6 to 13 × 10^9 years (*8*). Preliminary results from experiments run concurrently with those reported here confirm these earlier results. These larger ages are not discussed here; it is merely pointed out that the Ar^{40}/K^{40} ratios measured in Sikhote-Alin are two to three orders of magnitude smaller than those found in several other meteorites selected at random. This is taken to indicate a lower age for Sikhote-Alin.

It is not clear how to interpret this result. It could be simply the result of heating to some unknown extent at any time within the past 1.7 × 10^9 years. But if the lead excesses are radiogenic, the data define a time interval during which uranium decay contributed to the abundances of lead-207 and lead-206. Because of the absence of uranium at the present time there must have been a uranium-lead fractionation late in the meteorite's history. The potassium-argon "age" reported here indicates that this fractionation did not take place more recently than 1.7 × 10^9 years ago; specifically, the possibilities that lead was added to the meteorite 0.77 × 10^9 years ago or that uranium was removed about 0.1 × 10^9 years ago must be rejected, and the calculated lead-lead "age" of 4.6 × 10^9 years is invalid.

A calculation of the lead-lead "age" is strongly dependent on the uranium isotopic ratio in the Sikhote-Alin meteorite; this ratio has not been measured, nor is it clear how one might be able to measure it, owing to the extremely low abundance of uranium. It is therefore not possible to deduce any "ages" directly from the data; some specific and prejudicial assumptions are necessary. One particular model with which the data can be reconciled is the following. All the material of the present solar system withdrew at some time from nucleosynthesis processes, so that the isotopic abundances of uranium are the same in iron meteorites, stone meteorites, and Earth. The primordial isotopic abundances of lead are identical with those measured in the Canon Diablo meteorite (*9*). Radiogenic lead evolved in Sikhote-Alin from the time of its solidification until 1.7 × 10^9 years ago. Then

$$\frac{Pb^{207}}{Pb^{206}} = \frac{k(e^{\lambda_1 T} - 1)}{(e^{\lambda_2 T} - 1)}$$

where Pb^{207} and Pb^{206} are the radiogenic components only, and where k is the ratio $U/^{235}U^{238}$ at the time 1.7 × 10^9 years ago ($k = 34$). A lead-lead "age" of 2.5 × 10^9 years can then be calculated, leading to a total solidification age of (4.2 ± 0.2) × 10^9 years. This "age" is presumably analogous to the total lead-lead "ages" of stone meteorites, which cluster at (4.55 ± 0.15) × 10^9 years. It should be noted that an age calculated from the Pb^{208} data in Sikhote-Alin does not agree with this; this may be due to a Th/U ratio in the iron meteorites which is different from that in the stones and Earth. There may well be alternative interpretations of the data (*10*).

DAVID E. FISHER
Cornell University, Ithaca, and
Brookhaven National Laboratory, Upton, New York

References and Notes

1. I. E. Starik, E. V. Sobotovich, G. P. Lovtsyus, M. M. Shats, A. V. Lovtsyus, *Soviet Phys. "Doklady" English Transl.* **134**, 555 (1960).
2. A. P. Vinogradov, *Proc. Intern. Atomic Energy Agency Conf. Radiocarbon Dating,* discussion following paper by D. E. Fisher.
3. R. R. Marshall and D. C. Hess, *Geochim. Cosmochim. Acta* **21**, 161 (1961); V. R. Murthy and C. C. Patterson, *J. Geophys. Res.* **67**, 1161 (1962).
4. E. L. Fireman and D. E. Fisher, *Nature* **192**, 644 (1961).
5. O. A. Schaeffer and J. Zahringer, *Phys. Rev.* **113**, 674 (1959).
6. D. E. Fisher and O. A. Schaeffer, *Geochim. Cosmochim. Acta* **20**, 5 (1960).
7. H. Stauffer and M. Honda, *J. Geophys. Res.* **67**, 3503 (1962).
8. R. W. Stoenner and J. Zahringer, *Geochim. Cosmochim. Acta* **15**, 40 (1958).
9. C. C. Patterson, *ibid.* **10**, 230 (1956).
10. I am grateful to Dr. R. Dodson, chairman of the Department of Chemistry of Brookhaven National Laboratory, and especially to Dr. R. Davis, Jr., of that department for their cordiality and hospitality and to Dr. Davis for many valuable suggestions. I also express gratitude to Academician E. L. Krinov of the Committee on Meteorites of the Academy of Sciences of the U.S.S.R. for supplying a generous sample of Sikhote-Alin, and to the U.S. Atomic Energy Commission for financial support.

