second might be expected to be about two stellar magnitudes.

Experimental measurement (5) of the actual reduction of apparent brightness under such conditions was carried out as follows. Intermittent solar reflections from the surface of a polyhedral satellite were simulated by viewing various planets and stars through the interception of a rotating metal disc of about 10-in. radius from which had been cut a sector ⅓ in. wide; this gave a clear opening effectively 1/200 the total area of the disc. The intercepted, flashing image of one star—say Arcturus—viewed with one eye was compared in brightness to the image of another—say Spica—viewed simultaneously, without interception, with the other eye. From the known magnitudes of each star the diminution of the intermittent image was estimated for three typical flash rates, with the results shown in Table 1. For this the flash frequencies and durations were derived from the rotational rate of the disc, as measured with a tachometer.

The graph (Fig. 1) shows these three values of brightness reduction compared to theoretical curves of such reduction for sources, like stars, for which the intermittent images would appear fused for frequencies 15 per second.

For a polyhedral satellite rotating once per second, the mean duration of a reflected sunbeam would be 0.0009 second, and this would vary inversely as the spin rate (1). If, also, the complete polyhedron had 856 faces, the mean frequency would be 2 per second, and this would vary directly with both the spin rate and the number of faces. Since a spherical reflector is optically equivalent, for solar reflection, to a polyhedron having about 200,000 faces (the number of angular solar areas on a sphere), the optical gain from use of the 856-face polyhedron would be about 250, or six stellar magnitudes. Since the present measures indicate a visual reduction, in this case, of only about one magnitude, the net visual gain from use of a polyhedral rather than a spherical satellite would be five stellar magnitudes.

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24 June 1958

Physicochemical Study in Water of a Mucoprotein with Virus-Inhibiting Activity

Abstract. Human urinary mucoprotein precipitated with cetyltrimethylammonium bromide and suspended in distilled water has a light-scattering molecular weight of 2.8×10^6, an intrinsic viscosity of 225, a refractive index increment of 1.73×10^{-4}, and an absorption coefficient ($E^{1\%}{}_{1\,cm}$) of 11.4. The molecule is therefore smaller than that of the mucoprotein isolated by Tamm and Horsfall but retains its biological activity.

A mucoprotein derived from human urine which reacts with influenza, mumps, and Newcastle disease virus has been isolated and characterized physicochemically by Tamm and Horsfall (1, 2). This fibrous mucoprotein, soluble in distilled water and isolated as a single component in the ultracentrifuge, was found from ultracentrifuge and diffusion measurements (2, 3) to have the very large molecular weight of 7×10^6 and to be highly asymmetric.

A mucoprotein with similar antiviral properties and chemical analysis has been isolated by Di Ferrante (4), by a different method. In the ultracentrifuge this is a single component whose sedimentation constant in water suggests that its molecular weight is considerably smaller than that of the mucoprotein isolated by Tamm and Horsfall.

The work discussed in this report (5) is an attempt to characterize physicochemically the mucoprotein isolated by Di Ferrante and to indicate its relationship to that of Tamm and Horsfall. The large molecular weight, the high asymmetry, and the poor solubility in salt solution render light scattering the method of choice in the investigation of this mucoprotein.

The mucoprotein was prepared by the method of Di Ferrante (4) from the urine of two male diabetic patients. Ten grams of cetyltrimethylammonium bromide were added to 18 lit. of urine. After standing 3 days in the cold, the precipitate was removed in a continuous-flow refrigerated Sharples supercentrifuge and washed four times with ethyl alcohol saturated with sodium chloride. The precipitate was suspended in, and dialyzed against, distilled water and clarified by centrifugation. The supernatant was brought to 0.58*M* sodium chloride, and the new precipitate was removed, redissolved, and dialyzed in water. The dialysis was continued with frequent changes for 3 days, and then the precipitate was clarified by centrifugation. All investigations reported here were made on this distilled water solution.

Through the kindness of Igor Tamm, I investigated the biological activity of two samples of this mucoprotein in his laboratory at the Rockefeller Institute for Medical Research and found these to exhibit a hemagglutination-inhibiting activity of 0.013 μg for a fresh sample of mucoprotein and of 0.1 μg for a sample which has been standing at 4°C for several weeks. This activity is expressed as amount (in micrograms) of mucoprotein required for complete inhibition per hemagglutinating unit of heated Lee virus (56°C for 30 minutes).

