and a watchful eye should be kept to prevent such funds from working to the detriment of real science. It is the young generation, who will profit from the incoming funds, who should also be alerted against the danger that politicians, both those within and those outside the universities, will take over science. The young researcher must insist upon the right to think for himself, to plan for himself, to make his own mistakes, and to be happy over an unplanned, unforeseen discovery. Real progress in science has always been made and will always be made by the free mind, left to its own working under a system where science is free.

Based upon a presidential address given at a meeting of the Phi Sigma Society held December 30, 1948 at the University of New Mexico.

Age Determination by Radiocarbon Content: World-Wide Assay of Natural Radiocarbon[1]

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SOME TIME AGO THE OCCURRENCE of radiocarbon in living matter and dissolved ocean carbonate was reported (*1, 2, 4, 5*) as a result of researches on sewage methane gas from the City of Baltimore. The postulated origin (*5*)—cosmic ray neutrons reacting with atmospheric nitrogen to give radiocarbon at high altitudes—clearly predicted that all material in the life cycle and all material exchangeable with atmospheric carbon dioxide, such as carbonate dissolved in sea water, would be radioactive. The long half-life of radiocarbon, 5,720 ± 47 years (*3*), further seemed to ensure that the mixing processes would have ample time to distribute the radiocarbon uniformly throughout the world.

Since completing the first tests using isotopic enrichment with Dr. Grosse and his associates, an improvement in counting technique has enabled us to investigate materials without enrichment to about 5–10% error. The samples are counted in the form of elementary carbon in a screen wall counter (*6*). Six grams of carbon are spread uniformly over an area of 300 cm², to give an "infinitely thick" layer; about 5.9% of the disintegrations register in this arrangement. The background of the counter has been reduced from 150 cpm (when shielded by 2″ of lead) to 10 cpm by means of anti-coincidence shielding and the addition of a 4″ iron liner inside the lead shield. The technique will be described in detail elsewhere. A world-wide assay has been completed, and the uniformity apparently established. The data are presented in Table 1.

TABLE 1

WORLD-WIDE ASSAY OF RADIOCARBON

Sample	Assay (cpm/gm of carbon)
Baltimore sewage methane (*1, 2*)	10.5 ± 1
Ironwood from Marshall Islands	11.5 ± 0.6
" " " "	12.6 ± 1.0
Elmwood, Chicago Campus	12.7 ± 0.8
" " "	11.9 ± 0.7
Pine, Mt. Wilson, New Mexico, (10.000′ altitude)	12.5 ± 0.6
Bolivian wood	13.5 ± 0.6
" "	11.3 ± 0.8
Ceylon wood	12.5 ± 0.7
Tierra del Fuego wood	12.8 ± 0.5
Panamanian wood	13.0 ± 0.5
Palestinian wood	12.4 ± 0.4
Swedish wood	12.6 ± 0.5
New South Wales wood	13.3 ± 0.4
North African wood	11.9 ± 0.4
Weighted average	12.5 ± 0.2
Sea shell, Florida west coast	13.3 ± 0.5
" " " " "	14.9 ± 0.7
" " " " "	14.6 ± 0.5
Weighted average	14.1 ± 0.3
Seal oil, Antarctic	10.4 ± 0.7

The numbers quoted are intended to be absolute disintegration rates per gram of carbon. It must be

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said, however, that our absolute calibration of the counters used may have as much as 10% error. We hope to improve this in the near future. Since all the samples were measured with the same technique, the relative comparison does not involve this point. With the exception of the Antarctic seal sample, which has been run only once to date, the uniformity is well within experimental error. Since one expects the arctic samples if anything to be high, because the neutron intensity is lowest at the equator and rises towards the poles (*9*), and since the deviation of the seal oil from the mean is not much larger than the error of the measurement, it is believed that further measurements will show this sample to be normal also. The result on the sea shell sample is interesting. It has been shown (*7, 8*) that C^{13} occurs in higher abundance in carbonates than in organic material. The result we find for radiocarbon in sea shells versus wood and other organic material is in line with this earlier finding for C^{13}. It is true, however, that the difference may be somewhat larger in our case than that predicted from the earlier results, though the error of our measurement is so large at present as to well overlap the predicted value.

Age Determination

Having established the world-wide uniformity of the radiocarbon assay at the present time, it seems a logical assumption that this would have been true in ancient times. Assuming this, and using the half-life of radiocarbon, 5,720 ± 47 years (*2*), one can calculate the specific activity to be expected after any given time interval elapsed since the removal of any carbonaceous material from equilibrium with the life cycle. For living materials this probably coincides with the time of death; for carbonates it would correspond to the time of crystallization (assuming no further interchange with the solution or atmospheric carbon dioxide to occur). On this basis we have undertaken examination of wood samples of well established age from the ancient Egyptian tombs. Two such samples were used, one from the tomb of Sneferu at Meydum (furnished by Froelich Rainey, of the University of Pennsylvania Museum, Philadelphia) which was 4,575 ± 75 years old; the other from the tomb of Zoser at Sakkara (furnished by Ambrose Lansing, of the Metropolitan Museum of New York) which was 4,650 ± 75 years old. The former sample is cypress wood; the latter is acacia. John Wilson, of the Oriental Institute of the University of Chicago, has given the dates quoted, at the behest of a committee of the American Anthropological Association, consisting of Frederick Johnson, chairman, Froelich Rainey, and Donald Collier. The expected assay for 4,600-year material is easily calculated to be 7.15 ± 0.15 cpm/gm of carbon on the basis of the present assay and the half-life. Table 2 presents the data obtained on these materials.

TABLE 2

Age Detemination on the Ancient Egyptian Samples

Sample	Specific activity found (cpm/gm of carbon)
Zoser	7.88 ± 0.74
"	7.36 ± 0.53
Sneferu	6.95 ± 0.40
"	7.42 ± 0.38
"	6.26 ± 0.41
Weighted average (both samples)	7.04 ± 0.20
Expected value	7.15 ± 0.15

The data on both samples were averaged since the error in ages almost overlaps the difference, and the weighting was taken according to the error quoted in each run. The errors quoted here and in Table 1 also are standard deviations determined strictly from the statistical counting error, and, since the data agree within these errors, we believe that no other appreciable error is involved in the measurement. It is gratifying that the mean of the determinations agrees with the expected value within 1 standard deviation unit. An error of 0.4 cpm/gm in the specific activity corresponds to an error of 450 years in a 4,600-year-old sample.

On this basis we feel encouraged to proceed with further tests on younger samples of known age. This work is now in progress. It is hoped that certain unknowns can be measured in the near future. A large thermal diffusion column similar to the one used by Dr. Grosse and his associates has been installed in the laboratory and a considerable increase in accuracy should result, permitting the measurement of samples as old as 20,000 to 25,000 years.

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