6 December 1962

Sonar Signals of the Sea Lion

Abstract. *Tape recordings were made of the underwater noises of captive sea lions swimming in a concrete pool at night. When approaching pieces of fish that were thrown into the water, the sea lions emitted trains of sound signals like those of the bat and the porpoise. A detailed analysis of these noises shows that they meet the criteria of a pulse-modulated sonar system and, in fact, reveal an amazing sophistication so far as echo ranging is concerned.*

Within the past 2 years I have had occasion to make numerous visits to a small uninhabited island off the California coast (*1*). This island is occupied at certain times of the year by thousands of seals and sea lions. Occasionally I have seen one of these animals which, by its behavior and by such tests as I could make, appeared to be totally blind. Yet it was well fed and avoided rocks as well as other sea lions while in the water. The use of echo ranging or sonar for obtaining its food at once suggested itself.

I therefore obtained tape recordings of the underwater noises made by captive sea lions at the San Francisco and San Diego zoos. For these recordings (*2*) I used a magnetic tape recorder, with a barium titanate hydrophone having a resonance frequency of 125 kcy. The hydrophone was placed at one end of the pool and the pieces of fish were thrown in adjacent to a small island in the pool so that the animals could approach from either side. Since the major portion of the energy in these recordings occurred at frequencies below 20 kcy and so much work remains to be done before any reasonable analysis can be made of the high frequency components, this report deals primarily with that portion of the signals of the California sea lion, *Zalophus californianus* (Lesson), occurring below 20 kcy. Several of these animals were kept in concrete pools, with means for isolating those animals that were not involved in the recordings. Recordings were made with from one to as many as 20 animals and with light conditions ranging from daylight to so dark that the pieces of fish, and much of the time the animals, were not visible to the human eye. The sounds recorded under these conditions are quite distinct from the raucous barks which the sea lion makes in the air. They consist of a series of short pulses which are similar in many ways to the sonar pings of the porpoise as described by Kellogg (*3*). Since the animals will pick up pieces of fish thrown into the tank just as quickly under the darkest conditions mentioned above as they do in daylight, I believe these sounds to be echo-ranging signals of a complex and sophisticated nature. An acoustical analysis of many of these pulses was made by playing the tapes at a reduced speed through a Minneapolis-Honeywell recording oscillograph (Visicorder) model 1508, which was necessary to observe wave form and measure the fractional millisecond time intervals.

Although many different types of signals are used under different conditions, one of the most characteristic type used by the California sea lion when approaching a piece of fish in the dark has been analyzed in some detail. It is, in fact, a kind of double