The intensity of light of wavelength 436 mμ scattered from serial dilutions of mucoprotein in a cylindrical cell at angles of from 26° to 135° from the direction of the incident beam was measured in a Brice-Phoenix light-scattering photometer and recorded in the form of a Zimm plot. The Zimm plot is, of course, highly distorted (6) in the case of media of low ionic strength, and a dissymmetry of less than unity was observed at the highest concentrations used. The extrapolated curve of scattering at zero angle which determines the interaction constant, and the intercept of this curve with the axis of KC/R_θ, which yields the molecular weight independent of the shape of the molecule, are not distorted. The weight average molecular weight was determined by this method to be 2.8×10^6. The interaction constant B is $+0.88 \times 10^{-3}$, indicating that water is indeed a good solvent for the mucoprotein. The solution did not fluoresce at this wavelength and showed a small depolarization.

Viscosity data (Fig. 1) extrapolate linearly at low concentrations to an intrinsic viscosity of 225. The high intrinsic viscosity suggests a highly asymmetric molecule. In view of the electroviscous effect, it would be misleading to calculate an axial ratio from these data. The intrinsic viscosity of a sample of mucoprotein prepared by the method of Tamm and Horsfall was found to be 630.

The refractive index increment (Fig. 1) is 1.73×10^{-4} and remains constant, over the concentration range tested, from $0.6 + 10^{-3}$ to 2.0×10^{-3} g/ml. This is lower than the usual values for proteins but is in line with the values reported for mucoproteins.

The ultraviolet absorption spectrum (pH 5.7) has a single major peak at

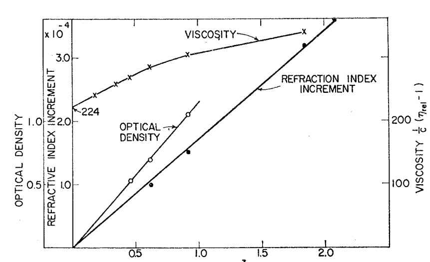

Fig. 1. Urinary mucoprotein: viscosity, optical density, and refractive index increment as a function of concentration.

278 mμ, with shoulders at 284 and 290 mμ. There is a suggestion of a component at 260 mμ. The visible and near-infrared spectra show no peaks from 340 mμ to 1000 mμ. The optical density at 278 mμ follows Beer's law (Fig. 1) throughout the concentration range tested. The absorption coefficient $E^{1\%}_{1\,cm}$ is 11.4. The absorption spectrum of a sample of mucoprotein prepared according to the method of Tamm and Horsfall is found to be identical with this.

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9 July 1958

Artificially Induced Circulation of Lakes by means of Compressed Air

Abstract. Turbulence induced by air bubbles causes circulation in small thermally stratified lakes. Tests were made under summer and winter (ice-cover) conditions. Homoiothermal conditions, isometric concentrations of phosphorus, and increases of dissolved oxygen were achieved, at various rates of treatment. The application of the technique for lake management and in studies of lake dynamics is suggested.

Stratified lakes in the Temperate Zone present certain problems. (i) They accumulate astonishing amounts of phosphorus in their lower regions. At the same time they exhibit a dearth of this element in the euphotic zone (*1*). (ii) In some there is no vernal circulation, as there is in typical dimictic lakes. (iii) In the winter some tend to have serious oxygen deficits under the ice cover, often resulting in the winterkill of fish fauna. These problems appear to be rectifiable by some means of induced circulation (*2–4*). The actual circulation of lake basins with water pumps has been demonstrated (*3*), and other techniques, such as the use of the turbulent effect of compressed air, offer promise.

Compressed air is used in natural waters, chiefly for reoxygenation (*5*) or to remove the ice from water surfaces (*6*). It was the purpose of the study described in this report to test the effect of air-induced circulation in stratified lakes.

In tests under summer conditions, compressed air was used to bring hypolimnetic water up into the euphotic zone. A small experimental lake, Sawmill Pond, with a maximum depth of 7.1 m and an area of 1250 m² was used. Air was delivered through small perforations spaced along the length of an air conductor, suspended just above the bottom. The daily rate of flow was 101 lit. (1 atm, 20°C) per cubic meter of lake volume. The effect was immediate and pronounced. An almost homoiothermal condition was observed after 4½ hours of treatment (Fig. 1). The concentrations of soluble phosphorus became isometric with depth. Prior to treatment they exhibited the typical high concentrations in the 2- to 3-m zone. It was observed that the absolute content of the total phosphorus in the upper 2 m was higher in every case than the mean of the pretreatment values.

In an experiment conducted in Tub Lake (0.7 hectare) in which lower daily rates of treatment (5.6 lit. of air per cubic meter of lake volume) were used, it was shown that radioactive phosphorus which had previously been placed in the hypolimnion could be brought to the surface (*7*). In this case the thermocline was lowered, but it retained its identity.

