tion. Despite fundamental differences between the two groups, the many overlapping areas of attitude and belief would seem to support this hypothesis.

In any case, it would be interesting to compare the beliefs, attitudes, and personalities of the members of these two groups with those of a sample of nonactivists in the same community, to see whether the differences between the joiners and the nonjoiners is any greater than the differences between the two groups of joiners.

EDWARD J. JAY

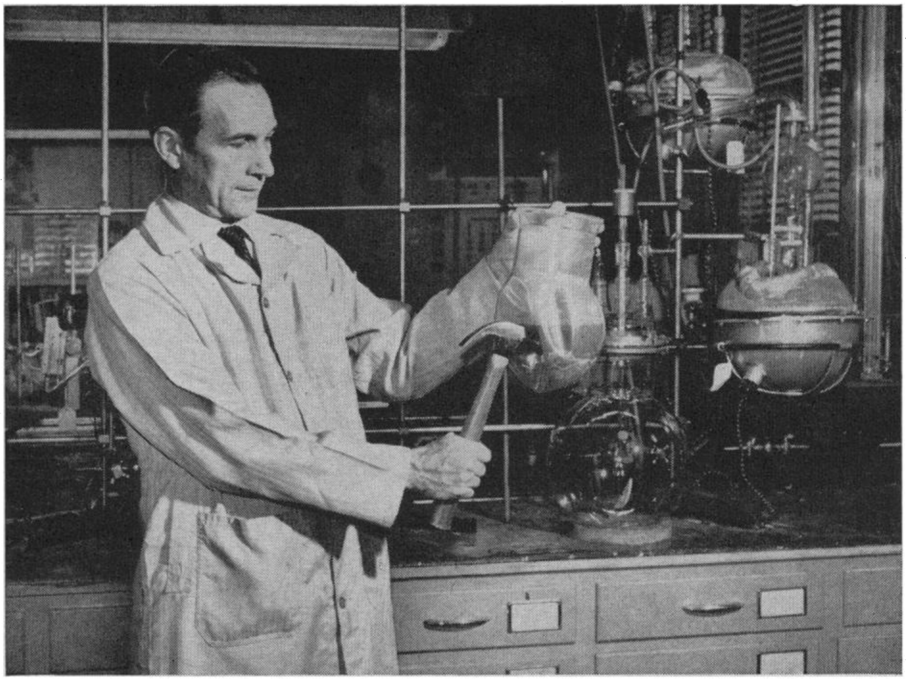
Department of Anthropology,
University of California, Berkeley

Ultrafiltration Membrane Performance

Clark states (*1*) that the driving force for ultrafiltration is the chemical potential. This is a misleading statement. Any difference in chemical potential that arises across the membrane is a (hitherto unexplained) *result* of the pressure ultrafiltration process and not its *cause*. The driving force for ultrafiltration is the applied-pressure difference across the membrane. It is immaterial whether this pressure difference be expressed as such, or as, for instance, a chemical potential gradient, but in order not to confuse cause and effect, and in order to explain clearly the various phenomena inherent in pressure ultrafiltration, it is best to consistently view the external energy source, the applied-pressure difference, as the driving force for ultrafiltration.

A paradoxical phenomenon is this: The higher the pressure is, the more salt the cellophane membrane retains in an ultrafilter containing a solution of salt in water. Clark (*1*) has not explained this phenomenon. For its explanation one needs more facts than just the data from Ambard and Trautmann's Table 2 (*2*), given by Clark. A few more useful data can be found elsewhere in their book: Tables 4, 5, and 6 demonstrate that salts with bivalent anions and monovalent cations are more strongly retained than salts with monovalent anions and monovalent cations, while salts with bivalent cations and monovalent anions are hardly retained at all, as compared to salts with monovalent cations and anions.

When we relate these data to the



fact that cellophane is negatively charged, it becomes clear that the salt retention must be due to electrostatic repulsion of the anions by the negatively charged membrane, a repulsion which is strongest when the anions carry the highest charge and weakest when the cations carry the highest charge (*3*).

