veins consist of melted and recrystallized salt and contain minute, opaque black minerals disseminated between the salt crystals and sharp-bordered fragments of clear, unmelted, plastically deformed salt. Some of the unmelted salt fragments have a very thin selvage suggesting partial melting, and many of the fragments show warping and bending of bedding and cleavage suggesting plastic deformation. In one thin section a tiny vein displays flow textures with warped and swirled fragments reminiscent of that commonly seen in welded tuffs. Tiny fragments of copper and steel wire are not uncommon constituents.

About 15 percent by weight of samples of the vein material is insoluble in water and consists of opaque black minerals, a few doubly terminated quartz crystals, and a micaceous mineral—probably muscovite. Slight effervescence in acid indicates that some carbonate is present.

X-ray diffractometer patterns of the residue, studied by Theodore Botinelly of the Geological Survey, indicate the presence of the lead minerals laurionite (*3*) (lead hydroxide-chloride) and galena (lead sulfide). Lead in these minerals was derived from lead block used in the device performance measurements (*4*). The extent of distribution of the lead minerals is not known. The samples analyzed came from 100 to 110 feet from the shot point.

About 6 percent of the insoluble residue is carbon which was derived, at least in part, from organic material present in the device chamber at shot time. The quartz and mica were derived from impurities present in the pre-shot salt. No significant increase in iron was found over that contained in pre-shot samples, although a large quantity of iron was present near the device and was vaporized by the blast. The lead combined with chlorine from the sodium chloride and with water to form laurionite and with sulfur derived from the sulfate mineral polyhalite to form the galena. Copper content has increased from about 0.003 percent to 0.7 percent, perhaps owing to the contained wire fragments.

The presence of the OH radical in the laurionite suggests that the mineral was formed at a temperature of less than 142°C, above which point laurionite breaks down into lead chlorides and lead oxides. The components lead and chlorine probably were injected in a vapor state through openings that were closed immediately thereafter. They were deposited in fractures in the cooler portions of the salt. Surviving plastic and rubber cable covering and scorched wood fragments as well as unmelted bits of fine copper wire indicated that the temperature here could not have been very high. The melted salt may have been formed locally by extremely high pressures between the button-hook drift and the shot point or possibly by direct contact with heat released from the device.

Thin sections of the veins show that the melt has narrow chill borders where it is in contact with many of the larger fragments and wall rock. The chill borders are relatively free of lead minerals, whereas the interior of the veins contains the minerals as dust lying between the tiny crystals of melted salt (*5*).

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References and Notes

1. Written communication from the Lawrence Radiation Laboratory, 19 January 1962.
2. Oral communication from T. S. Sterrett, U.S. Geological Survey.
3. Laurionite was first found at Laurium, Greece, where it is formed by the action of seawater on slags from lead mines operated during the time of Pericles (4th century B.C.).
4. A semiquantitative spectrographic analysis of the residue shows a small amount of silver. The presence of silver suggests that the lead used in shielding the device came from a smelter in the western United States.
5. Publication authorized by the director, U.S. Geological Survey. Work done on behalf of the U.S. Atomic Energy Commission.

15 January 1963

Plasma Protein Synthesis in the Liver: Method for Measurement of Albumin Formation in vivo

Abstract. *l-Arginine labeled with carbon-14 at the guanido group was injected into rabbits, and the ratio of the rates of entry of radioactivity into the protein and urea was determined. This ratio, multiplied by the rate of arginine utilization in urea synthesis and by the ratio of protein to protein arginine weights, gives the rate of protein synthesis. The method applies to albumin and should apply to any plasma protein synthesized in those liver cells which also synthesize urea.*

At present, though rates of synthesis of plasma proteins in the steady state in animals can be measured indirectly by determining catabolic rates with proteins labeled with I^{131} they cannot be measured over short periods of time, nor when synthetic and catabolic rates are unequal. The method reported here avoids these disadvantages. Its kinetic basis is defined in Fig. 1; All symbols are defined in the legend. Albumin is used as an example of a protein to which the method applies.

