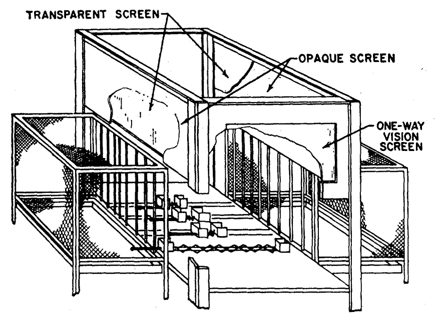

Fig. 1. Schematic drawing of the communication test apparatus.

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 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.

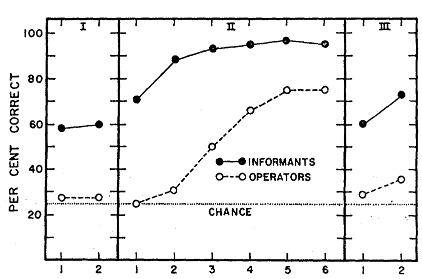

Fig. 2. Percentage of correct responses by the operator and correct positionings by the informant during the three phases of the experiment. Each pair was given 240 trials in every block of 5 days.

William A. Mason*
Psychology Department, University of Wisconsin, Madison

Notes

1. I wish to acknowledge the assistance of Jess W. Harris in the design and construction of the apparatus. Support for this research was provided by funds received from the Graduate School of the University of Wisconsin, grant G6194 from the National Science Foundation, and grant M-722 from the National Institutes of Health.

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

13 May 1959

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-

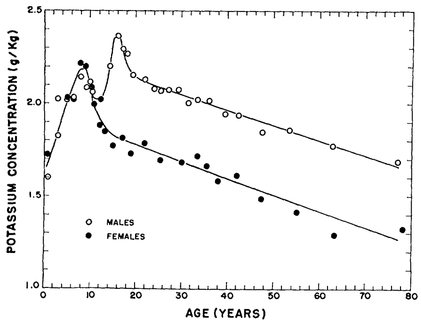

Fig. 1. Average body potassium concentrations of males and females as a function of chronologic age (grams per kilogram of gross body weight).

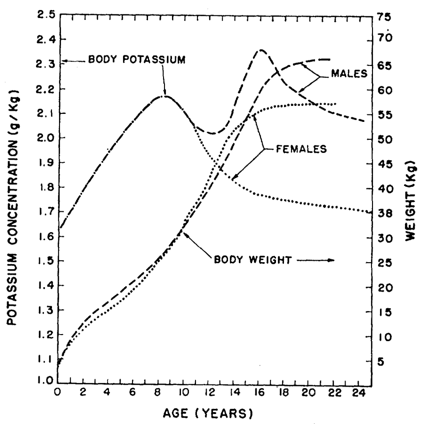

Fig. 2. Change in male and female potassium concentrations in relation to growth (as indicated by weight gain).

tween the ages of about 9 and 14, potassium concentration continues to drop rapidly; this suggests that relatively less muscle mass is added with increasing age and weight. Accelerated muscular growth occurs in the male at puberty, giving rise to a second maximum in potassium concentration at about age 16. The absolute rate of muscular development, however, is even more pronounced than is indicated by the potassium values (since this is also a period of continuing rapid skeletal growth which would tend to lower the potassium concentration). The pronounced decline in potassium concentration in males between the ages of 16 and 20 was rather surprising, since this is a period during which the rate of weight gain is decreasing also. Evidently gain in weight after age 16 is a result of a "filling out" process involving the addition of fat, connective tissue, and bone, with relatively little addition of muscle tissue. The foregoing interpretation of changes in potassium concentration in males and females with age is quite in accord with observations of age and sex variations in total body water reported by Edelman *et al.* (*8*).

The steady decrease in potassium concentration beyond age 20, with similar slopes for males and females (Fig. 1), is very interesting and worthy of further study. Multiplication of the potassium concentration by the average weight for each adult age group gives a measure of the amount of lean, oxidizing, protoplasmic mass and an indication of its variation with age and sex. Mean weights for the adult male age groups measured in our study showed essentially no increase in weight with age; therefore, the observed decrease in potassium concentration must represent a net loss in lean, protoplasmic mass. Between ages 20 and 60, this net loss in males amounted to about 18 percent. After correction for increase in gross body weight with increasing age, the net decrease in lean protoplasmic mass in females between ages 20 and 60 was only about 6 percent. This interpretation is in general agreement with observations of decrease in basal metabolic rate with increasing age (*9*) and supports von Döbelin's suggestion (*10*) that standard metabolic rate be expressed in relation to fat-free body mass.

Measurement of potassium-40 may offer an effective, statistical means of studying some aspects of the physiology of aging, exercise, starvation, and such wasting diseases as muscular dystrophy. The ease with which the potassium-40 measurements can be made [over 4000 people were measured, to a precision of 10 percent, during the recent 15-day Geneva Conference on Peaceful Uses of Atomic Energy, with an improved 2π counter (*11*) and counting time of 40 seconds] enhances the attractiveness of this method for the study of large population groups (*12*).

E. C. ANDERSON
W. H. LANGHAM
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico

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12. We are grateful to Mrs. B. E. Clinton for making the measurements on which this report is based. The cooperation of the many volunteer subjects is acknowledged, especially that of the Cub Scouts and Brownies who supplied data in the interesting region from ages 8 to 10. H. I. Israel was most helpful in programing for electronic data processing. This work was performed under the auspices of the U.S. Atomic Energy Commission.

30 April 1959

Changes in the Pattern of Nitrogen Excretion during the Life Cycle of the Newt

Abstract. In the course of its life cycle the eastern newt, *Triturus* (*Diemyctylus*) *viridescens*, undergoes two metamorphoses, the first from the aquatic larva to the terrestrial red eft; the second, 2 to 3 years later, from the eft to the permanently aquatic and sexually mature adult newt. The pattern of nitrogen exretion changes during both transformations. Older larvae excrete about 75 percent of the nitrogen as ammonia, 25 percent as urea; during the first metamorphosis the ratio of ammonia to urea is about 57:43; completely transformed efts excrete 87 percent of the nitrogen as urea. Adult aquatic newts show a partial return to the larval pattern, with an increase in the proportion of ammonia from the 13 percent typical for the eft to 26 percent, a highly significant difference.

The studies reported in this paper were inspired by G. Wald's article "The significance of vertebrate metamorphosis," which appeared in the 12 Dec. 1958 issue of *Science* (*1*). Wald emphasized the basic biochemical changes that occur during metamorphosis from aquatic to terrestrial existence, and that are correlated with morphological and ecological changes. He also stressed the occurrence of a "second metamorphosis" at the time of reproduction, and the return of many sexually mature vertebrates to their natal environment, which they had left during the first metamorphosis.

No other species of amphibia exhibits these two metamorphoses as strikingly as the eastern newt, *Triturus* (*Diemyctylus*) *viridescens*. During the first transformation, the aquatic larva changes into the terrestrial red eft, which, during its 2 or 3 years of life on land, shows many morphological adjustments to the new environment. The epidermis is roughened and covered by a thicker cuticle; numerous multicellular glands appear in the skin; the lateral-line organs sink below the surface and become nonfunctional; nasal glands of various types are formed; eyelids and lacrymal glands protect the eye against drying; the tongue becomes muscular, protrusible, and well equipped with glands whose secretion aids in the capture of prey.

At the end of its terrestrial growth