The paradoxical phenomenon that the salt retention becomes more pronounced at higher pressures can only be due to the contribution of the streaming potential to the charge of the membrane (*4*). For the streaming potential *E*, caused by pressing the solution through a charged membrane, is proportional to the applied pressure *P*, to the potential of the membrane ζ, and to the dielectric constant ϵ, and inversely proportional to the viscosity η of the solution and to its conductivity λ. This relationship is usually expressed, according to Overbeek (*5*), as

$$E = \frac{P\epsilon\zeta}{4\pi\eta\lambda} \qquad (1)$$

A final proof of this hypothesis would be furnished if it could be shown that salt retention is higher at higher values of ζ potentials of otherwise identical membranes and under otherwise identical conditions. I recently made an experiment along these lines, ultrafiltering salt solutions at various *p*H's, and I found that the salt retention is indeed highest at the highest *p*H (when the acid groups of cellophane are highly dissociated), and lowest at the lowest *p*H(when these acid groups are hardly dissociated) (*6*).

Equation 1 for the streaming potential also shows why at the lowest salt concentrations the salt retention is highest: When the conductivity λ of the solution is lowered, the streaming potential *E* becomes higher (see *2*, Tables 4 and 5). The necessity for turbulence above the membrane for obtaining maximum salt retention (see *2*, Table 1; *4*) is now easily understood, for without it salt enrichment just above the membrane would occur, locally raising the conductivity λ of the solution, which would cause a lowering of the streaming potential *E* (*7*). The at-first-sight surprisingly small influence of temperature changes becomes clear when it is realized that while the conductivity λ rises with the temperature, the viscosity η diminishes at a slightly higher rate. So a rise in temperature will result in a slight decrease in $\eta\lambda$, resulting in a small increase in the streaming potential *E*—an increase even further attenuated by a slight decrease in the dielectric constant of water, ϵ. Thus, the theoretical increase in streaming potential E, when the temperature is raised from 8° to 18°C, can be calculated to be of the order of 1.6 percent—a value in reasonably good agreement with Ambard and Trautmann's observation (*2*, Table 3), that the salt retention rises 1.8 percent under these conditions.

It becomes evident that the requirements for an ideal membrane for desalting with the pressure method are as follows. (i) It has to have the highest possible charge (either negative or positive); (ii) it has to have a very small pore size, of the order of 30 Å or less [otherwise the electrostatic repulsion of small ions seems to be ineffective (*4*)]; (iii) it has to be as thin as possible (to allow for the highest rate of filtration at a given pressure); and (iv) it has to be strong (to withstand the highest possible pressure) (*8*).

C. J. VAN OSS

Laboratory of Physical Biochemistry,
National Veterinary College,
Alfort, France, and *National Institute of Agronomical Research, Paris*

References and Notes

1. W. E. Clark, *Science* **138**, 148 (1962).
2. L. Ambard and S. Trautmann, *Ultrafiltration* (Thomas, Springfield, Ill., 1960).
3. Ambard and Trautmann's thesis is that all these phenomena can be explained by invoking differences in hydrated volumes of ions at different concentrations. But (hypothetical) differences in hydration can explain neither the difference in influence of multivalency of anions and cations nor the enhanced salt retention at higher pressures.
4. C. J. van Oss, thesis, Sorbonne (1955).
5. J. Th. G. Overbeek, in H. R. Kruyt, *Colloid Science* (Elsevier, Amsterdam, 1960), vol. 1, p. 204.
6. C. J. van Oss, in preparation. (When a 10-milliequivalent sodium chloride solution is ultrafiltered under a pressure of 110 lb/in.^{2}, the salt retention rises from 5 percent at *p*H 3 to 20 percent at *p*H 11 for the first ultrafiltrates.)
7. The obvious necessity for agitating the solution has nothing to do with the overcoming of Clark's "film resistances," for the rate of filtration remains unchanged, whether or not the salt solution is agitated.
8. I am indebted to Professor A. M. Monnier (Laboratoire de Physiologie Générale, Sorbonne) for the many fruitful discussions we have had on this subject.