Figure 1 shows three interlinked systems: *system 1*, consisting of arginine in the liver, receiving arginine from the plasma; *system 2*, comprising the albumin in the plasma, in the interstitial fluids and at catabolic sites; and *system 3*, consisting of the urea in the body fluids and that passed into the urine. Present evidence is that essentially all the urea of *system 3* is formed from the guanidine portion of the arginine of *system 1* (*1*), and that all plasma albumin is synthesized in the liver (*2*) so that the albumin of *system 2* receives its arginine from *system 1*. All symbols are explained in the legend of Fig. 1. The albumin of *system 2* consists of that in the plasma, A_∞, that in the interstitial fluids, A_u, and that passing to the catabolic sites. Albumin passes from the plasma to the interstitial fluids at a rate of k_1A_∞ per day and to the catabolic sites at a rate of k_3A_∞ per day. These rates have been measured with I^{131}-albumin in healthy men (*3*, *4*) and rabbits (*5*).

Figure 1 shows that the amount of liver arginine, $A(t_0,t_1)$, entering the plasma albumin of *system 2* in the interval t_0,t_1 is given by

$$A(t_0,t_1) = k_a \int_{t_0}^{t_1} L(t)\,dt \qquad (1)$$

where the symbols are defined in the legend of Fig. 1. If n is the ratio of the number of milligrams of albumin to the number of milligrams of arginine in albumin, then $nA(t_0,t_1)$ is the quantity of albumin synthesized between t_0 and t_1 which we wish to measure.

Figure 1 also shows that the amount of liver arginine required for the synthesis of the urea, $U(t_0,t_1)$, of *system 3* formed between t_0 and t_1 is

$$2.9\,U(t_0,t_1) = k_u \int_{t_0}^{t_1} L(t)\,dt \qquad (2)$$

where 2.9 is the ratio of the molecular weight of arginine to the molecular weight of urea. The quantity $U(t_0,t_1)$ is easily measured, provided bacterial destruction of urea is blocked, as shown in the legend of Fig. 1.

