active in the cracks in the cores. In a few instances, ants had penetrated the larger cracks and had enlarged the spaces by nibbling at the fungi on the soil faces. The cores in the eroded garden were less affected by roots, fungi, and small animals than the cores in the old field.

As a result of these observations, a third series of cores was prepared from soil of even lower organic content, from the B_2 horizon of Crosby silt loam. One set of control cores was made by adding only water to the soil; to a second set, inorganic fertilizer and sufficient lime to bring the *p*H to neutrality were also added; to a third set, alfalfa meal was added; and to a fourth set, the insecticide, chlordane, was added. These cores were buried in late May and early June in two sites, a woodland and an open field, both of Crosby silt loam. All were buried at 1-ft intervals 5 in. beneath the surface, the types being distributed by a standard randomized formula. Half of the cores in the field were given clean surface cultivation, and the remainder were sodded over by grass that was clipped regularly.

The most rapid transformations occurred in the alfalfa-meal cores (Fig. 1) that were buried in the open field. Molds and bacteria grew quickly throughout the mass of the cores. In a few weeks the initial aggregate stability (as determined by the S.C.S. modification of the Yoder wet-sieving technique) had increased from about 20 to nearly 100 percent. There was little change in volume from wetting and drying. Earthworms ingested the material of the cores from all sides, so that within 3 mo some of them had the appearance of almost-eaten apples. Worm casts from the cores were recognizable for several inches in all directions. The nature and extent of the worm tunnels was recorded by making latex casts of the voids by a process developed earlier (*2*). Ants and microarthropods were active on the eroded surfaces of the cores.

Fig. 2. Core with no additive, exhumed after 4 mo. The shrinkage cracks and exfoliated structure are the results of alternate wetting and drying.

At the end of the first summer the remaining three types of cores in the open field showed relatively little change except for the development of horizontal shrinkage cracks with platy structure (Fig. 2). Their aggregate stability continued to be very low. Fungi developed to some extent on crack faces. Some nematodes, mites, and collembolans were found.

The cores of the various types buried in the forest soil underwent less transformation than their replicates buried in the open fields. We were surprised by the low level of faunal activity. The full implication of this phenomenon requires further study.

These experiments indicate that the restoration of compacted soil occurs in orderly processes that vary widely according to location and organic content. Cores rich in organic matter and buried in open areas develop a mass stability that retards the formation of shrinkage cracks. However, earthworms ingest large quantities of the soil and fungi, thus mixing the material of these cores with the surrounding soil. Cores low in organic matter lack this stability and develop extensive cracks into which roots may penetrate. Fungi developing on the interfaces may be eaten by microarthropods, with possible subsequent enlargement of the spaces.

Recognition of further details of the restorative process may be expected as the experiment continues. We believe that the techniques of preparing and burying standardized cores of soil, compacted by puddling and variously treated to attract or repel organisms, offer a means of studying the processes of change in soil structure through the interaction of physical and biological factors that will be useful in many aspects of soil research.

References and Notes

1. An interdepartmental team at Earlham College is carrying on a project in soil research under a grant from Charles F. Kettering and the Kettering Foundation.
2. M. R. Garner, *Science* **118**, 380 (1953).

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New Design of Ultrafiltration Apparatus

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Ultrafiltration is superior to other methods for the concentration of colloidal solutions in that it (i) avoids the denaturing action of precipitating agents or heat, (ii) provides for removal of salts as well as solvent, (iii) assures essentially quantitative recoveries of the colloids, and (iv) requires little attention from the operator. A new apparatus for this purpose, similar to a filter press in design, is described in this paper. This apparatus is versatile with respect to capacity and does not require disassembly for collecting the concentrates. With its aid we have readily succeeded in obtaining up to 94-fold concentration of large vol-

