Table 1. Production of unresponsiveness in rabbits by injection of copolymers of alpha amino acids within 24 hours after birth. The results are based on passive cutaneous anaphylactic tests (adj., adjuvant; i.v. intravenous injection).

Group	Injections given	Rabbits reacting after immunizations	
		1st*	2nd†
	GA		
I Test	adj., adj.	0/12	7/11
I Control	adj., adj.	5/7	4/7
II Test	i.v., adj.	0/6	0/6
II Control	i.v., adj.	0/3	3/3
	GLA30		
I Test	adj., adj.	0/12	9/12
I Control	adj., adj.	5/6	5/6
II Test	i.v., adj.	0/6	0/6
II Control	i.v., adj.	1/4	2/4
	GLAT		
I Test	adj., adj.	0/9	8/8
I Control	adj., adj.	5/5	5/5
II Test	i.v., adj.	2/10	5/10
II Control	i.v., adj.	4/5	5/5

* Results obtained 3rd week after adjuvant or last intravenous injection. † Results obtained 3rd week after second adjuvant injection.

and glu_{36} lys_{24} ala_{35} tyr_5 (GLAT) have been described previously (*3*, *4*, *6*). The average molecular weights were 33,000, 62,000, and 35,000, respectively.

Unresponsiveness was induced by injecting New Zealand white rabbits intraperitoneally within 24 hours after birth with 100 mg of the antigen. Eighteen animals were used for each antigen and litter mates were kept as controls (ten rabbits per antigen). At 2½ months of age, the experimental and control rabbits were bled for serum and then divided into two groups. Animals of group I were injected in the toe pads with 20 mg of the polymer in complete Freund's adjuvant. The animals were bled after 2 and 3 weeks. Three weeks later, the animals received another injection of the polymer in adjuvant and were bled again after 2 and 3 weeks.

The rabbits in Group II received an intravenous injection of 20 mg of the polymer in solution on day 1 (2½ months of age), day 8 and day 22; they were bled 1 week and 3 weeks later. The rabbits were then injected with 20 mg of the polymer in complete adjuvant. Serums were obtained 2 and 3 weeks later. All serums were tested for the presence of antibody by the passive cutaneous anaphylaxis method (*8*), and the serums from animals injected with GLA30 and GLAT were tested by the passive hemagglutination method (*3*). This latter method could detect both 7*S* and 19*S* antibody. All serums that were negative by the passive cutaneous anaphylaxis test were also negative by the hemagglutination test.

To test the specificity of the depressing effect of the injections of polymer which had been given soon after birth, all rabbits were also injected with bovine serum albumin. Normal responses were noted in all animals.

The results presented in Table 1 indicate that although immunological tolerance was produced in a large proportion of the rabbits injected with each of the antigens on the day of birth, the tolerant state was limited. Of the rabbits in Group I that received adjuvant injections of the polymer 6 weeks apart, seven out of eleven, nine out of twelve, and eight of eight responded to GA, GLA30, and GLAT, respectively, indicating a "breaking" of the tolerant state. This is in contrast to no reactors in the experimental group, but a significant number of reactors among the control animals after the first adjuvant injection of polymer.

The data also show that intravenous injection of polymer extended the state of immunological unresponsiveness in the rabbits that were treated initially with GA and GLA30. The quantitative differences in the antibody response in the various groups will be discussed in a subsequent publication. In general, however, significantly higher levels of antibody were produced in the control rabbits.

Thus, tolerance can be conferred by exposing newborn rabbits to antigenic synthetic polyamino acids. Tolerance has also been produced recently in rabbits toward two multichain polymers by Sela *et al.* (*9*; *10*).

