Table 1. Summary of distribution of polygon faces in bubbles, vegetable cells, metal grains, α-tetrakaidecahedron (Kelvin), and β-tetrakaidecahedron.

Edges per face (*1*) (No.)	600 Uniform bubbles 0.1 or 0.2 cm^3 (*1*) (%)	100 Small bubbles (0.05 cm^3) in mixture (*8*) (%)	50 Large bubbles (0.4 cm^3) in mixture (*8*) (%)	Mixture of 50 large and 100 small bubbles (*8*) (%)	450 Vegetable cells (*1*) (%)	30 Beta brass grains (*3*) (%)	Kelvin and alternative forms of the tetrakaidecahedron (%)	
							α	β
3					5.1	2.5		
4	10.5	32.9	11.3	22.9	27.3	20.2	42.9	14.3
5	67.0	58.1	48.1	56.1	39.7	43.6		57.1
6	22.1	8.9	28.3	19.8	25.4	28.7	57.1	28.6
7	0.4		11.2	6.0	6.3	4.6		
8			5.9	0.3	0.8	0.7		
9			1.1	0.05	0.1			

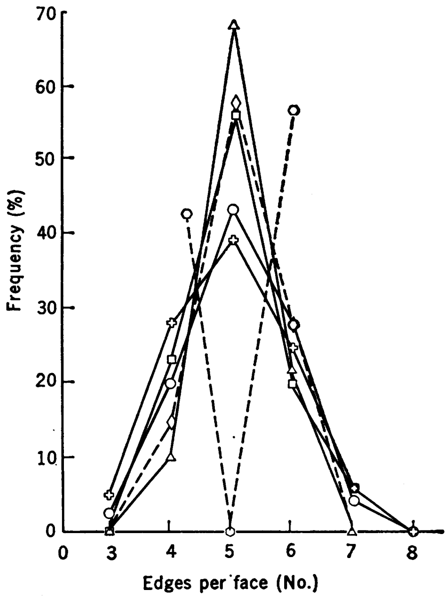

Fig. 2. Percentage distribution of polygon faces in vegetable cells (crosses), uniform bubbles (triangles), β brass grains (circles), mixed bubbles (squares), α-tetrakaidecahedron (hexagons), and β-tetrakaidecahedron (diamonds).

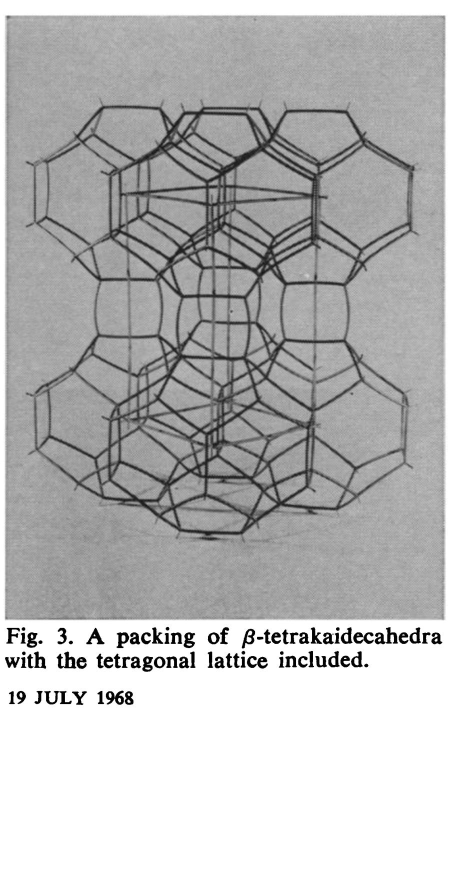

Fig. 3. A packing of β-tetrakaidecahedra with the tetragonal lattice included.

no surprise that the β-tetrakaidecahedron is related to the α-tetrakaidecahedron, which is a basic polyhedron packing in the body-centered cubic configuration.