Numerous ultrafiltration data show that salt rejection increases as the pressure difference across the membrane increases (*1–3*). Two hypotheses were advanced to explain the increase in salt rejection with increase in pressure: (i) that pressure on the membrane increased the resistance to flow of salt (*2*); (ii) that pressure affected the hydrated ions, presumably increasing hydration (*1*). The first purpose of my report (*4*) was to show that neither of

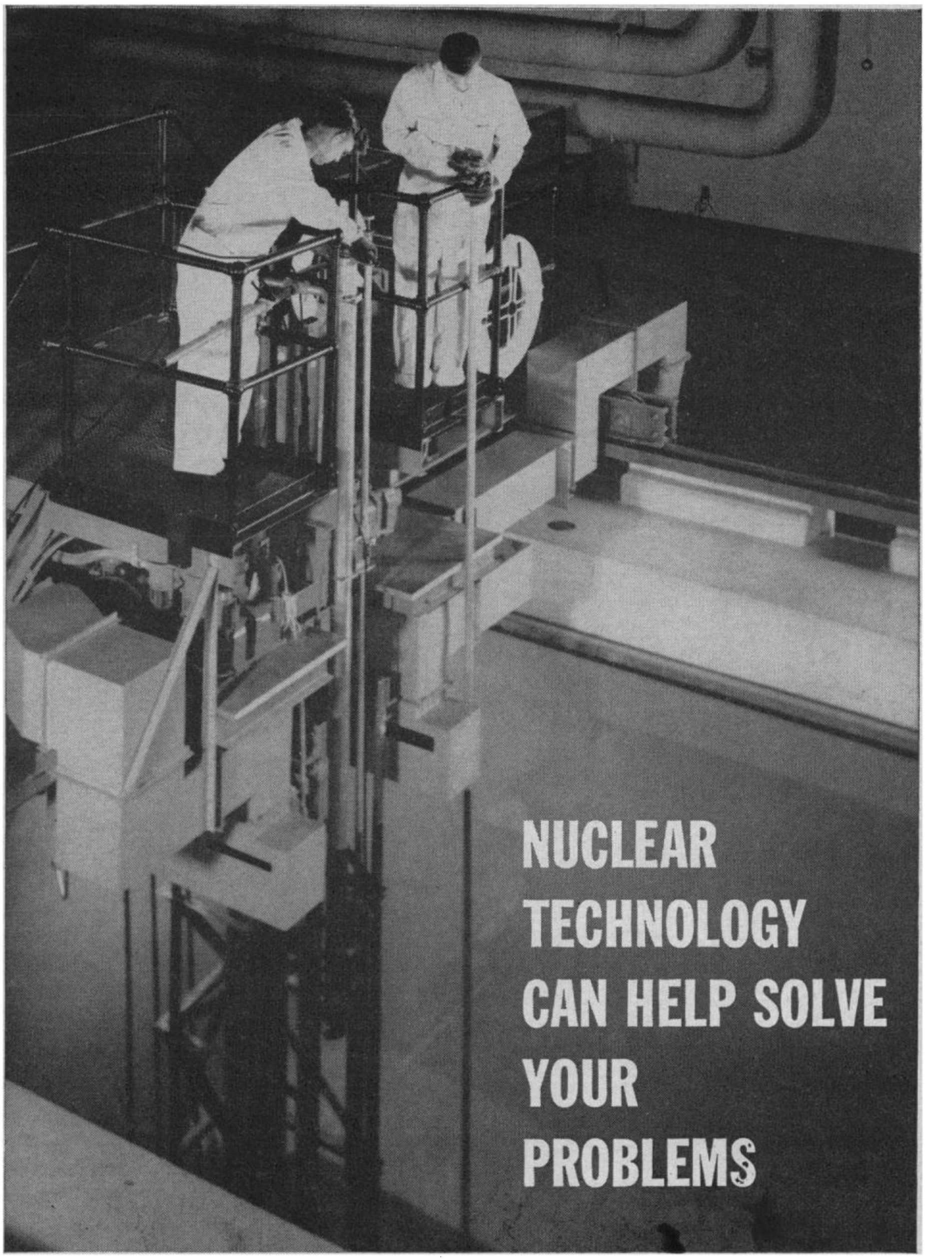


Table 1. Summary of calculations for Fig. 1 from data of Ambard and Trautmann (*1*).

