calibrated points were within about 5% of the best fitting line. When calibration lines using water were compared with calibration lines using 6% gum acacia (relative viscosity 7.5), the difference was never greater than 3%.

In a somewhat similar manner, Stephenson (1) has constructed a flow meter in which the height of a fluid column was related to the rate of discharge through a capillary. Due to pneumatic coupling to the recording device, this meter would seem to be sensitive to temperature and barometric pressure changes. The meter would also seem very sensitive to changes in viscosity and surface tension because of its dependence on capillary flow and the presence of drop formation at the orifice. Due to these factors, and to the presence of turbulent flow, there is no simple mathematical expression for its performance.

In our arrangement of the heart-lung apparatus, the meter was placed at the end of the arterial system, the outflow from the funnel going directly to the venous reservoir. A sample blood flow recording is shown in Fig. 3.

Since small changes in flow may be obscured due to frictional resistance of the writing stylus on the paper, it is suggested that a small electric vibrator be placed on the flow meter support. When the flow is pulsatile, as in the heart-lung preparation, the vibrator is unnecessary.

When the vessel diameter is increased, a larger volume increment is required in order to reach equilibrium and the response time is therefore lengthened. This results in a reduction in the oscillations due to transient changes and the meter approximates, to a finer degree, mean flow.

Summary. An inexpensive direct recording flow meter, relatively independent of viscosity changes and with an accuracy of about 5% was constructed. Its chief advantage lies in its extreme simplicity. The calibration curve, closely approximating a parabolic function, was reduced to a straight line by plotting log height against 2 log flow on log-log graph paper.

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Transport of Radioactive Sodium Across the Synovial Membrane of Normal Human Subjects.* (19721)

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(Introduced by William S. McCann.)

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Any investigation of physiological function of the synovial membrane of joints is limited by suitable technics for the study of this relatively inaccessible structure. The availability of a variety of isotopes obviates some of these difficulties. The present investigation was designed to study the sodium clearance of the synovial membrane by means of radioactive sodium.

A group of 35 healthy adults were injected in the knee synovial space with Na^{24} and the clearance rate determined. The results of this study of normal subjects reveal that significant differences are encountered between normal men and women. The present report describes these variations.

Method. Radioactive sodium (Na^{24}) was obtained from the Oak Ridge National Laboratories as $Na^{24}{}_2CO_3$. It was converted to $Na^{24}Cl$ and suitably diluted to produce an 0.85% sodium chloride solution with an adjusted pH of 7.3. The concentration of Na^{24} was 30-40 μc in each milliliter. After local novocaine anesthesia a 20-gauge needle was inserted under the lateral inferior border of the patella into the synovial space of the knee. Two milliliters of the sterile radioactive

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TABLE I. Rate of Absorption of Na^{24} from Synovial Space of Knee.

	No.	% remaining after 30 min
Men	14	$\bar{X} = 48.2 \pm 2.3$
Women (total)	24	$\bar{X} = 40.8 \pm 1.8$
1st 10 days	7	$\bar{X} = 35.9 \pm 3.3$
2nd 10 "	10	$\bar{X} = 42.1 \pm 2.8$
3rd 10 " of menstrual cycle	7	$\bar{X} = 43.8 \pm 3.3$

sodium chloride were injected and the needle withdrawn. By means of a Geiger-Mueller counter tube placed 6-10 cm from the lateral aspect of the knee, the amount of gamma radiation from the knee was automatically recorded on a rate meter at 2-minute intervals. The subject was not allowed any activity during the course of the experiment. All recordings were made with the leg in extension. Continuous observations were made over a 40-minute period. A total of 35 healthy adults consisting of 12 males and 23 females was studied. Two of the males and one of the females were studied on 2 different occasions. None had any preceding history of arthritis or traumatic injury to the knee. The ages of the subjects ranged from 18-40 years.

Results. This technic for the study of Na^{24} clearance from the knee joint reveals that there is a continuous decrease of Na^{24} from the synovial space which proceeds in an exponential curve. Variations from individual to individual occur only as variations in the slopes of the logarithmic curves. The logarithmic concentration of Na^{24} within the joint was plotted against time elapsed from injection of Na^{24} into the joint space. From these data one can determine percent remaining after a 30-minute period, or calculate a clearance constant from Kety's(1) formula, $K = \frac{(\log C_1 - \log C_2)}{0.4343\ (t_2 - t_1)}$, where C_1 and C_2 equal counts per minute at times t_1 and t_2, respectively.