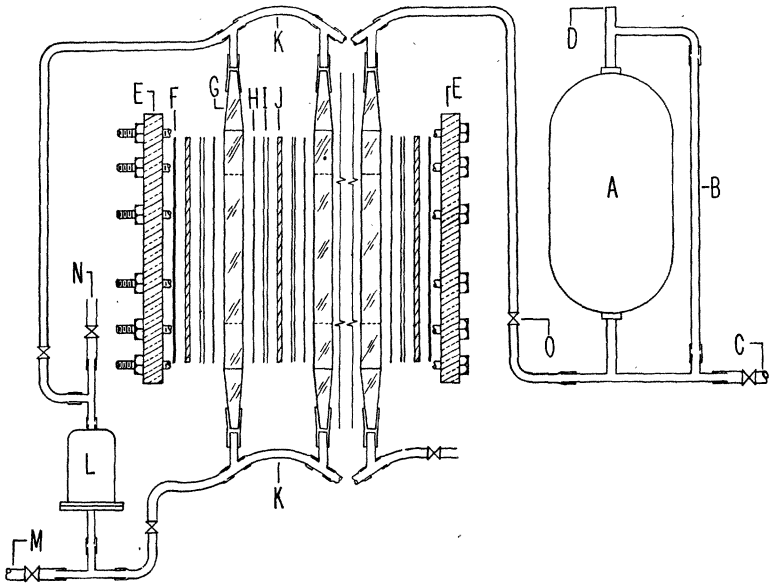

Fig. 1. Schematic diagram of assembled ultrafiltration apparatus. Filter unit is shown in exploded view: *A*, reservoir (*3*); *B*, level gauge; *C*, reservoir inlet; *D*, compressed gas inlet; *E*, end plate; *F*, rubber pad; *G*, Cell; *H*, membrane (*4*); *I*, filter paper (*5*); *J*, filter plate (*6*); *K*, manifold; *L*, receiving flask (*7*); *M*, concentrate tap; *N*, air bleeder; *O*, screw clamp.

umes of various fungal enzyme preparations. Few apparatus have previously been described for ultrafiltration on a large scale (*1, 2*).

The assembly (Fig. 1) consists principally of a reservoir *A*, a multiple filter unit *E–K*, and a receiving vessel *L*. The filter unit is made up of any desired number of cells *G* separated by semipermeable membranes *H*, double layers of filter paper *I*, and Alundum filter plates *J*, in the order shown. The cells consist of Plexiglas rings fitted with threaded Plexiglas nipples, as specified in Fig. 2. The nipples are sealed into opposite edges of the rings with Duco cement.

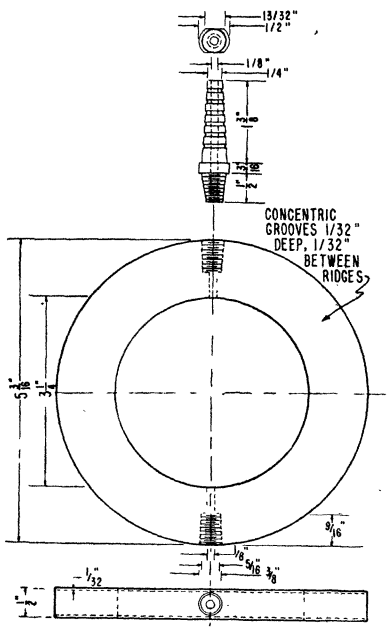

Fig. 2. Details of Plexiglas cell.

The flat surfaces of the cells are grooved as indicated to improve the seals with the semipermeable membranes. The different elements of the filter unit are clamped together by means of 12 ¼-in. bolts passing through ½-in. brass plates *E* at the ends. The openings in the cells are connected in parallel through manifolds *K* at the top and bottom. The manifolds consist of 2-mm capillary T-tubes, connected by means of cloth insert rubber tubing. Screw clamps *O* are introduced at various points in the system to facilitate filling and emptying the apparatus.

The apparatus is filled with the dilute colloid solution to be concentrated by first siphoning the solution through the lower manifold into the receiving vessel and the cells, displacing all air in these parts of the system. The bulk of the solution is then introduced through inlet *C* into the reservoir. Pressure is applied from a tank of compressed nitrogen connected to inlet *D*, forcing the water and other dialyzable materials through the membranes and filter plates. The filtrate drips from the edges of the plates into a suitable pan or trough. The contents of the cells are continuously replaced by the solution from the reservoir, which enters the cells through the upper manifold. The nondialyzable colloidal materials are held back at the surfaces of the membranes where they form concentrates of relatively high density. The concentrates flow by convection through the lower manifold into the receiving vessel. The unconcentrated solution which is displaced from the receiving vessel flows into the cells through a connection from the top of the receiver to the upper manifold. When all the dilute colloid solution has been forced out of the reservoir, the pressure is relieved, and the highly concentrated material in the receiving vessel, as well as the less concentrated contents of the cells, are finally collected through tap *M*. After use, the apparatus is cleaned by rinsing and by forcing water through the membranes and filter plates.

It is then stored at 5°C with the cells filled with water and without disassembling.

In a typical test, 17,800 ml of dilute fungal enzyme preparation were concentrated to yield 170 ml of concentrate in the receiving vessel and connecting tubes and 632 ml in the cells and manifolds. The operation, carried out at 5°C, required 5 days with an 8-cell unit. The material in the receiving vessel was found to contain 49 percent of the original enzyme, concentrated 51-fold; the material remaining in the cells contained 39 percent of the original enzyme, concentrated 11-fold. About 5 percent additional enzyme was recovered in rinsings.