Experiment			
2	3	4	5
Data: Filtering solution (NaCl, mg/lit.)			
500	200	100	50
Filtrate (NaCl, mg/lit.)			
460	160	70	28
Calculations: n_1 *(10^{-7} mole NaCl/mole H_2O)*			
1,540	616	308	154
n_2 *(10^{-7} mole NaCl/mole H_2O)*			
1,417	493	215	86
RT ln (n_1/n_2) (cal/mole)			
49	130	208	338
$n_1^2 (\mu'_1-\mu'_2)$, *(10^{-9} cal/mole)*			
1,170	494	197	80
J′/J (10^{-6} g NaCl/g H_2O)			
460	160	70	28

these hypotheses was necessary. Mahon had suggested earlier that the driving force for water flow was pressure, and that the predominant driving force for salt flow was difference in concentration (*5*). The second purpose of my report was to show that a single driving force was sufficient.

My reasoning was as follows. Salt and water will flow through a permeable membrane, even in the absence of a pressure difference, until equilibrium is established. At equilibrium, the chemical potential of the salt is the same on both sides of the membrane, and the chemical potential of the water is the same on both sides. Therefore, difference in chemical potential, or some quantity related to difference in chemical potential, is a logical choice as a general driving force for flow. In keeping with the formalism of the thermodynamics of irreversible processes, I selected difference in chemical potential as the single driving force and found, as shown in my report, that the flows of water and salt could be considered independent of each other for the range of data presented there. The rate of flow of water was directly proportional to the difference in chemical potential of the water, and the rate of flow of salt was directly proportional to the difference in chemical potential of the salt. Skiens and Mahon, viewing difference in activity as the driving force, have independently reached similar conclusions (*3*).

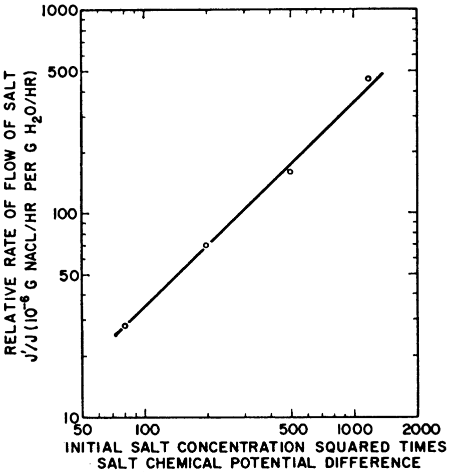
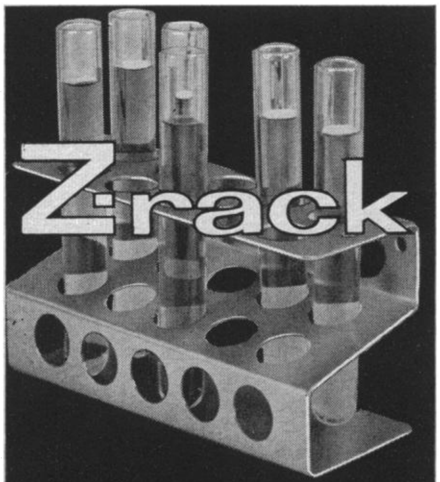
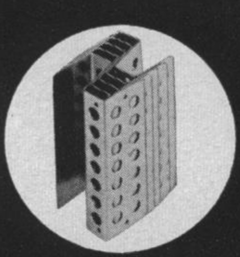


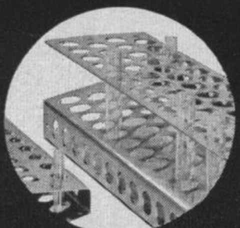
Fig. 1. Relative rate of flow of salt across an ultrafiltration membrane. The slope of the line is unity, showing that the rate of flow of salt is directly proportional to the difference in chemical potential of the salt [From data of Ambard and Trautmann (*1*)].