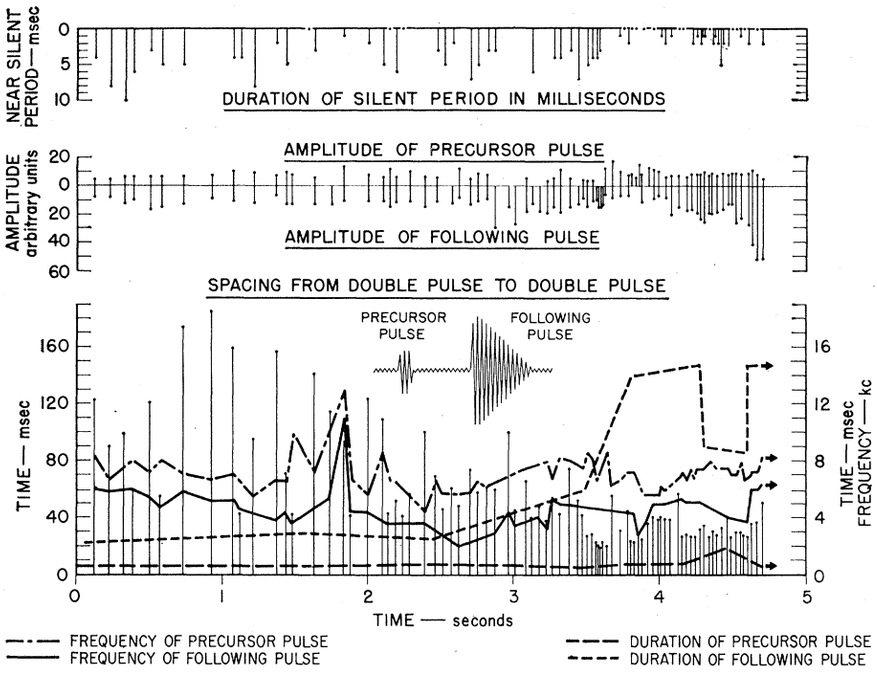

Fig. 1. Composite figure showing features of the double sound-pulse used by the California sea lion in echo ranging. A sample of 83 double pulses extending over a time period of 4.6 seconds is diagramed in this figure. Reading from the top downward, the eight variables represented are: duration of the silent period between units of the double pulse, amplitude of the precursor pulse, amplitude of the following pulse, frequency of the precursor pulse, frequency of the following pulse, duration of the precursor pulse, duration of the following pulse, and the time interval between adjacent double pulses.

pulse. The first portion contains from three to nine oscillations or waves, with an average of about five. In our recordings the length of this precursor (*4*) pulse ranges from 0.3 to 1.0 msec, with a sonic frequency of approximately 5 to 13 kcy/sec. After the initial pulse there is a silent or nearly silent period, after which the second portion of the double pulse comes to full amplitude in about 2.4 cycles and persists for about 25 msec. These double pulses are repeated—as in the case of the porpoise —at the rate of a few to a great many per second. An idealized tracing of one of these double pulses is shown near the middle of Fig. 1.

The changes which can occur in a train of sea lion pulse patterns of this sort are also indicated in Fig. 1, where eight aspects of these pulses have been charted. The figure depicts the essential characteristics of a series of 83 double pulses as a single sea lion approached a piece of fish in the dark. This entire approach from 10 feet required only 4.6 seconds. Reading from top to bottom in Fig. 1, the variables diagramed are as follows: duration of silent interval between the subpulses of each double pulse, relative amplitude of the precursor pulse, relative amplitude of the following pulse, frequency of precursor pulse, frequency of following pulse, duration of precursor pulse, duration of following pulse, and time interval elapsing from double pulse to double pulse.

Each of the 83 double pulses is represented at the bottom of the figure by a vertical line with a dot on top. The lines are arranged on a time scale along the abscissa so as to show the interspacing between double pulses. The length of each line gives another indication of the time elapsing between adjacent double pulses. The spacing between pulses extends over a sixfold range, but it decreases progressively as the animal approaches a fish. In other words, the pulses are repeated at a faster rate as the distance between the sea lion and piece of fish decreases.

The auditory frequency of the separate pulses (horizontal lines) shows that the precursor pulse in this case extends from 4.5 to 13.4 kcy/sec. The following pulse (solid line) is always lower in pitch and ranges from 2 to 11 kcy.

The duration of the precursor pulse averages approximately 0.71 msec. The length of the following pulse, on the other hand—although it is subject to much less accurate measurement—is about eight times as long as the precursor pulse. In the present sample, the duration of the silent period between the two subpulses varies from 0.0 to 1.0 msec.

The measurement of absolute intensity is not possible in a free-swimming animal whose distance from the hydrophone is unknown, but measures of relative intensity have been graphed on an arbitrary scale along the line which is second from the top of the chart in Fig. 1. It appears that the amplitude of the precursor pulse fluctuates irregularly throughout most of the record but is steadier in approximately the last second of time. During the corresponding time period, that is, when the sea lion gets close to the piece of fish, the following pulse increases in intensity.