Continuous topological transformations of points and bonds permit a number of other space-filling polyhedra to be derived from this polyhedron. For example, as the parameters x and z approach zero (that is, as position $8j$ approaches position $2b$), the β-tetrakaidecahedron packing transforms to the rhombic dodecahedron packing (basic polyhedron packing in a face-centered cubic configuration). If z goes to zero ($8j \rightarrow 4f$), the β-tetrakaidecahedron transforms to a space-filling polyhedron with eight curved pentagonal faces and four rhombic faces. Then continuing from this polyhedron, if y ceases to equal x ($4f \rightarrow 8i$), a distorted form of α-tetrakaidecahedron is defined. This is the minimum symmetry version of the α-tetrakaidecahedron packing in this space group.

The properties of this polyhedron and its packing must be more thoroughly examined; namely, the dihedral angles must be calculated, the reciprocal polyhedron and net determined, relationship of this polyhedron to ellipsoid packing systems and its hierarchical placement in the family of unitary space-filling polyhedra found, and relationship of the surface area to volume calculated. The relevance of this polyhedra packing to the structure of liquids (*10*) and to clathrate compounds such as the gas hydrates must also be considered.

In preliminary calculations of the ratio of surface area to volume, the β-tetrakaidecahedron was found to require roughly 4 percent more surface area to enclose the same volume as the α-tetrakaidecahedron. Nonetheless, for reasons as yet unknown, natural packings of bodies seem to prefer the composition of faces exemplified on the β-tetrakaidecahedron to the more regular composition of faces on the α-tetrakaidecahedron.

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11. I thank Dr. P. J. Schlicta for his discussions and suggestions and for his help in determining the symmetry properties. I also thank Dr. L. Larmore and Dr. A. G. Wilson for supporting this research through the McDonnell Douglas Corporation.

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Distilled-Deionized Water: A System for Preparing and Distributing Large Volumes

Abstract. *A system for preparing and distributing 100 liters of distilled-deionized water per day is described. Novel features are an overflow regulator, a "barometer" tube (permitting secondary reservoirs), and a pressure-controlled shutoff valve.*

A simply operated, inexpensive, and self-regulated system for preparing and distributing large volumes of distilled-deionized water is described (Fig. 1).

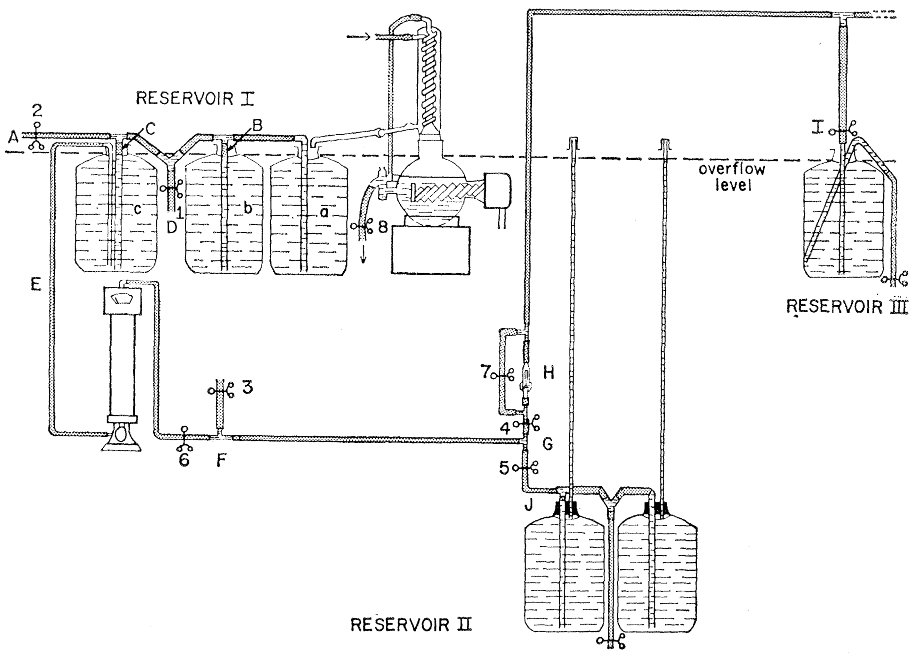
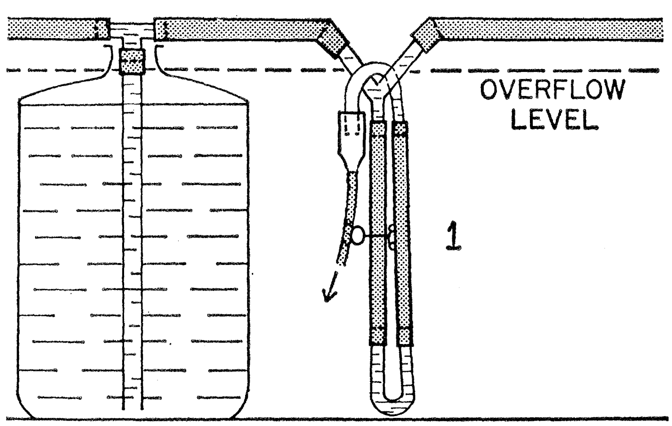