When arginine labeled in the guanidocarbon (arginine-G-C^{14}) is injected in-

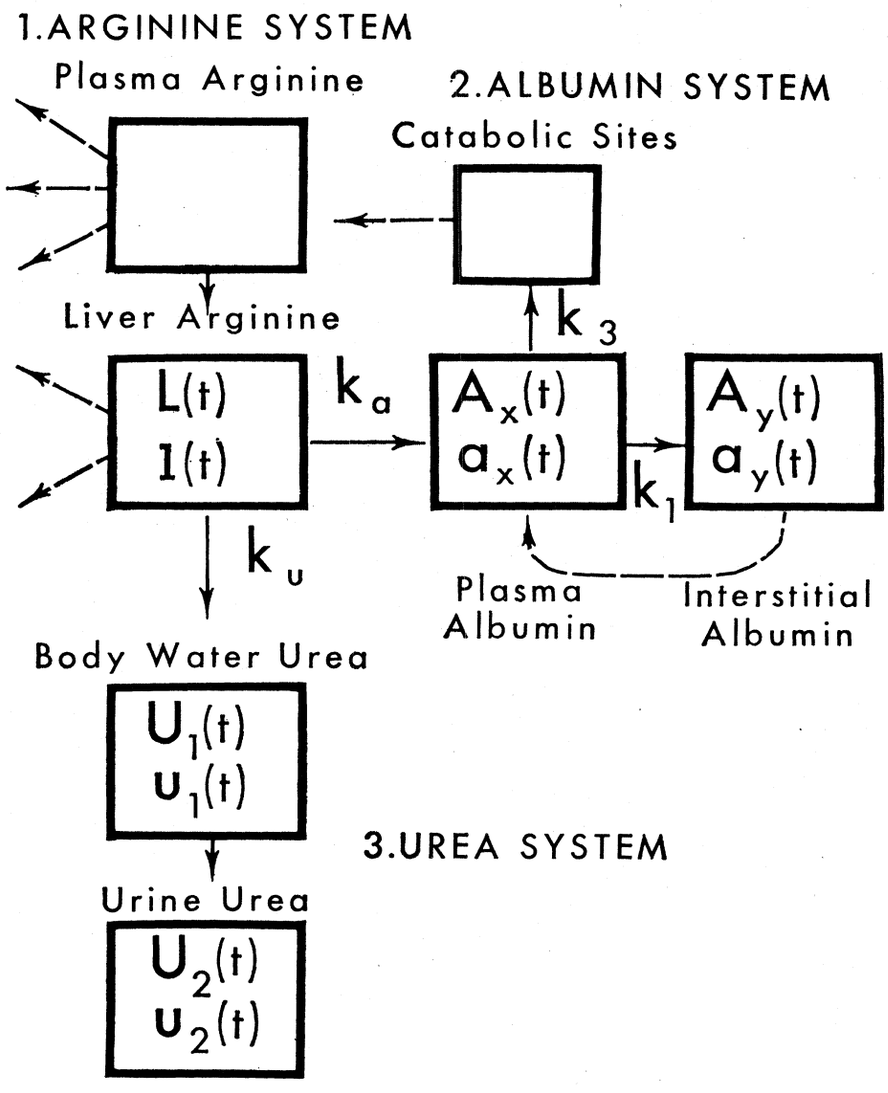

Fig. 1. Some paths of arginine metabolism. The continuous arrows show paths required for the formulation of the method of measurement, dashed arrows show other paths. Capital letters in the boxes refer to weights of arginine or urea, lower case letters to radioactivity of arginine-guanidyo-C^{14} or urea-C^{14}. The symbols are defined as follows:

t_0, time of injection of arginine-guanidyo-C^{14} (arginine-G-C^{14}).

t, a variable time, ranging from t_0 to t_1, at which measurements are made.

$L(t)$, milligrams (mg) of liver arginine at time t available for synthesis of urea and plasma protein (albumin).

$U_1(t)$, mg of urea in body fluids at time t, given by (mg urea/ml plasma) at time t, multiplied by V_u, the distribution volume of urea in milliliters.

$U_2(t_0,t_1)$, mg of urea passed in urine in interval t_0,t_1.

$U(t_0,t_1)$, sum of $[U_1(t_1) - U_1(t_0) + U_2(t_0,t_1)]$.

$A_x(t_0,t_1)$, mg of arginine in albumin in plasma synthesized in interval t_0,t_1.

$A_y(t_0,t_1)$, mg of arginine in albumin in interstitial fluids synthesized in interval t_0,t_1.

$A(t_0,t_1)$, sum of $A_x(t_0,t_1)$, $A_y(t_0,t_1)$, and the albumin synthesized between t_0 and t_1 which has been catabolized.

$l(t)$, radioactivity of arginine-guanidyo-C^{14} per mg of the liver arginine, L, at time t.

$L(t)l(t)$, total radioactivity of the liver arginine, L, at time t.

$a_x(t)$, total arginine-guanidyo carbon (G.C) activity in the albumin in the plasma at time t, given by the albumin arginine-G-C^{14}/ml plasma at t, multiplied by Vp, the plasma volume in milliliters.

$a_y(t)$, total G.C activity in the albumin in the interstitial fluids at time t.

$a(t_0,t_1)$, sum of $a_x(t_1)$, $a_y(t_1)$ and the G.C activity of albumin catabolized in the interval t_0,t_1.

$u_1(t_1)$, total urea G.C activity in the body fluid urea at time t_1, or V_u • urea activity/ml plasma [see $U_1(t)$].

$u_2(t_0,t_1)$, total urea G.C activity excreted in the urine between t_0 and t_1.

$u(t_0,t_1)$, sum of $u_1(t_1)$ and $u_2(t_0,t_1)$.

k_a, fraction of the liver arginine, L, entering albumin per unit time.

k_u, fraction of L required for urea formation per unit time.

k_1, fraction of albumin in the plasma passing to the interstitital fluids per day (*4, 5*).

k_3, fraction of albumin in the plasma catabolized per day (*4, 5*).

travenously, the labeled carbon passes with arginine into albumin and enters urea as shown in Fig. 1. Then the radioactivity entering urea, $u(t_0,t_1)$, between t_0 and t_1 is

$$u(t_0,t_1) = k_u \int_{t_0}^{t_1} L(t)l(t)\,dt \quad (3)$$

which is easily measured, as shown in the legend of Fig. 1.