In one remarkable instance, the pulsating squeak of a water pump was picked up by the hydrophone along with the sputtering signals of a sea lion. At first the sea lion superimposed a series of random pulses over this pump noise and then introduced a unique pattern of about ten pulses between successive squeaks of the pump. In one consecutive series of 35 such groups of ten to twelve pulses analyzed, the first pulse had a frequency of 3 to 4 kcy/sec, and the frequency of successive pulses went up to about 8 kcy/sec and then gradually dropped down to 3 kcy/sec. This is an example, I think, of the astonishing modifications which are possible in the application of the method. The California sea lion seems not only to be able to manipulate the different variables shown in Fig. 1, but it alters its sonar signals in many other ways.

Additional records have been made of the underwater noises of the Steller sea lion, the elephant seal, the harbor seal, and fur seals. Although an analysis has not yet been attempted, indications are that these animals also make use of pulse-type sonar signals.

THOMAS C. POULTER
Stanford Research Institute,
Menlo Park, California

References and Notes

1. Año Nuevo ("New Year") Island is ½ mile offshore and about 40 miles south of San Francisco. This island is described in detail by R. T. Orr and T. C. Poulter in *Pacific Discovery* **15**, 13 (1962).
2. These recordings were made with a Precision Instrument Co. seven-channel magnetic tape recorder and a tape speed of 60 in./sec. This P1-200 instrument has a frequency response of 300 cy to 1000 kcy/sec. Different amplifiers and filter systems were used such as: Epsco DA-102 amplifier with a frequency

response from 0 to 200 key/sec, Tectronix 122 amplifier with a frequency response of from 1.6 cy to 40 kcy/sec, and a Quan-Tec 210 preamplifier with a frequency response up to 100 kcy/sec. The hydrophone was a highly directional barium titanate unit designed by the U.S. Navy Electronics Laboratory at Point Loma, Calif. It had a resonant frequency of 125 kcy/sec and a nearly flat response below 100 kcy/sec. I used a Tectronix 535 oscilloscope to monitor these signals and the frequency response of the system depended upon the combination of the instruments named above and band-pass filter setting used. I have designed and am having built a special set of portable equipment for continuing this work.

→ W. N. Kellogg, R. Kohler, H. N. Morris, *Science* **117**, 239 (1953); W. N. Kellogg, *Porpoises and Sonar* (Univ. of Chicago Press, Chicago, 1961).

4. I have chosen to call this first very sharp pulse a "precursor" pulse because it so closely resembles in appearance the precursor pulse in certain shock-pulse phenomena with which I have done extensive work.

24 December 1962

Genetic Control of Hemerythrin Specificity in a Marine Worm

Abstract. *A biochemical polymorphism of coelomic hemerythrin has been found in the sipunculid* Golfingia gouldii; *the electrophoretically "fast" and "slow" coelomic hemerythrins differ in their oxygen equilibria and by a single peptide in tryptic and chymotryptic "fingerprints." All individuals of this sipunculid have the same vascular hemerythrin, which is electrophoretically different from any of the coelomic hemerythrins. Vascular and coelomic hemerythrins of another sipunculid,* Dendrostomum cymodoceae, *have quite different "fingerprints." Thus, on the basis of two separate types of evidence the tissue-specific hemerythrins appear to have a distinct genetic basis. The embryological and phylogenetic implications are discussed.*

Vascular (blood) hemoglobin and muscle hemoglobin (myoglobin) have been known for many years to be biochemically distinct proteins. Recently it has been shown that the amino acid sequences are different (*1*); this means that myoglobin and hemoglobin are the product of different structural genes (cistrons). Further evidence for this separate genetic basis has come from the failure to find any difference in the myoglobin from normal human beings (Hb A homozygous) and from individuals with sickle-cell anemia (Hb S homozygous) (*2*). Thus, these tissue-specific hemoglobins are under the control of separate genes. Several researchers have suggested that tissue-specific proteins—for example, the "isozymes"—are significant with regard to the general problem of the genetic control of development (*3, 4*). If this is true, then tissue specificity of certain proteins should be a very widespread phenomenon.

