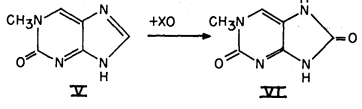
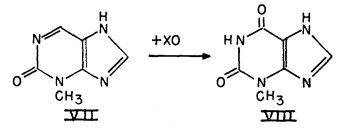
Table 1. Physical properties of 2-hydroxypurine and its derivatives.

Substance	$\lambda_{max.}$ at *p*H 8.0 (mμ)	R_f* acid solvent	R_f* basic solvent	Fluorescence†	Relative rate of oxidation‡ (xanthine = 100)
2-Hydroxypurine (*4*)	314	0.27	0.24	Blue	16.0
2,8-Dihydroxypurine (*4*)	304	0.28	0.28	Blue-violet	0.2
1,2-Dihydro-1-methyl-2-oxopurine (V)	318	0.36	0.30	Blue	180.0
1,2-Dihydro-1-methyl-2-oxo-8-hydroxypurine (*5*)	311	0.34	0.38	Sky-blue	Not attacked
2,3-Dihydro-2-oxo-3-methylpurine (VII)	315	0.51	0.39	Blue	100.0
2,3-Dihydro-2-oxo-3-methyl-8-hydroxypurine (*5*)	320	0.43	0.42	Blue	2.1
3-Methylxanthine	272	0.43	0.45	Black-violet	Not attacked

* Descending method; the following solvents were used for development: Acid solvent: 95 percent ethanol, 85 ml; glacial acetic acid, 5 ml; water, 10 ml. Basic solvent: 95 percent ethanol, 70 ml; pyridine, 20 ml; water, 10 ml.
† Fluorescence was observed with the aid of a Mineralight ultraviolet lamp, which emits light of λ about 255 mμ.
‡ All substrates were used at a concentration of 6 to 7 × $10^{-5}M$.

lem of purine oxidation in general. In order to determine the "active" form of a substrate entering into reaction with the prosthetic group of the enzyme, we have examined two isomeric monomethyl derivatives of I, in which a single tautomeric structure of the latter has become fixed. It was found that 1,2-dihydro-1-methyl-2-oxopurine (V) is oxidized in position 8 and thus resembles I. On the other hand, 2,3-dihydro-2-oxo-3-methylpurine (VII) is converted by xanthine oxidase into 3-methylxanthine. In both cases, identification of the oxidation product was facilitated by the fact that the enzymatic reaction does not proceed beyond the first step. Comparison of the accumulating end products with synthetic materials by paper chromatography and ultraviolet absorption spectra establishes their identity beyond doubt (see Table 1).





These results suggest that I combines with xanthine oxidase in a tautomeric form, corresponding to V. The latter is the fastest reacting substrate of xanthine oxidase yet found, for it is attacked almost twice as rapidly as xanthine. This leads to the conclusion that the pathway of oxidation of purines is determined not so much by the intrinsic polarity of a substrate as by the polarity of the specific enzyme-substrate complex. The active surface may attract preferentially a single structure out of a mixture of tautomeric forms, thereby inducing a shift in the tautomeric equilibrium of the substrate. This could provide an explanation of the fact that the rate of oxidation of I is only about one-tenth of the rate of V.

HANNA KWIETNY
GERSHON LEVIN
FELIX BERGMANN
Department of Pharmacology, Hebrew University–Hadassah Medical School, Jerusalem, Israel

D. J. BROWN
Department of Medical Chemistry, Australian National University, Canberra

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24 April 1959

Development of Communication between Young Rhesus Monkeys

Abstract. A communication situation is described in which the rewards of both members of a pair of monkeys cannot exceed chance levels unless the operator monkey responds to cues provided by the informant monkey which indicate the location of food. Performance under these test conditions improved progressively to levels consistently above chance.