PAUL H. MAURER
RICHARD LOWY
CARL KIERNEY

Seton Hall College of Medicine and Dentistry, Jersey City 4, New Jersey

References and Notes

1. P. H. Maurer, D. Subrahmanyam, E. Katchalski, E. R. Blout, *J. Immunol.* **83**, 193 (1959); ———, *ibid.* **88**, 330 (1962); S. Fuchs and M. Sela, *ibid.*, in press; T. J. Gill and P. Doty, *J. Mol. Biol.* **2**, 65 (1960); ———, *J. Biol. Chem.* **236**, 2677 (1961).
2. M. Sela and R. Arnon, *Biochim. Biophys. Acta* **40**, 382 (1960); M. Sela, in *Poly Amino Acids, Polypeptides, and Proteins*, M. A. Stahmann, Ed. (Univ. of Wisconsin Press, Madison, 1962); M. Sela, S. Fuchs, R. Arnon, *Biochem. J.* **85**, 223 (1962).
3. P. H. Maurer, B. F. Gerulat, P. Pinchuck, *J. Immunol.*, in press.
4. P. H. Maurer, *ibid.*, in press.
5. P. H. Maurer and T. Cashman, *ibid.*, in press.
6. P. H. Maurer, B. F. Gerulat, P. Pinchuck, *J. Exptl. Med.* **116**, 521 (1962).
7. R. T. Smith, *Advan. Immunol.* **1**, 67 (1961).
8. Z. Ovary, *Progr. Allergy* **5**, 459 (1958).
9. M. Sela, S. Fuchs, M. Feldman, personal communication.
10. Supported by grant E 3514, 2E 196, from the U.S. Public Health Service and contract DA-49-193-MD-2113 from the office of the Surgeon General.

22 January 1963

Prediction of the Comparative Reinforcement Values of Running and Drinking

Abstract. *The probability of free drinking and running in rats was controlled by sucrose concentration and force requirements on an activity wheel. Drinking and running were then made contingent on pressing a bar. Bar-pressing increased monotonically with the associated response probability, and equally for drinking and running. The results support the assumption that different responses of equal probability have equal reinforcement value.*

The reinforcement value of two different behaviors, running and drinking, may be compared despite their differences, with a model of reinforcement that (i) equates reinforcement value with response probability and (ii) treats the probabilities of different responses as commensurable magnitudes (*1*). Although comparing the strength of different drives and reinforcers has been a classical problem in psychology, progress has been slight. Early work by Warden (*2*), comparing the number of times that rats crossed an electrified grid for food, water, mate, and so forth, has been widely criticized, most constructively perhaps by suggesting that the same comparisons be made without shock. More recently, Guttman (*3*) has predicted that different sugars equated for sweetness on the basis of concentration will have equal reinforcement value. However, this kind of prediction is limited to stimuli located on a single dimension. Overcoming this restriction is a principal aim of my present work (*4*).

Consider that a rat, in separate operant drinking and running sessions, divides each session, on the average, between drinking and running, so that the estimated mean probabilities of drinking and running are both 0.5. According to the present model, if these behaviors are made contingent upon, for example, bar pressing, they will produce equal increments in probability. More generally, different responses of equal probability will have equal reinforcement value; when made contingent upon some less-probable response, they will produce equal increments in that response.

Testing this prediction requires establishing an overlapping range of probabilities (P) of free drinking (D) and free running (R) and then determining

a reinforcement value of each value of P. These requirements were met by first establishing a range of P_D through the use of different sucrose concentrations and a range of P_R through the use of different force requirements on an activity wheel, and then conditioning the animals to press a bar for sucrose concentrations and wheel conditions.

Four female albino rats of the Sprague-Dawley strain, about 200 days old, were used. The apparatus was a modified activity wheel equipped with a brake, a retractable drinkometer, and two bars. In operant drinking sessions, only the tube was free; in operant running sessions, only the wheel was free. During conditioning the appropriate bar was inserted and its corresponding item, tube or wheel, was made contingent upon the bar press. Sessions lasted 10 minutes; all running sessions, operant and conditioning, occurred in the morning, all drinking sessions in the afternoon. Animals were given operant running sessions with a given force requirement and operant drinking sessions with a given sucrose concentration until both behaviors were relatively stable. They then pressed a bar, in the morning for the wheel, and in the afternoon for the tube, with the same stimulus values as in the preceding operant series. Sucrose solutions, in the order of presentation, were 32, 16, and 64 percent by weight; force requirements, in the order of presentation, were about 18 and 80 inch grams. The same conditioning parameters were used in both cases: each time the rat pressed the bar three times, either the wheel or the tube was made available for 15 seconds.