In Table I the results of calculation of mean absorption rate are recorded. It will be observed that the men had a mean of 48.2 ± 2.3% remaining after 30 minutes, whereas the women had a mean of 40.8 ± 1.8% remaining after 30 minutes. Statistical analysis of these figures reveals that this is a significant difference.†

When the results on female subjects are related to the day of the menstrual cycle, it is observed that more rapid clearance occurs in the early stages of the cycle. The mean percent of Na^{24} remaining after 30 minutes for each of the 3 periods was 0-9 days: 35.9 ± 3.3%, 10-19 days: 42.1 ± 2.8%, 20-28 days: 43.8 ± 3.3% (Table I).

Because of the high degree of variability among the means of the group of women in different stages of the menstrual cycle, one cannot state that there is statistical evidence of differences. However, on the basis of the means alone there is some evidence of a trend in the rate of clearance of Na^{24} during the menstrual period. These data suggest that most rapid clearance of Na^{24} is present during the early phase of the menstrual cycle.

The possibility exists that these variations might be attributable to a difference in absorbing surface area within the knee joint. On the assumption that an estimation of body surface area may be proportional to the synovial surface area, a comparison of body surface area with Na^{24} clearance was made. No correlation is found.

A comparison of clearance of Na^{24} from the synovial space with the rate of removal from muscle and subcutaneous tissue reveals that removal from synovial space is the least rapid (Table II). From the data obtained by Forbes(2) and Kety(1) it is evident that Na^{24} injected subcutaneously is removed most rapidly, while intramuscular injection of Na^{24} shows an intermediate clearance rate between subcutaneous tissue and joint space.

Kety(1) has shown that the rate of transport of Na^{24} from muscle is dependent on a constant circulation of blood. Similar ob-

TABLE II. Comparison of Clearance of Na^{24} from Various Body Sites.

Sites of administration	Mean K value	Range of K	No. of observations
Subcutaneous	.104	.040–.150	7(2)
Intramuscular	.050	.033–.066	8(1)
Synovial space of knee	.029	.014–.041	38

† "Students" t = 2.5 which has a probability of about .03 if there is no difference between the means.

servations were made in the present investigation on 2 subjects who developed a mild circulatory collapse immediately after injection of Na^{24} into the synovial space. Continuous recordings of Na^{24} concentration in the knee were made. During the period of faintness and hypotension the Na^{24} absorption was slow. Upon recovery the absorption of Na^{24} was more rapid. Thus the removal of sodium from the knee joint is dependent on both membrane permeability and circulation.

Discussion. The implication of these observed variations in Na^{24} clearance from the joint space of the knee is not clear. The possible difference attributable to the stage of the menstrual cycle at which the experiment is carried out suggest, however, an hormonal control of synovial permeability to Na^{24}. The experimental work done in rabbits by Seifter (3) supports an hormonal explanation for the variations of synovial permeability found in this investigation. When phenolsulphonthalein was injected into the rabbit synovial space, the clearance was accelerated by parenteral administration of desoxycorticosterone but retarded if cortisone was administered.

Paul and coworkers(4), however, have failed to find any effect of cortisone and ACTH on synovial permeability. Utilizing the same methods as described by Seifter, they found no significant alteration of synovial membrane permeability unless cortisone was injected into the joint. The use of Na^{24} may obviate inherent difficulties of previous methods described for the study of electrolyte exchange across the synovial membrane(5) and may serve as a useful technic for the study of the influence of endocrine substances on joint physiology.

Summary. 1. By means of injection of Na^{24} into the knee joint, the clearance of Na^{24} through the synovial membrane has been studied. 2. A significantly more rapid clearance of Na^{24} from the knee joint occurs in women than in men. There is suggestive evidence that the accelerated Na^{24} clearance in women depends upon an hormonal influence associated with the menstrual cycle. 3. Removal of Na^{24} from the joint space is less rapid than it is from subcutaneous or muscle tissue.

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Effects of Liver Fractions and Vitamin B_{12} on Body and Organ Weights of Thyroid-Fed Rats. (19722)

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The recent data of Ershoff(1,2), Betheil *et al.*(3,4), and Emerson and Folkers(5,6) indicate that liver contains an "anti-thyrotoxic factor" which counteracts the growth retardation of young rats when fed a purified diet containing thyroid. According to Ershoff (7-10), this factor is present mainly in the water insoluble fraction of liver (liver residue) and is reported to be distinct from vit. B_{12}.

This communication confirms these reports and includes new data on the effects of thyroid, defatted liver residue, liver concentrate N.F., and vit. B_{12} on some organ weights of immature rats.