The total radioactivity entering albumin arginine, $a(t_0,t_1)$, between t_0 and t_1 is

$$a(t_0,t_1) = k_a \int_{t_0}^{t_1} L(t)l(t)\,dt \quad (4)$$

This consists of that in the plasma at time t_1, $a_x(t_1)$, and that which has passed from the plasma to the interstitial fluids and catabolic sites in the interval t_0,t_1. The latter (see Fig. 1) is given by

$$(k_1 + k_3) \int_{t_0}^{t_1} a_x(t)\,dt.$$

(If the experiment lasts only a few hours the small return of interstitial albumin activity, a_y, to the plasma may be neglected.) The integral

$$\int_{t_0}^{t_1} a_x(t)\,dt$$

is obtained by graphic integration of the plot of $a_x(t)$, which is determined from analysis of four to six samples withdrawn over the interval t_0,t_1. The rate constants k_1 and k_3 may be measured with I^{131}-albumin (*4–6*) or average values may be used.

If k_a and k_u are constants over the experimental interval, the fundamental relation follows that

$$\frac{k_a \int_{t_0}^{t_1} L(t)\,dt}{k_u \int_{t_0}^{t_1} L(t)\,dt} = \frac{k_a \int_{t_0}^{t_1} L(t)l(t)\,dt}{k_u \int_{t_0}^{t_1} L(t)l(t)\,dt} = \frac{k_a}{k_u} \quad (5)$$

or, in words, over the interval t_0,t_1 the quantity of arginine entering albumin divided by that required for the synthesis of urea is equal to the quantity of guanido-C^{14} entering albumin divided by that entering urea, which equals k_a/k_u. Rearranging Eq. 5,

$$k_a \int_{t_0}^{t_1} L(t)\,dt = \frac{k_a}{k_u} \cdot k_u \int_{t_0}^{t_1} L(t)\,dt \quad (6)$$

or, in words, the quantity of arginine entering albumin in the interval t_0,t_1 is given by the activity of guanido-C^{14} entering albumin divided by that entering urea in t_0,t_1, multiplied by the quantity of arginine required for the forma-

Table 1. Comparison of synthetic and catabolic rates in rabbits. The rates are expressed as the fractions of albumin in the plasma replaced by synthesis or broken down by catabolism per day.

Rabbit No.	Weight (kg)	Fractional synthetic rate	Fractional catabolic rate
727	2.18	.25	.28
728	2.30	.26	.21
731	2.33	.28	.27
788	3.10	.19	.24
733	2.42	.20	.24
Mean		.236	.248

tion of urea in t_0,t_1. By Eq. 2 the latter is readily determined. Thus the left hand side of Eq. 6 is measured, and when multiplied by n gives the total albumin synthesized in the interval t_0,t_1.

If $k_a(t)$ and $k_u(t)$ vary with time, then the above method holds only if $k_a(t)/k_u(t)$ remains constant during the experiment. If this is not so, the rate of albumin synthesis may still be measured. Since, however, the effective experimental time ranges between 1 and 3 hours this is believed short enough for k_a and k_u to remain essentially constant.

Brief technical details of the method are as follows. Immediately after the bladders are completely emptied, one to two hundred microcuries of *l*-arginine G-C^{14} (specific activity 13 mc/mmole) are injected into neomycin-treated rabbits. Blood samples and complete urine collections are then obtained at intervals. Albumin from the plasma is separated by a modification of Korner's method (*7*) and hydrolyzed with 6*N* HCl; the hydrolyzate is treated with arginase. Conway's method (*8*) is used to measure the urea content, and thus the arginine content, of the digest, and also the urea content of the plasma and urine. The C^{14} of arginine-G-C^{14} and urea-C^{14} is liberated as $C^{14}O_2$ by means of arginase and urease; it is absorbed in hyamine and measured in a liquid-scintillation counter.