Fig. 1. System for distilling, deionizing, and distributing water. Stippled tubing represents Tygon; clear tubing represents glass. Capital letters refer to specific locations on the tubing; lower case letters to carboys; Arabic numbers to Mohr pinchcock clamps. To construct and operate the first reservoir, I, a Bellco (Vineland, N.J.) No. 5004 4-liter still is mounted so that it empties into one of the carboys of reservoir I. Reservoir I consists of two or more 15-liter carboys joined by a branching siphon system of ½-inch (1.27-cm) diameter glass and Tygon tubing connected with T-tubes. Between any two carboys, the overflow regulator (Fig. 2) is attached to the interconnecting siphon system at D. The long "barometer" tubes in reservoir II are of ¼-inch diameter. If a logical order of opening and closing of the various Mohr pinchcock and hemostat clamps (indicated by lower case letters) is followed, the siphons can be readily established (*3*). In order to obtain the large pressures needed to initially establish the siphon, a vacuum aspirator can be used at points A or F.

Once assembled, this system requires little effort to operate and minimum surveillance. One need merely turn on the tap water and heating element until all the reservoirs are full. We collect about 100 liters of distilled-deionized water daily, and we use it in biological and chemical systems notorious for requirements of purity: the culture of freshwater invertebrates (*1*) and ultramicro fluorometric analyses (*2*).

The novel features are three. (i) An overflow regulator (Fig. 1, D; Fig. 2) allows the still to run continuously; when all the reservoirs are full, excess distilled water exits through a single opening into a sink. (ii) By use of a "barometer" tube, large amounts of distilled water can be gravity-fed through a deionizing cartridge and stored in reservoirs (Fig. 1, II) kept below the level of the distilled water reservoir (Fig. 1, I). (iii) A pressure-controlled shutoff valve (Fig. 1, H; Fig. 3) allows distilled-deionized water to be automatically fed to all secondary water reservoirs (Fig. 1, III) kept on the same floor of the building.

Other than routine removal of mineral-scale accumulation in the flask, little maintenance is necessary. Because large volumes of water are constantly