I have found tissue-specific hemoglobins in the annelid worm *Travisia* (*5*); in addition, two species of sipunculid worms were found to have separate vascular (tentacular) and coelomic hemerythrins occurring in morphologically different cells (hemerythrocytes) and possessing different denaturation, solubility, electrophoretic, and oxygen-equilibrium properties (*6*). As the differences between vascular and coelomic hemerythrins are very great, and because they persist in spite of purification and dialysis against common buffer solutions, it has been suggested that the proteins differ in their primary structure (*6*). During my investigation, 50 individuals of two populations of the sipunculid *Dendrostomum zostericolum* were surveyed, by electrophoresis and analysis of oxygen equilibria, to find if any differences existed between individuals; none were found, and thus no genetic speculation was possible.

In a survey of the sipunculid *Golfingia*—erroneously called *Phascolosoma* (*7*)—*gouldii*, variations in hemerythrin type have been found which are proof of separate structural genes for vascular and coelomic hemerythrins (*8*).

Coelomic and vascular hemerythrins were obtained without contamination, as described elsewhere (*6*). In *Golfingia gouldii* the amount of vascular hemerythrin is very small, less than 0.005 ml of cells in a large individual. This quantity is sufficient, however, for a single starch gel electrophoretic analysis. For the initial screening of individuals, unpurified hemerythrins were used. For other chemical studies hemerythrins were purified by ammonium sulfate fractionation; these preparations showed no trace of contamination with other proteins, either when tested in starch gel electrophoresis or in the analytical ultracentrifuge. Hemerythrin can be detected in starch gels by virtue of its reddish-brown color; a more sensitive test involves the Nitroso-R Salt staining procedure for iron (*9*).

In Fig. 1 it may be seen that individual sipunculids have any one of three different coelomic hemerythrin patterns, whereas the vascular hemerythrins are identical. In the experiment reported here, the latter were pooled to obtain comparable concentrations and to emphasize the identity of the vascular hemerythrins in each individual. It is also apparent that the vascular hemerythrin has a more rapid electrophoretic mobility under the conditions of the experiment than any of the coelomic hemerythrins. Studies in other starch gel buffer systems indicate that the vascular hemerythrin has a more acid isoelectric point. Three coelomic hemerythrin electrophoretic types were found in a population of 181 individual sipunculids: 73 individuals were of the "slow" type, 16 were of the "fast" type, and 92 gave the intermediate electrophoretic pattern, which represents the heterozygote (*10*). Since the hemerythrin molecule dissociates in 6*M* urea to an ultracentrifugally and electrophoretically homogeneous subunit of approximately one-eighth the normal molecular size (*11*), the heterozygote, according to hypothesis, should possess a family of molecules containing different proportions of the two kinds of polypeptide chains; this would account for the intermediate electrophoretic pattern and the presence of traces of the "slow" and "fast" hemerythrins in the heterozygote. In addition, an artificial mixture of equal amounts of "fast" and "slow" hemerythrins, after standing at room temperature for a few hours, will give an electrophoretic pattern identical to that of the presumed heterozygote.

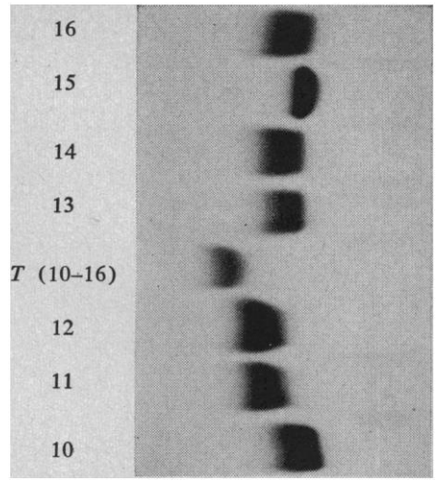

Fig. 1. Starch gel electrophoresis of coelomic and vascular hemerythrins from seven individuals of the sipunculid worm *Golfingia gouldii* (borate buffer; final gel *p*H, 8.3; electrophoresis at 250V for 16 hours at 0°C). The coelomic hemerythrins of sipunculids 11 and 12 are the "fast" type, sipunculid 15 is the "slow" type, and sipunculids 10, 13, 14, and 16 are the heterozygotes. The vascular (tentacular) hemerythrins are identical, and in the experiment were pooled [*T* (10–16)].

Another approach to the problem involves the "fingerprinting" technique, which has been used so successfully in