Table 1 shows comparisons of measurements of the rate of synthesis made by this method with measurements of catabolic rate made with I^{131}-albumin (*5*). The albumin was labeled by the iodine monochloride method (*9*). Measurements of synthesis were made either during the course of the I^{131}-albumin measurements or 1 to 3 weeks before these were started. The average value for the ratio k_a/k_u was 0.0084 and over the course of 5 hours about 20 percent of the administered guanido-C^{14} entered the urea and albumin. Agreement is good considering that rates of synthesis are measured over a few hours but catabolic rates over 1 to 3 weeks.

Further technical details with some kinetic refinements will be described in a later report, but two points must be emphasized. First, the method depends on the assumption that the liver arginine, L, is equally available for the synthesis of urea and plasma albumin. The data of Table 1 offer strong evidence in favor of this assumption, for kinetic analysis shows that if albumin and urea were made at sites not sharing the same arginine "pool," then the probability of obtaining the results in Table 1 is very small. Thus, as noted by McFarlane (*10*) and confirmed by us, when the method is applied to gamma globulin, which is not made in the parenchymal cells of the liver, grossly erroneous results are obtained.

Second, the method requires the isolation of the plasma protein under study in sufficiently pure form. McFarlane's observations (*10*), confirmed by us, emphasize that the most dangerous contaminant is gamma globulin, which may have five to ten times the guanido-carbon specific activity of plasma albumin. Thus gamma globulin must be excluded from the protein being analyzed.

A possible source of error is significant extrahepatic arginase action. The experiments of Table 1 appear to exclude this in the neomycin-treated rabbit (*11*).

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11. The technical aspects of this work have been helped by fruitful discussions with A. S. McFarlane and by his participation in the experiment on rabbit 788. His generosity at the start of our experiments in allowing us to study some of his data, which indicated the common site for synthesis of urea and albumin, permitted the formulation of the kinetics from which our experimental studies followed. Supported by grant H-2262 from the National Heart Institute.

19 December 1962

Gamma Emitters in Marine Sediments near the Columbia River

Abstract. *Samples from sediment cores collected at 26 different locations 5 to 35 miles offshore in and around Astoria Submarine Canyon were analyzed for gamma emitters. Chromium-51 and zinc-65 were the principal radionuclides found, although several fission products and natural potassium-40 were also present. Radioactivity fell off sharply with distance from the mouth of the Columbia River, indicating that the river serves as a common source of the artificial radionuclides.*

The Columbia River is a low-level source of radionuclides formed by neutron activation of impurities in the river water used to cool the nuclear reactors at Hanford, Washington (*1*). Zinc-65 from the river has previously been reported in sessile marine organisms from the intertidal region adjacent to the river mouth (*2*) and in the oceanic plankton at some distance from the Columbia River (*3*). Gross (*4*) found both zinc-65 and chromium-51 in sediments taken off the Oregon-Washington coasts, but the present study is the first effort to measure local variations of the radioactivity in sediments from a restricted area. The area of investigation lies from 5 to 35 miles off the mouth of the Columbia River and includes the upper reaches of Astoria Canyon, a submarine canyon which heads at about 70 fathoms 10 miles offshore and extends some 60 miles to a depth of 1000 fathoms (*5*). Measurements were made on samples from both the submarine canyon and the continental shelf, in water depths ranging from 30 to 640 fathoms.

Sediment cores 1.5 inches in diameter were collected with a Phleger gravity corer from 39 different locations in and around Astoria Canyon from 22 to 24 August 1962; 26 were considered to have sufficiently undisturbed surface sediments of uniformly fine texture to be of use in our study. The samples analyzed range from silty sand to silty clay.

The sediment was carefully extruded about 0.25 inch from the plastic core liners, and the surface layers were removed evenly until the 13-cm^3 spectrometer "counting tube" was filled. Where excess sea water was present above the sediment in the plastic liner, it was carefully decanted to within an inch of the sediment. The remaining excess water was evaporated, but not to the point of drying the sediment. This precaution was taken to avoid pouring off any radioactive material not