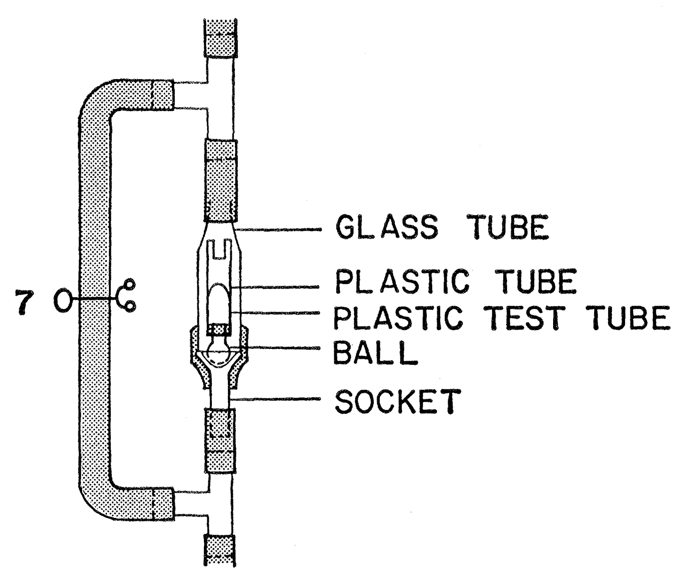


Fig. 2 (left). The overflow regulator is attached to the Y-tube at point D on the main siphon line (Fig. 1) by ½-inch diameter Tygon tubing. The tubing is connected to a ½-inch diameter loop of glass tubing. The loop must rest at the bottom level of the carboys in order that the siphon be maintained. The other end of the loop is connected by Tygon tubing to a piece of L-shaped ½-inch diameter glass tubing. This L-tube hooks over the Y-tube of the siphon line with the bend of the L at a height equal to the uppermost water level attainable in the carboys. The outlet of the L-tube should extend about 3 inches from the bend and empty into a receptacle-funnel that in turn empties, by means of flexible tubing, into a nearby sink. The receptacle-funnel, which can be made by cutting off the bottom of a 100-ml polyethylene bottle, is attached to the Y-tube by means of wire. The outlet of the L-tube should extend only a short distance (about 3 inches) below the upper water level; otherwise, once water begins to overflow, the L-tube could serve as an open siphon itself and drain reservoir. I. In addition, the wide diameter of the L-tube prevents even a short siphon from being established. Fig. 3 (right). The automatic one-way valve can be constructed with a ground-glass ball-and-socket assembly (Fisher No. 11-371-5 and 11-371-10; joint size 12/5). The assembly is attached to the siphon line as illustrated. The critical feature is that the ball part of the joint be of the correct weight so that slight changes in pressure will either open or close the valve. The proper weight of the ball part of the valve can be obtained by cutting off most of the glass stem attached to the ball, sealing the remaining tip, and fastening to it a piece of plastic test tube by means of a small ring cut from Tygon tubing. The bottom of a second test tube is cut off and two large holes are cut in its side; it is then fitted over the tip of the first tube. This second tube is necessary to prevent the tip of the first tube, while floating, from obstructing the upper outlet of the valve assembly. By regulation of the amount of air space in the first plastic tube, the proper weight can be attained.

being prepared and used, there is little detectable bacterial growth.

Such a system can be constructed for $300 to $500 in 4 to 6 hours. It should serve well in teaching laboratories, small departmental research laboratories, marine stations, and laboratories not blessed with abundant funding to permit a built-in central distilling unit (*3*).

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3. To facilitate construction, operation, and care of this distilled-deionized water system, we have prepared detailed directions that will be appended to all requests for reprints.
4. We thank Mr. R. Pearson for assistance in the construction of parts of this system. This project was an outgrowth of research supported by NIH grant GM 12779 and by PHS research career development award GM 5011 to H.M.L.

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Triops (Entomostraca) Eggs Killed Only by Boiling

Abstract. *Temporary rainpools near Khartoum, Sudan, are inhabited by the notostracan crustacean* Triops *which completes its life cycle within 4 weeks. The annual rains fall in late summer, and throughout the winter and early summer the eggs of* Triops *remain in the dried mud or dust where they may be exposed to temperatures up to 80°C. Laboratory experiments show that they can withstand temperatures up to within 1°C of boiling, but are killed in partial vacuum by 70°C, at atmospheric pressure by 100°C, or under pressure by 105°C. Exposure to high temperature seems to be necessary to break the egg diapause.*

Khartoum, capital of the Republic of the Sudan, lies about 15°30′N in the tropical zone at the junction of the Blue Nile with the White Nile; its annual rainfall averages about 12 or 15 cm, almost all falling within 2 months in late summer. Between September and May there is no rain and the skies are generally cloudless. The extensive rainpools that form during the rainy season last about 4 to 6 weeks (depending on the frequency of rainstorms) before drying for the rest of the year. The mud in the pools first dries to a cracked crust before disintegrating to a dust that may reach a temperature of 80°C during the heat of the day between March and May. Even in midwinter in January the dust may be so hot in the afternoon that bare feet are blistered by contact for only 2 or 3 minutes.

