the human population. One way of limiting this intake would be to remove a contaminating radionuclide from a food that forms an important part of the diet and that also contains high levels of the nuclide. It has been suggested that when potato tubers are an important item in the diet they may be one of the main sources of Cs^{137} (*1*). Thus a method of removing Cs^{137} from tubers could effect a significant reduction in the intake of Cs^{137} by man (*2*). We present here details of a simple and economical decontamination procedure that removes at least 95 percent of the Cs^{137} from potato tubers without significantly changing either the nutritional value or the flavor of the cooked tuber.

Tubers containing high concentrations of Cs^{137} were produced under "natural" conditions by painting the leaves of the plants (*Solanum tuberosum* L., cv. Netted Gem) with a $Cs^{137}NO_3$ solution (*3*). For Cs^{137} determinations, the tubers (17 to 65 g fresh weight) were digested in concentrated HNO_3 until a clear solution was obtained. The radioactivity of samples of the solution was measured, to within 2 percent standard error, on glass planchets in an argon-methane gas-flow proportional counter equipped with a thin (80 $\mu g/cm^2$) window. No self-absorption corrections were necessary. In the decontamination experiments, one-half of a peeled tuber (cut longitudinally) always served as a control for the other half since the Cs^{137} content varied somewhat between tubers from the same plant. The radioactivity was symmetrically distributed about the longitudinal axis. The removal of a peel approximately 1 mm thick and representing 17 to 20 percent of the fresh weight of the tuber resulted in the loss of only 25 to 27 percent of the Cs^{137} present in the intact tuber.

It was assumed that removal of the Cs^+ ion from the living cells of a potato tuber could be effected by a simple diffusion process. In the selection of conditions that might accelerate this process, the exchange of Cs^{137} ions with ions of stable Cs was ruled out as being too costly. Hypo-, hyper-, and isotonic solutions of KCl and NaCl were not as effective in removing Cs^{137} as was water alone, either at 20°C or at 36°C. Although the degree of decontamination effected in all solutions was much higher at 36°C than at 20°C, raising the temperature of any solution to 100°C resulted in the removal of only about 54 percent of the Cs^{137}, presumably owing to decreased permeability to ions of the cooked, starchy outer cells of the tubers. In the foregoing experiments, palatability of the tubers was inversely related to the efficacy of the decontamination procedure used. Although the degree of decontamination could be increased by adding finely divided vermiculite (exploded mica) to the treatment solution, treated tubers were virtually inedible after cooking. We attribute our inability to develop a practical decontamination procedure making use of vermiculite to the difficulty of changing the chemical composition of this ion-exchange material to correspond to that of the tuber. We thus concluded that a highly effective decontamination process based on the principle of accelerated diffusion of Cs^{137} ions from the cells should be possible if an ion-exchange agent capable of removing these ions from an isotonic treatment solution more effectively than vermiculite could be found. If an ion-exchange agent itself was not detrimental to the tuber (as was the vermiculite) and if the time of treatment could be kept short, then preservation of a high proportion of the nutritional value and the palatability of the tuber should also