Although field studies show that communication is of fundamental importance in the organization and control of nonhuman primate societies, there have been no experimental demonstrations of communication of specific information between monkeys. This report describes an apparatus for the investigation of communication and presents the results obtained in a preliminary experiment (*1*). The test situation, shown schematically in Fig. 1, consisted of two barred restraining cages separated by a table. Four pairs of food carts were mounted on fixed runways on the table, and each pair of carts was connected by an expandable rack so that movement of one cart simultaneously extended the other in the opposite direction. Brass handles were attached to each pair of carts on the operator's side, and all carts were equipped with metal food containers which prevented the operator monkey from seeing the food but permitted the partner (informant) to see it.

Before a trial, both opaque screens and the transparent screen in front of the operator were lowered, the food containers of the appropriate pair of carts were baited, and the one-way vision screen was lowered. The trial was initiated by raising both opaque screens simultaneously and by raising the transparent screen in front of the operator 5 seconds later. (The transparent screen on the informant's side was not used in this experiment.) The operator was permitted only one response per trial (noncorrection procedure), and after this response the operator's choice and the position of the informant prior to the response were recorded. All pairs were tested twice a day, in the morning and the afternoon, and received 24 trials in each test session. The location of the reward varied randomly, with the restriction that each pair of carts was baited with equal frequency in every block of 24 trials.

The subjects were six pairs of rhesus monkeys, approximately 18 months old, born in the laboratory and removed from the mother at birth. All animals had had previous experience in the apparatus in a series of food-sharing tests in which the food was visible to the subjects and in which all responses by the operator were equally rewarded. For communication testing, one member of each pair was arbitrarily designated the operator, and each pair was given a total of 480 training trials (phase 1). At the conclusion of phase 1, the operator and informant roles were reversed and each pair received 1440 trials under the reversed-role condition (phase 2). Upon completion of this phase of the experiment, the subjects were given an additional 480 trials in the original roles (phase 3).

The results for each phase of the experiment are presented in Fig. 2. The data on the informant's position, the only direct measure of informant behavior obtained in the present experiment, are included for purposes of com-

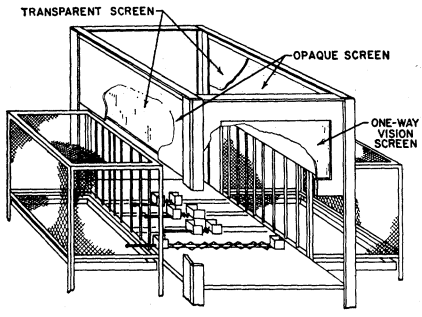

Fig. 1. Schematic drawing of the communication test apparatus.

parison. The analysis, however, is restricted to the performance of the operators. There is no evidence of learning during phase 1, and the percentage of correct responses for individual pairs on the last 5 days of this training period ranged from 23 to 31. Performance during phase 2 improved progressively for all pairs, and this effect of practice is significant at the .001 level as determined by the Friedman nonparametric analysis of variance. Three pairs had two or more errorless sessions during the last half of this phase. To check on possible utilization of nonsocial cues, each operator was given 48 control trials between sessions 46 and 47 of phase 2 in which procedures were identical in all respects to those observed during the regular communication tests except that the informant was not present. For every operator, performance dropped to chance levels.

The differences between performance levels for phase 1 and for the first 10 days of phase 2 were not statistically significant, indicating that efficiency under the reversed-role condition was not initially superior to that demonstrated during the previous phase. Phase 3, in which the monkeys were returned to their original roles, may be regarded as a test of transfer across roles. During the intensive training given in phase 2, each pair achieved performance levels substantially above chance. It might be

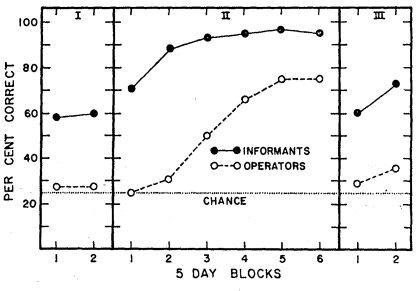

Fig. 2. Percentage of correct responses by the operator and correct positionings by the informant during the three phases of the experiment. Each pair was given 240 trials in every block of 5 days.