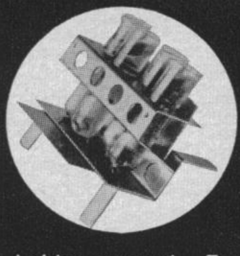
The data from Ambard and Trautmann which appeared in my report were selected because they illustrated the points which I wished to make quite clearly. Unfortunately, those data also masked other effects, because the initial salt concentration was held constant. Van Oss is quite correct when he maintains that the kind of salt and the concentration have marked effects on the rate of flow of salt across the membrane. Table 1 and Fig. 1 show the results of some calculations based on other data from Ambard and Trautmann (*1*, Table 4) in which the initial salt concentration, n_1, is allowed to vary. The approximation that the difference in chemical potential, $\mu'_1 - \mu'_2$, is equal to $RT \ln (n_1/n_2)$ is used in the calculations. Since the slope of the line in Fig. 1 is equal to unity, the data show that the rate of flow of the salt, J', remains directly proportional to the difference in chemical potential of the salt even though the initial concentration of the salt changes tenfold. The data also show that the resistance to flow varies inversely with the square of the initial concentration of the salt. Thus, in the method which I suggest for predicting the flows of salt and water during ultrafiltration, the changes in flow rate for different salts and different concentrations which cannot be accounted for by changes in chemical potential are ascribed to differences in resistance to flow. Why these resistances vary as they do is an interesting problem, on which van Oss's views may shed some light. I am sure that, as we learn more about ultrafiltration, the viewpoints of both van Oss and myself will be modified until we meet upon some common ground.

W. E. Clark
Midwest Research Institute,
Kansas City, Missouri









References

1. L. Ambard and S. Trautmann, *Ultrafiltration* (Thomas, Springfield, Ill., 1960), pp. 13–15.
2. E. J. Breton, Jr., *U.S. Dept. Comm. Office Tech. Serv. PB Rept. 161391* (1957), pp. 18–19.
3. W. E. Skiens and H. I. Mahon, "Permeation rate constants for water and salt flux through synthetic membranes," paper presented at the American Chemical Society meeting in Washington, D.C., March 1962.
4. W. E. Clark, *Science* **138**, 148 (1962).
5. H. I. Mahon, "Hollow fibers as membranes for reverse osmosis," paper presented at the National Academy of Sciences–National Research Council Desalination Research Conference, Woods Hole, Mass., 1961.

Emotional Response to Nonreinforcement

In an interesting report describing cycles in the force of a lever response during the execution of fixed-ratio reinforcement sequences [*Science* **138**, 516 (1962)], D. E. Mintz interprets his results in the light of a supposition that the animal discriminates the strength of its own response on the occasions when reward is obtained. This explanation places the phenomena in the category of response-shaping by operant discriminations.

There is, however, a clear possibility that the changes in response force during fixed ratio reinforcement sequences reflect, rather, an emotional reaction of the organism to nonreinforcement. One would expect such responses, if they occur, to contaminate the strength of instrumental level press, because tension of both smooth and skeletal muscle is part of the pattern of emotional discharge.

That conditioning procedures produce emotionality is, of course, a classic finding of Pavlov and Liddell. A particular verification as regards the case of the fixed-ratio paradigm demonstrates that gradually shifting the ratio toward higher values produces, in the cat, muscular tension which may conveniently be measured by the number of vocalizations emitted but which includes, in a pattern, tail-flicking, flexion of limbs, pacing, and so on [M. F. Halasz and H. F. Hunt, report to the 3rd World Congress of Psychiatry, Montreal (1961)]. Thus, the schedule employed by Mintz seems to be one where failure to obtain reward may have emotional repercussions. If the consequent tonus be thought of as cumulating from one nonreinforced response to the next, and as declining over successive reinforced presses, the curves presented might well be accounted for by simple superposition of general tension on the lever response.