The amount of work theoretically required to compress the air to the necessary hydrostatic pressure (and hence to expand the rising bubble) was compared with the change in volume of the epilimnion resulting from the treatment. This was done in order to provide a basis for comparison of treatments in lakes of different sizes. The values obtained ranged from 8.17×10^2 g cm to 19.4×10^2 g cm for the work applied to each cubic meter of lake volume for each cubic meter of increase of the volume of the epilimnion.

Tests under conditions of ice cover were conducted with essentially the same physical installation. Daily additions of 3.4 and 1.9 lit. of air per cubic meter of lake volume were applied in two consecutive years on Katharine Lake (6.1 hectares). These applications maintained areas of open water continuously and concentrations of dissolved oxygen at about 7 and 2 parts per million, respectively. It should be emphasized that, under normal conditions, levels of oxygen concentration in this water are less than 3 parts per million and are periodically less than 1 part per million. It was noted that average water temperatures were reduced to as low as 0.7°C at the higher rate of treatment.

The force of the wind, exerted on the surface of a stratified lake, has a relatively small effect. An example of this is presented by Hutchinson (*8*) for Linsley Pond, where the thermocline of the lake was little affected by the hurricane of September 1938. By contrast, controllable forces, when applied in the manner described in this report, act from within the basin with, figuratively speaking, tornadic effect.

It is suggested that for the experimental limnologist the "air-lift" procedure can serve as a tool in the study of lake dynamics. He can achieve homoiothermal or isochemical conditions down to any contour level or can establish a thermocline in a desired position.

The technique affords a means of "intrafertilization" under certain conditions. Whether or not this effect is translatable into sufficiently large amounts of desirable end products—that is, increased zooplankton or fish production—cannot be

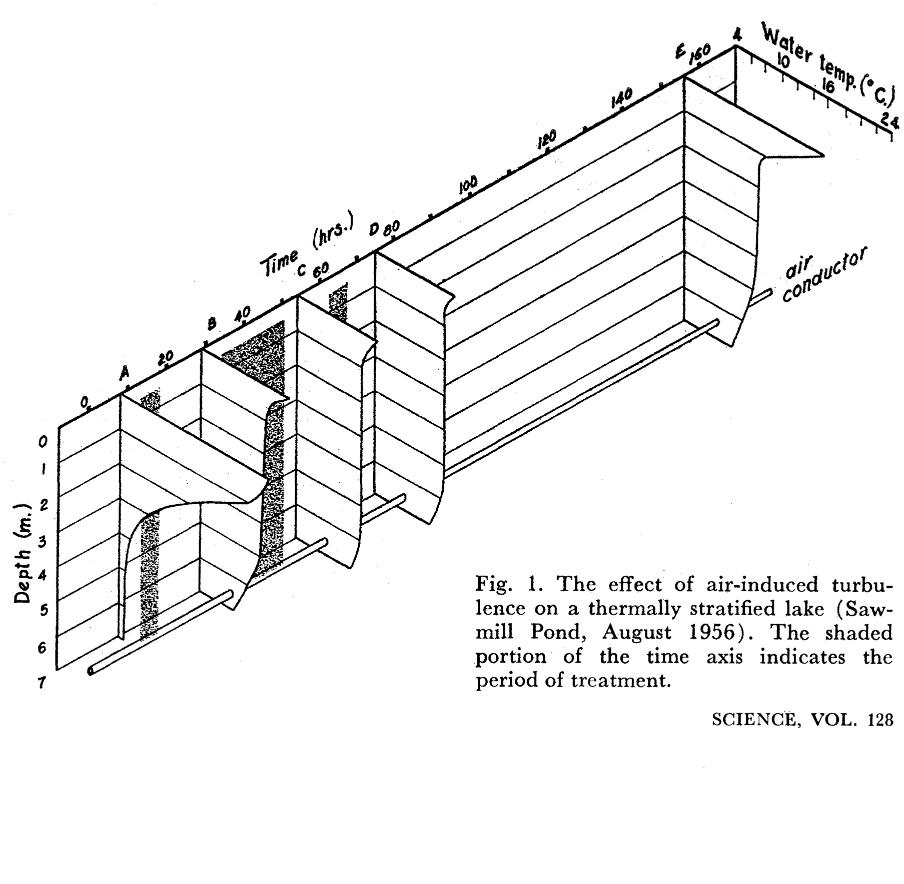

Fig. 1. The effect of air-induced turbulence on a thermally stratified lake (Sawmill Pond, August 1956). The shaded portion of the time axis indicates the period of treatment.