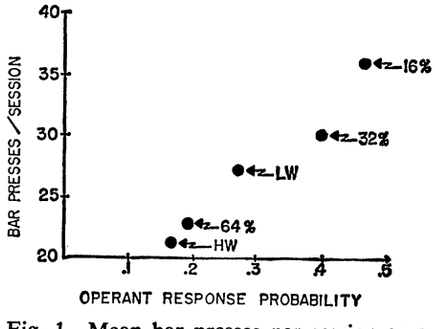

Fig. 1. Mean bar presses per session as a function of the associated operant response probability. The abscissa shows proportion of the operant session for which the animal responded—for example, duration in seconds for which it ran or drank divided by duration of the session. Points are labeled according to the sucrose concentration (16, 32, and 64 percent) or force requirement (light, LW; heavy, HW) that was used to control the operant response probability.

A photoelectric cell, activated each time the wheel turned 90 degrees, measured running; a drinkometer counted licks. Both devices could be used to measure duration of running and drinking by arranging that a precision timer operate continuously when receiving seven or more pulses per second from the drinkometer or four or more pulses per second from the wheel. The procedure eliminates spurious measures due to wheel-rocking and incidental contacts with the drinkometer, since these occur below the prescribed rates.

Figure 1 shows bar presses per session, plotted as a function of the proportion of the session the animals drank and ran, respectively, expressed as the probability of free running and drinking. Thus, a "P_R of .33" indicates that the animal ran or drank for 200 seconds in a 600-second session. Points are averages for the group taken from the last four sessions given at each value of sucrose concentration and force requirement. The order of the points for all animals was the same as that shown in Fig. 1.

The points in Fig. 1 are labeled according to the associated sucrose concentration or force requirement; their rank order on the abscissa shows that the present combination of sugars and force requirements did produce at least partly overlapping probabilities of free running and drinking. Thus the lowest probability of free drinking, produced by the 64 percent solution, fell between the two probabilities of free running. Conversely, the higher probability of running, produced by the light force requirement, fell between the two probabilities of drinking that were associated with the 64 and 32 percent solutions, respectively.

The functional relation shown in Fig. 1 supports the present prediction: bar pressing increased monotonically with the associated operant response probability and did so whether this was a probability of drinking or of running. Not only is bar pressing reinforced by an activity proportional to the operant duration of that activity but, more important, the proportionality is the same for different activities. Figure 1 also suggests that the relation may be linear, although no attempt was made here to determine the function.

An earlier test of the model, using the same behaviors, showed that running reinforced drinking as effectively as, more conventionally, drinking reinforced running. More important, the effective direction of reinforcement was determined by which behavior was relatively more probable in the given interval of time (*5*). The new results thus substantially strengthen the suggestion that reinforcement value is predictable from the proportion of time the animal spends responding, and is so commensurately for different behaviors (*6*).

DAVID PREMACK
Department of Psychology,
University of Missouri, Columbia

References and Notes

1. D. Premack, *Psychol. Rev.* **66**, 219 (1959); *J. Exptl. Psychol.* **61**, 163 (1961).
2. C. J. Warden, *Animal Motivation, Experimental Studies on the Albino Rat* (Columbia Univ. Press, New York, 1931).
3. N. Guttman, *J. Comp. Physiol. Psychol.* **54**, 358 (1954).
4. D. Premack, *J. Exptl. Analysis Behavior* **6**, 81 (1963).
5. ———, *Science* **136**, 255 (1962).
6. This report is based upon a paper read at the meeting of the Psychonomic Society, St. Louis, Mo., 1962. Aided by grant G-19574 from the National Science Foundation and by grant M-5798 from the National Institutes of Health.

4 January 1963

Apparent Concentration Quenching of Morphine Fluorescence

Abstract. *Fundamental fluorescence equations were examined. Deviations from the theoretical were observed by varying the light path length to determine effects on "apparent" fluorescence. It was found that the decrease in emission of morphine solutions with the increase in concentration was caused by absorption effects that prevented excitation of the whole system.*

The formula

$$F = I_0 (1 - 10^{-\varepsilon c b}) \phi \qquad (1)$$

expresses the fluorescence intensity F in solution, where I_0 is the intensity of exciting light, c the concentration, ε the molar absorptivity, b the sample path length, and ϕ the quantum efficiency. All of these values are expressed in appropriate units (*1*). When a fixed-slit instrument is used, for example, the Aminco-Bowman spectrophotofluorometer, the F values are only apparent fluorescence (F'), since factors of detector response and slight differences of optics vary for each instrument (*2*). Corrections for both excitation and fluorescence spectra can be made (*1*, *3*), but the response for each instrument for a constant I_0 should be repro-