expected that in the course of this training the subjects had acquired incidentally some proficiency in the complementary role and if so, that this would be reflected in a high initial level of correct responses on return to the original role. As can be seen from Fig. 2, however, a comparison of data for phases 1 and 3 provides little evidence to support this expectation. Although there is some indication that performance improved during the final five days of phase 3, this effect was not statistically significant and can safely be attributed to practice in the specific role rather than to incidental learning in the course of the previous role.

WILLIAM A. MASON*
Psychology Department,
University of Wisconsin, Madison

Notes

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* Present address: Yerkes Laboratories of Primate Biology, Orange Park, Fla.

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Average Potassium Concentration of the Human Body as a Function of Age

Abstract. Potassium-40 measurements on 1590 males and females ranging in age from less than 1 year to 79 years show sex differences and age trends in the ratio of muscle mass to the mass of other body constituents. A sex difference first appears at approximately 12 years of age. While females show a continuous decrease in potassium concentration, males show a rapid increase between the ages of 14 and 16. During adult life both sexes show a persistent and parallel decrease, which may be related to physiologic aging.

In previous papers (*1, 2*) we reported some of the results of our in vivo measurements of total potassium content of the human body. Measurements were made by counting the gamma rays from natural potassium-40, with a 4π liquid scintillation gamma counter (*2, 3*). We now report the results of an analysis of data for 1590 individuals ranging in age from less than 1 year to 79 years. Figure 1 shows the average body potassium concentration (in grams per kilogram of gross body weight) of males and females, plotted as a function of chronologic age. The curves show a surprising amount of structure.

Potassium concentration in both males and females increases from the first year of life and reaches a maximum at age 8 or 9, followed by a sharp decline. The curves for males and females show no significant sex differentiation until approximately the age of puberty (11 to 12 years) in the female. In this age range differentiation begins to occur, and the potassium concentration in females continues to drop rapidly until about age 16 (at which time it assumes a slope characteristic of adult females). Potassium concentration in males shows another sharp increase beginning at age 14 (the age of male puberty) and reaches a second maximum at age 16. The female does not show the second peak at all, and the sex difference is greatest at this age. After the second maximum, potassium concentration in males shows a rapid decline to about age 21 (comparable to that seen in females between the ages of 12 and 16). Beyond age 16 in females and age 21 in males, there is a persistent decrease in potassium concentration with age, with parallel slopes throughout adult life. While the adult decline is shown here as a linear function of age, the data are equally compatible with an exponential decrease.

A statistical analysis of the data for each age group was performed to determine the standard deviation. Since the frequency distribution curves appear to be normal, the precision of the mean for each age group was estimated by dividing the standard deviation by the square root of the number of subjects in the group. The standard deviation of a single datum in the age range from 5 to 68 years (*4*) was 7 to 15 percent. The standard deviation of the mean for the same age groups was from 1 to 4 percent. The observed scatter of the averaged points about the regression lines is consistent with this degree of precision. The principal cause of variability is the normal biological variation (due largely to difference in amount of fat) among individuals. By contrast, the statistical counting error for each determination was only about 3 percent.

Change in potassium concentration in males and females in relation to growth [as indicated by weight gain (*5*)] is shown in Fig. 2. Since about 98 percent of body potassium is intracellular (*6*), change in potassium concentration reflects a change in the ratio of lean, oxidizing, protoplasmic mass to the mass of other body constituents containing little or no potassium (for example, skeleton and fat). The rise in potassium concentration in early childhood reflects increasing muscular development of similar magnitude in both sexes. The decline that begins at about 9 years of age may result, at least in part, from the rapid acceleration in skeletal growth [this is responsible also for the increase in strontium-90 uptake that begins at about this age (*7*)]. Although growth rate in the female is at a maximum be-