For such short-lived pools the fauna is surprisingly diverse; Rzóska (*1*) lists 12 species of entomostracan Crustacea. The most spectacular are the notostracan *Triops granarius* (Lucas), which grows to 40 mm in length, and the anostracans *Streptocephalus proboscideus* Frauenfeldt and *S. vitreus* Brauer which may reach 25 mm. Both the Notostraca and the Anostraca survive the dry period as eggs. In pools between 30° and 33°C *Triops* mature within 16 to 20 days of the first rainfall and establishment of the pools; after 25 days they are all dead, even if the pools persist longer (*1*). There is clearly only one generation a year, and Rzóska suggests that the eggs must be desiccated before they can hatch. In contrast, the Cladocera and Copepoda inhabiting the pools may go through many generations within the brief rainy season, a generation being completed within 2 or 3 days (*1*).

It seems that more than desiccation is required before eggs of *Triops* and *Streptocephalus* can hatch. Samples of mud placed in river water in the laboratory in November and December yield hatches of Cladocera and Copepoda but no signs of Anostraca or Notostraca. Samples collected at the beginning of March, however, show rapid hatches of notostracans and anostracans, even when placed in water at the midwinter temperature of the Nile River—22°C —instead of the normal 30° to 33°C of their pools: *Triops* emerged 2 days after the mud was wetted and grew at the rate of 2 mm/day in water at 22°C, apparently passing through one instar daily, at least until they attained an overall length of 20 mm; *S. proboscideus* appeared on the 3rd day and *S. vitreus* appeared on the 4th day after the mud was wetted. Five days after the first appearance of *S. proboscideus*, 20-mm-long females were carrying egg masses; *S. vitreus* were slower in developing and did not bear eggs until 10 days after hatching.

Since during the summer the mud may reach temperatures of 80°C, it was of interest to know the temperatures that these notostracan and anostracan eggs can withstand. *Triops* was hatched from mud that had been placed dry in an incubator for 1 week at 80°C, and also from mud samples that had been kept for 16 hours in an oven at 98° ± 1°C (longer periods were not tried). Fifteen-minute incubation at 102°C, however, killed any eggs that may have been present in the mud. When mud samples were placed under vacuum such that water boiled at 70°C the eggs were killed by 30-minute exposure to 75°C. Conversely, when mud samples were placed in a pressure vessel and subjected to pressures such that water boiled at 105°C, the eggs withstood 16 hours at 103° ± 1°C but were killed by 15 minutes at 106°C. Eggs of *Triops* hatched from wet mud kept overnight at 50°C but not from wet mud kept at 60°C. Each sample consisted of 100 g of mud (dry weight), and all samples yielded between five and 12 hatchlings if any hatched at all; all conditions were tested with triplicate samples, and the numbers hatching after the various treatments that allowed survival showed no significant differences. In other words, death was an all-or-none effect.

Thus it is apparent that desiccated eggs survive much higher temperatures than do eggs after wetting; indeed they can withstand temperatures within 1°C of the local boiling point of water. But they are killed by the temperature of boiling water whether the temperature is reduced by partial vacuum or raised by pressure. The mechanism of death in desiccated eggs must therefore involve the boiling of any water retained within the eggs: when the water boils, the eggs are killed; if it does not reach boiling point they survive.

Preliminary investigations indicate that not merely is a prolonged period of desiccation required for hatching of eggs both of *Triops* and of *Streptocephalus* in the Sudan; also they require exposure to temperatures exceeding 50°C. This result, however, needs confirmation by another season's work.

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