The effects of volume filtered and of pressure used on the rate of filtration of distilled water and on the rate of filtration of a fungal enzyme preparation are shown by the sample data plotted in Fig. 3. The rate

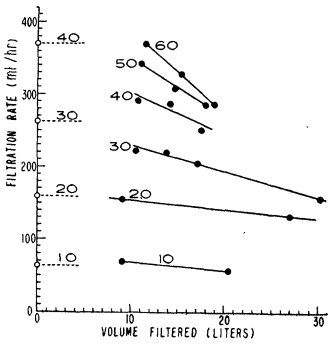

Fig. 3. Effects of volume filtered and of pressure on rate of filtration. Open circles and dotted lines represent data for distilled water; solid circles and solid lines represent data for enzyme solution. Numbers above lines represent pressures (lb/in.^{2}). Tests were made at 5°C with an 8-cell unit.

of filtration of distilled water remained constant regardless of the volume filtered. Furthermore, an approximately linear relationship obtained between the pressure and the filtration rate. The rate of filtration of the enzymes preparation decreased, however, as the volume filtered was increased, and in this case a linear relationship was no longer maintained between the pressure and the filtration rate.

The decrease in the filtration rate of the fungal enzyme preparation was caused by the accumulation of colloidal concentrate near the membranes and by the formation of an insoluble film on the surfaces of the membranes. Partial restoration of the filtration rate was brought about when the accumulated concentrate was removed by draining the cells. Final restoration was effected by removing the insoluble film, which was accomplished by partially filling the cells with water and shaking the apparatus vigorously.

Some accumulation of colloidal material at the membranes resulting in a loss in filtration rate, appears to be unavoidable. It is probably minimal, however, in this new apparatus since the membranes are mounted vertically rather than horizontally and the convective process continuously removes most of the colloid from the neighborhood of the membranes.

References and Notes

1. F. B. Seibert, *Am. Rev. Tuberc.* **30**, 713 (1934).
2. J. J. Bullen, C. Thurlbourn, and P. Brown, *Nature* **173**, 254 (1954).
3. Stainless steel pressure tank, capacity 35 liters.
4. Schleicher and Schuell Co., Type II ultrafilter, very dense, diameter 150 mm.
5. Whatman No. 4.
6. Norton Alundum filter plate, coarse, RA 98, diameter 125 mm.
7. Seitz filter, Model L6.

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Adaptable Time Switch

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In experiments with the citrus red mite (*Metatetranychus citri* McG.) it became necessary to spray water at frequent intervals on infested lemons as they revolved on a turntable. The time schedule called for 48 sprays of ½-min duration at 15-mm intervals each day. Since there was no inexpensive time switch available that would control the necessary solenoid air valve and the turntable motor with this frequency, a special time switch was constructed, which may be useful in other types of scientific work.

This device (Fig. 1) consists of a revolving paper disk *A* attached to a clock *B*. Perforations are made in the disk and so placed that silver contact points *D*, otherwise held apart by the paper, make contact at the required times. A 24-hr recording thermometer chart approximately 9½ in. in diameter is a satisfactory disk.

The switch mechanism *C* is composed of two spring brass strips *E*, approximately ¼ in. wide and 2½ in. long, each fastened at one end to an insulating wooden or plastic block *F*. To the free ends are soldered two rounded silver contact points *D*, which are held in ontact by slight tension of the brass strips. To prevent damage to the points, an electromotive force of not more than 10 v is used. This current is supplied by the transformer *G*, which is connected in series with the coil of relay *H*. This relay (*1*) is a high-capacity sen-

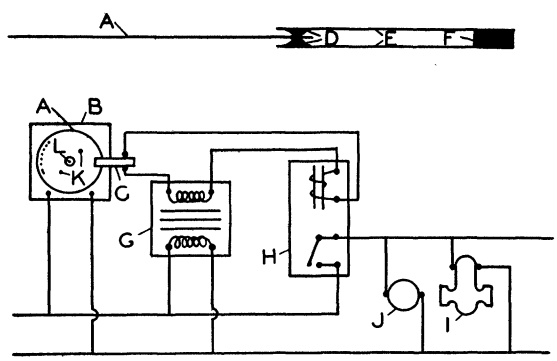

Fig. 1. Below, parts and wiring diagram of time switch. Above, enlarged sectional view of switch mechanism *C*.